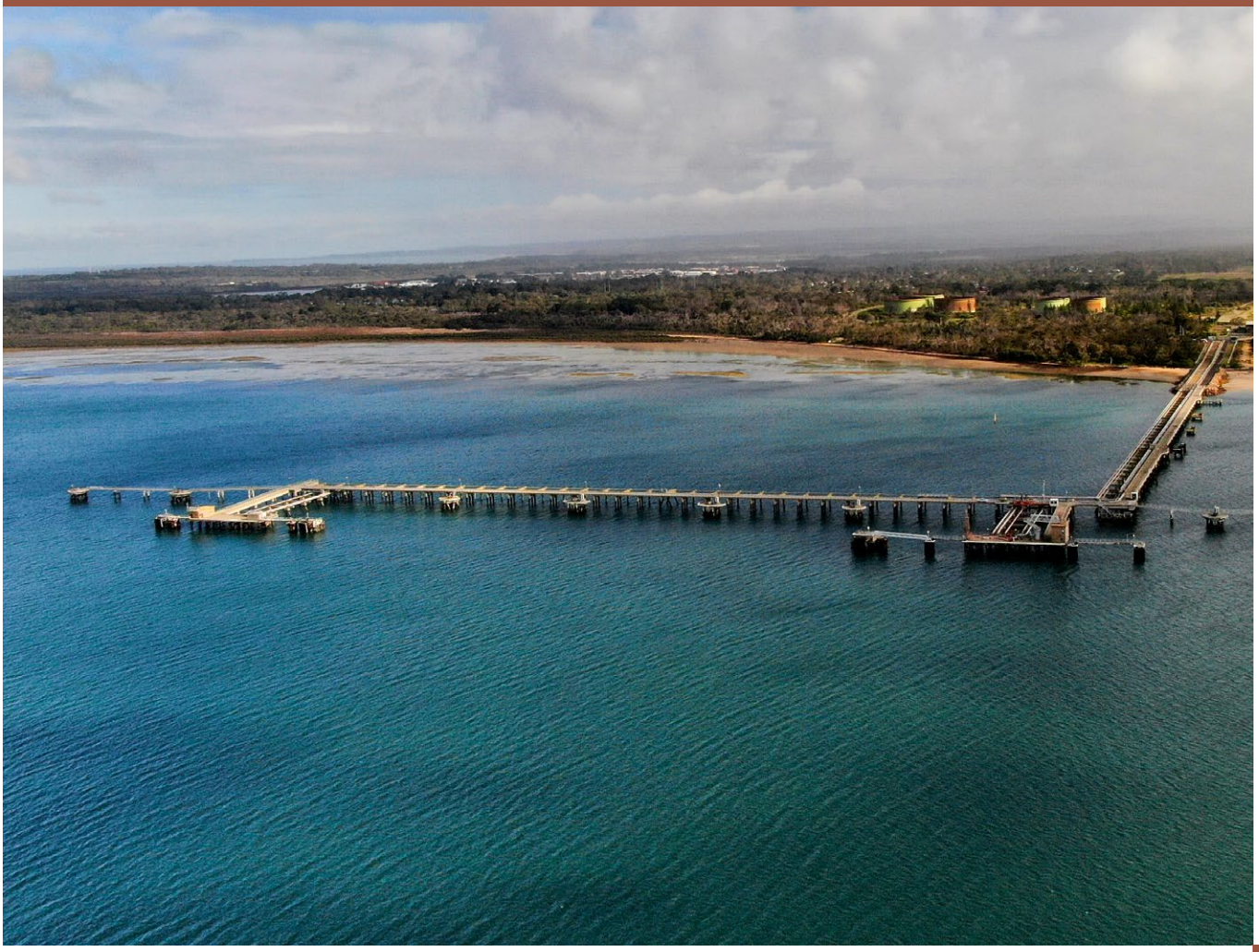
Gas Import Jetty and Pipeline Project

Environment Effects Statement

July 2020



Attachment VIII

Works Approval Application

EPA Works Approval Application

Gas Import Jetty (FSRU) - Crib Point, Victoria

EPA Works Approval Application

Gas Import Jetty (FSRU) - Crib Point, Victoria

Client: AGL Wholesale Gas Limited

ABN: 26 072 948 504

Prepared by

AECOM Australia Pty Ltd
Level 10, Tower Two, 727 Collins Street, Melbourne VIC 3008, Australia
T +61 3 9653 1234 F +61 3 9654 7117 www.aecom.com
ABN 20 093 846 925

22-Jun-2020

Job No.: 60592634

AECOM in Australia and New Zealand is certified to ISO9001, ISO14001 AS/NZS4801 and OHSAS18001.

© AECOM Australia Pty Ltd (AECOM). All rights reserved.

AECOM has prepared this document for the sole use of the Client and for a specific purpose, each as expressly stated in the document. No other party should rely on this document without the prior written consent of AECOM. AECOM undertakes no duty, nor accepts any responsibility, to any third party who may rely upon or use this document. This document has been prepared based on the Client's description of its requirements and AECOM's experience, having regard to assumptions that AECOM can reasonably be expected to make in accordance with sound professional principles. AECOM may also have relied upon information provided by the Client and other third parties to prepare this document, some of which may not have been verified. Subject to the above conditions, this document may be transmitted, reproduced or disseminated only in its entirety.

Table of Contents

Acronym List i
1.0 Primary information 1
1.1 Introduction 1
1.2 Company legal entity 1
1.3 Application fee 1
1.4 Need for Works Approval 1
1.4.1 Utilities: K01 – Power stations 2
2.0 Project Overview 3
2.1 Project background 3
2.2 Scope of Works Approval application 5
3.0 Land use 7
3.1 Planning and other approvals 7
3.2 Choice of location 8
4.0 Environmental performance and track record 10
5.0 Supporting EES documentation 11
6.0 Community engagement 12
6.1 Communication and consultation 12
6.1.1 Phase 1: Proposal (2017 – September 2018) 12
6.1.2 Phase 2: Post EES Referral Decision (October 2018 – January 2019) 12
6.1.3 Phase 3: EES Preparation (January 2019 – early/mid 2020) 13
6.1.4 Phase 4: EES Public Exhibition and Panel Hearings (mid 2020) 14
6.2 Consultation findings and response 15
7.0 Process and integrated environmental assessment 16
7.1 Existing conditions 16
7.2 Floating Storage and Regasification Unit (FSRU) 16
7.2.1 Regasification modes 18
7.2.2 Proposed FSRU operating mode and parameters 22
7.2.3 FSRU engines 23
7.2.4 Technical specifications and process 23
7.3 Environmental best practice 24
7.4 Choice of process and technology 24
7.5 Integrated environmental assessment 25
8.0 Energy use and greenhouse gas emissions 28
8.1 Existing conditions 28
8.2 FSRU energy use and GHG emissions 28
8.2.1 Construction 28
8.2.2 Operation 29
8.3 Best practice energy and GHG management 30
8.3.1 Step 1: Estimate energy consumption 30
8.3.2 Step 2: Estimate direct GHG emissions 30
8.3.3 Step 3: Identify and evaluate opportunities to reduce GHG emissions 31
8.3.4 Step 4: Document the information generated in steps 1 – 3 32
8.4 Climate change risk 32
8.5 Summary 35
9.0 Water resource use 36
9.1 Water use in process 36
9.1.1 Seawater use associated with regasification 36
9.1.2 Other seawater uses 37
9.2 Water use best practice 39
10.0 Air emissions 40
10.1 Separation Distances 40
10.2 Air emissions assessment 40
10.3 Air quality modelling 41
10.3.1 Operational pollutants of interest 41
10.3.2 Study area 41

10.3.3 Sensitive receptors 43
10.3.4 Background air pollutant concentrations 43
10.3.5 Meteorology and climate 45
10.3.6 Operational modelling scenarios 46
10.3.7 Model selection 47
10.4 Air emission sources 47
10.4.1 Air Emissions Inventory 47
10.4.2 FSRU air emissions 49
10.5 Air quality management best practice 50
10.6 Air quality impact assessment 51
10.6.1 Stationary source emissions 51
10.6.2 Modelling predictions for FSRU operational scenarios 52
10.6.3 Fugitive emissions 60
10.6.4 Other information 60
10.7 Further air emissions assessment 61
10.7.1 Emission during plant start-up or shut down 61
10.7.2 Risk assessment 61
10.7.3 Impacts on airshed 62
10.8 Odour 62
10.9 Summary 62
11.0 Noise emissions 64
11.1 Noise and vibration emissions assessment 64
11.2 Existing conditions 64
11.3 Noise emission sources 69
11.3.1 Operational modelling scenarios 69
11.3.2 Noise emitting equipment 70
11.4 Best practice noise control measures 74
11.5 Noise impact assessment 75
11.5.1 Determining noise limits 75
11.5.2 Predicted noise levels 75
11.5.3 Mitigation measures 77
11.5.4 Multiple premises emitting noise 78
11.5.5 Commissioning and decommissioning 78
11.6 Summary 78
12.0 Water 80
12.1 Managing stormwater run-off discharges 80
12.2 Discharge to surface water (Western Port waters) 80
12.2.1 Justification for discharging to surface waters 80
12.2.2 Background condition of receiving water 81
12.2.3 Beneficial uses 93
12.2.4 FSRU seawater discharge characteristics 95
12.2.5 Impact and risk assessment 98
12.2.6 Assessment of a mixing zone 131
12.2.7 Potential impacts on Ramsar values 133
12.2.8 Summary 135
13.0 Land and groundwater 137
14.0 Waste 138
14.1 Industrial waste generation 138
14.1.1 Waste generation 138
14.1.2 Best practice waste management 139
14.2 Prescribed Industrial Waste 140
15.0 Environmental management 141
15.1 Risk assessment of operations 141
15.1.1 Unplanned release – hazardous materials storage 141
15.1.2 Unplanned release – waste storage 142
15.1.3 Extreme weather events 142
15.1.4 Managing environmental risks 142
15.2 Environmental Management System 143

15.3 Project Construction impact management 143
16.0 Post-decision – Operational requirements 145
16.1 Monitoring 145
16.2 Reporting annual performance 145
17.0 References 150

Appendix A
ASIC extract A

Appendix B
Supporting EES documentation B

Appendix C
Technical specifications and drawings C

Appendix D
FSRU Systems and Emissions Schematic D

Appendix E
Energy use and greenhouse gas emissions calculations E

Appendix F
Air emissions – meteorology and climate data F

Appendix G
Air emissions - manufacturer emissions specifications G

Appendix H
Air emissions – modelling predictions H

Appendix I
Air emissions - Human Health Risk Assessment (HHRA) I

Appendix J
Noise – operational noise criteria J

Appendix K
Noise – operational noise maps K

Appendix L
Water - risk assessment L

Appendix M
Water – Chlorine guideline value M

Appendix N
Water - Toxicity test report N

List of Figures

Figure 1 Gas Import Jetty and Pipeline Project 4
Figure 2 WA application boundary 6
Figure 3 Visualisation of FSRU and LNG carrier berthed side by side at Crib Point Jetty 17
Figure 4 Open loop regasification process 19
Figure 5 Open loop regasification seawater intake and discharge (not to scale) 20
Figure 6 Closed loop regasification process 21
Figure 7 Natural gas engine heat rate comparison (kJ/kWh) 31
Figure 8 Comparison of GHG emission intensity of various fuels per GJ of energy content (DoEE 2019) 32
Figure 9 Study area for air quality impact assessment 42
Figure 10 Sensitive receptors locations 44
Figure 11 Gas-fuelled open loop FSRU scenario, NO_2 concentration results, 99.9th percentile including background (µg/m^3) 54

Figure 12 Gas-fuelled open loop FSRU scenario, PM_{10} results, 99.9th percentile including background (µg/m^3) 54
Figure 13 Gas-fuelled open loop FSRU scenario, Formaldehyde results, 99.9th percentile, no background (µg/m^3) 55
Figure 14 Gas-fuelled FSRU, two boiler scenario, NO_2 concentration results, 99.9th percentile including background (µg/m^3) 55
Figure 15 Gas-fuelled FSRU, two boiler scenario, PM_{10} concentration results, 99.9th percentile including background (µg/m^3) 56
Figure 16 Gas-fuelled FSRU, two boiler scenario, Formaldehyde concentration results, 99.9th percentile, no background (µg/m^3) 56
Figure 17 Gas-fuelled FSRU, three boiler scenario, NO_2 concentration results, 99.9th percentile including background (µg/m^3) 57
Figure 18 Gas-fuelled FSRU, three boiler scenario, PM_{10} concentration results, 99.9th percentile including background (µg/m^3) 57
Figure 19 Gas-fuelled FSRU, three boiler scenario, Formaldehyde concentration results, 99.9th percentile, no background (µg/m^3) 58
Figure 20 Liquid-fuelled FSRU scenario, NO_2 concentration results, 99.9th percentile including background (µg/m^3) 58
Figure 21 Liquid-fuelled FSRU scenario, PM_{10} results, 99.9th percentile including background (µg/m^3) 59
Figure 22 Unattended noise monitoring locations 67
Figure 23 Attended noise monitoring locations 68
Figure 24 Crib Point Jetty (Berth 2) proposed layout 72
Figure 25 Crib Point Receiving Facility proposed layout 73
Figure 26 Comparison on background noise levels to predicted levels at French Island 77
Figure 27 Western Port bathymetry (CEE 2020) 82
Figure 28 Bathymetry of Lower North Arm near Crib Point 83
Figure 29 Lower North Arm tide ranges 85
Figure 30 Mid-water Currents at Crib Point Jetty Berth 2 86
Figure 31 Crib Point half-tidal fluxes (10^6 m^3) 86
Figure 32 Benthic habitats in Western Port 88
Figure 33 Key to benthic habitat categories in Lower North Arm, Western Port 89
Figure 34 Benthic habitats near Crib Point 90
Figure 35 Ten most abundant infauna families at sites in Lower North Arm 92
Figure 36 Variation in seabed temperature over time 100
Figure 37 Area above Temperature Guideline Value during peak operation (Open loop LNG Carrier at berth) 101
Figure 38 Area above Temperature Guideline Value – Lower North Arm during peak operation (Open loop LNG Carrier at berth) 102
Figure 39 Area above temperature Guideline Value– Western Port during peak operation (Open loop LNG Carrier at berth) 103
Figure 40 Chlorine exposure on FSRU – inlet to 5 minutes 110
Figure 41 CPO exposure inlet to 10 minutes including the time after discharge 110
Figure 42 Exposure of benthic marine biota to intermittent chlorine discharge 111
Figure 43 Area above the Chlorine Guideline Value during peak operation (open loop LNG carrier at berth) 112
Figure 44 Area above the Chlorine Guideline Value– North Arm during peak operation (open loop LNG carrier at berth) 113
Figure 45 Area above Chlorine Guideline Value– Western Port during peak operation (Open loop LNG Carrier at berth) 114
Figure 46 Chlorine toxicity results as function of duration of exposure 115
Figure 47 Combined area above temperature and chlorine Guideline Values – Crib Point 121
Figure 48 Combined area above temperature and chlorine Guideline Value – North Arm 122
Figure 49 Combined area above temperature and chlorine Guideline Value – Western Port 123
Figure 50 Entrainment Model Ecological Zones for Entrainment Calculations 125
Figure 51 Waste hierarchy (EPA 2020) 140

Figure 52 9am and 3pm wind rose comparison AERMOD Crib Point 2014 –2018 to long-term BoM Cerberus F-3
Figure 53 AERMOD Crib Point seasonal wind rose, 2014-2018 F-4
Figure 54 AERMOD Crib Point individual annual wind rose comparison 2014-2018 F-5
Figure 55 Terrain elevations of model grid F-6
Figure 56 Gas-fuelled FSRU, three boiler scenario, Formaldehyde concentration results, 99.9th percentile, no background (µg/m³) I-2
Figure 57 The eight locations chosen for frequency of occurrence analysis, Gas-fuelled FSRU, three boiler scenario, Formaldehyde concentration results, 99.9th percentile, no background (µg/m³) I-3

List of Tables

Table 1 AGL Company Details 1
Table 2 Summary of surrounding land use and sensitive receptors 5
Table 3 State and Commonwealth Approvals for the Gas Import Jetty Works 7
Table 4 Summary of short-listed options assessment and assessment of operability 8
Table 5 Summary of engagement activities during Phase 3: EES Preparation to date (January 2019 – early/mid 2020) 13
Table 6 Summary of key data for the FSRU 17
Table 7 Maximum seawater flow rates for open loop regasification 19
Table 8 Seawater flowrates for closed loop regasification 22
Table 9 Proposed FSRU regasification operating parameters 23
Table 10 Integrated Environmental Assessment of Key Environmental Aspects for the Project 26
Table 11 Victorian GHG emissions by source for 2017 NGER 28
Table 12 Summary of construction GHG emissions related to the FSRU (one-off event) 29
Table 13 Summary of annual operational GHG emissions in closed loop mode 29
Table 14 Summary of annual operational GHG emissions in open loop mode 30
Table 15 Summary of climate hazards 33
Table 16 Summary of climate risk to the FSRU 34
Table 17 Seawater use from the FSRU 37
Table 18 Adopted Project background air pollutant concentrations 45
Table 19 Yearly AERMOD Crib Point wind statistics 2014-2018 45
Table 20 Operational modelling scenarios (worst case) 46
Table 21 FSRU exhaust parameters 49
Table 22 Air emissions estimated rates (per source) for the gas fuelled FSRU operational modelling scenarios 49
Table 23 Air emissions estimated rates (per source) for the liquid fuelled FSRU operational modelling scenario 50
Table 24 Comparison of NOx emissions: proposed FRSU plant and reference plant 51
Table 25 SEPP (AQM) Schedule E - Emission limits for stationary sources 51
Table 26 Summary of maximum predicted air pollutant concentrations from operation of the FSRU modelled at sensitive receptor locations, 99.9th percentile 52
Table 27 Comparison of predicted FSRU air emissions to scheduled premises air emissions thresholds 60
Table 28 Formaldehyde Acute Exposure Screening Criteria 61
Table 29 Summary of modelled air emissions on airshed 62
Table 30 Unattended noise measurements – background and ambient noise monitoring results 65
Table 31 Attended noise measurements – background and ambient noise monitoring results 65
Table 32 Operational modelling scenarios 70
Table 33 Modelled noise emitting plant / equipment 70
Table 34 Summary of design features to minimise noise emissions from equipment on board of FSRU 74
Table 35 Recommended Maximum Noise Levels – Gas Import Facility 75
Table 36 Gas Import Facility: Operation (within 10m of the building) 75

Table 37	Summary of predicted noise levels at the Gas Import Facility	79
Table 38	Volume and area of Western Port and the Lower North Arm at Tidal Stages	83
Table 39	Summary of the existing water quality	87
Table 40	Beneficial uses - Western Port	94
Table 41	Continuous open loop discharges[1]	95
Table 42	Continuous closed loop discharges[1]	96
Table 43	Intermittent discharges during open and closed loop	96
Table 44	Chlorine discharge for various modes of operation of FSRU	97
Table 45	Range of temperature variation at Crib Point, Jan to Nov 2019	98
Table 46	Summary of results of temperature predictions	99
Table 47	A summary of impact assessment and risk of discharge of cooled water	104
Table 48	Summary of results for chlorine predictions	108
Table 49	Summary of results for lower production rate	109
Table 50	A summary of impact assessment and risk of discharge of chlorinated water	116
Table 51	North Arm entrainment rate predictions for various production rates	126
Table 52	A summary of impact assessment and risk of biological entrainment	126
Table 53	Summary of assessment of the Project on Critical Components, Processes and Services for the Western Port Ramsar site	134
Table 54	Summary of waste generated from FSRU operation	138
Table 55	Summary of proposed monitoring programs for operational phase of the FSRU	146
Table 56	A summary of construction and operation GHG emissions relevant to the FSRU	E-1
Table 57	A summary of inputs related to fuel consumed for FSRU vessel transportation to Crib Point	E-2
Table 58	Inputs used in calculating stationary fuel emissions during operations	E-3
Table 59	Inputs used in calculating fugitive emissions during operations	E-6
Table 60	BoM climate average statistics at Cerberus station (1986 to 2019)	F-1
Table 61	Summary of TAPM modelling parameters	F-2
Table 62	Yearly AERMOD Crib Point wind statistics 2014 –2018	F-2
Table 63	Gas-fuelled FSRU, open loop scenario, pollutant concentration results at sensitive receptor locations, 99.9th percentile including background (µg/m³)	H-1
Table 64	Gas-fuelled FSRU, two boiler scenario, pollutant concentration results at sensitive receptor locations, 99.9th percentile including background (µg/m³)	H-2
Table 65	Gas-fuelled FSRU, three boiler scenario, pollutant concentration results at sensitive receptor locations, 99.9th percentile including background (µg/m³)	H-3
Table 66	Liquid- fuelled FSRU pollutant concentration results at sensitive receptor locations, 99.9th percentile including background (µg/m³)	H-4
Table 67	Formaldehyde Acute Exposure Screening Criteria	I-2
Table 68	Frequency of occurrence, three boiler scenario, formaldehyde concentration results	I-4
Table 69	Consequence rating criteria	L-2
Table 70	Likelihood rating criteria	L-2
Table 71	Risk assessment matrix	L-2

Acronym List

Term	Description
AAQ NEPM	National Environment Protection (Ambient Air Quality) Measure
AGL	AGL Wholesale Gas Limited
AHD	Above Height Datum
AMSA	Australian Maritime Safety Authority
ANZECC Guidelines	Australian and New Zealand Guidelines for Fresh and Marine Water
APA	APA Transmission Pty Limited
AV	Aboriginal Victoria
BoM	Bureau of Meteorology
CEMP	Construction Environmental Management Plan
CHMP	Cultural Heritage Management Plan
CO	Carbon Monoxide
CPO	Chlorine Produced Oxidants
CPS	Components, Processes and Services
CSIRO	Commonwealth Scientific Industrial Research Organisation
DELWP	Department of Environment, Land, Water and Planning
DNV GL	Det Norske Veritas and Germanischer Lloyd
DoEE	Department of the Environmental and Energy
EES	Environment Effects Statement
EETM	Emission Estimation Technique Manuals
EMS	Environmental Management System
EOLSS	End of Line Scraper Station
EP Act	*Environment Protection Act 1970*
EPA	Environment Protection Authority Victoria
EPL	Environment Protection Licence
EQI	Environmental Quality Indicators
ESV	Energy Safe Victoria
FFG Act	*Flora and Fauna Guarantee Act 1988*
FSRU	Floating Storage and Regasification Unit
GHG	Greenhouse Gas
GLC	Ground Level Concentrations
HAP	Hazardous Air Pollutants
HAZID	Hazard Identification
HAZOP	Hazard and Operability Study
HFO	Heavy Fuel Oil
HHRA	Human Health Risk Assessment

Term	Description
HMAS	Her Majesty's Australian Ship
HOCl	Hypochlorous acid
IMO	International Maritime Organisation
ISM	International Safety Management
LAC	Limits of Acceptable Change
LFO	Light Fuel Oil
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MHF	Major Hazard Facility
MLA	Marine Loading Arms
MLC	Maritime Labour Convention
MLV	Mainline Valve
MMSCFT	Million standard cubic feet
MSL	Mean Sea Level
MSO	Minimum Send Out Compressor
NIRV	EPA Publication 1411: Guideline Noise from Industry in Regional
NNE Community	Upper North Arm/Corinella Segment
NOx	Nitrogen oxides
NSW	New South Wales
NSW EPA	NSW Environment Protection Authority
OEMP	Operational Environmental Management Plan
PAC	Protective Action Criteria
PAH	Polycyclic Aromatic Hydrocarbons
PEM	Protocol for Environmental Management
PFAS	Polyfluoroalkyl Substances
PJ	Peta Joules
PM	Particulate matter
PoHDA	Port of Hastings Development Authority
QRA	Quantitative Risk Assessment
RAP	Registered Aboriginal Party
SEPP (AQM)	State Environmental Protection Policy (Air Quality Management) 2001
SEPP (Waters)	State Environment Protection Policy (Waters) 2018
SEPP N-1	EPA Publication S31: State Environmental Protection Policy (Noise from Industry, Commerce and Trade) No. N-1
SIGTTO	Society of International Gas Tanker and Terminal Operators
SOx	Oxides of sulphur
STP	Sewage Treatment Plant
TAPM	The Air Pollution Model

Term	Description
TRG	Technical Reference Group
TWA	Time Weighted Average
VOC	Volatile Organic Compounds
VTS	Victorian Transmission System
WA	Works Approval

1.0 Primary information

1.1 Introduction

This document is an application on behalf of AGL Wholesale Gas Limited (AGL) to the Environment Protection Authority Victoria (EPA) for a Works Approval (WA) under section 19B of the *Environment Protection Act 1970 (Vic)* (EP Act) for continuous mooring of a Floating Storage and Regasification Unit (FSRU) at the Crib Point Jetty (Berth 2). Prior to FSRU operations commencing, a licence under section 20 of the EP Act will be required.

The FSRU would store and regasify imported Liquefied Natural Gas (LNG) and supply it to the gas distribution network via a new pipeline that would connect to the Victorian Transmission System (VTS). The FSRU is a component of the Gas Import Jetty and Pipeline Project (the Project). The Project seeks to establish a LNG import facility at Crib Point Jetty and an underground gas pipeline from Crib Point to Pakenham. This WA application relates solely to the proposed mooring and operation of the FSRU, and the proposed discharges from the FSRU. In accordance with the EP Act, an EPA Victoria discharge licence will be required prior to commencing FSRU operations.

An Environment Effects Statement (EES) has been prepared for the Project under the *Environment Effects Act 1978 (Vic)*. The EES has been prepared in accordance with the scoping requirements, risk assessments, relevant legislation, policy and guidelines and has been informed by the environmental risk assessments and specialist studies completed for the EES. This WA application has been informed by the EES and the supporting specialist studies prepared for the Project.

1.2 Company legal entity

AGL Wholesale Gas Limited (AGL) company details are provided in **Table 1** below. The Gas Import Jetty Works outlined in **Section 2.0** will be undertaken by AGL.

Table 1 AGL Company Details

	Details
Company Name	AGL Wholesale Gas Limited (AGL)
ACN	072 948 504
ABN	26 072 948 504
Registered Address	Level 24, 200 George Street, Sydney, NSW 2000
ASIC Extract	Provided in **Appendix A**
Application contact	Stuart Galway - Senior Manager Land & Approvals sgalway@agl.com.au

1.3 Application fee

Due to the complexity of the WA application, EPA has advised that the cost of the application fee is likely to be the upper limit fee. This equates to a WA application fee of $66,645.00.

1.4 Need for Works Approval

Under the *Environment Protection Act 1970* (EP Act), an occupier of scheduled premises likely to cause the discharge of waste to the environment must obtain a works approval. For the purpose of the EP Act, the FSRU is a ship which constitutes premises.

Scheduled premises are prescribed in the *Environment Protection (Scheduled Premises) Regulations 2017*. The FSRU is not included in an industry category as a scheduled premises, but due to the emissions to air (based on the emission inventory for the FSRU in AGL Gas Import Jetty Project Air

Quality Impact Assessment 29 August 2018), the Facility (FSRU only) is a scheduled premises as ***Other: L01 – General Emissions to Air***.

Schedule 1 of the *Environment Protection (Scheduled Premises) Regulations 2017* prescribes premises that discharge or emit, or from which it is proposed to discharge or emit, to the atmosphere at least:

- 100 kilograms per day of volatile organic compounds (VOC), or particulates, or SOx (oxides of sulphur) or NOx (nitrogen oxides); or
- 500 kilograms per day of Carbon Monoxide (CO).

NOx, CO, VOC and particulate emissions from the FSRU are predicted to equal or exceed the scheduled premises thresholds. Consequently, the FSRU requires a works approval and a licence under the EP Act.

This WA application is an application for a works approval for the continuous mooring of the FSRU at the Crib Point Jetty, having regard to its likely emissions and discharges during operation. Prior to operations commencing, a discharge licence for the operation of the FSRU will be required.

1.4.1 Utilities: K01 – Power stations

In addition, the FSRU could be included in scheduled category ***Utilities: K01 – Power stations*** which include premises that generate electrical power from the consumption of a fuel at a rated capacity of at least 5 megawatts (MW) of electrical power.

The proposed FSRU will be equipped with four dual-fuel reciprocating engines. The four engines drive gensets that provide electrical power for the equipment onboard the FSRU (e.g. driving pumps, gas compressors etc.) and for propulsion. All power generated will be generated and used onboard the FSRU for ship operations. No power will be exported from the FSRU to the electricity grid.

The generators onboard the FSRU comprise:

- One generator with 5,670 kilowatts (kW) of maximum electrical output
- Three generators with 7,580 kW of maximum electrical output per generator.

This equates to a total of 28.4 MW of electrical power from the four generators onboard the FSRU.

The power required for propulsion of the FSRU is approximately 20.6 MW. Although the maximum electrical power of all four engines combined is 28.4 MW, the FSRU will never generate and/or consume this maximum.

The FSRU is self-sufficient with regards to electrical generation. Connection to the electricity grid is not required to power any of the electrical facilities on board the FSRU. This removes the requirement for new or augmented electricity infrastructure that would otherwise be required.

Greenhouse gas emissions from the FSRU have been minimised through:

- the selection of engines for the proposed FSRU which are more efficient than the 2018 average efficiency for gas engine power generators
- the use of natural gas for power generation which has a lower greenhouse gas emissions intensity compared to other fuels
- the use of economisers to recover and use waste heat from flue gases.

Refer to **Section 8.3** for discussion on best practice for energy and greenhouse gas management.

Emissions to air will meet the *State Environment Protection Policy (Air Quality Management) 2001* design criteria at sensitive receptors. The engines of the proposed FSRU have low-NOx emissions technology. Refer to **Section 10.5** for discussion of best practice for air quality management.

2.0 Project Overview

2.1 Project background

AGL and APA Transmission Pty Limited (APA) propose to respectively establish a LNG import facility at Crib Point Jetty which includes the continuous mooring of a FSRU and an underground gas pipeline from Crib Point to Pakenham.

The FSRU will be situated at the existing Crib Point Jetty within Western Port, which is a large tidal bay opening into Bass Strait. The Port of Hastings is a commercial port within Western Port, with a maintained shipping channel and facilities at Stony Point Jetty, Crib Point Jetty and Long Island Point Jetty (which are managed by the Port of Hastings Development Authority (PoHDA)) and the BlueScope steel wharves.

Western Port is also designated as a wetland of international significance under the Ramsar Convention. The Western Port Ramsar site covers 59,950 hectares and is the third most important area for wading birds in Victoria.

The Project comprises two sets of works: the Gas Import Jetty Works (AGL) and the Pipeline Works (APA).

Key components of the Gas Import Jetty Works proposed to be undertaken by AGL include:

- the continuous mooring of a floating storage and regasification unit (FSRU) at Berth 2 of the existing Crib Point Jetty – the FSRU would store LNG and regasify LNG into natural gas
- jetty infrastructure on the Crib Point Jetty including marine loading arms (MLAs) and gas piping to transfer gas from the FSRU to the Crib Point Receiving Facility
- Crib Point Receiving Facility, including metering, odorant injection and nitrogen injection, which would be located on land adjacent to the Crib Point Jetty.

Key components of the Pipeline Works proposed to be undertaken by APA include:

- an underground bi-directional gas transmission pipeline approximately 57 kilometres long that would transport gas from the Crib Point Receiving Facility to the Victorian Transmission System (VTS) east of Pakenham
- the pigging facility at the Crib Point Receiving Facility to enable in-line inspections of the pipeline with a pipeline inspection gauge (pig)
- the above-ground Pakenham Delivery Facility to monitor and regulate the gas which would be located adjacent to the Pakenham East rail depot
- the below-ground End of Line Scraper Station (EOLSS) located at the connection point to the VTS north of the Princes Highway in Pakenham
- two above-ground mainline valves (MLVs) located at different points along the pipeline alignment to enable isolation of the pipeline in an emergency.

Construction and commissioning of the Project is expected to take 18 to 27 months. The Project life is anticipated to be approximately 20 years, which is the period of the transportation agreement between AGL and APA. The FSRU will have a design life in excess of 20 years.

The Project and its key components are shown in **Figure 1**.

The Pipeline Works to be undertaken by APA and the Crib Point Receiving Facility and jetty infrastructure components of the Gas Import Jetty Works are not a part of the scope of this WA application as these components do not require WA. This WA application relates to the FSRU only.

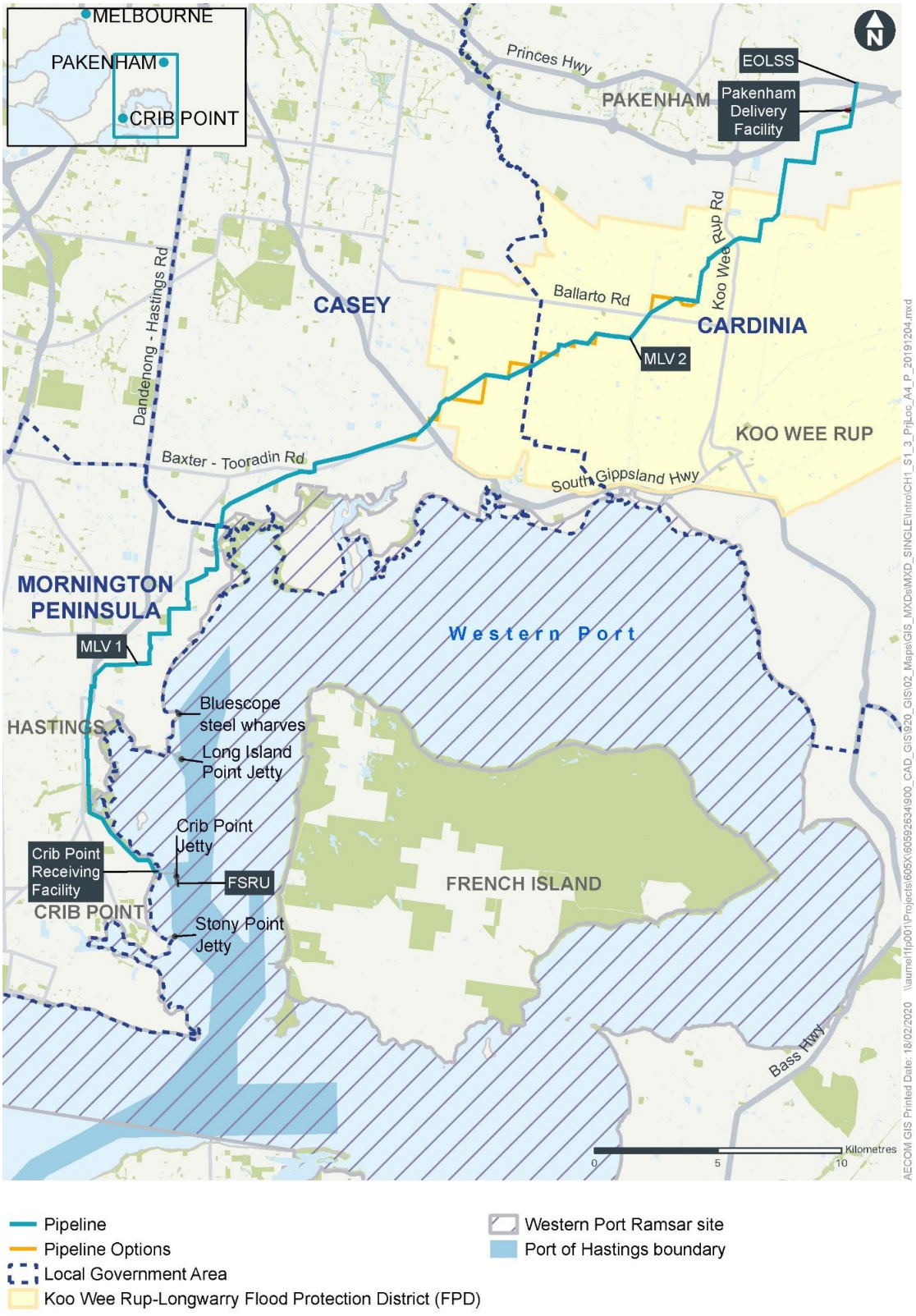


Figure 1 Gas Import Jetty and Pipeline Project

2.2 Scope of Works Approval application

When in operation, it is expected that the FSRU will receive LNG from ships known as LNG carriers. It is intended that the FSRU, when commissioned and in operation, will be subject to an agreement between AGL and a third party operator experienced with floating LNG import facilities. The third party operator will manage operations on board the FSRU and will require a licence from the EPA prior to the commencement of operation of the FSRU. Accordingly, prior to the issue of a licence to the third party operator, the third party operator will need to satisfy the EPA that it meets the criteria for grant of a licence, including being a fit and proper person. The third party operator will be the "occupier" of the FSRU, as defined under the *Environment Protection Act 1970 (Vic)*, and will be required to comply with the obligations under that Act.

Hoegh LNG is likely to be the third party operator, subject to finalisation of the commercial arrangements. Hoegh LNG is an industry leader in the development, ownership, and operation of modern FSRUs globally. The LNG carriers will be operated by contracted third-party LNG ship owners.

The FSRU will store approximately 140,000 cubic metres (m^3) to 170,000 m^3 of LNG and regasify it as required to meet gas demand. This amount of LNG is equivalent to around four petajoules (PJ) of gas. The gas will be transferred under pressure from the FSRU to the Crib Point Receiving Facility via Marine Loading Arms (MLAs) and gas piping that will be mounted on the jetty. The MLAs will be fitted with a quick connect/disconnect isolation and in the event the FSRU is required to disconnect from the jetty, the MLA will vent, and the MLA will be safely disconnected from the FSRU. Note that the MLAs and the Crib Point Receiving Facility are not a part of the scope of the WA application and this information is provided for full context of the operations related to the FSRU.

The FSRU will initially receive approximately 45 PJ of LNG per annum (approximately 12 LNG carriers per year). The amount of LNG could increase to 160 PJ per annum (approximately 40 LNG carriers per year) depending on demand in the gas market. The number of LNG carriers will also be dependent on their storage capacity that will vary between 140,000 and 170,000 m^3.

Waterside restricted zones (exclusion zones) are currently in place within 100 metres of the Crib Point Jetty. For this development, the waterside restricted zone is proposed to be increased to 200 metres to the east of Berth 2 and also to the south is shown in **Figure 2**, subject to approval of the maritime security plan by the Department of Aviation and Maritime Security Division within the department of Home Affairs under the *Maritime Transport and Offshore Facilities Security Act 2003 (Cth)*. Access to the waterside restricted zone is controlled and unauthorised entry is an offence.

A Works Approval is required for the FSRU only and therefore the boundary of this WA application will include the FSRU up to the connection flanges to the wharf (refer to **Figure 2**). Further detail on the need for a Works Approval is provided in **Section 1.4** and further detail on the FSRU process operation is provided in **Section 7.2**.

The surrounding land use and nearest sensitive receptors to the proposed FSRU location at Berth 2 of the Crib Point Jetty are summarised in **Table 2**.

Table 2 Summary of surrounding land use and sensitive receptors

Direction		Sensitive receptors
North		• United Petroleum –Crib Point Jetty Berth 1 located 370 m north of Berth 2 is used as a working industrial site by United Petroleum • Within Western Port Ramsar Site
South		• Within Western Port Ramsar Site • Stony Point Ferry Terminal – 2 km
East		• Within Western Port Ramsar Site • French Island – 5 km
West	North west	• Woolley's Beach – 900 m • HMAS Otama Lookout Beach – 1 km • Victorian Maritime Centre – 1.1 km • Residential area – 1.5 km

Direction		Sensitive receptors
		• Jacks Beach – 1.9 km
	West	• Woolley's Beach Reserve – 900 m
	South west	• Residential area – 1.8 km

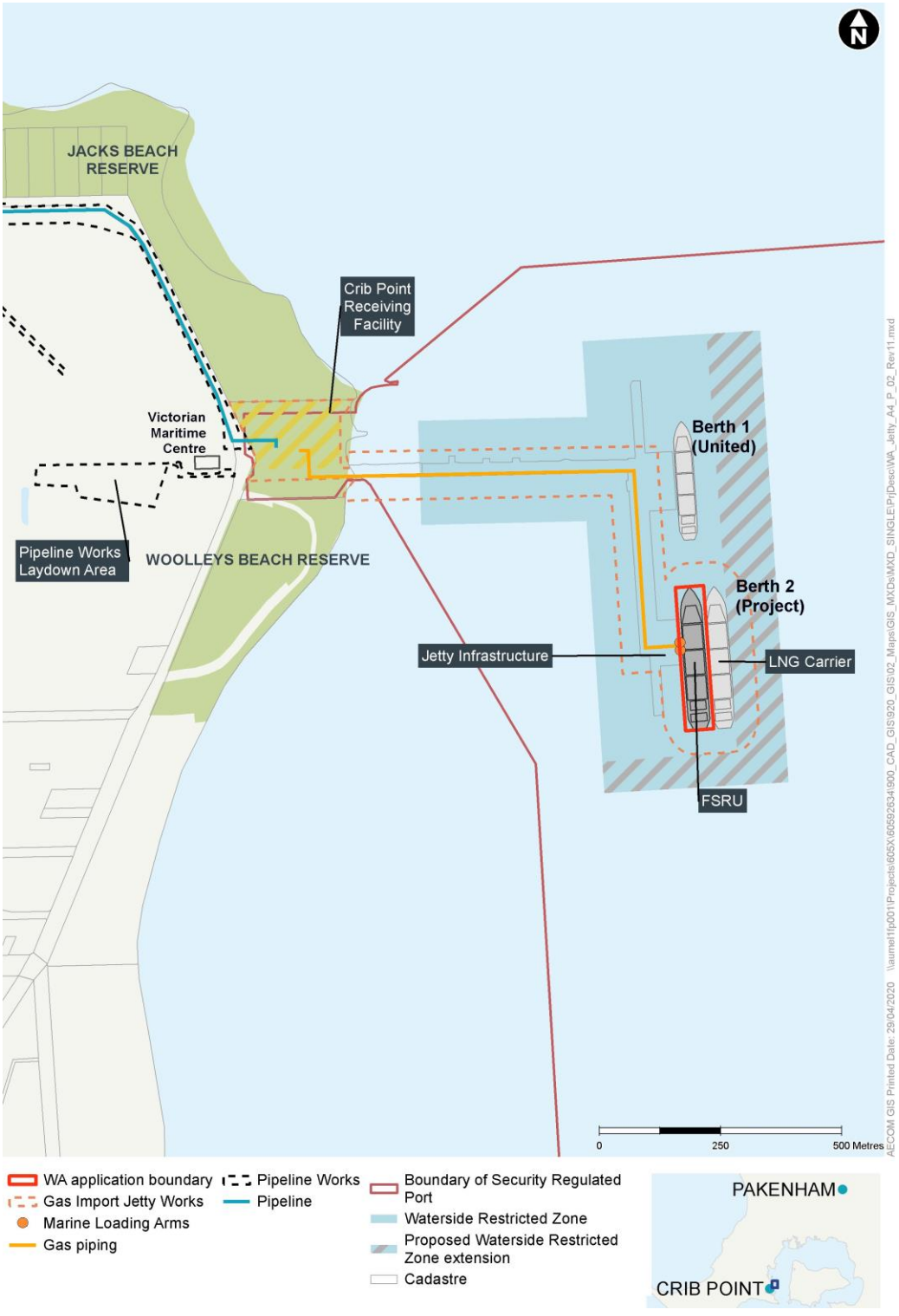


Figure 2 WA application boundary

3.0 Land use

3.1 Planning and other approvals

In addition to a WA under the EP Act for operation of the FSRU, AGL must obtain a number of statutory approvals for the Gas Import Jetty Works (including the FSRU) at the state and Commonwealth levels. A summary of the approvals is provided in **Table 3**.

Table 3 State and Commonwealth Approvals for the Gas Import Jetty Works

Jurisdiction	Legislation	Regulator	Approval
Commonwealth	*Environment Protection and Biodiversity Conservation Act 1999*	Commonwealth Minister for Environment and Energy	Approval of the Gas Import Jetty Works controlled action
State	*Aboriginal Heritage Act 2006*	Aboriginal Victoria (AV) and relevant Registered Aboriginal Party (RAP)	An approved Cultural Heritage Management Plan (CHMP) 16300
State	*Environment Protection Act 1970*	Environment Protection Authority Victoria (EPA)	Works Approval – FSRU only, including a discharge licence
State	*Marine and Coastal Act 2018*	Minister for Energy, Environment and Climate Change	Consent for the components of the Gas Import Jetty Works on marine and coastal Crown land (including the continuous mooring of the FSRU)
State	*Planning and Environment Act 1987*	Minister for Planning	Planning Scheme Amendment to the Mornington Peninsula Shire Planning Scheme to include an Incorporated Document which will facilitate use and development of the Gas Import Jetty Works (including the continuous mooring of the FSRU)
State	*Gas Safety Act 1997*	Energy Safe Victoria (ESV)	Gas Safety Case for natural gas infrastructure under Part 3 for Crib Point Receiving Facility and gas piping on the jetty (Gas Import Jetty Works excluding the FSRU)
State	*Occupational Health and Safety Act 2004* (potential amendment to apply to the FSRU)	WorkSafe Victoria	Preparation of Safety Case or a document that is consistent with a safety case of this kind[1] as if the OHS Regulations apply to the FSRU

Jurisdiction	Legislation	Regulator	Approval
State	*Flora and Fauna Guarantee Act 1988*	Department of Environment, Land, Water and Planning (DELWP)	A permit to take native flora and fauna species listed under the *Flora and Fauna Guarantee Act 1988*

[1] The FSRU is currently not classified as a Major Hazard Facility (MHF) under the Occupational Health and Safety Act 2004 (OHS Act) and Occupational Health and Safety Regulations 2017 (OHS Regulations). WorkSafe Victoria is considering a change to the OHS Regulations that would classify the FSRU as a MHF for the purposes of the OHS Act. While the MHF laws do not currently apply, AGL have committed to developing a safety case or a document that is consistent with a safety case of this kind.

3.2 Choice of location

By way of background information, eight potential sites were identified and initially evaluated by AGL as potential locations to import LNG into south-eastern Australia which included the following:

- Port of Newcastle, Port Botany and Port Kembla in New South Wales (NSW)
- Corio Quay Precinct, Port of Melbourne and Crib Point in Victoria
- Port Adelaide in South Australia
- Bell Bay in Tasmania.

The eight sites were assessed against initial screening criteria, which included the proximity of the location to hazards, buildings and nearby activities, the availability of berths with suitable capacity, the ease of access into channel and depth of water in the area and the separation distance from the shipping channel.

The initial screening assessment resulted in the identification of three shortlisted options. The other sites evaluated were ruled out due to several factors, including the lack of suitable berths, shipping channel access and operating congestion in existing shipping channels and limited existing gas transmission pipeline network to deliver gas to the market effectively and in a timely manner. The three shortlisted locations identified were:

- Port Adelaide in South Australia
- Port Kembla in NSW
- Crib Point in Victoria.

An assessment of operability was also undertaken to consider the ability of the berthing location to keep the FSRU in a safe and reliable functioning condition given existing operational requirements. A summary of the findings from the short-listed options assessment is included in **Table 4** .

Table 4 Summary of short-listed options assessment and assessment of operability

Location	Advantages	Disadvantages
Port Adelaide	• Space available to construct a new berth • Available land in the port precinct for facilities at the port and an associated pipeline • Access to existing gas pipelines via a new six kilometre pipeline	• Extensive dredging required (in excess of 2,000,000 m^3 of dredge spoils expected) with potential to impact nearby dolphin breeding grounds

Location	Advantages	Disadvantages
Port Kembla	• Available berth with berthing dolphins, and capacity for further facility upgrades • Land available near berth for facilities at the port and an associated pipeline • A connection point available to Eastern Gas Pipeline	• Extensive dredging required (estimated at 600,000 m^3 of dredge spoils) • Potential for contaminated dredge spoils
Crib Point	• An existing jetty with berth capacity and suitable size to accommodate the FSRU • Land available for facilities at port • Proximity to AGL's largest gas demand centre	• Existing jetty located within a Ramsar site • Minor bed levelling works required (sweeping)

Based on the short-listed options assessment and the assessment of operability, the preferred option for the Project was selected as Crib Point in Victoria. This option makes use of the existing berth in the Port of Hastings, and other available infrastructure in a contextually appropriate setting (Port zoning and adjacent to the former BP refinery land). Potential environmental impacts associated with establishment of infrastructure would be minimised due to not requiring dredging and the use of an already highly disturbed landside footprint. However, this location is also a Ramsar site, and as such, requires development to be particularly sensitive to its environs. Under the *State Environment Protection Policy (Waters) 2018* (SEPP (Waters)), the Western Port Ramsar site is listed under Schedule 5 as an area of high conservation value.

4.0 Environmental performance and track record

AGL regards sound environmental management and protection as an integral part of its business and of playing its part in the community and is committed to excellence in this area of activity. This commitment is reflected in the AGL Group Health, Safety and Environment Policy.

The AGL Group has over 180 years of history in the energy industry operating across the supply chain with investments in energy retailing, thermal electricity generation and renewable projects. The AGL Group is one of Australia's largest retailers of gas and electricity with more than 3.6 million customers in Victoria, New South Wales, South Australia, Western Australia and Queensland.

AGL's businesses are subject to a range of environmental laws and regulations as well as project and site-specific environmental permits and approvals issued at both the Federal and State Government levels. There are no past or present proceedings under a Commonwealth, State or Territory law[1] associated with AGL Wholesale Gas Limited[2]. Recent information on AGL Group's environmental performance is available in the sustainability report. A summary of AGL Group's environmental performance during FY19 is also available in the Annual Report. This information can be found at the following links respectively:

- *https://www.agl.com.au/about-agl/sustainability/sustainability-performance*
- *https://www.2019annualreport.agl.com.au/business-value-drivers/environment*
- *https://www.2019annualreport.agl.com.au/directors-report/other-required-disclosures/environmental-regulation*.

[1] Specifically, AGL Wholesale Gas Limited has not been found guilty of a relevant offence as defined in section 20C of the EP Act 1970 either within Victoria or for any equivalent offence outside of Victoria.
[2] This includes directors and any person who is involved in the management of AGL Wholesale Gas Limited.

5.0 Supporting EES documentation

This WA application has been prepared in parallel with the preparation of the EES and associated documentation. As discussed, and agreed with EPA, this WA application has been prepared based on information in the EES and the supporting specialist studies prepared for the Project.

The EES chapters and associated specialist studies that were used to prepare this WA application include the following:

- Chapter 26: *Stakeholder and community*
- Technical Report A: *Marine impact assessment*
- Technical Report E: *Contamination and acid sulfate soils impact assessment*
- Technical Report F: *Greenhouse gas impact assessment*
- Technical Report G: *Air quality impact assessment*
- Technical Report H: *Noise and vibration impact assessment*
- Technical Report K: *Safety, hazard and risk assessment*
- Attachment IV: *Climate change risk report*

These reports are provided in **Appendix B**.

6.0 Community engagement

This section briefly sets out the key stakeholder engagement and consultation that has been undertaken to support the preparation of the EES and, more broadly, to assist in the development of the Project. Further information about the consultation activities undertaken and planned for the Project are provided in EES Chapter 26: *Stakeholder and community* (refer to **Appendix B**).

Consultation with key stakeholders including people living, working, recreating and visiting near the Project Area, community groups and regulatory authorities has been an ongoing part of the Project since July 2017. AGL and APA have prepared a joint communications and consultation plan for the EES, outlining the opportunities and approaches for community engagement during the preparation of the EES.

In addition, an overarching EES Consultation Plan was prepared and can be found on the Department of Environment, Land, Water and Planning (DELWP) website here: https://www.planning.vic.gov.au/environment-assessment/browse-projects/projects/crib-point.

6.1 Communication and consultation

Stakeholder engagement activities for the Project consist of several phases:

- Phase 1: Proposal (June 2017 – September 2018)
- Phase 2: Post EES Decision (October 2018 – January 2019)
- Phase 3: EES Preparation (January 2019 – early/mid 2020)
- Phase 4: EES Public Exhibition and Panel Hearings (early/mid 2020 – early 2021)
- Phase 5: Project construction (early 2021 – early 2022)
- Phase 6: Project operation and maintenance (early 2022 onwards)

An overview of the stakeholder engagement activities that were conducted during the early phases as well as stakeholder engagement activities that are planned for the current phase (Phase 3) and upcoming phase 4 is provided in **Sections 6.1.1** to **6.1.4**.

6.1.1 Phase 1: Proposal (2017 – September 2018)

Phase 1 of the engagement process consisted of raising public awareness and understanding of the Project. Conducted from July 2017 to September 2018, this phase involved a variety of communication and engagement activities, which included stakeholder meetings, community presentations, launching the Project website and email updates.

6.1.2 Phase 2: Post EES Referral Decision (October 2018 – January 2019)

Engagement during this period aimed to introduce the EES process and inform the community about regulatory commitments.

In December 2018, AGL held information sessions in Cardinia and Hastings with around 60 people attending in total. The objectives of these sessions were to:

- Inform the community of the EES process
- Promote the opportunity to comment on the Minister's draft Scoping Requirements
- Provide details of the regulatory agencies which would be represented on the Technical Reference Group (TRG) for the Project
- Collect preliminary feedback on demographics, potential impacts of the Project and preferences for future engagement activities.

DELWP representatives attended the sessions and answered questions regarding the regulatory process. In total, 50 submissions were received in relation to the Minister's draft Scoping Requirements, which were then finalised in January 2019.

AGL and APA's EES Consultation Plan was posted on the DELWP website and outlined the engagement activities that were committed to throughout the EES process.

6.1.3 Phase 3: EES Preparation (January 2019 – early/mid 2020)

During Phase 3, the focus of community engagement activities has moved from discussing the Project and EES process, to sharing the outcomes of key investigations and technical studies performed for the EES. AGL has introduced early EES findings to the community for comment before the EES is placed on public exhibition (planned for in mid-2020).

This phase involves a variety of communication and engagement activities, with the specific objectives of:

- Gathering further feedback from the community on the Project and technical studies to inform the development of the EES
- Informing the community of regulatory commitments to complete an EES
- Continuing engagement with Gas Import Jetty Works near neighbours and other stakeholders
- Reporting back to key stakeholders and the wider community on the engagement activities and how their feedback was used.

A summary of the engagement activities that have occurred during Phase 3 to date in relation to the FSRU is provided in **Table 5** below.

Table 5 Summary of engagement activities during Phase 3: EES Preparation to date (January 2019 – early/mid 2020)

Activity	Results	Target group
Advertising	Two half-page advertisements in several editions of six local newspapers with a combined readership of 161,000. Letterbox drop of a flyer across the Project area to 30,000 residents and businesses.	Wider community
E-news	Seven emails sent (397 AGL subscribers)	Near neighbours and landholders, interest and community groups, recreational users and the wider community
Government briefings	18 Council briefings held, several emails sent to four government representatives and three letters received from two government representatives.	Local councillors and council officers within Project Area, state MPs and federal MPs including Neale Burgess MP (Hastings); Greg Hunt MP (Flinders); Chris Brayne MP (Nepean); Jordan Crugnale MP (Bass)
Fact sheets and publications	Seven EES factsheets Two publications	Wider community
Online discussion forum	55 participants posted over 185 comments	Capturing interested people beyond the Project area. Demographic that could not attend face-to-face engagement activities.
Online interactive feedback map (Social Pinpoint)	20 comments received	Community members with geographical questions/concerns. Demographic that could not attend face-to-face engagement activities.

Activity	Results	Target group
Project telephone hotlines	Over 35 phone enquiries (AGL and APA combined)	Wider community
Project email addresses	Over 100 email enquiries (AGL and APA combined)	Wider community
Proposed Community Pavilion	Opening mid-2020, subject to COVID-19 restrictions	Wider community in Hastings and surrounding suburbs
Surveys	Two surveys online and hardcopy available at face-to-face engagement activities 68 survey responses collected	Community members attending face-to-face engagement activities or wanting to provide detailed feedback online
TRG sessions	12 meetings held	Agencies and Councils have been engaged through the Technical Reference Group and through individual meetings and workshops, and provided extensive review and advice which has informed the preparation of the Project and EES process.
Webpages	AGL and APA joint EES webpage, hosted on AGL website, linking to two Project webpages on AGL and APA websites respectively AGL Project webpage – 33,898 unique visits and average time on page 4:27 minutes *(8 October 2018 – 31 March 2020)* AGL and APA joint EES webpage – 3,017 unique visits and average time on page 10:57 minutes *(8 October 2018 – 31 March 2020)*	Wider community
Workshops	Two workshops held in Hastings 13 people attended in total	Affected stakeholders such as the 'near neighbours' and local groups.

6.1.4 Phase 4: EES Public Exhibition and Panel Hearings (mid 2020)

As part of the EES process, the EES and WA application, together with the Pipeline Licence Application and Planning Scheme Amendment, will be placed on public exhibition and public submissions will be received by the appointed inquiry advisory committee.

The WA application will be advertised jointly with the EES in accordance with section 20AA of the EP Act.

Submitters will have the opportunity to make written submissions and to present a submission to a public hearing addressing the WA application.

6.2 Consultation findings and response

In total, 1027 community feedback responses were collected between 8 October 2018 and 31 March 2020. Queries and community feedback received have been categorised into eleven themes. The eleven themes have been ordered from one to eleven, high to low, based on the frequency of mention during the engagement period.

1. Marine impacts
2. Consultation
3. Land impacts
4. Safety
5. Project rationale
6. Regulatory Approvals
7. Climate Change
8. Community impacts
9. Noise or vibration
10. Construction
11. Visual Impact

Further information about the key consultation findings and the manner in which they have been responded to during the EES process are provided in EES Chapter 26: *Stakeholder and community*.

7.0 Process and integrated environmental assessment

7.1 Existing conditions

There are no existing AGL operations at the proposed Project Area and the proposed works are for a new development.

Crib Point Jetty is an existing operational industrial jetty within Western Port that has been utilised for petroleum related activities for more than 50 years. It is owned and managed by the Port of Hastings Development Authority (PoHDA). The area is a diverse but compact marine environment. It comprises vast intertidal mudflats with saltmarsh, seagrass and mangrove habitats as well as steep subtidal sloping banks with seagrass and deep channels that connect the north of the Western Port Bay with oceanic waters of the Bass Strait in the south. These characteristics contribute the listing of a large part of Western Port as a Ramsar wetland. The Ramsar wetland covers an area of 59,950 hectares of Western Port including Crib Point.

Western Port receives approximately 150 commercial vessels annually, based on data from previous years, and over 100 of these were oil and gas tankers. The Crib Point Jetty is located on the shores of a deep-water commercial shipping channel with a wide stretch of water between the jetty and French Island (also known as the swing basin). Western Port is a naturally deep-water port within a sheltered bay, with a maintained berth depth of approximately 13 metres at the lowest tide level, with an additional three metres during high tides.

The Crib Point Jetty has two berths (Berth 1 and Berth 2) that are located adjacent to each other. Berth 2 is currently not in use and is of suitable size to moor a vessel similar in length to a FSRU and double berth another vessel, around 300 metres in length, alongside the moored FSRU. The berthing locations are within a sheltered location allowing safe ship to ship transfer when double berthed during changing wave conditions. The Crib Point Jetty has previously been used for ship-to-ship transfers of crude oil.

7.2 Floating Storage and Regasification Unit (FSRU)

The FSRU is approximately 300 metres long and 50 metres wide with an operational draft of 12 metres (the distance between the surface of the water and the lowest point of the vessel).

The FSRU is a double-hulled ocean-going vessel with four cargo tanks suitable for storing LNG at very low temperatures (-163 ºC). The cargo tanks are lined with specialised membranes to allow the storage of chilled LNG. The cold temperature and insulation will keep the LNG cargo in a liquid state until it is required for regasification.

The FSRU has the capability to receive LNG from an LNG carrier, return the LNG to a gaseous state using the onboard regasification unit ('regasification'), and transfer the gas into the gas piping on the jetty. Regasification would use the ‘open loop mode’, meaning that seawater would be used to warm the LNG into a gaseous state. The FSRU would also be able to operate in closed loop regasification mode and combined loop regasification mode.

The FSRU will be continuously moored at Berth 2 of the Crib Point Jetty. The FSRU will receive LNG from LNG carriers. Arriving LNG carriers will berth north immediately alongside the FSRU as shown in **Figure 3**. Tugboats contracted by the PoHDA will be required to moor the LNG carrier safely next to the FSRU.

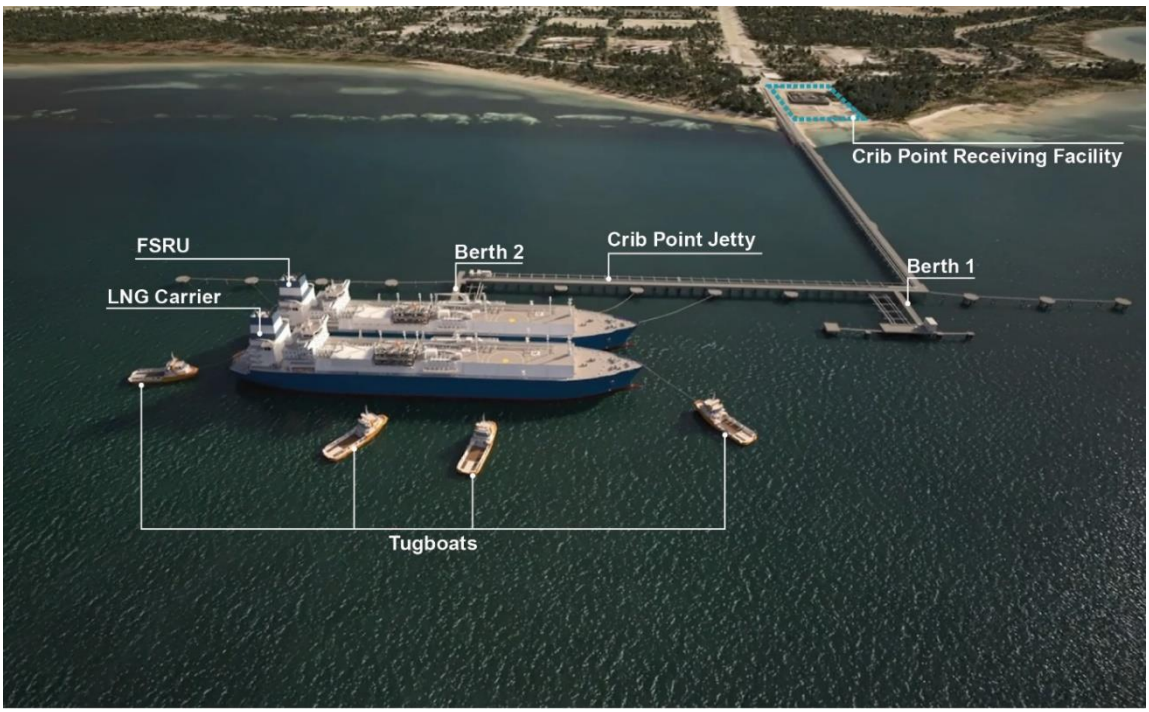


Figure 3 Visualisation of FSRU and LNG carrier berthed side by side at Crib Point Jetty

Up to 40 LNG carriers per year will typically tether next to the FSRU for up to approximately 36 hours per LNG carrier, while LNG is transferred into the cargo tanks of the FSRU. Four 10-inch purpose-built flexible cryogenic hoses on single reducers will be used to transfer the LNG from the LNG carriers to the FSRU. Vapour return from the cargo tanks will occur via two 10-inch hoses connected by a y-piece to the vapour manifold. LNG may be reloaded back from the FSRU to an LNG carrier if this ever became necessary. This will generally only be required if the LNG is not being used in the market, to avoid the LNG composition changing.

Once the transfer of LNG is complete, the LNG carrier will depart from alongside the FSRU with the assistance of tugboats.

Table 6 provides a summary of key data for the FSRU.

Table 6 Summary of key data for the FSRU

FSRU key data	
FSRU length	Approximately 300 m
FSRU breadth	Approximately 50 m
Number of LNG cargo tanks on the FSRU	4
FSRU LNG storage capacity	approximately 170,000 m^3
Temperature of LNG storage	-163 ˚C
Number of LNG carriers per annum	Base case of 12, which could increase to approximately 40
Energy equivalent of LNG per annum	45 - 160 PJ
Number and diameter of flexible hoses to receive LNG	4 x 10 inch
Number and diameter of flexible hoses to return vapour	2 x 10 inch
Number of engines	4 x dual fuel engines
Number of regasification trains	3

FSRU key data		
Maximum output of each regasification train		250 million standard cubic feet per day (mmscf/d)
FSRU gas send out capacity		Maximum output of 750 million standard cubic feet per day (mmscf/d) (3 trains)
Chlorine concentration in seawater at point of discharge		100 parts per billion or 0.1 milligrams per litre (mg/L) at the point of discharge from the FSRU and before any mixing with seawater
Open loop regasification mode	seawater intake and discharge volume	1 train – 156 ML/day 2 trains – 312 ML/day 3 trains – 468 ML/day
	seawater intake velocity	< 0.15 m/s
	seawater discharge velocity	≥ 5 m/s
	temperature difference of seawater at discharge point	No more than 7 ˚C below ambient seawater temperature
	Number of seawater discharge ports	6
Closed loop regasification mode	Seawater intake volume	Approximately 500 m^3 Cooling water for engines and auxiliary machinery – 184,000 m^3/day Excluding cooling of freshwater generator and intermittent flows relating to ballast water, water curtain and fire testing water
	Number of gas-fired boilers	Up to 3

7.2.1 Regasification modes

The FSRU converts stored LNG into natural gas via a process called regasification using an onboard regasification unit. A heat-exchanger is used as an interface to transfer heat from a heat source to the LNG in the regasification train.

Further details about the different modes of regasification that can be used on the FSRU are provided in **Section 7.2.1.1** to **7.2.1.3**.

Note that the FSRU can switch between different regasification modes and have all regasification trains operating in the same regasification mode, however, it is not possible to run regasification trains in different regasification modes simultaneously. Change over from one regasification mode to another is not instantaneous and there will be no send out during the changeover period.

7.2.1.1 Open loop mode

The FSRU regasification unit would use open loop to regasify LNG under normal operations. In open loop regasification mode, seawater would be continuously drawn into the FSRU through seawater inlets on the side of the FSRU and circulated through the heat exchangers. The heat exchangers rely on two phases of heat exchange process:

- between seawater (as the heat source) and an intermediate fluid (propane)
- between propane and LNG.

Circulated seawater would be continuously discharged from the FSRU. The discharged seawater used in regasification would be up to 7 ºC below ambient seawater temperature, before any mixing.

In open loop regasification mode, cooling water for the engines and auxiliary machine systems would be redirected to the open loop regasification cycle instead of being directly discharged to Western Port.

Figure 4 provides a simplified diagram of open loop regasification.

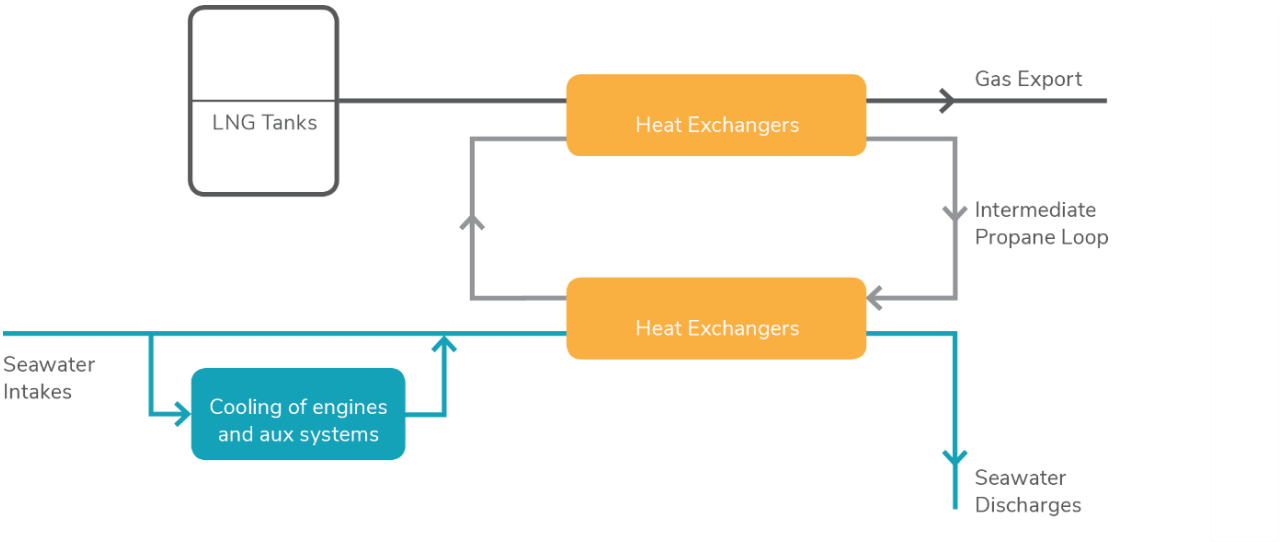


Figure 4 Open loop regasification process

All the seawater pumps onboard the FSRU are fixed speed. Pumps would be turned on or off as required based upon cooling/heating demand onboard the vessel. While the gas production rate is variable (the rate at which the onboard regasification unit converts stored LNG into gas), the required water flow used to heat the LNG is dependent on the number of regassification trains running. **Table 7** shows the maximum seawater flow rates for open loop regasification (m^3/day) based on the number of regasification trains operating. While the water flow demand may be less based on operations, the maximum flow rate has been used throughout the EES assessment process as a predicted worst-case seawater flow scenario.

Table 7 Maximum seawater flow rates for open loop regasification

Number of regasification trains in operation	Gas production rate (mmscf/day)	Number of pumps in operation	Maximum seawater flow rates in the open loop regasification system (m^3/day)
1	50–250	2	156,000
2	250–500	4	312,000
3	500–750	6	468,000

Seawater intakes will be located on either side of the FSRU and will be at least two metres from the surface to avoid entrainment of surface-associated biota and drifting debris and at least three metres above the seabed to minimise sediment and marine species near the seabed from being drawn into the FSRU. The seawater intake velocity will be limited to less than 0.15 metres per second to allow mobile marine biota to swim away and the seawater intakes will be fitted with a mesh screen with bar grills. These screens will typically have 100 millimetre horizontal by 100 millimetre vertical spacing to minimise the risk of intake of marine biota and debris.

Following its use in the heat exchangers, seawater will be discharged from the FSRU back into the marine environment, initially up to 7°C below ambient seawater temperature, prior to any mixing.

To optimise dilution of the seawater discharge from the FSRU and to minimise thermal differences, a six discharge port configuration has been selected. The six discharge ports will be located above the seawater inlets and will be spaced at minimum distance of 10 metres. Two discharge ports will be used per operating regasification train. Seawater will be discharged horizontally at a velocity of no less than 5 metres per second to facilitate mixing of seawater.

In addition to seawater used for regasification, seawater is required for cooling of the engines and auxiliary machines in open loop mode. This seawater is reused in the regasification process and discharged back into the marine environment through the open loop heat exchange process. In addition to the six seawater discharge ports for regasification water, several auxiliary discharge ports would be situated near the FSRU engine room, including for cooling water and ballast water as is typical for ocean-going vessels. Further detail about seawater use is discussed in **Section 9.0**.

A simplified diagram of the proposed seawater intake and discharge configuration in open loop regasification mode is shown in **Figure 5**.

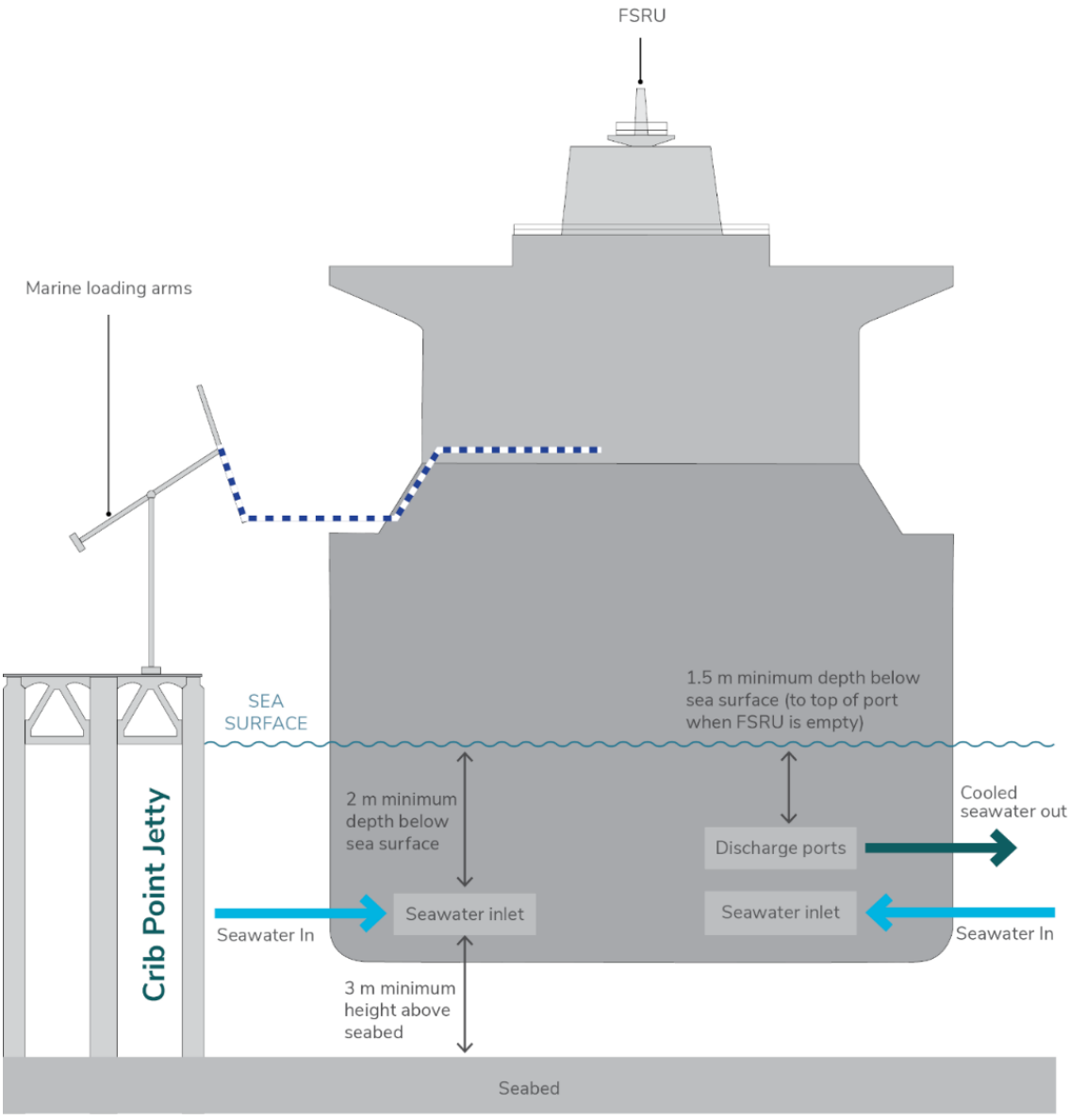


Figure 5 Open loop regasification seawater intake and discharge (not to scale)

7.2.1.2 Closed loop mode

The closed loop mode involves a single intake of seawater (approximately 500 cubic metres) to fill the piping and once filled, the seawater intake and discharge ports will be isolated, and the seawater circulated within a closed loop. Seawater cooled in the heat exchanger is then reheated by steam from gas-fired boilers and continually circulated in the process, instead of being discharged from the FSRU as per the open loop mode. Refer to **Figure 6** for a simplified diagram of how the closed loop regasification mode operates.

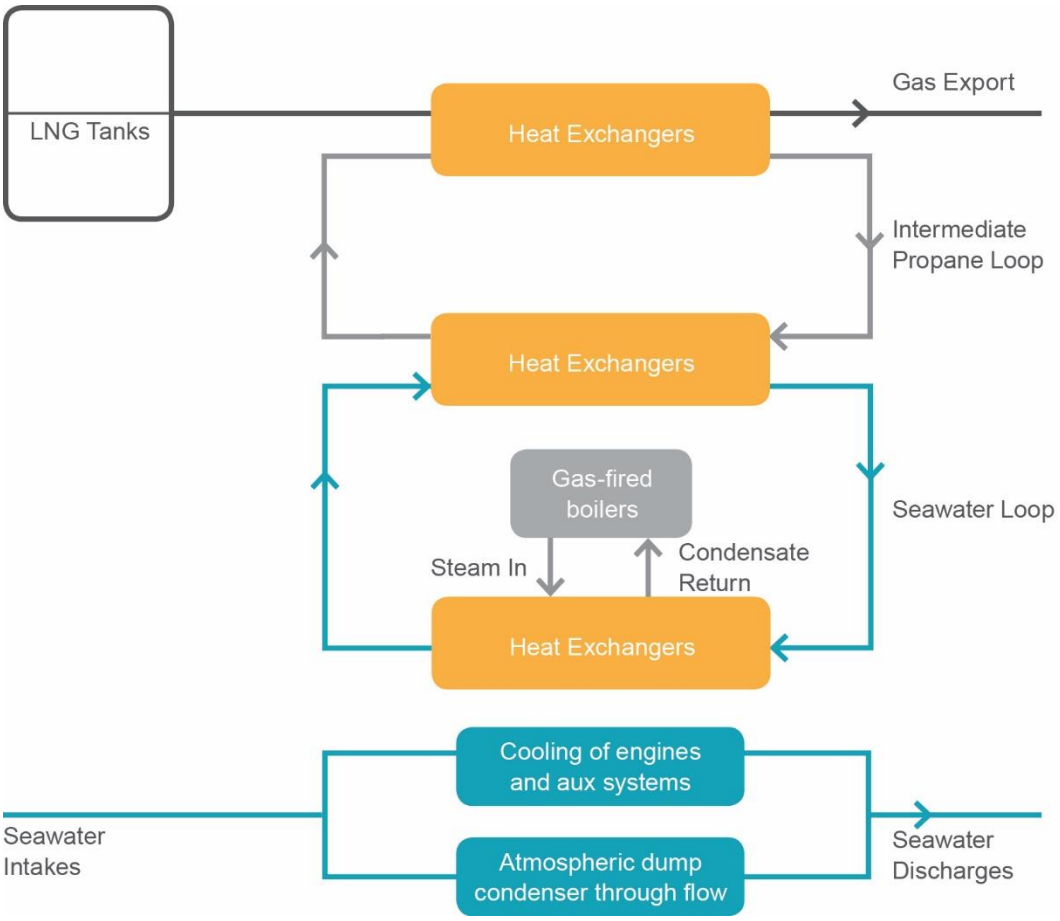


Figure 6 Closed loop regasification process

In addition to seawater used for regasification, seawater is required for cooling of the engines, auxiliary machines and the atmospheric dump condenser in closed loop mode. This seawater is continuously discharged back into the marine environment following its use. Further detail about seawater use is discussed in **Section 9.0**. Seawater flow rates (intake and discharge) in the closed loop mode are shown in **Table 8**. Under closed loop regasification mode, seawater used for engine cooling would be discharged at the rear of the FSRU.

The seawater used in the closed loop system will be discharged back to the marine environment when maintenance is required or if the system is to be switched to open loop mode. Discharged seawater from the closed loop process would be around 5 °C warmer than the ambient Western Port water temperature.

Table 8 Seawater flowrates for closed loop regasification

Seawater usage in closed loop regasification mode	Maximum seawater flow rates in closed loop regasification mode [1] (m^3/day)
Cooling of engines	58,560
Cooling of auxiliary machinery systems	45,840
Cooling of atmospheric dump condenser	80,400
Total (m^3/day)	**184,800**

Table note:
1. excluding cooling of freshwater generator and intermittent flows relating to ballast water, water curtain and fire testing water.

An atmospheric dump condenser is required on the FSRU to remove the energy from any excess steam generated by the FSRU boilers. In normal operation, when in closed loop mode, there is no excess steam and water runs through the atmospheric dump condenser without any change in temperature. However, if there is an unforeseen operational upset that causes a regasification train to shutdown unexpectedly, then the atmospheric dump condenser is used to safely remove the energy of the excess steam until the system is fully shutdown. The atmospheric dump condenser is also used to remove the heat from burning any excess boil-off gas in the regasification boiler if the minimum send out (MSO) compressor cannot be used due to maintenance or any unexpected outage.

7.2.1.3 Combined loop mode

In addition to being able to operate in open loop and closed loop regasification modes, the FSRU has been designed to operate in what is termed combined loop mode. The combined loop mode operates similar to open loop mode, however, seawater is heated via steam from gas-fired boilers prior to reaching the regasification system on the FSRU. The seawater is continuously drawn into the FSRU through seawater inlets and the seawater is heated by heat exchange with steam. Seawater use associated with combined loop mode regasification is the same as seawater use for open loop regasification shown in **Table 7**.

The purpose of combined loop mode is to add additional heat to the seawater to improve operational efficiency with respect to regasification when the water temperature is close to 10ºC or below. Combined loop mode may be required during winter due to the seawater temperature being as low as 11ºC in Western Port.

7.2.2 Proposed FSRU operating mode and parameters

The EES has assessed the significance of potential adverse impacts and environmental risks of operating in open and closed loop modes for a range of operating scenarios. These have been assessed in consideration of key requirements and objectives under statutory provisions (such as toxicant default guideline values for protecting aquatic ecosystems) and Project-specific performance criteria where statutory criteria are not available.

The purpose of assessing open and closed loop was to inform the selection of the FSRU regasification mode and the development of a set of proposed operating parameters for the FSRU that would:

- ensure the ability of the Project to provide gas supply certainty and security for gas customers in south-eastern Australia
- meet the relevant environmental evaluation objectives as established in the scoping requirements for the EES.

Based on the EES investigations, open loop regasification mode is the proposed operational mode for the FSRU. The main benefit of the open loop regasification mode is that seawater from Western Port can be used by the onboard regasification plant on the FSRU to heat the LNG. This is an efficient and readily available means of heating the LNG without using additional fuel for gas fired boilers to generate heat for LNG vaporisation. Greenhouse gas emissions from open loop mode are substantially less than closed loop (see **Section 8.0**), and other emissions during operation of the

FSRU including noise, air and discharges to marine waters have been assessed as having acceptable and low risk impacts.

Closed loop regasification could be used as an alternative to open loop regasification mode, however open loop is the preferred operation mode for the Project. The seawater flows associated with closed loop regasification are shown in **Table 8**.

Combined loop regasification mode would be used when the water temperature is close to 10ºC or below to improve operational efficiency with respect to regasification. This mode is unlikely to be used for more than 30 days during winter in any given year. The seawater flows when using the combined loop regasification mode are the same as those for the open loop regasification mode.

Table 9 sets out the proposed FSRU regasification operating parameters for open loop regasification, expressed as mean daily flows in cubic metres per day (m^3/day). The equivalent gas production rate is also shown.

To minimise potential entrainment impacts during periods of the year when fish eggs and larvae are more prevalent in Western Port North Arm, a 14-day average (mean) regasification flow of 312,000 m^3/day is proposed between September and February (inclusive) (see **Section 12.2.5.4** for further discussion).

Table 9 Proposed FSRU regasification operating parameters

Season	FSRU regasification mode	Mean daily seawater[1] regasification flows (m^3/day, 14-day average)	Equivalent gas production rate (mmscf/day)
Autumn and winter (Mar – Aug)	Open loop	468,000	500-750
Spring and summer (Sep – Feb)	Open loop	312,000	250-500

Table note:

1. excluding cooling of freshwater generator and intermittent flows relating to ballast water, water curtain and fire testing water.

7.2.3 FSRU engines

Dual fuel reciprocating engines are used to provide all the power required on board the proposed FSRU, including for driving the compressors, pumps, ventilation fans, general utility and other equipment. The engines will also provide electric power for propulsion of the proposed FSRU. The engines normally operate on boil-off gas with marine diesel oil used as a pilot fuel and can also operate on marine diesel oil if required.

The Wärtsilä 50DF is a four-stroke dual-fuel engine manufactured in configurations giving 950/975 kW per cylinder. The proposed FSRU will be fitted with one 6L50DF and three 8L50DF engines. The 6L50DF has a mechanical output of 5,850 kW and the 8L50DF has a mechanical output of 7,800 kW. The four engines drive gensets that provide electrical power for the equipment onboard the FSRU and for propulsion. The maximum electrical output of one generator is 5,670 kW and the maximum electrical output of the remaining three is 7,580 kW each.

7.2.4 Technical specifications and process

Technical specifications of a reference FSRU operating in the following modes of delivery is provided in **Appendix C**:

- Open loop mode, delivering up to 750 mmscf/d
- Closed loop mode with two boilers, delivering a total of 500 mmscf/d. A third boiler may be installed on the FSRU, if the regasification operations are limited to closed loop mode.

The technical specifications provide a general description of capabilities of the FSRU that will be purchased for the Project and a detailed description of the drydock regime, LNG and regasification systems (including LNG ship to ship transfer), fuel and boil-off performance, seawater intake and discharge system and performance as an LNG ship. General and painting specifications are also discussed. The layout and dimensions are discussed in the technical specification, and a general arrangement drawing of the reference FSRU has also been provided in **Appendix C**.

7.3 Environmental best practice

This section describes how AGL has demonstrated environmental best practice in the selection and modification of the FSRU, in accordance with EPA requirements set out in the EPA Guideline – Demonstrating Best Practice (Publication 1517 February 2017) (Best Practice Guidelines).

AGL and APA are jointly preparing an EES under the Victorian *Environment Effects Act 1978* to assess how the proposed Project works could affect the environment and how any potential impacts could be managed. Prior to this stage, a number of decisions were made with regard to the technologies to be used for regasification and storage of LNG, taking into consideration environmental, social and economic factors.

AGL has adopted best practice through consideration of the most suitable option for regasification and storage of LNG, the selection of best available technology and selection of regasification operational modes based on environmental risks and potential impacts.

Both onshore and offshore regasification and storage technologies were considered during the gas import options screening phase of the Project. A literature review of a Lloyd's Register guidance document, titled, '*Floating Storage and Regasification Units Version 1.3 / June 2017* (Lloyd's 2017) was conducted. Lloyd's 2017 states that compared with land based LNG storage and regasification, FSRUs offer "lighter environmental footprints". A FSRU-based option was selected as opposed to an on-shore facility for the following reasons:

- Removal of the requirement to construct large land-based infrastructure;
- Receiving infrastructure to be developed on land has a smaller footprint;
- Improved site safety due to the flexibility of FSRU to leave berth during emergencies and an additional safety buffer by being further from existing residential receptors; and
- Shorter project lead time as construction of the FSRU is not required.

The selection of best available technology and regasification operational mode is discussed in **Sections 7.4** and **7.5** respectively.

7.4 Choice of process and technology

The type of FSRU proposed is designed and constructed in accordance with prevailing requirements and recommendations from authorities such as the International Maritime Organisation (IMO) and the Society of International Gas Tanker and Terminal Operators (SIGTTO). The FSRU will be issued a Class notation (classification) by (Det Norske Veritas and Germanischer Lloyd (DNV GL). The FSRU is equipped with systems and solutions to operate efficiently and to limit the impact on the surrounding environment.

The FSRU will be fitted with four Wärtsilä 50DF dual-fuel engines (one 6L50DF and three 8L50DF engines). The Wärtsilä 50DF was selected as these engines are 22% more efficient than the average gas engine power generator and are considered as best available technology for powering the FSRU both in terms of propulsion and also on board power generation. The four engines will be fitted with economisers that enable the use of waste heat from the flue gases (exhaust gases) within the process and silencers in the exhaust funnels to limit noise emission levels.

The FSRU will be fitted with either two or three MAC-90BF gas-fired boilers. The boilers will only be required in either closed loop mode or combined loop mode to heat the LNG. The boilers will operate on boil-off gas and will also be fitted with economisers to enable the use of waste heat from the flue

gases. In addition, the boilers have a flue gas recirculation system installed as a NOx control technique to minimise NOx emissions.

In the open loop regasification operational mode, heated cooling water from engine room consumers and the auxiliary machinery is transferred to the regasification seawater loop instead of being discharged directly to sea. This feature reduces the overall seawater consumption and makes use of waste heat within the process.

The FSRU has a larger maximum allowable LNG tank pressure (0.7 bar (g)) than conventional LNG carriers (0.25 bar (g)) and has the ability to use a temporary increase in tank pressure to manage generated boil-off gas. Boil-off gas will be used as the primary fuel for both the engine and boilers on board the FSRU. The regasification system is equipped with a recondensing system that includes a re-condenser to condense excess boil-off gas back to LNG during regasification operations. The FSRU will be equipped with an Minimum Send Out (MSO), which is sized to compress and export all excess boil-off gas to the shore pipeline. By using the MSO, the excess boil-off gas generated in extended idle conditions, or during low gas send out volumes can be sent to the shore gas grid instead of being combusted on board the FSRU.

In addition to the large conventional ballast water pumps, the FSRU will be equipped with an additional small ballast pump, for optimised ballast water handling during regasification operations when the LNG tank inventory rate of change is much lower than during normal LNG loading or discharge operations.

7.5 Integrated environmental assessment

An integrated environmental assessment was conducted as part of the development of the EES and WA application to compare air emissions, greenhouse gas emissions, noise emissions and surface water discharges during open and closed loop regasification modes. The assessment evaluated the possible gas production scenarios to determine the ideal set of operating parameters for the FSRU. As a result of the investigation, the open loop regasification mode was selected as the preferred option as discussed in **Section 7.2.2**. Although the open loop regasification mode is preferred, the EES and the WA application have identified the potential impacts associated with both open loop and closed loop mode to allow all operating scenarios to be considered as part of the assessment and approvals process.

A summary of the integrated environmental assessment is provided in **Table 10**. A schematic of the emissions and discharges associated with the operation of the FSRU during open and closed loop regasification mode is shown in **Appendix D**.

Table 10 Integrated Environmental Assessment of Key Environmental Aspects for the Project

Environmental Aspect	Feature	Open loop	Closed loop	Comparison of regasification modes
Air	Source of fuel for engine and boilers (boilers required for closed loop only)	Boil-off gas (natural gas) used in engines	Boil-off gas (natural gas) used in engines and boilers	The use of natural gas rather than other fuel sources such as diesel, reduce particulate matter, SOx and NOx emissions. Due to the use of fewer pieces of equipment, the anticipated air emissions are lower during operation in open loop mode.
Greenhouse Gas	Source of heat for regasification process	Seawater is used as the heating medium for regasification. As the seawater is continuously consumed and discharged there is no requirement to reheat the seawater resulting in less energy consumption and therefore less Greenhouse Gas (GHG) emissions. Total operational GHG emissions of 57,454 tCO_2-e/year.	A once-off intake of 500 kL of seawater that is recirculated in a closed loop. Boilers are required to generate steam to reheat seawater for the regasification process that requires additional energy (compared to open loop), resulting in increased GHG emissions. Boil-off gas is used as the fuel for the boilers. Total operational GHG emissions of 238,027 tCO_2-e/year.	Less GHG emissions (approximately 180,573 tCO_2-e/year) anticipated during operation in open loop mode compared to closed loop mode.
Noise	Noise emission sources	Fewer pieces of noise generating equipment used during operation in open loop mode e.g. no boilers required.	Use of boilers (additional noise generating equipment) to generate steam for the regasification process.	Less noise emissions sources due to fewer pieces of equipment during operation in open loop mode (i.e. no boilers required).

Environmental Aspect	Feature	Open loop	Closed loop	Comparison of regasification modes
Water	Discharge of regasification process water (seawater) to the marine environment	Continuous seawater intake and discharge of a large volume of cooler chlorinated seawater during regasification. Maximum continuous discharge of approximately 468,000 m^3/day at -7^oC for the regasification process, plus ballast water and other minor discharges, compared to ambient seawater temperature.	A once-off intake of 500 kL of seawater and a once-off discharge of 500 kL of sea water when closed loop mode is turned off. There is also a continuous intake and discharge of seawater during closed loop mode related to cooling water requirements of the engines, atmospheric dump condenser, auxiliary machines and freshwater generator. Maximum continuous discharge of approximately 187,000 m^3/day (including the volume of seawater (cooling water) from the engine room, auxiliary machine, the atmospheric dump condenser and the freshwater generator) at approximately +4 ^oC when mixed compared to ambient seawater temperature.	A larger volume of continuous discharge of seawater (284,000 m^3/day) to the marine environment is anticipated during operation in open loop mode compared to closed loop mode. Impacts on the marine environment assessed as acceptable and low risk in both cases.

8.0 Energy use and greenhouse gas emissions

Preparation of this section of the WA application was based on information provided in the EES Technical Report F: *Greenhouse gas impact assessment* (refer to **Appendix B**). The greenhouse gas (GHG) technical report has undergone an external peer review to ensure that the report adequately addresses the matters set out in the scoping requirements and to ensure that the study sufficiently examines and clearly documents the potential environmental impacts and risks of the operation of the FSRU.

8.1 Existing conditions

As this Project involves a new development, to determine the existing energy usage, GHG emissions related to the stationary energy sector were considered at the state level. Victorian GHG emissions data was sourced from *Australian National Greenhouse Accounts: State and Territory Greenhouse Gas Inventories, 2017* report (Commonwealth of Australia 2019).

According to the *State and Territory Greenhouse Gas Inventories 2017* report, Victoria's total GHG emissions were 110.2 mega-tonnes of carbon dioxide equivalent (Mt CO_2-e). A breakdown by emissions source is provided in **Table 11**.

Table 11 Victorian GHG emissions by source for 2017 NGER

Emissions Source and Sink Category	GHG Emissions (Mt CO_2-e)	Percentage
Energy Industries	59.0	54%
Transport	22.7	21%
Fugitive Emissions from Fuels	3.3	3%
Other Energy	15.1	14%
Agriculture	14.9	14%
Industrial processes and product use	3.8	3%
Land Use, Land Use Change and Forestry	(11.2)	-10%
Waste	2.6	2%
Total	**110.2**	**100%**

8.2 FSRU energy use and GHG emissions

8.2.1 Construction

The GHG emissions associated with the FSRU during construction include emissions related to the following activities and are a one-off event:

- Mobilisation of the FSRU (i.e. transportation of vessel from an assumed port (Korea) to Crib Point and return at the end of the project life).

A summary of the total GHG emissions relevant to the use of transport fuel for the FSRU is presented in **Table 12**. A number of inputs were used for calculating transport fuel GHG emissions associated with the FSRU during construction. The details of the inputs and calculations used to determine the GHG emissions during construction are shown in **Appendix E**.

Table 12 Summary of construction GHG emissions related to the FSRU (one-off event)

Emission Source	Project Activity	Total Emissions (t CO_2-e)		
		Scope 1	Scope 2	Scope 3
Transport fuel	Fuel consumed for FSRU transportation to Crib Point (including return at the end of project life)	8,012 (4006 t CO_2-e per journey)	-	-
Total		**8,012**	**-**	**-**

8.2.2 Operation

The GHG emissions associated with the FSRU during operation have been assessed based on the two possible regasification modes defined in **Section 7.2.1**.

- Closed loop using gas fired boilers to heat an intake of circulating seawater; and
- Open loop using a continuous supply of seawater as a heat source.

All power requirements on the FSRU are supplied through combustion of boil-off gas in the dual-fuel engines and GHG emissions associated with power supply to ship systems have been incorporated into the open and closed loop operations calculations.

Table 13 summarises the estimated annual GHG emissions for the operation of the FSRU under a closed loop operational profile and **Table 14** summarises the estimated annual GHG emissions for the operation of the FSRU under an open loop operational profile. A conservative approach was taken, and operating scenarios that are anticipated to have the highest emissions, were used to calculate GHG emissions during operation. A number of inputs were used for calculating GHG emissions associated with the FSRU during operation. The details of the inputs and calculations used to determine the GHG emissions during operation are shown in **Appendix E**.

Table 13 Summary of annual operational GHG emissions in closed loop mode

Emission Source	Project Activity	Total Emissions (t CO_2-e)		
		Scope 1	Scope 2	Scope 3
Stationary fuel	Fuel consumed by the FSRU four reciprocating gas engines & three gas fired boilers during operation	236,145	-	-
Fugitive emissions	Fugitive emissions during transfer of LNG from LNG carrier to FSRU	1,882	-	-
Fugitive emissions	Fugitive emissions during transfer of LNG from FSRU to Crib Point Receiving Facility	<1	-	-
Total		**238,027**	**-**	**-**

Table 14 Summary of annual operational GHG emissions in open loop mode

Emission Source	Project Activity	Total Emissions (t CO_2-e)		
		Scope 1	Scope 2	Scope 3
Stationary fuel	Fuel consumed by the FSRU four reciprocating gas engines during operation	55,572	-	-
Fugitive emissions	Fugitive emissions during transfer of LNG from LNG carrier to FSRU	1,882	-	-
Fugitive emissions	Fugitive emissions during transfer of LNG from FSRU to Crib Point Receiving Facility	<1	-	-
Total		**57,454**	**-**	**-**

8.3 Best practice energy and GHG management

The FSRU will require energy during construction (transport of the FSRU to Crib Point) and operation. Implementation of best practice and eco-efficient practices with respect to GHG emissions and energy consumption is required. A review of best practice with respect to GHG emissions and consumption is provided in this section.

EPA's Protocol for Environmental Management (PEM): Greenhouse gas emissions and energy efficiency in industry (2002) is an incorporated document of the *State Environmental Protection Policy (Air Quality Management) 2001* (SEPP (AQM)) and is a regulatory instrument that is used to align GHG assessment methodology and approach with the requirements under the EP Act and SEPP (AQM). A Works Approval and a Licence are required for the FSRU as a result of air emissions exceeding specified thresholds (Type ***Other: L01 – General Emissions to Air***) and K01 – Power stations, therefore the PEM applies to the construction and operation of the FSRU. Achieving the objectives of the SEPP (AQM) and the PEM will mean that the commitment to implement best practice will be satisfied.

The steps that need to be taken, and the nature of the information that needs to be provided, are outlined in the PEM. AGL has undertaken the four steps outlined in the PEM for applicants for a Works Approval to demonstrate best practice related to energy and GHG management, which include:

- Step 1: Estimate energy consumption;
- Step 2: Estimate direct GHG emissions;
- Step 3: Identify and evaluate opportunities to reduce GHG emissions; and
- Step 4: Document the information generated in steps 1 – 3.

A summary of the results of each step are summarised in **Sections 8.3.1** to **8.3.4**.

8.3.1 Step 1: Estimate energy consumption

GHG emissions discussed in this section are related to the use of fuel and excludes fugitive emissions. The total amount of GHG emissions associated with energy consumption during construction (transport of the FSRU to Crib Point) is approximately 4,006 t CO_2-e at Project commencement and another 4,006 t CO_2-e at the end of the project life (8,012 t CO_2-e in total). The total amount of GHG emissions associated with energy consumption during operation in closed loop mode is 238,027 t CO_2-e and open loop mode is 57,454 t CO_2-e per year. The combined loop regasification process would potentially be used when the ambient seawater temperature is too low for open loop regasification to operate effectively. This has been assumed to be 30 days a year. Should the combined loop be required it would lead to a further 17,370 t CO2-e per annum in addition to the emissions associated with the open loop mode.

8.3.2 Step 2: Estimate direct GHG emissions

Direct GHG emissions are associated with fugitive emissions (i.e. gas leaking from pipes or valves) during operation. The total amount of direct GHG emissions associated with fugitive emissions is approximately 1,882 t CO_2-e per year regardless of the mode of regasification.

8.3.3 Step 3: Identify and evaluate opportunities to reduce GHG emissions

With respect to GHG emissions the main emission sources are the FSRU dual-fuel engines used for both power and propulsion. Therefore, FSRU GHG emissions are a direct function of fuel type and consumption.

The more efficient the engine, the less fuel consumption and GHG emissions per unit of power generated. The FSRU will be fitted with four Wärtsilä 50DF four-stroke dual-fuel engines. Based on data published by the US Energy information Administration for gas engine power generators in the US between 2008 and 2018, the Wärtsilä engines are approximately 22% more efficient than the 2018 average heat rate (efficiency) for gas engine power generators. With a heat rate of 7397 kJ/kWh the Wärtsilä engines are considered as best available technology for powering the FSRU both in terms of propulsion and also on-board power generation.

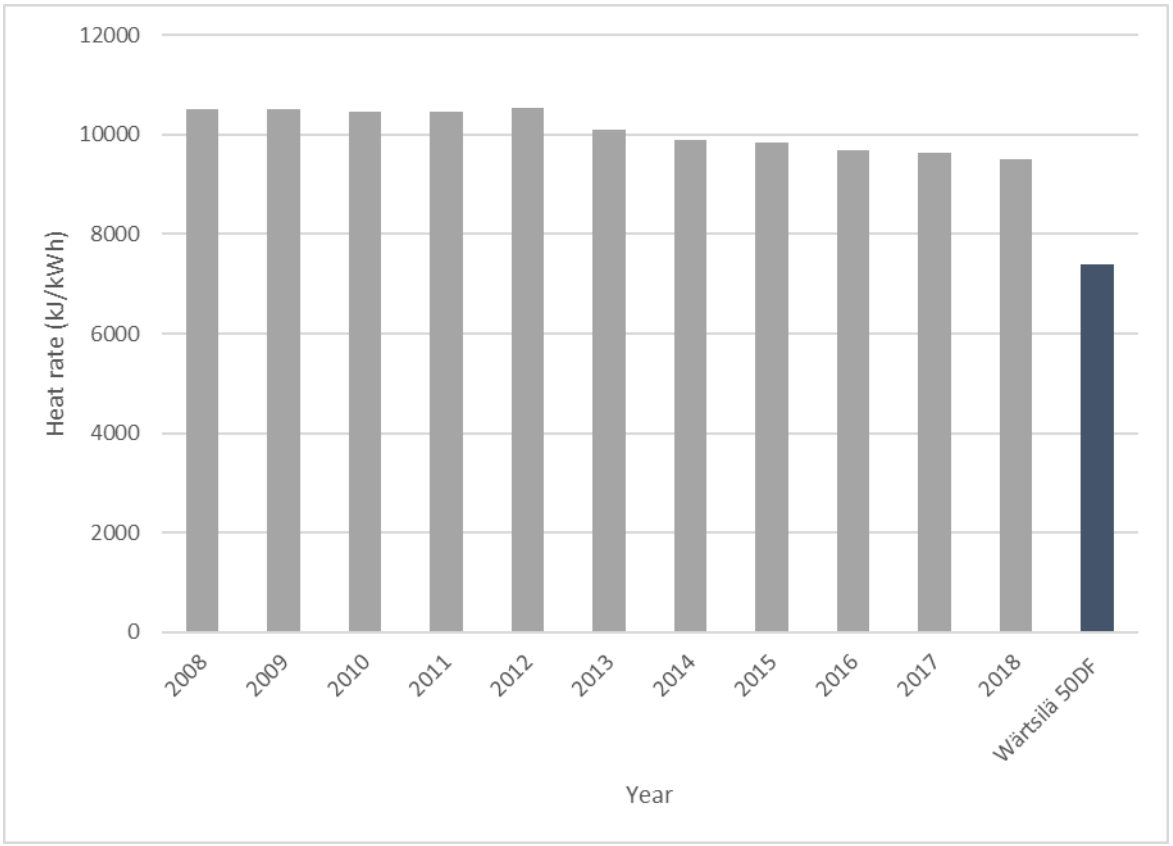


Figure 7 Natural gas engine heat rate comparison (kJ/kWh)

Natural gas burns more efficiently than other fuel sources such as diesel oil or fuel oil. **Figure 8** shows the GHG emission intensity of various fuels per gigajoule (GJ) of energy content based on emission factors outlined in the *National Greenhouse Accounts Factors - Australian National Greenhouse Accounts* (Department of the Environmental and Energy (DoEE) 2018).

The Wärtsilä 50DF is a dual fuel engine and can be run on natural gas or marine diesel oil/light fuel oil. The engine will operate predominantly on boil-off gas from LNG storage rather than marine diesel oil, which is only used as the pilot flame fuel or back up fuel during emergency and maintenance, which further reduces GHG emissions.

The four Wärtsilä 50DF dual-fuel engines and the boilers on board the FSRU are fitted with economisers which enables the use of waste heat from the flue gases (exhaust gases) within the process, reducing the overall consumption of energy and therefore reducing GHG emissions.

Energy consumption and GHG emissions are significantly less during operation in open loop mode in comparison to operation in closed loop mode. This is due to consumption of energy in the boilers to heat the feedwater and generate steam for the regasification process. Operation in open loop mode is the preferred option to reduce GHG emissions.

Natural gas imported to Crib Point will be injected to the Victorian gas transmission network for a variety of domestic, industrial and commercial purpose in south-eastern Australia. Bringing natural gas into the Victorian transmission network, has the potential to assist in reducing Victoria's overall GHG emissions and give support to Victoria's transition to a low-carbon economy. The Project also maintains energy security to support the state's growth and development. LNG imports offer a flexible option of short-term and long-term energy supply that will provide customers with a secure, stable source of energy supply as the energy sector becomes decarbonised and transitions to more renewables.

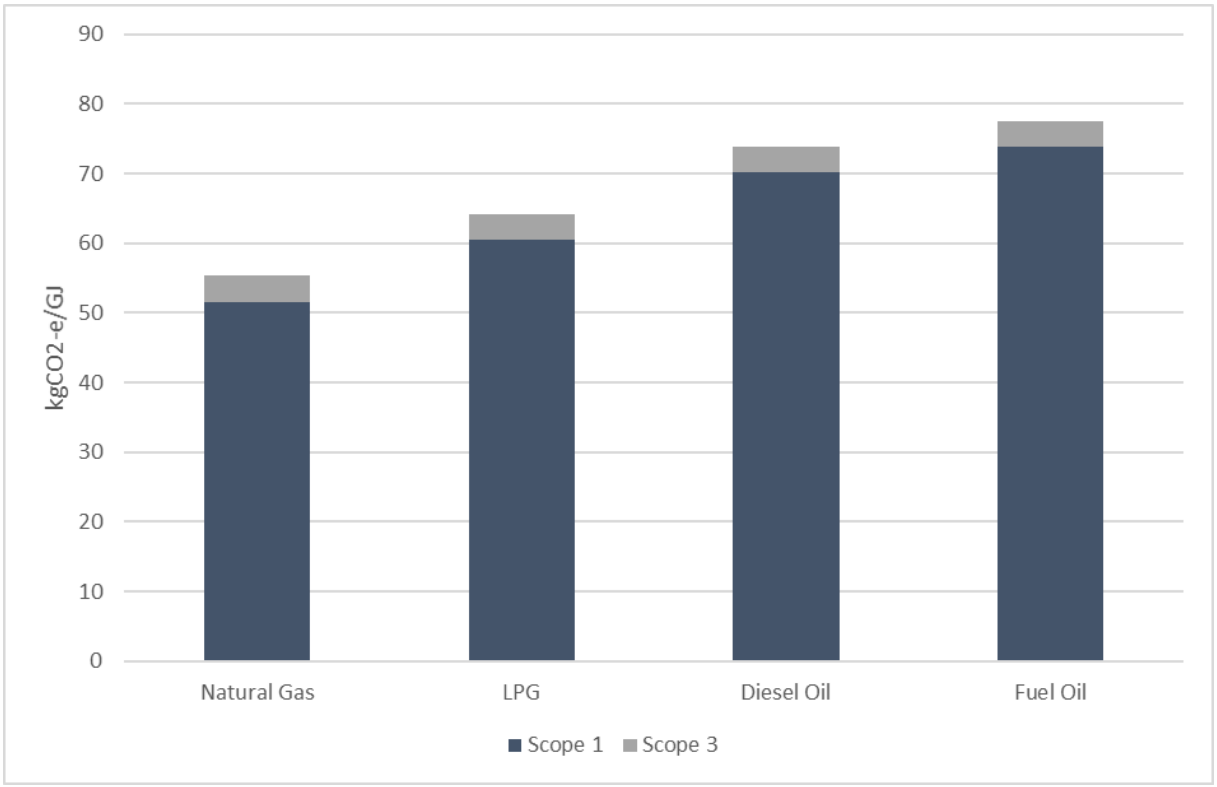


Figure 8 Comparison of GHG emission intensity of various fuels per GJ of energy content (DoEE 2019)

8.3.4 Step 4: Document the information generated in steps 1 – 3

The information generated in steps 1 – 3 are documented in this WA application and in the Gas Import Jetty and Pipeline Project EES (refer to EES Technical Report F: *Greenhouse gas impact assessment* (refer to **Appendix B**)).

8.4 Climate change risk

This section discusses the potential impacts of climate change risks on the Project. This section is based on the climate change risk assessment presented in EES Attachment IV: *Climate change risk report* (refer to **Appendix B**).

Climate change puts infrastructure at increased risk of degradation, failure and increased maintenance or replacement costs. The long lifespan of infrastructure assets makes it important to assess climate change risks and integrate adaptation strategies early in the design or development process so that

risks can be 'designed out' if identified early, or relevant adaptation measures can be developed and embedded in a project or program as appropriate.

A climate change risk assessment was undertaken in line with AS 5334-2013 *Climate change adaptation for settlements and infrastructure – A risk-based approach.* The risk assessment focuses on the potential physical risks that may impact the Project as a result of climate change. For the Project, RCP8.5 projections were applied for assessment of risks relevant to the near-term (2030) as a worst-case scenario assessment. For far-term assessments (2090), projections for RCP4.5 as well as RCP8.5 were considered to reflect potential emission reductions.

A summary of climate hazards with potential to impact the FSRU is outlined in **Table 15**.

Table 15 Summary of climate hazards

Hazard	Description
Extreme heat	• Temperatures in Victoria over the last two decades have increased steadily and climate projections indicate there will be an increase in average temperatures and extreme temperatures. • Extreme heat includes days where the maximum temperature exceeds 35°C and heatwaves, a period of three or more days of unusually high maximum and minimum temperatures. On average there are currently 14.2 days a year above 35°C, per records from the Viewbank weather station (station number 86068). This is projected to increase to an average of 24 days in 2090 under RCP8.5.
Extreme rainfall	• Recent climate data and future projections show longer periods with little rainfall and conversely more intense rainfall events. As temperatures increase the water cycle intensifies with more evaporation which is what results in more intense rainfall events. • Increased extreme rainfall intensity will likely increase the extent and depth of flooding across the Project Area.
Sea level rise/coastal flooding and erosion	• Oceans have warmed over the past century resulting in thermal expansion and melting of ice caps causing rising sea levels. • Under RCP8.5, sea levels are projected to rise by 0.61 to 1.10 metres by 2090 (IPCC 2019b). • Projection ranges of sea level rise are considered likely (at least 66% probability) and could be subject to further rise if a collapse in the marine based sectors of the Antarctic ice sheet were initiated. Limitations in the understanding of Antarctic ice sheets create uncertainty in sea level projections, though it is estimated that ice sheet loss could increase sea level rise projections later in the century. • Sea level rise has the potential to inundate land adjacent to the coast. Projected sea level rise combined with increased storm events producing greater wave run up can result in areas typically immune from coastal flooding impacts being affected. • Key impacts of sea level rise include associated erosion and exacerbated storm surge and storm tides. Crib Point has been identified as an area of risk from coastal erosion in the Western Port Coastal Villages and Surrounding Settlements Strategy. Storm surge, elevated sea levels resulting from atmospheric wind and low pressure, and storm tide, sea levels resulting from the combination of storm surge and astronomical tides may also impact the area.
Change in groundwater levels	• Groundwater levels can be influenced by the action of ocean tides and increase of sea level. • More severe storm surges and rising sea levels will have direct impacts on groundwater, including increasing its elevation and saltwater intrusion.
Saltwater intrusion	• Groundwater quality can be influenced by saltwater intrusion from ocean tides.

Hazard	Description
Bushfire	• Climate change is likely to result in more intense and frequent bushfire weather in the future. Historically, the Project Area had an average of 2.7 severe fire danger days per year. This is projected to double by 2090. • Parts of the Project Area are situated in a Bushfire Management Overlay.
Extreme wind/ storms	• High winds can cause disruption and damage to infrastructure. • More regular and severe storm events are projected to occur in the region surrounding the Project Area as an impact of climate change.

A total of 11 climate change risks were identified and assessed. Of these risks, non were considered 'high' or above, taking into consideration relevant controls or mitigation measures to be implemented for the Project. Six of the 11 that were identified are applicable to the FSRU and are summarised in **Table 16**. Refer to EES Attachment IV: *Climate change risk report* (refer to **Appendix B**) for further detail about the full risk register.

Table 16 Summary of climate risk to the FSRU

ID*	Risk description	Hazard	Existing controls	Risk rating
5	Extreme heat causes heat stress on personnel working onsite, resulting in reversible health effects and reduced productivity	Extreme heat	• Policies/Permit to work procedures to manage work appropriately on hot days (FSRU, Crib Point Jetty and Crib Point Receiving Facility)	**Moderate**
7	External bushfire causes damage to assets, resulting in operational disruption and additional cost for replacement of assets	Bushfire	• Fire water systems • FSRU will depart in case of bushfire • Emergency Management Plans, including liaison with relevant local authorities and other port operators (e.g. United Petroleum) as required • Failsafe of isolation valving	**Low**
8	Bushfire restricts the ingress/egress to assets and services (e.g. power), resulting loss of production and safety impacts to workers onsite	Bushfire	• Minimising need for operational and maintenance staff physically located at site • FSRU is designed to accommodate workforce • Maritime Security Plan coordination by PoHDA	**Low**
9	Extreme heat causes damage to assets and restricts services (e.g. power), resulting in disruption of operations and loss of productivity	Extreme heat	• Uninterruptible Power Supply (UPS) for safe shutdown • FSRU electrically isolated from jetty and generates its own power	**Low**
10	Extreme wind/storms causes damage to assets (e.g. failure of mooring system) and	Extreme wind/ storms	• Uninterruptible Power Supply (UPS) for safe shutdown	**Low**

ID*	Risk description	Hazard	Existing controls	Risk rating
	impacts services (e.g. powerlines), resulting in disruption of operations and loss of productivity		• FSRU electrically isolated from Jetty and generates its own power • Mooring system designed to meet greater than 1 in 50-year storm event • PoHDA Emergency Management Plan/Victorian Regional Channels Authority Harbour Master response manages requirement to put vessels to sea for extreme weather events	
11	Low rainfall causes restricted water availability, resulting in operational disruption and/or increased operational costs	Extreme rainfall	• Alternative water sources and/or water efficiency equipment • The FSRU is self-sufficient with respect to cooling water and boiler feed water for steam generation.	**Low**

*ID refers to risk register risk reference number. The risk register is provided in EES Attachment IV: *Climate change risk report* (refer to **Appendix B**)

AGL would monitor climate impacts, projections and policy for the Project area throughout the Project life cycle. Monitoring may include operational controls such as routine and preventative maintenance checks. As required, Project-specific adaptation measures would be investigated, assessed and implemented to minimise any climate change risks to the Project components, including the FSRU.

8.5 Summary

As reported in the *State and Territory Greenhouse Gas Inventories 2017* report, the total GHG emissions for Victoria in 2017 were 110.2 Mt CO_2-e. The construction (transport of the FSRU to Crib Point including return of the FSRU at the end of the project life) and operation of the FSRU represents:

- Approximately 0.42% of the Energy industries' annual GHG emissions under a closed loop mode and 0.11% under an open loop mode; and
- Approximately 0.22% of Victoria's annual GHG emissions under a closed loop mode and 0.06% under an open loop mode.

A climate change risk assessment was undertaken to determine the potential impacts of climate change on the Project, aiming for more climate resilient assets. A total of 11 risks were identified and assessed. Of these risks, none were considered 'high' or above, taking into consideration proposed controls. Seven of the 11 that were identified are applicable to the FSRU. Proposed controls are considered adequate to manage the potential impacts of climate change on the Project, including the FSRU.

9.0 Water resource use

9.1 Water use in process

Seawater will be used by the FSRU for the following processes:

- Regasification of LNG (seawater will be used as the heat source).
- Ballast water, to maintain the vessel's stability.
  - The FSRU would take in seawater as ballast during regasification operations, to compensate for the reduction of LNG volume in the cargo tanks as the natural gas is exported to shore. Ballast water would be discharged from the FSRU during LNG loading from LNG carriers.
  - Visiting LNG carriers would arrive full of LNG and would not need to discharge ballast water into Western Port. They would take on seawater as ballast as they unload their cargo.
- A water spray ("Water Curtain"), to ensure there is no direct contact between LNG carrier and the hull of the FSRU, if LNG were to escape during unloading operations from the LNG carrier to the FSRU.
- Emergency fire water (firefighting system).
- Water for regasification backflush filter (each filter is flushed for 1hr/day)
- Cooling water for the engines and auxiliary machine systems, which will be directed to the open loop regasification process instead of directly discharged to sea, reducing the overall seawater use. In closed loop mode, the cooling water for the engines and auxiliary machine systems as well as cooling water for the atmospheric dump condenser will bypass the open loop discharge ports and be discharged to the sea as per normal vessel operations.
- Generation of freshwater from seawater for technical use on board the FSRU. Freshwater generated for technical use is referred to as 'technical water' which has quality suitable for industrial use (e.g. boiler feed water, engine wash etc.) but not suitable for drinking or other human use (potable water will be supplied directly to the FSRU for domestic uses).

The FSRU seawater usage will vary depending on whether the vessel is operating in open or closed loop mode, and the nominated send-out rate. The seawater usage values presented in **Table 17** have been developed focusing on normal operating scenarios, with the peak regasification send-out rate of 750 million standard cubic feet per day (mmscf/d).

9.1.1 Seawater use associated with regasification

In open loop mode, seawater will be continuously drawn in through screened seawater intakes on each side of the FSRU for the regasification process. In closed loop mode, there will be a single seawater intake of approximately 500 kL to fill the internal piping through screened seawater intakes for the regasification process. In closed loop operation, once filled, the seawater intakes and discharge ports will be isolated, and this water will be continuously circulated in a 'closed loop' through the heat exchange with gas-fired steam boilers providing heat to maintain the temperature in this process.

In addition to seawater for regasification, seawater for cooling purposes will be continuously drawn in through screened seawater intakes for both open loop mode and closed loop mode. In open loop, the heated cooling water will be redirected to the regasification loop and reused. In closed loop mode the seawater will be discharged.

In both open loop mode and closed loop mode, following the intake of seawater into the FSRU, an electric current will be passed through the seawater (a process known as electrolysis). Electrolysis breaks up salt molecules and produces chlorine and hypochlorite from the seawater, which prevents the growth of marine organisms in the internal piping system of the FSRU. When the seawater is

discharged from the FSRU to the marine environment as wastewater, some residual chlorine products (mostly bromine) will remain.

Seawater used in the regasification process during open loop operations will be returned from the FSRU to Western Port waters using a six discharge port configuration on the side of the vessel. Typically, two discharge ports will be used per operating regasification train. Discharge ports will be orientated to deliver a horizontal water jet just below the water surface to optimise mixing so that the discharged seawater returns to ambient conditions as quickly as possible.

Seawater used in the regasification process during closed loop will be returned from the FSRU to Western Port waters via several closely spaced pipes at the rear of the vessel.

9.1.2 Other seawater uses

In addition to the seawater discharge ports for regasification water, several auxiliary discharge points will be situated in the FSRU engine room, including for cooling and ballast water. These types of discharges are typical for vessels of this nature.

Maximum daily seawater intake and discharge flows from the FSRU for open loop and closed loop regasification modes are listed in **Table 17**. Intermittent and minor flows associated with the purposes listed above are also presented in **Table 17**. Seawater intake and discharges for the combined loop regasification mode would be the same as for the open loop regasification mode.

Table 17 Seawater use from the FSRU

Water use	Assumption	Maximum seawater use rates (m^3/day)			Temperature change relative to background seawater
		Open loop mode	Closed loop mode	Idle	
Intermittent flows					
Ballast water during LNG unloading	Total ballast water capacity is 53,500 m^3	53,500	53,500	-	0˚C
Water curtain during LNG loading		5,760	5,760	-	0˚C
Fire water (open and closed loop)	System tested for 1 hour every 2 weeks	1,550	1,550	1,550	0˚C
Continuous flows					
Cooling of freshwater generator (open and closed loop)	There are 2 freshwater generator units. Only 1 unit operates at any given time	2,112	2,112	2,112	+8˚C
Heating for regasification operation (open loop)	All 6 regasification pumps in use	468,000	-	-	-7˚C
Heating for regasification operation (closed loop)	Single seawater intake. Discharged when switching to open loop mode or when maintenance is required.	-	500 m^3	-	+4˚C
Regasification backflush filter (open and closed loop)	Each filter is flushed for 1 hr/day	723	723	-	0˚C

Water use	Assumption	Maximum seawater use rates (m^3/day)			Temperature change relative to background seawater
		Open loop mode	Closed loop mode	Idle	
Cooling of auxiliary machinery systems* (open and closed loop)		45,480	45,480	45,480	+5˚C
Cooling of engines* (open and closed loop)	Two independent seawater cooling systems. One for the starboard generator pair and one for the port side generator pair. Only 1 main generator cooling pump when operating in idle mode	58,560	58,560	29,280	+12˚C
Cooling of atmospheric dump condenser (closed loop)	In closed loop mode, steam is not dumped during normal operation. However, if there is operational upset such as a regas plant trip causing an unexpected shutdown, the steam in the boilers may be dumped in the condenser. In idle mode, the minimum send out compressor (MSO) will not be operating hence excess boil-off gas will be burned in the boiler and the steam dumped in the atmospheric dump condenser.	-	80,400	80,400	+16.5˚C (idle mode only - full steam dumping) 0˚C in normal operation

* Cooling water for auxiliary machinery systems and engines are redirected to the regasification loop in open loop mode and therefore these streams will not be an additional use

9.1.2.1 Freshwater generator

The FSRU will be equipped with two freshwater generators with one discharging to port and the other discharging to starboard from the rear of the FSRU. Only one freshwater generator will operate at any given time with the other on standby. The FSRU will be equipped with freshwater generators for conversion of seawater by vacuum distillation for the supply of high quality fresh water for technical use (process utilisation).

Each freshwater generator is able to produce 30 tonnes (approximately 30m^3) of freshwater per day with a seawater inlet flowrate of 2,112 m^3/day. The outlet brine stream will be mixed and discharged with the cooling water stream at a rate of 2,082 m^3/day with an increase of salinity of approximately 1.4% compared to ambient conditions.

The freshwater generators will use cooling water from the engines as the heating medium. In addition, one freshwater generator can use steam as an alternative heating medium. The feedwater to be evaporated is taken from the seawater intake header. It enters the evaporator where it evaporates at

about 40-60ºC. The evaporating temperature corresponds to a vacuum of 85-95%. The produced vapour is condensed by the (cooling) sea water. Entrained sea water (brine) is ejected and mixed with the discharged cooling sea water stream, while the condensed vapour is collected and pumped to the freshwater tanks. The brine is discharged together with the sea cooling water to sea from the rear of the FSRU.

In order to avoid scaling on the heating surfaces, anti-scaling chemicals are injected into the feedwater stream of the evaporator in the freshwater generator. Altreat 400, an organic antiscalant will be used as the anti-scaling agent and is certified for potable water use based on the company information. For a freshwater production rate of 30 m^3/day, approximately 0.62 L/day of Altreat 400 is anticipated.

9.2 Water use best practice

Best practise options that apply to seawater usage include reuse and recovery of wastewater and energy within the process including:

- Heated cooling water from the engine room is transferred to the regasification seawater loop in open loop mode, instead of being discharged directly to the sea. This results in reduction of the total volume of seawater (up to 58,560 m^3/day) intake in open loop mode and recovery of heat in the regasification process;
- Heated cooling water from the auxiliary machinery is transferred to the regasification seawater loop in open loop mode, instead of being discharged directly to the sea. This results in reduction of the total volume of seawater (up to 45,840 m^3/day) intake in open loop mode and recovery of heat in the regasification process; and
- In closed loop the condenser generates a steam condensate stream following heating of the seawater, which is returned to the boiler feed filter tank where it can be reused as boiler feed water.

Through the reuse of seawater and heat within the FSRU during both the open and closed loop operational modes, the overall use of seawater and energy is reduced, and the discharge of wastewater is reduced.

10.0 Air emissions

Preparation of this section of the WA application was based on information provided in the EES Technical Report G*: Air quality impact assessment* (refer to **Appendix B**). The air quality technical report has undergone an external peer review to ensure that the report adequately addresses the matters set out in the scoping requirements and to ensure that the study sufficiently examines and clearly documents the potential environmental impacts and risks of the operation of the FSRU.

10.1 Separation Distances

The FSRU has four LNG storage tanks with a capacity of 170,000m^3 (approximately 73,000 tonnes). In accordance with EPA Publication 1518 Recommended Separation Distances for Industrial Residual Air Emissions (March 2013), the FSRU can adopt the approach taken to Storage of Petroleum and hydrocarbon products in fixed roof tanks requiring a separation distance of 250m from sensitive land uses (e.g. residential). The nearest sensitive receptor (a residence) is 1.2 km (refer to **Figure 10**) and the distance to the shoreline is approximately 770 m.

10.2 Air emissions assessment

An air emissions assessment was conducted as part of the EES process to assess the potential air quality impacts due to construction and operation of the FSRU at Crib Point. The assessment was prepared in accordance with the following:

- *National Environment Protection Measure (Ambient Air Quality)* (AAQ) (AAQ NEPM);
- *Environment Protection Act 1970* (EP Act);
- *State Environmental Protection Policy (Air Quality Management) 2001* (SEPP (AQM)); and
- Schedule 1 of the *Environment Protection (Scheduled Premises) Regulation 2017*.

Air emissions of interest for the construction activities are primarily related to the pipeline works and as such, will not be discussed further in this WA application. The construction of the FSRU will occur overseas and therefore air emissions associated with the construction of the FSRU were not considered. Similarly, the air emissions from transport of the FRSU to Crib Point were not considered.

The operation of the FSRU requires fuel combustion in the dual-fuel engines and the gas-fired boilers. These processes emit various pollutants that have the potential to reduce air quality if their concentration exceeds certain air emission thresholds.

The following tasks were undertaken as part of the air emissions assessment:

- Identification of the operational pollutants of interest (refer to **Section 10.3.1**)
- Identification of sensitive receptors (refer to **Section 10.3.3**)
- Characterisation of the background air quality using available monitoring data (refer to **Section 10.3.4**)
- Preparation of a five-year meteorological dataset using local meteorological data (refer to **Section 10.3.5**)
- Identification of expected operational modelling scenarios (refer to **Section 10.3.6**)
- Selection of a dispersion model for use in the impact assessment (refer to **Section 10.3.7**)
- Preparation of AERMOD atmospheric dispersion models for FSRU air emissions
- Compilation of an air emissions inventory for the FSRU (refer to **Section 10.4**)
- Comparison of predicted ground level air pollutant concentrations to the design criteria listed in the SEPP (AQM) (refer to **Section 10.6**)

10.3 Air quality modelling

10.3.1 Operational pollutants of interest

The primary pollutants from the FSRU gas-fuelled engines are expected to be nitrogen oxides (NOx), carbon monoxide (CO), and to a lesser extent, volatile organic compounds (VOC) (USEPA 2000a). Particulate matter (PM_{10} and $PM_{2.5}$) is also a primary air pollutant for engines using liquid fuels. CO, VOC, hazardous air pollutants (HAP), and particulate matter are primarily the result of incomplete combustion. For natural gas fired engines, formaldehyde accounts for about two-thirds of the total HAP emissions (USEPA 2000a). Polycyclic aromatic hydrocarbons (PAH), benzene, toluene, xylenes, and others account for the remaining one-third of HAP emissions. The pollutants of interest for the FSRU under operational conditions are expected to consist of the following:

- Nitrogen dioxide (NO_2);
- Carbon monoxide (CO);
- Particulate matter (PM_{10} and $PM_{2.5}$);
- Sulphur dioxide (SO_2);
- Volatile organic compounds (VOCs); and
- Formaldehyde.

Where available, background air pollutant concentrations provided by EPA were used for the assessment of potential cumulative impacts (cumulative concentrations represented by the FSRU predicted concentrations plus background pollutant concentrations). Background air pollutant concentrations are outlined in **Section 10.3.4** with data presented in terms of the different pollutant concentrations for different averaging times.

10.3.2 Study area

The operational air emissions assessment comprised a 10 x 10-kilometre multi-tier receptor grid surrounding the proposed FSRU location (Berth 2 at Crib Point Jetty). The grid around the FSRU was used to assess air emissions at 38 selected sensitive receptors. **Figure 9** shows the study area, pipeline alignment and fixed facilities of the Project. The study area relevant to this WA application includes the ‘Air quality study area – operation’ shown in **Figure 9**.

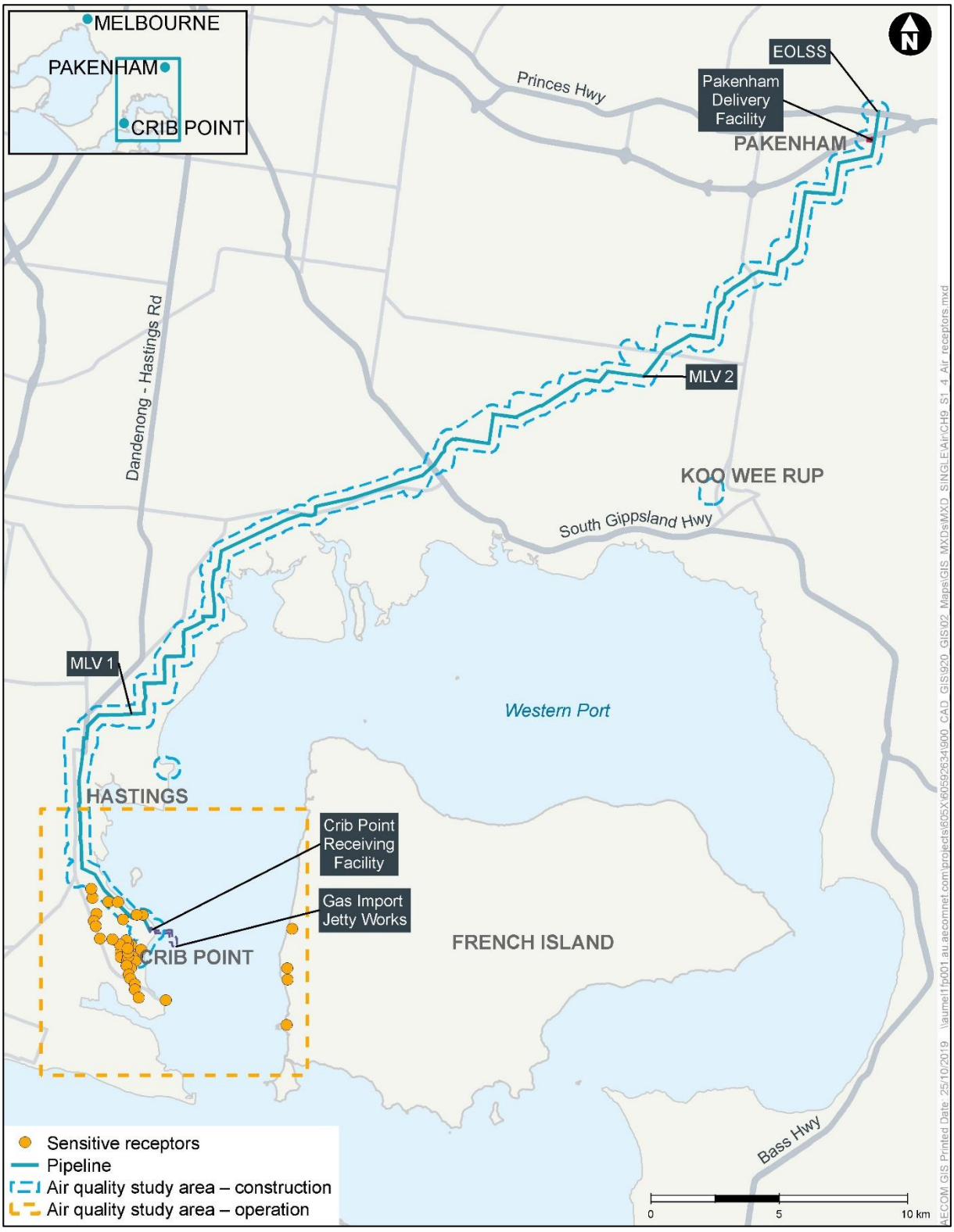


Figure 9 Study area for air quality impact assessment

10.3.3 Sensitive receptors

For the purposes of the air emissions assessment, sensitive receptor locations are described as per Schedule C, Part B, 5(c) of SEPP (AQM) to include '*hospitals, schools or residences'*. 38sensitive receptors were allocated to predict pollutants concentrations at specific locations in the study area. Modelling results show that pollutant concentrations are greatest near the FSRU and decrease over distance. Therefore, sensitive receptors were chosen based on proximity to the FSRU.

The area surrounding the proposed FSRU location is characterised by a mixture of open waters, industrial uses, commercial areas and residential dwellings. The nearest sensitive receptor is located at 103 The Esplanade approximately 1.2 kilometres north west from the proposed FSRU location. A graphical display of the sensitive receptors included in this assessment is provided in **Figure 10**.

10.3.4 Background air pollutant concentrations

EPA Victoria operates several ambient monitoring stations in the Port Phillip region to establish compliance with the AAQ NEPM criteria. The air quality monitoring stations measure CO, NO_2, ozone (O_3), SO_2, PM_{10} and $PM_{2.5}$.

Given that there is no site-specific background monitoring data available for this assessment, background data was sourced from the following monitoring stations:

- CO and SO_2 data were sourced from Alphington and Geelong
- NO_2 data was sourced from Alphington, Footscray and Brighton
- PM_{10} data was sourced from Dandenong and Brighton
- $PM_{2.5}$ data was sourced from Footscray and Alphington which use an Australian Standard method to collect data. Dandenong and Brighton use an indicative monitoring methodology and therefore the data was not considered accurate enough for this assessment.

The FSRU will be located in a rural area where the density of emissions such as NO_2, CO, SO_2, PM_{10} and $PM_{2.5}$ are expected to be significantly less than the metropolitan areas. Therefore, the background concentrations measured by the EPA are expected to be generally higher than those near the proposed FSRU location and their use as the background data in this assessment is considered conservative.

The EPA releases annual compliance monitoring reports that summarise the most recent several years' results for various pollutants. The most recent report, used to gain the Project background data, is as follows:

- *Air monitoring report 2017 – Compliance with the National Environment Protection (Ambient Air Quality) Measure* (EPA, 2018).

The *Air Monitoring Report 2017* (EPA 2018) summary includes provision of various percentile values, of which the required background 70th percentile under the SEPP (AQM) is one. Particulates are presented as 24-hour averages, while CO is presented as an eight-hour average, as the purpose of the reporting is to compare against the NEPM criteria, which are in these average periods. As such, the shorter one-hour average time required for comparison against the SEPP (AQM) has been calculated using the power law provided in EPA (2013). Should the results approach the criteria then the use of the calculated data may be revisited. The highest value from the previous five years data was applied in this assessment as the background concentration value. Adopted background air pollutant concentrations are provided in **Table 18**.

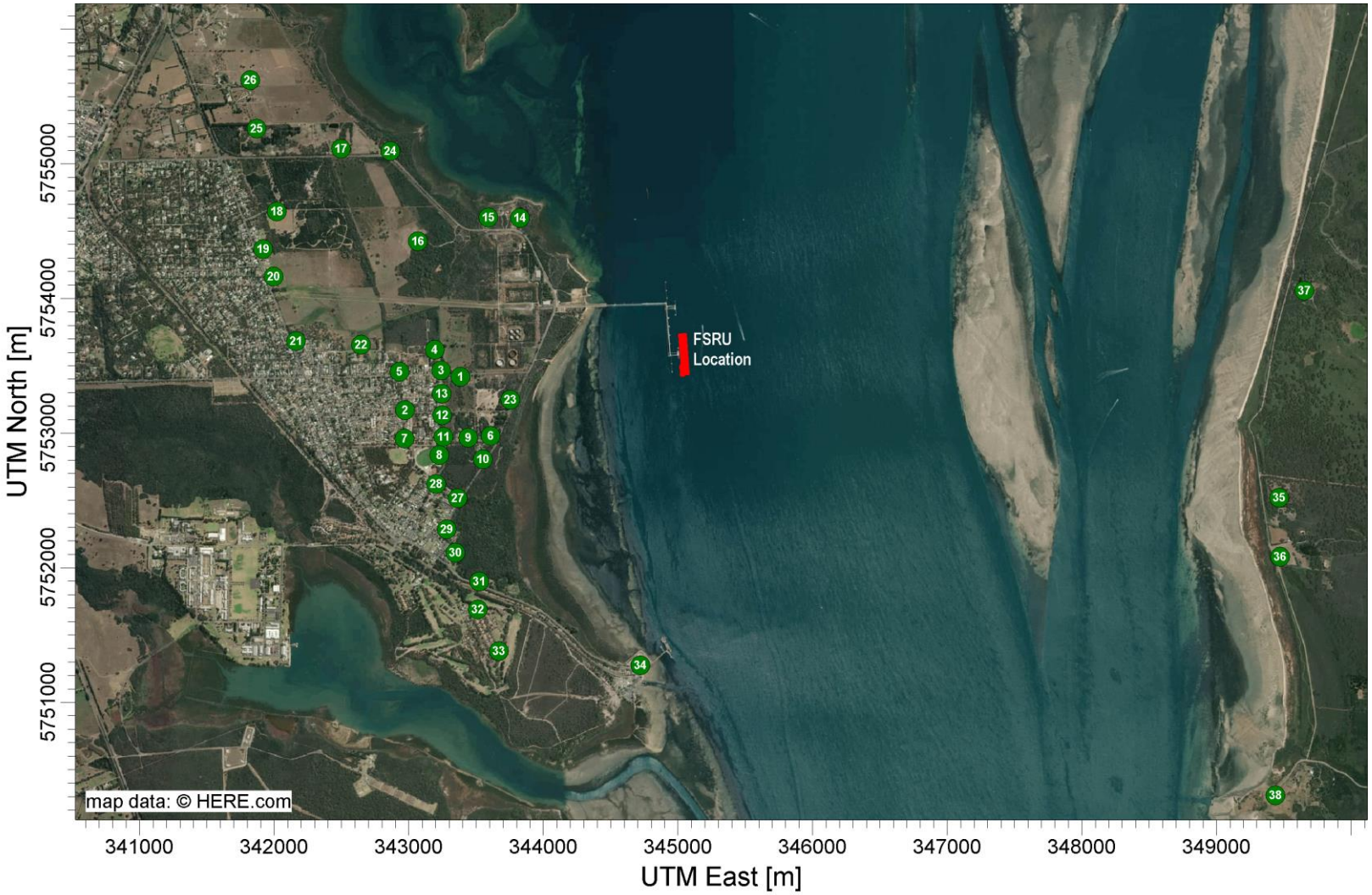


Figure 10 Sensitive receptors locations

Table 18 Adopted Project background air pollutant concentrations

Air Pollutant	Averaging Period	Adopted Background Air Pollutant Concentrations		Data Source	
		ppm	µg/m^3	Monitoring station	Land use category
NO_2	1 hour	0.027	54.7	Alphington	Residential/ light industrial
	Annual	0.012	24.3	Footscray	Industrial/ residential
CO	1 hour	1.1	1360	Alphington	Residential/ light industrial
	8 hour	0.7	863		
PM_{10}	1 hour	-	44.6	Dandenong	Light industrial
	24 hour	-	23.6		
	Annual	-	19.9		
$PM_{2.5}$	1 hour	-	19.3	Alphington	Residential/ light industrial
	24 hour	-	10.2		
	Annual	-	7.9		
SO_2	1 hour	0.006	16.9	Geelong	Light industrial/ residential

10.3.5 Meteorology and climate

The closest Bureau of Meteorology (BoM) station to the proposed FSRU location is at Cerberus (Station number 086361), approximately five kilometres to the south-west of the Crib Point Jetty. Cerberus is situated in similar terrain to the FSRU and is sufficiently close to provide an adequate representation of the site meteorology.

Long-term climate data has been recorded at the Cerberus BoM site between 1986 and 2019. The annual mean rainfall is 720 millimetres over 106 days per year. August is the wettest month, with a mean rainfall of 75 millimetres, while January is the driest month with a mean rainfall of 37 millimetres. Humidity follows a diurnal cycle, with higher humidity in the morning compared to the afternoon.

The surface data file for AERMOD is based on BoM Cerberus observations with the exception of solar radiation and cloud data, which was generated from The Air Pollution Model (TAPM). TAPM is a predictive meteorological and air pollution model developed by the Commonwealth Scientific Industrial Research Organisation (CSIRO) connected to various databases, which can be used to predict three-dimensional meteorology, including terrain-induced air circulation.

Wind predictions have been extracted from AERMOD for the proposed FSRU location using the BoM and TAPM inputs. The yearly wind speed statistics for 2014 to 2018 are presented in **Table 19**. It shows that there has been little variation of wind speed in the last five years, with a minor variation in both average and maximum wind speed. The greatest percentage of calm winds occurred in 2015 and 2016.

Table 19 Yearly AERMOD Crib Point wind statistics 2014-2018

Wind Parameters	2014	2015	2016	2017	2018
Average (m/s)	3.06	2.82	2.99	2.95	3.19
Maximum (m/s)	13.3	11.4	12.2	11.4	12.8
Calms (%) (<0.5 m/s)	6.5	20.2	20.1	7.1	6.9

m/s = metres per second

The seasonal data shows that the wind speed is generally highest from the north-west and south-west in autumn and spring, the north-west in winter and the south-west in summer.

The predicted meteorology is considered to be acceptable for use in modelling of air emissions from the proposed FSRU location. Refer to **Appendix F** for further detail.

10.3.6 Operational modelling scenarios

To ensure the air emissions assessment is as representative as possible of different Project operational conditions, several scenarios have been considered.

The FSRU is intended to be operated on LNG boil-off gas as the primary fuel. The proposed FSRU used for assessment purposes has dual-fuel engines, with the primary fuel being natural gas and back-up fuel being marine diesel oil ("liquid fuel"), which would be used in the event of a gas outage or emergency or for maintenance. Marine diesel oil is also used as a pilot flame fuel and anticipated usage is minimal.

As discussed in **Section 7.2.1**, the FSRU will have the ability to operate two regasification modes:

- Open loop mode – using a continuous supply of seawater as a heat source
- Closed loop mode – using steam generated from gas-fired boilers and using steam heated recirculating seawater as a heat source.

To predict worst case air emissions from the FSRU, four modelling scenarios were undertaken (refer to **Table 20**). Gas-fuelled scenarios assume continuous operation of the FSRU in the closed or open loop mode. Open loop scenario assumes four reciprocating gas engines operating at peak power (as the boilers are not used for regasification when operating in open loop mode). Closed loop scenarios assume four reciprocating gas engines and either two or three boilers operating at peak power. Worst case scenarios, with the FSRU operating at peak capacity are only expected to occur for 10 per cent of the year.

The liquid-fuelled scenario assumes two reciprocating engines are operating at 25 per cent load and burning 14.6 tonnes of marine diesel oil per day. This is a worst-case liquid fuelled scenario as the FSRU will only operate under the liquid fuelled scenario during the following instances:

- in emergencies or for testing and maintenance, except if the LNG tank inventory is so low that the engines will have to be run on liquid fuel
- during start-up and operation of engines when liquid fuel is used as the pilot fuel.

The FSRU will not use liquid fuel for regasification so this scenario has not been modelled.

Table 20 Operational modelling scenarios (worst case)

Modelling scenario	Description
Gas-fuelled, open loop	Four natural gas-fuelled engines operating at 100 per cent load (750 mmscf/d)
Gas-fuelled, closed loop, two boilers	Four natural gas-fuelled engines and two natural gas-fuelled boilers operating at 100 per cent load (500 mmscf/d)
Gas-fuelled, closed loop, three boilers	Four natural gas-fuelled engines and three natural gas-fuelled boilers operating at 100 per cent load (750 mmscf/d)
Liquid-fuelled	Two diesel fuelled engines operating at 25 per cent load, total fuel usage 14.6t/d

Emissions from a berthed LNG carrier were not included in the operational modelling scenarios based on the following justifications:

- LNG carriers will be berthed for only 16 per cent of the year
- Berthed LNG carrier fuel consumption is negligible (6 per cent) in comparison to the FSRU

- It is unlikely the FSRU engines will operate at 100 per cent when unloading from the LNG carrier
- AERMOD modelling indicates that results have a low sensitivity to LNG carrier emissions.

Tugboats operated by PoHDA to assist with mooring the LNG carrier have also been excluded from the emissions modelling.

10.3.7 Model selection

The AERMOD (V19191)[3] dispersion modelling package was used for this assessment. AERMOD is a Gaussian plume dispersion model, designed to predict ground level concentrations or the deposition of pollutants emitted from one or more sources, and is endorsed by EPA as the regulatory model for use in air quality assessments in Victoria, as per the draft guideline document (EPA 2013a) *Guidance notes for using the regulatory air pollution model AERMOD in Victoria* [Publication 1551].

There are conditions in which alternative modelling approaches may be required in Victoria. These conditions are '*Complex geographical locations whereby factors such as: terrain, coastal and land-use influences; in combination with the spatial scale of the impact zone of the sources; require the use of fully 3-dimensional meteorological fields'* (EPA 2013a). The Project is situated in a quasi-coastal setting which triggers the consideration of whether AERMOD should be utilised. The concern in relation to coastal environments relates to the potential for a plume, released from a tall stack within a stable (or neutral) onshore breeze, to be entrained into the growing thermal internal boundary layer that forms over land. The plume is subsequently mixed to the ground by convective turbulence, which may result in higher actual ground level concentrations downwind of the boundary layer. The formation of the internal boundary layer close to the proposed FSRU location is unlikely due to turbulence generated by the French Island landmass five kilometres to the east. On this basis, the AERMOD model was considered acceptable for use of the air quality impact assessment. EPA and the independent technical reviewer have agreed to the use of AERMOD.

10.4 Air emission sources

10.4.1 Air Emissions Inventory

The key sources of air emissions identified for assessment were the four dual-fuel reciprocating engines and either two or three boilers with 60 MW steam heating capacity. The modelled sources were the FSRU engine stacks or funnels, or 'point' sources as they are described in dispersion modelling. The FSRU exhaust parameters provided by AGL are set out in **Table 21**. As the FSRU is a seagoing vessel, the exhaust stacks are designed to reach a height that is higher than the living quarters and accommodation block, to make sure that these areas do not block the dispersion from the stacks. The FSRU will be positioned in a way, such that the discharge points from the stack, point towards the south and away from the jetty infrastructure and sensitive receptors.

The capture and reuse of boil-off gas is maximised in operation of the FSRU to reduce any requirement for the combustion of boil-off gas as follows:

- using boil-off gas by onboard consumers
- using the re-condenser to reliquefy and send out during export operations
- increasing the operating pressures of the LNG tanks to retain the boil-off gas
- using the MSO to compress and export all excess boil-off gas to the shore pipeline

Combustion of the boil-off gas would occur if no other option is available and as a last resort (Note: the combustion can be via the boilers with the steam dumped in the atmospheric dump condenser or via a combustion unit dependent on the FSRU technology installed)

During export (open or closed loop) the boil-off gas is able to be reliquefied using the re-condenser and exported with the export gas. It is anticipated that tank pressures are able to be maintained at export rates greater than 80 mmscf/d. It is only anticipated that the MSO will be required after multiple days of zero gas export to manage tank pressures. In the event that the MSO is not available, the boil

[3] This is the current version of AERMOD at the time of writing

off gas will need to be combusted to maintain safe tank pressures, this is not expected to occur during normal operations. Air emissions from the FSRU gas combustion unit have therefore been excluded.

In accordance with prevailing requirements, the FSRU is equipped with an emergency diesel generator set, providing emergency power in case the power from the main generators should be lost. The emergency generator set consists of a diesel engine with a rated output of 1007 kW, and an alternator with a rated output of 750 kW (937.5 kVA). The FSRU is also equipped with an auxiliary boiler with a 14 ton/hr steam heating capacity. The auxiliary boiler will not be used during normal operation, as the economisers (i.e. waste heat recovery units) on the dual fuel engines are sized to supply the regular heating demand. It is expected that running the auxiliary boiler may only be required in very low temperatures when the heat demand in the living quarter may be excessive, or if the vessel should be lying idle with only very low “accommodation related” power consumption. As the emergency diesel generator set and auxiliary boiler will not be used during a normal operating scenario, they have not been included in air emissions modelling.

The Wärtsilä 50DF is a four-stroke dual-fuel engine that can be run on natural gas and marine diesel oil and is manufactured in configurations giving 950/975 kW per cylinder and a total maximum mechanical output of 17,100 kW. The FSRU will be fitted with one 6L50DF and three 8L50DF engines. Wärtsilä 50DF engines operate on the lean-burn principle: the mixture of air and gas in the cylinder has more air than is needed for complete combustion. Lean combustion reduces peak temperatures and therefore NOx emissions. The Wärtsilä 50DF engine is initially started in marine diesel oil mode, then gas admission is activated when combustion is stable. It is assumed start-up will take approximately 10 minutes. The change over from marine diesel oil to gas takes less than one minute under load. When operating in gas mode, the pilot fuel amounts to less than one tonne of diesel per day in normal operations.

Up to three generators would be in use on the FSRU for most of the time. The gas flow rate and therefore the number of generators operating would generally only vary intermittently in response to short-term changes in gas demand (i.e. in response to short-term issues such as responding to outages from other projects). The use of the fourth generator is expected to be very rare and only for short periods of time.

The generators would typically be operated in an n+1 configuration, providing some operational flexibility against unexpected shutdowns of one generator and/or in case of sudden and unplanned increase in power demand.

The load demand for each generator would vary for nominated gas flow rates depending on other operations potentially going on at the same time. Examples include when the ship-to-ship LNG transfer operations are occurring, which would lead to a brief increase in total power demand due to additional consumers. Other operational parameters such as the pressure in the gas pipeline would also affect the power demand.

The FSRU will be fitted with either two or three MAC-90BF gas-fired boilers with a power rating of 60 MW steam heating capacity and maximum evaporation of 90 t/h. The boilers will only be required in closed loop and combined loop mode for the regasification process (to heat the LNG).

Table 21 FSRU exhaust parameters

Parameter	Engine Exhaust 1	Engine Exhaust 2, 3 and 4	Boiler 1, 2 and 3
Make & model	Wärtsilä 6L50DF	Wärtsilä 8L50DF	MAC-90BF Boiler
Power rating	5850 kW	7800 kW	60 MW steam heating capacity
Rotational speed	514 RPM	514 RPM	-
Fuel type	Gas or Diesel	Gas or Diesel	Gas
Height above deck	35.9 m	35.9 m	35.9 m
Outlet orientation	Tilted 45˚ aftwards	Tilted 45˚ aftwards	Tilted 45˚ aftwards
Outlet location	Main funnel	Main funnel	Main funnel
Diffuser description	Silencer and economiser	Silencer and economiser	Economiser
Outlet area	0.90 m^2	1.00 m^2	1.70 m^2

RPM – revolutions per minute

10.4.2 FSRU air emissions

The following air emissions data is relevant to the FSRU:

- Exhaust gas emission data for Wärtsilä 50DF engines operating on gas with marine diesel as pilot fuel
- Exhaust gas emission data for Wärtsilä 50DF engines when running on light fuel oil
- Performance Data for Mitsubishi Heavy Industries MAC-90BF Boiler and emission factors from Emission Estimation Technique Manuals (EETM) Combustion in boilers December 2011 (Australian Government 2011).
- Maximum daily diesel usage (14.6 tonnes) for a worst-case liquid fuelled scenario

The air emissions estimates for gas and liquid-fuelled FSRU operational modelling scenarios, are set out in **Table 22** and **Table 23**, respectively. The emission factors for the Wärtsilä 50DF engines were taken from the manufacturer's emissions specifications, which are provided in **Appendix G**. Emission factor tolerances are provided in the specifications and are as high as ±32% (for VOCs), however it is likely that any emission rate fluctuations due to these tolerances will cancel out with four units operating concurrently. Based on this, emission rates for the Wärtsilä 50DF were calculated based on the listed emission factors without consideration for the tolerances.

Table 22 Air emissions estimated rates (per source) for the gas fuelled FSRU operational modelling scenarios

Parameter	Engine Exhaust 1		Engine Exhaust 2, 3 and 4		Boiler 1, 2 and 3	
	g/kWh[1]	g/s	g/kWh[1]	g/s	kg/t[2]	g/s[3]
NOx (as NO_2)	1.2	1.95	1.2	2.60	2.16	2.86
CO	0.9	1.46	0.9	1.95	1.82	2.41
VOC[5]	0.49	0.796	0.49	1.06	0.119	0.157
Formaldehyde	0.23	0.374	0.23	0.498	-	0.0737[4]
Particles (as PM_{10})	0.064	0.104	0.064	0.139	0.160	0.212
Parameter	**Engine Exhaust 1**		**Engine Exhaust 2, 3 and 4**		**Boiler 1, 2 and 3**	
Flow Rate (normal cubic metres per second Nm^3/s)	7.3		9.7		25.9	

Parameter	Engine Exhaust 1		Engine Exhaust 2, 3 and 4		Boiler 1, 2 and 3	
	g/kWh[1]	g/s	g/kWh[1]	g/s	kg/t[2]	g/s[3]
NOx (as NO_2)	1.2	1.95	1.2	2.60	2.16	2.86
CO	0.9	1.46	0.9	1.95	1.82	2.41
VOC[5]	0.49	0.796	0.49	1.06	0.119	0.157
Exit Velocity at 45˚ angle (m/s)	24.1		26.7		30.2	
Vertical velocity (m/s)	17.1		18.9		21.4	
Temperature (˚C)	303		319		450	

[1] From Wärtsilä 50DF design specification – refer to Appendix E

[2] From Table 22 Emission factors for natural gas (>30MW wall-fired), EETM for Combustion in Boilers (Australian Government 2011)

[3] Based on manufacture's specified 100% load fuel gas consumption rate of 4,760 kg per hour

[4] Table 22 in EETM for Combustion in Boilers (Australian Government 2011) does not list formaldehyde emission factor. Formaldehyde fraction conservatively calculated using FSRU design specifications (refer to Appendix E)

[5] VOC excluding methane

Table 23 Air emissions estimated rates (per source) for the liquid fuelled FSRU operational modelling scenario

Parameter	Engine Exhaust 1 (50% load, 3862kW)		Engine Exhaust 4 (50% load, 3862kW)	
	g/kWh	g/s	g/kWh	g/s
NOx (as NO_2)	10.40	5.13	10.40	5.13
CO	2.90	1.43	2.90	1.43
VOC	1.02	0.50	1.02	0.50
Particles (as PM_{10})	0.30	0.15	0.30	0.15
SO_2	0.80	0.40	0.80	0.40
Parameter	**Engine Exhaust 1 (50% load, 3862kW)**		**Engine Exhaust 4 (50% load, 3862kW)**	
Power Generation (kW)	1776[1]		1776[1]	
Fuel usage (t/d)	7.3		7.3	
Flow Rate (Nm^3/s)	4.9		6.5	
Exit Velocity at 45˚ angle (m/s)	15.6		17.3	
Vertical velocity (m/s)	11.1		12.2	
Temperature (˚C)	284		297	
Temperature (Kelvin)	557		570	

[1]Calculated based on fuel consumption rate and diesel heating value of 38.21 mega joules (MJ) per litre (from table 61 in NPI 2008) and conversion from MJ to kW (1 MJ = 0.2778 kW) and 46 per cent energy efficiency of Wärtsilä 50DF engines.

10.5 Air quality management best practice

The SEPP (AQM) defines 'best practice' as: '*the best combination of eco-efficient techniques, methods, processes or technology used in an industry sector or activity that demonstrably minimises the environmental impact of a generator of emissions in that industry sector or activity*'. From an air quality perspective, best practice design parameters and air emissions standards will be applied to ensure air emissions will be minimised to the extent practicable.

As discussed in **Section 10.4.1**, the engines and boilers for the proposed FSRU are the Wärtsilä 6L50DF dual-fuel engine, Wärtsilä 8L50DF dual-fuel engine, and Mitsubishi MAC-90BF boiler. Both the engines and boilers will be run on natural gas with marine diesel oil only used as a pilot fuel for the engines, or during emergency operation. The use of natural gas as a fuel, rather than diesel, provides the advantage of considerably lower emissions of air pollutants such as PM_{10}/$PM_{2.5}$, SO_x and PAH.

In addition, the engines and boilers have low-NOx emissions technology that is currently the best in class for natural gas-fired power plants. The boilers have flue gas recirculation systems installed as a NOx control technique to limit NOx emissions. A comparison of the proposed FSRU's NOx emission factors compared with reference plant is presented in **Table 24**. The Wärtsilä engines and Mitsubishi boiler provide an 80 percent and 65 percent respective reduction in NOx emissions compared with the reference plant (USEPA 2000b). The use of the proposed FSRU for the Project is considered best practice from an air quality emissions perspective. It is likely that no further major benefits in air quality could be gained by choosing different plant or power source technology.

Table 24 Comparison of NOx emissions: proposed FRSU plant and reference plant

Air Pollutant	Emission factor (g/kWh)			
	Wärtsilä 6L50DF/ 8L50DF	Reference 4-stroke lean-burn reciprocating engine[1]	Boiler MAC-90BF	Reference gas-turbine[2]
NOx	1.2	6.3	0.17	0.49

[1] From AP42 Table 3.2-1 (USEPA 2000b)

[2] From AP42 Table 3.1-1 for uncontrolled natural gas-fired turbines (USEPA 2000a)

10.6 Air quality impact assessment

This section provides an assessment of the potential air quality impacts on sensitive receptors and the surrounding environment during operation of the FSRU in comparison to the SEPP (AQM) design criteria. It also provides a summary of the FSRU design specifications in comparison to SEPP (AQM) emission limits.

10.6.1 Stationary source emissions

Combustion emissions from the operational FSRU include a range of air pollutants, such as NO_2, CO, PM_{10}, $PM_{2.5}$, SO_2 and VOC. All these air pollutants have been assessed in isolation, with selected pollutants further assessed in terms of their cumulative concentrations. **Table 25** compares gas-fuelled FSRU design specifications (refer to **Appendix G**) to SEPP (AQM) emission limits for stationary sources (Schedule E). FSRU design specifications comply with SEPP (AQM) emission limits for particulate matter, CO, and NOx from the boilers. Note that NOx emission limits for internal combustion engines are excluded by the SEPP (AQM).

Table 25 SEPP (AQM) Schedule E - Emission limits for stationary sources

Emissions source	Air Pollutant	Emission limit (mg/Nm^3)[1]	Gas-Fuelled FSRU Design Specification (mg/Nm^3)	
			50% load	100% load
All stationary sources[2]	Particulate matter	250	23	15
	CO	2500	607	217
Boiler[3]	NOx	350	60	78

[1] Gas volumes are expressed as milligrams per normal cubic metre (mg/Nm^3) at 25˚C and at an absolute pressure of one atmosphere (1013.25 hectopascal)

[2] At typical stack oxygen concentration of 11.8 per cent

[3] As NOx at a 7 per cent oxygen reference level

10.6.2 Modelling predictions for FSRU operational scenarios

A summary of the maximum predicted 1-hour NO_2, PM and CO, and 3-minute VOC, PAH, benzene and formaldehyde concentrations resulting from operation of the FSRU for each modelling scenarios is presented in **Table 26**. The data is presented for FSRU air emissions predictions excluding background air pollutant concentrations, and FSRU air emissions predictions including background air pollutant concentrations (cumulative), and these has been compared against SEPP (AQM) design criteria (Schedule A).

Figure 11 to **Figure 21** provide a graphical representation of model predictions across the gridded modelling domain for NOx, PM_{10} and formaldehyde for the gas fuelled scenarios and NOx and PM_{10} for the liquid fuelled scenario. Refer to **Appendix H** for the full results of each modelling scenario, at each of the 38 sensitive receptor locations.

Table 26 Summary of maximum predicted air pollutant concentrations from operation of the FSRU modelled at sensitive receptor locations, 99.9th percentile

Air Pollutant	SEPP (AQM) design criteria (µg/m^3)	Averaging Period	Excluding Background		Including Background	
			Concentration (µg/m^3)	Per cent of Criteria (%)	Concentration (µg/m^3)	Per cent of Criteria (%)
1. Gas-fuelled – open loop scenario						
NO_2	190	1 hour	14.5	8%	69.2	36%
CO	29,000	1 hour	36.2	0.12%	1396	4.8%
VOC	-	3 minute	35.9	-	-	-
PM_{10}	80	1 hour	2.58	3.2%	47.2	59%
$PM_{2.5}$	50	1 hour	2.16	4.3%	21.5	43%
PAH	0.73	3 minute	0.000052	0.007%	-	-
Benzene	53	3 minute	0.134	0.25%	-	-
Formaldehyde	40	3 minute	16.9	42%	-	-
2. Gas-fuelled – closed loop, two boilers scenario						
NO_2	190	1 hour	16.2	9%	70.9	37%
CO	29,000	1 hour	41.0	0.14%	1401	4.8%
VOC	-	3 minute	36.5	-	-	-
PM_{10}	80	1 hour	3.00	3.7%	47.6	59%
$PM_{2.5}$	50	1 hour	2.51	5.0%	21.8	44%
PAH	0.73	3 minute	0.000053	0.007%	-	-
Benzene	53	3 minute	0.136	0.26%	-	-
Formaldehyde	40	3 minute	17.1	43%	-	-
3. Gas-fuelled – closed loop, three boilers scenario						
NO_2	190	1 hour	17.2	9%	71.9	38%
CO	29,000	1 hour	43.9	0.15%	1404	4.8%
VOC	-	3 minute	36.8	-	-	-
PM_{10}	80	1 hour	3.25	4.1%	47.9	60%

Air Pollutant	SEPP (AQM) design criteria (µg/m^3)	Averaging Period	Excluding Background		Including Background	
			Concentration (µg/m^3)	Per cent of Criteria (%)	Concentration (µg/m^3)	Per cent of Criteria (%)
$PM_{2.5}$	50	1 hour	2.72	5.4%	22.0	44%
PAH	0.73	3 minute	0.000054	0.007%	-	-
Benzene	53	3 minute	0.137	0.26%	-	-
Formaldehyde	40	3 minute	17.3	43%	-	-
4. Liquid-fuelled - engines scenario						
NO_2	190	1 hour	24.7	13%	79.4	42%
CO	29000	1 hour	23.0	0.1%	1383	4.8%
VOC	-	3 minute	19.9	-	-	-
PM_{10}	80	1 hour	2.38	3%	47.0	59%
$PM_{2.5}$	50	1 hour	1.99	4%	21.3	43%
SO_2	450	1 hour	6.35	1.4%	23.2	5.2%
PAH	0.73	3 minute	0.0000029	0.00040%	-	-
Benzene	53	3 minute	0.20	0.37%	-	-
Formaldehyde	40	3 minute	0.020	0.050%	-	-

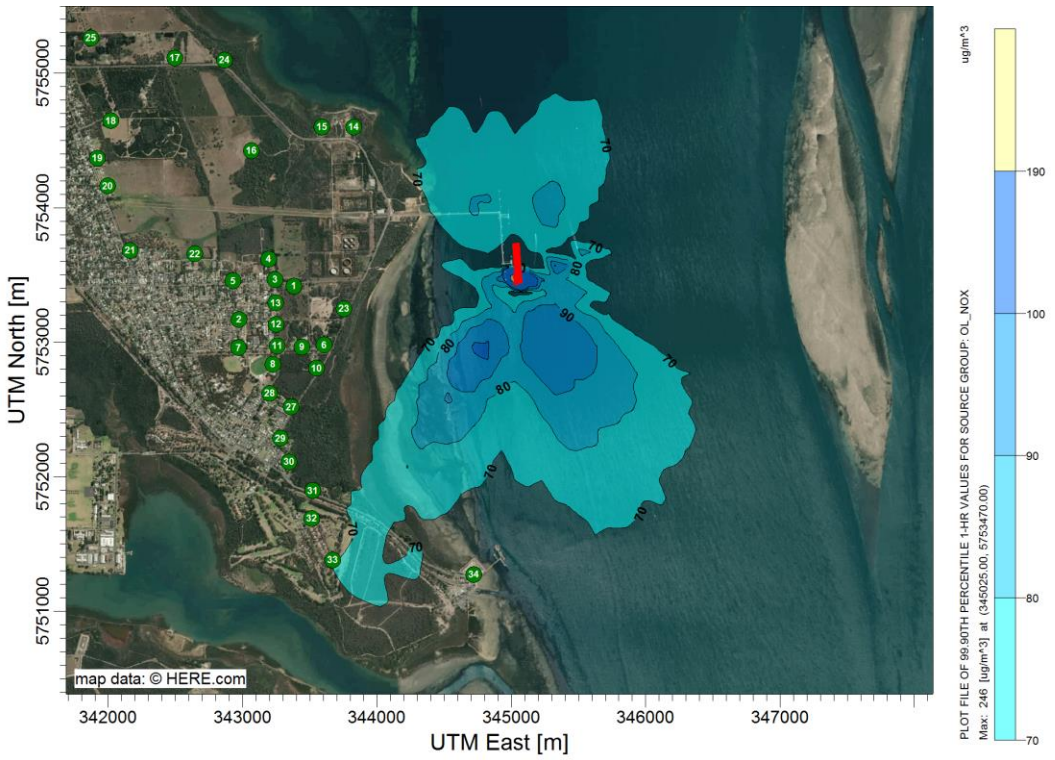


Figure 11 Gas-fuelled open loop FSRU scenario, NO_2 concentration results, 99.9th percentile including background (µg/m³)

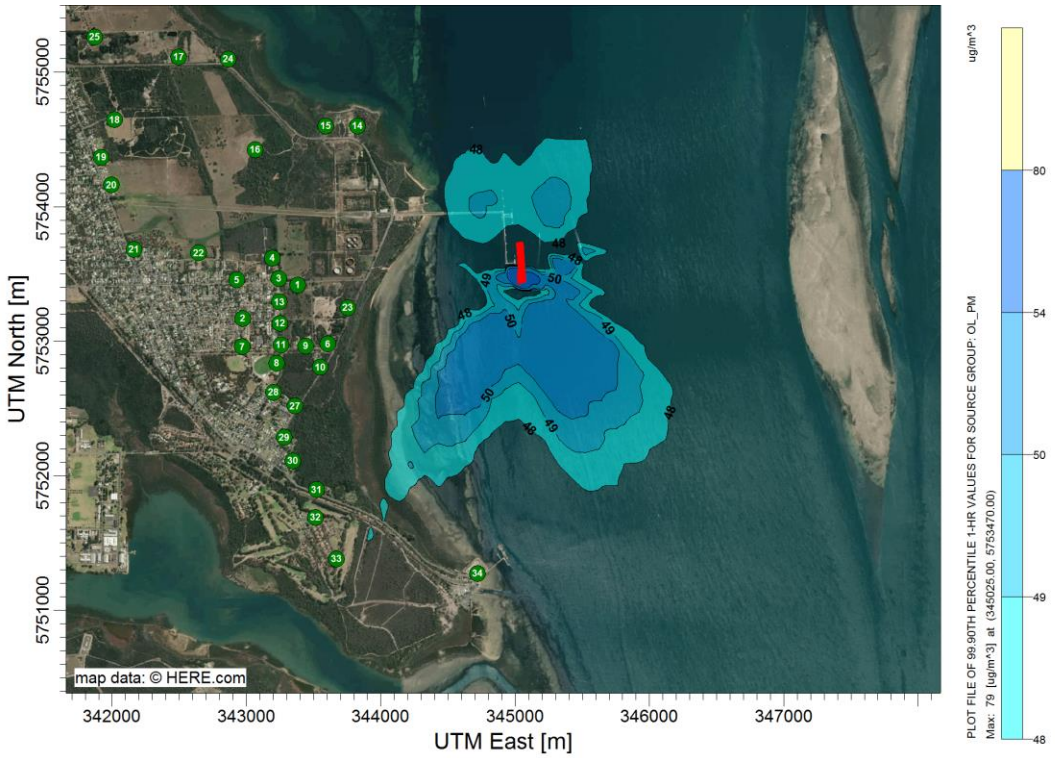


Figure 12 Gas-fuelled open loop FSRU scenario, PM_{10} results, 99.9th percentile including background (µg/m³)

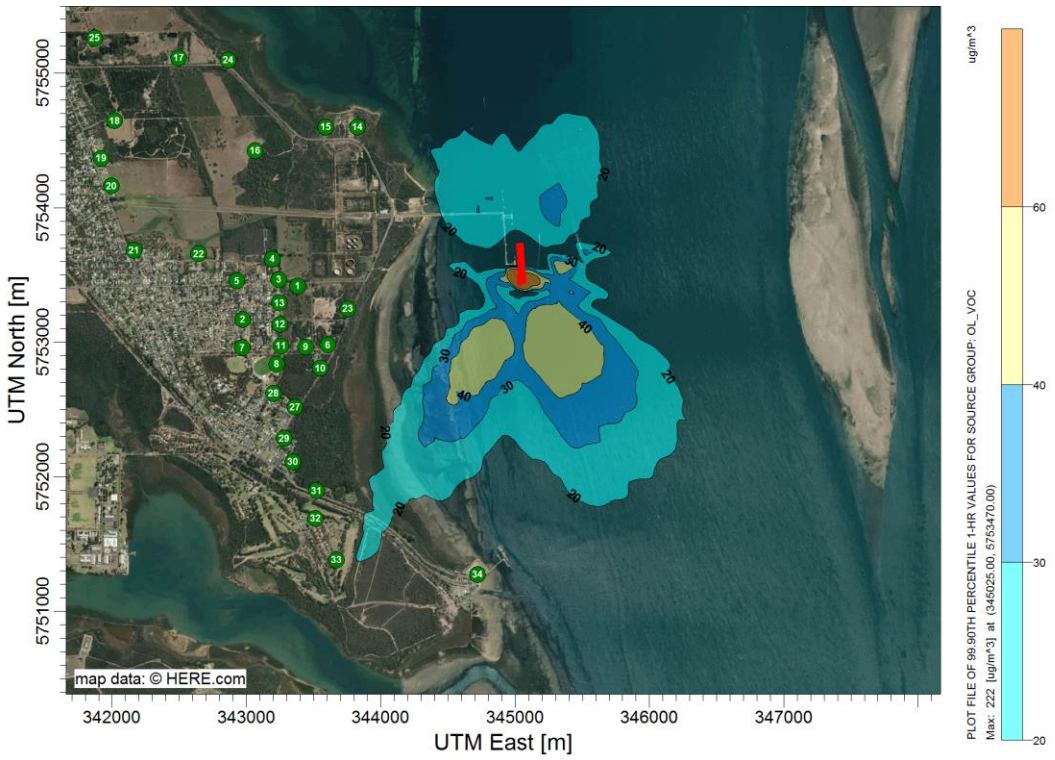


Figure 13 Gas-fuelled open loop FSRU scenario, Formaldehyde results, 99.9th percentile, no background (µg/m³)

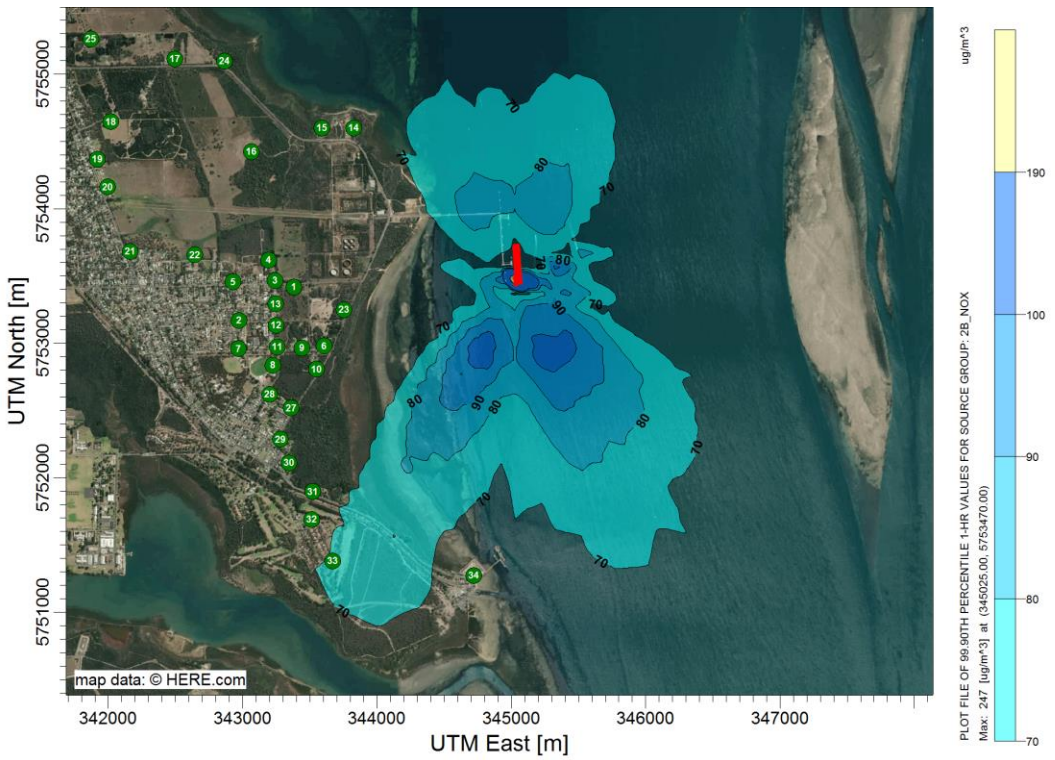


Figure 14 Gas-fuelled FSRU, two boiler scenario, NO_2 concentration results, 99.9th percentile including background (µg/m³)

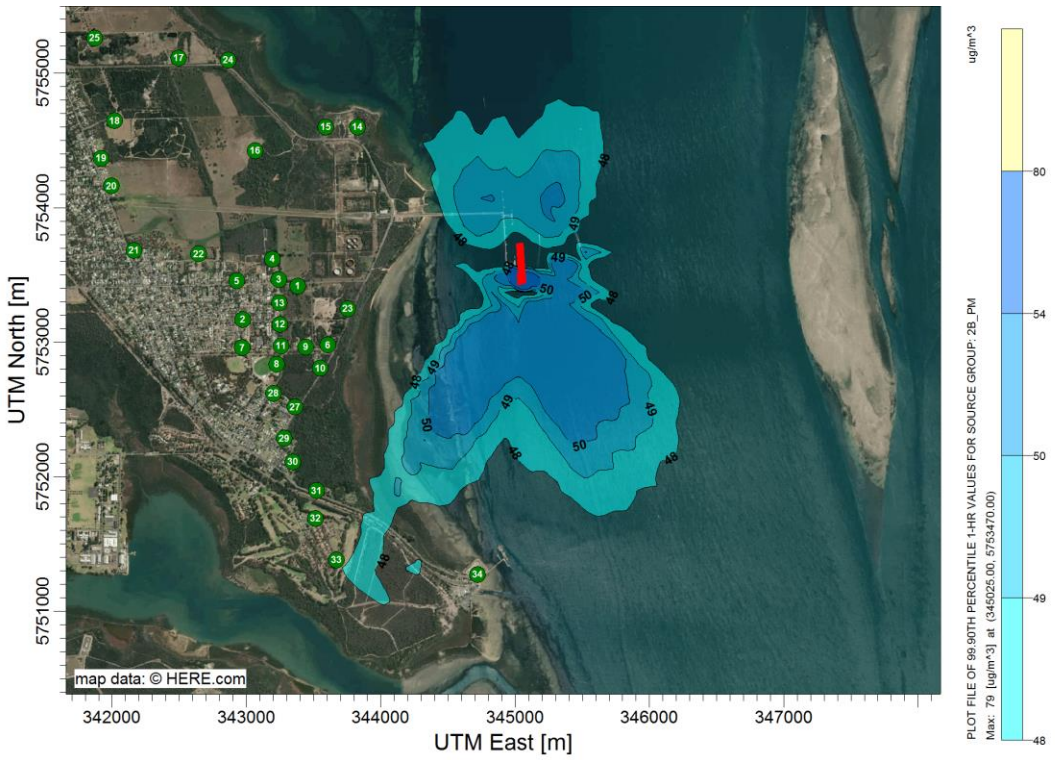


Figure 15 Gas-fuelled FSRU, two boiler scenario, PM_{10} concentration results, 99.9th percentile including background (µg/m³)

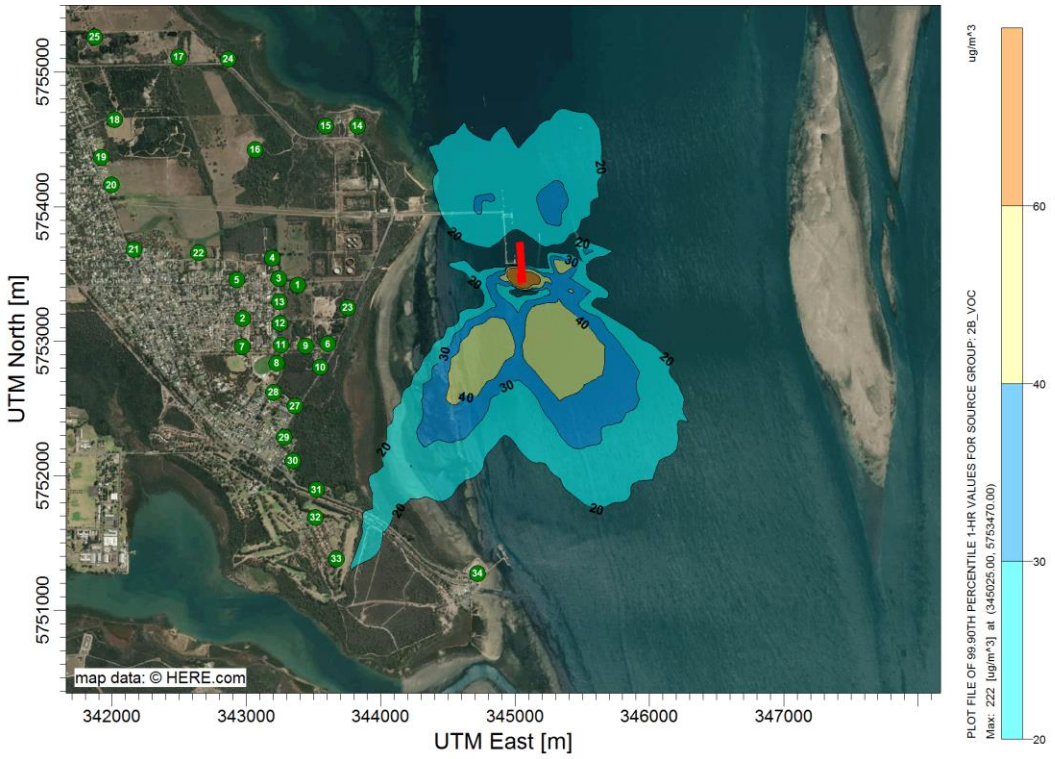


Figure 16 Gas-fuelled FSRU, two boiler scenario, Formaldehyde concentration results, 99.9th percentile, no background (µg/m³)

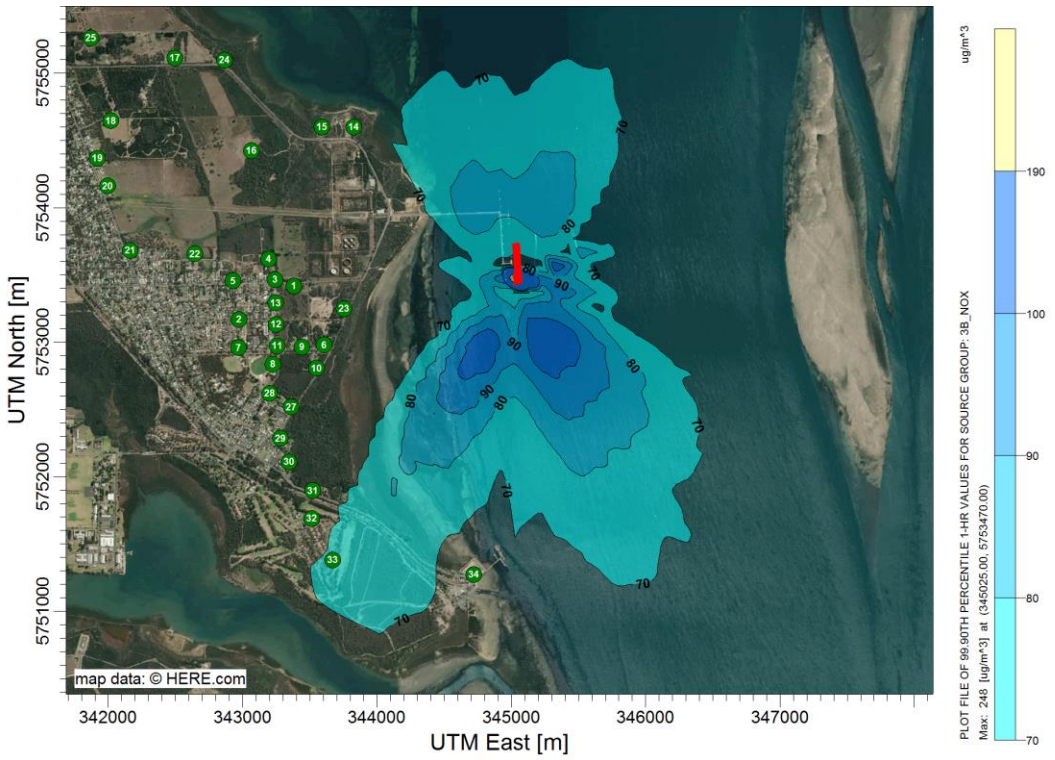


Figure 17 Gas-fuelled FSRU, three boiler scenario, NO_2 concentration results, 99.9th percentile including background (µg/m³)

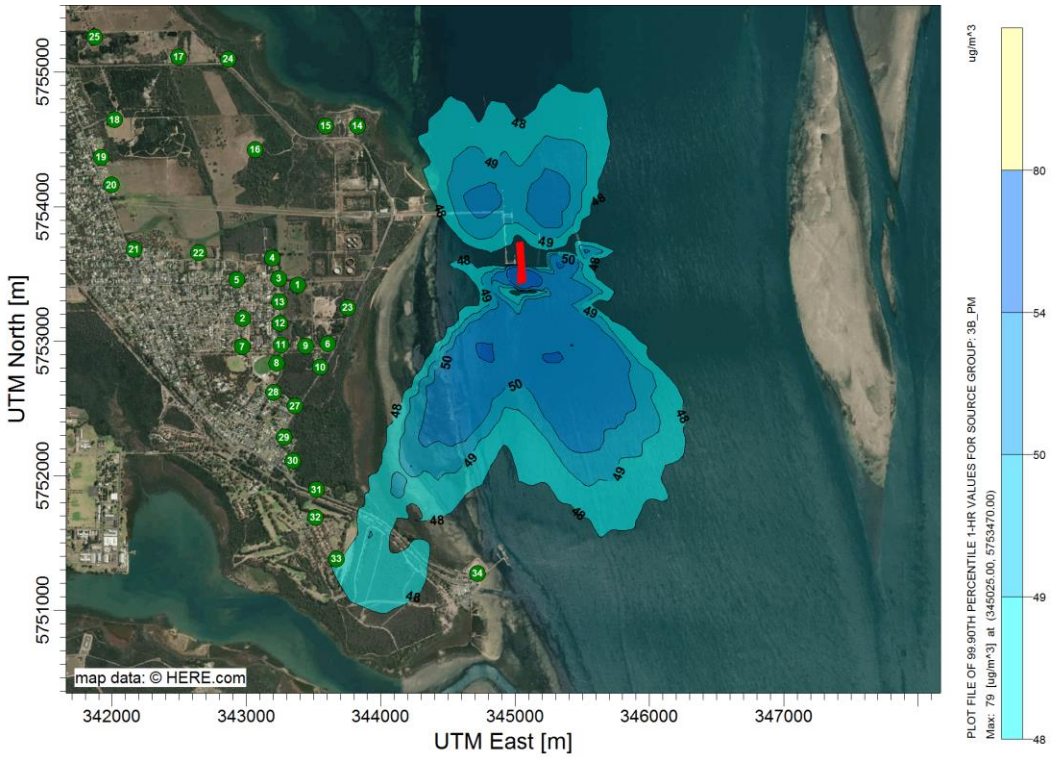


Figure 18 Gas-fuelled FSRU, three boiler scenario, PM_{10} concentration results, 99.9th percentile including background (µg/m³)

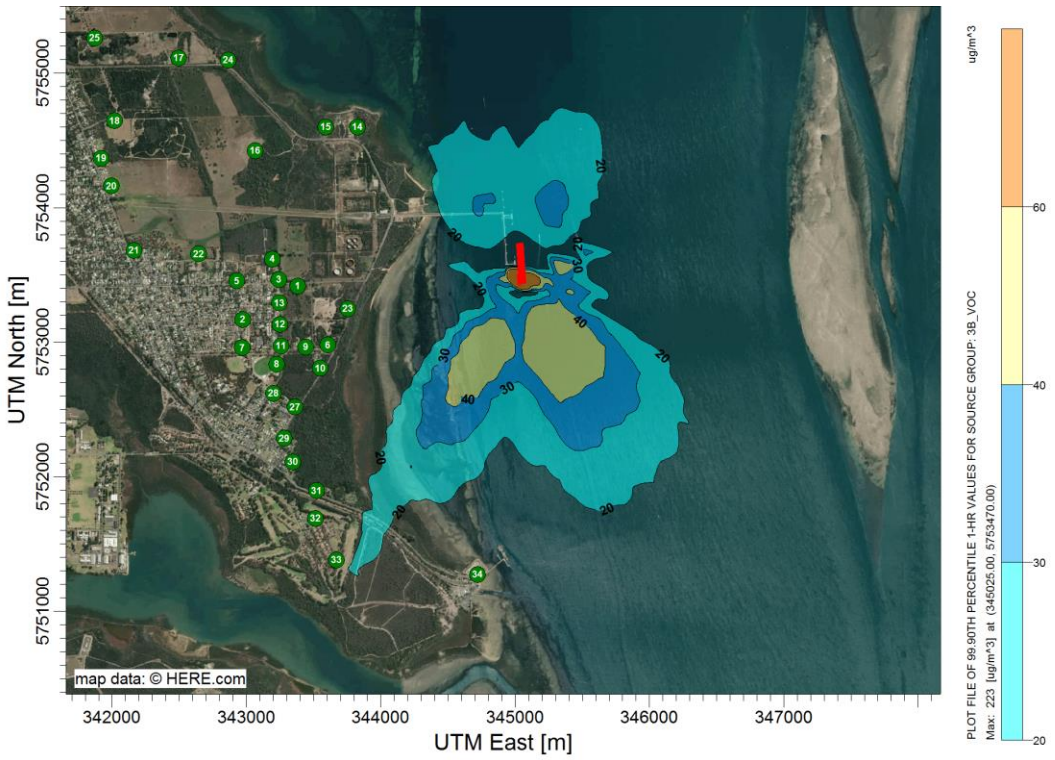


Figure 19 Gas-fuelled FSRU, three boiler scenario, Formaldehyde concentration results, 99.9th percentile, no background (µg/m³)

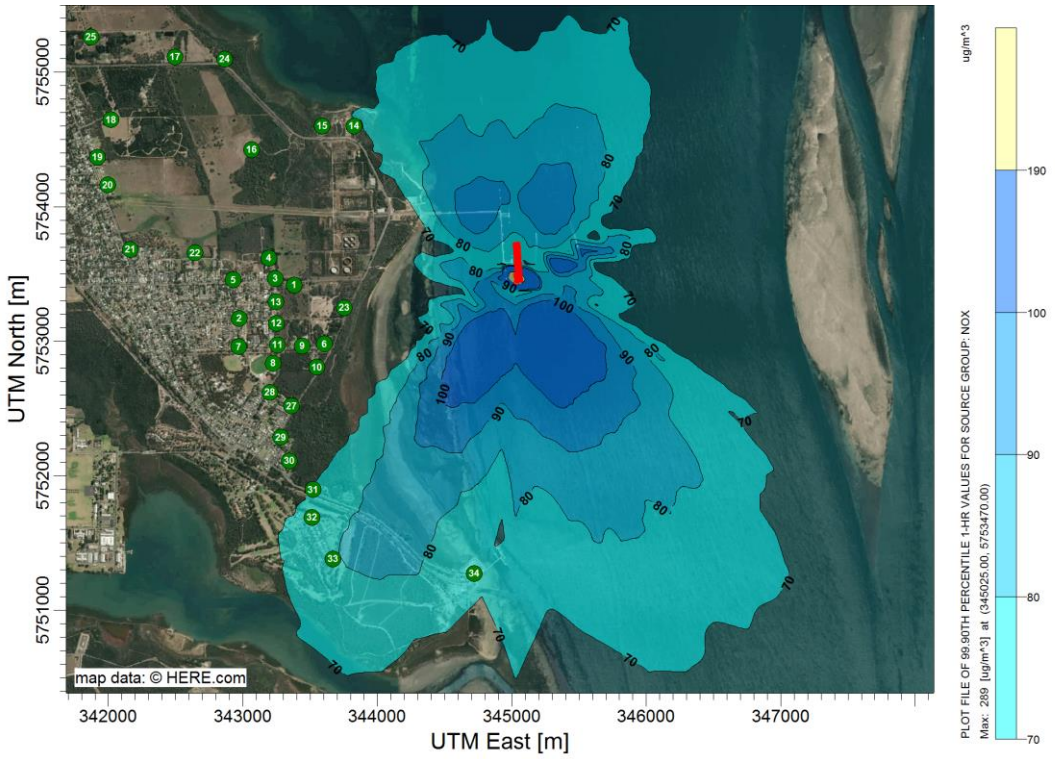


Figure 20 Liquid-fuelled FSRU scenario, NO_2 concentration results, 99.9th percentile including background (µg/m³)

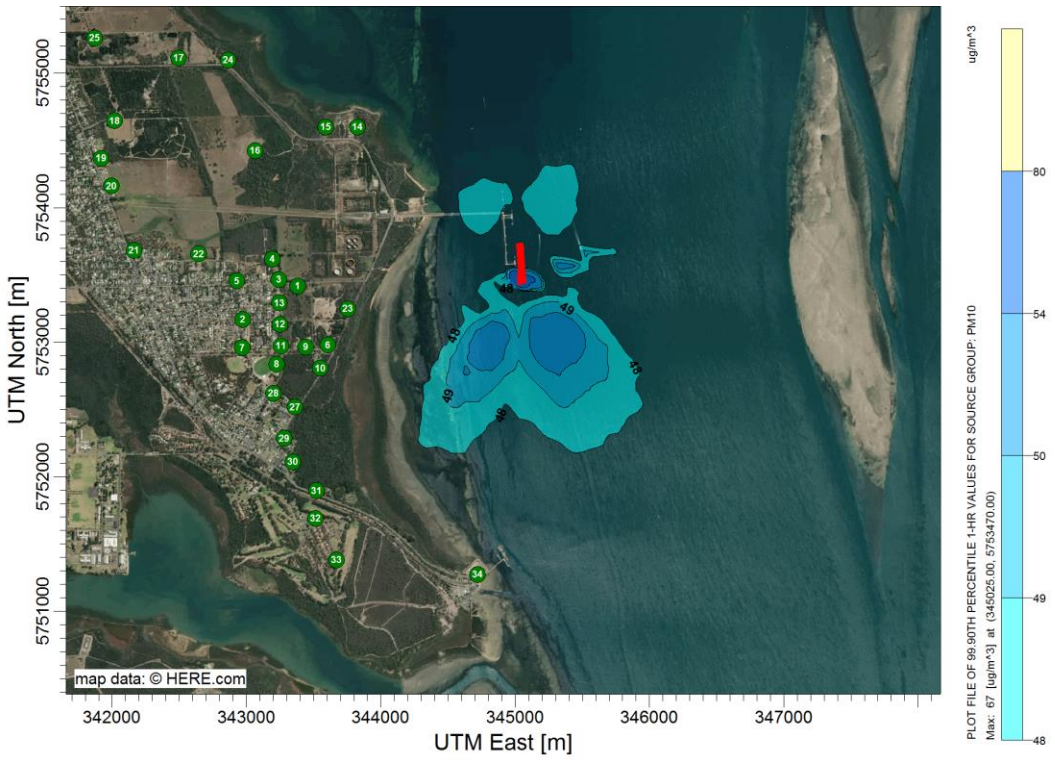


Figure 21 Liquid-fuelled FSRU scenario, PM_{10} results, 99.9th percentile including background (µg/m³)

Results from the FSRU operational modelling show air pollutant concentrations including estimated background levels are well below the SEPP (AQM) design criteria at sensitive receptors. It is considered unlikely that any local emission sources would lead to a spike in combustion pollutants sufficiently high to result in an exceedance of the design criteria.

Results demonstrate that a third boiler will increase air pollutant concentrations by less than one per cent at sensitive receptor locations, compared to the two-boiler modelled scenario. This means that running a third boiler is feasible from an air quality impact assessment perspective.

Although the FSRU operational modelling shows that there are no exceedances of the SEPP (AQM) design criteria at sensitive receptors, the following exceedances were noted:

- **Gas-fuelled FSRU open loop:**
  - NO_2 concentrations exceed the design criterion of 190 µg/m³ (when combined with 54.7 µg/m³ background) within approximately 50 metres of the FSRU. Waterside restricted zones (exclusion zones) are currently in place within 100 metres of the Crib Point Jetty. This waterside restricted zone is proposed to be increased to 200 metres to the east of Berth 2 and also to the south. Exceedances of NO_2 occur within the exclusion zone and as such there are no sensitive receptors located in which predicted concentrations are elevated; and
  - Formaldehyde concentrations exceed the design criterion of 40 µg/m³ within approximately 200 metres of the FSRU, at number of areas over water to the south and east of the FSRU and a small area of the Crib Point foreshore. These areas are shaded yellow in **Figure 13** Formaldehyde concentrations within the yellow shaded areas are predicted to be below the criterion for at least 99 per cent of the year. The implications of these elevated concentrations above the design criteria (for example, for workers on the FSRU) are further discussed in Section **10.7.2**.
- **Gas-fuelled FSRU closed loop (two and three boilers):**
  - NO_2 concentrations exceed the design criterion of 190 µg/m³ (when combined with 54.7 µg/m³ background) within approximately 50 metres of the FSRU. Exceedances of NO_2 occur

within the exclusion zone and as such there are no sensitive receptors located in which predicted concentrations are elevated;

- Formaldehyde concentrations exceed the design criterion of 40 µg/m^3 within approximately 200 metres of the FSRU, at number of areas over water to the south and east of the FSRU and a small area of the Crib Point foreshore. These areas are shaded yellow **Figure 16** and **Figure 19**.
- When all four engines and two or three boilers are operating at 100 per cent load, the formaldehyde design criterion could be exceeded over water outside the 100m maritime exclusion zone and a small area of the Crib Point foreshore. The implications of these elevated concentration above the design criteria (for example, for workers on board the FSRU) are discussed in **Section 10.7.2**.

- **Liquid-fuelled FSRU:**
  - NO_2 concentrations exceed the design criterion of 190 µg/m^3 (when combined with 54.7 µg/m^3 background) within 50 metres of the FSRU. Exceedances of NO_2 occur within the exclusion zone and as such there are no sensitive receptors located in which predicted concentrations are elevated.

10.6.3 Fugitive emissions

Air quality impacts related to fugitive emissions have not been assessed, as the impacts are likely to be negligible compared to emissions related to fuel combustion. GHG emissions related to fugitive emissions during operation of the FSRU are discussed in **Section 8.0**.

10.6.4 Other information

After completing the construction and commissioning phase, a discharge licence will be required under the EP Act to operate the FSRU.

A summary of the worst-case air emissions rates from the FSRU compared to the scheduled premises threshold as defined in Schedule 1 of the EP Act to determine whether a licence and/or works approval is required is provided in **Table 27**.

NOx, CO and VOC are predicted to exceed the threshold when the FSRU operates on gas in open loop mode and on gas with two boilers in closed loop mode. NOx, CO, VOC and particulate emissions are predicted to equal or exceed the scheduled premises thresholds when the FSRU operates on gas with three boilers at 100 per cent load. In addition, SO_2 is predicted to exceed the threshold when the FSRU operates on liquid fuel.

Consequently, the FSRU will require a works approval and a discharge licence under the EP Act.

Table 27 Comparison of predicted FSRU air emissions to scheduled premises air emissions thresholds

Air Pollutant	Operating Scenario	Total air emissions		Scheduled premises threshold (kg/day)	Exceeds Threshold (Yes / No)
		g/s	kg/day		
NOx (as NO_2)	Gas-fuelled, Open Loop	9.75	842	100	Yes
CO		7.31	632	500	Yes
VOC		3.98	344	100	Yes
Particulates		0.52	44.9	100	No
NOx (as NO_2)	Gas-fuelled, Closed Loop, two boilers	15.46	1336	100	Yes
CO		12.13	1048	500	Yes
VOC		4.30	371	100	Yes
Particulates		0.94	81.5	100	No
NOx (as NO_2)		18.32	1583	100	Yes

Air Pollutant	Operating Scenario	Total air emissions		Scheduled premises threshold (kg/day)	Exceeds Threshold (Yes / No)
		g/s	kg/day		
CO	Gas-fuelled, Closed Loop, three boilers	14.53	1256	500	Yes
VOC		4.45	385	100	Yes
Particulates		1.15	100	100	Yes
SO_2	Liquid-fuelled, two engines at 25% load	5.69	492	100	Yes

10.7 Further air emissions assessment

10.7.1 Emission during plant start-up or shut down

Modelling was conducted to predict the worst-case emissions from the FSRU, using the four modelling scenarios described in **Section 10.3.6**. It is assumed the FSRU engines will take approximately 10 minutes to start-up or shut down. The change over from marine diesel oil to gas takes less than one minute under load. In addition, the engines in the FSRU have been designed to efficiently respond to changes in load when output requirements change based on customer demand. Due to the short duration of these scenarios, air emissions during plant start-up, shut down or changes in load are not expected to exceed the modelled scenarios, which are considered worst-case.

10.7.2 Risk assessment

It is a requirement to undertake a risk assessment when predicted Ground Level Concentrations (GLC) are above the design criteria set out in the SEPP (AQM). All modelled FSRU operational scenarios described in **Section 10.3.6** demonstrated there are no exceedances of SEPP (AQM) design criteria at any of the sensitive receptor locations, with all predicted air emissions concentrations well below the design criteria. However, when all four engines and two or three boilers are operating at 100 per cent load, the formaldehyde design criterion could be exceeded over water outside the 100 m exclusion zone and a small area of the Crib Point foreshore. A Human Health Risk Assessment (HHRA) has been undertaken as part of the air emissions impact assessment for this Project.

Depending on the likely or predicted exposure period, acute (short-term) and chronic (long-term) screening criteria can be considered in the HHRA. As the FSRU is expected to operate at peak capacity in short durations for only 10 per cent of the year, Acute 1-hour Criteria has been considered for the purpose of screening formaldehyde emissions from the FSRU.

The acute screening criteria for Formaldehyde are shown in **Table 28**.

Table 28 Formaldehyde Acute Exposure Screening Criteria

Chemical	Concentration (µg/m^3)	Source
Formaldehyde	PAC-1 (1 hour): 1,190	Acute Exposure Guideline Levels (AEGL) -1 - converted from 0.90 ppm[1]
	PAC-2 (1 hour): 18,500	AEGL-2 - converted from 14 ppm[1]
	PAC-3 (1-hour): 74,000	AEGL-3 - converted from 56 ppm[1]

[1] Based on a molecular weight of 30.031g/mol

The maximum predicted 1-hour and 3-minute formaldehyde concentrations for the gas-fuelled, three-boiler scenario is 178 µg/m^3 and 324 µg/m^3, respectively. The 99.9th percentile 1-hour and 3-minute average concentrations are 123 µg/m^3 and 223 µg/m^3, respectively. Refer to **Figure 19** for 99.9th percentile 3-minute concentration contours.

The following is noted in terms of compliance with the criteria for workers health and general compliance with the formaldehyde acute exposure screening criteria:

- Predicted maximum 1-hour average concentration (178 µg/m^3) represents approximately 15 per cent of the Time Weighted Average (TWA) criterion (1,200 µg/m^3) and Protective Action Criteria (PAC) -1 criterion (1,190 µg/m^3)

Modelling results demonstrate that formaldehyde concentrations will be much less than the TWA and PAC-1 criteria, indicating that from an acute health risk perspective, there are no adverse health impacts expected for workers or receptors in the vicinity of the FSRU.

The air modelling assessment and HHRA demonstrates that there is a low risk of air quality impacts from the FSRU operations. FSRU air emissions are unlikely to have regionally or State significant effects on the air environment. An air quality monitoring programme will be designed and implemented to confirm FSRU air emissions rates comply with design specifications (refer to **Section 16.0**).

The full human health risk assessment has been included in **Appendix I** and can also be found in the EES Technical Report G*: Air quality impact assessment* (refer to **Appendix B**).

10.7.3 Impacts on airshed

The FSRU will be located in an air quality control region (the Port Phillip airshed). Air emissions from the operation of the FSRU were assessed against background air quality of the Port Phillip airshed to determine the influence of FSRU operation on the airshed.

A comparison between the largest modelled air emissions against what is considered a very large emission for each of the relevant pollutants as per the EPA Publication 1658 – Works Approval Application Guideline is summarised in **Table 29** .

Table 29 Summary of modelled air emissions on airshed

Air Pollutant	Very large air emission criteria (t/year)	Largest modelled emission (t/year)
NO_2	>1000	578
VOC	>2000	141
Particulate matter (PM_{10} and $PM_{2.5)}$	>200	37

Based on these results, the operation of the FSRU will not involve very large air emissions in or around the airshed.

10.8 Odour

The operation of the FSRU is not expected to generate odour emissions as the anticipated air pollutants do not generate odour. Therefore, an odour emissions assessment was not conducted. In addition, odour associated with the storage and handling of waste will be managed and conducted in accordance with legislative requirements to ensure that there are no odour emissions.

10.9 Summary

Modelling predictions show that the FSRU operational air pollutants of interest are NO_2, CO, VOC, PM_{10}, $PM_{2.5}$, SO_2 (liquid fuel scenario only) and PAH. Benzene and Formaldehyde from the FSRU including background concentrations are well below the SEPP (AQM) design criteria at sensitive receptors.

Results do however show that NO_2 concentrations exceed the design criterion of 190 µg/m^3 (when combined with 54.7 µg/m^3 background) within approximately 100 metres of the FSRU during all operational modelling scenarios. In addition, Formaldehyde concentrations exceed the design criterion of 40 µg/m^3 during the all operational modelling scenarios excluding the liquid fuelled scenario.

When all four engines and two or three boilers are operating at 100 per cent load, the formaldehyde design criterion could be exceeded over water outside the 100m exclusion zone and a small area of

the Crib Point foreshore. Therefore, a HHRA has been undertaken. Modelling results demonstrate that formaldehyde concentrations will be much less than the TWA and PAC-1 criteria, indicating that from an acute health risk perspective, there are no adverse health impacts expected for workers or receptors in the vicinity of the FSRU.

The air modelling assessment and HHRA demonstrates that there is a low risk of air quality impacts from the FSRU operations. FSRU air emissions are unlikely to have regionally or State significant effects on the air environment.

11.0 Noise emissions

Preparation of this section of the WA application was based on information provided in the EES Technical Report H: *Noise and vibration impact assessment* (refer to **Appendix B**). The noise and vibration technical report has undergone an external peer review to ensure that the report adequately addresses the matters set out in the scoping requirements and to ensure that the study sufficiently examines and clearly documents the potential environmental impacts and risks of the operation of the FSRU.

11.1 Noise and vibration emissions assessment

A noise and vibration emissions assessment was conducted as part of the EES process to assess the potential noise and vibration impacts due to construction and operation of the FSRU at Crib Point. Noise and vibration emissions from construction activities are not related to the FSRU directly and as such, will not be discussed further in this WA application.

Although this WA application is related to the FSRU only, the noise assessment has considered noise emissions from the entire Gas Import Facility (including the FSRU, the jetty infrastructure to be installed at the existing Crib Point Jetty (Berth 2), and the Crib Point Receiving Facility) as this is more representative of the noise emissions that are expected during Project operation.

Victoria has two EPA Publications, which apply to all operational noise from 'commercial industrial or trade premises' noise from industry in Victoria:

- EPA Publication 1411: *Guideline Noise from Industry in Regional Victoria* (NIRV). This guideline applies to noise from commerce, industry and trade premises in regional Victoria.
- EPA Publication S31: *State Environmental Protection Policy (Noise from Industry, Commerce and Trade) No. N-1* (SEPP N-1). This is a statutory policy that applies to noise from commerce, industry and trade premises in the Metropolitan Melbourne area.

Statutory noise limits are only imposed by SEPP N-1 within the SEPP N-1 boundary for metropolitan Melbourne. No part of the project area falls within the SEPP N-1 boundary, and as such, operational noise from the project has been assessed using the NIRV guidelines. NIRV outlines two methods for determining the Recommended Maximum Levels (Recommended Levels) for the Project. As the area around Crib Point falls into the area between the SEPP N-1 boundary and the Melbourne Urban Growth Boundary (UGB), the SEPP N-1 procedure for calculating the Recommended Levels was used for sensitive receptors in this location. The NIRV procedure for calculating the Recommended Levels was used for sensitive receptors on French Island.

11.2 Existing conditions

As this Project involves a new development, from a noise perspective, the existing conditions are characterised by the location of sensitive receptors (such as residences, schools and hospitals), and the existing noise conditions at each of the selected sensitive receptors. The nearest noise-sensitive residential receptors to the Crib Point Jetty is at 103 The Esplanade and is located approximately 1.2 km north west of the proposed FSRU location.

To determine background noise levels and ambient noise levels, unattended noise monitoring was undertaken at 14 locations over a continuous two-week period between 18 January 2019 and 5 February 2019. Three of the 14 locations are considered sensitive receptors to the operation of the FSRU.

The meteorological data captured from Her Majesty's Australian Ship (HMAS) Cerberus and obtained through the Bureau of Meteorology was used to identify periods where measured noise levels should be adjusted or removed due to extraneous weather. Adverse weather conditions were considered where wind speeds were noted to be greater than 5m/s and/or rainfall was measured to be greater than 3mm in an hour. The data from each location was investigated and data was omitted where adverse weather conditions, or extraneous noise events, affected the measurements.

A summary of the background noise levels (L_{A90}) and ambient noise levels (L_{Aeq}) at each of the three monitoring locations that are considered sensitive receptors to the operation of the FSRU is shown in **Table 30**.

Table 30 Unattended noise measurements – background and ambient noise monitoring results

Address	Measured level, dB	Day			Evening			Night		
		Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
103 The Esplanade, Crib Point	L_{A90}	33	36	35	32	37	35	23	32	26
	L_{Aeq}	43	55	49	42	55	50	37	48	42
43 Disney Rd, Crib Point	L_{A90}	32	36	34	31	38	34	21	25	22
	L_{Aeq}	49	56	52	48	57	54	40	52	45
Lorimer St, Crib Point	L_{A90}	31	46	35	34	38	35	23	30	27
	L_{Aeq}	43	69	59	42	48	45	35	52	44

The lowest of the average background levels (L_{A90}) have been used to calculate the Recommended Maximum Levels discussed in **Section 11.5.1**.

The following observations were made from data collected during the unattended noise monitoring:

- Overall, background noise levels in rural areas had limited exposure to major transportation or industrial noise during the Night period.
- Background noise in the vicinity of major roads was typically higher than those in rural areas and in Hastings. Background noise measurements are greatest at locations near the Princes Highway and Freeway.
- The evening background noise levels are marginally greater than the day-time background levels at some locations. This is likely due to external noise sources such as evening peak hour traffic.
- Noise from the existing landside pump at Crib Point Jetty is audible at nearby residences while a United Petroleum vessel is moored at Berth 1.

Attended noise measurements were also conducted at 103 The Esplanade, Crib Point, measuring noise from the Crib Point Jetty when a United Petroleum vessel was berthed and unloading at Berth 1, on Friday 18 January 2019. Several additional attended noise measurements were conducted on Tuesday 9 April 2019 to supplement the terrestrial noise impact assessment. These results are presented in **Table 31**.

Table 31 Attended noise measurements – background and ambient noise monitoring results

Location	Start time of measurement	Measured noise level. dB(A)	
		Ambient noise level (L_{Aeq})	Background noise level (L_{A90})
103 The Esplanade, Crib Point	10:36AM 18/01/2019	40	37
Woolley's Beach Reserve, Crib Point	3:03PM 09/04/2019	48	44
Jacks Beach, Crib Point	3:44PM 09/04/2019	41	35
Warringine Park, near Reid Pde, Hastings	4:19PM 09/04/2019	48	45
Warringine Park, Bittern Coastal Wetlands Boardwalk	1:55PM 17/04/2019	44	42

The following observations were made from data collected during the attended noise monitoring:

- **103 The Esplanade, Crib Point**:
  - Weather conditions at the time of monitoring were still and overcast. There was no rain at the time of measurement, although storms did pass through the area on this day. Noise measurements were not impacted by any rain or thunderstorm activity.
  - From this location, a sustained low rumble and a mid-frequency humming noise could be heard from the Crib Point jetty while a ship was docked at Berth 1. The overall L_{Aeq} sound pressure level of the noise that could be heard from the Crib Point Jetty while a ship was docked at Berth 1 was ~40 dB(A).
  - The low frequency component noted at 63 Hz was noticeable and provided the highest contribution to the overall noise level (~33 – 35 dB(A)). This noise is due to the operation of the landside pump offloading petroleum from a ship docked at Crib Point Jetty Berth 1 (United Petroleum operations).
- **Parks and reserves:**
  - The weather at the time of monitoring was overcast with regular light rain showers and moderate (19km/h) wind speeds.
  - Sounds from the natural environment were most prominent throughout these measurements.
  - A ship was not docked at the Crib Point Jetty (Berth 1) at the time of the attended measurements at Jacks Beach and Woolley's Beach Reserve.

Baseline unattended noise monitoring locations are shown in **Figure 22** and attended noise monitoring locations are shown in **Figure 23**. The existing conditions in terms of noise levels were considered typical of rural and regional areas and were used to develop noise criteria for the noise impact assessment.

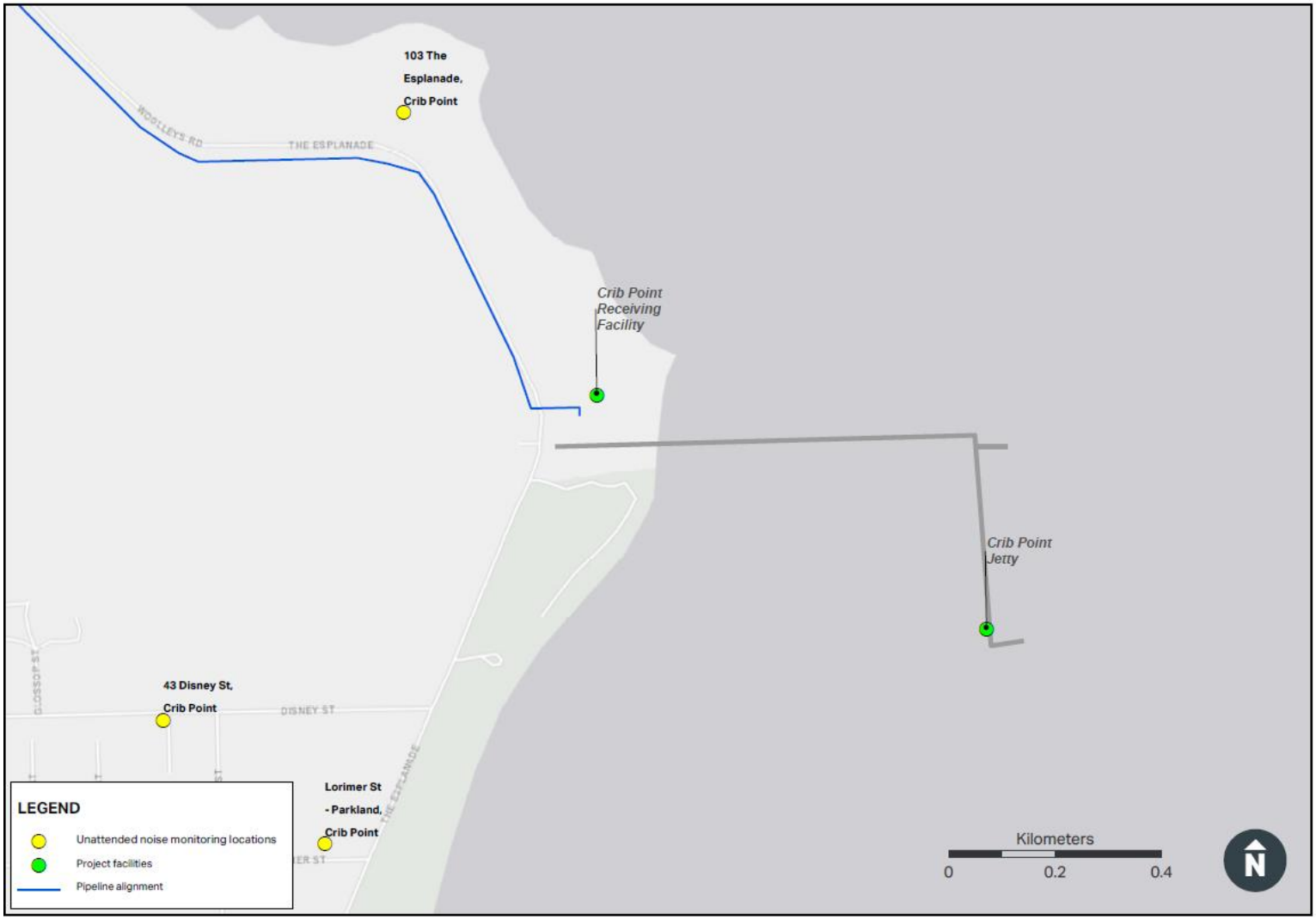


Figure 22 Unattended noise monitoring locations

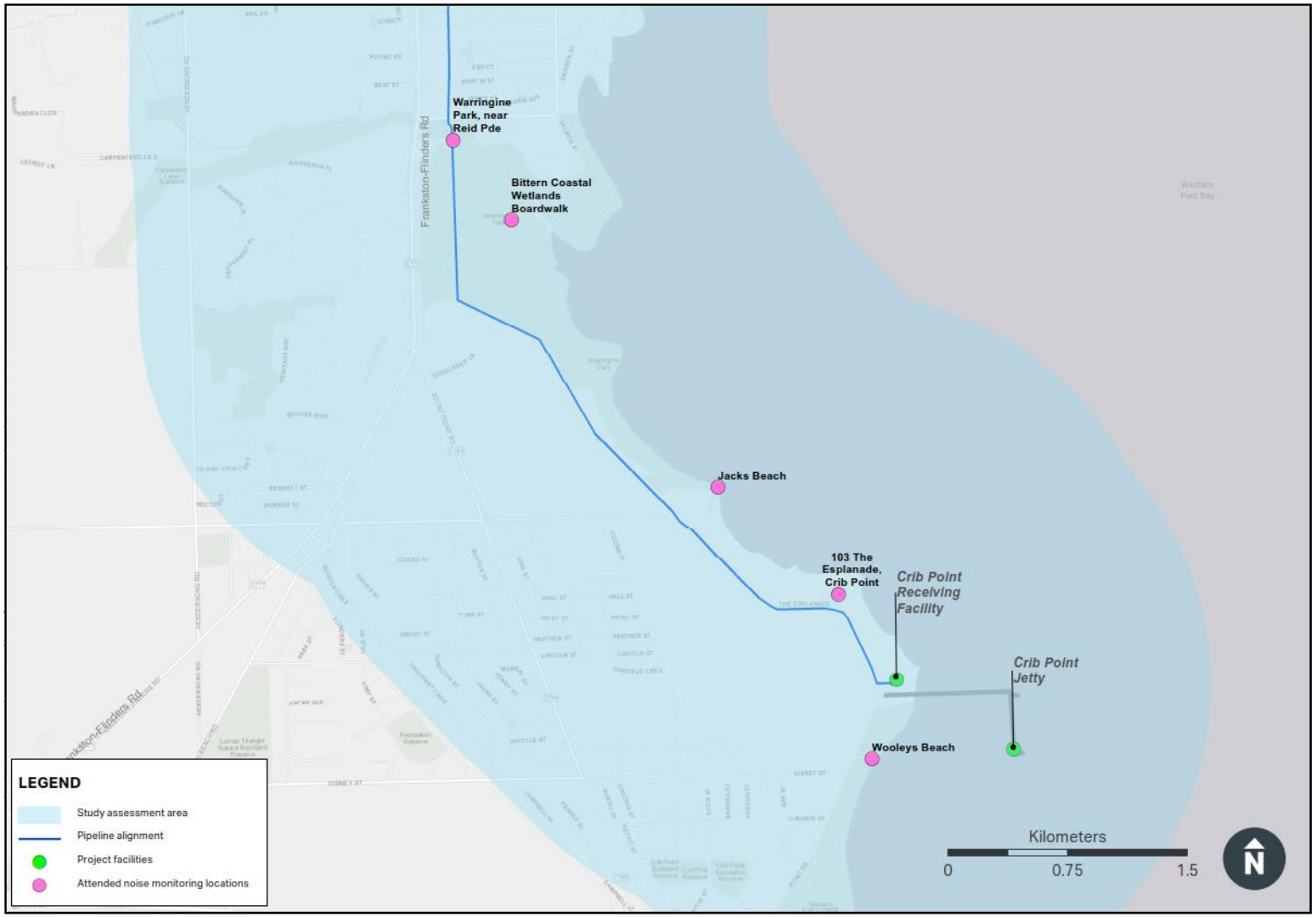


Figure 23 Attended noise monitoring locations

11.3 Noise emission sources

The proposed Gas Import Facility would require the operation of the following project components:

- FSRU
- Jetty infrastructure
- Crib Point Receiving Facility
- LNG carriers (including any tugboats that will assist with mooring)

As mentioned previously, although this WA application is for the FSRU only, noise modelling based on operation of the entire Gas Import Facility will be discussed, rather than placing a focus on the FSRU noise emissions in isolation. This is more representative of the anticipated noise emissions during Project operation.

11.3.1 Operational modelling scenarios

Modelled noise scenarios have been based on proposed operating conditions outlined in the Project description.

- The FSRU can operate in closed loop, open loop or a combined loop mode
- Regasification boilers in the engine casing area and steam heaters in the steam heater skid area are specific to closed loop and combined loop operation.
- Twelve LNG carriers are expected at the Crib Point Jetty (Berth 2) in the first year of operation, and up to 40 LNG carriers per year are predicted per year in future.
- LNG carriers would berth for approximately 36 hours at a time.
- LNG carriers would take around one-hour to arrive and to depart while tug-assisted during mooring.
- The number of times that mooring scenarios would occur is twice the number of LNG carrier arrivals (this accounts for both the arrival and the departure of the LNG carriers).
- The vessel would be designed to achieve operating noise levels in accordance with the Maritime Labour Convention (MLC), 2006 and Marine Order 11 (Living and working conditions on vessels), 2015

The preferred operating mode will be open loop, which will predominantly operate up to 500 mmscf/d. However, closed loop operation has been adopted as the worst-case noise modelling scenario due to the additional noise produced by the boilers during operation.

The two scenarios that are expected to require the most plant and machinery (in any operating mode) to be operated concurrently on the FSRU and at the Crib Point Jetty (Berth 2) are:

- The FSRU operating at maximum capacity (three trains / closed loop) while LNG carrier mooring is being undertaken. This should occur approximately 2 hours at time, 8 times a year based upon 4 cargoes being received and operating at maximum capacity.
- The FSRU operating at moderate capacity (two trains / closed loop) while LNG carrier mooring is being undertaken. This should occur approximately 2 hours at a time, up to ~80 times per year based upon 40 cargoes per annum.

There is minimal difference between the equipment required for peak regasification and moderate regasification. Peak regasification (three trains) has been assumed as the worst-case scenario.

The Crib Point Receiving Facility will alternate between the following modes of operation:

- Nitrogen injection with nitrogen offloading: Injection of nitrogen into the gas pipeline while nitrogen trucks are offloading to replenish the onsite nitrogen storage tanks
- Nitrogen injection only: Injection of nitrogen into the gas pipeline.

Noise produced by nitrogen injection has been assumed when developing the worst-case modelling scenarios.

Furthermore, nitrogen offloading is planned for EPA normal working hours (day and evening periods). Accordingly, noise levels caused by nitrogen offloading have not been included in the noise impact assessment of night times.

Table 32 shows the operational modelling scenarios that have been developed based on the above assumptions and associated plant / equipment.

Table 32 Operational modelling scenarios

Scenario	Stage	Description
1	LNG carrier berthing	• FSRU operating in closed loop • Peak regasification send-out (Three trains / 750 mmscf/d) • LNG carrier mooring with four tugs • Nitrogen injection at the Crib Point Receiving Facility
2	LNG carrier berthed	• FSRU operating in closed loop • Peak regasification send-out (Three trains / 750 mmscf/d) • LNG carrier moored next to FSRU • Nitrogen injection at the Crib Point Receiving Facility
3	FSRU operation	• FSRU operating in closed loop • Moderate regasification send-out (Two trains / up to 500 mmscf/d) • Nitrogen injection at the Crib Point Receiving Facility
4	LNG carrier berthed (open loop)	• FSRU in open loop • Peak regasification send-out (Three trains / 750 mmscf/d) • LNG carrier moored next to FSRU • Nitrogen injection at the Crib Point Receiving Facility
5	LNG carrier berthed and nitrogen offloading (closed loop)	• FSRU in closed loop • Peak regasification send-out (Three trains / 750 mmscf/d) • LNG carrier moored next to FSRU • Nitrogen injection at the Crib Point Receiving Facility • Nitrogen unloading at the Crib Point Receiving Facility

11.3.2 Noise emitting equipment

The equipment items assumed for each of the operational modelling scenarios and their corresponding sound power level (sound level that is emitted at the source) are outlined in **Table 33**. The source of these assumptions has been listed in the EES Technical Report H: *Noise and vibration impact assessment* (refer to **Appendix B**). Note that the MSO has not been modelled as it operates infrequently. The proposed locations of the referenced noise sources is shown in **Figure 24** and **Figure 25**.

Table 33 Modelled noise emitting plant / equipment

Ref	Modelled plant / equipment	Sound Power Level	Scenario				
			1	2	3	4	5
FSRU							
F1	Engine room walls and roof	50 dBA per m^2	✓	✓	✓	✓	✓
F2	Engine exhaust	100 dBA per flue	✓	✓	✓	✓	✓
F3	MSO – minimum send out compressor	93 dBA	Not operating				

Ref	Modelled plant / equipment	Sound Power Level	Scenario				
			1	2	3	4	5
F4	Regasification boiler exhaust	99 dBA per flue	✓	✓	✓		✓
F5	Control valves	93 dBA per valve	✓	✓	✓	✓	✓
LNG Carrier							
L1	Engine room walls and roof	50 dBA per m^2	✓	✓		✓	✓
L2	Engine exhaust via 4 x flues	100 dBA per flue	✓	✓		✓	✓
L3	Tugboat exhaust	100 dBA per boat	✓				
Pierhead 2							
L4	Step-up transformer	90 dBA	✓	✓	✓	✓	✓
L5	Instrument air compressor	91 dBA	✓	✓	✓	✓	✓
L6	Marine loading arms	100 dBA	✓	✓	✓	✓	✓
Crib Point Receiving Facility							
C1	Natural gas pipework	68 dBA per metre	✓	✓	✓	✓	✓
C2	Control valve at mixing point	83 dBA	✓	✓	✓	✓	✓
C3	Vaporiser fans	85 dBA per fan	✓	✓	✓	✓	✓
C4	Electric TRIM heater	93 dBA	✓	✓	✓	✓	✓
C5	Liquid nitrogen pumps	93 dBA per pump	✓	✓	✓	✓	✓
C6	Control room HVAC	68 dBA	✓	✓	✓	✓	✓
C7	Nitrogen offloading	101 dBA per truck					✓
C8	Nitrogen tanker movement	68 dBA per metre					✓
C9	Gantry ventilation fans x 2	88 dBA per fan	✓	✓	✓	✓	✓

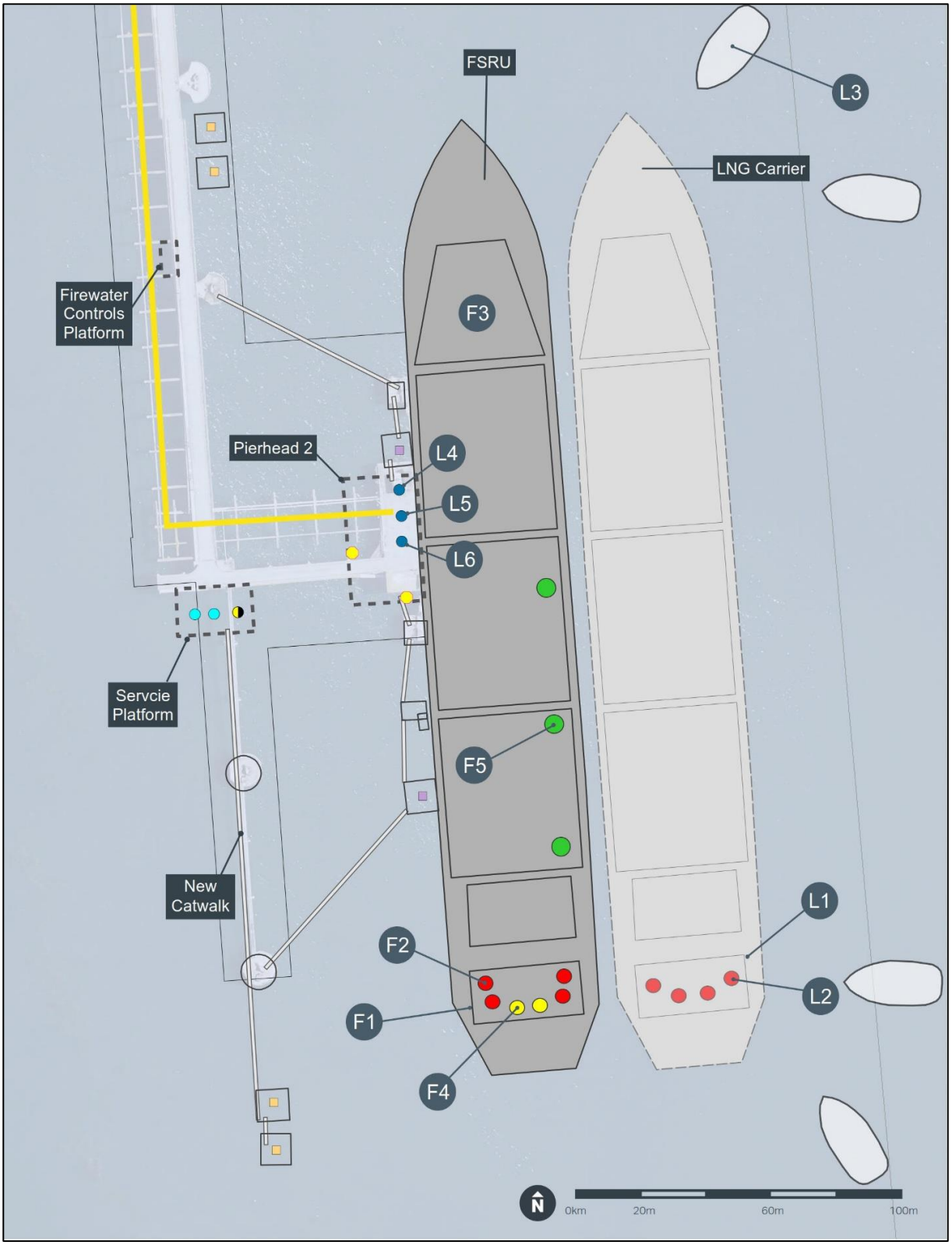


Figure 24 Crib Point Jetty (Berth 2) proposed layout

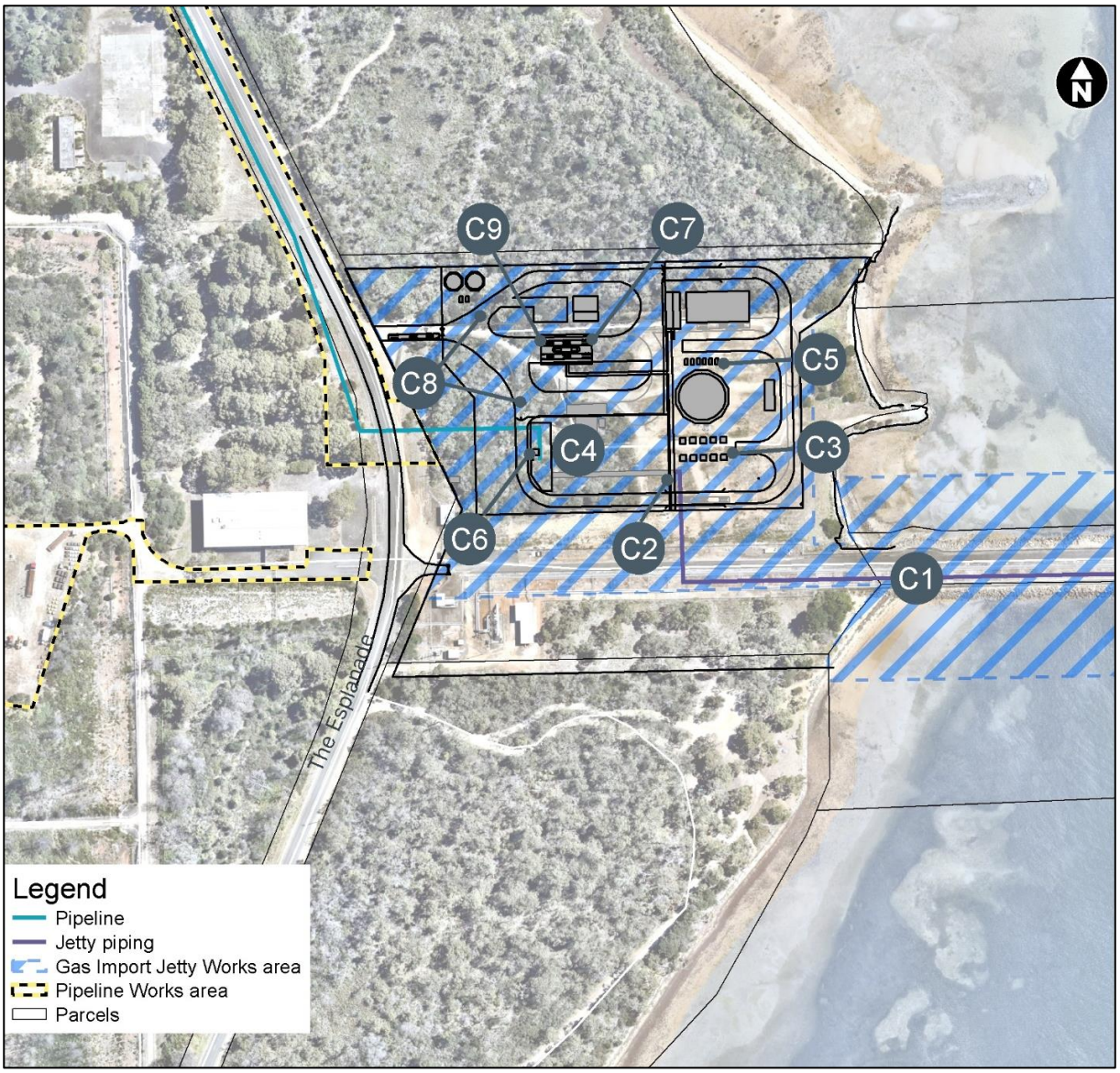


Figure 25 Crib Point Receiving Facility proposed layout

11.4 Best practice noise control measures

The FSRU is designed and constructed in accordance with prevailing requirements and recommendations from authorities such as IMO and the SIGTTO. Therefore, the vessel is equipped with systems and solutions to operate efficiently and limit noise impact on the surrounding environment.

In accordance with IMO requirements, the FSRU is designed to maintain an (external) noise level below 90 dB(A) anywhere on deck. **Table 33** contains a list of all assumed noise emitting equipment on board the FSRU.

The design features to minimise noise emissions from noise emitting equipment on board the FSRU is summarised in **Table 34**.

Table 34 Summary of design features to minimise noise emissions from equipment on board of FSRU

Ref	Noise emitting equipment	Design features
F1	Engine room walls and roof	The four Wärtsilä 50DF dual-fuel engines will be located below deck. A sound pressure level of 95 dB(A) within the engine room is expected based on Hyundai noise level measurements. As the engines are located below deck a reduction of 45 dB(A) is expected due to hull/walls and roof of the engine casing (above deck).
F2	Engine exhaust	The four Wärtsilä 50DF dual-fuel engines will be equipped with silencers installed in the exhaust funnel to limit noise emission levels. The sound power level at the tip of each exhaust opening is assumed to be attenuated to 100 dB(A).
F3	MSO – minimum send out compressor	An MSO may be fitted to the FSRU prior to start-up however it would not operate during the typical or worst-case modelling scenarios included within this assessment. The spectrum is based on empirical data for large electric motor between 750kW-4MW and 1800-3600 rpm and a maximum sound power level of 93 dB(A) based on IMO *Code of noise level on board ships* design requirement.
F4	Regasification boiler exhaust	Two of the regasification boilers will be located on the lower deck with the third potentially located in a fully enclosed new deck house. Noise breakout from these enclosures is not considered to be a significant noise source on the FSRU. The sound power level at the tip of each operating source has been assumed to be no more than 93 dBA.
F5	Control valves	The FSRU will contain six control valves in the regasification area, two control valves on the starboard side deck area and six control valves in steam heater skid area. An assumed combined sound power level of 101 dB(A) has been based on the design requirements to meet the IMO *Code of noise levels on board ships*.

11.5 Noise impact assessment

The operational noise impact assessment considered surface infrastructure only as the noise impact of buried infrastructure is considered to be negligible.

As the FSRU will be located above water, operation of the vessel will not produce vibrations that would be felt by sensitive receptors. Each MLA connecting the FSRU to the Crib Point Jetty infrastructure is anticipated to be a source of vibration during operation however these connections will be designed in accordance with design standards to minimise vibration during operation. Therefore, the risk of human disturbance because of vibration generated by the operation of the Project is considered **Very low**. Accordingly, potential vibration impacts during Project operation have not been assessed.

11.5.1 Determining noise limits

The derived Recommended Levels (Compliance Criteria) for nearby residential locations and that apply to operational noise from the operation of the Gas Import Facility are presented in **Table 35**. A detailed derivation of Recommended Levels is presented in **Appendix J.**

Table 35 Recommended Maximum Noise Levels – Gas Import Facility

Noise Sensitive Receptor	NIRV Recommended Maximum Noise Levels $L_{Aeq,30min}$ dB		
	Day	Evening	Night
103 The Esplanade	47	42	35
43 Disney Street	48	43	36
132 The Esplanade	45	42	35
French Island Residential Locations	45	37	32

11.5.2 Predicted noise levels

The noise modelling results based on the design features discussed in **Section 11.4** are shown in **Table 36**. The purpose of the assessment was to determine if additional mitigation would be required to achieve Recommended Levels.

Table 36 Gas Import Facility: Operation (within 10m of the building)

Noise Sensitive Receptor	NIRV Recommended Level [$L_{Aeq,30min}$ dB(A)]			Modelled Project contribution for each scenario [$L_{Aeq,30min}$ dB(A)]				
	Day	Evening	Night	1	2	3	4	5[1]
132 The Esplanade	47	42	35	35	34	30	33	38
43 Disney Street	48	43	36	31	30	29	29	32
103 The Esplanade	45	42	35	35	35	34	34	35
French Island	45	37	32	22	<20	<20	<20	22
Victorian Maritime Centre	No criteria applicable			48	48	48	46	52
Woolley's Beach Reserve				46	46	46	45	52
HMAS Otama Lookout Beach				44	44	44	43	49
Jacks Beach Reserve				26	26	26	24	27

[1] Operational modelling scenario 5 has not been assessed against the Night Recommended Levels as nitrogen offloading is planned for EPA normal working hours (day and evening periods).

Operational noise maps of the modelled operational noise levels with mitigation are shown in **Appendix K**.

11.5.2.1 Penalties for noise source characteristics

Information provided in **Section 11.3.1** included a description of the acoustic environment adjacent to the FSRU. The noise from the FSRU operation was described as a continuous sound that was typical of industrial sites. There was no evidence within the data reviewed that suggested that impulsive, tonal or intermittent characteristics were present.

Accordingly, adjustments have not been applied to the predicted noise levels. Furthermore, the application of NIRV Section 2.3 *Apply suitable controls for noise not addressed by the recommended levels* was not considered applicable based on the information available.

11.5.2.2 French Island

Noise at French Island is predicted to comply with the Recommended Maximum Levels. However, compliance with these levels may not be appropriate as per section *2.1 Consider the effects of noise on quiet rural areas* within NIRV.

The introduction of a new noise source to the area may impact the existing tranquillity and might not match the expectations associated with the local acoustic environment at French Island.

NIRV recommends a number of methods to support the protection of locations with significant environmental and cultural values. The three recommendations replicated below are considered most relevant to this assessment:

- *Consideration for applying more stringent levels is typically made during environmental effects statements, EPA works approvals or other proposals with EPA input.*
- *The approval process should explore the possibilities of applying commonly available technology to attain the lowest achievable noise outcome.*
- *The aim should be to meet linear 'octave-band' levels of the background level plus five to 10 decibels.*

It is assumed that the first 2 items have been addressed in **Section 11.5.2** and **Section 11.4** respectively. The predicted levels demonstrate that the highest predicted level from the Gas Import Facility operation is 10 dB below the Recommended Maximum Levels. Furthermore, the design would incorporate the necessary acoustic technology to achieve onboard IMO *Code of noise levels on board ships* and Recommended Maximum Levels.

To address the third point, a review was undertaken by comparing the lowest linear octave band background levels measured at the Crib Point Jetty to the highest predicted levels at French Island. It is expected that the lowest background levels at the jetty would be comparable to those at French Island in lieu of measurements.

A comparison of the levels for Day, Evening and Night periods are presented in **Figure 26**.

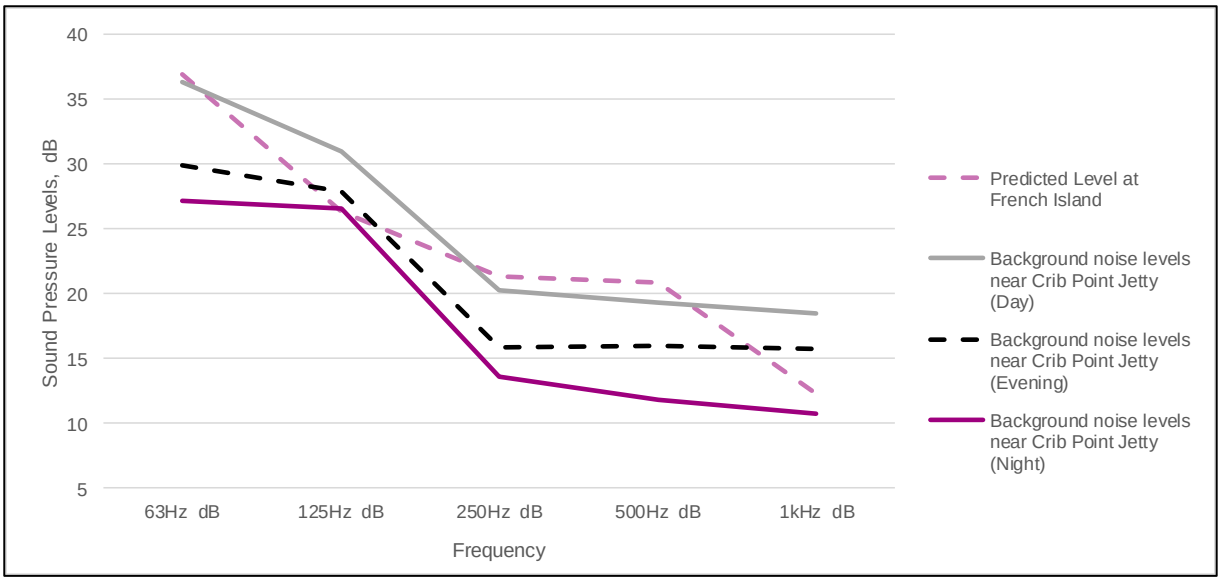


Figure 26 Comparison on background noise levels to predicted levels at French Island

It was found that the background levels were all within *plus five to 10 decibels* of the highest predicted noise level at French Island.

This assessment suggests that the design of the Gas Import Facility and the mitigation measures adopted for the Gas Import Facility would allow for the existing acoustic values at French Island to be preserved.

11.5.2.3 Discussion

All modelled scenarios are predicted to comply with the Recommended Levels. Closed loop has been assumed as the worst-case scenario for noise emissions from the Gas Import Facility. Accordingly, where compliance is shown for a closed loop scenario, it is assumed that the same scenario in open or combined loop modes would also comply.

The typical operating scenario where and LNG carrier is not moored (modelled with worst-case assumptions for approximately 300 days per year) is predicted to achieve compliance.

Noise modelling also shows that there would likely be an increase in background noise levels as a result of Gas Import Facility operation. When ambient noise levels are similar to the background noise levels, it is likely that noise from the operation of the Gas Import Facility would be easier to distinguish in outdoor locations from other sounds in the environment, i.e. when the existing environmental noise is low, noise generated by the project would not be masked. This change would be more noticeable at Woolley's Beach Reserve and at the Victorian Maritime Centre, which are located closer to the project infrastructure compared to nearby residential locations.

11.5.3 Mitigation measures

Gas Import Facility operational noise should be measured within six months of the beginning of commercial operation to confirm compliance with the Recommended Maximum Levels for each operating scenario.

Noise measurements should be undertaken in accordance with current Victorian EPA requirements to verify conformance with the Recommended Maximum Levels applied at 132 The Esplanade Crib Point, 43 Disney Street Crib Point and 103 The Esplanade Crib Point.

Onsite noise mitigation (administrative, operating or engineering controls) should be undertaken as soon as practicable if the measured noise levels demonstrate that the Recommended Maximum Levels are exceeded.

Offsite noise mitigation (noise screening, offers of respite during noisy periods of work or architectural acoustic treatment to the exterior of rooms used for sleeping) will be considered where onsite noise

mitigation cannot be feasibly constructed to reduce external noise to below the Recommended Maximum Levels.

11.5.4 Multiple premises emitting noise

Potential cumulative impacts were identified between the Gas Import Facility and the existing United Petroleum operations in Berth 1, as these two facilities will be co-located at Crib Point Jetty. There is a risk that while each facility will meet the Recommended Maximum Levels, in combination, they could exceed when the landside pump is offloading petroleum from a ship docked at Berth 1 (United Petroleum operations).

A three-decibel reduction has been applied to the Recommended Levels for the Gas Import Facility, as discussed in the EPA Publication 1413 (Guidelines on applying NIRV) with respect to Major Urban Areas, as these Project elements are located within a Major Urban Area. This adjustment of the Recommended Levels allows for equal contribution of industrial noise from the existing United Petroleum facilities (Crib Point Jetty Berth 1). Note that this reduction is not applied to French Island sensitive receptors as they are not located within a Major Urban Area.

Although a three-decibel reduction has been applied, there may be times when sensitive receptors located on the Esplanade are exposed to cumulative noise levels above the Recommended Levels, if United Petroleum were operating at the same noise level as the Gas Import Facility. To manage this potential cumulative impact, AGL will engage with the EPA to plan and implement a future compliance plan. This will be done during the detailed design and operational phase of the Project.

Attended noise measurements at a nearby residence were undertaken while a United Petroleum vessel was moored at Berth 1 of Crib Point Jetty. The measured noise levels are presented in **Section 11.2**. The measured noise levels, and the identification of tonal noise characteristics indicated a high risk that the noise levels from the United Petroleum operations could exceed the Recommended Maximum Levels. Noise from the Project when operating near existing industry should be managed in accordance with Section 5 - Managing Noise from Multiple Premises within the EPA Publication 1413 - *Applying NIRV to Proposed and Existing Industry* where relevant. Where required, other infrastructure operators on the jetty and Project surrounds will be engaged to offset noise sources contributing to potential cumulative impacts. Additional cumulative impact management strategies should be developed in consultation with EPA, if required.

11.5.5 Commissioning and decommissioning

A commissioning stage, which involves testing, would be required before the FSRU is ready for operation and may occur anytime over a 24-hour period.

Transmission of gas from the FSRU would involve the operation of each train individually at 250 mmscf/d before testing at a rate of up to 750 mmscf/d. The noise levels produced by the FSRU during commissioning testing are expected to be less than what has been modelled for the operation stage of the Project (See **Section 11.5.2**). Note that there will be no flaring during commissioning on the FSRU.

There are no noise impacts expected from the decommissioning of the FSRU. The vessel would be disconnected from the MLAs and depart the jetty with the assistance of tugboats. The LNG remaining in the FSRU would be used for fuel by the FSRU when it departs.

The potential noise and vibration impacts produced during commissioning and decommissioning have not be assessed within the EES Technical Report H: *Noise and vibration impact assessment* (refer to **Appendix B**) based on these assumptions.

11.6 Summary

The modelling results demonstrate that Recommended Levels can be achieved for all time periods. A summary of the modelled noise levels at each of the three nearest sensitive receptors is shown in **Table 37**.

Table 37 Summary of predicted noise levels at the Gas Import Facility

Noise Sensitive Receptor	NIRV Recommended Level [$L_{Aeq,30min}$ dB(A)]			Modelled Project contribution for each scenario [$L_{Aeq,30min}$ dB(A)]				
	Day	Evening	Night	1	2	3	4	5[1]
132 The Esplanade	47	42	35	35	34	30	33	38
43 Disney Street	48	43	36	31	30	29	29	32
103 The Esplanade	45	42	35	35	35	34	34	35

[1] Operational modelling scenario 5 has not been assessed against the Night Recommended Levels as nitrogen offloading is planned for EPA normal working hours (day and evening periods).

12.0 Water

Preparation of this section of the WA application is based on information provided in the EES Technical Report A: *Marine impact assessment* (refer to **Appendix B**).

The marine impact assessment has undergone an external peer review to ensure that the report adequately addresses the matters set out in the scoping requirements and to ensure that the study sufficiently examines and clearly documents the potential environmental impacts and risks of the operation of the FSRU. The peer review found, overall, the methodology and software used to model the effects of the discharge plume in the near field were appropriate for the purposes of this EES. The processes of wind, sea level variability (tidal and non-tidal), temperature and salinity are all adequately represented in the regional model. The conclusions drawn from the models on seawater temperature variations seem reasonable; the representation of chlorine in the model is sound; the methodology and results for residual chlorine concentrations seem reasonable; and the method of using different particle release zones is appropriate for assessing the impacts of the FSRU on plankton and fish larvae/eggs populations. Overall, the peer review concluded, “the methodology is sound”.

The current legal framework for assessment and approval of a WA application under the *Environment Protection Act 1970*, requires consideration of the proposed wastewater discharge's consistency with the State Environment Protection Policy (Waters) 2018 (SEPP (Waters)). SEPP (Waters) has been used for the assessment of risks of seawater discharges from the FSRU.

12.1 Managing stormwater run-off discharges

The FSRU was not considered in the stormwater management assessments as it will be continuously moored at the Crib Point Jetty and is not part of the landside portion of works.

The deck of the FSRU is equipped with deck scuppers to collect stormwater, sea spray and wash water. The scuppers are closed during normal operation and opened during a rain event, storm or during testing of the firewater system to allow the water to drain overboard. Equipment on the FSRU deck that may be subject to oil spills or leaks are equipped with coamings to collect and contain spills. The coamings and scuppers will be regularly inspected for oil spills and any contaminated water.

Any contaminated water from the deck will be collected and manually pumped to the bilge holding tank which would then either be discharged to shore/barge for off-site disposal by a licensed waste contractor or sent to the oily bilge separator on board the FSRU where the bilge water will be treated to an oil content of less than 15 part per million (ppm). Oil is sent to the Oily Bilge Tank and treated water is sent to the Clean Bilge Holding Tank prior to off-site disposal by a licensed waste contractor (refer to **Section 14.0**).

Small volumes of stormwater runoff from the sides of the FSRU into Western Port are expected. Due to the small volume of stormwater run-off discharges, potential impacts of these discharges on the receiving environment have not been assessed. The risk of oil spills or leaks on the deck of the FSRU is considered low as the equipment located on the deck of the FSRU that may be sources of oil spills or leaks have been minimised. In addition, these pieces of equipment (e.g. winches or cranes) contain small inventories of oil.

12.2 Discharge to surface water (Western Port waters)

12.2.1 Justification for discharging to surface waters

The FSRU will require seawater for different purposes during operation (refer to **Section 9.0**). The use of seawater as process water and cooling water is the preferred and most feasible option for operation of the FSRU as it is readily available in large quantities and at low cost compared to other sources of water (e.g. potable water or recycled water).

Following use of the seawater in the FSRU operational processes, wastewater discharges are necessary for the viable operation of the FSRU. It is not viable to avoid the discharge of wastewater, which has been used as process water and cooling water given the large volumes required to operate the FSRU. In these circumstances, removal of all wastewater from the FSRU for offsite disposal is not

viable and would create other risks of harm to the environment. As outlined in **Section 9.0**, efforts have been made to reuse and recycle the wastewater prior to discharge and to reduce the volume of wastewater discharged. This application has assessed alternative modes of regasification and provided an integrated assessment of the impacts of these alternative modes. In closed loop operations less process water and cooling water is required, however there is a significant increase in greenhouse gas emissions.

SEPP (Waters) has been used for the assessment of risks of seawater discharges from the FSRU. The discharge of wastewater will support a scheduled beneficial use for the Entrances and North Arm of Western Port (namely a commercial or industrial use). The SEPP (Waters) also recognises that a discharge of wastewater to surface waters can provide water for the environment or a broad range of other uses. In this context, the FSRU will return seawater to the marine waters of Western Port for reuse. Seawater exiting the regasification process units and a number of other process units will have altered temperature and contain residual chlorine oxidants. The FSRU seawater discharges will be discharged into the marine environment via high-velocity discharge ports and pipes, within the area around Crib Point Jetty Berth 2 occupied by the FSRU.

The area in which the seawater returns to ambient conditions is defined as a 'mixing zone' and is discussed further in **Section 12.2.6**. The discharged seawater will be able to be used as marine waters, which after returning to ambient conditions preserves all of the identified beneficial uses in the SEPP (Waters).

The potential impacts on the marine environment from alteration in temperature and residual chlorine concentrations is discussed in **Section 12.2.5**.

12.2.2 Background condition of receiving water

Western Port is a tidal embayment in central Victoria surrounding Phillip Island in the south and French Island in the north. There are two entrances from Bass Strait: a large western entrance between Flinders on the Mornington Peninsula and Point Grant on Phillip Island and a much smaller and constricted eastern entrance between Phillip Island and San Remo. Western Port comprises five segments, which includes, Western Entrance Segment, Lower North Arm, Upper North Arm, Corinella Segment and Rhyll Segment. The area north of a line between Pt Leo on the Mornington Peninsula and Cowes on Phillip Island is designated as the '*Western Port Ramsar Wetland'*. The Western Port Ramsar site was designated as a wetland of international significance in 1982 and covers an area of 59,297 hectares.

The key physical features of Western Port are:

- deep tidal channels in the entrance, North Arm (along the west and north side of French Island) and East Arm (along the north coast of Phillip Island and east coast of French Island)
- large areas of intertidal mudflats and sand bars.

The key hydrodynamic features of Western Port are:

- three-metre tidal range in the north of the bay
- large tidal prism (volume of water moving with each tide)
- strong tidal currents.

The key habitat features of Western Port are:

- saltmarsh, mangrove and seagrass habitats
- subtidal sediment habitats
- very small area of rocky reef habitat.

The SEPP (Waters) is the current legal framework to protect and improve Victoria's water environment and aims to provide a coordinated approach for protection of the health of water environments. SEPP (Waters) has been used in this WA application to delineate the background condition of the receiving waters of this project and to minimise potential adverse impacts.

The Crib Point Jetty is located within the Lower North Arm and within the Western Port Ramsar Wetland. The area of focus is shown in **Figure 27**.

12.2.2.1 Bathymetry

The bathymetry of Western Port comprises a combination of deep channels, drainage channels, networks of dendritic (branch-like) channels, sand bars and shallow intertidal and subtidal mudflats. Water enters Western Port mainly through the western entrance along a deep channel that is 10 to 15 metres deep with holes and short sections that can range to 40 metres depth. At the southern tip of French Island, the western channel splits and is diverted into the North Arm (which runs to the west and north of French Island) and the Eastern Arm (which runs to the east of French Island and comprises the Rhyll and Corinella Segment).

There is a large area of intertidal mudflats with a dendritic network of channels in the northeast of Western Port. Water from North Arm and East Arm flow to and from the mudflats via the dendritic channels on the flood and ebb tides respectively. The waters of North Arm and East Arm meet at the tidal divide located between the north-east corner of French Island and the mainland near Lang Lang. The path of the North Arm and East Arm channels, and the location of the 'Tidal Divide' are shown in the bathymetric map in **Figure 27**.

Figure 28 shows the detailed bathymetry in the Lower North Arm near Crib Point where the FSRU will be located. There are two channels in this part of Lower North Arm – a 2.5 km wide and 20 m deep main channel immediately offshore from Crib Point, and a narrower and shallower channel between Middle Bank (a large sand bar) and French Island. Parts of the main channel have been dredged to provide a minimum depth of 14 m so ships can access port facilities at Crib Point. There are intertidal mudflats on the west side of the channel to the north and south of Crib Point. The area within the main channel where the FSRU will be located has a depth of approximately 15 m.

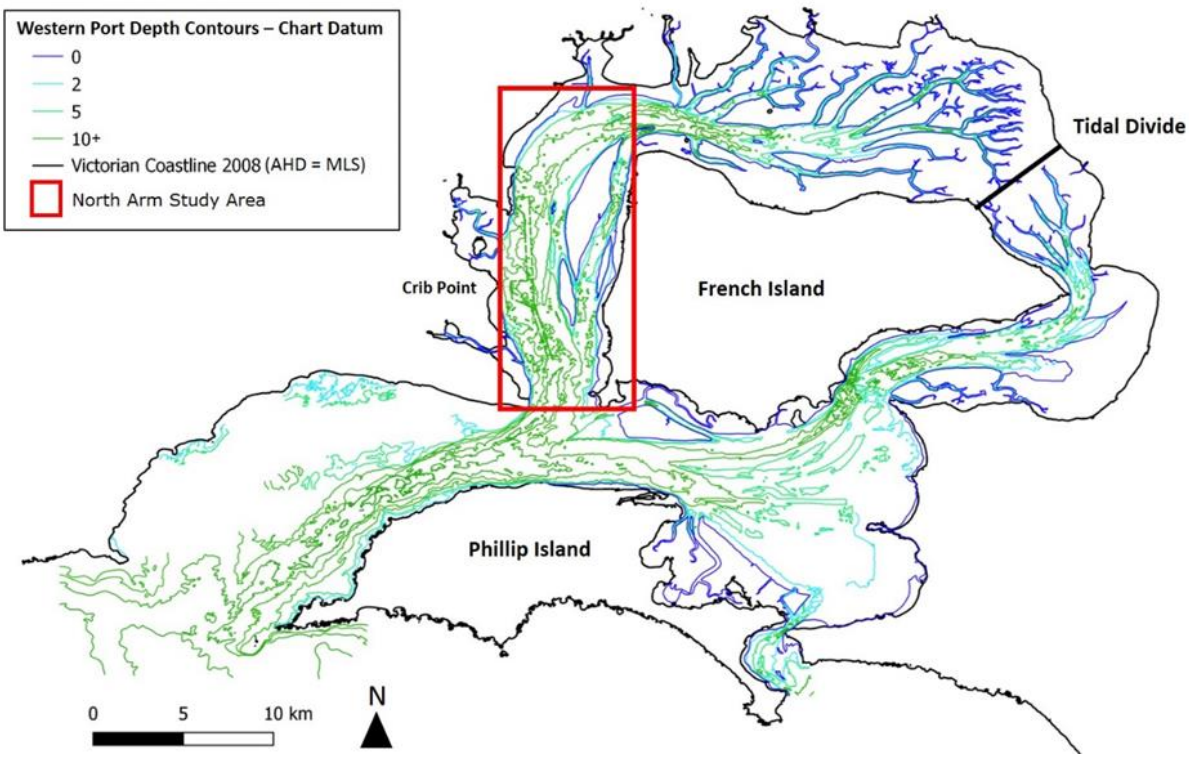


Figure 27 Western Port bathymetry (CEE 2020)

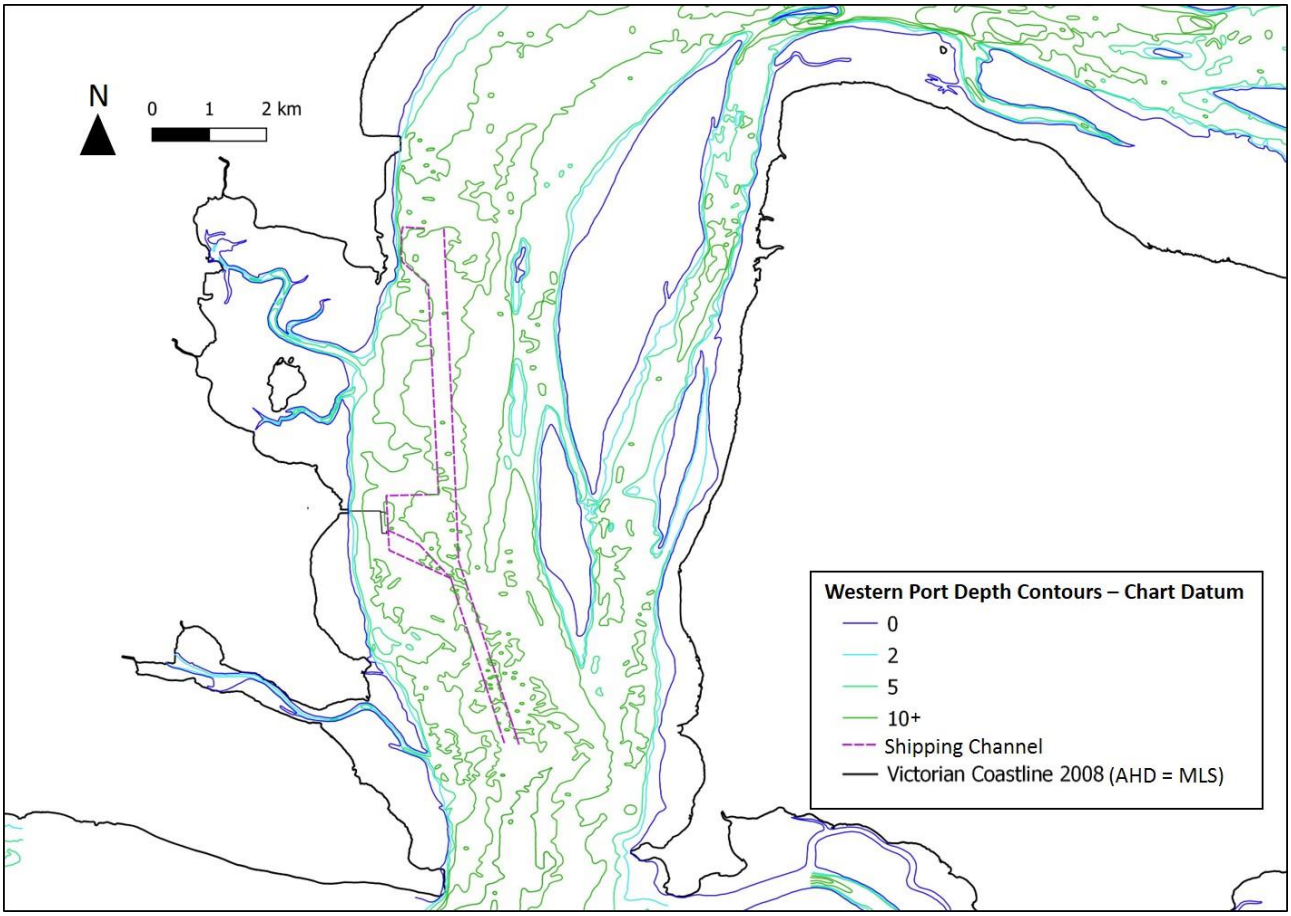


Figure 28 Bathymetry of Lower North Arm near Crib Point

12.2.2.2 Tides

Tides in Western Port are semidiurnal lunar tides, as in Bass Strait. Tides are the major process driving water movement in Western Port with wind having a smaller effect. The tide ranges are 2.4 m for spring tides and 1.3 m for neap tide. This means that there is a marked difference between spring and neap tide heights and corresponding tidal current speeds.

The large tidal range leaves large areas of intertidal mudflats exposed during each low tide. **Table 38** lists the volumes and areas for the whole of Western Port and the Lower North Arm at high, mean and low tide. The bay contains 6 per cent (567 GL) less water at Low tide than at high tide, which means that there is a large volume of water movement with each tide (large tidal prism). The water area covered at low tide is 523 km^2 which means that approximately 30 per cent of the Western Port seabed is intertidal.

Table 38 Volume and area of Western Port and the Lower North Arm at Tidal Stages

Area	High Tide		Mean Tide		Low Tide	
	Volume (GL)	Area (km^2)	Volume (GL)	Area (km^2)	Volume (GL)	Area (km^2)
Western Port	9,654	754	9,613	717	9,087	523
Lower North Arm	1,019	114	839	101	696	69
Western Port	9,654	754	9,613	717	9,087	523
Lower North Arm	1,019	114	839	101	696	69

Figure 29 shows the tidal areas of Lower North Arm in more detail. The blue colour shows the area below low tide, the green area shows mean sea level (MSL) to low tide and the orange area represents high tide to MSL.

12.2.2.3 Currents

Tides are the main process that drive currents north and south in the Lower North Arm past Crib Point. There are other minor factors that influence currents including; wind, long period waves in Bass Strait, meteorological pressure and inflow of freshwater during floods. **Figure 30** shows the north/south current speeds near the FSRU location at Crib Point Jetty Berth 2.

The positive values depict northward movement of water on a flood tide while the negative numbers depict southward movement of water on an ebb tide. The spring to neap to spring variation in tidal currents is evident in the graph. Peak flood tide current speeds during spring tides are a little over 0.6 m/s, while during neap tides, they are only around 0.4 m/s. Ebb tides are somewhat stronger at this location, with spring tide peaks currents of 0.8 m/s and neap tide peaks currents of around 0.4 m/s. The net current at Crib Point over the month was small and in a southerly direction.

At low tide the currents are typically weak at around 0.05 m/s over a period of 20 minutes although, there is hardly ever zero-current speed at either high or low tide (CEE 2018). The bathymetry near Crib Point creates lateral currents at both high and low slack water within the main channel meaning that the current roses are elliptical (they include some east and westerly flows, and no periods of calm).

Tidal currents in Western Port push and pull the seawater back and forth (rather than driving a circulation) meaning the flux of water moving into the bay is very similar to the flux of water out of the bay on the following tide. Half-tidal fluxes were measured along a tidal cross section from the Crib Point Jetty across to French Island. The net flow of seawater at Crib Point is south whereas the movement through the areas closest to French Island are to the north. The half-tidal fluxes show that the total volume of water moved per half tide is 441×10^6 m^3 north and 440×10^6 m^3 south (**Figure 31**).

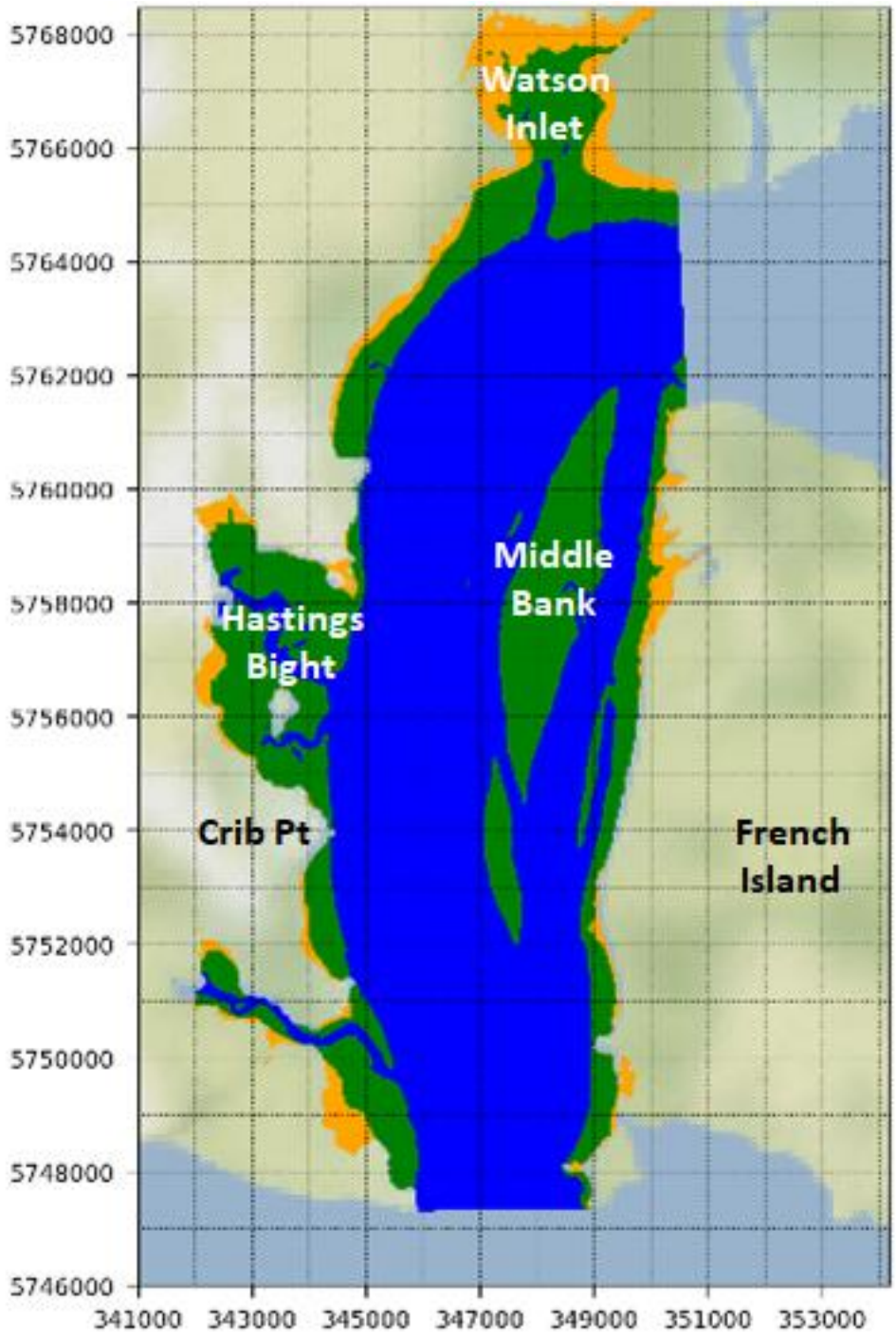


Figure 29 Lower North Arm tide ranges

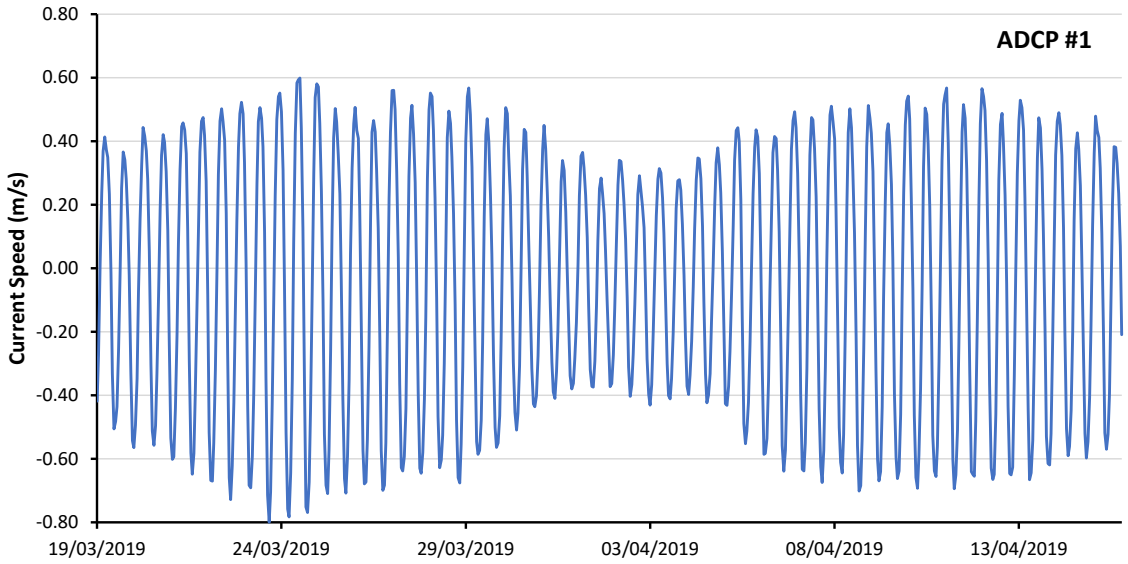


Figure 30 Mid-water Currents at Crib Point Jetty Berth 2

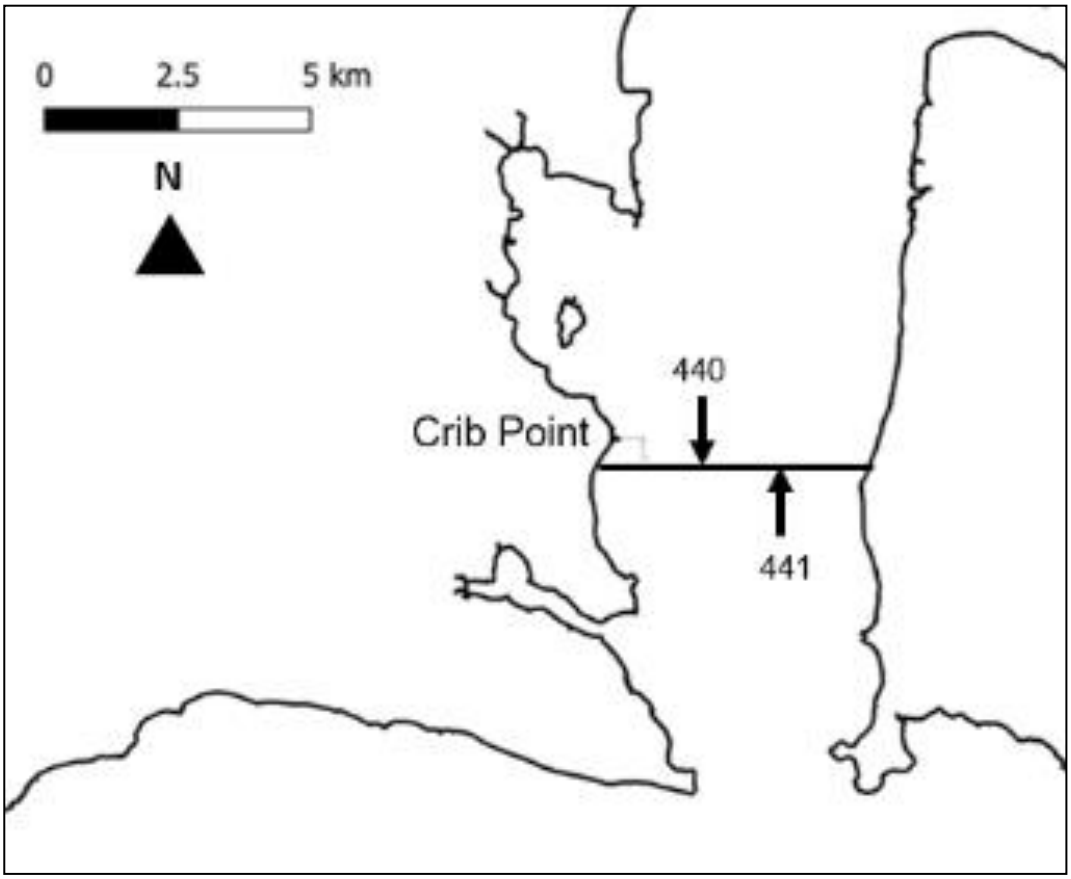


Figure 31 Crib Point half-tidal fluxes (10^6 m^3)

12.2.2.4 Water quality

A summary of the existing water quality at Western Port is summarised in **Table 39** below.

Table 39 Summary of the existing water quality

Water Quality Indicator	Description
Salinity	Salinity in Western Port has a small range and a small seasonal variation. Salinity in the North Arm of Western Port ranges from 35 g/L in winter-spring to 37 g/L in late summer. The increase in salinity in summer can be attributed to the local effect of evaporation from the shallow mudflats during the summer months.
Suspended Solids	Suspended solids concentrations in Western Port are much higher than in Bass Strait or Port Phillip Bay due to re-suspension of sediment from the mudflats and channels. Levels of total suspended solids in North Arm are typically around 6-7 mg/L. These levels cause generally low water clarity.
Dissolved Oxygen	Dissolved oxygen levels are generally over 90 per cent of saturation.
Nutrients	Nutrient inputs to Western Port from the catchment are relatively low due to the small freshwater inputs, especially compared to Port Phillip Bay (Melbourne Water 2011, Shapiro 1975). The nutrient regime in Western Port is strongly linked to that in Bass Strait owing to the large tidal exchange. The average total nitrogen varies from a low of 0.12 mg/L in Winter to a peak of 0.16 mg/L in late Summer, which is a small annual range. The water quality index for Western Port shows that since the year 2000 nutrient concentrations have been classed as Good in four years and Very Good in 12 years (Yarra and Bay, 2020).
Overall Water Quality	Water quality testing shows that the water quality has generally been classed as ‘good’ (EPA, 2011) and levels of two key indicators, enterococci and E. coli, have been within state guideline limits for the bay.

12.2.2.5 Temperature

As with other water quality parameters, seawater temperature in Western Port is strongly linked to conditions in Bass Strait, though there is additional variation in the bay due to local effects. Additional heating and cooling occur predominantly over the shallow mudflats due to seasonal air temperatures, winds, insolation and inundation and exposure of the mudflats. Maximum temperatures of 21-22°C occur in February and minimum temperatures of 11-12°C occurs in July.

Temperature monitoring at Crib Point

A project-specific 12-month assessment of short-term and long-term natural variations in seawater temperature was conducted using temperature loggers deployed at Crib Point Jetty. Seawater temperature was measured every 15 minutes from January 2019 to January 2020. This data was used to determine the magnitude of seasonal, daily and hourly variation in temperature experienced by marine biota near Crib Point (and is indicative of conditions throughout Lower North Arm).

It was found that the maximum temperature in 2019 was 24°C, and the minimum was around 11°C. The variation between daily maximum and minimum temperatures was highest in Summer and Winter at around 2°C and smaller in Autumn and Spring at around 1°C. Monitoring data showed that marine biota at Crib Point (and Lower North Arm) naturally experience a 13°C seasonal variation in temperature, and a variation of up to 2°C on a daily basis. The monitoring data showed that there was little to no stratification through the water column in any month as temperature is consistent at all depths. This is likely due to strong tidal currents causing regular mixing of the water column, meaning that the water column does not become stratified in any month or season.

12.2.2.6 Benthic habitat and biodiversity

Saltmarsh, mangrove, seagrass and unvegetated sediment are the major benthic habitats in Western Port. Maintenance of these habitats, along with the diverse range of benthic invertebrates and fish

associated with each habitat are critical to the ecological character of the Western Port Ramsar site (KBR 2010).

The seabed of Western Port is characterised by extensive intertidal mudflats intersected by deep channels. Sediments in the deeper channels of Lower North Arm are medium sand (Wentworth size class) while the intertidal banks comprise fine sand, silt and clay (Marsden et al 1979). Reef forms a very small proportion of benthic habitat in Western Port. Reef habitat in North Arm includes bedrock, boulder and cobble at Crawfish Rock and Eagle Rock and small isolated areas associated with headlands or rock outcrops.

A map of the marine habitats in Western Port combining mapping compiled between 2001 and 2016 is shown in **Figure 32**. Almost 70 per cent, or 523 km^2 of the benthic habitat in Western Port is subtidal channel and basin and basin with sandy sediment being the dominant substrate. Subtidal habitats in Western Port include seagrass, mobile sand and mixed sediments of sand, shell and other biogenic substrate. The remaining 30 per cent, or 231 km^2 of seabed in Western Port is intertidal and includes mangrove, mudflat and seagrass habitat. There is a further 11 km^2 of saltmarsh habitat inshore of mangroves above the mean high tide mark in Western Port (Boon 2011). Around 40 per cent of seabed habitat in Lower North Arm is subtidal channel and basin. Around 60 per cent of seabed habitat in Lower North Arm is intertidal mangrove, mudflat and seagrass. Intertidal habitats are mostly broad, level, sand and mud flats.

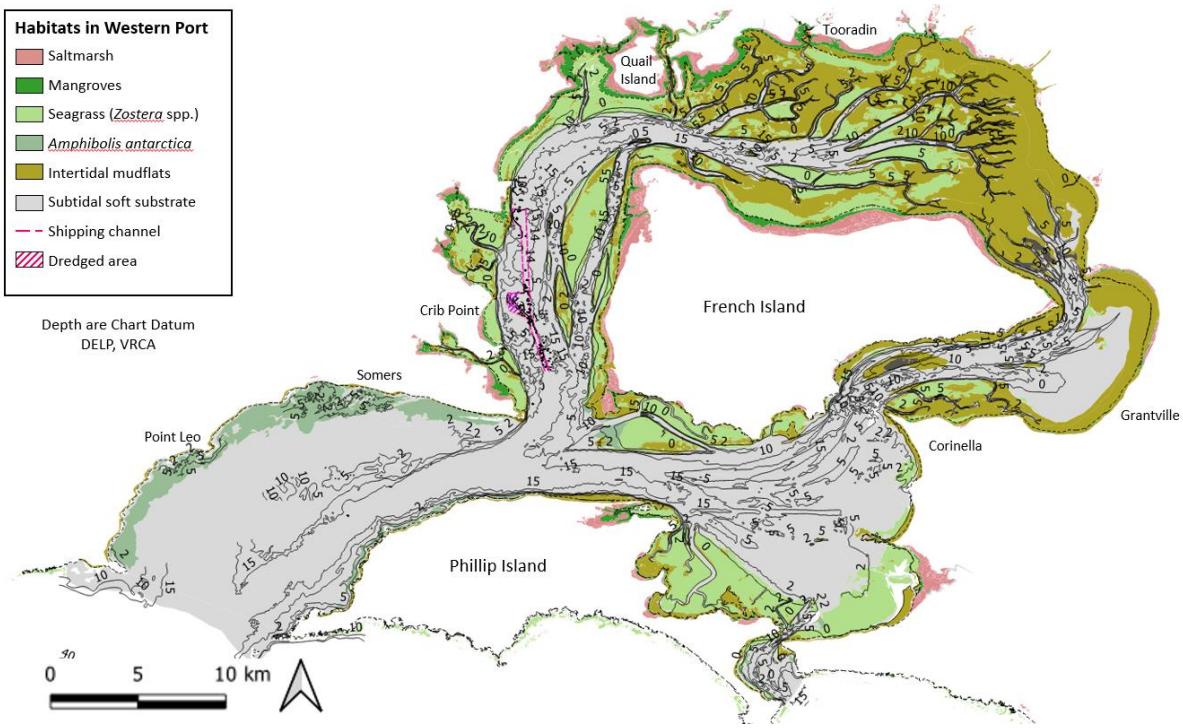


Figure 32 Benthic habitats in Western Port

Saltmarsh and Mangrove habitat occur along the west and north shorelines of North Arm. Saltmarsh and mangrove habitats form two of the three important marine vegetation components (the other is seagrass) in the Western Port Ramsar site (DSE 2003 and Boon, 2011). The nearest saltmarsh and mangrove habitat occur near the HMAS Otama Lookout approximately 1 km west-northwest from the proposed FSRU and to the south of Woolley's Beach around 1 km west-southwest FSRU. The wave and current exposure at Crib Point is too high for the establishment of saltmarsh and mangroves.

Unvegetated intertidal mudflats occur extensively in Western Port. Unvegetated intertidal mudflats occur between the seaward extent of mangroves (or the shoreline where mangroves are absent) and the landward extent of intertidal seagrass, as well as in between patches of intertidal seagrass below

mean sea level. Unvegetated intertidal mudflats occur directly inshore from Crib Point Jetty, as well as along the shoreline to the north and south of Crib Point.

Four species of seagrass occur in Western Port: *Zostera nigricaulis* (black-stemmed eel grass), *Zostera muelleri* (Mueller's eelgrass), *Amphibolis antarctica* (sea nymph), and *Halophila australis* (southern paddlegrass). The nearest seagrass habitat to the proposed FSRU and jetty infrastructure are around 450 m inshore and comprise *Zostera nigricaulis* and *Halophila australis* habitat in the subtidal and *Zostera nigricaulis* and *Zostera muelleri* habitat in the intertidal. Surveys were conducted to inform the EES Marine Impact Assessment, Results from these surveys show that the lower depth limit of seagrass inshore of the Crib Point jetty is near 3.5 m depth (Mean Sea Level (Above Height Datum (AHD)) (MSL)). This distribution of subtidal seagrass is consistent with seabed slopes and current speeds that are intermediate between The Bluff and LIP/Stony Point.

Extensive areas of intertidal and shallow subtidal seagrass extend from Crib Point throughout Hastings Bight to the north, and to the south towards Stony Point. Intertidal and shallow subtidal seagrass also occurs on Middle Bank, around 2 km east of the proposed FSRU. The intake and discharge on an FSRU at Crib Point jetty would be located approximately 450 m offshore from the lower limit of subtidal seagrasses at Woolley's Beach at Crib Point.

Subtidal benthic habitat survey

As part of marine investigations for the EES, towed underwater imaging equipment (video and stills) was used to characterise subtidal benthic habitats around Western Port North Arm along 40 transects. Twenty different habitat classes and a wide range of species were identified from the towed video records. **Figure 33** provides a key to the categories of benthic habitats used. It is recommended that this page is viewed or printed separately when examining the maps.

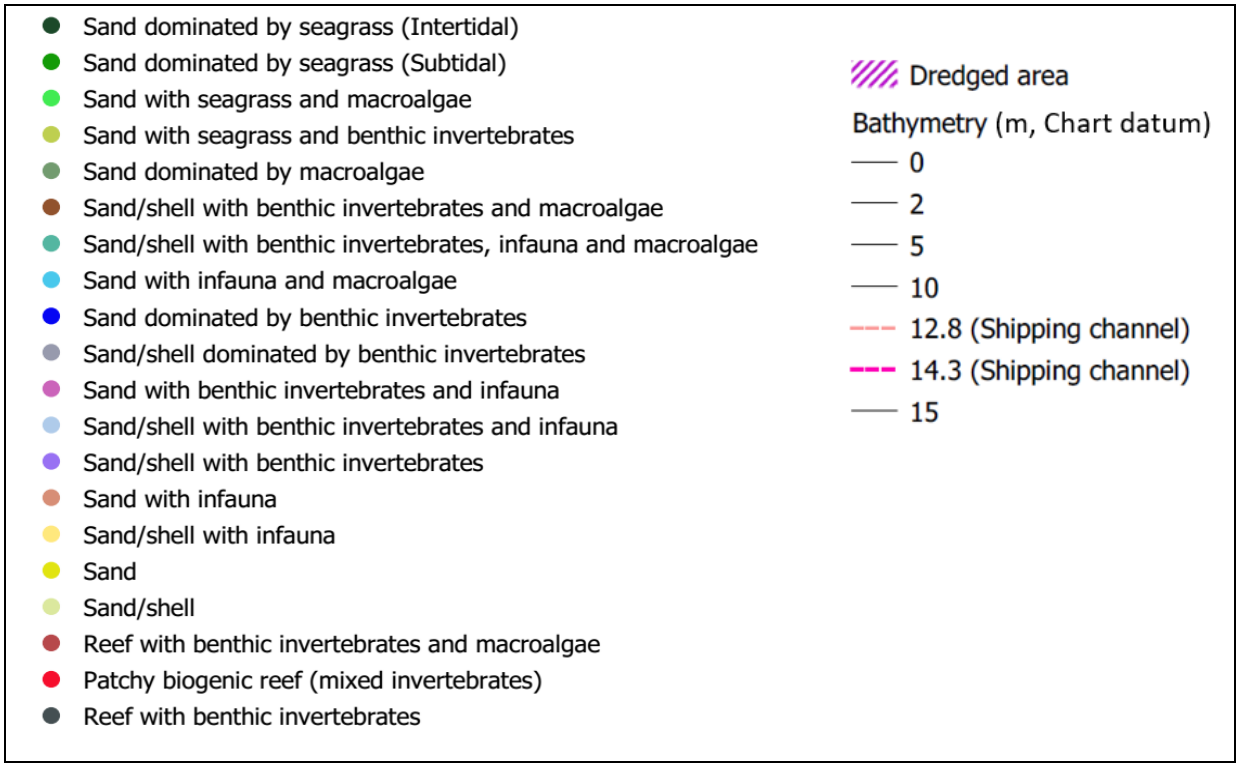


Figure 33 Key to benthic habitat categories in Lower North Arm, Western Port

The transects near Crib Point shown in **Figure 34** indicated the presence of a wide range of benthic habitat types. The seabed adjacent to Crib Point Jetty berths 1 and 2 along with the seabed in the swing basin to the east of Crib Point Jetty has been dredged and is deeper than adjacent natural seabed levels. Around 350,000 m^3 of seabed material has been removed from this area in past

dredging campaigns. The proposed FSRU is located over an already disturbed seabed habitat within the swing basin and berth pockets at Crib Point Jetty.

Habitats with a significant cover of seagrass and macroalgae near Crib Point are confined to shallow depths and show clear zonation, from dense seagrass cover (sand dominated by seagrass) on intertidal and shallow subtidal seabed to sparse seagrass and macroalgae between 2 m and 6 m depth.

The most common subtidal habitats near Crib Point are sand/shell and sandy sediment with epibenthic invertebrates and infauna, or sediment dominated by epibenthic invertebrates. These habitat types accounted for an average of 64 per cent of benthic habitat along each transect, of which 52 per cent was sand/shell with epibenthic invertebrates and infauna. These habitats were widely distributed around Crib Point below depths of 4 to 5 metres, particularly within the port area. These habitats are highly heterogeneous at small scales due to variable density and composition of epibenthic invertebrates (and infauna, see sections below).

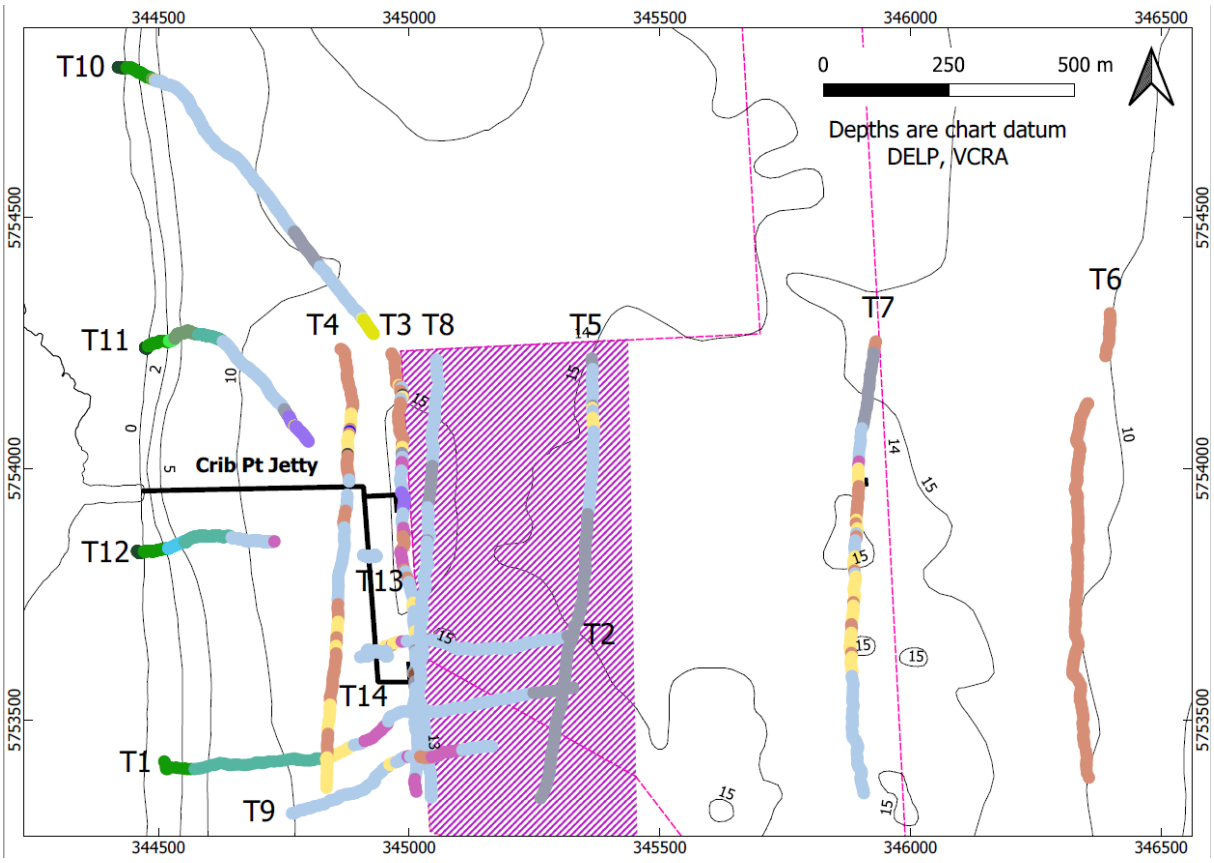


Figure 34 Benthic habitats near Crib Point

12.2.2.7 Subtidal epifauna and infauna

Infauna comprise a wide range of macroinvertebrates that live within unconsolidated sediments. Coleman *et al* 1978 documented infauna communities in Western Port's different sediment habitats between 1974 and 1975, including a number of sites in Lower North Arm. They found that the infauna of Western Port could be divided into two groups based on sediment character. One group of infauna were characteristic of the fine sand and mud habitats found on the channel margins and intertidal flats in Western Port. The second group, and the most relevant to the area where the FSRU will be berthed, were the infauna associated with medium sand (with low silt/mud content) found in the deeper channel and basin habitats.

Seabed conditions in dredged berth pockets and swing basins adjacent to jetties appear to be particularly favourable for invertebrate epibiota (CEE 2018). Epibiota include a wide range of sponges, bryozoans, hydroids, ascidians, crustaceans, echinoderms. There are a number of notable sessile epibenthic invertebrate species including the brachiopod *Magellania flavescens*, the 'living fossil' bivalve *Neotrigonia margaritacea*, tube-forming polychaete worm *Eunice* sp., sea-pen *Sarcoptilus grandis*, ascidian *Pyura dalbyi* and bryozoans *Celleporaria* and *Tryphyllozoon*. Mobile species include the sea urchins *Goniocidaris tubaria* and *Heliocidaris erythrogramma* and the seastars *Nectria ocellata, Tosia magnifica* and *Meridiastra gunnii* and the spider grab *Leptomithrax gaimardii*.

Benthic macrophytes such as seaweeds and seagrasses are important primary producers in coastal ecosystems and provide habitat for algal and invertebrate epiphytes, invertebrates and fish (particularly small or juvenile fish). Subtidal seagrasses do not currently extend much past 4-5 m depth in lower north arm due to the high light attenuation of the typically turbid waters in Western Port (CEE 2009).

Macroalgae occur to greater depths than seagrasses owing to their lower light requirements. Macroalgae in Lower North Arm mostly occur sparsely as drift or attached to shell or cobble (mostly red algae species). *Caulerpa cactoides* (green algae) can form dense patches on sediment within and around the edge of subtidal and intertidal seagrass beds. Macroalgae are most diverse and abundant on hard substrates, including Crawfish Rock and jetty piles.

Infauna were sampled at 29 sites in Lower North Arm to document the distribution and diversity of infauna. **Figure 35** shows the distribution and abundance of the top-ten infauna families. Sites in the 'West', 'Berth 1' and 'development footprint' zones at Crib Point had similar infauna community composition. Abundance was higher in the 'development footprint' zone at Berth 2 than to the west and at Berth 1. Berth 2 is characterised by greater depth (dredged), lower current speeds and winnowing (such as by shipping at Berth 1) and more shell, silt and epibiota than adjacent seabed so may be favourable for abundant infauna community.

Ampharetidae (polychaete worms) were the largest group at most sites within the development footprint zone, while Tanaidacea (crustaceans) were present at all sites in moderate to very high abundance. Corophiidae (amphipod crustaceans) dominated at the west sites, all of which were around 10 m deep, and comprised almost 90 per cent of the infauna at E10a.

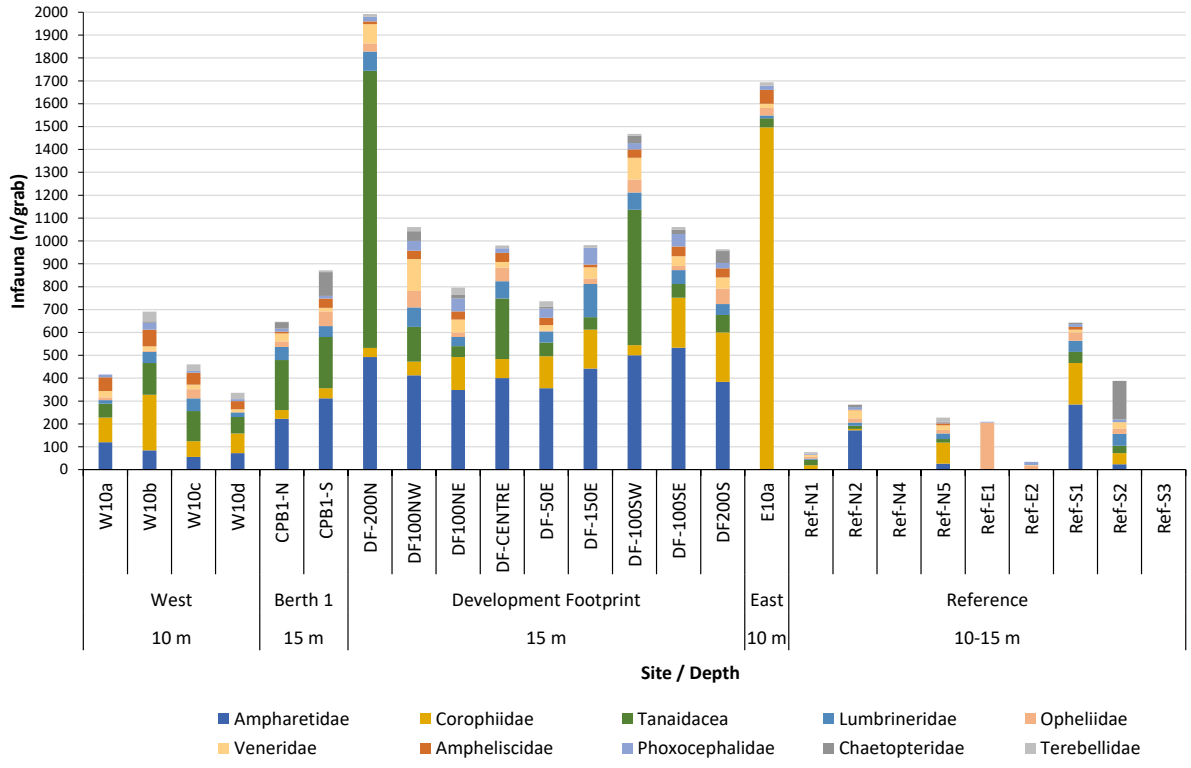


Figure 35 Ten most abundant infauna families at sites in Lower North Arm

12.2.2.8 Plankton

The plankton community of Lower North Arm is subject to a gradient process between the larger plankton community of Upper North Arm/Corinella Segment (NNE Community) and the smaller (but variable) Bass Strait plankton community.

A gradient zone is ecologically known as an ecotone which shares the characteristics of the communities that it separates. The distribution of the characteristics is dependent on a range of physical, chemical and ecological factors. In the case of Western Port, the key factor affecting the development, character and permanence of the NNE community is the high nutrient and suspended solids content of the waters in this region, which affects the penetration of light into the water column and the conversion of this light to biomass by the primary producers.

Another factor determining the extent and character of the NNE community is the nature of exchange of Bass Strait water around Western Port. Although tidal currents are strong in the Western Entrance and Lower North Arm, flushing of the segments with Bass Strait water takes progressively longer with distance from Bass Strait. Previous hydrodynamic models indicate the flushing time for the NNE of Western Port is several months. This is sufficient for phytoplankton and zooplankton populations adapted to high levels of suspend solids to sustain themselves locally.

Plankton studies were conducted as part of the marine impact assessment studies for the EES. The studies recognised that water depth, water exchange, current speed, turbulence and proximity of seabed habitats play are strong influences on the composition of plankton likely to pass the FSRU intake. The studies aimed to document the planktonic character of the water mass of the main North Arm Channel that would be entrained by the FSRU. The methods used were those typically used to quantitatively sample phytoplankton, mesozooplankton (including some meroplankton) and ichthyoplankton (including larger invertebrate meroplankton). A full description of the methods used to monitor plankton is provided in the EES Technical Report A: *Marine impact assessment* (refer to **Appendix B**).

Phytoplankton

The study documented 148 phytoplankton taxa (species or higher taxonomic classification) that occur in lower north arm. Nineteen of these species account for 85 per cent of the phytoplankton by number. Diatoms accounted for 55 per cent of the phytoplankton, 14.5 per cent were cryptophytes (flagellates), 8.9 per cent were prymnesiophytes (flagellates), 8.6 per cent were dinoflagellates and 6.5 per cent were prasinophytes (green algae). The community includes autotrophs (all the diatoms and many of the flagellates), heterotrophs and mixotrophs (some of the flagellates).

The study detected spatial gradients in the abundance of some groups of phytoplankton: diatoms tend to be more abundant in the north of the study area, while flagellates tend to be more abundant in the south. There were no consistent differences in the number of species at each site. The phytoplankton community at Crib Point Berth 2 showed no differences to other sites other than those expected given the documented spatial gradients.

Zooplankton

The characteristic North Arm zooplankton community in Western Port has lower diversity and a different species mix from Port Phillip and Bass Strait. The difference between Western Port and Port Phillip/Bass Strait communities is due to tidal current turbulence, low nutrient input and high concentrations of suspended sediment in Western Port.

The study found that a single genus dominated the zooplankton community. *Acartia* is well-adapted to living and feeding in bays with high particulate content, dominates the zooplankton community in Western Port. Not only did *Acartia* numerically dominate the zooplankton community, it also directly preyed on juveniles of next most abundant species (*Paracalanus indicus*) during spring. Cannibalism by *Acartia* adults on their own larvae may be responsible for up to 2% of the mortality of their larvae during the peak growing season (Kimmerer and McKinnon 1987)

Ichthyoplankton

The abundance of fish larvae in the Lower North Arm was strongly seasonal, with highest abundances in spring and summer and low abundance in autumn and winter. Larvae of the cobbler were abundant in both the Lower North Arm and in Port Phillip in late winter – spring (Jenkins 2019; Neira and Sporcic 2002).

12.2.2.9 Fish and other protected species

Western Port supports a rich and diverse fish fauna due to its many and varied habitats (Jenkins et al. 2015). Many of these habitats occur in the Lower North Arm. Fish in Western Port include species of ecological, conservation and fishing importance. Small numbers of seals enter Western Port and can be commonly seen around the jetties and wharves in Lower North Arm. Penguins can be found in the western entrance of Western Port. As penguins spend the majority of time at sea, they rarely swim up in Western Port or into the vicinity of Crib Point. Individuals are occasionally sighted or heard in Lower North Arm.

There are 33 marine threatened or migratory species listed under the EPBC Act and the *Flora and Fauna Guarantee Act 1988* (FFG Act) that may occur in the vicinity of the Project at Crib Point. These include:

- 13 species listed under the EPBC Act, including:
  - 8 EPBC Act listed threatened species
  - 12 EPBC Act listed migratory marine species (including seven of the EPBC threatened species above)
- 26 FFG listed threatened species may occur (including six species also listed under the EPBC Act).

For further information about fish and other protected species refer to the EES Technical Report A: *Marine impact assessment* (refer to **Appendix B**).

12.2.3 Beneficial uses

The *State Environment Protection Policy (Waters) 2018* (SEPP (Waters)) aims to provide a coordinated approach for protection of the health of Victoria's water environments. SEPP (Waters) has been used for the assessment of risks of seawater discharges from the FSRU.

The SEPP Waters classifies Western Port in two subsegments:

- Entrances and North Arm
- East Arm.

The FSRU will be located in the entrances and North Arm subsegment of Western Port. The SEPP (Waters) identifies 'beneficial uses' of waterways and establishes environmental quality objectives at levels that will ensure the protection of these beneficial uses.

In addition to general provisions, Schedule 5 of the SEPP (Waters) provides for Areas of High Conservation Values, which includes Ramsar wetlands, and has relevance to the project. **Table 40** summarises the beneficial uses relevant to Western Port.

Table 40 Beneficial uses - Western Port

Segment	Subsegment	Beneficial uses
Western Port	Entrances and North Arm	• Marine and estuarine waters – aquatic ecosystems: - Largely unmodified • Human consumption of aquatic foods • Aquaculture (where the environmental quality is suitable, and an aquaculture license has been issued under the **Fisheries Act 1995**) • Industrial and commercial • Primary contact recreation • Secondary contact recreation • Aesthetic enjoyment • Traditional Owner cultural values • Cultural and spiritual values • Navigation and shipping

The SEPP (Waters) provides Environmental Quality Indicators (EQI) for the Entrance and North Arm of Western Port such as:

- nutrients (Nitrogen and Phosphorus species)
- physical characteristics such as dissolved oxygen
- Chlorophyll – a (indicative of algae)
- total suspended solids
- salinity
- pH
- light attenuation.

The SEPP (Waters) also nominates the percentage protection for toxicants water as the percentage ecosystem protection. For the Entrance and North Arm at Western Port, the SEPP Waters identifies that as being 99 per cent. An EQI is not provided for temperature. There are also EQIs for bacterial water quality associated with the beneficial uses of Primary and Secondary contact and Aquaculture.

The operation of the FSRU will need to minimise the potential adverse impacts on beneficial uses by meeting the environmental quality objectives for biological indicators and pollutant target loads for Western Port, as far as reasonably practicable.

The operation of the FSRU will not alter nutrient concentrations, dissolved oxygen, suspended solids pH or light attenuation. It has been identified that the main impact pathways from the project that are different from normal activities in the region that could impact on beneficial uses are discharge of either cooler or warmer seawater and discharge of chlorinated water.

Other than these parameters, it is not anticipated that other characteristics of the discharged seawater have the potential to impact on beneficial uses identified for Western Port subsegment Entrances and North Arm.

It is noted that changes in temperature has the potential to impact on the saturated dissolved oxygen concentrations, with the potential for:

- increases in seawater temperature to reduce saturation levels
- reductions in seawater temperature to increase saturation levels.

Dissolved oxygen concentration can only increase if oxygen is available. These are not anticipated to adversely impact on the environment as the changes are small.

12.2.4 FSRU seawater discharge characteristics

This section summarises the seawater discharge characteristics that are anticipated (temperature and chlorine concentrations) during operation of the FSRU.

12.2.4.1 Temperature

During open loop operation of the FSRU, the seawater that is taken in by the vessel for the regasification process is discharged approximately 7°C cooler than the ambient seawater temperature. During peak production, the FSRU discharges 468,000 m^3/d of cooler seawater through six discharge ports on the starboard (east) side of the vessel (refer to **Table 41**). The FSRU has other minor flows such as the freshwater generator and seawater filter (refer to **Table 41**) and intermittent flows (refer to **Table 43)** during open loop operation. However, these additional intermittent flows are much less than the regasification discharge and are not discharged cooler than ambient seawater. Thus, the minor and intermittent flows were not included in the temperature assessment

Table 41 Continuous open loop discharges[1]

Open loop discharges	Peak flow rate (m^3/d)	Average flow rate (m^3/d)	Temperature (°C)	Comment
Regasification Process	468,000	312,000	-7	Maximum at full production, Discharge through six high velocity ports on east side of FSRU
Freshwater Generator	2,100	2,100	+8	Discharge at rear of FSRU
Seawater filter discharge	700	700	0	Discharge at rear of FSRU on starboard side
Total	**471,000**	**315,000**		The total flow rate is rounded

Table note:

1. excluding intermittent flows relating to ballast water, water curtain and fire testing water.

The largest flow of seawater into and from the FSRU is involved in the open loop regasification process. This process involves the extraction and discharge of up to 468,000 m^3/d of seawater from Western Port. The seawater would be taken in through sea chests on the side of the FSRU, pass through heat exchangers and be discharged back to Western Port through six ports on the east side of the FSRU at 7 °C cooler than ambient seawater.

There are three regasification trains, each with heat exchangers on the FSRU and two discharge ports. Depending on the rate of gas production, two, four or six seawater discharge ports can be operating concurrently. The hydrodynamic modelling simulated the dilution and transport of the open loop seawater discharge at the peak production rate (six ports) and at a normal average production rate (four ports) over a typical year. The seawater discharge rates for the continuous discharges in open loop operation are listed **Table 41**, including the freshwater generator and the seawater filter. Intermittent flows for ballast, water curtain and fire water testing are listed separately in **Table 43**.

In closed loop operation the LNG would be heated using gas-fired boilers and there would be a discharge of warmer seawater (the seawater used to cool the FSRU's generators and auxiliary systems) which is from 5°C to 12°C warmer than ambient seawater. **Table 42** shows the various flows and temperature changes in closed loop operation for the discharges in continuous operation. In closed loop operation, there would be a discharge from the various cooling systems, atmospheric dump condenser and the freshwater generator. There is a main generator freshwater cooler on each side of the vessel. At peak production in closed loop, the discharge would total 187,000 m^3/d (excluding the intermittent flows for ballast water, water curtain and fire water testing).

The warm seawater would be discharged via several closely spaced pipes at the rear of the vessel. Closed loop operation involves a smaller rate of seawater discharge than open loop.

Table 42 Continuous closed loop discharges[1]

Closed loop discharges	Flow rate (m^3/d)	Temperature (°C)	Comment
Main Generator FW Cooler	58,600	+12	Duty - discharge to rear
Auxiliary FW Cooler	45,800	+5	Discharge to rear starboard
Atmospheric Dump Condenser	80,400	0	Discharge to rear port side
Freshwater Generator	2,100	+8	Discharge at rear of FSRU. Note, flowrate has been rounded.
Total for closed loop	**187,000**		Peak

Table note:

1. excluding intermittent flows relating to ballast water, water curtain and fire testing water and the one-off intake of seawater for the regasification process.

There are additional discharges of seawater that occur intermittently, including ballast water (which is taken in and released to maintain vessel stability), water curtain and fire water testing, as listed in **Table 43**. Intermittent flows were not included in the temperature assessment as these are not discharged cooler or warmer than ambient seawater.

During gas production, the LNG tanks on the FSRU are progressively emptied and ballast water is taken into the FSRU to maintain the vessel's stability. The ballast water is discharged over the approximate 36-hour period when LNG is loaded into the FSRU from the visiting LNG carrier. The ballast water is discharged intermittently through a 0.715 metre diameter pipe at the rear starboard quarter of the FSRU.

During LNG unloading (when an adjacent LNG carrier is moored adjacent to the FSRU) a seawater spray ('water curtain') is discharged at a rate of 240 m^3/hr. on the starboard side of the FSRU to ensure there is no direct contact between LNG and the hull of the FSRU vessel (as a safety precaution). A firewater pump is tested for one hour every two weeks with a discharge rate of 1,550 m^3/d, so the discharge is about 70 m^3 per test. The water spray and fire pump discharge seawater at approximately ambient temperature.

Table 43 Intermittent discharges during open and closed loop

Intermittent discharges	Flow rate (m^3/day)	Temperature (°C)	Comment
Ballast water discharge	35,000	0	Only during LNG transfer. Up to 53,500 m^3 in 2 days
Water curtain between vessels	1,500	0	Only during LNG transfer
Fire water discharge	70	0	For 1 hour every 2 weeks
Average in peak month	**7,000**		Assuming peak 8-day cycle

12.2.4.2 Residual chlorine oxidants

A fundamental part of the operation of the FSRU is the use of chlorine to prevent the growth of biota in internal pipework and control fouling in the pipes, pulps and heat exchangers. The chlorine is produced from natural sea salt by an electrolytic process at the seawater intake (see below) before the seawater is pumped through the network of pipes, valves and heat exchangers in the vessel. The chlorine degrades during the passage through the process pipework, however, there are residual levels of chlorine left in the water prior to discharge. The residual levels of chlorine in the various modes of operation are listed in **Table 44**.

Table 44 Chlorine discharge for various modes of operation of FSRU

Operation	Seawater Discharge	Max Flow, m^3/d	Chlorine, µg/L
Open Loop Peak Rate	Heat Exchanger	468,000	All 100 µg/L (47 kg/d)
	FW Generator	2,112	
	SW Filter	723	
Open Loop Average Rate	Heat Exchanger	312,000	All 100 µg/L (32 kg/d)
	FW Generator	2,112	
	SW Filter	723	
Closed Loop Peak or Average rate	Main Generator FW Cooler	58,560	All 100 µg/L (19 kg/d)
	Auxiliary Machinery FW Cooler	45,840	
	Atmospheric Dump Condenser	80,400	
Extra Flows*	Water Curtain	5,760	All 100 µg/L (0.6 kg/d)
	Fire Water	1,550	
	Ballast	53,500	Max 21 µg/L (1 kg/d)

* Note that discharges of water curtain and ballast water are likely to occur during loading and/or unloading of LNG to and from the FSRU and fire water discharge is likely to occur during fire water testing. These 'extra flows' are additional to the open and closed loop scenarios.

Seawater taken into the FSRU for all purposes passes through an electrolysis cell that converts the dissolved chloride (Cl^-) naturally present in seawater to chlorine gas (Cl_2) which reacts rapidly in seawater to produce a range of oxidants known as Chlorine Produced Oxidants (CPO).

The generation of chlorine from electrolysis of seawater results from a series of steps involving the initial creation of chlorine gas (Cl_2) from the chloride ions (Cl^-) naturally present in high concentration in seawater.

$$2Cl^- + 2H_2O \rightarrow Cl_2 + H_2 + 2OH^-$$

The chlorine dissolves in the seawater and instantaneously dissociates to hypochlorous acid (HOCl) and hypochlorite ion (OCl-). The hypochlorite ion is the main equilibrium product in seawater.

$$Cl_2 + 2OH^- \rightarrow OCl^- + Cl^- + H_2O$$

The hypochlorite rapidly reacts with natural bromide salt (Br-) in seawater to create hypobromous acid, while the chlorine component of the hypochlorite returns to the original chloride ion.

$$OCl^- + Br^- \rightarrow OBr^- + Cl^-$$

This series of reactions is rapid and almost complete within 10 seconds. The chlorine and bromine oxidation chemicals used to prevent biological growth in seawater supplies are referred to as CPO. CPO are expressed with concentration of mg/l or µg/L chlorine for consistency with the original form of the oxidant and its analytical measurement.

The electrolysis process on the FSRU would produce an initial CPO concentration of 500 µg/L. This concentration would decay rapidly in the pipe network to less than 200 µg/L and by the time the flow has passed through pumps, pipes and heat exchangers, the residual chlorine concentration in all discharges is assured by the FSRU supplier to be less than 100 µg/L. For all flows except ballast water, the level of CPO in the discharges is taken as 100 µg/L, the maximum level assured by the FSRU supplier. Ballast water undergoes longer storage, and there is more chlorine decay, so the level of CPO in the ballast discharge is taken as 21 µg/L.

The quantity of chlorine or CPO discharged is estimated to be 47 kg/d at peak open production, 32 kg/d at average open loop production and 19 kg/d with closed loop production. On the days when there is an LNG carrier unloading LNG to the FSRU, there is an extra discharge of 0.6 kg/d from the fire management system and about 1 kg/d from the ballast water system (during an unloading period of approximately 36 hours up to 40 times per year).

12.2.4.2.1 Consideration of alternatives to chlorine

AGL considered alternatives to chlorine as a biofouling inhibitor at the intake to prevent growth of biota and prevent biofouling. Alternatives such as the ultrasonic system by Hazytec was explored. This system uses ultrasound to prevent growth and remove biofilm. However, the transducers have not yet been certified for hazardous area use and therefore cannot be used. In addition, the alternatives that were explored were considered incapable to deal with a large seawater flow rate up to the maximum send out rate of 750 mmscf/d. A UV treatment-based system developed by Alfa Laval was also explored as an alternative to the use of chlorine. One of the main issues identified with this solution was the large amount of space that would be required for the UV system equipment to treat large volumes of seawater and therefore this was considered impractical.

12.2.5 Impact and risk assessment

The potential risks to the marine environment during the operation of the FSRU are:

- Discharge of seawater colder than ambient or warmer than ambient temperature, depending on the mode of operation on the FSRU;
- Discharge of chlorine produced oxidants and products from the electrolysis of seawater used to control biofouling in the piping network and heat exchangers on the FSRU; and
- Entrainment of plankton and other small biota during intake of seawater into the FSRU for the regasification process and other purposes such as cooling water for generators.

12.2.5.1 Cooled/warmed water discharge

12.2.5.1.1 Guideline values for temperature change

Modelling and analysis have been undertaken to determine the potential implications to the marine ecosystem of cool and warm water discharge from the FSRU.

Over 2019, measured seawater temperature varied from a maximum of 24^{o}C in February to 11^{o}C in August. In most months, the water temperature varied by 2^{o}C or more in a day or so in response to the large-scale hydrodynamic process in Bass Strait, or variations in daily climate.

Temperature can cause biological stress due to impacts on the metabolism of biota, the toxicity of contaminants or levels of stressors such as pH and dissolved oxygen. An appropriate method for establishing a guideline value for a water quality stressor is set out in SEPP (Waters). The Victorian SEPP (Waters) states that water quality guideline objectives can be established by calculating the 25th and/or 75th percentiles for reference sites using data collected at least monthly over a minimum of 12 months.

The 25th percentile, 50th percentile and 75th percentile temperature change values were calculated from the collected data for half tidal (6 hour), full tidal (12 hour) and 24-hour time periods. There is negligible increase between the 6-hour and 12-hour periods and only a small increase to the 24-hour period. The 1-hour period (shown in **Table 45**) was much smaller than the 6-hour temperature changes.

Table 45 Range of temperature variation at Crib Point, Jan to Nov 2019

Exposure Duration	25th percentile	75th percentile	Interquartile range (25% - 75%)
6-hours	0.34°C	0.83°C	0.5°C
12-hours	0.34°C	0.83°C	0.5°C
24-hours	0.46°C	0.96°C	0.5°C

The guideline value used to assess temperature change was determined based on the interquartile range difference that was calculated in **Table 45**. For each of the exposure durations, the range was calculated to be 0.5 °C. This represents a short-term temperature variability that marine biota are currently accustomed to. The suggested guideline value of 0.5ºC provides a metric that:

- is based on measured seawater variation at Crib Point over an eleven-month period (January 2020 was excluded due to large temperatures changes caused by the Victorian bushfires);
- includes high and low variations either side of the mean annual temperature;
- represents natural temperature variation experienced by biota in the water column and on the seabed in the channel in the vicinity of Crib Point on 6, 12 and 24 hourly timescales; and
- Provides a conservative basis for assessing the risk to marine biota from thermal differences resulting from the FSRU heat exchanger discharge.

For the assessment of changes in seawater temperature, two limits were used:

- A conservative guideline of 0.5ºC; and
- A maximum acceptable change of 0.8ºC based on the 75th percentile of the measured ranges.

12.2.5.1.2 Potential impact and risk

Potential temperature impacts were modelled for various conditions and flow patterns. The overall guideline value for temperature variation at Crib Point of 0.5ºC was used. Further details on the modelling conducted, and assumptions can be found in EES Technical Appendix A: *Marine Impact Assessment* (refer to **Appendix B**).

A conservative assumption of 40 LNG carriers per year unloading for a period of 36 hours each has been used to assess the potential impact on plume dispersion created by LNG carriers berthing adjacent to the FSRU. The modelling has identified that there are changes to the pattern of flow from the six discharge ports on the FSRU when an LNG carrier is present due to the discharge water being diverted by the presence of the carrier.

Unloading of carriers has been assumed to occur for approximately 16 per cent (60 days) of the year, and normal operations (either peak or average) has been assumed to occur for 84 per cent of the year.

Table 46 summarises the temperature predictions of the regional model for four different operation scenarios. All scenarios presented in the table below are for peak operations.

Table 46 Summary of results of temperature predictions

Yearly frequency	Operational scenario	LNG carrier presence	Predicted area of temperature difference >0.5ºC	Location of predicted impact
84%	Peak operation in open loop	No LNG carrier present	0.7 ha	Under and near FSRU
	Peak operation in closed loop	No LNG carrier present	0.2 ha	Under and near FSRU
16%	Peak operation in open loop	LNG carrier moored next to FSRU	20 ha	Under and near FSRU and LNG carrier
	Peak operation in closed loop	LNG carrier moored next to FSRU	0.3 ha	Under and near FSRU and LNG carrier

Figure 36 shows the variation in seabed temperature with time over the modelled 28-day cycle, at sites north, south, east and west of the FSRU. The largest temperature change corresponds to slack

water when cold-water accumulates on the seabed. The peak change is predicted to be greatest on the seabed under the discharge ports and is seldom more than 0.5ºC at 340 m north, is always less than 0.5ºC at 340 m south, extends for more than 100 m but less than 200 m west and is always less than 0.5ºC at 200 m east of the discharge.

Figure 37 shows the area above the temperature Guideline Value under the peak operating scenario when operating in open loop mode where an LNG carrier is berthed adjacent to the FSRU (worst case scenario).

As listed in **Table 46**, when the FSRU is operating in open loop mode and there is an adjacent LNG vessel, a pool of cold-water forms under the FSRU and LNG vessels during slack water due to the discharge from the FSRU being interrupted by the side of the adjacent LNG vessel. The pool is then eroded and mixed as the tidal currents strengthen during the ebb or flood tide following the slack water events. There is reduced dispersion during these events.

The extent of seabed that would experience temperature change of more than 0.5ºC from ambient is listed in **Table 46**.for peak operations in open and closed loop. This worst-case pool of cold water will only occur at times when an LNG carrier is berthed adjacent to the FSRU (up to 40 times per year for a duration of up to 36 hours each time).

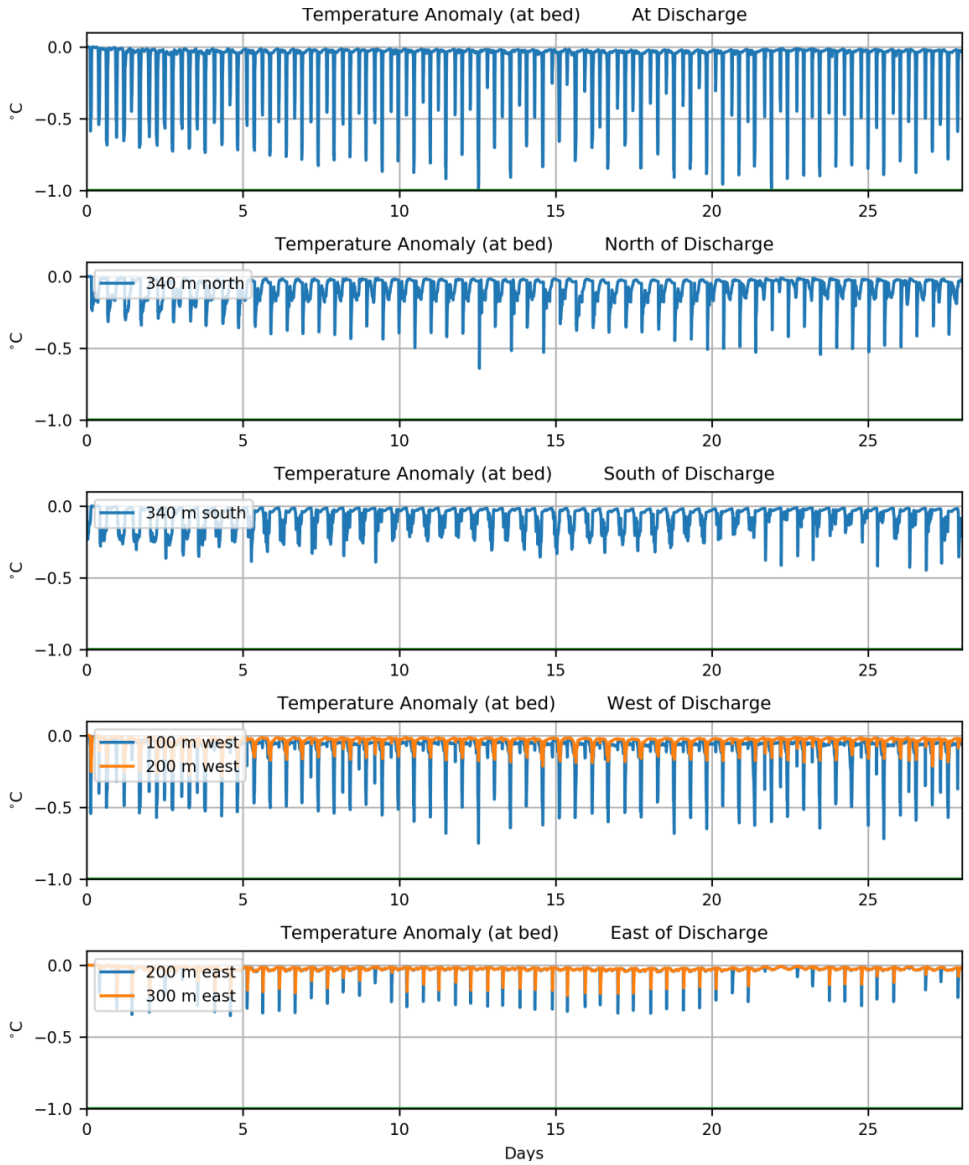


Figure 36 Variation in seabed temperature over time

This area encompasses all the seabed and water column in which the cold-water level could exceed the guideline limit of 0.5ºC and encompasses an area of approximately 20 ha, all of which is within the declared Port of Hastings Port Waters boundary and also within the area that was dredged (or the adjacent area altered by the jetty construction). **Figure 38** and **Figure 39** shows the area above the Guideline Value within the context of the Lower North Arm and within the context of the whole of Western Port respectively.

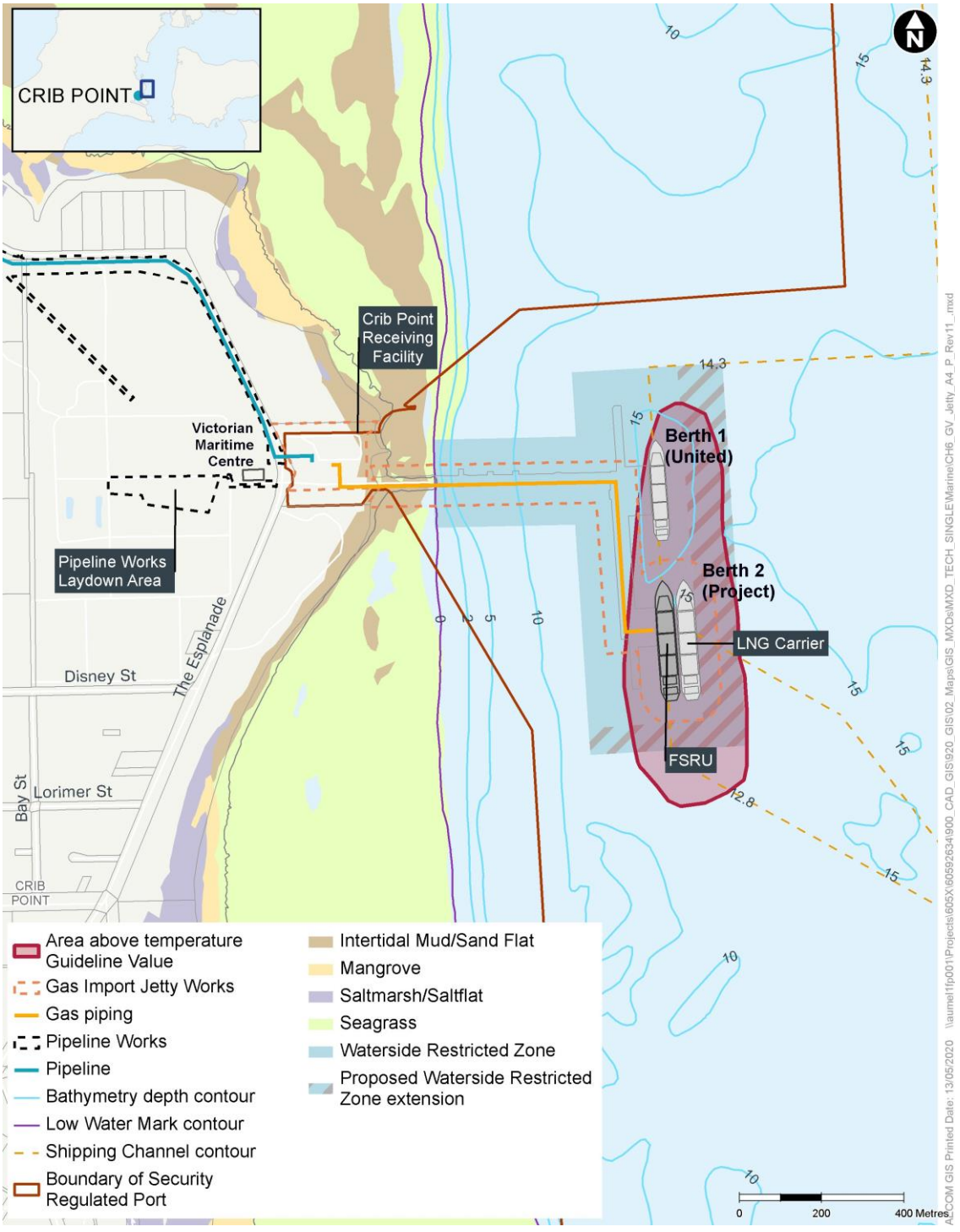


Figure 37 Area above Temperature Guideline Value during peak operation (Open loop LNG Carrier at berth)

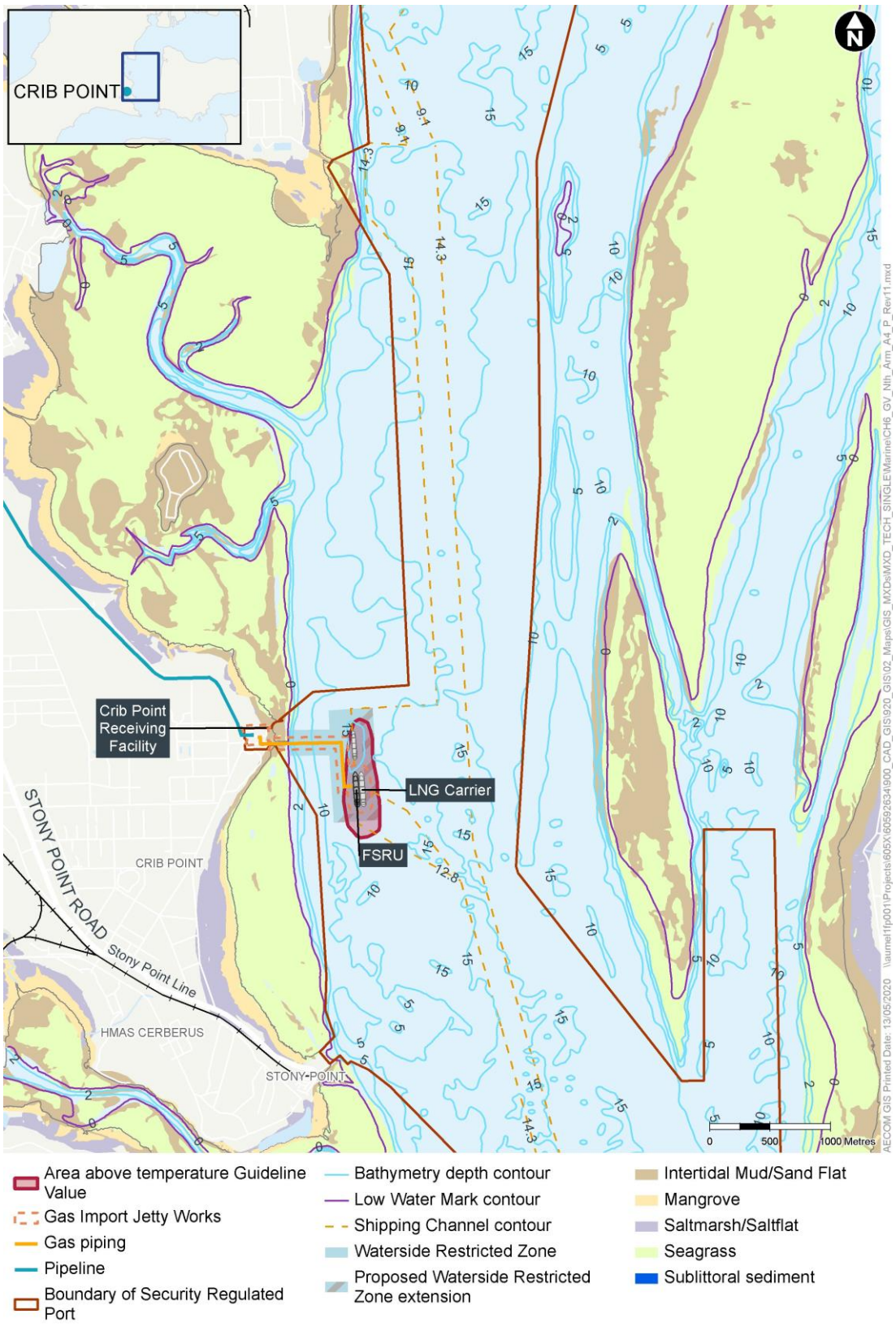


Figure 38 Area above Temperature Guideline Value – Lower North Arm during peak operation (Open loop LNG Carrier at berth)

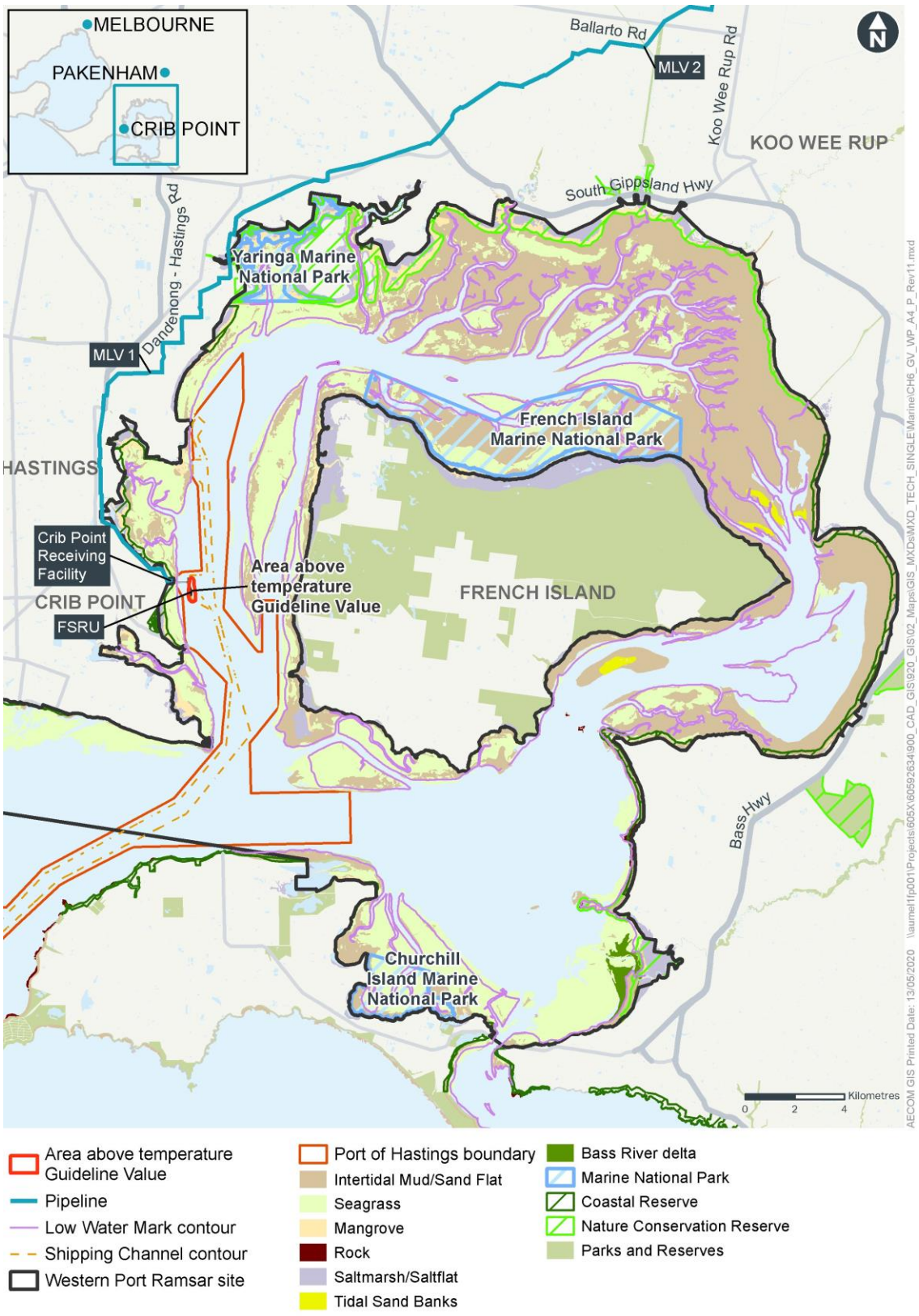


Figure 39 Area above temperature Guideline Value– Western Port during peak operation (Open loop LNG Carrier at berth)

An impact assessment was carried out to determine potential impacts on specific environmental segments related to the operation of the FSRU. A risk assessment was carried out using an approach that is consistent with the AS/NZS ISO 31000:2018 *Risk Management Process*. A detailed description of the methodology used to determine risk is provided in **Appendix L**,

Table 47 summarises the impact assessment outcome and the risk of discharge of cold water on the environment.

Table 47 A summary of impact assessment and risk of discharge of cooled water

Environmental segment	Impact assessment outcome	Reasoning	Risk
Saltmarsh and mangroves	No impact because cold water does not reach mangroves and saltmarsh	The closest patch of saltmarsh and mangrove vegetation is approximately 420 metres away from the area above the temperature Guideline Value. The likelihood of cooler water reaching the patch is very low and the temperature difference would be well below any Guideline Value by the time it reached that patch meaning the potential impact is negligible.	Very Low
Intertidal mudflat invertebrates	No impact because cold water does not reach intertidal zone	The nearest intertidal benthic communities are over 500 metres west of the proposed FSRU location. The likelihood of cooler water concentrations reaching mudflat habitats is very low. Due to the distance of intertidal mudflat habitats from the proposed FSRU location, the temperature difference would be well below any Guideline Value by the time it reached the habitat, meaning the potential impact is negligible.	Very Low
Intertidal and subtidal seagrasses	No impact because cold water does not reach seagrass zone	The closest seagrass vegetation is located 700 metres to the west of the proposed FSRU location. All seagrass areas are well away from the area where the Guideline Value for temperature is predicted to be exceeded. The likelihood of cooler water reaching the seagrass vegetation is very low and the temperature difference would be well below any Guideline Value by the time it reached vegetation meaning the potential impact is very low.	Very Low
Benthic subtidal invertebrates	No impact for infauna population in North Arm as a whole, but localised impact for infauna within the temperature footprint in the port area.	Infauna were found near the wharf (100 – 300/L sediment). Therefore, cooler water concentrations reaching infauna would occur. The benthic habitats and species present at Crib Point Berth 2 are widely represented in the Lower North Arm over an area of about 36,000 hectares. The potential impact on benthic communities over 20 hectares due to discharge of cooler water is therefore considered negligible in terms of changes to the ecological processes and nutrient and carbon cycles in Western Port.	Low for infauna in port area

Environmental segment	Impact assessment outcome	Reasoning	Risk
Pelagic and demersal fish	Negligible impact on fish populations in North Arm. Potential local effects for fish populations under Crib Point jetty Berth 2, in conjunction with effects of shading, avoidance or attraction and dredging.	Pelagic and demersal species move around in Western Port and some would be in the vicinity of the FSRU where they could have direct contact with the cooler water plume as it dilutes and spreads out. Although the discharge plumes extend over a very small area in the context of Western Port, the potential for contact with fish is highly likely. Given that fish are very mobile and have the opportunity and ability to move away quickly from the discharge area, the potential impact is considered negligible.	Low
Plankton	No impact on plankton populations in North Arm. Potential very small effects for populations passing Crib Point jetty Berth 2.	Field sampling of zooplankton and phytoplankton in North Arm established that plankton is abundant and widely distributed through Western Port and around Crib Point. Direct contact with the cooler water discharge is highly likely. Only a very small amount of plankton are predicted to be impacted by the cooler water discharge compared with the high abundance in North Arm and Western Port generally meaning the potential impact is negligible.	Low
Subtidal reef	No impact because cold water does not reach subtidal reef	The main examples of subtidal reefs in Western Port are at Eagle Rock and Crawfish Rock located approximately 12 kilometres north of Crib Point Jetty. Given the distance, the likelihood of cooler water reaching the subtidal reef is very low and the temperature difference would be well below any Guideline Value by the time it reached the reef, meaning the potential impact is negligible.	Very Low
Ramsar	No impact because cold water does not affect the defined Ramsar uses	There is a significant distance between the area where the temperature Guideline Value is predicted to be exceeded and the various habitat types recognised under the Ramsar convention. Due to the distance, the likelihood of there being any effect from the discharge of cooler water on the subtidal reef (for seagrass, estuarine areas, intertidal mud flats, intertidal forested wetlands, salt marshes, mangroves and waterbirds) is rated is very low. The only part of the Ramsar area that is potentially affected by the proposal is the waters of North Arm within the area where the Guideline Value is exceeded. All these waters are part of the declared and operating Port of Hastings and are used by approximately 150 commercial vessels each year, including for the import and export of petroleum products, and the seabed is subject to periodic dredging. Therefore, the potential impact is considered negligible.	Very Low

Environmental segment	Impact assessment outcome	Reasoning	Risk
Protected areas	No impact because cold water does not affect the National Parks	Western Port has several Marine National Parks with the closest to Crib Point being the Yaringa Marine National Park approximately 12 kilometres away. Given the distance between the area where the temperature Guideline Value is predicted to be exceeded and the subtidal reef at Yaringa the likelihood of there being any effect from the discharge of cold water on the subtidal reef is very low. The large distance between the FSRU and Yaringa means that several tidal cycles would be involved in the travel time and cooler water would have dispersed before it reached the reef. Therefore, the potential impact is considered negligible.	Very Low
Protected species	No impact because there are no known ghost shrimp present within the temperature footprint	There are several protected species that have potential to come within the vicinity of Crib Point including whales, turtles, fish and infauna such as the ghost shrimp. Most of these species are not expected to be close to the FSRU and any contact with the area where the Guideline Value for cooler water is predicted to be exceeded is likely to be for very limited periods of time. As a result, they have very low exposure time and the potential impact is very low.	Low

The identified risks for warmer water discharge in the event that the FSRU was operated in closed loop are the same as the cooler water risks listed in **Table 47** above. However, due to the much smaller volume of warm water that is discharged into the bay under closed loop operation compared to when the FSRU is operating in open loop (less than 30 per cent), there is a lower chance of nearby sensitive receptors being impacted.

All of the potential risks associated with both cooler and warmer water discharges from the FSRU into Western Port are ranked as either very low or low and are not considered to have any adverse impacts on the environment of the Lower North Arm or more widely in Western Port.

12.2.5.2 Residual chlorine oxidants

12.2.5.2.1 Guideline values for chlorine

Chlorine concentration modelling and analysis has been undertaken to determine the potential implications for the marine ecosystem from any residual chlorine in the seawater discharge from the FSRU.

In Australia and New Zealand, in the absence of sufficient chlorine toxicity data for marine species, a low reliability environmental concern value of 3 µg/L was adopted in 2000. To develop an up-to-date Guideline Limit for marine waters, the CSIRO was contracted to review all available toxicity data for chlorine and develop a Guideline Limit applicable to marine waters in Western Port that provided 99 % species protection.

The maximum acceptable chlorine level or Guideline Limit was obtained through consideration of the SEPP (Waters) that indicates 99% species protection, Australian and New Zealand Guidelines for Fresh and Marine Water (ANZECC Guidelines) and a CSIRO report specifically addressing the chlorine limit in marine waters (refer to **Appendix M**).

Based on the CSIRO assessment, a time-averaged chlorine guideline value of 6 µg/L was adopted, using the average chlorine concentration over a 12-hour tidal cycle. Currents in the North Arm are tidal, flowing north on the flood tide and south on the ebb tide. The tidal excursion on neap tides is 4 km to the north and 4.3 km to the south. The tidal excursions are larger on spring tides. Sites in the tidal channels of the North Arm within 4 km north and 4.3 km south of the FSRU are considered to experience intermittent chlorine exposure and the guideline value of 6 µg/L applies to the average chlorine exposure at those sites over a 12-hour tidal cycle. Sites well away from the FSRU are assessed in terms of the chlorine guideline value of 2 µg/L for continuous exposure.

12.2.5.2.2 Potential impact and risk

Chlorine concentrations were modelled for a range of conditions and flow patterns. Details of the modelling conducted, and assumption can be found in EES Technical Appendix A: *Marine Impact Assessment* (refer to **Appendix B**).

The key features of the resulting modelled plumes, for all discharge scenarios are described below:

- The travel path depends entirely on the tidal water movement. In ebb tides, the plumes formed from the seawater discharges are carried to the south, in flood tides, the plumes are carried to the north. There is considerable dilution (reducing the chlorine level from 100 µg/L at the discharge point to less than 5 µg/L within about 40 m of the point of discharge)
- At slack water, the tidal currents are weak and there is less dilution, with the partly diluted discharge pooling beside and under the FSRU until the pool is carried away and diluted in the following tidal cycle.
    - In open loop operation, the chlorine pool extends over an area on the seabed of about 160 m north/south and 150 m east/west.
    - In closed loop at slack water, the pool extends over an area on the seabed of about 100 m north/south and 100 m east/west.
    - The time-averaged chlorine level exceeds 6 µg/L in the footprint of the pool described above for open loop and closed loop. The pool for closed loop is smaller than for open loop because the discharge rate of seawater is 60% lower and the discharge is warm, which aids dispersion due to the extra dilution produced by buoyant rise.
- As described above there may be short-term events of local chlorine concentrations above 6 µg/L in weak currents at slack water, however, due to low chlorine concentrations through the majority of the tide cycle, the time-averaged chlorine levels are below 6 µg/L.
- When an LNG carrier is unloading, it blocks the high velocity discharge ports in open loop mode. This reduces dilution in the tidal currents and causes more accumulation of partly diluted discharge under the two vessels (FSRU and LNG) at slack water. In open loop, the pool extends over an area on the seabed of about 360 m north/south and 200 m east/west. The time-averaged chlorine level exceeds 6 µg/L in the footprint of the pool.
- The effect of the parallel LNG carrier is less for closed loop discharge because the ports that discharge during closed loop operations are at the rear of the FSRU. Even so, when an LNG carrier is unloading, there is reduced dilution and a pool of partly diluted discharge forms under the two vessels (FSRU and LNG) at slack water. In closed loop, the pool extends over an area on the seabed of about 200 m north/south and 150 m east/west. The time-averaged chlorine level exceeds 6 µg/L in the footprint of the pool.

These outcomes with associated frequencies are set out in **Table 48**. Note that the frequencies in the table assume worst-case 40 LNG carriers per year.

With an LNG carrier unloading to the FSRU, there is an area under and adjacent to the vessels in which the guideline value will be exceeded. The estimated dimensions of the area in which the chlorine concentration exceeds 6 µg/L is shown in **Table 48**. As can be seen, the area above 6 µg/L reduces from 5 ha (peak open loop) to 0.2 ha (closed loop, not dependent on rate of production).

Without an LNG carrier, there is an area under and adjacent to the vessel in which the guideline value will be exceeded for a short period of time in weak currents at slack water. There may be short-term

events of local chlorine concentrations above 6 µg/L in weak currents at slack water, however, due to low chlorine concentrations through the majority of the tide cycle, the time-averaged chlorine levels are below 6 µg/L. Operations in open loop up to peak operations when an LNG carrier is not present are therefore assessed as being compliant with the time-averaged chlorine guideline value of 6 µg/L.

The area above 6 µg/L is significantly smaller during both open and closed loop without an LNG carrier in comparison to the exceedance area when an LNG carrier is berthed next to the FSRU.

Under all operating scenarios, chlorine concentrations over 6 µg/L are confined to the dredged port basin within the operating Port of Hastings.

Table 48 Summary of results for chlorine predictions

Yearly frequency	Operational scenario	LNG carrier presence	Area of seabed above 6 µg/L (12-hour average)	Location
84 %	Peak operation in open loop	No LNG carrier present	None	Complies using 12-hour tidally averaged guideline value of 6 µg/L
	Peak operation in closed loop	No LNG carrier present	None	Complies using 12-hour tidally averaged guideline value of 6 µg/L
16 %	Peak operation in open loop	LNG carrier present	5 ha	Under and near FSRU and LNG carrier
	Closed loop (all rates of production)	LNG carrier present	0.2 ha	Under and near FSRU and LNG carrier

Table 49 demonstrates that in open loop, reduced operations result in reduced discharge and a reduced area where exceedances of the tidally averaged chlorine guideline value are predicted. In closed loop mode, the discharge remains the same whatever the level of production and so therefore the predicted area of exceedance is also the same.

Table 49 Summary of results for lower production rate

Yearly frequency	Operational scenario	LNG carrier presence	Area of seabed above 6 µg/L (12-hour average)	Location
Open Loop operation	Peak operation	LNG carrier present	5 ha	Under and near FSRU
	2/3 operation (average rate)	LNG carrier present	2 ha	Under and near vessels
	1/3 operation (reduced rate)	LNG carrier present	1 ha	Under and near FSRU and LNG carrier
Closed loop operation	Closed loop (all rates of production)	LNG carrier present	0.2 ha	Under and near FSRU and LNG carrier

As illustrated in **Figure 40**, marine organisms that enter the seawater intake pipe network will be subjected to a short-term dose of chlorine that varies from at 500 µg/L at the inlet chlorinator to 100 µg/L at the outlet over a maximum passage duration of five minutes (other than in ballast water) before being discharged. Organisms that might attach to the wall of the heat exchange are continuously exposed to a constant dose of chlorine for as long as they are fixed to the wall of the heat exchanger.

An organism suspended in the tidal currents passing next to the discharge ports will experience a lower chlorine concentration reducing from 100 µg/L at the outlet to less than 10 µg/L after approximately 3 minutes because of the dilution of the discharge at it mixes with the surrounding seawater. The chlorine concentration continues to decrease with time due to subsequent dilution (refer to **Figure 41**). Only organisms sensitive to a low level and short duration of exposure to chlorine will be affected during the passage through the FSRU or in the plume - others will survive this short-term event. Nonetheless, a precautionary approach has been followed in determining the potential environmental effects from use of chlorine to control biofouling in the FSRU.

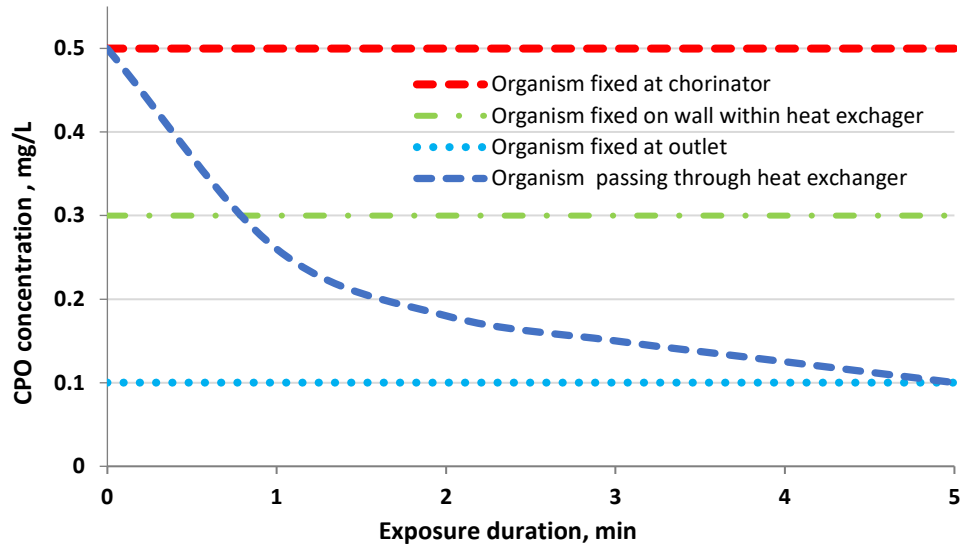


Figure 40 Chlorine exposure on FSRU – inlet to 5 minutes

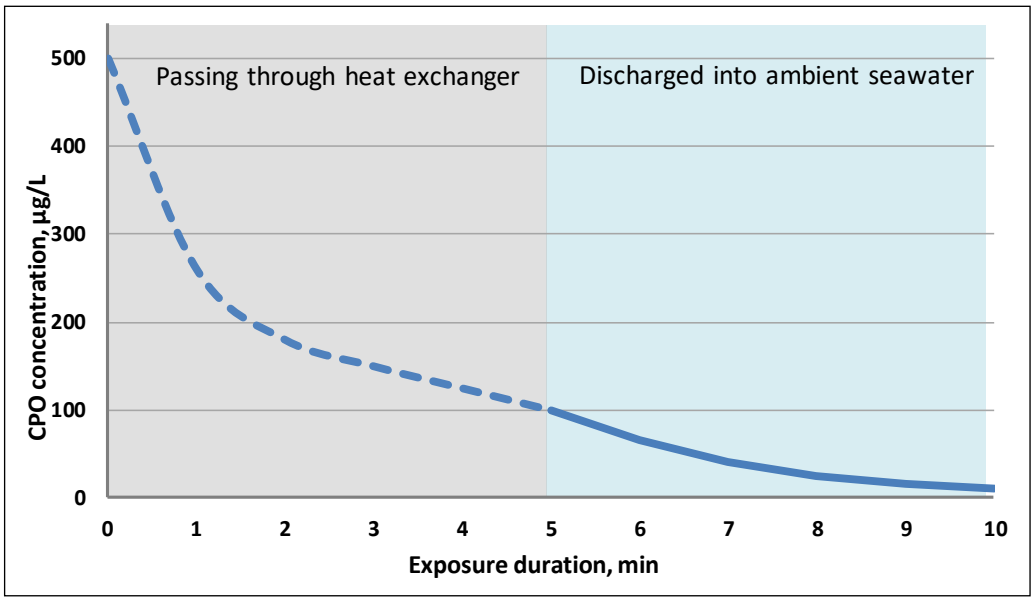


Figure 41 CPO exposure inlet to 10 minutes including the time after discharge

The potential impacts on marine organisms and communities due to chlorine oxidants are directly related to the concentration, duration and frequency of exposure to chlorine. The net effect on phytoplankton populations is the result of the integrated exposure profile. The exposure to chlorine is either continuous (e.g. on the seabed immediately below the discharge ports) or intermittent (every 6 hours, in response to the cycle of tidal currents) as illustrated in **Figure 42**.

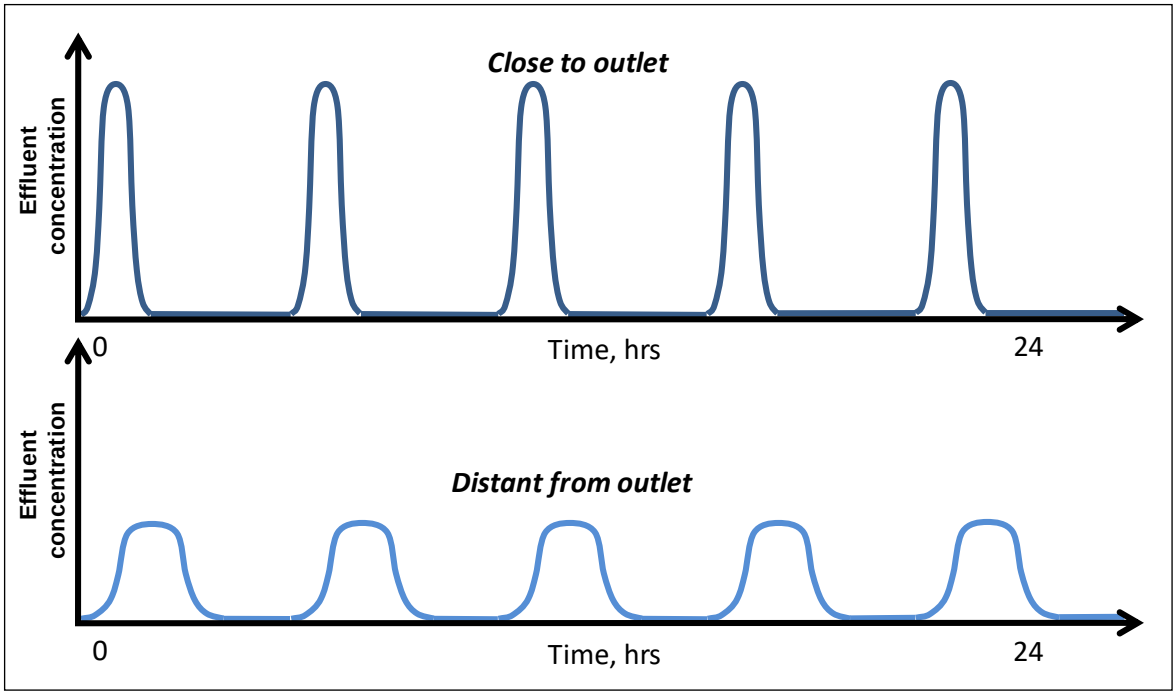


Figure 42 Exposure of benthic marine biota to intermittent chlorine discharge

There may be short-term events of local chlorine concentrations above 6 µg/L in weak currents at slack water, however, due to low chlorine concentrations through the majority of the tide cycle, the time-averaged chlorine levels are below 6 µg/L. Due to dilution over time and decay of the chlorine product, there is no long-term accumulation of chlorine in Western Port and the cumulative effects of the FSRU on chlorine concentration in the project area is expected to be negligible.

As listed in **Table 48**, when there is an adjacent LNG vessel, a pool with more elevated chlorine levels forms under the FSRU and LNG vessels every slack water. The pool is then eroded and mixed as the tidal currents strengthen during the ebb or flood tide following the slack water events. There is reduced dispersion during these events. **Figure 43** shows the area above the chlorine Guideline Value during peak operation in open loop mode when an LNG carrier is berthed adjacent to the FSRU (worst case pool of elevated time-averaged chlorine levels). This area encompasses all the seabed and water column in which the time-averaged chlorine level could exceed 6 µg/L.

The area is approximately 5 ha in extent, all of which is in the defined Port of Hastings, and also within the area that was dredged (or the adjacent area altered by the jetty construction). **Figure 44** and **Figure 45** show the area above the chlorine Guideline Value within the context of the Lower North Arm and within the context of the whole of Western Port respectively.

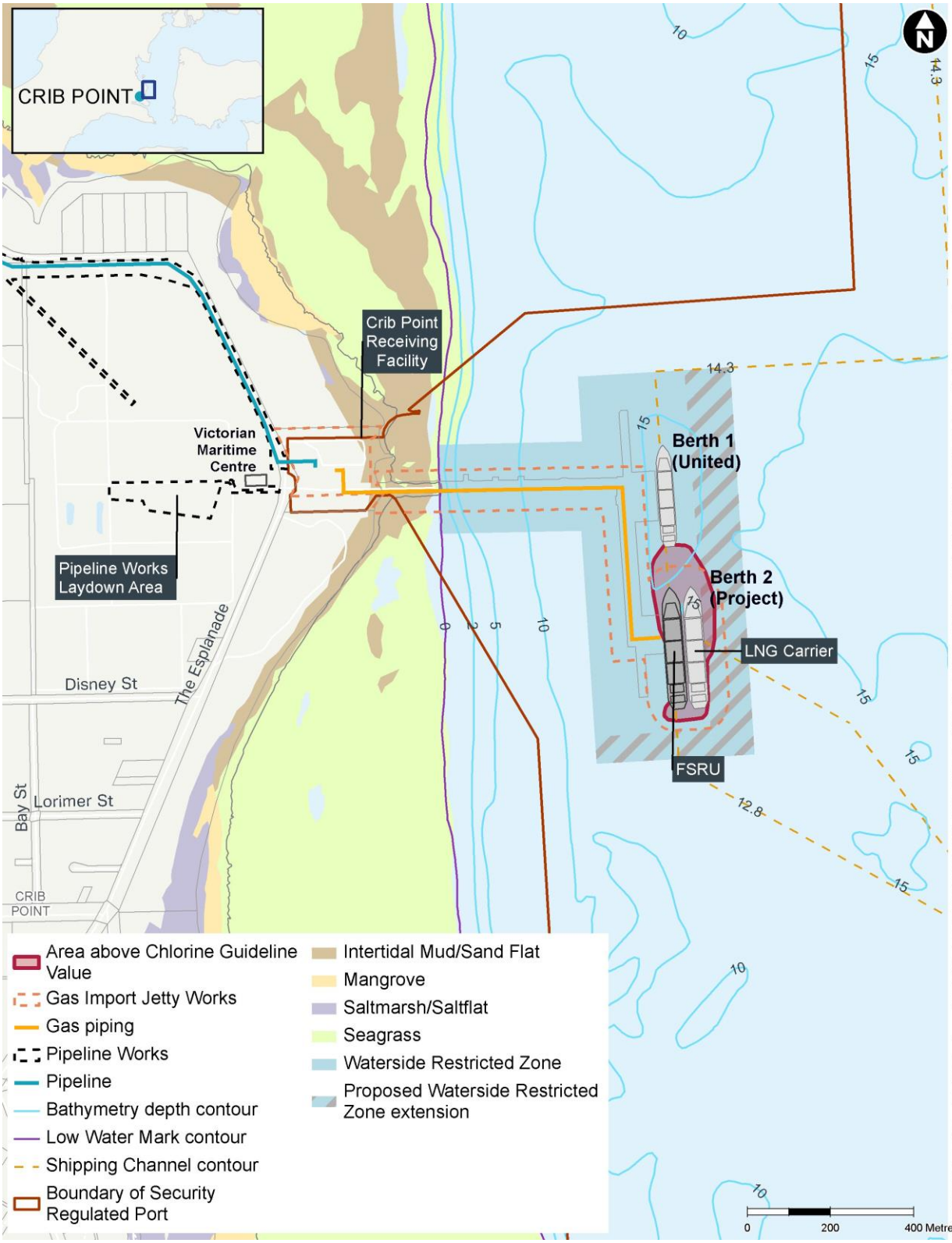


Figure 43 Area above the Chlorine Guideline Value during peak operation (open loop LNG carrier at berth)

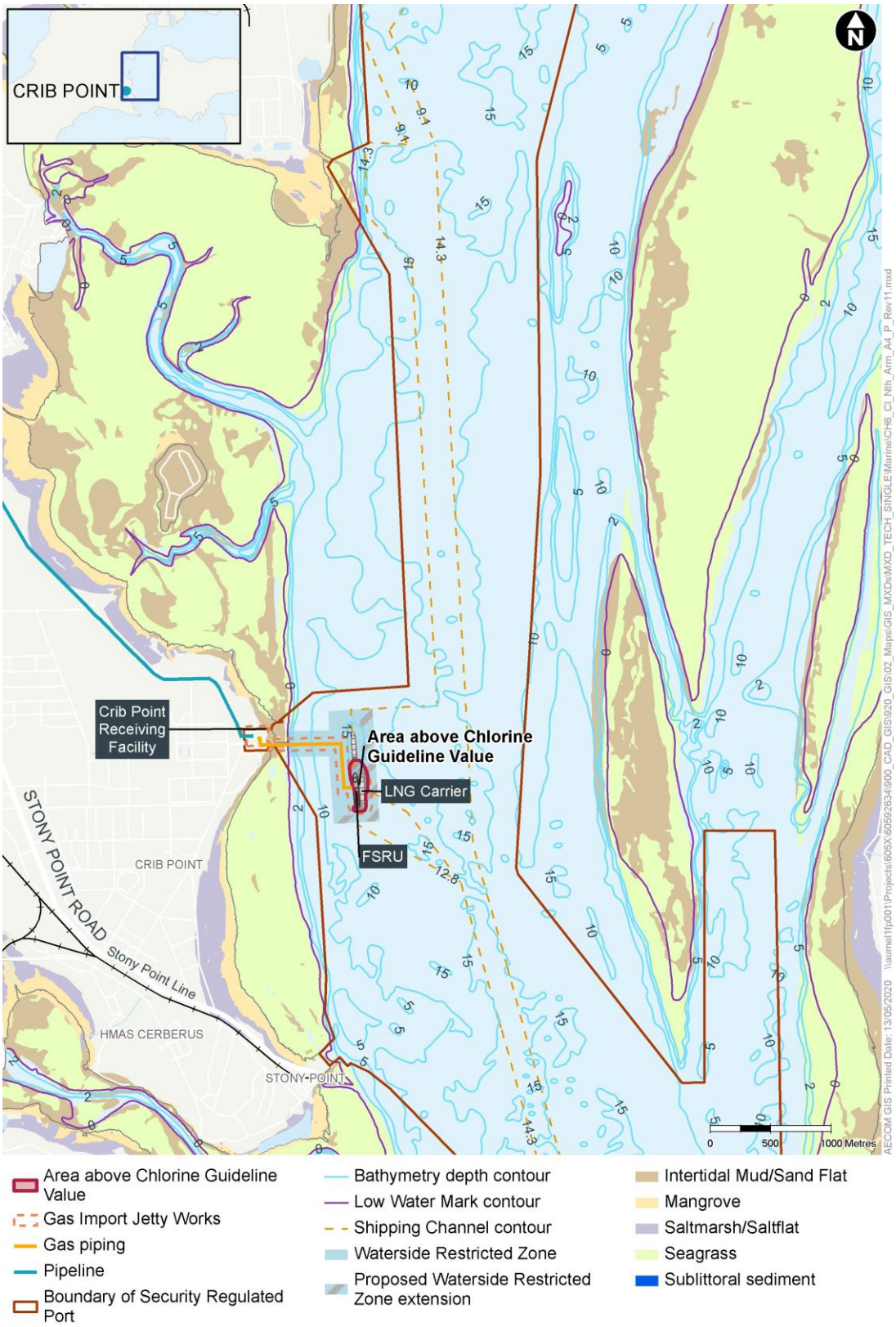


Figure 44 Area above the Chlorine Guideline Value– North Arm during peak operation (open loop LNG carrier at berth)

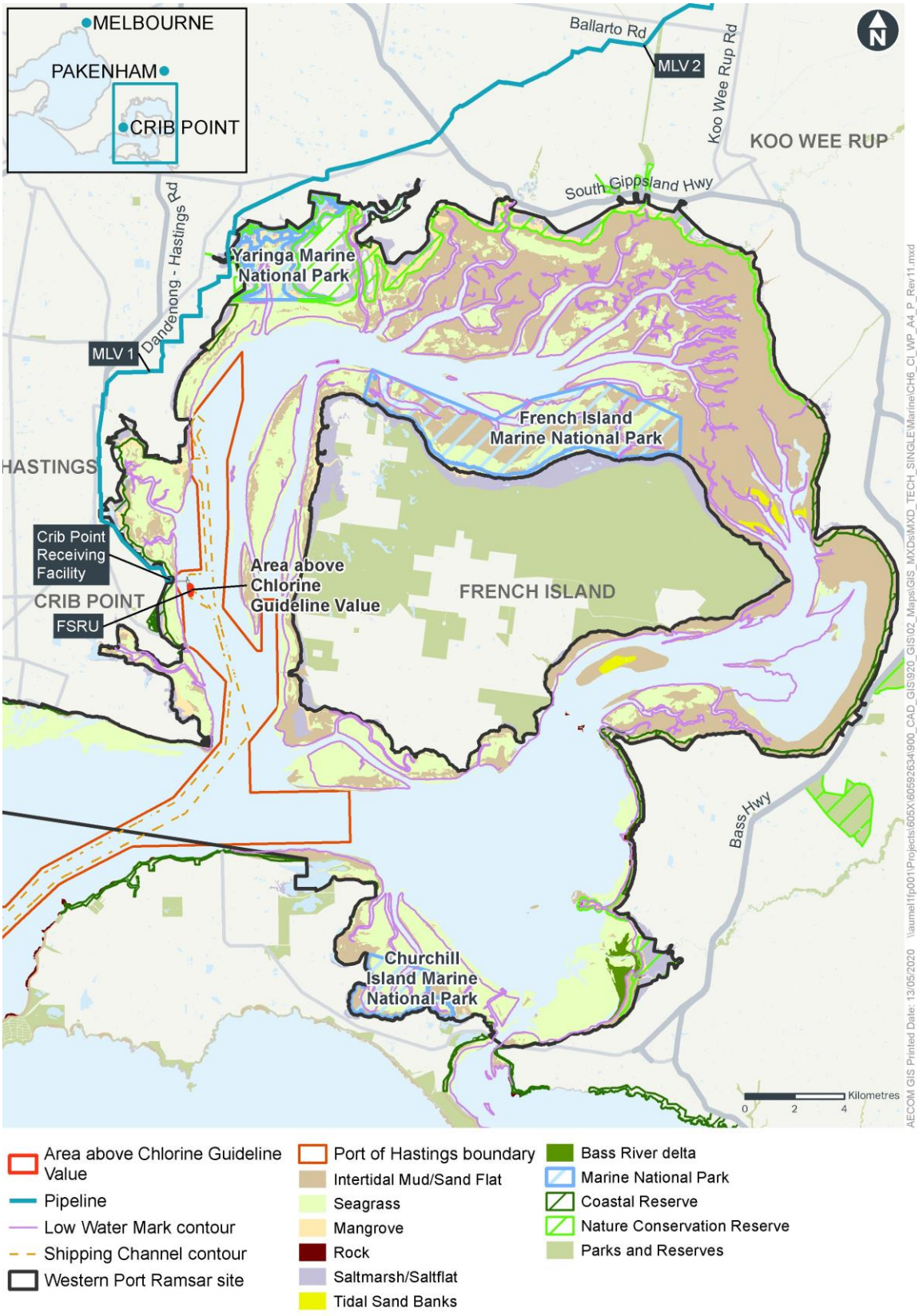


Figure 45 Area above Chlorine Guideline Value– Western Port during peak operation (Open loop LNG Carrier at berth)

The hydrodynamic model predicts that, for most of the volume within the chlorine impact area, the chlorine level ranges from zero to 12 µg/L depending on the stage in the tide cycle. There is a small area, extending from the discharge ports to the adjacent seabed, where higher chlorine occurs. Exposure to the higher chlorine occurs for biota entrained into the plumes during the dilution phase.

The extent of impacts of short bursts of chlorine on marine organisms and communities is directly related to the concentration and duration of exposure. Exposure over a short period may not cause significant adverse responses but exposure to the same level of stress over a long period may cause chronic adverse effects.

Figure 46 plots the toxicity results from the CSIRO review of chlorine for all whole organism tests as a function of time. The time scale is logarithmic, in hours. The concentration scale is logarithmic, in µg/L. The blue diamond's show the results of tests on different species over different durations. The lowest effect in tests on whole biota was observed at 21 µg/L for a 96-hour test. The dashed orange line is the lower envelope of the test results. The green squares show the CSIRO Guideline Values for chlorine of 6 µg/L for intermittent time-averaged exposure (taken as 12 hours) and of 2 µg/L for long term consistent exposure. They are well below the orange line, reflecting the factor of safety in the Guideline Values.

The orange triangle shows the chlorine level corresponding to a short exposure (0.1 hours) in the discharge plume which commences at the discharge concentration of 100 µg/L. The worst-exposed biota would be exposed to chlorine concentrations of zero up to 100 µg/L and down to 10 µg/L in 5 minutes. This means there may be short bursts of exposure of marine organisms to chlorine concentrations above 6 µg/L. Exposure over a short period may not cause significant adverse responses but exposure to the same level of stress over a long period may cause chronic adverse effects. As the worst-exposed biota is exposed over a short period the effect would be minor.

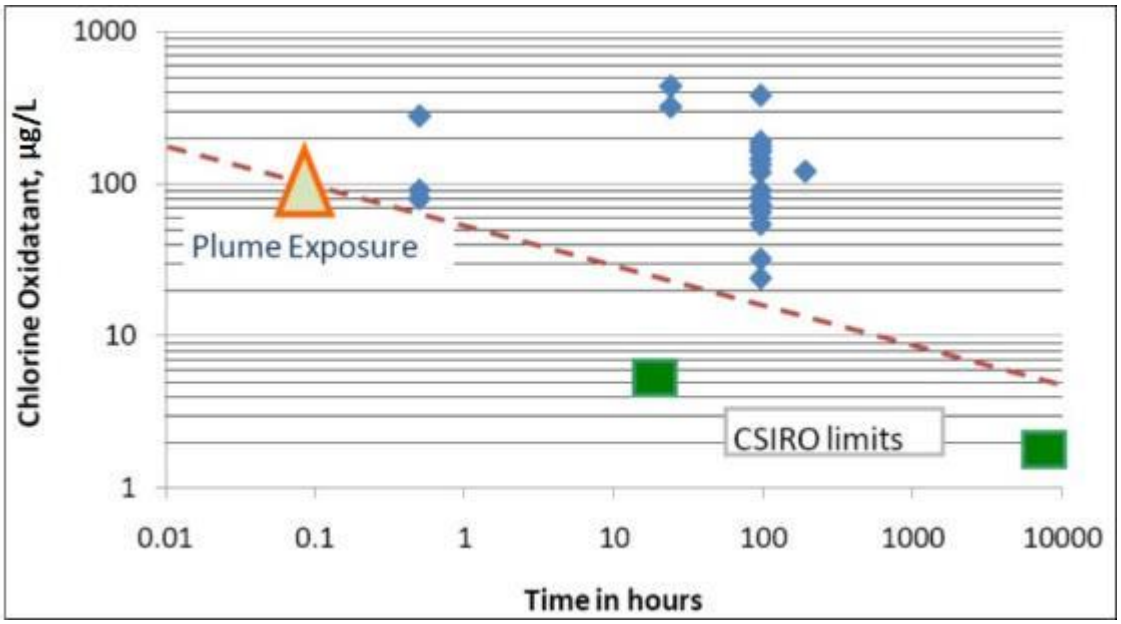


Figure 46 Chlorine toxicity results as function of duration of exposure

A risk assessment was carried out using an approach that is consistent with the AS/NZS ISO 31000:2018 *Risk Management Process*. A detailed description of the methodology used to determine risk is provided in **Appendix L**.

Table 50 summarises the impact assessment outcome and the risk of discharge of chlorinated water on the environment.

Table 50 A summary of impact assessment and risk of discharge of chlorinated water

Environmental segment	Impact assessment outcome	Reasoning	Risk
Saltmarsh and mangroves	No impact because chlorine does not reach mangroves and saltmarsh.	There is salt marsh and mangrove vegetation along the southern shore of the Port of Hastings with the closest patch approximately 420 metres distant from the area above the chlorine Guideline Value. Due to the distance, the likelihood of chlorine reaching the mangrove or saltmarsh habitats is very low. If chlorine was to reach the mangrove and saltmarsh vegetation, the concentration would be well below any Guideline Value and the potential impact would be negligible.	Very Low
Intertidal mudflat invertebrates	No impact because chlorine does not reach intertidal zone.	The nearest intertidal benthic communities are over 500 metres west of the proposed FSRU location. Due to the distance, the likelihood of chlorine reaching the intertidal mudflat habitats is very low. If chlorine was to reach the habitat, the concentration would be well below any Guideline Value and the potential impact would be negligible.	Very Low
Intertidal and subtidal seagrasses	No impact because chlorine does not reach seagrass zone.	The closest seagrass vegetation is located 700 metres to the west of the proposed FSRU location. All seagrass areas are well away from the area above the chlorine Guideline Value. The likelihood of chlorine concentrations reaching the seagrass vegetation is low due to the distance. If chlorine was to reach the seagrass habitat, the concentration would be well below any Guideline Value and the potential impact would be negligible.	Very Low

Environmental segment	Impact assessment outcome	Reasoning	Risk
Benthic subtidal invertebrates	No impact for infauna population in North Arm as a whole, but localised impact for infauna within the temperature footprint in the port area.	Infauna were found near the wharf (100 – 300/L sediment). The benthic habitats and species present at Crib Point Berth 2 are widely represented in the Lower North Arm over an area of about 36,000 hectares. An area of approximately 5 hectares where chlorine levels at all area of the seabed and water column could exceed 6 µg/L is anticipated during LNG unloading at slack tide. There are anticipated to be no acute impacts on infauna due to the chlorine concentrations in the discharge and exposure to elevated concentration of chlorine is expected to occur for short periods of time. The impact on benthic communities over 5 hectares due to discharge of chlorinated water is therefore considered negligible in terms of changes to the ecological processes and nutrient and carbon cycles in Western Port even though the communities would be exposed to the discharge.	Low
Pelagic and demersal fish	Negligible impact on fish populations in North Arm. Potential local effects for fish populations under Crib Point Jetty Berth 2, in conjunction with effects of shading, avoidance or attraction and dredging.	Pelagic and demersal species move around in Western Port and some would be in the vicinity of the FSRU where they could have direct contact with the chlorinated water plume as it dilutes and spreads. Although the discharge plumes extend over a very small area in the context of Western Port, the potential for fish to come into contact with the discharge is highly likely. Given that fish are very mobile and have the opportunity and ability to move away quickly from the discharge area, the potential impact is considered negligible.	Low
Plankton	No impact on plankton populations in North Arm. Potential very small effects for populations passing Crib Point Jetty Berth 2.	Field sampling of zooplankton and phytoplankton in North Arm established that plankton is abundant and widely distributed through Western Port and around Crib Point. The likelihood of direct contact with plankton is almost certain. Only a very minor amount of plankton are predicted to be impacted by the discharge when compared with the high abundance in North Arm and Western Port generally and the potential impact is considered negligible.	Low

Environmental segment	Impact assessment outcome	Reasoning	Risk
Subtidal reef	No impact because chlorine would not reach subtidal reef.	The main examples of subtidal reefs in Western Port are at Eagle Rock and Crawfish Rock, located approximately 12 kilometres north of Crib Point Jetty. Given the distance between the area where the Guideline Value for chlorine is predicted to be exceeded and the subtidal reef, the likelihood of there being any effect from the discharge of chlorinated water on the subtidal reef is very low. The large distance between the FSRU and the subtidal reef means that several tidal cycles would be involved in the travel time and chlorine would have dispersed and decayed to zero before it reached the reef. Therefore, the potential impact is considered negligible.	Very Low
Ramsar	No impact because chlorine would not affect the defined Ramsar site uses.	There is a significant distance between the area where the Guideline Value for chlorine is predicted to be exceeded and the various habitat types recognised under the Ramsar convention. Due to the distance, the likelihood of there being any effect from the discharge of chlorine on the subtidal reef (for seagrass, estuarine areas, intertidal mud flats, intertidal forested wetlands, salt marshes, mangroves and waterbirds) is rated is very low. The only part of the Ramsar area that is potentially affected by the proposal is the waters of North Arm within the area above the chlorine Guideline Value. All these waters are part of the declared and operating Port of Hastings and are used by approximately 150 commercial vessels each year, including for the import and export of petroleum products, and the seabed is subject to periodic dredging. Therefore, the potential impact is considered negligible.	Very Low
Protected areas	No impact because chlorine does not affect the Ramsar site (see above) and the marine national parks.	Western Port is listed under the Ramsar Convention as an area of significant importance. Western Port has several Marine National Parks with the closest to Crib Point being the Yaringa Marine National Park approximately 12 kilometres away. Given the distance between the area above the chlorine Guideline Value and the subtidal reef at Yaringa the likelihood of there being any effect from the discharge of chlorine on the subtidal reef is very low. The large distance between the FSRU and Yaringa means that several tidal cycles would be involved in the travel time and chlorine would have dispersed and decayed to zero before it reached the reef. Therefore, the potential impact is considered negligible.	Very Low

Environmental segment	Impact assessment outcome	Reasoning	Risk
Protected species	No impact because there are no known ghost shrimp present within the footprint.	There are several protected species that have potential to come within the vicinity of Crib Point including whales, turtles, fish and infauna such as the ghost shrimp. Most of these species are not expected to be close to the FSRU and any contact with the area above the chlorine Guideline Value is likely to be for very limited periods of time. As a result, they have very low exposure time and the potential impact is very low.	Low

All of the potential risks associated with discharge of chlorinated water from the FSRU into Western Port are ranked as either very low or low and are not considered to have any adverse impacts on the environment of Lower North Arm or Western Port.

12.2.5.2.3 Acute Toxicity

The SEPP (Waters) has regard to acute lethality in determining whether a mixing zone can be approved. The current policy provides that a mixing zone must not be approved which, according to approved tests, results in acute lethality at the point of discharge. The approved tests are considered to be standard 'toxicity tests'. SEPP (Waters) also states that a discharge that results in chronic toxicity may be permitted by EPA under certain conditions. National guidelines for toxicity tests are labelled ‘acute' or 'chronic' depending on the endpoint of the test and the duration of the test in relation to the particular organism (biological test subject) characteristic being tested (Warne et al 2015).

In this case, lethality refers to the endpoint and acute refers to the duration of the standard test. Two standard acute toxicity tests were chosen to test the acute toxicity of chlorine in seawater at concentrations ranges around that of the proposed discharge from the FSRU. Refer to **Appendix N** for the full toxicity test report. The test organisms were (1) juvenile marine stage barramundi (*Lates calcarifer*) and (2) adult marine sand fleas (*Allorchestes compressa*). They were exposed to a range of initial doses of chlorine in seawater from 0.006 mg/L up to 1 mg/L and were exposed for 96 hours after the initial dose. The results showed no acute lethality to initial doses of 0.006 mg/L up to 1 mg/L of chlorine as hypochlorite in seawater and subsequently over 96 hours of continuous exposure to the mixture after the initial dose. The concentration of chlorine at the point of discharge from the FSRU is estimated to be 0.1 mg/L chlorine. Hence, in the framework described above, the tests (two species, 96-hour acute lethality tests) show that the discharge would not result in acute lethality.

12.2.5.3 Combined temperature and chlorine impacts

A key outcome from the modelling and assessment of chlorine and seawater temperature risks for the marine environment is the extent of the predicted combined area above the chlorine Guideline Value and temperature Guideline Value. These comprise the area where exceedance of the combined Guideline Value for temperature and chlorine is predicted.

As discussed earlier, the ‘worst-case’ modelled scenario for temperature and chlorine is when the FSRU is operating in open loop at peak regasification (that is, all three regasification trains are operating with the largest seawater discharge rate) and an LNG carrier is berthed adjacent to the FSRU. The LNG carrier when berthed adjacent partially obstructs the discharge ports on the starboard side of the FSRU, decreasing the efficiency of mixing.

For all modelled scenarios, the predicted extent of the combined area above the temperature Guideline Value and the area above the chlorine Guideline Value is limited to the shipping basin and ship berthing areas within the Port of Hastings boundaries. This comprises seabed that has been previously dredged and is regularly subject to sediment resuspension by propeller wash from existing shipping activities at Crib Point Jetty.

The area above the chlorine Guideline Value for the worst-case modelled scenario, where the time-averaged chlorine level is predicted to exceed the Guideline Value (6 µg/L), extends for approximately 300 metres north/south and 160 metres east/west from the FSRU discharge ports, over an area of

five hectares for approximately one hour during slack tide and then reduce in size once the tidal currents increase. Most of this area is directly under the FSRU and the LNG carrier.

The area above the temperature Guideline Value for the worst-case modelled scenario, where the short-term temperature change is predicted to exceed 0.5 °C from ambient seawater (temperature Guideline Value), extends for approximately 800 metres north/south and 250 metres east/west of the FSRU, over about 20 hectares under and near the FSRU and the LNG carrier for approximately one hour during slack tide and then reduce in size once the tidal currents increase.

Figure 47 shows the combined area above the chlorine Guideline Value and the area above the temperature Guideline Value in the Port of Hastings. **Figure 48** shows the combined area in a wider context, in the context of the width of North Arm. **Figure 49** shows the combined area in the context of the whole of Western Port. In each of these figures, the outer extent of the predicted areas represents the area where the Guideline Value for temperature would be exceeded. The area where the Guideline Value for chlorine (0.6 ug/L time-averaged) is predicted to be exceeded is smaller and contained within the area above the temperature Guideline Value.

In summary, in the worst-case scenario, the area of potential impact for residual chlorine and seawater temperature change extends over 20 hectares around the proposed FSRU location. The worst-case predicted combined area above the chlorine and temperature Guideline Values would be localised to the Port of Hastings area around the Crib Point Jetty. There are no predicted effects on the shallow edges of North Arm, all seagrass and mangrove areas, all of the northern area of Western Port and all areas used by wading birds.

The likelihood of these impacts occurring would further decrease under other modelled scenarios, such as when an LNG carrier is not berthed adjacent to the FSRU and so mixing and dilution is more readily achieved, and when the FSRU is operating at lower gas production rates (and so the seawater discharge volume is lower).

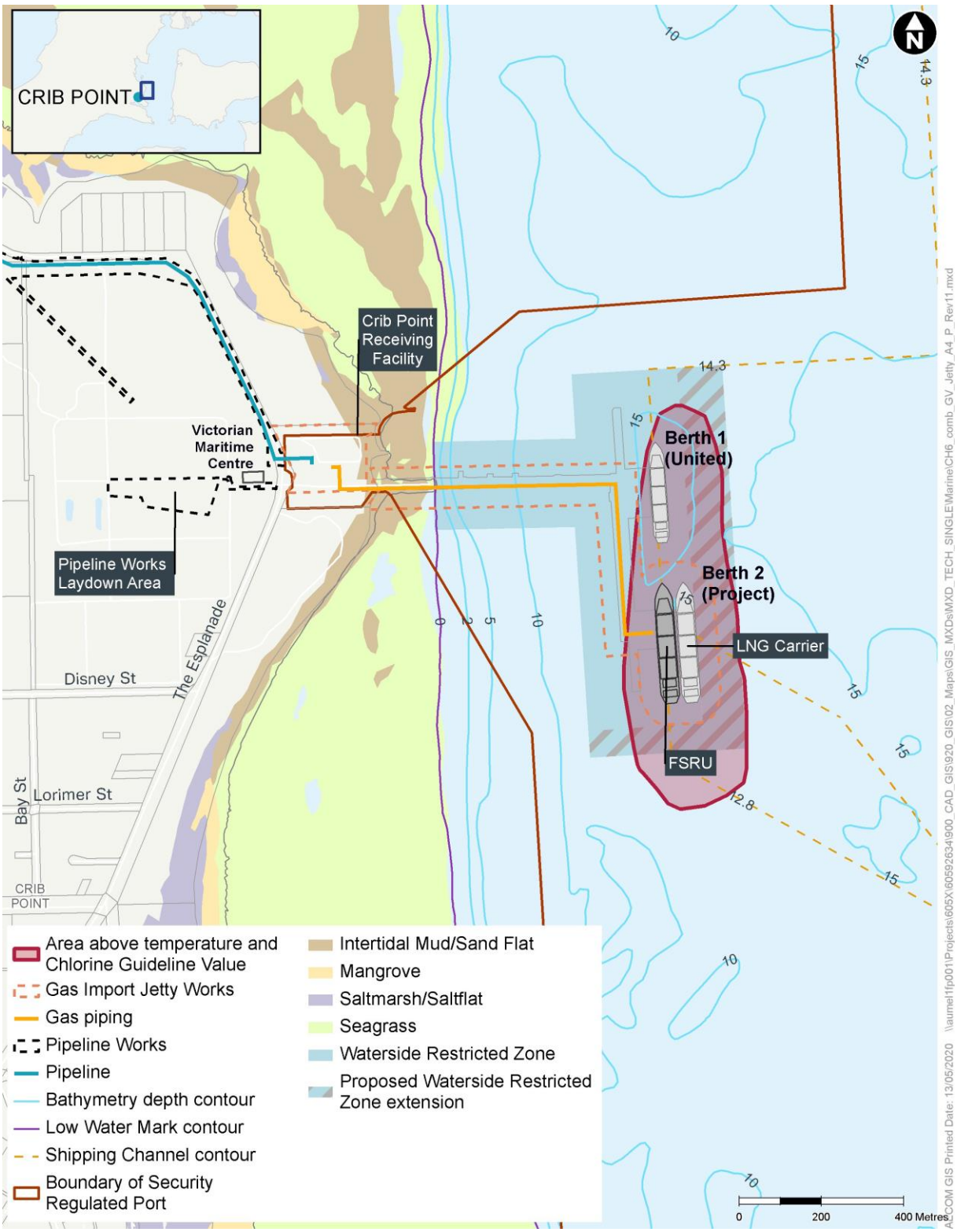


Figure 47 Combined area above temperature and chlorine Guideline Values – Crib Point

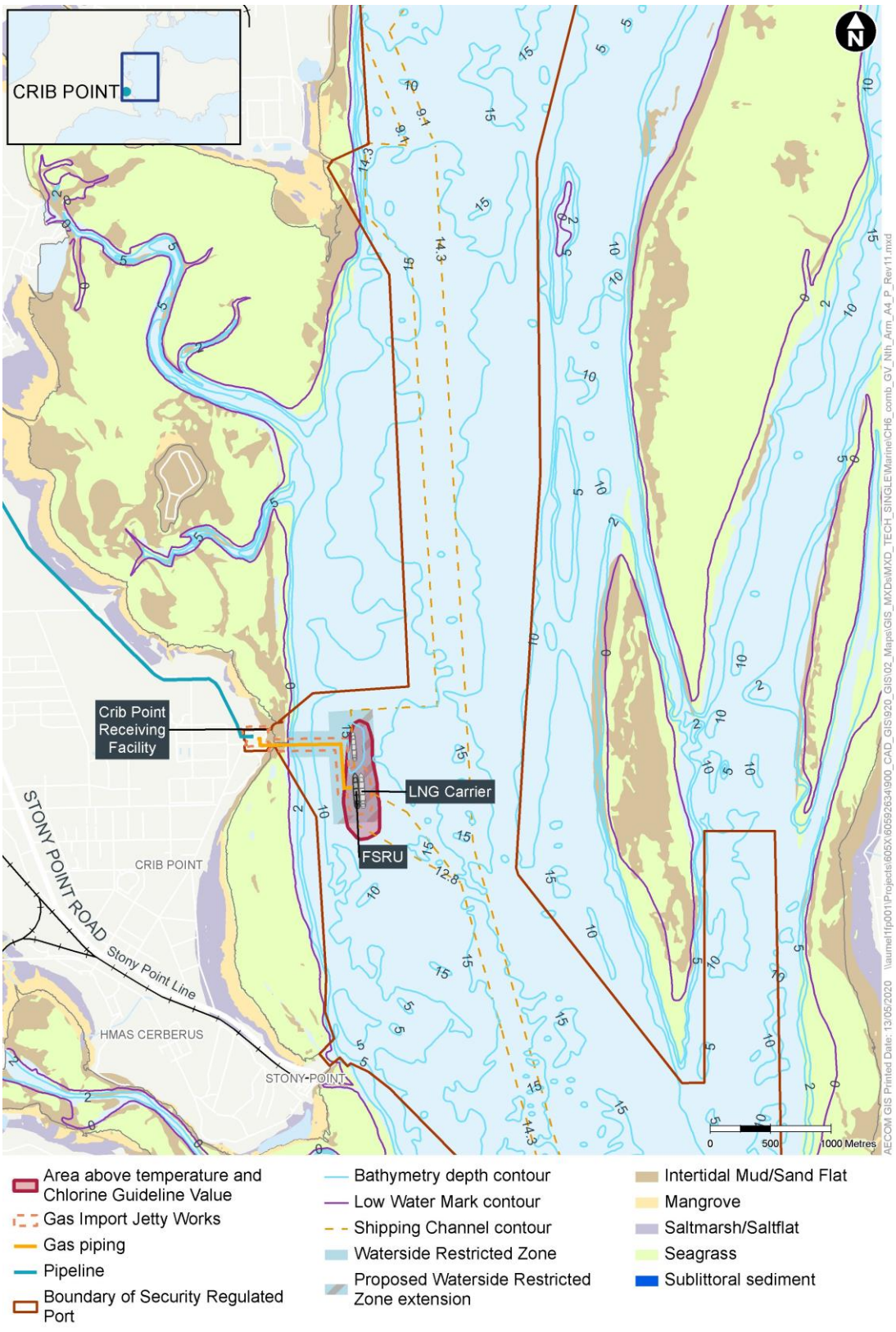


Figure 48 Combined area above temperature and chlorine Guideline Value – North Arm

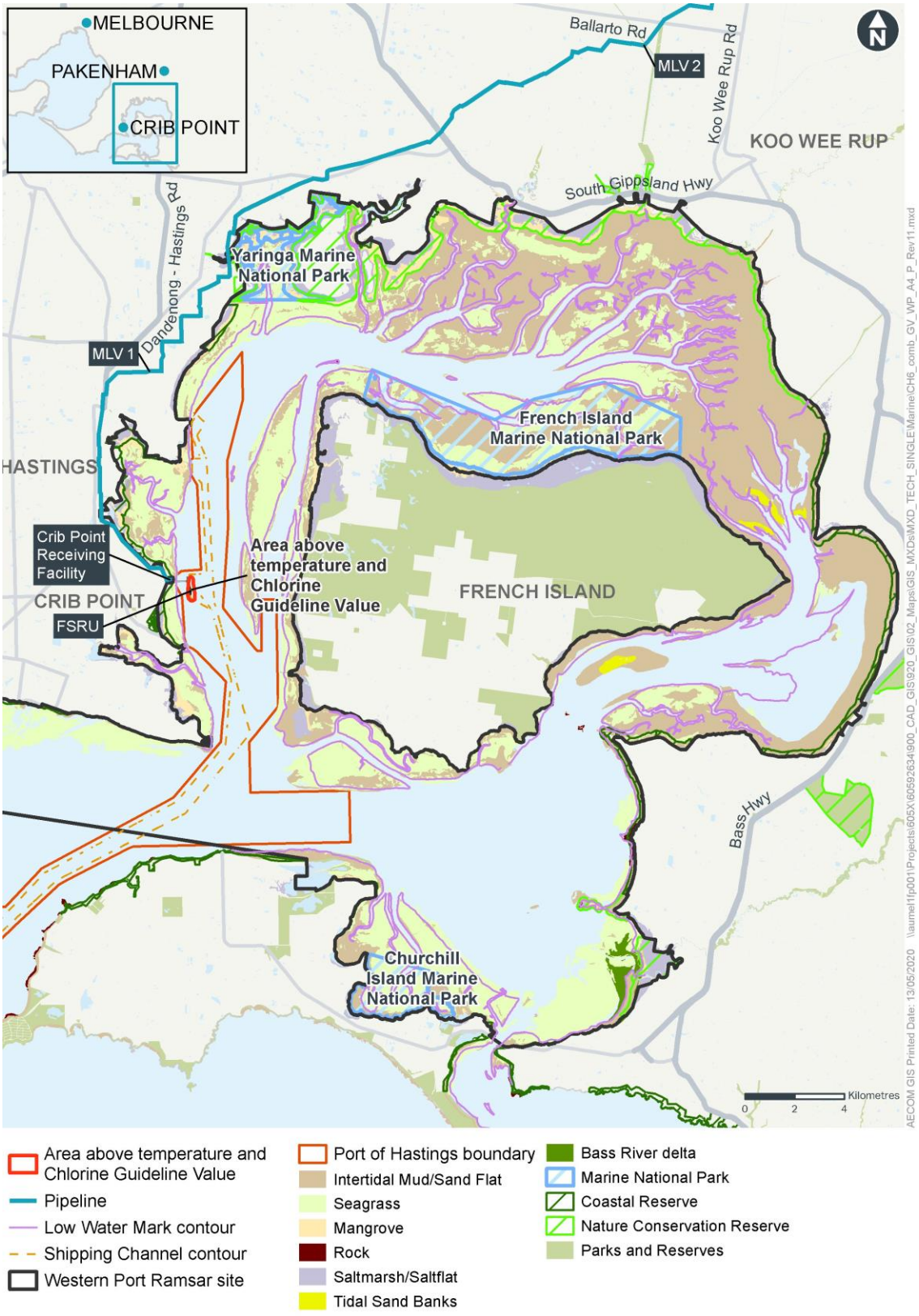


Figure 49 Combined area above temperature and chlorine Guideline Value – Western Port

12.2.5.4 Biological entrainment

During operation, the FSRU will intake large volumes of sea water from Western Port for the heat transfer process associated with regasification, and for other purposes such as for cooling, ballast water, firefighting and freshwater production. The seawater is taken into the FSRU through large inlets on the sides of the FSRU and chlorinated by an electrolytic process before being pumped through a network of pipes, valves and heat exchangers in the vessel.

The main potential adverse effect of seawater intake is entrainment of smaller marine organisms (very small fish, zooplankton and phytoplankton), drifting eggs and larvae in the central part of the water column adjacent to the intake. The effects of entrainment are assessed in terms of the volume of seawater that passes through the FSRU over representative time periods. This enables subsequent assessment of the scale of effects on the marine ecosystem in relation to the volume of water passing through North Arm over the same time period and the biota most affected according to their planktonic population replacement rate or planktonic larval period. This enables subsequent assessment of the scale of effects on the marine ecosystem in relation to the volume of North Arm and the biota most affected according to their planktonic population replacement rate or planktonic larval period.

The effect of entrainment on plankton and other small biota was modelled using a combined mathematical hydrodynamic and particle dispersion model. Model particles simulating planktonic biota were released from various ecological zones in Western Port and were tracked daily over a 28-day period (refer to the EES Technical Report A: *Marine impact assessment* (refer to **Appendix B**). for a detailed description of the hydrodynamic modelling carried out as part of these investigations).

The North Arm of Western Port was divided into eight ecological zones for the purposes of assessing plankton entrainment. The zones are shown in **Figure 50**.

The outcomes of the modelling particles used in the hydrodynamic models were recorded in terms of:

- Percentage of particles in the ecological zone that were entrained in seawater taken into the FSRU;
- Percentage of particles flushed from an ecological zone to Bass Strait;
- Percentage of particles dispersed from one ecological zone into other zones in Western Port; and
- Percentage of particles remaining in the ecological zone where they started.

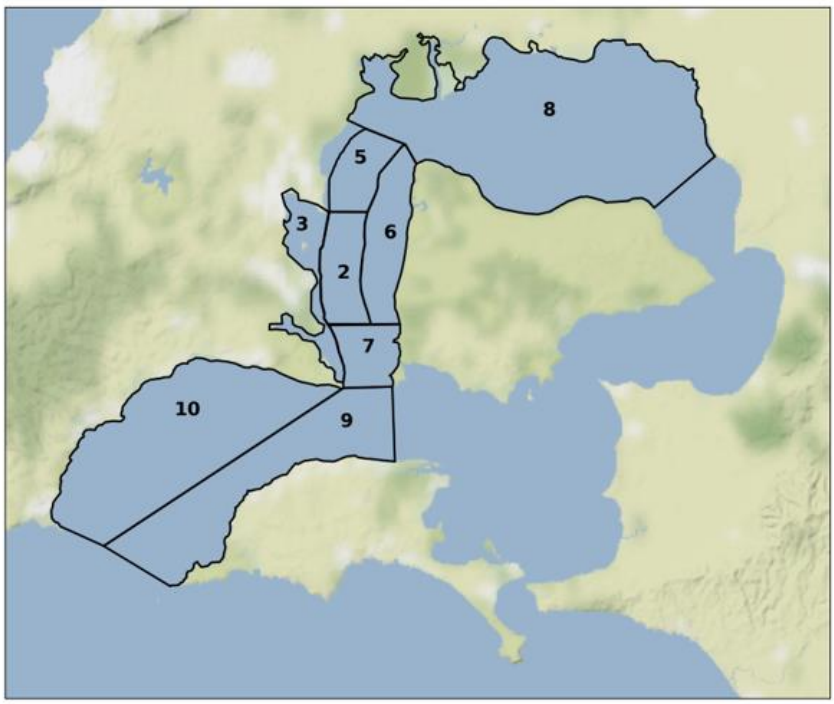


Figure 50 Entrainment Model Ecological Zones for Entrainment Calculations

The rate of particle entrainment depended on how close the modelled zone is to the FSRU. The FSRU will be located in ecological zone 2. The highest predicted rate of entrainment for any modelled zone (0.63% of the particles in zone 2 after 21 days or about 0.03% of the particles in zone 2 per day) is from zone 2 which covers the western side of Lower North Arm including the FSRU but excluding the mudflats and near shore waters to at least 6 m depth. By comparison, the zones for the western entrance close to Bass Strait have a very high rate of flushing (82% of the particles in zone 9/10 after 21 days) and consequently have a very low rate of entrainment (only 0.04% of the particles in zone 9/10 after 21 days or less than 0.002% of the particles in zone 9/10 per day).

The rate of flushing to Bass Strait depends on how close the sector is to Bass Strait. The zone in the north of the Bay is flushed at a very slow rate (only 7% of the particles in zone 8 after 21 days). This finding shows a hydrodynamic reason for different plankton species and abundance characteristics in the north of the Bay (where the flushing rate is low) compared those near the Western Entrance (where the flushing rate is high) and plankton populations are more representative of those in Bass Strait generally.

There is always a general flushing process operating along the axis of the entire North Arm with plankton populations from the north of the Bay being gradually flushed to Bass Strait. There is a high rate of mixing from zone to zone within 7 days. This result shows that there is substantial mixing between different parts of Western Port, and that the loss of plankton in one sector will be quickly made up by plankton mixing in from adjacent sectors.

Table 51 summarises the percentage of particles and, by inference, the percentage of biota that would be entrained from all ecological zones in the North Arm of Western Port at various rates of gas production in open loop and in closed loop for periods up to 28 days. For the peak rate of production, the rate of entrainment is 0.22% of the particles in all ecological zones in the north arm of Western Port after 14 days or 0.40% of the particles in all ecological zones in the north arm of Western Port after 28 days. This corresponds to an additional mortality rate of 0.014% per day compared to natural mortality in the same environment.

Table 51 North Arm entrainment rate predictions for various production rates

	Peak production open loop	Average production open loop	Closed Loop	Loss to Bass Strait
North Arm	Entrainment	Entrainment	Entrainment	Flushed from Zone 2
1	0.04 %	0.03 %	0.02 %	0.4 %
7	0.13 %	0.08 %	0.05 %	2.7 %
14	0.22 %	0.14 %	0.09 %	7 %
21	0.30 %	0.20 %	0.12 %	18 %
28	0.40 %	0.26 %	0.16 %	26 %

*Percentage of the particles in all ecological zones of the North Arm of Western Port

A risk assessment was carried out using an approach that is consistent with the AS/NZS ISO 31000:2018 *Risk Management Process*. A detailed description of the methodology used to determine risk is provided in **Appendix L**. **Table 52** summarises the impact assessment outcome and the risk of biological entrainment on the environment.

Table 52 A summary of impact assessment and risk of biological entrainment

Environmental segment	Impact assessment outcome	Reasoning	Risk
Mangrove and saltmarsh	No impact	Areas of mangrove and saltmarsh are not located in the vicinity of the FSRU with the closest communities located in ecological zone 3 in Figure 53. Saltmarshes are rarely inundated, and the plants or associated community members do not rely on planktonic dispersion for continuation of the community and, as such, there no viable pathway for entrainment. Mangroves in Western Port are the white (or grey) mangrove *Avicennia marina*, which produce fruit that float when they fall from the tree. These propagules are buoyant and float at the surface. Positioning the FSRU intake at least two metres from the sea surface would decrease the opportunity for mangrove seeds and propagules to be entrained. The likelihood of entrainment of saltmarsh or mangrove vegetation seeds or fruit is considered to be very low. The proportion of any saltmarsh or mangrove vegetation seeds or fruit entrained in relation to the total population would be negligible.	Very Low

Environmental segment	Impact assessment outcome	Reasoning	Risk
Intertidal mudflat and invertebrates	Negligible impact	The intertidal benthic invertebrate fauna in Western Port is an unusual mix with different proportions and distributions of species present compared to Port Phillip Bay or Bass Strait. This is due primarily to the range and arrangement of the physical habitats and the large tidal range in Western Port. This will not be affected in any way by entrainment. Any adverse impact by entrainment on intertidal invertebrate's species abundance or distribution is considered to be highly unlikely within the proximity (shipping basin) of the intake and the wider Western Port community.	Very Low
Intertidal and subtidal seagrasses	No impact	The closest intertidal and subtidal seagrasses to the FSRU proposed location are located in ecological zones 3 and 6 in Figure 53. Seagrasses release seeds and vegetative propagules. The seeds disperse over the seabed with wave action and seabed currents in much the same way as sediment is transported. Larger propagules drift along the seabed with currents, or sometimes float at or near the surface with other seagrass flotsam. The propagules are fully independent plants and may remain functional for long periods while drifting, before they take root in a preferred shallow subtidal or intertidal seabed. Positioning the FSRU intake at least two metres from the sea surface and at least three metres from the seabed would decrease the opportunity for seagrass propagules to be entrained. The likelihood of entrainment of intertidal and subtidal seagrass propagules is considered highly unlikely. The proportion of any seagrass vegetation seeds or fruit entrained in relation to the total population is considered negligible.	Very Low
Benthic subtidal invertebrate fauna	Negligible impact	The subtidal benthic invertebrate fauna in Western Port is an unusual mixture, with different proportions and distributions of species present compared to Port Phillip Bay or Bass Strait. This is due primarily to the range and arrangement of the physical habitats and the large tidal range in Western Port. The range and arrangement of the physical habitats will not be affected in any way by entrainment. Any adverse impact of entrainment on subtidal invertebrate species abundance or distribution is considered to be highly unlikely within the proximity (shipping basin) of the FSRU seawater intake and the wider Western Port community.	Very Low

Environmental segment	Impact assessment outcome	Reasoning	Risk
Fish eggs and larvae Spring-Summer	Moderate impact	Pelagic eggs are usually buoyant. As the seawater intake on the FSRU will be a minimum of two metres below the water surface (even at low tide), the relative risk of entraining floating eggs is reduced (compared to if the intake was near to the surface). The potential effects of entrainment on fish larvae and fish eggs would be highest over spring and summer given the strong seasonal pattern in ichthyoplankton abundance. Spring and summer also coincide with the period when larvae of most of the ecologically important, fishing and conservation species are in the water column. Considering the typical range of mortality (around 10 % per day) and the extra effect of flushing from North Arm to Bass Strait (around 1 % per day) and the growth rate, it is considered that 14 days is the appropriate period to assess the effects of entrainment. At the peak intake rate the entrainment is 0.22% (refer to **Table 51**), which corresponds to a significant reduction in numbers of fish larvae and eggs. There is potential for some fish larvae and eggs to be entrained. Most fish only produce eggs and larvae at this time of year in particular areas according to the preferred breeding habitat and environmental condition preferences of the adults. The high concentrations present and the restricted habitats they prefer are not widespread in Victoria. Hence, at the peak intake rate, the potential impact of reduced recruitment success during spring and summer is considered to be of moderate impact.	Medium
Fish eggs and larvae Autumn-Winter	Negligible impact	The investigations carried out for this assessment indicate that few fish larvae are present in the waters of Lower North Arm in autumn and even fewer over winter. However, it is possible that some entrainment could occur during this period. The species that are present are common throughout Western Port and Victoria and are highly fecund. As such, the proportion of the total number of larvae and eggs entrained would be small. The potential impact of entrainment during this period is considered to be negligible.	Low

Environmental segment	Impact assessment outcome	Reasoning	Risk
Plankton (NNE Zone)	Negligible impact	Hydrodynamic modelling of entrainment shows that the FSRU is relatively remote from the core area of the NNE Community and the modelled entrainment rate was very low. Hence, the likelihood of entrainment adversely affecting the core population is considered highly unlikely. The core NNE area is large, with a long residence time. The plankton population replacement rates in this area are likely to be at the high end of the distribution due to the higher nutrient concentrations in this area relative to elsewhere in Western Port. Hence, the potential impacts are considered to be negligible.	Very low
Plankton (North Arm)	Minor impact	Hydrodynamic modelling of entrainment shows that the likelihood of entrainment occurring in the Lower North Arm zone where the FSRU would be located is possible with a predicted rate of entrainment of 0.4% of the particles in all ecological zones in the north arm of Western Port per month during peak operating conditions. Lower North Arm is relatively large with an ecological gradient along the length from the core region in the north to the confluence zone in the south with a corresponding flushing rate (with Bass Strait) of months in the north and weeks in the south, to weeks in the confluence zone and days in the Western Entrance. The area will be continuously replenished from the core region in the north on about a monthly basis. Hence, the potential impacts of entrainment are considered to be minor.	Low
Plankton (Western Port)	Negligible impact	Hydrodynamic modelling of entrainment shows that the FSRU is relatively remote from the core area of the Western Port plankton community and from the eastern and south-eastern parts of Western Port. Hence, the likelihood of entrainment occurring throughout Western Port is highly unlikely. Western Port is a large area relative to the volume of seawater that may be entrained. Other physical and ecological factors are more important in determining the characteristics of the plankton community over Western Port as a whole. Hence, the potential impact of entrainment over the whole of Western Port is considered to be negligible.	Very low

Environmental segment	Impact assessment outcome	Reasoning	Risk
Protected areas (Ramsar)	Negligible impact	Entrainment is largest in the zones close to Crib Point and much smaller for the distant zones. Given the minor level of entrainment even at Crib Point, and the large volume of water and long residence time in the distant zones, the potential impacts of entrainment on the adult population of plankton in the Western Port Ramsar site as a whole is considered to be negligible.	Very low
Protected areas (other)	Negligible impact	Entrainment is largest for the zones close to Crib Point and negligible from the Marine National Parks and other protected areas. The potential impacts of entrainment on the adult population of plankton in Marine National Parks and other protected areas is considered to be negligible.	Very low
Protected species (Ghost Shrimps)	Negligible impact	Two species of ghost shrimps (*Eucalliax tooradin* and *Michelea microphylla*) may occur in Lower North Arm of Western Port. No adults of either species were found Lower North Arm during targeted investigations during the EES studies. It is suggested that Lower North Arm represents a small part of the physical habitat range and that they may be found more commonly in other locations or more suitable habitat. Hence, the rarity of these two ghost shrimp species represents either the sparseness of their natural population or no sampling of their more common location or habitat. The likelihood of listed threatened species of ghost shrimp larvae being entrained is considered to be extremely low. The potential impacts of entrainment of listed threatened species of ghost shrimp on their population are considered to be negligible.	Very low
Protected species (Australian Grayling)	Negligible impact	No eggs or early larvae of Australian Grayling were identified in the EES ichthyoplankton sampling program in Lower North Arm. Hence, the likelihood of Australian Grayling eggs and early larvae being entrained is considered highly unlikely. Given the large volume of water and long residence time in East Arm, and the low likelihood of even a small proportion of eggs or early larvae being transported back into Lower North Arm, the potential impacts of entrainment on the adult population are considered to be negligible.	Very low

Environmental segment	Impact assessment outcome	Reasoning	Risk
	Negligible impact	A late larval Australian Grayling individual was caught during the ichthyoplankton sampling program in Lower North Arm in September when it was likely returning to freshwater habitat in the Upper North Arm. Hence, the likelihood of Australian Grayling late larvae or juveniles being entrained is considered to be highly unlikely. As the larger proportion of returning Australian Grayling late larvae or juveniles will follow the easier migratory current paths and freshwater cues into the East Arm, the potential impacts are considered to be minor.	Very low

12.2.5.4.1 Limit regasification intake in spring and summer

All but one of the identified potential risks associated with biological entrainment due to the operation of the FSRU are ranked as either very low or low and are not considered to have any adverse impacts on the environment of the Lower North Arm or more widely Western Port. The risk of entrainment of fish eggs and larvae during the spring/summer period at the peak intake rate, has been ranked as **medium** and has the potential to have adverse impacts on the marine environment.

To minimise potential entrainment impacts during periods of the year when fish eggs and larvae are more prevalent in Western Port North Arm, a 14-day average (mean) regasification flow of 312,000 m^3/day is proposed between September and February (inclusive). Note that this flow applies to the seawater flow for the regasification process only and does not apply to intermittent flows including ballast water, water curtain and fire water. Refer to **Section 7.2.2** for further detail about the proposed regasification operating parameters. The proposed maximum intake rates are based on the projected levels of entrainment (drawing in) of marine biota (plankton and larvae) over a 12-month period and have been established through detailed investigations of the Western Port marine environment. The use of a two-week moving average reflects the sensitivity of certain marine biota and accounts for their renewal rate and flushing rate in North Arm of Western Port that has been established as part of the marine entrainment investigations

At a reduced (average) intake rate, the entrainment is 0.14% (compared to 0.22% at a peak intake rate), which corresponds to a reduction in the number of fish larvae and eggs entrained. Due to the reduced intake rate and the estimated reduction in number of fish larvae and eggs, the likelihood is rated as **possible** and the consequence is rated as **minor**. This corresponds to a reduced risk rating of **Low.**

12.2.6 Assessment of a mixing zone

This section seeks to assess the application of a mixing zone to the discharge of seawater from the FSRU. The FSRU will require seawater for different purposes during operation. The use of seawater is preferred as it is readily available in large quantities and at low cost compared to other sources of water. Seawater exiting the regasification process units and a number of other process units will have altered temperature and chlorine concentrations however, these streams are considered suitable for discharge back into the marine environment as the seawater returns to ambient conditions within the area around the berthing pocket occupied by the FSRU.

As discussed throughout the WA application, and in addressing the concepts in 21 (2) (b) of the SEPP (Waters), all reasonably practical measures have been undertaken to ensure that the wastewater discharge (sea water as cooling water) does not exceed the environmental quality objectives and that risks to the beneficial uses have been minimised. This is discussed further below.

The SEPP (Waters) provides guidance regarding assessment and approval of a mixing zone under clause 23.

For the FSRU a mixing zone will be defined by the chlorine impacts and the temperature impacts, which provide different mixing zones (for chlorine see **Section 12.2.5.2** and **Figure 43** and for temperature see **Section 12.2.5.1** and **Figure 37**).

In assessing a mixing zone for the FSRU there are three key aspects to be considered

- acute toxicity impacts at the discharge point due to chlorine
- chronic toxicity outside the mixing zones due to chlorine
- risks to beneficial uses at the boundary of the mixing zone due to chlorine and temperature.

12.2.6.1.1 Acute lethality

Two standard acute toxicity tests were chosen to test the acute toxicity of chlorine in seawater at concentration ranges around that of the proposed discharge from the FSRU. The test organisms were:

- juvenile marine stage barramundi (*Lates calcarifer*)
- adult marine sand fleas (*Allorchestes compressa*).

They were exposed to a range of initial doses of chlorine in seawater from 0.006 mg/L up to 1 mg/L and were exposed for 96 hours after the initial dose. The results showed no acute lethality to initial doses of 0.006 mg/L up to 1 mg/L of chlorine as hypochlorite in seawater and subsequently over 96 hours of continuous exposure to the mixture after the initial dose. The concentration of chlorine at the point of discharge from the FSRU is estimated to be 0.1 mg/L chlorine. Hence, in the framework described above, the tests (two species, 96-hour acute lethality tests) demonstrate that the discharge would not result in acute lethality.

12.2.6.1.2 Chronic toxicity outside the mixing zone

For all flows except ballast water, the level of CPO in the discharges is taken as 100 µg/L, the maximum level assured by the FSRU supplier. Ballast water undergoes longer storage, and there is more chlorine decay, so the level of CPO in the ballast discharge is taken as 21 µg/L. The quantity of chlorine or CPO discharged is estimated to be 47 kg/d at peak open production, 32 kg/d at average open loop production and 19 kg/d with closed loop production. On the days when there is an LNG carrier unloading LNG to the FSRU, there is an extra discharge of 0.6 kg/d from the fire management system/water curtain and about 1 kg/d from the ballast water system (for approximately 36 hours up to 40 times per year). In addition, on days where periodic fire water system testing is carried out there will extra discharges related to the fire water stream. **Table 44** lists the maximum flowrates and residual levels of chlorine or CPO of seawater discharge streams in various modes of operation. The operation of the FSRU will need to minimise the potential adverse impacts on beneficial uses by managing seawater discharges of either cooler or warmer seawater and discharge of chlorinated water and meeting the environmental quality objectives. Adverse impacts on beneficial uses are not anticipated as seawater returns to ambient conditions within the mixing zone and within a short time frame.

The amount of seawater discharge has been minimised through the reuse of discharge streams within the regasification process during open loop mode and through the recirculation of seawater for regasification in closed loop mode.

The maximum acceptable chlorine level or Guideline Limit was obtained through consideration of the SEPP (Waters) that requires 99% protection, ANZ Water Quality Guidelines, revised method for deriving water quality guideline values (Warne et al 2015) and the CSIRO report using revised method to calculate a guideline value for chlorine in marine waters. A time-averaged chlorine guideline value of 6 µg/L was determined for intermittent exposure

A key outcome from the modelling and assessment of chlorine and seawater temperature risks on the marine environment is that the extent of elevated chlorine and seawater temperature changes, in relation to the guideline limits, is limited to a zone in the shipping basin and ship berthing areas within the Port of Hastings boundaries that was previously dredged and is regularly subject to sediment resuspension by propeller wash from existing shipping activities at Crib Point Jetty. The mixing zone can be defined as follows:

For a worst-case plume dispersion scenario where the FSRU is operating at peak gas production in open loop mode and an LNG carrier is berthed adjacent to the FSRU:

- The area above the chlorine Guideline Value, where the time-averaged chlorine level exceeds 6 ug/L, extends for approximately 300 m north/south and 160 m east/west, over 5 ha (refer to **Figure 43**)
- The area of temperature above the Guideline Value of 0.5ºC, extends for approximately 340 m north/south and 200 m east/west, over 20 ha (refer to **Figure 37)**.

The area of chlorine and temperature above the Guideline Value is localised to the Port of Hastings area, and well separated from the edges of North Arm, all seagrass and mangrove areas, all of the northern area of Western Port and all areas used by wading birds. Mangroves, saltmarsh, seagrasses, subtidal reefs and water birds are therefore not impacted by the regasification processes under both open loop and closed loop regasification modes operating up to peak production.

12.2.6.1.3 Risk to beneficial uses at the boundary of the mixing zone

An assessment of impact and risk is presented in

- **Section 12.2.5.1** with respect to temperature
- **Section 12.2.5.2** with respect to CPO
- **Section 12.2.5.4** with respect to entrainment.

The identified risks and impacts for warm-water discharge are the same as the cold-water risks listed in **Table 47**. However, due to the much smaller volume of warm water that is discharged into Western Port compared to when the FSRU is operating in open loop (less than 30%) there is a lower chance of the nearby sensitive receptors being impacted.

All the associated risks for cold and warm water discharge are ranked as either very low or low (**Table 47**) indicating that cold or warm water discharges are not likely to have any significant impact on the surrounding environment of the Lower North Arm.

The risks and impacts identified due to residual CPO in the discharges are assessed in **Table 50**. All the associated risks are low or very low which indicates that the discharge residual chlorine is not likely to have any significant impact on the environment of the Lower North Arm.

The risks and impacts identified due to entrainment were assessed and are presented in **Table 52**. All the associated risks are low or very low which indicates that entrainment is not likely to have any significant impact on the environment of the Lower North Arm.

To minimise potential entrainment impacts during periods of the year when fish eggs and larvae are more prevalent in Western Port North Arm, a 14-day average (mean) regasification flow of 312,000 m3/day is proposed between September and February (inclusive). The use of a two-week moving average reflects the sensitivity of certain marine biota and accounts for their renewal rate and flushing rate in North Arm of Western Port that has been established as part of the marine entrainment investigations.

On this basis it has been concluded that the beneficial uses have been protected and therefore harm to humans, plants and animals is unlikely. Similarly, there should be no loss of aesthetic enjoyment as the activities are consistent with port activities and there is no source of objectionable odour (see **Section 10.8**).

12.2.6.1.4 Monitoring and minimising the mixing zone

The proposed mixing zone monitoring regime (as required by clause 23 (3) above) is described in **Section 16.1**.

As part of the continuous improvement inherent in the operations such as minimising fuel use, minimising seawater intake, etc., the operational objective will be to minimise the size of the mixing zone. This will be explicit in the monitoring program described in **Section 16.1**.

12.2.7 Potential impacts on Ramsar values

The Ecological Character description of the Ramsar Values of Western Port was proposed in 2010 (KBR, 2010) and most recently reassessed in 2016 (Hale, 2016). The assessment was based on a review of recent information against the Limits of Acceptable Change (LAC) to Critical Components,

Processes and Services (CPS) specific to the Western Port Ramsar site. A summary of the reassessment outcomes is shown in **Table 53**.

The Project is not expected to significantly impact on any CPS that are considered critical to the ecological character of the Western Port Ramsar site on the basis that none of the LAC which establish quantifiable criteria for potential impacts on CPS have been adversely affected. **Table 53** outlines the critical CPS of the Western Port Ramsar site, along with an assessment of the Project against each of these components.

Table 53 Summary of assessment of the Project on Critical Components, Processes and Services for the Western Port Ramsar site

Critical components processes and services	Limit of Acceptable Change (2016 revision)	Assessment of the Project on critical components processes and services
Wetland bathymetry	No loss of intertidal mudflat area (270 km^2)	No change to wetland bathymetry or loss of intertidal mudflat area. The Project would not involve any direct physical disturbance of intertidal mudflats and is not expected to indirectly impact on these communities from cold water or chlorine discharge. CPS would not be impacted, and LAC would not be exceeded.
Geomorphology and sedimentation	No LAC set	No change to geomorphology. Minor change to resuspension of sediments within the area of the existing port due to vessel movements and operations. Additional sediment loads from Pipeline Works in the catchment unlikely to occur (see Chapter 8 *Surface water*). CPS would not be impacted.
Flora – seagrass	Total seagrass extent will not decline below 5,400 hectares for a period of greater than 10 continuous years.	No loss of seagrass from the Project. The nearest seagrass in 700 metres from the proposed FSRU location and would not be impacted by cold-water or chlorine discharges. CPS would not be impacted, and LAC would not be exceeded.
Flora – mangrove and saltmarsh	Total mangrove extent will not decline below 900 hectares. Total saltmarsh extent will not decline below 850 hectares.	No loss of mangrove or saltmarsh from the Project. The nearest mangrove and saltmarsh are 400 metres from the proposed FSRU location and would not be impacted by cold-water or chlorine discharges. CPS would not be impacted, and LAC would not be exceeded.
Fauna - Waterbirds	Abundance of waterbirds will not decline below the following (calculated as a rolling five-year average of maximum annual count): Total waterbirds – 12,000 Migratory waders – 5,300	No impact to waterbird habitat from cold water or chlorine discharge as plumes would not reach waterbird habitat (see Chapter 7 *Terrestrial and freshwater biodiversity*) CPS would not be impacted, and LAC would not be exceeded.

Critical components processes and services	Limit of Acceptable Change (2016 revision)	Assessment of the Project on critical components processes and services
	Australasian waders - 800 Ducks - 500 Fishers - 550 Gulls - 1600 Large wading birds - 980 Swans – 1,600 Breeding of beach nesting birds annually within the site	
Fauna - Marine invertebrates	No LAC set	Potential minor impacts to subtidal invertebrate species over 20 hectares within the Port of Hastings area (shipping basin). No impact elsewhere in 36,000 hectares of soft sediments in Lower North Arm or the wider Western Port community.
Fauna –fish	No LAC set	The Project would have negligible impacts on fish populations in North Arm. Potential local effects for fish populations under Crib Point Jetty Berth 2, in conjunction with effects of shading, avoidance or attraction and dredging. CPS would not be impacted.
Supports threatened species - birds	Abundance of eastern curlew, curlew sandpiper and fairy tern will not decline below 1% of the population as stated in the most recent Wetlands International Population estimate (based on a five-year rolling average of annual maximum counts). Presence of bar-tailed godwit, lesser sand plover and red knot in at least three out of every five years.	The Project would not involve any direct physical disturbance of intertidal mudflats and there would be no impact to waterbird habitat from cold water or chlorine discharge plumes. No change to the abundance of threatened bird species (see Chapter 7 *Terrestrial and freshwater biodiversity*). CPS would not be impacted, and LAC would not be exceeded.
Supports threatened species - fish	Australian grayling continues to be supported in one or more of the catchments draining into Western Port	No change to the occurrence of Australian grayling populations in the Western Port catchments. CPS would not be impacted, and LAC would not be exceeded.

Based on the risk and impact assessments conducted as part of the EES Technical Report A: *Marine impact assessment* (refer to **Appendix B**) for the Project, it is considered the Ramsar requirements that limit change in Western Port are not at risk from the Project.

12.2.8 Summary

Using the SEPP (Waters) approach to assess the risks of a wastewater discharge, involves a broad consideration of the matters identified in the SEPP (Waters). The SEPP (Waters) identifies Ramsar sites, such as Western Port Ramsar Site, as waters of high conservation value.

It has been demonstrated that the risks to the components of the wetlands are low or very low. The chlorine and temperature areas above the guideline value are limited to a zone in the shipping basin and ship berthing areas within the Port of Hastings boundaries. This area has been previously dredged and is regularly subject to sediment re-suspension by propeller wash from existing shipping activities at Crib Point Jetty. These areas are well separated from the edges of North Arm, all seagrass and mangrove areas, all of the northern area of Western Port and all areas used by wading birds. Mangroves, saltmarsh, seagrasses, subtidal reefs and water birds are therefore not impacted by the regasification processes under both open loop and closed loop regasification modes operating up to peak production. Therefore, the objective of protecting the Ramsar wetlands has been demonstrated and in particular this wastewater can be treated and managed to a level to protect beneficial uses in Western Port.

Consistent with the considerations under the SEPP (Waters) for grant of a works approval under the EP Act the risks of the proposed development have been assessed and found that:

- The chlorine and temperature areas above the guideline value are localised to the Port of Hastings area, and well separated from the edges of North Arm, all seagrass and mangrove areas, all of the northern area of Western Port and all areas used by wading birds.
- Mangroves, saltmarsh, seagrasses, subtidal reefs and water birds are therefore not impacted by the regasification processes under both open loop and closed loop regasification modes operating up to peak production.

13.0 Land and groundwater

The land and groundwater impact assessment focus on areas where intrusive works are proposed that may intersect land or groundwater as well as surrounding areas where groundwater levels or groundwater quality could be impacted. The FSRU was not considered in the land and groundwater assessments as it will be continuously moored at the Crib Point Jetty (Berth 2) and is not part of the landside portion of works.

14.0 Waste

Preparation of this section of the WA application was based on information provided in Section 7.1.6 and Section 7.2.2 of the EES Technical Report E: *Contamination and acid sulfate soils impact assessment* (refer to **Appendix B**).

14.1 Industrial waste generation

14.1.1 Waste generation

A summary of the waste that is anticipated to be generated through the operation of the FSRU is provided in **Table 54** .

Table 54 Summary of waste generated from FSRU operation

Waste type	Volume	Source	Destination
Grey water	300 – 400 m^3/month	Wastewater generated in accommodation and office facilities on board the FSRU from sources without faecal contamination (i.e. sinks, showers, baths, washing machines and dishwaters etc.).	Grey water will be stored in a holding tank on board of the FSRU prior to off-site treatment and disposal by a licensed waste contractor.
Black water	30 m^3/month	Wastewater generated in toilets on board the FSRU.	Black water will be treated in the Sewage Treatment Plant (STP) on board the FSRU in accordance with relevant Commonwealth and State regulations, and the IMO/ Australian Maritime Safety Authority (AMSA) regulations and subsequently stored in a treated sewage holding tank prior to off-site disposal by a licensed waste contractor.
Sludge	15 – 25 m^3/month	Sludge from liquid fuel and lubricant oil purifiers, as well as oil residue from drain, drip trays, oil water separators and the sludge unit produced during ongoing operation of the FSRU.	The sludge will be collected in holding tanks on board the FSRU prior to off-site treatment and disposal by a licensed waste contractor. This is likely to be Prescribed Industrial Waste (PIW) under the current EP Act and will be managed using Waste Transport Certificates.

Waste type	Volume	Source	Destination
Bilge water	70 – 100 m^3/month	Wastewater generated in the bilge of the FSRU (lowest space of the ship) and does not drain off the side of the deck.	Bilge water will be collected in a holding tank on board of the FSRU, which would then either: 1) be pumped to deck for discharge to shore/barge for off-site disposal by a licensed waste contractor, or 2) sent to the Oily Bilge Separator where the bilge water will be treated to an oil content of less than 15 part per million (ppm). Oil is sent to the Oily Bilge Tank and treated water is sent to the Clean Bilge Holding Tank prior to off-site disposal by a licensed waste contractor. This is likely to be Prescribed Industrial Waste (PIW) under the current EP Act and will be managed using Waste Transport Certificates and licensed waste transporters and disposal facilities.
Mixed solid waste	Unknown	Mixed solid waste (such as food scraps, paper, glass, packaging and other recyclables) generated from accommodation and office facilities on board of the FSRU.	All solid wastes produced on-board the FSRU will be collected and disposed of by a licensed waste contractor.

With the exception of seawater used for regasification (open loop and closed loop mode) and cooling of the atmospheric dump condensers, generators and auxiliary machinery which is discharged to the marine environment (refer to **Section 12.0**); all waste generated on board the FSRU will be treated and/or stored and pumped to deck for off-site disposal by a licensed contractor, in accordance with the relevant Commonwealth and State regulations, and the IMO regulations.

14.1.2 Best practice waste management

The waste hierarchy (refer to **Figure 51**) has been applied for the minimisation and management of industrial wastes generated as a result of operation of the FSRU.

Figure 51 Waste hierarchy (EPA 2020)

Segregation of solid and liquid waste streams will be implemented to maximise their potential reuse and recycling, and to ensure that the appropriate level of treatment is being applied to each waste type. Segregation of waste generated on board the FSRU results in small volumes of concentrated waste that is easier to manage with targeted treatment rather than large volumes of diluted and mixed waste streams that require multiple levels of treatment. In addition, waste is segregated to allow waste receivers to make use of waste reuse potential.

Treated and raw waste will be collected in secured waste storage containers on board the FSRU that are designed for different types of waste generated. The containers will be lidded to mitigate fauna access. Collected waste will then be pumped (liquid waste streams) to shore and transported by licensed contractors for disposal at appropriately licensed facilities. Solid waste may be lifted by crane to the jetty if there is truck access or lifted by crane to a barge and/or supply vessel prior to being transported by licensed contractors for disposal at appropriately licensed facilities.

14.2 Prescribed Industrial Waste

Prescribed Industrial Waste (PIW) generated during operation of the FSRU including, but not limited to sludge and bilge water will be managed in accordance with regulatory requirements and the waste management system that will be established as part of the broader Environment Management Plan. Only small quantities of PIW are expected to be generated during the operation of the FSRU.

15.0 Environmental management

15.1 Risk assessment of operations

Operation of the FSRU will introduce bulk storage and distribution of hazardous substances, as defined in the Dangerous Goods (Storage and Handling) Regulations 2012 (Vic), of sufficient volume to have the potential for off-site environmental and safety consequences.

The following key studies related to the FSRU safety, hazard and risk have been completed to identify potential process upsets or failures:

- Fire Safety Studies: a critical element in the safety assurance process, this study is conducted to ensure that the fire protection systems in place and available at a facility are suitable to manage risks presented by a potential fire scenario. A preliminary fire safety study has been completed for the jetty topsides and the Crib Point Receiving Facility. The fire safety study will be updated as the Project design develops and in consultation with the Country Fire Authority;
- Suite of Hazard Identification (HAZID) studies: A HAZID study is a qualitative technique for identification of hazards and threats that have the potential to result in major incidents and can be applied all stages of the Project. Early identification and assessment of hazards during concept development provides essential input to project development decisions at a time when a change of design has a minimal cost penalty. A number of HAZID studies have been completed for the Project and additional HAZIDs will be undertaken as necessary during design development;
- Suite of Hazard and Operability Studies (HAZOP): A HAZOP study is a design review technique used for hazard identification, and for the identification of design deficiencies which may give rise to hazards or operability problems. HAZOPs have been conducted for all areas of the project, including a HAZOP that looked specifically at the interfaces between the project areas that have different Operating organisations. HAZOPs will be held at any stage in the project if there is a material change to the design post the original HAZOP; and
- Quantitative Risk Assessments (QRA): The objective of the QRA is to systematically address the likelihood and consequence of all potential hydrocarbon related risks for the Project in order to determine if such risks are tolerable in accordance with the established risk criteria. Recommendations can then be made for risk reduction measures if the resulting risk levels exceed the tolerable risk criteria. A preliminary QRA has been completed for the FSRU,

Further detail about the studies that were conducted is provided in the EES Technical Report K: *Safety, hazard and risk assessment* (refer to **Appendix B**).

15.1.1 Unplanned release – hazardous materials storage

The highest risk associated with the storage and distribution of flammable gases and liquids is the unplanned release with subsequent ignition leading to a fire or explosion. The primary material stored and distributed on board the FSRU is LNG. LNG will be stored on the FSRU at a very cold temperature (-163 ºC) to keep it in liquid form. At atmospheric pressure, LNG will boil at -161ºC. A release of LNG (in an emergency scenario) would form a vapour cloud that disperses in the atmosphere. A portion of the cloud would likely be flammable, giving rise to the possibility of ignition. There have been no confirmed occurrences of vapour cloud explosions initiated from LNG in any operating LNG facility. Although the likelihood is low, the risk of unplanned release is high due to the potential to cause catastrophic consequence.

Location specific risk contours were modelled based on the results from the QRA. The three areas of interest with respect to off-site risk selected for evaluation in the model included the Victorian Maritime Centre (1 km north west of FSRU), Picnic Point (0.97 km west of FSRU) and the Crib Point Receiving Facility (0.78 km north west of FSRU). In the event of an explosion, the model demonstrates that the level of risk resulting from a major incident is within the suggested acceptable thresholds as defined by Hazardous Industry Planning Advisory Paper No. 4 (HIPAP4). The thresholds presented in HIPAP4 are implemented by jurisdictions in Australia in assessing if a risk is proportional and tolerable to that which would normally be experienced. The completion of formal safety studies, including the QRA and

meeting the HIPAP4 thresholds, is demonstration of adequacy that risks have been identified, assessed and mitigated so far as is reasonably practicable.

The most significant environmental impacts associated with a fire or explosion are related to the use and release of firefighting chemicals during firefighting and fire suppression. The FSRU is equipped with dry chemical powder (BC KARATE), which is a fire extinguishing agent that is Per-and polyfluoroalkyl substances (PFAS) free, seawater and high-pressure CO_2. In addition to the dry powder monitors located in the manifold area, the FSRU is equipped with a sea water spray system and water monitors, for testing and for firefighting. There are also portable fire extinguishers located throughout the vessel. The firefighting system on board the FSRU is tested using seawater only.

Further detail about how the potential environmental and public health risks caused by spills during operation of the FSRU are managed is provided in the EES Technical Report K: *Safety, hazard and risk assessment* (refer to **Appendix B**).

15.1.2 Unplanned release – waste storage

Liquid wastes will be treated as required and collected in holding tanks on board the FSRU and collected periodically for off-site treatment and disposal by a licensed waste contractor. The holding tanks are located below deck with piping up to the manifolds on deck. Holding tanks are located below deck to ensure containment of any spills, and to minimise environmental impact, in the event of a loss of containment. Wastes collection operations are normally carried out 1-2 times a month in controlled environments, as there is a risk of unplanned release due to rupture of transfer pipes. There are drip trays located under the manifolds and a local control station with emergency stop features, and a crew watchman is posted by the manifold during the waste transfer operation.

15.1.3 Extreme weather events

Extreme weather events leading to unsafe conditions for FSRU operation is another risk that may lead to process upsets. Extreme weather conditions, although unlikely, have the potential to cause damage to infrastructure and the environment. In the event of extreme weather conditions, the FSRU can leave Crib Point Jetty, relocate to a safe location and return when it is deemed safe to do so.

15.1.4 Managing environmental risks

The FSRU will be issued a Class notation (classification) by DNV GL. Classification attests to the vessel and process units being designed and operated in accordance with a prescribed set of DNV GL rules and engineering standards. Classification covers both the ship and the LNG regasification unit. As such, it is considered that the selected FSRU arrangement will be safe to operate at Crib Point Jetty due to the following:

- The FSRU will be designed and operated to recognised international standards
- The FSRU will carry a Safety Management Certificate or interim safety management certificate – which certifies compliance with the International Safety Management (ISM)
- The FSRU will carry an International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk
- The FSRU will carry Class Notation issued by a globally recognised classification society
- A Safety Case will be developed consistent with the requirements of a Major Hazard Facility (MHF)
- Regulatory oversight will be provided by Australian Maritime Safety Authority (AMSA), Worksafe and EPA
- FSRUs have operated and continue to operate in other parts of the world without significant incidents.
- FSRUs have been approved in other parts of the world under similar regulatory regimes.

Environmental risks have been managed by applying a hierarchy of control to the potential process failures and risks identified. The following mitigation measures will be implemented to manage environmental risks:

- Plant and equipment on board the FSRU will be maintained appropriately according to an inspection and maintenance schedule to minimise the risk of unintended spills, leaks and/or uncontrolled air emissions that may cause environmental impacts;
- Emergency response procedures will be developed and implemented as part of the Operational Environmental Management Plan (OEMP);
- Spill kits will be readily available and accessible for use in the event of a fuel or chemical spill;
- FSRU contingency plans will include pollution prevention (e.g. oil spills and cargo liquid leaks on deck); and
- The FSRU will be fitted with an Emergency Shutdown system that covers both the LNG loading/unloading and regasification equipment. The Emergency Shutdown system will bring all vessel systems to a safe, low pressure condition, which will be triggered by either instrument detection of a hazardous situation or by manual activation of clearly labelled shut-down buttons located throughout the vessel.

15.2 Environmental Management System

When commissioned and in operation, the FSRU will be subject to an agreement between AGL and a third-party operator experienced with floating LNG import facilities. The third-party operator will manage operations on board the FSRU.

The proposed Planning Scheme Amendment under the Mornington Peninsula Shire Planning Scheme which is required for approval of the FSRU will apply a Specific Controls Overlay and Incorporated Document which permit the use and development of land with the Gas Import Jetty Works. The proposed Incorporated Document requires the preparation of an OEMP which includes the FSRU operations. Operations will be managed in accordance with the OEMP. A monitoring program will be developed (discussed further in **Section 16.1**) to monitor operation of the FSRU and ensure compliance with conditions of statutory approvals such as the WA and licence.

In addition, operation of the FSRU will be required to comply with all requirements of PoHDA as the port operator. The safety and environment management plans that are developed for the operation of the FSRU need to be compliant with the PoHDA Health, Safety and Environment Management System and PoHDA Safety and Environment Management Plan. Safety and environment management plans that are developed will need to be approved by PoHDA.

15.3 Project Construction impact management

No construction works are required for the FSRU directly. However, modifications to the current Crib Point Jetty (Berth 2) infrastructure are required to enable the installation of required jetty infrastructure and berthing of the FSRU at Berth 2. This will involve remediation works and installation of jetty infrastructure.

PoHDA will undertake upgrades to the jetty, which will enable the installation of the Jetty Infrastructure and berthing of the FSRU at Berth 2. PoHDA remediation works include replacement of the pier head and repairs to concrete on the jetty, pylons, mooring dolphins (marine structures for mooring vessels) and pipe racks.

The proposed jetty infrastructure to be fitted at the Crib Point Jetty by AGL will include:

- Two MLAs to be installed at Berth 2 of the Crib Point Jetty, with a space for a future third MLA if required. MLAs are composed of rigid pipe sections which can swivel to transfer gas from the FSRU to the gas piping to be installed on the Crib Point Jetty. The top of the MLAs will be approximately 30 metres above the deck of the jetty.
- Gas piping approximately 1.5 kilometres that will be mounted on the Crib Point Jetty. The gas piping will run from Berth 2 along the existing pipe rack on the western and southern side of the trunk way (the north-south part of the Crib Point Jetty) and approach jetty (the east-west part of the Crib Point Jetty that extends between the land at Crib Point and the trunk way) respectively. The new gas piping will be mounted adjacent to this existing piping.

- Associated infrastructure will be installed on the deck pierhead, including:
  - hydraulic gangway tower to access the FSRU
  - substation
  - air compressor
  - firefighting system
  - spill management system
  - lighting and CCTV security system.

The remediation works that will be undertaken by PoHDA will not be subject to the EES process however cumulative impacts of the remediation works conducted by PoHDA and the jetty infrastructure work to be conducted by AGL will be considered in the EES.

PoHDA developed a Construction Environmental Management Plan (CEMP) to manage the remediation works and this has been approved pursuant to the consent under the *Marine and Coastal Act 2018 (Vic)*. The construction contractor for the Gas Import Jetty Works will be responsible for preparing a CEMP which includes the proposed jetty infrastructure work. The Gas Import Jetty Works CEMP will be approved pursuant to the proposed requirements for an Environmental Management Plan under the Incorporated Document in the proposed Planning Scheme Amendment. These requirements include incorporating the mitigation measures from the Environmental Management Framework established as part of the EES process.

16.0 Post-decision – Operational requirements

16.1 Monitoring

The third party operator in collaboration with AGL will develop, implement and maintain a continuous risk-based monitoring program to assess environmental management at the site and to monitor implementation of the EPA works approval and license conditions during operation of the FSRU.A summary of the proposed monitoring programs is shown in **Table 55**.

Verification noise emissions monitoring will be conducted within six months of the beginning of commercial operation (discussed in **Table 55**). In addition, a number of management measures will be implemented to ensure noise emissions are managed including:

- **Stakeholder Engagement Management Strategy:** Stakeholder Engagement Management Strategy will be implemented to facilitate ongoing consultation with relevant stakeholders (including Councils, authorities, businesses, residents and community groups) throughout the operational life of the Project to ensure that all stakeholders have access to complete information regarding the nature of the proposed activities and their likely impacts. Advanced notice will be given to affected residents, business or industries prior to commencement of works.
- **Complaints Management System:** A complaints management system will be put in place that documents:
  - Name of persons receiving complaint.
  - Name of person making the complaint.
  - Date and time of complaint.
  - Nature of the complaint.
  - Actions taken to rectify.
  - Actions to minimise risk of reoccurrence.
  - Name of person(s) responsible for undertaking the required actions.
  - Communication in response to the complaint.

  Performance related to noise emissions will be monitored based on the data within the complaints management system
- **Compliance Plan:** A plan developed in collaboration with United Petroleum and in consultation with EPA which outlines strategies to minimise cumulative noise impacts at Crib Point Jetty.

Waste management performance will be monitored based on the Operational Waste Management System that will be developed and implemented.

16.2 Reporting annual performance

AGL will submit an online annual performance statement based on the results and reporting of the monitoring program discussed in **Section 16.1**, in accordance with legislative requirements.

Table 55 Summary of proposed monitoring programs for operational phase of the FSRU

Environmental aspect	Description	Monitoring event	Monitoring method	Monitoring Frequency	Reporting
GHG	Implementation of the Protocol for Environmental Management (GHG emissions and energy efficiency in industry) for the operation of the FSRU will include conducting an audit on the FSRU to identify inefficiencies for GHG emission reduction.	Level 2 audit (minimum)	A level 2 audit should: • Identify source(s) of energy consumption related to the operation of the FSRU; • Determine the amount of energy consumed for operation of the FSRU; • Identify the purpose for which the energy was used; • Identify areas where energy savings can be made; • Recommend measures to be taken to reduce energy consumption; and • Provide statement of costs and potential savings.	Annually for a period of 3 years	• Preparation and submission of an action plan for implementing GHG emissions reduction measures; and • Preparation of an annual performance statement report to be submitted to EPA.
Air Quality	An air quality monitoring programme will be designed and implemented to monitor FSRU emissions and confirm FSRU emission rates comply with design specifications.	Stack emissions monitoring of the FSRU	Testing will be conducted when the engines are being run on gas fuel. The concentration of the following pollutants will be sampled: • NO_2 • SO_2 • CO • PM • Total VOC • Formaldehyde.	Annual	• Preparation and submission of a testing report • Preparation and submission of National Pollutant Inventory (NPI) reporting (potentially) • Preparation of an annual performance statement report to be submitted to EPA.
Noise	Verification noise monitoring should be conducted on noise produced by the Gas Import Facility within six months of the beginning of commercial operation to confirm	Verification noise monitoring	Noise measurements should be undertaken in accordance with current Victorian EPA requirements to verify conformance with the Recommended Maximum Levels	Once within 6 months of commencing commercial operation	• Preparation of a compliance report

Environmental aspect	Description	Monitoring event	Monitoring method	Monitoring Frequency	Reporting
	compliance with the Recommended Maximum Levels.		applied at 132 The Esplanade Crib Point, 43 Disney Street Crib Point and 103 The Esplanade Crib Point.		
Water	A marine monitoring program will be prepared in consultation with the EPA and will be included in the Gas Import Jetty Works Operational Environmental Management Plan. The monitoring program will be designed in collaboration with a statistician.	Monitoring rates and characteristics of all discharges	Monitoring and recording of the flow rate, temperature and chlorine residual concentration of all major discharges, excluding fire water, water curtain and ballast water will be conducted. The objectives are to keep a record of all discharges, confirm that the discharge rate and chlorine concentration are within the values set out in EPA licences and, if not, provide the trigger for remedial actual.	Frequent monitoring (as per requirements of EPA licence conditions)	A record of all discharges to confirm the following: • Discharge rate is within the value used in the EES (and any EPA documents) • Chlorine concentration is within the value used in the EES (and any EPA documents) If the discharge rate or chlorine concentration does not meet the criteria, triggers for remedial action should be recommended (including reducing production).
		Plankton viability study	This study will involve collecting plankton samples on the seawater intake and discharge of the FSRU and analysing samples to determine the percentage of zooplankton and fish larvae survival. The EES risk assessment is based on the conservative assumption of 100 per cent loss of small biota that is entrained in the FSRU. The objective of this task is to establish whether a smaller loss might actually occur in practice, so the effect of the Project on primary	Once per quarter for three years (12 sampling events in total)	

Environmental aspect	Description	Monitoring event	Monitoring method	Monitoring Frequency	Reporting
			productivity in North Arm is less than calculated.		
		Seabed biota monitoring in Port Area	This monitoring event will involve baseline surveys and post-commissioning of benthic infauna abundance, diversity and composition to detect if there are any significant changes to infauna communities in the Port area and within the North Arm. The objective is to check whether the impact on infauna is less or more than the impact predicted in the EES from the combined area of chlorine and temperature change on the seabed near Berth 2.	Every six months for three years	
		Water quality sampling	The water quality sampling will involve sampling of seawater at six sites down current of the FSRU to accurately determine CPO concentration and temperature change as a result of FSRU operation. Replicate samples will be collected for quality control. The objective is to check whether the predicted extent of chlorine concentration and the temperature anomaly matches the EES predictions and, if a greater extent, what corrective actual should be taken to limit the extent. The distribution of CPO can be	Every quarter for three years	

Environmental aspect	Description	Monitoring event	Monitoring method	Monitoring Frequency	Reporting
			calculated from the measured extent of temperature.		
		Transplanted mussel monitoring	This monitoring event will involve deploying 10 sets of mussels at different sites, for example sites 100 m, 200 m, 400 m, 800 m and 1,500 m north and south of the FSRU. The mussels will be left in place for 21 days before being retrieved and analysed for chlorinated organics The objective is to check whether there is measurable or significant accumulation of chlorinated or brominated organics in biota. Mussels are recognised as an appropriate method to accumulate any collect chlorinated organics (if present) for analysis. If there are elevated levels (e.g. exceeding background levels at reference sites) then a review of chlorination rates and procedures will be undertaken	Two times per year for three years	

17.0 References

Commonwealth of Australia 2019. State and Territory Greenhouse Gas Inventories 2017

ASC NEPM (2013). National Environment Protection (Assessment of Site Contamination) Measure as amended and in force on 16 May 2013.USDOE (2016). Temporary Emergency Exposure Limits for Chemicals: Methods and Practice, U.S. Department of Energy, May 2016.

Australian Government (2011). Australian Government, NPI Emission Estimation Technique Manual for Combustion in boilers, Version 3.6, December 2011

Boon, Paul I, Allen, Tim, Brook, Jennifer, Carr, Geoff, Frood, Doug, Hoye, Jasmine, Harty, Chris, McMahon, Andrew, Mathews, Steve, Rosengren, Neville, Sinclair, Steve, White, Matt and Yogovic, Jeff (2011). *Mangroves and Coastal Saltmarsh of Victoria : Distribution, Condition, Threats and Management.* Technical Report. Victoria University, Melbourne. August 2012

Consulting Environmental Engineers (CEE) (2009). Port of Hastings Stage 1 Development. Marine Ecosystem Preliminary Considerations. Report to AECOM and Port of Hastings Corporation. August 2009.

CEE (2018). Plume Modelling of Discharge from LNG Facility at Crib Point, Western Port – AGL Gas Import Jetty Project. Report for AGL.

CEE (2020). Marine Impact Assessment for Crib Point EES – AGL Gas Import Jetty Project. Report for AGL.

Department of the Environment and Energy (DoEE) 2018. NGER, 2018: National Greenhouse Accounts Factors, Australian National Greenhouse Accounts, July 2018

DSE (2003). Action Statement No. 115: Australian Mudfish Neochanna cleaveri. Victorian Government Department of Sustainability and Environment, East Melbourne.

EPA (2011). Environment Report - Port Phillip and Western Port Receiving Water Quality Modelling: Hydrodynamics. (2011) EPA Publication 1377

EPA (2013). Environment Protection Authority Victoria, Future air quality in Victoria – Final report, Publication 1535, July 2013.

EPA (2013a). Guidance notes for using the regulatory air pollution model AERMOD in Victoria, Publication 1551, October 2013.

EPA (2018). Air monitoring report 2017 – Compliance with the National Environment Protection (Ambient Air Quality) Measure, July 2018.

EPA (2020). Your environment - Waste. Available: https://ref.epa.vic.gov.au/your-environment/waste. Accessed 20 February 2020.

EPA Publication 1411: Guideline Noise from Industry in Regional Victoria (NIRV). October 2011.

EPA Publication 1517.1: Demonstrating Best Practice. October 2017

EPA Publication 1658: Works Approval Application. June 2017

EPA Publication 824: Protocol for Environmental Management - Greenhouse Gas Emissions and Energy Efficiency in Industry. January 2002.

EPA Publication S31: State Environmental Protection Policy (Noise from Industry, Commerce and Trade) No. N-1 (SEPP N-1). October 2011.

Hale, J. (2016). Ecological Character Description Addendum – Western Port Ramsar Site. Report to Department of Environment, Land, Water and Planning, East Melbourne.

Jenkins (2019). Technical Report: Overview of Fish, Fisheries and Aquaculture in the Lower North Arm, Western Port. Technical report to CEE Pty Ltd. School of Biosciences. October 2019. The University of Melbourne

Kellogg Brown and Root (KBR) (2010). Western Port Ramsar Wetland Ecological Character Description. Report for Department of Sustainability, Environment, Water, Population and Communities, Canberra.

Kimmerer and McKinnon (1987). Zooplankton in a marine bay.II. Vertical migration to maintain horizontal distributions. Mar Ecol Prog Ser 41: 53-60 and Zooplankton in a marine bay.I. Horizontal distributions to estimate net population growth rates. Mar Ecol Prog Ser 41: 43- 52.

Marsden, M.A.H., Mallett, C.W., Donaldson, A.K. (1979). Geological and Physical Setting, Sediments and Environments, Western Port, Victoria. Marine Geology 30:11-46.

Neira, F. J., and Sporcic, M. I. (2002). Use of ichthyoplankton ecology to evaluate ecosystem changes: a case study in a large, semi-enclosed Australian bay. Marine and Freshwater Research 53, 339-354.SEPP (AAQ), Victoria Government, State Environment Protection Policy (Ambient Air Quality), Victoria Government Gazette, SPECIAL No. S 19, 9 February 1999.

SEPP (AQM), Victoria Government, State Environment Protection Policy (Air Quality Management), Victoria Government Gazette, SPECIAL No. S 240, 21 December 2001.

U.S. Energy Information Administration, Form EIA-860, 'Annual Electric Generator Report.'

USEPA (2000a). AP42 AP 42, Fifth Edition, Volume I Chapter 3: Stationary Internal Combustion Sources. Section 3.1 Stationary Gas Turbines. April 2000.

USEPA (2000b). AP42 AP 42, Fifth Edition, Volume I Chapter 3: Stationary Internal Combustion Sources. Section 3.1 Natural Gas-fired Reciprocating Engines. August 2000.

USEPA (2019) Proposed Designation of Formaldehyde (CASRN 50-00-0) as High-Priority Substance for Risk Evaluation, August 2019.

Appendix A

ASIC extract

ASIC
Australian Securities & Investments Commission

Australian Company

AGL WHOLESALE GAS LIMITED
ACN 072 948 504

Extracted from ASIC's database at AEST 16:53:14 on 17/10/2019

Company Summary

Name:	AGL WHOLESALE GAS LIMITED
ACN:	072 948 504
ABN:	26 072 948 504
Registration Date:	20/02/1996
Next Review Date:	15/08/2020
Former Name(s):	AGL WHOLESALE GAS PTY LIMITED, AGL PIPELINES (QLD) PTY LIMITED
Status:	Registered
Type:	Australian Public Company, Limited By Shares
Locality of Registered Office:	SYDNEY NSW 2000
Regulator:	Australian Securities & Investments Commission

Further information relating to this organisation may be purchased from ASIC.

Appendix B

Supporting EES documentation

This section contains supporting technical documentation from the EES Technical Reports and Main Report chapters. The following can be viewed as part of the EES:

- Technical Report A: *Marine biodiversity impact assessment*
- Technical Report E: *Contamination and acid sulfate soils impact assessment*
- Technical Report F: *Greenhouse gas impact assessment*
- Technical Report G: *Air quality impact assessment*
- Technical Report H: *Noise and vibration impact assessment*
- Technical Report K: *Safety, hazard and risk assessments*
- Attachment IV: *Climate change risk assessment*
- Chapter 26 *Stakeholder engagement.*

Appendix C

Technical specifications and drawings

FSRU Technical Specifications

THIS TECHNICAL SPECIFICATION COVERS THE FSRUS OPERATING IN OPEN LOOP MODE DELIVERING UP TO 750 MMSCFD (AS AVAILABLE) AND IN CLOSED LOOP MODE WITH TWO BOILERS CAPABLE OF DELIVERING A TOTAL OF 500 MMSCFD (FIRM). A REVISION WILL BE REQUIRED TO REFLECT PERFORMANCE WITH THREE BOILERS INSTALLED TO DELIVER 750 MMSCFD (AS AVAILABLE) IN CLOSED LOOP.

1. HÖEGH ESPERANZA

Höegh Esperanza is a new, state of the art 170,000 m^3 jetty moored Floating Storage and Regasification Unit (FSRU) with full trading capabilities and a fuel-efficient open loop regasification system and is also equipped with regas boilers and steam heaters for combined and closed loop operations. The FSRU was delivered from HHI in April 2018.

Definitions

An Open Loop Regasification System continuously draws seawater into the FSRU for heat exchange in the LNG regasification skids and subsequently discharges the seawater back to the sea. The FSRU when operating in open loop mode will discharge seawater that will be up to and no more than 7°C cooler than the ambient water temperature.

A closed loop regasification system uses gas fired steam boilers to heat a closed loop of circulating seawater within the FSRU for heat exchange in the LNG regasification skids. The circulating seawater has no continuous supply from, or discharge to, the surrounding sea. Flushing of the seawater closed loop may be required periodically for maintenance or Class inspections. Any seawater used for regas heating which is discharged as part of any closed loop operations will be within 5°C to ambient water temperature.

1.1 General Description

This section presents a general description of the capabilities of the HLNG fleet of FSRUs from HHI and SHI. The first of the new generation of FSRUs was delivered from HHI 2014, while the last one currently on order will be delivered from SHI in 2019.

The FSRUs are equipped with GTT Mark III reinforced membrane tanks, with a total storage volume of 170 000 m^3 divided between four cargo tanks. It is possible to gas-free and enter one cargo tank while the other tanks are in operation. Several technical improvements have been made for the latest Mark III technology such as structural reinforcement against sloshing load, improved boil off rate, assurance of gas tightness for barriers, and enhancement of work quality. Liquefied natural gas will be stored at atmospheric pressure at approximately -163°C in the vessel's cargo tanks and will be heated and evaporated based on onshore gas demand. A reinforced and insulated cargo containment system protects the double hull from exposure to low temperature and reduces the rate at which the liquid is evaporated due to heat influx from the environment.

One major benefit of the new generation of FSRUs is the high reliability through maintenance friendly solutions and reduced fuel consumption compared to existing regasification vessels based on conversion of existing LNG carriers.

The newbuilt FSRUs are equipped with Dual Fuel Diesel Electric (DFDE) machinery, connected to electrical generator sets, providing all power necessary for all operating modes. The DFDE machinery normally operates on Boil-Off Gas (BOG) but can also be operated on Marine Diesel Oil (MDO) and some of the FSRUs in the fleet may also operate on Heavy Fuel Oil (HFO) in special cases. The DFDE engines benefit from higher efficiency than traditional steam turbine machinery typically equipped in existing regasification vessels, which makes the proposed FSRU a fuel-efficient regasification terminal.

For Höegh Esperanza offered for the AGL project, the following capabilities may be emphasized:

(a) Higher cargo tank design pressure (0.7 Barg) allows for higher flexibility in LNG loading operations and storage periods.

(b) Reinforced membrane containment system with greatly improved sloshing tolerance.

(c) The regassification trains with a 250 MMscfd capacity each, allowing for a regas send-out capacity from 50 MMscfd and up to a maximum peak capacity of 750 MMscfd

(d) Fuel efficient Dual Fuel Diesel Engines with low fuel consumption.

(e) Exhaust gas economizer for the main dual fuel engine generators to utilize waste heat.

(f) Recondenser for handling boil-off gas.

(g) Additional top filling of tank no 1 to prevent LNG stratification and "roll-over".

(h) Retractable regas feed pumps with dedicated column for extraction without opening the cargo tanks.

(i) Possible to empty one cargo tank while the others are in service, ensuring high reliability and flexibility.

(j) MSO Compessor

(k) Backup Regas SW line (meaning maintenance on main SW line while in regas operation)

The vessel is a new, state of the art 170,000m^3 FSRU with a 750 MMscfd (3 x 250 MMscfd) regasification capacity in open loop, capable of operating in either open, combined or closed loop

General Information	**Description**
Type of Unit	Existing FSRU, open, combined and closed loop operation
Builder and yard	Hyundai Heavy Industries Co., Ltd.
Delivery date	April 5th 2018
Classification Society	DNV GL
Date of last dry-dock	N/A
Time to dry-dock from charter start	Refer to 2.2
FSRU Storage capacity	170,100m^3 (Gross)
Boil-off Rate	0.15%/day
No. and capacity of regas trains	3 x 250 MMscfd
Regas heating medium	Propane intermediate Closed loop with seawater heated by steam
Maximum Noise Level from Vessel	90 dB(A) at any outside location

1.2 Drydocking Regime

(a) The design of the FSRU is prepared for 20 years operation without dry-dock, implying necessary modifications for sea water system, hull, cargo tanks etc. are carried out to allow for on-site class inspections while the FSRU is in operation.

(a) Prior to long term FSRU contracts, if the vessel for instance is trading as an LNG carrier, normal 5 years class surveys and drydocking regimes are followed. However, for long term FSRU contracts, the FSRU is designed for in situ surveys, and DNV GL as class society has issued a Memoranda for Owners stating that Höegh Esperanza is designed to perform all periodical surveys while afloat at a fixed location. In such

cases, class shall be contacted for acceptance prior to any shifting of vessel to other location or vessel resuming normal trading and drydocking may then be required.

(b) Note that the flag state also need to approve of on-site renewal surveys without drydocking, and not all flag states will approve of such inspection regime. Höegh Esperanza is currently flagged with the Norwegian International Ship (NIS), and may have to revert to the Marshall Islands ship registry, who accepts on-site renewal surveys for permanently moored FSRUs for extended periods passing 5 and 7.5 years.

(c) If the vessel starts trading as an LNG carrier during the charter, or if the vessel is moved to a different location to operate as an FSRU, a bottom survey in drydock may be required by Class and Flag

1.3 Layout and Dimensions

Dimensions	**Units**	
Length overall (LOA)	meter	294.07
Length between Perpendiculars (LBP)	meter	282.00
Breath moulded	meter	46.00
Depth moulded	meter	26.00
Distance bow to mid-point manifold	meter	144.54
Distance stern to mid-point manifold	meter	149.54
Distance mid-point manifold to Crew Gangway Access Point	meter	74 aft
Distance mid-point manifold to HP gas manifold #1	meter	30.0
Distance mid-point manifold to HP gas manifold #2	meter	36.5
Height of HP gas manifold above vessel keel	meter	31.386
Distance of HP gas manifold flange from HP manifold deck end	meter	3.84

Parallel Body Dimensions	**Units**	**Ballast**	**Summer DWT**
Parallel body Total Length	meter	132.75	144.78
- forward to mid-point manifold	meter	56.44	62.46
- aft to mid-point manifold	meter	76.31	82.32

Load Line	**Units**	**Ballast**	**98% LNG tanks**	**Summer***	**Winter**
Freeboard	meter	10.74	8.38	7.36	7.62
Draft	meter	9.26	11.62	12.62	12.36
Deadweight	Tonnes	54,958	80,869	92,216	89,214

Displacement	Tonnes	91,100	117,011	128,358	125,356

* The summer load line corresponds to scantling draft

1.4 LNG and Regas Systems

(a) LNG Ship to Ship Transfer

LNG transfer from the carrier moored side-by-side is provided by four 10 inches hoses on single reducers, i.e. each liquid manifold is connected to one transfer hose. Vapour return is by two 10 inches hoses connected by a y-piece to the vapour manifold. Figure 2-1 presents a schematic overview of ship-to-ship equipment installed.

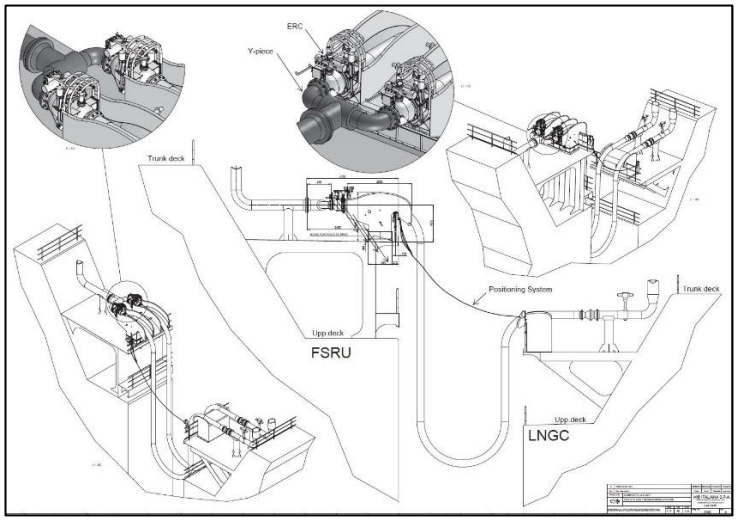


Figure 2-1 Example of schematic overview of STS equipment installed

LNG Reception from LNG Ships	**Units**	
Number and diameter of flexible hoses to receive LNG	N/A	Four 10 inch Gutteling hoses
Number and diameter of flexible hoses to return vapour	N/A	Two 10 inch Gutteling hoses
Guaranteed rate at which LNG can be received	m^3/h	9000*
Maximum back pressure to LNG Ship manifold	Barg	5
Method of monitoring LNG quality and composition	N/A	Onboard gas chromatograph detecting C1 to C6+, and bottle sampling for lab analysis

* A send out rate of 150 MMscfd is needed to handle all excess boil-off at loading condition and to obtain the maximum loading rate of 9,000 m3/h. For send-out rates lower than this, excess boil-off gas will have to be consumed to maintain max transfer rate. Alternatively, the loading rate should be reduced. The LNGCs shall have a maximum tank pressure of 0.1 barg prior to unloading.

(b) LNG Regas Open / Closed Loop Operation

The boiler package will include Economizer for improved fuel efficiency, and a Flue Gas Recirculation (FGR) system to minimize the NOx emissions. The FSRU is designed for both combined and closed loop operations, with full closed loop regas capabilities up to 500 MMscfd send-out capacity.

Regas Rated Capacity	Units	
Max Delivered Pressure at export gas manifold	Barg	98
Min Delivered Pressure at export gas manifold	Barg	46
Gas Supply Rate Minimum	MMscfd	50
Gas Supply Rate Firm Open Loop	MMscfd	500
Gas Supply Rate As Available Open Loop	MMscfd	750
Gas Supply Rate Firm Closed Loop	MMscfd	500
Gas Supply Rate As Available Closed Loop	MMscfd	500 (with 2 boilers installed)
Train cool down time	Hours	12
Ramp-up time per train (open loop)	Mins	30
Ramp-up time per train (closed loop)	Mins	120
Closed Loop Min gas send-out temperature	degC	5

For the regas process onboard Höegh Esperanza with propane as intermediate heating medium, the design parameters allow for a minimum ambient sea water temperature of 13 degC for maximum send-out in open loop to meet a minimum gas send-out temperature of 5 degC. For lower sea water temperature, the maximum send-out capability of 750 MMscfd may have to be derated if open loop operation is to be continued, pending however actual send-out pressure, temperature and LNG composition, and actual sea water temperature. The table below presents calculated theoretical values for sea water temperatures below 13 degC.

Regas Open Loop Performance vs Seawater Temperature					
	Units				
Min Seawater Temp	degC	10.9	10.9	8.5	8.5
Min Delivered Temp	degC	2	2	2	-0.4
Gas Rate	MMscfd	500	750	675	500
Reliability		Firm	As Available	As Available	Firm

1.5 FSRU Fuel and Boil-off Performance

(a) Fuel Consumption

Please note the assumptions forming basis for the fuel consumption calculations, given below the tables with the estimated consumption. The table provides estimated fuel gas consumption for regas operations both with and without LNG loading from LNG Carriers moored side-by-side. For the closed loop all the heat comes from the steam heated water, the FSRU is designed for closed loop operation up to 500 MMscfd gas send-out only.

FSRU fuel gas consumption at gas send-out rates and regas modes					
Regas Mode	**Units**	**No Send-out**	**50 mmscfd**	**500 mmscfd**	**750 mmscfd**
Without LNG Loading					
Open Loop	tonne/hour	0.52	0.90	2.40	3.26
Closed Loop	tonne/hour	0.52 1.31 (Boiler on standby)	1.65	9.81	N/A
With LNG Loading					
Open Loop	tonne/hour	0.75	1.01	2.61	3.33
Closed Loop	tonne/hour	0.75 1.54 (Boiler on standby)	1.76	10.02	N/A

Assumptions

- Pressure of 98 Barg at gas export manifold
- LNG with a density of 446 kg/m^3
- Gas HHV of 50098 kJ/kg
- Gas Wobbe Index of 47.39 MJ/Sm^3
- LNG transfer rate of 9000 m^3/hr

Höegh Esperanza is equipped with a 4.5 tonne / hour MSO compressor. The MSO has a fixed speed electric motor, and can operate at 50% and 100% load. The additional fuel consumption on the FSRU due to the MSO operating on full load is 0.41 tonne / hour.

Marine Diesel Oil consumption refers to pilot fuel demand while the generators are running on gas. The pilot fuel demand is less than one ton of MDO / day for all send-out rates.

(b) BOG Generation and Handling

In accordance with the ship building contract, the vessel shall have a cargo boil off rate not greater than 0.15% per day of the cargo volume at fully loaded condition (98% of the total capacity) during a loaded voyage

The boil off rate shall be calculated in accordance with GTT external document No. 1392, Rev 6; "BOR Measurement" In ballast transit, the boil off rate may roughly be assumed to be ~10% (per day) of the heel in the tanks.

Calculated boil-off rates for the vessel operating in FSRU mode are given in section 1.5 (d)

GTT has calculated tank pressure holdings time for a range of tank conditions. Note that these are theoretical values only and have not been validated towards operational data. Please also consider the assumptions for the calculations stated in a bullet point list below the table.

Capacity to Contain Boil Off Gas	Units	
Relief Pressure of LNG Tanks (*FSRU mode*)	mBarg	700
Time to reach relief pressure: 98% Full LNG Tanks	Hours	470
Time to reach relief pressure: 50% Full LNG Tanks	Hours	Not available
Time to reach relief pressure: Heel only LNG Tanks (*10% full*)	Hours	210

Assumptions:

(i) Initial tank vapour pressure 100 mBarg

(ii) Initial LNG temperature -158.8 degC

(iii) ~420 kg / hour gas consumption (assumed hotel load)

(iv) LNG Composition: Nitrogen 0.02%, Methane 86.2%, Ethane 8.47%, Propane 3.94%, N-Butane 1.37%

Höegh Esperanza is equipped with several boil-off gas management systems to handle the BOG generated onboard the FSRU, with the purpose of recovering the BOG and hence minimizing the operational cost and emissions.

The following design features and equipment is installed on the FSRU to handle and recover the BOG energy:

(i) Fuel for DFDEs; BOG is the primary source of fuel for the dual fuel engines, which can run on MDO and/or gas

(ii) Higher cargo tank operating pressure; the FSRU may utilize a higher cargo tank operating pressure of 0.5 Barg, with maximum design pressure 0.7 Barg

(iii) Recondenser; during regas operations BOG will be condensed back to liquid in the recondenser system which has a capacity of 5 tonne/hour per train at maximum capacity and an overall total capacity of 8 tonne/hour.

(iv) Minimum send-out compressor, Burckhardt: 4.5 tonne/hour; An MSO compressor is installed to export excess BOG in scenarios where maximum cargo tank pressure is obtained or only small quantities of gas are required

(v) Regas Boiler steam dump; The regas boiler has sufficient steam dump capacity to consume the max boil-off with engines stopped

As part of the project development HLNG shall work closely with AGL to identify the best solutions for BOG handling.

(c) Boil Off Gas Management Performances

The ability of FSRU systems to manage Boil Off Gas is summarised below.

Capacity to Manage Excess Boil Off Gas	Units	
Through condenser at 50 MMscfd send-out	tonne/hour	2.0

Through condenser at 250 MMscfd send-out	tonne/hour	8.0
Gas send-out rate for condenser to keep tank pressure stable (without LNG loading	MMscfd	80
Gas send-out rate for condenser to keep tank pressure stable (with LNG loading)	MMscfd	150
Through Minimum Send-out Compressor (Option)	tonne/hour	4.5
	MMscfd	5.15*

* Based on a BOG composition of 80 mol-% Methane and 20 mol-% Nitrogen

BoG management system can maintain tank pressure indefinitely under normal operating conditions (no LNG loading), with MSO running and hotel load fuel consumption. During LNG loading at guaranteed rate with no send-out, some excess BoG may be expected. See also section 1.5 (e).

(d) Gas Energy Balance

The calculated gas balance for various send-out rates in open loop regas mode, without and with LNG loading are calculated based on the following assumptions:

- 98 Barg pressure at gas export manifold
- LNG with a density of 446 kg/m^3
- Gas HHV of 50098 kJ/kg
- LNG transfer rate of 9000 m^3/hr
- MSO running at 100% load

Vessel Gas Balance: Open Loop Regas Mode (No LNG Loading)					
	Units	**No Send-out**	**50 MMscfd**	**500 MMscfd**	**750 MMscfd**
Passive boil-off	tonne/hour	4.67	4.54	3.35	2.69
Fuel demand	tonne/hour	0.52	0.90	2.40	3.26
To Condenser	tonne/hour	-	2.0	0.96	-
Excess boil-off - To MSO if running (Gas Export) - MSO fuel if running	tonne/hour	 3.73 0.41	 1.23 0.41	-	-
To Steam Dump	tonne/hour	-	-	-	-

Vessel Gas Balance: Open Loop Regas Mode (LNG Loading in Progress)					
	Units	**No Send-out**	**50 MMscfd**	**500 MMscfd**	**750 MMscfd**
Passive Boil-off	tonne/hour	7.28	7.15	8.97	8.30
Fuel Demand	tonne/hour	0.75	1.01	2.61	3.33
To Condenser	tonne/hour	-	2.0	6.36	4.97
Excess boil-off - To MSO if running (Gas Export) - MSO fuel if running	tonne/hour	 4.5 0.41	 3.73 0.41	-	-
To Steam Dump	tonne/hour	1.62	-	-	-

Vessel Gas Balance: Closed Loop Regas Mode (No LNG Ship Unloading)					
	Units	**No Send-out**	**50 MMscfd**	**500 MMscfd**	**750 MMscfd**
Passive boil-off	tonne/hour	4.67	4.58	3.70	N/A
Fuel demand	tonne/hour	0.52	1.65	9.81	N/A
To Condenser	tonne/hour	-	2.0	-	N/A
Excess boil-off: - To MSO if running (Gas Export) - MSO fuel if running	tonne/hour	 3.73 0.41	 0.52 0.41	-	N/A
To Steam Dump	tonne/hour	-	-	-	N/A

Vessel Gas Balance: Closed Loop Regas Mode (LNG Ship Unloading in Progress)					
	Units	**No Send-out**	**50 MMscfd**	**500 MMscfd**	**750 MMscfd**
Passive boil-off	tonne/hour	7.28	7.19	9.32	N/A
Fuel demand	tonne/hour	0.75	1.76	10.02	N/A
To Condenser	tonne/hour	-	2.0	-	N/A
Excess boil-off: - To MSO if running (Gas Export) - MSO fuel if running	tonne/hour	 4.5 0.41	 3.01 0.41	-	N/A
To Steam Dump	tonne/hour	1.62	-	-	N/A

Please note the following considerations related to the above four tables:

- If the MSO is not running, the excess boil-off to MSO export and fuel given above will have to be combusted by regas boiler steam dump.
- The passive Boil-off rates given in the tables represent the net Boil-off from the tanks after allowing for increased void space as levels fall in the tanks with LNG consumption.
- The cool-down or standby operation of regas trains does not significantly impact boil off gas rates.

(e) Internal Use

The Internal Use on the FSRU, excluding the unaccounted for gas, is measured by the flow metering to the generators and the regas boilers

The gas energy balance as established in section 1.5 (d) forms basis for the defined Internal Use limits excluding the unaccounted for gas. The FSRU's internal use excluding the unaccounted for gas when made fast at the mooring and regasifying LNG according to the nominated discharge quantity shall not exceed the parameters defined in the Internal Use Limit tables, provided that the Assumptions and Conditions listed below are met.

Internal Use Limits - Open Loop						
Regas Mode	Units	No Send-out	50 MMscfd	250 MMscfd	500 MMscfd	750 MMscfd
Without LNG Loading						
Fuel Demand	tonne/hour	0.52	0.90	1.63	2.40	3.26
Excess Boil-Off Gas*	tonne/hour	4.14	1.64	0.0	0.0	0.0
With LNG Loading						
Fuel Demand	tonne/hour	0.75	1.01	1.70	2.61	3.33
Excess Boil-Off Gas*	tonne/hour	6.53	4.14	0.0	0.0	0.0

Internal Use Limits - Closed Loop						
Regas Mode	Units	No Send-out	50 MMscfd	250 MMscfd	500 MMscfd	750 MMscfd
Without LNG Loading						
Fuel Demand	tonne/hour	0.52 / 1.31 (Boilers on standby)	1.65	5.33	9.81	N/A
Excess Boil-Off Gas*	tonne/hour	4.14	0.93	0.0	0.0	N/A
With LNG Loading						
Fuel Demand	tonne/hour	0.75 / 1.54 (Boilers on standby)	1.76	5.41	10.02	N/A
Excess Boil-Off Gas*	tonne/hour	6.53	3.42	0.0	0.0	N/A

*There is an option to export excess Boil-Off-Gas via MSO with a capacity constraint of 4.5 tonne/hour. If the MSO is operating, the additional fuel consumption from this shall not exceed 0.41 tonne / hour.

Assumptions and Conditions:

(i) A gas export pressure of between forty-six (46) and ninety-eight (98) Barg

(ii) An LNG transfer rate of 9000 m^3/hr for the LNG Ship Unloading cases

(iii) LNG with a density of 446 kg/m^3, and a gas HHV of 50098 kJ/kg. The figures are according to ISO 3046/1, and Wärtsilä's 5% tolerance is included

(iv) The fuel consumption figures exclude daily pilot fuel consumption (MDO or MGO). This is defined in section 1.5 (a)

(v) Where the regasification flow rate differs from the points specified in the Internal Use Limit tables in this section, fuel gas consumption shall be interpolated on linear basis from a minimum regasification flow rate of fifty million Standard Cubic Feet per day (50 MMscfd). A ten per cent (10%) margin on interpolation result is allowed to account for changes in generator efficiency at different loads

The Total Internal Use shall be calculated based on the gas sent to the generators and regas boilers, and unaccounted for gas which shall be calculated based on the LNG loaded as per LNG sampling, the settled cargo volume of LNG as per Custody Transfer Metering System (CTMS) readings and fuel consumption and send-out as per flow and export meters, using the following inaccuracies:

- ±0.5% for the gas export meter
- ±3% for the flow meters to the engines and the regas boilers
- ±7.5 mm for cargo tank level measurement by radar gauges
- Inaccuracy of the LNG Sampling system to be installed, in accordance with international recognized standards
- LNG and gas in piping and regasification module during operation

1.6 Sea Water Intake and Discharge

This section presents details on the sea water system onboard the FSRU and responds to the request for information on this topic raised in the RFP.

(a) Sea Water Intake Configuration

There are two main sea water intakes on Höegh Esperanza, serving both the regasification plant and other consumers. They are located on each side of the vessel in the engine room and combined with a cross over, allowing for 100% water intake from each side. The FSRU draft in ballast and laden condition is given in section 1.2, as input for estimating submergence of the sea chests in the various loading conditions.

Sea Chests	Units	Higher (port side)	Lower (starboard side)
Distance from Aft Perpendicular	meter	50.4 - 56.8	50.4 - 56.8
Suction Pipe Diameter	meter	1.60	1.60
Height above Keel	meter	2.5 - 6.4	0 – 3.2

Intake Below Waterline (laden)	meter	>5.2	>8.4
Intake Below Waterline (ballast)	meter	>2.8	>6.0

(i) The FSRU is equipped with a cover for each sea chest, allowing for inspection of bottom valves while the vessel is in operation afloat at site. The sea chests are also designed with inlet strainers

(ii) For the grating, each sea chest is fitted with twelve openings, with opening dimensions of either 600 x 825 mm or 750 x 925 mm. Detailed drawings of the sea chest arrangement in engine room with dimensions and layout of the gratings are available and will be provided upon request.

(iii) Note that the sea chest data given in the table and text above are representative for the current (as built) configuration onboard Esperanza. As described next, mesh screen boxes will be fitted on the hull to meet the water intake velocity and elevation requirements outlined in the General Specifications at the Owner's cost

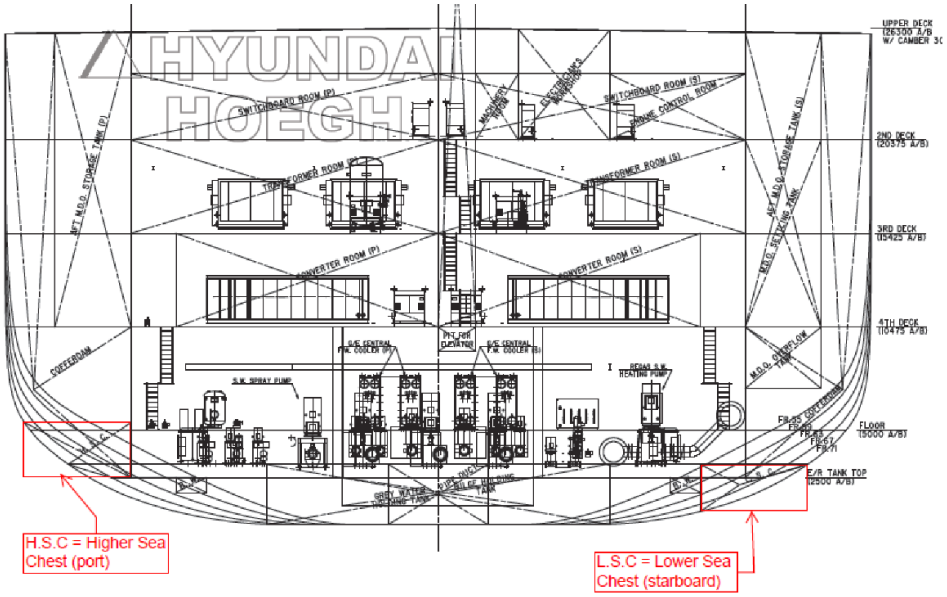


Figure 2.2 FSRU cross-section showing higher and lower sea chest

In order to meet the intake velocity requirement of max 0.15 m/s, the sea chests are planned to be fitted with additional mesh screen boxes which will be installed on the hull. We have boxes installed on HLNG FSRU Independence, which is a jetty moored, combined loop FSRU operating in the port of Klaipeda in Lithuania.

The General Specifications (section 1.8) also present requirements to where in the water column the sea water intakes shall be located. The mesh screen boxes will be designed so that the intakes are located >5m above the sea bed, and a target of >4m from the sea level in full load condition. The design of the mesh screen boxes will be carried out as part of the project development.

Note that there is also a small emergency fire pump sea chest in the forward pump room, more details on this will be provided as FSRU owner input to the EES process.

(b) Marine Growth Inhibition

The FSRU is equipped with both Chloropac Electro-chlorination System from Evoqua and with Copper Anodes System for marine growth prevention in the sea water systems onboard the vessel. The Chloropac

system will be used for the project while the Copper system will be deactivated. The system produces a dilute solution of sodium hypochlorite onsite for direct injection into the sea water circuit in the sea chest. Titanium is used as the cathode material whereas titanium coated with 100 micro-inches of platinum is used as anodes. Titanium is an electrochemically inert element at positive voltages less than 9 volts. The anode/cathode voltage is kept 7 volts. Chlorine is generated at the anodes along with other elements to form sodium hypochlorite

The chlorination is absorbed by the seawater back to its natural state during the exposure time in the piping and heat exchangers, which means that the residue can be zero by correct dosing at the immediate discharge point. A chlorine dosing of 0.2 to 0.5 ppm in mass has been shown as sufficient to prevent all marine fouling in time. The chlorine dosing will be manually adjusted to meet the local sea water conditions on site, and residual values in the discharged sea water may be manually measured by samples to meet regulatory requirements. At the request of the Charterer a chlorine reduction system will be jointly defined by Owner and Charterer and installed as part of the project development at Charterer's cost.

Note: Understand that an electrochlorination system may be expected to be accepted by local environmental authorities, pending careful adjustment of the chlorine dosing. A potential chlorine reduction system solution may be investigated as part of the project development if required, however there is no clear definition of how such a system could be implemented.

It should be emphasized that constant chlorination is considered the best method for safe and efficient antifouling, as the chlorine system has a high decay rate through the seawater system and the dose is reduced at the outlet of the seawater at the vessel. The decay rate continues in the sea until the chlorine is absorbed by the surrounding seawater. This technology makes it possible to avoid handling of chemicals for the seawater system, or separation of copper from anodes into the sea water and the environment around the FSRU.

During commissioning of the FSRU, residual chlorine (hypochlorite) in the discharge sea water will be manually measured, and the chlorine dosing calibrated so that any residual hypochlorite is kept to a minimum. The Evoqua Chloropac system which is installed on the FSRU offers a step system where the dosing may be adjusted to seawater flow, the latter being dependent on the nominated gas send-out. Industry standard has been to provide a small positive residue at the outlet of the seawater to prevent biofouling and variances in seawater flow. However, with the step-wise dosing and by adjusting the Chloropac settings for the various levels of water throughput, the residue chlorine can be reduced to almost zero.

(c) Sea Water Discharge Configuration

Höegh Esperanza is equipped with one regas sea water discharge line, with the following particulars:

(i) Regas SW Discharge pipe diameter: 1350 mm

(ii) Longitudinal position of discharge: 98.5m from AP

(iii) Vertical position of discharge: 10.6 m above keel

Prior to delivery to the project, the Höegh Esperanza will be fitted with multiple regas water discharge ports to improve dispersion of cold water from the FSRU and the arrangements are as following:

- There will be 3 regas water discharge ports on each side of the vessel
- Two discharge ports will be used per operating regas train to maintain seawater discharge velocity at the ports
- Discharge ports will be sized to achieve a water exit velocity of greater of equal to 5m/s, subject to confirmation by AGL that such velocity is actually needed following further mooring analysis and discharge modelling

The exact discharge positions will be developed with inputs from AGL as part of project development at the Owner's cost.

In addition to the main regas sea water discharge line, several auxiliary discharge points are found in the FSRU engine room between 3 to 5 meter above keel. The discharge points are listed below, more details on these will be provided as FSRU owner input to the EES process as part of the project development.

- 2 x G/E Central fresh water cooler discharge Portside
- Fresh water generator discharge Portside
- 2 x G/E Central fresh water cooler discharge Starboard
- Fresh water generator discharge Starboard
- Ballast water discharge point
- Backup regas SW outlet line

(d) Sea Water Discharge Conditions

The design values are based on parameters chosen to encompass all likely operating scenarios including the most conservative, that means the temperature and flow rates given in the table account for e.g. a low send-out pressure (46 bar g) and rich LNG composition. Hence, the design values may be considered as slightly conservative allowing for a certain operating margin, and for projects with a higher send-out pressure and an LNG composition lighter than the richest LNG, and when also taking into account recondensing of generated BOG, it could be anticipated that the delta temperature and flow rate may be somewhat reduced.

Open Loop regas operation Seawater discharge conditions from regas system					
Parameter	**Units**	**50 MMscfd**	**250 MMscfd**	**500 MMscfd**	**750 MMscfd**
Temp below ambient	degC	7	7	7	7
Flow rate	m^3/day	78 000	156 000	312 000	468 000

1.7 Performance as an LNG Ship

The following data is provided for operation of the FSRU as an LNG Ship on the basis that the owner will have had the opportunity to clean the vessel hull before the vessel enters service as an LNG Ship.

	Maximum Fuel Consumption Tonne /day FOE	
Speed (Knots)	Laden	Ballast
19.5	N/A	N/A
19	N/A	N/A
18	111.9	108.9
17	96.1	95.1

16	83.3	84.3
15	71.5	74
14	60.8	63.3
13	52.6	54.7

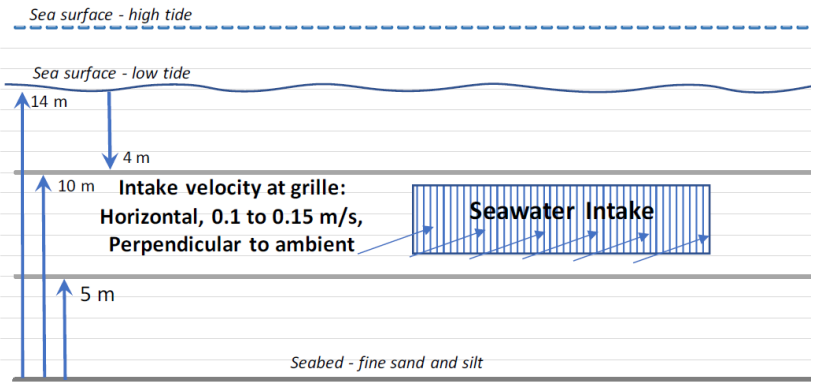
Performance Metrics for Operation as an LNG Carrier	Units	
Trial speed at maximum power and ballast draft	Knots	18.3
Service speed	Knots	18
In port (cargo unloading)	tonne/day FOE	36
In port (idle at ballast)	tonne/day FOE	13.6
Inert gas generation at design capacity	tonne/day FOE	33.5

1.8 General Specifications

If there is any inconsistency between the technical specifications in this section 1.8 and other technical specifications in this Appendix B (other than those which apply to Hoegh Giant -), then the Owner shall without undue delay review such inconsistency and confirm to the Charterer the corrections that need to be made to the applicable technical specifications to resolve such inconsistency.

Item	Description
Health, Safety, Security and Environmental (HSSE)	The vessel shall be designed, constructed, commissioned and operated to international (HSSE) standards including International Maritime Organisation (IMO), Safety of Life at Sea (SOLAS), Flag State, Classification Society, PoHDA requirements, the PoHDA Safety and Environment Management Plan, the Port Operating Handbook and Australian Regulatory requirements. The safety and risk assessment for the FSRU Vessel shall also apply appropriate offshore oil and gas standards for the assessment of the LNG HP regasification systems and any other standards deemed to be appropriate, as agreed between the parties. LNG spillage protection systems shall be used to ensure structural integrity of the vessel is not compromised by exposure to cryogenic temperatures. All equipment and piping systems shall be protected against pressure and temperature in excess of design limits due to error, malfunction or incident through use of Pressure Safety Valves and Temperature Safety Valves or high integrity instrumented systems provided this meets the relevant design codes. All potential ignition sources will be located outside of Hazardous Areas. An Emergency Shut Down system will be installed that brings all vessel systems to a safe, low pressure condition, which will be triggered by either instrument detection of a hazardous situation or by activation of clearly marked shut down buttons located throughout the vessel Escape routes will be provided on-board the FSRU Vessel including both primary and alternate temporary safe refuge and muster areas. A bridge watch will be maintained by Standards of Training, Certification and Watchkeeping (STCW) qualified officers of the watch at all times; and In event of an emergency the vessel will be able to disconnect its LNG cargo transfer system, let go the moorings, and move off the berth in thirty (30) minutes, or less.

Item	Description
	Such emergency disconnection time is subject to availability of tugs and that necessary equipment i.e remote jetty quick release hooks and control panel, properly manned jetty (i.e. a qualified person on the jetty being able to release the FSRU mooring lines from the jetty QRH panel) or similar equipment being arranged by Charterer. No waste streams will be discharged to port waters.
Vessel Characteristics	The FSRU shall be designed to meet all Classification Society requirements in all operating modes as both an FSRU and a trading LNG Ship. The FSRU is designed to not require periodical dry-docking during the 10 years of initial charter period. The FSRU owner shall provide a plan describing how this will be achieved within the constraints of the Classification Society including mitigation plans to address key risks. The vessel will be equipped with sufficient power generation equipment to be self-sufficient for power in all operating modes and will have a black start capability. The vessel will be maintained in a state that is ready to make a controlled departure to sea at two hours' notice. The vessel must be designed and licensed to operate in channels and ports in Victoria, Australia. Existing and converted FSRUs greater than fifteen years old must achieve a condition assessment of at least CAP 2 or equivalent.
LNG Reception from LNG Ship	The FSRU will have sufficient Quick Release Hooks to moor an LNG Ship on its starboard side. LNG will be transferred from LNG Ships directly to the FSRU by double berthing the LNG Ship alongside the FSRU, using flexible hoses for transfer and in accordance with GIIGNL LNG Custody Transfer Handbook (latest edition).
LNG Storage Tanks	LNG storage tanks shall be constructed to the International Code of the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, IGC Code. LNG storage tanks should be designed to withstand sloshing forces in the event that it must sail away in a partially loaded condition. LNG storage tanks will be equipped with bi-directional loading and transfer piping systems to allow simultaneous LNG loading from the LNG Ship and regasification of LNG for gas send-out. LNG storage tanks shall be designed to be individually isolated, made gas free and inspected while the FSRU Vessel is at berth at the jetty.
HP Gas Delivery from the FSRU to the Delivery Point	HP Gas will be delivered to a manifold with connection points for 2 x 12" Marine Loading Arms circa 30m forward of the mid-point manifold. Please refer to Section -1.3 for the location of the high pressure loading arms on the FSRU, measured from the vapour manifold. The gas discharge system will be equipped with: • multi-path ultrasonic gas flow meter for custody transfer • gas composition analyser • Safety devices to ensure that gas cannot be delivered from the FSRU outside of the pressure and temperature limits Gas send-out volumes shall be measured by the FSRU's onboard metering system
Maintenance and Equipment Sparing	Static equipment that requires shut-down for maintenance less than once per year and is not prone to unplanned maintenance events can be installed without any redundant or spared trains.

Item	Description
	Rotating equipment and equipment with moving parts that is crucial to the continuous delivery of HP gas, including utility and supporting systems and LNG cargo pumps, and that require a shut-down for maintenance at least once per year, or which experiences unplanned maintenance events will be spared.
Boil-off and Fuel Gas	The FSRU must be equipped with a condenser which combines Boil-off Gas with LNG send-out in the regas system and an MSO. The FSRU must be equipped to manage Boil-off Gas for the entire range of gas send-out rates specified for the FSRU and also for extended periods during which there is no gas send-out. Disposal of excess Boil-off Gas (which cannot be usefully deployed in either the Condenser or Fuel Gas system or MSO) in a gas combustor should be minimized. The FSRU will only operate on MDO in emergencies or for testing and maintenance except if the LNG tank inventory is so low that the generators will have to be run on MDO as back-up fuel, and some during start-up and operation of generators when MDO is used as pilot fuel, or if otherwise requested by Charterer.
LNG Regas Heat Sources	The FSRU is berthed in an area listed as an environmentally important RAMSAR wetland with winter sea water temperatures below 12 degC. The FSRU will be able to operate in open loop mode utilising seawater as a heat source to regas the LNG. The FSRU will be offered with an option to operate in closed loop mode using boilers to supply all regas heat if required.
Seawater for LNG Regas Heating	Temperature change of discharged seawater compared to ambient seawater temperature shall not to exceed 7 degC (whilst operating in open loop mode) and 5 degrees Centigrade (whilst operating in closed loop mode). Concentration of Total Residual Chlorine (marine growth inhibitor) in discharged seawater shall not to exceed 100 parts per billion (ppb). If requested by the Charterer, a chlorine reduction system shall be installed to allow dosing of neutralizing agents to reduce residual chlorine in discharged seawater. Subject to the FSRUs variable cargo condition affecting the draft, seawater intakes shall be able to be sited to draw water from the middle section of the water column. The FSRU is berthed in relatively shallow water (12.7m at stern to 15m at bow at LAT) and intakes shall, subject to changes in draft due to low or high cargo inventory, be capable of being located >4m away from the water surface (where drifting debris and sea creatures may become entrained) and >5m away from the seabed (where sediments and sea creatures may become entrained). The intake velocity will be limited to <0.15 m/s and must be fitted with a mesh screen which will require periodic cleaning. This will minimize entrainment of fish and fish larvae as well as seagrass debris.  Illustration of Water Intake Location in a 14m Water Column

Item	Description
	Unless otherwise agreed between Charterer and Owner, seawater mesh screen sizing shall be no greater than 100 mm x 100 mm,. Water discharge ports must be located under water, but close to the water surface. Discharge ports will be orientated to deliver a horizontal discharge water jet below the water surface. Discharge velocity has an important impact on cold water dispersion and configurations will be capable of maintaining minimum required velocities of 5 m/s at all operating conditions. The FSRU closed loop system, for the LNG regas heating process shall be capable of operating without any seawater being taken in or discharged to Western Port, provided a means of disposal of the inventory of the closed loop seawater system from the FSRU is available (for example via a barge), or unless specifically authorised by Applicable Laws and Approvals. The closed loop system will be designed to be able to discharge the sea water inventory to a barge, to shore or by other means of disposal than discharge to Western Port if requested by Charterer, at Charterer's cost.
Noise	The Maximum Noise Level from the FSRU will be 90 dB(A) at any outside location.

1.9 Painting Specifications

The painting specification for Höegh Esperanza is given in the following document:

- Hyundai Heavy Industries Co., Ltd., Painting Specification, Ship no 2865, Drw no. IP-7030-002-300, Rev 300, Mar 08 2017

1.10 Gas Form C Höegh Esperanza

See next page

Vessel Name: Höegh Esperanza

Date: 26/04/2018

select form status below

Final

General

(a)	Name of Vessel	**Höegh Esperanza**
(b)	Builder and Yard	Hyundai Heavy Industries Co. Ltd Ulsan Shipyard
(c)	Hull No.	2865
(d)	Year Built	2018
(e)	Date Delivered	05/04/2018
(f)	Vessel type	LNG/FSRU
(g)	Port of Registry and Flag	Majuro / Marshall Island or NIS
(h)	IMO Number	9780354
(i)	MMSI	358007664
(j)	Call Sign	V7ZR4
(k)	Classification Society	DNV-GL
(l)	Class notation	1A1 Tanker for liquefied gas BIS BWM(T) Clean COAT - PSPC CSA(FLS2) EO Gas fuelled NAUT(OC) NAUTICUS(Newbuilding) OPP-F Plus Recyclable REGAS TMONC
(m)	Protection and Indemnity Club	The Standard Club
(n)	Is vessel approved	USCG Yes ☐ No ☐ IMO Yes ☒ No ☐

1. Principal Particulars

(a)	Length overall (LOA)	294.07 m
(b)	Length Between Perpendiculars (LBP)	282.0 m
(c)	Breadth moulded	46.0 m
(d)	Depth moulded	26.0 m
(e)	Height overall — keel to highest fixed point	66.54 m
(f)	Maximum air draught (with full ballast and half bunkers) (corresponding draughts)	*57.17 m* *9.37 m*
(g)	Deadweight on summer load line	92,216.5 MT
(h)	Draught on summer load line (ext.)	12.621 m
(i)	Displacement summer Load Line	128,358 MT
(j)	Design Deadweight	92,424 MT
(k)	Design Draught	11.60 m
	TPC at design draught	112.51 MT
(l)	Design Displacement	117,014 MT
(m)	Gross Tonnage (International)	110,499
(n)	Net Tonnage (International)	36,793
(o)	Gross Tonnage (Suez)	113,167.04 MT
(p)	Net Tonnage (Suez)	100,484.53 MT
(q)	Light Ship Displacement	36,141.5 MT
(r)	Displacement (maximum)	128,358 MT
(s)	Windage: Lateral	7001 m2 Summer draft 7841 m2 Ballast draft
	Longitudinal transverse	1680.9 m2 Summer draft 1823.4 m2 Ballast draft

Classification: HLNG Confidential – Copyright Höegh LNG © all rights reserved

(t)	Classification designation	+1A1 Tanker for Liquified Gas, Ship type 2G (- 163DegC, 500kg/m3, 25kPa) NAUTICUS (Newbuilding), Regas-2, EO, NAUT-OC, CLEAN, BIS, CSA-FLS2, PLUS, COAT-PSPC(B), Recyclable, GAS FUELLED TMON OPP-F
(u)	Conditions of Carriage (as defined on Certificate of Fitness):	Methane (LNG) All cargo tanks: Maximum pressure Sea going condition: 25 kPa g FSRU mode and in harbour: 70 kPa g Maximum filling limit: 98.5% at ref. temp. Maximum cargo density: 500 kg/m3 Cargo tanks shall not be filled with liquid to levels between 2.75m and 70% of tank height when vessel is in open seas. Minimum temperature: -163 degree Celsius

2. Operating Draught and Deadweight

(a)	Draught filling to 98.5% (@ cargo density 0.47 kg/m^3)	11.62 m
(b)	Deadweight filling to 98.5%(@ cargo density 0.47 kg/m^3)	80,872 MT

3. Ballast System

(a)	Total capacity of ballast water tanks	53,499.9 m3
(b)	Number, capacity and head of pumps for handling ballast	3 sets, 2600 m3/h x 35 mTH 2 sets, 400 m3/h x 35 m TH 2 sets Eductors 300 m3/h
(c)	Is Vessel able to ballast / de-ballast within the cargo loading/discharging period?	Yes
(d)	Can the Vessel undertake ballast exchange at sea within 24 hours	No
(c)	Vessel equipped with Ballast Water Treatment system	Yes

4. Main Certificates:

(a)	Load line Certificate	Issued: **05/04/2018**
(b)	Safety Equipment Certificate	Issued: 05/04/2018
(c)	Certificate of Fitness (IGC)	Issued: 05/04/2018
(d)	Certificate of Tonnage	Issued: 07/02/2018
(e)	IOPP	Issued: 05/04/2018
(f)	Document of Compliance	Issued: 04/01/2016
(g)	USCG Certificate of Compliance	Issued: Click or tap to enter a date.
(i)	SIRE Inspection	15/04/2018
(j)	Port state control	Click or tap to enter a date.

Classification: HLNG Confidential – Copyright Höegh LNG © all rights reserved

4.1 Is certification held indicating compliance with the following?

(k)	ISPS Code	**Yes**
(l)	Rules and Regulations of Suez Canal Authorities	Yes
(m)	ISM	Yes

5. Propulsion

(a)	Type and make of propulsion plant	Dual Fuel Diesel Electric Driven Wärtsilä-Hyundai / GE Propulsion
(b)	Maximum rated power and RPM	20,600 kW x 76 rpm
(c)	Proposed service power and RPM	20,600 kW x 76 rpm
(d)	Grade of Fuel	Marine Diesel Oil (DMB class ISO 8217 with a viscosity of 6 cSt and above at 40oC) Marine Gas Oil (DMA/DMZ class of ISO 8217 with a viscosity of 3 cSt and above at 40oC) (Diesel Mode) Boil-off gas with pilot fuel (Gas Mode)
(e)	Dual Fuel Burning	Diesel Mode or Gas Mode
(f)	Propeller	1
(g)	Thrusters	No

6. Speed / Consumption

(a)		Maximum fuel consumption (Tonnes of Fuel Oil Equivalent / day)	
	Speed (Knots)	Laden	Ballast
	18	110	110
	17	96	96
	16	83	85
	15	72	73

(b)	Trial Speed at Maximum Power (with 21% sea margin at ballast draught)	18.30 knots
(c)	Service Speed (MPP with 21% sea margin at design draught)	18.00 knots
(d)	Consumption in Port (cargo operations)	36 MT per day (unloading) 21.9 MT per day (loading)
(e)	Consumption in Port (idle)	13.6 MT per day
(f)	Consumption for inert gas generation	33.5 t / 24 hrs

7. Boilers and Steam Capacity

(a)	Number and type of boilers	2 x Regas boilers 1 set, Mac-14SF
(b)	Maximum steam output available	2 x 90,00 kg/h 1 x 14,00 kg/h
(c)	Normal service output corresponding to 5(b)	0.8 Mpa

Classification: HLNG Confidential – Copyright Höegh LNG © all rights reserved

8. Cargo Tanks

(a)	Number of tanks		
(b)	Capacity of LNG tanks at normal filling level		
		No 1 Tank	**26,166.1 m3**
		No 2 Tank	**47,145.9 m3**
		No 3 Tank	**47,135.1 m3**
		No 4 Tank	**47,117.3 m3**
		Total	*167,564.4 m3*
(c)	Gross Capacity of LNG tanks at 100%		
		No 1 Tank	**26,564.6 m3**
		No 2 Tank	**47,863.9m3**
		No 3 Tank	**47,852.9 m3**
		No 4 Tank	**47,834.8 m3**
		Total	*170,116.1 m3*
(d)	Partial loading / filling restrictions		Between 2,75 m and 70% of tank height
(e)	The Vessel's cargo tanks can be cooled down from ambient in:		10 Hours
(f)	Maximum filling rate		10,000 m3 per hour
(g)	Relief valve settings (MARVS)		25 kPa / 70 kPA (gauge)
(h)	Loaded Condition Boil-Off rate		0,15 % of gross capacity per day in static mode
(i)	Ballast Condition Boil-Off rate		0,10 % of gross capacity per day in static mode

9. Cargo Discharge

(a)	Number of cargo pumps per tank	**2**
(b)	Make and type of cargo pumps	Shinko Electric motor driven, Vertical, Centrifugal, Submerged
(c)	Design rated capacity of each cargo pump and corresponding discharge head	2 main cargo pumps in each tank. Capacity: 1000 m3/h Head: 170 mlc 1 regas feed pump (retractable) in each tank Capacity: 550 m3/h Head: 170 mlc
(d)	Number of spray (stripping) pumps per tank	1
(e)	Make and type of spray (stripping) pumps	Shinko Electric motor driven, Vertical, Centrifugal, Submerged
(f)	Design rated capacity of each spray pump and corresponding discharge head	Capacity: 50 m3/h Head: 145 mlc
(g)	Number, Make and Capacity of Auxiliary Pumps (i.e. fuel gas for X-DF)	N/A
(h)	Bulk discharge time (not including start up and stripping periods) — assume head at ship's rail = 80 mlc and no restrictions on vapour return from shore.	16

Classification: HLNG Confidential – Copyright Höegh LNG © all rights reserved

10. Cryogenic Systems

(a)	Type of LNG containment system	Mark III Reinforced
(b)	Design temperature	-163 °C
(c)	Make and type of vapour return compressors	Cryostar CM400/55
(d)	Number and rated capacity of vapour return compressors and corresponding discharge head	2 x 30,000 m3/h
(e)	Is a steam dump system provided? If so, is the capacity sufficient to deal with all excess steam generated by the boilers at max designed Boil-Off rate with engines stopped according to Class & USCG Rules?	See pt 7
(f)	Total capacity of liquid nitrogen storage tanks (if nitrogen generator not fitted)	Generator fitted
(g)	Gas Heaters	1
(h)	Vaporisers	2

11. LNG Measurement and Tank Calibration

(a)	Are all tanks calibrated and certified by a qualified agency? (Specify agency)	Yes Intertek Kimsco Co., Ltd.
(b)	Make and type of primary system for measuring cargo level, temperature and pressure Level measuring system accuracy and range Temperature measuring system accuracy and range Pressure measuring system accuracy and range	- Radar Level Gauge : Maker : Kongsberg Type : GLA-310/5 - Temperature : Maker : Kongsberg Type : PT-100 ohm MN3927 - Pressure Transmitter : Maker : Kongsberg Type : Absolute Pressure transmitter GT 405 - Kongsberg Radar Level Gauge : ± 7.5 mm (45mm above of tank bottom) Range : 25 mm to tank top - Temperature : ±0.2 ℃ @ -165 ℃ ~ -145 ℃ ±1.2 ℃ @ -145 ℃ ~ 40 ℃ - Pressure Transmitter : ± 1.0% of Full span (± 10 mbar A) Range : 800 mbar A. ~ 1,800 mbar A.
(c)	Is secondary system for measuring LNG liquid level fitted and, if so, state type and measuring accuracy	Secondary Level Gauge Maker : Whessoe Type : Fig. 3304 Accuracy : ± 7.5 mm

Classification: HLNG Confidential – Copyright Höegh LNG © all rights reserved

12. Cargo Manifolds

(a)	Do manifolds follow requirements of Vol Category "B" of OCIMF *"Recommendations for Manifolds for Refrigerated Liquefied Natural Gas Carriers (LNG)" 2nd Edition — 1994*? (If "No", state variations)	**Yes**
(b)	State layout of liquid and vapour connections	L-L-V-L-L
(c)	Distance of the centre of manifolds from amidships	LOA/2 + 2.5 meter (Vapour Centre Line)
(d)	Distance of presentation flange from ship's side	3.634 m
(e)	Distance of presentation flange from ship's rail	3.138 m
(f)	Height of manifold centre above keel	31.386 m
(g)	Size and location of liquid nitrogen loading connection	N/A

13. Emergency Shutdown System and Ship/Shore Compatibility

(a)	At what cargo level (%) is overflow protection activated? (State if applicable both, LNGC Mode and FSRU Mode)	99% (LNGC) 98.5% (FSRU)
(b)	Does overflow protection activate the following: Trip ESD system? Close manifold valves? Trip cargo pumps? Trip ship/shore link system?	 PSD4.1 Yes Yes Yes
(c)	What ship/shore link systems are installed: Optical Fibre Link Electric Links — Pyle-National / Miyake connector Pneumatic ESD Link	 Yes Yes Yes

14. Bunkers

(a)	Capacity of heavy fuel oil bunker tanks @ 98% (SG 0.99)	N/A
(b)	Capacity of gas oil bunker tanks @ 98% (SG 0.90)	4,929.6 MT
(c)	Maximum bunker loading rate	500 MT/hr
(d)	Segregated low sulphur fuel oil storage capacity	N/A

15. Fresh Water Capacity

(a)	Capacity of fresh water generators	30 Ton/day x 2 sets
(b)	Distilled capacity	223.1 MT
(c)	Domestic capacity	223.1 MT
(d)	Distilled consumption	Less than 1 MT per day
(e)	Domestic consumption	12 MT per day

Classification: HLNG Confidential – Copyright Höegh LNG © all rights reserved

16. Inert Gas Generation

(a)	Type and make of equipment	Hamworthy Moss AS Inert Gas Generator Moss high turbulent type
(b)	Capacity	16,000 Nm3/h at 25kPag
(c)	Quality of gas O2 Max	1-2% (by volume)
(d)	Quality of gas CO Max	1-2% (by volume)
(e)	Quality of gas SO2 Max	10 ppm
(f)	Quality of gas NOx Max	100 ppm
(g)	Dew point	-45°C

17. Nitrogen

(a)	Type and capacity of nitrogen generation system	Air Products Prism Prism menbrane
(b)	Consumption	IBS/IS 5,5 Nm3/h
(c)	Liquid nitrogen storage	N/A
(d)	Nitrogen generator capacity	2 x 125 m3/h at 97% Nitrogen
(e)	Pressure tank	24 m3 / 1.0 MPa (max)

18. Gas Compressors

(a)	Low duty (fuel gas compressor): No. and capacity	3 x 4,400 m3 / hour
(b)	Low duty (fuel gas compressor): maker	Cryostar
(c)	High Duty Compressor: No. and Capacity	2 x 30,000 m3/h
(d)	High duty (fuel gas compressor): maker	Cryostar

19. Electrical Generating

(a)	Number of electric generators	4 Sets
(b)	Type of electric generators	HAJ7 183-14P x 1 set HAJ7 213-14P x 3 sets
(c)	Output of electric generators	5670 kW x 1 set 7580 kW x 3 sets
(d)	Fuel type and quantity at full load of electric generators	Boil-off gas with pilot fuel ISO8217:2010 DMA/DMB with pilot fuel Pilot fuel: ISO8217:2010 DMA/DMB
(e)	Power required for discharge / de-ballasting at full rate	7600 kW

Classification: HLNG Confidential – Copyright Höegh LNG © all rights reserved

20. Deck Machinery

(a)	Winches	10 sets Brake Holding Capacity: 102.4 tons (design) To be adjusted to 60% of working rope MBL
(b)	Wires	44mm dia. x 275 m
(c)	No. Wires Forward	11
(d)	No. Wires Aft	11
(e)	Wires Fitted with Synthetic Tails	72 mm dia x 11 m
(f)	Derricks, Cranes – Type and SWL	1 x Manifold/regas unit service crane , knuckle-boom type, offshore crane, 10 tons SWL 1 x Manifold service crane, 10 tons SWL 2 x Provision handling crane, 2 tons SWL (Port) and 10 tons SWL (SB) 1 x Cargo comp. room crane, Knuckle-boom type crane, 6 tons SWL 1 x air motor driven davit for emergency cargo pump handling davit, 3 tons SWL 1 x air motor driven davit for bosun store, 1.5 tons SWL 1 x air motor driven davit for steering gear room, 1 tons SWL
(g)	Anchors	2 sets 16,125 kg each
(h)	Emergency towing device	Yes

21. Navigation and Communications

(a)	Type and number of radar sets fitted	1 x Furuno FAR-3320 X 1 x Furuno FAR-3330 S
(b)	Is an approved GMDSS installed? (Type?)	Yes (Furuno A3 Area)
(c)	Is an additional Sat Com system installed? (Type?)	Yes (Furuno FB500)
(d)	Is Suez Canal Projector fitted?	Yes

Classification: HLNG Confidential – Copyright Höegh LNG © all rights reserved

22. List of compatible LNG Terminals:

Although the vessel or sister vessels has previously been found compatible with the below list of terminals, continued compatibility cannot be guaranteed and re-confirmation with the terminal may be required.

Load Ports	Discharge Ports
Algeria - Bethioua M5	Argentina - Bahia Blanca
Australia - Pacific LNG (APLNG) terminal	Belgium - Zeebrugge
Australia - Gladstone LNG (GLNG) terminal	Canada - Canaport
Australia - Queensland Curtis LNG (QCLNG) terminal	China - Shenzhen Guangdong Dapeng
Australia - Gorgon LNG project	China - Yuedong LNG
Australia - Wheatstone LNG project	China - Zhuhai
Australia - North West Shelf (NWS) LNG project	China - Zhejiang (Ningbo LNG)
Australia - Darwin LNG project	China - Fujian
Australia - Pluto LNG project	China - Hainan LNG
Australia - Whitnell Bay	France - Fos Cavaou
Egypt - Ain Sokhna	France - Montoir Upstream (GDF-1)
Egypt - Idku	France - Montoir Downstream (GDF-2)
Equatorial Guinea - Punta Europa	India - Dahej
Malaysia - Bintulu	India - Kochi
Nigeria - Bonny Jetty No.1	Japan - Oita
Norway - Snohvit	Japan - Himeji
Oman - Qalhat	Japan - Mizushima
Peru - Pampa Melchorita	Japan - Chita
Qatar - Ras Laffan No.1	Japan - Futtsu No.1 & No.2
Qatar - Ras Laffan No.2	Japan - Senboku II-1 & 2
Qatar - Ras Laffan No.3	Japan - Ohgishima
Qatar - Ras Laffan No.4	Japan - Sakai
Qatar - Ras Laffan No.5	Korea - Tong Yeong
Qatar - Ras Laffan No.6	Korea - Incheon No.1 & 2
Trinidad&Tobago - Atlantic - Jetty 1,2(Point Fortin)	Korea - Pyeong Taek No.1 & No.2
UAE - Das Island	Korea - Tongyuong No.1 & No.2
USA - Cove Point North	Mexico - Costa Azul
USA - Cove Point South	Portugal - Sines
Yemen - Bal Haf	Singapore - Singapore
- Bontang LNG Terminal	Spain - El Ferrol, Huelva, Barcelona, Bilbao, Sagunto, Cartagena
- Tagguh LNG terminal	Taiwan - Yung-An No.1 East
	Taiwan - Yung-An No.2 West
	UK - Isle of Grain
	USA - Sabine Pass

Classification: HLNG Confidential – Copyright Höegh LNG © all rights reserved

Oil Companies International Marine Forum

SIRE Programme

Harmonised Vessel Particulars Questionnaire v5

Höegh Giant

IMO/LR Number 9762962

09 November 2017

1 General Information

1 General Information

1.1.1	Date this HVPQ document completed	07 November 2017
1.1.2	Vessel identification	
1	Name of ship	Höegh Giant
2	LR/IMO number	9762962
3	Company IMO number	5479796

1.1.3 Previous names

	Name	Date of change
Last previous	N/A	
Second last previous	N/A	
Third last previous	N/A	
Fourth last previous	N/A	

1.1.4	Flag	
1	Flag	MARSHALL ISLANDS
2	Has the flag been changed?	No
3	What was the previous flag?	
1.1.5	Port of Registry	Majuro
1.1.6	Call sign	V7SS9
1.1.7	Ship contacts	
1	INMARSAT number	+870773924715
2	Ship's fax number	+870783934570
3	Ship's telex number	538006888-HGIA X
4	Mobile phone number	+47-94508188
5	Ship's email address	master.gian@hoeghlng.no
1.1.8	What is the type of ship as described in Form A or Form B Q1.11 of the IOPPC?	Gas
1.1.9	What is the Ship's Maritime Mobile Selective Call Identity (MMSI) number?	538006888
1.1.10	Type of Hull	Double hull
1.1.11	Name of P and I Club	The Standard Club
1.1.12	EEDI rating number	

2 Ownership and Operation

1.2.1	Registered owner	
1	Name	Hoegh LNG Giant Ltd.
2	Full address	PO Box 1350, Clifton House, 75 Fort Street, Grand Cayman KY1-1108 Cayman Island
3	Country	CAYMAN ISLANDS

4	Office telephone number	+47 97 55 74 00
5	Office telex number	
6	Office fax number	+47 97 55 74 01
7	Office email address	operation@hoeghlng.com
8	Contact person	Rune Karlsen
9	Contact person after hours telephone	+4797557450
1.2.2	Number of years this ship has been owned by Registered Owner	0.50 Years
1.2.3	Technical operator (if different from registered owner)	
1	Name	Hoegh LNG Fleet Management AS
2	Full address	Drammensveien 134, P.O.Box 4 Skyen, NO-0212 OSLO NORWAY
3	Country	NORWAY
4	Office telephone number	+47 97 55 74 00
5	Office telex number	
6	Office fax number	+47 97 55 74 01
7	Office email address	info@hoeghlng.com
8	Name of Designated Person Ashore (DPA)	Torfinn Jolle
9	After-hours telephone number of DPA	+47 97 55 74 99
10	Emergency callout number	+47 22 57 73 50
11	Emergency callout pager number	
1.2.4	Date current operator assumed technical control of the ship	27 April 2017
1.2.5	Total number of ships operated by this Technical Operator	9
1.2.6	Commercial operator (if different from registered owner)	
1	Name	Hoegh LNG AS
2	Full Address	Drammensveien 134, P.O.Box 4 Skyen, NO-0212 OSLO NORWAY
3	Country	NORWAY
4	Office telephone number	+47 97 55 74 00
5	Office telex number	
6	Office fax number	+47 97 55 74 01
7	Office email address	operation@hoeghlng.com
8	Contact person	Tommy Dahl
9	Contact person after hours telephone	+4797557426

3 Builder

1.3.1	Builder name	Hyundai Heavy Industries CO.,LTD
1.3.2	Date of building contract	03 October 2014
1.3.3	Hull number	2552
1.3.4	Date on which keel was laid or ship was at a similar stage of construction	28 December 2015

1.3.5	Date launched	29 April 2016
1.3.6	Delivery date as recorded in Form A or Form B Q1.8.3 of the IOPPC	27 April 2017
1.3.7	Major hull change	
1	Has a major hull change been undertaken?	No
2	What was the date of completion of the conversion as recorded in Form A or Form B Q1.9.3 of the IOPPC?	
3	List what changes were made	

4 Classification

1.4.1	Classification Society	DNV GL
1.4.2	Class notation	DNV, +1A1, Tanker for Liquefied Gas, Ship type 2G (-163oC, 500kg/m3, 25kPa), FSRU mode 2G(-163oC, 500kg/m3, 70kPa), NAUTICUS(Newbuilding), REGAS-2, E0, NAUT-OC, CLEAN, BIS, CSA-FLS2, PLUS, COAT-PSPC(B), Recyclable, GAS FUELLED, TMON, OPP-F
1.4.3	Change of classification Society	
1	Has Classification Society changed?	No
2	What was the previous Classification Society?	
3	Date of change	
1.4.4	Dry dock	
1	Date of last dry dock	
2	Date of second last dry dock	
3	Date next dry dock due	
1.4.5	Special survey	
1	Date of last special survey	
2	Was last special survey an enhanced special survey	No
3	Date next special survey due	
1.4.6	Condition Assessment Programme	
1	Does the ship have a Condition Assessment Programme (CAP) rating?	No
2	What is the latest rating?	
1.4.7	Date of last annual survey	16 July 2017
1.4.8	Date of last boiler survey	
1	Port boiler	
2	Starboard boiler	
1.4.9	Is the ship subject to a Continuous Machinery Survey	Yes

5 Dimensions

1.5.1	Length overall (LOA)	294.07 Meters
1.5.2	Length between perpendiculars (LBP)	282.00 Meters
1.5.3	Extreme breadth	46.00 Meters

1.5.4	Moulded breadth	46.00 Meters
1.5.5	Moulded depth	26.00 Meters
1.5.6	Keel to masthead	66.27 Meters
1.5.7	Distance bow to bridge	230.25 Meters
1.5.8	Distance bridge front - mid-point manifold	85.67 Meters
1.5.9	Distance bow to mid-point manifold	144.50 Meters
1.5.10	Distance stern to mid-point manifold	149.50 Meters

1.5.11 Parallel mid-body diagram

	Forward to mid-point	Aft to mid-point
Light ship	37.20	55.10
Normal ballast	56.44	76.31
At loaded summer	62.46	82.32

1.5.12	Does ship have a bulbous bow?	Yes

6 Tonnages

1.6.1	Net registered tonnage (NRT)	36793.00 Tonnes
1.6.2	Gross tonnage	110338.00 Tonnes

1.6.3 Suez tonnage

1	Suez tonnage	112970.21 Tonnes
2	Suez Canal Gross Tonnage (SCGT)	112970.21 Tonnes
3	Suez Canal Net Tonnage (SCNT)	99663.05 Tonnes
4	Panama Tonnage	108128.00 Tonnes

7 Loadline Information

1.7.1 Loadline information

	Freeboard	Draft	Deadweight	Displacement
Summer	7.38	12.62	93258.00	128358.00
Winter	7.65	12.36	90256.00	125356.00
Tropical	7.12	12.88	96272.00	131372.00
Lightship	16.14	3.86		35100.00
Normal Ballast Condition	10.74	9.26	56000.00	91100.00
Segregated Ballast Condition	10.74	9.26	56000.00	91100.00

1.7.2	Fresh Water Allowance (FWA) at summer Draft	280.00 Millimetres
1.7.3	Tonnes per Centimetre Immersion (TPC) at Summer Draft	114.41 Tonnes

1.7.4 Normal ballast conditions

	Draft	Freeboard
Forward	9.26	10.74
Aft	9.26	10.74

1.7.5 Multiple deadweights

1	Have multiple deadweights been assigned?	No
2	If yes, what is the maximum assigned?	

8 Recent Operational History

1.8.1	What is the max. height of mast above waterline (air draft) in normal SBT condition?	53.41 Meters
1.8.2	Has the ship traded continuously without requirement for unscheduled repairs since the last dry-dock, except for normal maintenance?	Yes
1.8.3	Unscheduled repairs	
1	Have unscheduled repairs been carried out?	No
2	What was the nature of the repairs?	N/A
1.8.4	Has ship been involved in a pollution incident during the past 12 months?	No
1.8.5	Has ship been involved in a grounding incident during the past 12 months?	No
1.8.6	Has ship been involved in a collision during the past 12 months?	No
1.8.7	If there is additional information relating to features of the ship or operational characteristics that may be of interest, please record details here.	N/A

2 Certificates

1 Certificates

2.1.1	Register number	9762962 / 6888
2.1.2	Does the ship comply with the International Convention for the Control and Management of Ships' Ballast Water and Sediments?	Yes
2.1.3	Type of tanker. If the ship is not an oil tanker specify the type as recorded in Part B Sect 1.11 of the IOPPC	LNGC / FSRU

2.1.4 Certificate dates

	Date issued	Date expires	Last annual	Last intermediate	Date of endorsement
Safety equipment certificate	16 June 2017	27 April 2022			
Safety radio certificate	16 June 2017	27 April 2022			
Safety construction certificate	16 June 2017	27 April 2022			
Loadline certificate	16 June 2017	27 April 2022			
International Oil Pollution Prevention Certificate (IOPPC)	27 June 2017	27 April 2022			
Safety management certificate (SMC)	12 October 2017	27 April 2022			
Document of compliance (DOC)	04 January 2016	01 February 2021			
International ship security certificate	12 October 2017	12 October 2022			
USCG letter of compliance	27 April 2017				

2.1.5	Minimum safe manning document	27 April 2017
2.1.6	Civil Liability Convention Certificate (1992)	27 April 2017
2.1.7	U.S. Certificate of Financial Responsibility	31 March 2017

2.1.8	Certificate of Fitness	
1	Chemicals	
2	Gas	27 April 2017
2.1.9	Noxious Liquids Certificate	
2.1.10	Date of issuance of the Unattended Machinery Space (UMS) Certificate	27 April 2017
2.1.11	Date of issuance of the International Tonnage Certificate	13 February 2017

2 Publications

2.2.1 Publications

	Present
IMO Safety of Life at Sea Convention (SOLAS 74)	Yes
International Life Saving Appliance Code (LSA Code)	Yes
International Code for Fire Safety Systems (FSS Code)	Yes
IMO International Code of Signals (SOLAS V-Reg 21)	Yes
IMO International Convention for the Prevention of Pollution from Ships (MARPOL 73/78)	Yes
IMO Ships Routeing	Yes
IMO International Regulations For Preventing Collisions at Sea (COLREGS)	Yes
IMO Standards of Training, Certification and Watchkeeping (STCW Convention)	Yes
ICS Guide to Helicopter/Ship Operations	Yes
OCIMF/ICS/IAPH International Safety Guide for Oil Tankers and Terminals (ISGOTT)	Yes
OCIMF/ICS Ship to Ship Transfer Guide (Petroleum)	Yes
OCIMF Recommendations for Oil Tanker Manifolds and Associated Equipment	No
OCIMF Mooring Equipment Guidelines	Yes
OCIMF Effective Mooring	Yes
Guidance Manual for tanker structures	Yes
Recommendations for equipment employed in the bow mooring of ships at SPM moorings	No
Anchoring Systems and Procedures	Yes
USCG Regulations for Tankers (USCG 33 CFR/46 CFR)	No
International Safety Management Code (ISM Code)	No
Oil Transfer Procedures (USCG 33 CFR 155-156)	No
Operator's ISM Manuals	Yes
Is the publication IMO-Inert Gas Systems, or Ship Technical Operator's equivalent manual on board?	Yes
Is the publication IMO-Cow Systems, or Ship Technical Operator's equivalent manual on board?	No
ICS Bridge Procedures Guide	Yes
IAMSAR Vol.3	Yes
Nautical Institute Bridge Team Management	Yes

International Medical Guide for Ships(or equivalent)	Yes
ISPS Code	Yes
Guidelines for the control of Drugs and alcohol on board ships	Yes
Guidelines on Fatigue	Yes
IMO Code for Construction & Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code)	Yes
IMO Index of Dangerous Chemicals Carried in Bulk	No
ICS Tanker Safety Guide (Chemicals)	No
IMO Code for Construction & Equipment of Ships Carrying Dangerous Chemicals in Bulk (BCH Code)	No
Chemical Data Guide (USCG 1990 CIM 16616.6A)	No
Medical First Aid Guide for Use in Accidents involving Dangerous goods (MFAG)	Yes
Procedures and Arrangements (P&A) Manual	No
IMO Code for Construction & Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)	Yes
ICS Tanker Safety Guide (Liquefied Gas)	Yes
SIGTTO Liquefied Gas Handling Principles on Ships and in Terminals	Yes
SIGTTO Guide to Pressure Relief Valve Maintenance and Testing	Yes
ICS Ship to Ship Transfer Guide (Liquefied Gases)	Yes
IMO International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)	Yes
IMO Code for Existing Ships Carrying Liquefied Gases in Bulk (EGC Code)	Yes

3 Publications - Gas tanker specific

2.3.1 Publications - Gas tanker specific

	Present
Liquefied petroleum gas sampling procedures	No
Manifold recommendations for liquefied gas carriers	Yes

3 Crew

1 Crew Management

3.1.1 Number of Officers on board

1	What is the minimum number of officers to be carried as recorded in the Minimum Safe Manning Document?	8
2	What is the actual number of officers on board?	12

3.1.2 Crew employment by the Ship Operator

1	Is the Master employed by the Ship Operator?	Yes
2	Are the officers employed by the Ship Operator?	Yes
3	Are the ratings employed by the Ship Operator?	No

3.1.3	What is the common language used on the Ship?	English
3.1.4	Manning agent for Officers	
1	Name	Zorovic Maritime Services Ltd
2	Full address	Trpimirova 2/XI, 51000 Rijeka, Croatia Tel: +385 51 345 664 Email: Natasa.Sirola@zorovic.hr
3	Office telephone number	+385 51 34 56 64
4	Office telex number	
5	Office fax number	
6	Office email address	natasa.sirola@zorovic.hr
3.1.5	Manning agents	
1	Are manning agent(s) wholly or partially owned by Operator?	No
2	If No, does Operator have selection rights?	Yes
3.1.6	Does the Operator maintain personnel files on officers assigned to its vessels?	Yes
3.1.7	What is the retention rate for officers for the past 3 years?	97.80 Percent
3.1.8	Ratings on board	
1	What is the minimum number of ratings to be carried as specified in the Minimum Safe Manning Document?	7
2	What is the actual number of ratings on board?	17
3	List nationality of ratings	Filipino
3.1.9	Manning agent for Ratings (if different to Officers)	
1	Name	Hoegh Fleet Services Inc, Philippines
2	Full address	Hoegh Building 4677 Arellano Str, Palanan Makati City Philippines
3	Office telephone number	+63 25 51 85 92
4	Office telex number	
5	Office fax number	+63 25 51 86 98
6	Office email address	crewops.hfsp@hoegh.com
3.1.10	Does the Operator maintain personnel files on ratings assigned to its ships?	Yes
3.1.11	What is the retention rate for ratings for the past 3 years?	86.30 Percent

2 Continuity

3.2.1	Do senior officers return to the same ship on a rotational basis?	Yes
3.2.2	Are senior officers rotated on ships of similar class within company fleet?	Yes
3.2.3	Are junior officers and ratings rotated on ships of similar class within company fleet?	Yes
3.2.4	If senior officers do not return to same ship on a rotational basis, are changes of Master, Chief Officer and Second Engineer organised to avoid a full change of officers at same time?	Yes

3 Training

3.3.1	List Operator sponsored training courses available:	
1	To officers (Bridge Management etc.)	Medical - First Aid, Advanced Fire Fighting, AMOS Maintenance Program, ARPA, Assessor Course, MOB and Lifeboat, ECDIS, LNG Sim Course, GMDSS, ISM, MARPOL Annex I and II, Paint Courses, Intro to HFS SMS system, Shiphandling, PEC - Bridge Management, Regas
2	To ratings (Fire Fighting etc.)	Basic Safety, Fire Fighting for Tanker, General Tanker Fam., IMDG-courses, Nav. watch, Welding Courses, PEC- courses
3.3.2	Are Masters and Chief Engineers required to attend company office before and after each tour of duty?	No
3.3.3	Does operator hold regular training seminars ashore for officers?	Yes
3.3.4	Are training seminars provided on board for officers and ratings?	Yes
3.3.5	What courses, exceeding statutory requirements, are provided:	
1	For senior officers	Medical - First Aid, Advanced Fire Fighting, AMOS Maintenance Program, ARPA, Assessor Course, MOB and Lifeboat, ECDIS, LNG Sim Course, GMDSS, ISM, MARPOL Annex I and II, Paint Courses, Intro to HFS SMS system, Shiphandling, PEC -
2	For junior officers	Medical - First Aid, Advanced Fire Fighting, AMOS Maintenance Program, ARPA, Assessor Course, MOB and Lifeboat, ECDIS, LNG Sim Course, GMDSS, ISM, MARPOL Annex I and II, Paint Courses, Intro to HFS SMS system, Shiphandling, PEC -
3	For ratings	Basic Safety, Fire Fighting for Tanker, General Tanker Fam., IMDG-courses, Nav. watch, Welding Courses, PEC- courses

4 Navigation

1 Navigation

4.1.1 Navigation equipment

	Installed	Type	Number installed
Magnetic compass	Yes	Saura Keiki Model: SR-165	1
Gyro compass	Yes	Yokogawa type CMZ900D	2
Gyro autopilot	Yes	Yokogawa type PT500A-K-K2T	2
Radar 1	Yes	Furuno type FAR-3320	1
Radar 2	Yes	Furuno type FAR- 3330	1
Radar plotting equipment	Yes	Furuno	2
ARPA	Yes	Furuno S-band and X-band	2

Depth sounder with recorder	Yes	Furuno FE-700 with recorderFuruno PP-505	1
Speed/distance indicator	Yes	Furuno type DS-60	1
Doppler log	Yes	Furuno type DS-60	1
Docking approach Doppler	Yes	Furuno type DS-60	1
Rudder angle indicator	Yes	Daeyang type FL-200	3
RPM indicator	Yes	Converteam	4
Controllable pitch propeller indicator	No	N/A	0
Bow thruster indicator	No	N/A	0
Stern thrust indicator	No	N/A	0
Rate of turn indicator	Yes	Yokogawa, MKR302	3
Navtex indicator	Yes	Furuno type NX-700A	1
Global positioning system (GPS)	Yes	Furuno type GP-170	2
Differential GPS	Yes	Furuno type GP-150-dual	2
Electronic Charts Display and Information System (ECDIS)	Yes	Furuno FMD-3300	3
Course Recorder	Yes	Yokogawa MKR 181A	1
Integrated Navigation System (INS)	Yes	Furuno type FMD-3200/3200-BB/3300	3
Off-course Alarm - Gyro	Yes	Yokogawa PT500A	2
Off-course Alarm - Magnetic	Yes	Yokogawa PT500A	1
Engine Order Logger	Yes	Oki Micronet 3320	1
Anenometer	Yes	Daeyang	1
Weather fax	Yes	Navtor	1

4.1.2	Is a repeating magnetic compass fitted?	No
4.1.3	Is there at least one radar operating in the 9 GHz frequency band (3cm/x band)?	Yes
4.1.4	Are the 3 GHz (10cm/S band) and 9Ghz (3cm / X band) radars fitted with an electronic switching unit?	Yes
4.1.5	Are the Radars fitted with ARPA?	Yes
4.1.6	Is the ECDIS an approved system?	Yes
4.1.7	Does ship carry sextant(s)?	Yes
4.1.8	Does ship carry a signal lamp?	Yes
4.1.9	Is each bridge wing fitted with:	
1	Rudder angle indicator	Yes
2	RPM indicator	Yes
3	Gyro repeater	Yes
4.1.10	If the ship is fitted with a controllable pitch propeller, are indicators fitted on the bridge wings?	No
4.1.11	Are steering controls and engine controls fitted on bridge wings?	Yes
4.1.12	Is a Bridge Watch Navigation Alarm (BWNAS) system fitted?	Yes

5 Safety

1 Safety Management

5.1.1	Quality management system:	
1	Is the ship operated under a Quality management system?	Yes
2	If Yes, what type of system? (ISO9002 or IMO Resolution A.741(18))?	ISO9001:2015, 14001-2015
3	If Yes, who is the certifying authority?	DNV-GL
4	Date of the ship's certification	12 October 2017

2 Helicopters

5.2.1	ICS Guide to Helicopter/Ship Operations	
1	Does the ship comply with the ICS Guide to Helicopter/Ship Operations?	Yes
2	If yes, state whether winching or landing area provided	Winching
3	If yes, what is the diameter of the circle provided	31.62

3 Firefighting and Lifesaving equipment

5.3.1	Fixed foam firefighting	
1	Is a fixed foam firefighting system installed for the cargo area?	No
2	If yes, what is the type of foam?	
3	What was the date of supply of the foam, or the date of the last Test Analysis Certificate?	
5.3.2	What type of fixed firefighting system is provided for:	
1	The paint locker?	CO2 / Water
2	The pump room?	
3	The engine room?	CO2, water mist
4	The void spaces?	
5.3.3	Is a fixed dry powder firefighting system installed for the cargo area?	Yes
5.3.4	Is a fixed water spray firefighting system installed for the cargo area?	Yes
5.3.5	Is the ship equipped with a compressor for recharging breathing apparatus air cylinders?	Yes
5.3.6	What type of lifeboat(s) is/are fitted?	Freefall
5.3.7	Dedicated rescue boats	
1	Is a dedicated rescue boat provided?	Yes
2	If a dedicated rescue boat is carried, what is its construction?	Rigid

6 Pollution Prevention

1 Pollution Prevention

6.1.1	Continuous deck edge fishplate	
1	Is ship fitted with a continuous deck edge fishplate enclosing the deck area?	Yes

2	If Yes, what is its minimum vertical height above the deck plating?	150.00
3	What is maximum vertical height above deck plating at the position where the fish plate adjoins the aft thwartships coaming?	150.00
4	How far forward of the athwartships coaming is this height maintained?	253.72
5	Is an athwartship deck coaming fitted adjacent to accommodation and service areas?	Yes
6	What is the height of the coaming?	150.00
6.1.2	Is spill containment fitted	
1	Under the cargo manifold?	Yes
2	Under all bunker manifolds?	Yes
3	Under the bunker tank vents?	Yes
4	Around the deck machinery?	Yes
6.1.3	What type of scupper plugs are provided?	Rubber
6.1.4	Preventing spill out entering the sea	
1	Are means provided to prevent spilled oil entering the sea?	Yes
2	If yes, what means are provided?	Coamings, Fish Plates, Scupper plugs and SOPEP Equipment
6.1.5	Is the following pollution control equipment available to clean up oil spilled on deck:	
1	Sorbents	Yes
2	Non-sparking hand scoops/shovels	Yes
3	Containers	Yes
4	Emulsifiers	Yes
5	Non-sparking pumps	Yes
6.1.6	Is the cargo piping system fully segregated from the sea chest?	Yes
6.1.7	What type of sea valves are fitted?	N/A
6.1.8	Pre-MARPOL tankers	
1	Is the ship a pre-MARPOL tanker?	No
2	If yes, is a cargo sea chest valve testing arrangement fitted which meets OCIMF recommendations?	
6.1.9	Are dump valves fitted to the slop tanks which will operate with normal inert gas pressure in the tank vapour space?	No
6.1.10	Are overboard discharges fitted with blanks or alternatively, is there a testing arrangement for the overboard valves?	No
6.1.11	Is there a discharge below the waterline for Annex II substances	No
6.1.12	Is there a discharge above the waterline for Annex I oily mixtures	No
6.1.13	Cargo piping pressure tests:	
1	On oil and chemical tankers, does the Operator have a policy to pressure test cargo piping at intervals no greater than 12 months?	No
2	If yes, specify pressure	
6.1.14	Bunker piping pressure tests:	
1	Does Operator have policy to pressure test bunker piping at intervals no greater than 12 months?	Yes

2	If yes, specify pressure	5.00 Bar
6.1.15	Is garbage incinerator fitted?	Yes

2 OPA 90 Requirements

6.2.1	Has the Operator submitted a Vessel Spill Response Plan to the US Coast Guard which has been approved by official USCG letter?	Yes
6.2.2	Has a Geographic Specific Appendix been filed with the Captain of the Port for each Port Zone the ship expects to enter or transit?	Yes
6.2.3	Has the Operator deposited a letter with the US Coast Guard confirming that the Operator has signed a service contract with an oil spill removal organisation for responding to a 'worst case scenario'?	Yes

7 Structural Condition

1 Structural Condition

7.1.1	Cargo tank coating	
1	Are cargo tanks coated?	No
2	If yes, specify type of coating	
3	If all tanks are not coated, specify those tanks which are not coated	
4	If cargo tanks are coated, specify to what extent	
5	What is the condition of coating?	
7.1.2	Ballast tank coating	
1	Are ballast tanks coated?	Yes
2	If yes, specify type of coating	Intershield 300
3	If yes, specify to what extent	Whole Tank
4	What is the condition of the ballast tank coating?	Good
7.1.3	Tank anodes	
1	Are anodes fitted to the cargo tanks?	No
2	Are anodes fitted to the ballast banks?	Yes
3	What type of anodes are fitted	Zink
4	What is the extent of wastage of the anodes in the cargo tanks	
5	What is the extent of wastage of the anodes in the ballast tanks	0.00
6	If anodes are aluminium, what is the height above tank bottom?	
7.1.4	Is a formal programme in place for regular inspection of void spaces, cargo and ballast tanks?	Yes
7.1.5	Planned Prevention Maintenance Programme	
1	Does ship have planned prevention maintenance programme (PPM)?	Yes
2	Is PPM manual (card system) or computerised?	Computerised
3	What areas of the ship does the PPM cover?	All Ship
4	If the PPM is Class-approved, what is the Class notation?	BIS

8 Cargo

1 Ballast Tanks

8.1.1 Ballast capacities at 100% full (M3)

Tank Number	Identity	Capacity	(Cu Meters)
1	Fwd WB tank (C)	4048.30	
8	No 4 WB tank (S)	5822.70	
3	No 1 WB tank (P)	5857.80	
5	No 2 WB tank (P)	5973.90	
4	No 2 WB tank (S)	5973.90	
9	No 4 WB tank (P)	5822.70	
6	No 3 WB tank (S)	6164.10	
2	No 1 WB tank (S)	5857.80	
7	No 3 WB tank (P)	6164.10	
10	APT	1813.10	

8.1.2 Total Ballast Tank Capacities at 100% full 53498.40 Cu Meters

2 Ballast Handling

8.2.1 Ballast Handling Data

	Number	Type	Type of prime mover	Capacity	At what head?
Main Pump	3	Centrifugal	Electric	2600	35
Stripping	2	Centrifugal	Electric	400	35
Eductors	2	Other	Other	300	

8.2.2 Ballast handling Main Pump

1	Normal back pressure	2.00
2	Max RPM	1190.00

8.2.3 Bunker connections

1	What is the number of bunker connections per side?	2
2	What is the size of the bunker connection?	201.00

9 Cargo Specific

90 General

9.90.1	Type of Cargo tank Containment System	Mark III Reinforced

9.90.2 Propulsion Type

1	What is the Propulsion Type	Dual Fuel HFO / Diesel Electric Driven Wartsila -Hyundai/Converteam
2	If other, then specify	

91 Transport and Carriage Conditions

9.91.1 What is the designed natural boil-off rate for fully laden condition?

1	By value	10.60 Cu Meters/Hour

2	By percentage of NBOG	0.15 Percentage NBOG

9.91.2 What are the means for handling boil-off gas?

	Means	Designed capacity (Cu Meters/Hour)
Primary	GCU	10.6 m3/h

9.91.3	Material of construction of cargo piping system	Stainless Steel
9.91.4	Filters	
1	Is cargo system fitted with filters	Yes
2	State which cargo piping system is fitted with filters	Manifold strainers
3	If yes, can cargo filters be by-passed or removed	Yes
9.91.5	What expansion arrangements are fitted?	
1	To cargo liquid lines	Anchor, Single acting support, double acting support
2	To cargo vapour lines	Expansion bellow
3	To cargo gas fuel	Expansion bellow
9.91.6	Line protection	
1	Are liquid lines protected from overpressure?	Yes
2	Liquid lines relief valves set pressure	10.00 Bar
3	Vapour lines relief valves set pressure	10.00 Bar
4	Where do LNG lines relief valve vent to?	Cargo tank

92 Cargo tanks

9.92.1	Tank type	
1	Type of cargo tanks	2G membrane
2	If Independent then Type	
9.92.2	What is the minimum design tank temperature?	-163.00
9.92.3	Design tank pressure	
1	What is the minimum design tank pressure?	-1.00
2	What is the maximum design tank pressure?	70.00
9.92.4	Maximum cargo specific gravity	500.00
9.92.5	Maximum rate of cool down of cargo tanks	10
9.92.6	State any limitations regarding partially filled cargo tanks	Not allowable between 2.75 m and 70% of tank height
9.92.7	State allowable combinations of filled and empty cargo tanks	No limitation
9.92.8	Membrane materials	
1	Primary membrane material	Stainless steel 304L
2	Secondary membrane material	Triplex
9.92.9	Moss tanks	
1	Tank construction material	
2	Is secondary barrier available?	
3	Type of secondary barrier	

4	Secondary barrier / drip pan material	
9.92.10	Are interbarrier spaces/ Insulation spaces inerted?	Yes
9.92.11	Inerting medium	Nitrogen

93 Cargo tank capacities

9.93.1 Cargo tank capacities

Tank number	Capacity (100%) at specified temp (Cu Meters)	Specified temperature (Deg C)	Capacity at max permissible filling limit (Cu Meters)	Lower sloshing limit (Cu Meters)	Upper sloshing limit (Cu Meters)
3	47867.64	-163.00	47149.62	4513.50	35562.39
4	47842.01	-163.00	47124.37	4512.17	35533.83
2	47854.27	-163.00	47136.45	4511.44	35566.06
1	26544.65	-163.00	26146.48	2100.37	18207.00

9.93.2	Total Capacity of all tanks (100%) at reference temperature	170108.57 Cu Meters

94 Cargo sampling

9.94.1	Indicate whether cargo samples may be obtained from the levels specified?	
1	Tank top level	No
2	Tank middle level	No
3	Tank bottom level	No
9.94.2	Can samples be drawn from tank vapour outlet?	Yes
9.94.3	Can samples be drawn from manifold vapour line?	Yes
9.94.4	Connection type/size	
1	State sample connection type	F type
2	State sample connection size	15a

95 Cargo tank protection

9.95.1	Tank relief valves	
1	Number of cargo tank relief valves per cargo tank	2
2	Maximum allowable relief valve set pressure	700.00 Mbar
3	Normal allowable relief valve set pressure (Moss)	250.00 Mbar
4	Vacuum set pressure of relief valve	-10.00 Mbar
5	Flow rate of individual relief valve	54560.00 Nm3/Hour
6	Where does the tank cargo relief valves vent to?	Dedicated vent mast
7	Are snuffers available in vent masts?	Yes
8	Is gas detection available in vent masts?	Yes
9.95.2	Common tanks venting system	
1	What means of common tanks venting systems is available?	Vent mast
2	Maximum venting capacity	12000.00 Nm3/Hour
3	Set pressure of mast riser	250.00 Mbar

9.95.3 Relief valves

	Number of valves per tank/hold	Set pressure (Mbar)	Min pressure (Mbar)	Vacuum set pressure (Mbar)	Flow rate (Nm3/Hour)
Interbarrier space relief	2	30.00	10.80	-800.00	540.00
Insulation space relief	2	35.00	10.40	-800.00	544.00
Hold relief	2	750.00	30.00	-10.00	25570.00

96 Inner hull protection

9.96.1 Cofferdam heating

1	Is cofferdam heating available?	Yes
2	Heating medium for cofferdam heating	Glycol
3	If other, then specify	

9.96.2 Is Inner hull temperature detection system available? Yes

97 Insulation spaces humidity detection

9.97.1 Insulation spaces water/humidity detection available? Yes

9.97.2 Insulation spaces water removal

1	Are means of water removal from Insulation spaces available?	Yes
2	If yes, then specify	Air driven pump

98 Interbarrier spaces

9.98.1 Interbarrier spaces LNG drainage

1	Is Interbarrier spaces LNG drainage system available?	Yes
2	If yes, then specify	By purging and LD compressor

99 Loading operations

9.99.1 Tank temperature criteria to commence full load -130

9.99.2 Typical ships liquid line cool down duration? 1.00 Hours

9.99.3 Is the vessel capable of cooling down ships liquid lines prior arrival load port? Yes

9.99.4 Loading rates/duration

	Maximum loading rate (Cu Meters/Hour)	Typical loading duration (Cu Meters/Hour)
With vapour return	10000.00	17.00

100 Discharging operations

9.100.1 Discharging rates/duration

	Maximum discharging rate (Cu Meters/Hour)	Typical time to discharge fully laden ship (Cu Meters/Hour)	Time to heel out (Cu Meters/Hour)
With vapour return	10000.00	21.00	24.00

9.100.2 Ship maximum discharging rate 10000.00 Cu Meters/Hour

9.100.3 Full Cargo Discharge Times (using all main pumps)

	Back Press 1 kP/cm2 (Hours)	Back Press 5 kP/cm2 (Hours)
With vapour return	17.00	21.00
Without vapour return	17.00	21.00

9.100.4 Emergency discharge

1	Is there an emergency discharge method available?	Yes
2	If yes, method of discharge	STS, Cargo Jettison
3	If other, then specify	

9.100.5 Maximum Pressure at Manifold 5.00 Bar

9.100.6 Counters fitted

	Counter fitted	Type
Gas to shore	Yes	wortex
Gas from shore	Yes	wortex
Gas to engine	Yes	wortex

101 Unpumpables

9.101.1 Unpumpables

Tank Number	Unpumpables (Cu Meters)
2	270.00
3	270.00
1	80.00
4	270.00

9.101.2 Total unpumpables 890.00 Cu Meters

102 Vapourizing unpumpables

9.102.1 Time to vaporize liquid unpumpables remaining after full cargo discharge 72.00 Hours

103 Pre refit cargo operations

9.103.1 Time required to warm up cargo tanks till the temperature of coldest point of Insulation space of each tank reaches + 5 deg C in membrane ships OR in Moss when the equator profile and tank bottom shel 42.00 Hours

9.103.2 Gas freeing

1	Time required to gas free to less than 2% Hydrocarbon by volume by displacement method?	21.00 Hours
2	Time required to gas free to less than 2% Hydrocarbon by volume by dilution method?	
3	Plant Used	Inertgas plant
4	If other, specify plant	

9.103.3 Time taken to aerate all cargo Tanks, cargo piping and cargo machinery from inerted condition till Oxygen is above 20% by Volume, CO2 less then 0.5%, CO less than 50ppm and dew point less than -40 de 21.00 Hours

104 Post refit cargo operations

9.104.1	Drying cargo tanks		
	1	Time taken to dry cargo tanks, piping and machinery till dew point is reduced to -20 deg C or lower?	20.00 Hours
	2	Plant used	Inert gas plant (dry air)
	3	If other, specifify plant	
9.104.2	Inerting cargo tanks		
	1	Time taken to inert cargo tanks, piping and machinery till Oxygen content is below 2% by volume and dew point below -40 deg C?	20.00 Hours
	2	Plant used	Inert gas plant
	3	If other, specifify plant	
9.104.3	Gassing-up		
	1	Time taken to gas up cargo tanks, piping and machinery till Hydrocarbon at tank tops, cargo piping and machinery exceed 95% by volume and CO2 content reduced to less then 1% by volume)?	20.00 Hours
	2	Volume of LNG required to gas up?	950.00 Cu Meters
9.104.4	Cooling Down		
	1	Time required to cool down cargo tanks from ambient temperature with vapour return line	10.00 Hours
	2	What is the ambient temperature	20.00 Deg C
	3	Cool Down Volume of LNG required (from ambient and after gassing up)	800.00 Cu Meters
	4	Time required to cool down cargo tanks from ambient temperature without vapour return line	
	5	Cool Down Volume of LNG required (from ambient)	

105 Cargo machinery

9.105.1	Is there a cargo compressor room?		Yes
9.105.2	Is there a separate Electric motor room?		Yes
9.105.3	Main cargo pumps		
	1	Type of main cargo pumps	Submerged
	2	Number of main cargo pumps per tank	2
	3	Total number of main cargo pumps	8
	4	Rated Flow	1000.00 Cu Meters/Hour
	5	At Delivery Head	160.00 Meters
	6	Maximum density	0.50 KH/Cu M
	7	Minimum Flow	400.00 Cu Meters/Hour
	8	Rated motor power	350.00 KW
	9	Motor restarting limilations (Starts per hour, delay)	
9.105.4	Stripping/spray pumps		
	1	Type of stripping/spray cargo pumps	Electrical motor driven, Vertical, Centrifugal, Submerged
	2	Number of stripping/spray cargo pumps per tank	1

3	Rated Flow	50.00 Cu Meters/Hour
4	At Delivery Head	145.00 Meters
5	Maximum density	0.50 KH/Cu M
6	Minimum Flow	20.00 Cu Meters/Hour
9.105.5	Emergency cargo pump	
1	Type of emergency cargo pumps	Regas Feed Pump
2	Location where emergency pump is kept?	Each Cargotank
3	Rated Flow	550.00 Cu Meters/Hour
4	At Delivery Head	160.00 Meters
5	Maximum density	500.00 KH/Cu M
6	Minimum Flow	220.00 Cu Meters/Hour
9.105.6	Fuel gas pump	
1	Number of fuel gas pumps	
2	Installed location (for example Cargo tank 3/4)	
3	Rated Flow	
4	At Delivery Head	
9.105.7	Gas compressors - high duty	
1	Number of High Duty compressors (Also referred to as Vapour Retur (VR) compressors on some ships)	2
2	Type of compressor	High Duty Compressors, Cryostar SA
3	Prime mover type	single speed ,asyncrhronous - 3 phase
4	If other, then specify	
5	Rated motor power	930.00 KW
6	Rated volumetric Capacity	32000.00 Cu Meters/Hour
7	Delivery pressure	196.00 Bar
9.105.8	Gas compressors - low duty	
1	Number of Low Duty compressor (Also referred to as Fuel Gas (FG) compressors on some ships)	3
2	Type of compressor	Low Duty compressors, Cryostar
3	Prime mover type	Centrifugal , two stage,dual speed , variable vanes
4	If other, then specify	
5	Rated motor power	710.00 KW
6	Rated volumetric Capacity	4400.00 Cu Meters/Hour
7	Delivery pressure	6.50 Bar
9.105.9	Vacuum pumps	
1	Number	1
2	Gas handling	
3	Designed vacuum capacity	345.00 Mbar
9.105.10	Vaporiser	
1	Number	1
2	Maximum heat exchange capacity	22000.00 KW

3	Heating medium of LNG vaporiser	steam
9.105.11	Forcing vaporiser	
1	Number	1
2	Rated capacity	4000
3	Heating medium of forced vaporiser	steam

9.105.12 Cargo heaters

	Number	Type	Heating medium	Maximum heating capacity (KW)
High duty cargo heater	1	Cryostar108-UT	steam	4535.00
Low duty cargo heater	0			

106 Inert gas

9.106.1	Does inert gas piping pass through accommodation spaces, service spaces or control stations?	No
9.106.2	Can the Inert Gas System be fully segregated from the cargo system where it is not needed?	Yes
9.106.3	Source of inert gas for tank-change over/preparation for Refit?	
9.106.4	Type of system fitted	Wartsila Moss Inert Gas Generator , type Moss high Turbulent
9.106.5	Capacities	
1	Capacity IG	16000.00 Cu Meters/Hour
2	Capacity air	16000.00 Cu Meters/Hour
9.106.6	Type of fuel used	MGO
9.106.7	Discharge Pressure	25.00 Bar
9.106.8	Composition of IG	
1	Oxygen	2.00 Perc by vol.
2	CO2	19.00 Perc by vol.
3	CO	100.00 PPM
4	Sox	10.00 PPM
5	N2	78.00 Perc by vol.
9.106.9	Lowest dewpoint achievable	-45.00 Deg C

107 Nitrogen generating plant

9.107.1	Type of System Nitrogen	Air Products Prism
9.107.2	Number of N2 generating systems?	2
9.107.3	Capacity	125.00 Cu Meters/Hour
9.107.4	Working pressure of N2 system	8.00 Bar
9.107.5	Outlet Oxygen content	3.00 Percent
9.107.6	Outlet N2 content	97.00 Percent
9.107.7	Lowest dewpoint achievable	-70.00 Deg C

108 Liquid nitrogen storage

9.108.1	Does vessel have Nitrogen storage capacity?	No
9.108.2	Liquid Nitrogen storage capacity	0.00 Cu Meters
9.108.3	Daily boil-off loss	
9.108.4	Maximum supply pressure	
9.108.5	Supply capacity	

109 Reliquifaction plant - General

9.109.1	Is electric motor room separate to compressor house?	
9.109.2	If electric motors fitted in Compressor house are the motors Ex rated?	
9.109.3	Is an Air-lock fitted for the electric motor room?	
9.109.4	Is the reliquefaction plant designed to trip in case of failure of positive pressure in Air-lock space?	
9.109.5	Delay for trip of Re-liq Plant?	
9.109.6	Can reliquefaction plant be operated concurrent with loading?	
9.109.7	Can reliquefaction plant be operated concurrent with discharging?	
9.109.8	What is the time needed for reliq plant to reach 'idle' condition?	
9.109.9	Time needed to reach full load condition from Idle	
9.109.10	Partial load operation restriction on reliquefaction plant	
1	Any partial load operation restriction on reliquefaction plant?	
2	If Yes, then specify	
9.109.11	Time needed to bring back Reliq plant to IDLE	
1	Time needed to bring back Reliq plant to IDLE after trip under IDLE condition?	
2	Time needed to bring back Reliq plant to IDLE after trip under Full load condition?	
9.109.12	Joint use of Re-liq plant and CGU	
1	Can Re-liq plant and GCU be used concurrently?	
2	Is there any other means of tank pressure control if reliq plant and GCU are not operational?	
3	If Yes, then specify	
9.109.13	Are gas detection sensors installed in Compressor house steam condensate returns?	
9.109.14	High voltage electric motors	
1	Are high voltage electric motors used?	
2	If Yes, specify voltage	
9.109.15	Are low insulation detectors/alarms available for high voltage cargo equipment?	
9.109.16	Oxygen sensors in compressor house	
1	Are Oxygen sensor installed in compressor house?	

2 Are Oxygen readings indication available outside compressor house entry points?

3 Are gas sensors installed in compressor house?

4 Are gas readings indication available outside compressor house entry points?

9.109.17 Compressor room/electric motor room fire protection system

1 Is a compressor room/electric motor room fire protection system available?

2 If Yes, which system is available?

9.109.18 Emergency manual trips for Re-liq plant

1 Are emergency manual trips for the Re-liq plant available?

2 If Yes, location of trips?

9.109.19 What protection is in place to prevent high level/overfilling situation in the tanks due to re liq returns?

110 Reliquifaction plant - Machinery

9.110.1 Plant design conditions

1 Air temperature

2 Sea temperature

9.110.2 Compander

1 Number of Companders

2 Coolant type

3 Compressor Maker/Type

4 Is compander multi staged

5 Number of compander stages

6 Motor Rated Duty

7 If more than one system is fitted, are they fully redundant?

8 If no, then specify

9.110.3 BOG Compressor

1 Number

2 Type of compressor

3 Prime mover type

4 If other, then specify

5 Rated motor power, if applicable

6 Rated Capacity (Mass flow)

7 Delivery pressure

9.110.4 BOG Condenser

1 Coolant Medium

2 Design heat transfer

3 Vapour flow rate

4 Coolant

9.110.5 BOG Heater

1 Numbers

2 Max heat transfer

3	Heating medium	
9.110.6	BOG high duty heater	
1	Numbers	
2	Max heat transfer	
3	Heating medium	
9.110.7	LNG Transfer pump	
1	Numbers	
2	Flow rate	
9.110.8	LNG Flash drum	
1	Number	
2	Maximum pressure	
3	Minimum temperature	
4	Designed heat transfer	
9.110.9	Counter Current Heat Exchanger	
1	Coolant	
2	Heat transfer	
9.110.10	Nitrogen Booster Compressor	
1	Number	
2	Rated capacity	

111 Reliquifaction plant - Gas Combustion Unit

9.111.1	Make of Equipment	
9.111.2	Designed Gas burning Capacity (BOG compressor running)	
9.111.3	Can GCU run in free flow?	
9.111.4	Designed Gas burning Capacity (Freeflow)	
9.111.5	Designed Gas burning waste gas flow	
9.111.6	Support oil	
1	Support oil type?	
2	Support oil flow rate?	
9.111.7	Start up of main burner	
1	Time for Main burner to start from stopped condition	
2	Time for Main burner to start after trip	
9.111.8	Gas to GCU counter	
1	Gas to GCU counter fitted	
2	Type	

112 Manifold - General

9.112.1	Manifold flanges are in accordance with BS 1560/ANSI B16.5	Yes
9.112.2	Number of Cargo liquid connections at each Manifold	4

9.112.3	Number of Vapour line connections at each manifold	1
9.112.4	Are ESD valves manually operable?	Yes
9.112.5	Is manually operated double shut off valve provided for each manifold ESD valve?	Yes
9.112.6	Are liquid drains fitted at cargo piping at Manifolds?	No
9.112.7	Are purge points fitted at cargo piping at Manifolds?	Yes
9.112.8	Are local pressure gauges fitted outboard of the manifold valves?	Yes
9.112.9	Is a temperature sensor fitted at or near the manifold?	Yes
9.112.10	Stern and bow manifolds	
1	Is vessel fitted with a stern manifold?	No
2	If stern manifold fitted, state size	
3	Is vessel fitted with a bow manifold?	No
4	If bow manifold fitted, state size	
9.112.11	Does ships presentation flange conform to ASME/ANSI B16.5, Class 150?	Yes
9.112.12	Does vessel utilise distance pieces at manifold?	Yes
9.112.13	Are distance pieces welded to manifold valve?	No
9.112.14	Are manifold blanks available and rated to same pressure as presentation flange?	Yes
9.112.15	Does vessel utilise manifold cargo strainers	Yes
9.112.16	Bunker connections	
1	Number of bunker connections available on the manifold?	2
2	Are same bunker connections available on both sides?	Yes
3	Is segregated drip tray available for bunkers?	Yes
4	Does capacity and specification meet IMO and USCG recommendations/requirements?	Yes
9.112.17	Is lighting in the Manifold Area adequate? (Minimum intensity of 70 Lux)	Yes
9.112.18	Vapour and liquid cargo line centrelines	
1	Are vapour and liquid cargo line centrelines marked on manifold gratings?	No
2	Are vapour and liquid cargo line centrelines marked on manifold hand-rails?	Yes
9.112.19	Gutter plate	
1	Is a Gutter plate installed at Manifold	No
2	Height of Gutter Plate	
9.112.20	Height of Shipside Rails at Manifold Drip tray	1000.00 Millimetres
9.112.21	Obstructions and inclinations	
1	There are no obstructions from 1 metre forward of the forward most liquid line to 1 metre aft of the after most liquid line outward of the manifold to shipside	No
2	Describe if any	
3	Are there any obstructions between railing stanchions and manifold platform?	No
4	If any, are the obstructions removable?	No

5	Is there any inclination between ship's manifold and manifold platform?	No
6	If any, state degree of Inclination	

9.112.22	Is a water deluge system installed to protect ship's hull?	Yes

9.112.23	Service lines	
1	Are air service lines on manifolds clearly marked?	Yes
2	Are nitrogen service lines on manifolds clearly marked?	Yes
3	Are fresh water service lines on manifolds clearly marked?	Yes

9.112.24	Cargo operations	
1	Are there provisions for cordoning off the manifold area during cargo operation?	Yes
2	Are there provisions for remote monitoring of cargo manifold pressures during cargo operation?	Yes
3	Are there provision for remote monitoring of differential pressures across the manifold strainers during cargo operation?	Yes

9.112.25	STS	
1	If involved in STS, Is a water deluge system is installed under drip tray?	Yes
2	If involved in STS, are temporary means of holding water under the manifold drip-tray available?	Yes
3	If involved in STS, are centreline of liquid and vapour lines marked on manifold gratings?	Yes

113 Manifold - Connections

9.113.1 Pipe flanges

Pipe flange	Duty	Rating (Bar)	Face size (Inches)	Thickness (Millimetres)	Face	Distance to neighbour (Millimetres)
A,B,D,E	Liquid	10.00	16.00	38.00	NA	3000.00
C	Vapour	10.00	16.00	38.00	NA	3000.00

9.113.2 Dimensions DD1 to DD7

1	Vertical height of cargo manifold centre above Keel (DD1)	31152.00 Millimetres
2	Vertical height from main deck to centre of cargo/vapour manifold (DD2)	5386.00 Millimetres
3	Diameter of handrails (DD3)	44.00 Millimetres
4	Distance of presentation flange from ship side (DD4)	3634.00 Millimetres
5	Distance of manifold face to first restraining bracket (DD5)	3634.00 Millimetres
6	Length of distance piece installed (if applicable) (DD6)	350.00 Millimetres
7	Height of handrails from grating of manifold (DD7)	1000.00 Millimetres

9.113.3	Vapour manifold distances	
1	Distance of midship to centre of vapour manifold	2.50 Meters
2	Distance of centre of vapour manifold to bow	144.53 Meters
3	Distance of centre of vapour manifold to stern	149.54 Meters

9.113.4	Height above waterline	
1	Height of the centre of cargo manifold connections above the waterline at loaded (Summer Deadweight) condition	18786.00 Millimetres

2	Height of the centre of manifold connections above the waterline in normal ballast condition	22126.00 Millimetres

114 Cargo strainers

9.114.1	Cargo/vapour manifold diameter (Without reducers)	135.00 Inches
9.114.2	Confirm Strainer is not obstructing any valves	Yes
9.114.3	Are Strainers onboard designed in accordance with ASME B31.3 Code	Yes
9.114.4	The designed pressure drop in dual direction strainers in clean state at maximum flow rate in either direction is less than 0.5 bar	Yes

9.114.5 Cargo strainers onboard

Type number	Mesh size	Strainer type	Maximum flow rate (Cu Meters/Hour)	Maximum design pressure drop across clean strainer at maximum flow rate? (Mbar/bars)	Are strainers designed in accordance to ASME B31.3 process piping code?
10	60	Combination L/D	10000.00	0.50	Yes

115 Bonding cable and connector

9.115.1	Position of connector	Main Deck aft of Manifold
9.115.2	Connector type	Clamp

116 Reducers

9.116.1	Are Certificates for reducers/spool pieces carried onboard	Yes

9.116.2 Description of ANSI Class 150 reducers carried onboard

Number	From - Diameter (Millimetres)	To - Diameter (Millimetres)	Flange rating (Bar)	Length (Millimetres)
4	16.00	10.00	10.00	1550.00
1	16.00	10.00	10.00	1550.00

117 Cargo measurement

9.117.1 Level Guages - Remote Gauging system

1	Make of Remote Gauging system	Konsberg
2	Type	K-Gauge CTS System GLA-100/5
3	Rated Accuracy (+/-)	10.00 Millimetres
4	Certifying Authority	Intertek
5	Are there any limitations on CTMS regarding measurable minimum liquid level in tanks?	Yes
6	If Yes, specify what are the limitations?	6cm

9.117.2 Level Guages - Local Gauging system

1	Make of Local Gauging system	Whessoe

2	Type	3304
3	Rated Accuracy (+/-)	7.50 Millimetres
4	Certifying Authority	Intertek
5	Is the local gauging independent of the remote gauging system?	Yes
6	If yes, Is remote read-out for Local gauges available?	Yes
7	Are there any limitations on local gauging system regarding measurable minimum liquid level in tanks?	No
8	If Yes, specify what are the limitations?	
9.117.3	Temperature Gauges	
1	No of Sensors per tank	5
2	Type	MN3927PU
3	Rated Accuracy	+-1C
4	Certifying Authority	Intertek
9.117.4	Pressure Gauges	
1	Type	Absolute pressor sensor GT402
2	Rated Accuracy	2.2mb
3	Certifying Authority	Intertek
9.117.5	Trim and List Indicators	0,1%
9.117.6	Independent High Level Alarm	
1	Is independent high level alarm installed in each cargo tank?	Yes
2	Is independent high-high level alarm installed in each cargo tank?	Yes
3	High level alarm activation level setting	95.00 Percentage full
4	High-high level alarm activation level setting	98.00 Percentage full
5	Does High-high level alarm shut the loading valve of the individual tank?	No
9.117.7	Calibrations	
1	Are Cargo tank calibration tables available?	Yes
2	Name of Measuring Company	Intertek Kimsco
3	Name of Certifying Authority	Intertek Kimsco
4	Calibration calculated to cm	No
5	Calibration calculated to 1/2 cm	No
6	Tables established to cm	No
7	Tables established to mm	Yes
8	Are trim and list corrections available?	Yes
9	Are temperature corrections available?	Yes
10	Are float gauge tape corrections available?	Yes
9.117.8	Gas Detection system	
1	Is there a permanently installed system of gas detection fitted?	Yes
2	Type of equipment for gas hazardous area	Infrared Optima E-Exd11C T6 e
3	Response time	
4	Areas monitored	cofferdams,pipetunnels,ER.fans and ducts, Regas plant, area adjacent to cargo tanks
5	Type of equipment for gas safe areas	Salwico GS5000

6	Response time	
7	Areas monitored	Cargo, Machinery Space, Engine room and Accommodation
8	Does compressor house gas detection alarm isolate the gas to compressor house?	Yes
9	Are gas detection sensors available in vent masts?	Yes

9.117.9	Does vessel carry portable gas detection equipment?	Yes

9.117.10 Portable gas detection equipment carried

Item number	Name	Number of units
1	RIKEN KEIKI GX-8000	1
3	RIKEN KEIKI GX-2009	2
2	RIKEN KEIKI RX-515	3

9.117.11	Does vessel carry personal gas detection equipment?	Yes

9.117.12 Personal gas detection equipment carried

Item number	Name	Number of units
1	RIKEN KEIKI GX-2009	2

9.117.13 Tension Monitoring System

1	Manufacturer	Trelleborg
2	System Type	N/A
3	FO Connection Type	1 X 6 + 2 X 6
4	Electric Connection Type	1 X 37 Pyle
5	Connection position from centre of Vapour Manifold (F+ / A-)	-5.00 Meters

118 ESD System and Communication

9.118.1 ESD System Connections

1	Is ESD connection to shore available?	Yes
2	Are ESD connections available on both sides of vessel?	Yes
3	Is the ESD link compatible with SIGTTO guidelines?	Yes
4	If yes, is the system pneumatic?	Yes
5	If yes, is the system electrical?	Yes
6	If yes, is the system fiber optic?	Yes

9.118.2 ESD System hoses and cables

1	Are ESD hoses or cables available on board?	Yes
2	If yes, length of pneumatic	50000.00 Millimetres
3	If yes, length of electrical	50000.00 Millimetres
4	If yes, length of fibre optic	50000.00 Millimetres

9.118.3 Make of Optical Fibre System

1	Connector type	Seatechnik 6 core connector
2	Connection position from centre of vapour manifold (F+ / A-)	5.00 Meters
3	Telephone provided	Yes
4	Hotline	Yes
5	Internal (PABX)	Yes

6	Public Line	Yes
7	Others (Specify)	
9.118.4	Make of Pneumatic System	
1	Connector type	SVHC8-8F-u (Female) SVHN8-8F (Male)
2	Connection position from centre of vapour manifold (F+ / A-)	5.00 Meters
9.118.5	Make of Electric System	
1	Connector Pyle	37 Way Electrical
2	Connector Miyaki	Seatechnik & Myaki Receptable
3	Connector ITT	37 Way Electrical
4	Connector Other	
5	Connection position from centre of Vapour Manifold (F+ / A-)	5.00 Meters
6	Make of telephone, if provided	
7	Hotline line	Yes
8	Internal (PABX)	Yes
9	Public line	Yes
10	Others (Specify)	
11	Is Independent overflow protection which activates ESD, fitted?	Yes
12	If yes, does the overflow protection shutdown system also switch off running cargo pumps?	Yes
13	Shut down level	
9.118.6	ESD activated by	
1	Manual Switches	Yes
2	Fusible Plug	Yes
3	Cargo Tank Level, High High	Yes
4	Hydraulic Oil low Pressure (Manifold Valve)	Yes
5	Control air pressure low (Manifold valve)	No
6	Cargo Switchboard Electric Power Failure	Yes
7	ESDS Signal from Shore	Yes
8	ESDS CPU Failure	Yes
9	Vapour Header Pressure low	Yes
10	Manifold valves open less than 100 %	No
11	Pneumatic Pressure low in Ship/Shore connection	Yes
12	Others (Specify)	
9.118.7	ESD fusible plugs	
1	Are ESD Fusible plugs fitted at tank domes?	Yes
2	Are ESD Fusible plugs fitted at manifolds?	Yes
9.118.8	Manifold ESD valve	
1	Type of manifold ESD valve	Butterfly
2	Closing time	25.00 Seconds
3	Is closing time adjustable?	Yes
9.118.9	Communication	
1	Is VHF provided in CCR?	Yes

2	Specify numbers	
3	Specify frequencies (including Private)	1

119 Ship to ship transfer

9.119.1	Hose handling cranes	
1	Hose handling cranes available?	Yes
2	Load carrying capacity SWL	10.00 Tonnes
3	Maximum outreach out of ships side?	34.00 Meters
4	Location of crane from manifold vapour centreline (F+ / A-)	-13.70 Meters
9.119.2	Transfer hoses	
1	Are transfer hoses available onboard?	Yes
2	Is hose saddle available?	Yes
3	Is Personnel transfer arrangement available?	Yes
9.119.3	If involved in STS operations, state the maximum time needed to re-arrange the cargo tanks to be out of sloshing limits, at any moment during discharging at a rate of 5400 m3/hr?	4.00 Hours
9.119.4	Maximum BOG handling/burning capacity	4.89 Tonnes/Hour

120 Safety protection

9.120.1	Are cargo areas covered by water-spray system?	Yes
9.120.2	Are accomodation areas covered by water-spray system?	Yes
9.120.3	Rated flow of Water Spray System	860.00 Cu Meters/Hour
9.120.4	Is Emergency cargo jettison equipment provided?	Yes
9.120.5	If yes, can Emergency cargo jettisoning be isolated from the cargo system when not in use?	Yes
9.120.6	Is personal protective equipment for the protection of crew members available on board?	Yes
9.120.7	Are two additional sets of respiratory and eye protection available on the navigating bridge?	No

10 Mooring

1 Mooring

10.1.1	Does the ship meet the recommendations contained in the latest edition of OCIMF Mooring Equipment Guidelines?	Yes
10.1.2	Mooring Winches	
1	Is brake testing equipment on board?	Yes
2	When were the brakes last tested?	27 April 2017
10.1.3	Mooring Wires (on drums)	

	Number	Diameter (Millimetres)	Material	Length (Meters)	Breaking Strength (Tonnes)
Forecastle	11	44.00	Galv.steel	275.00	128.00
forward Main Deck	0				
Main Deck	0				
Aft Main Deck	4	44.00	Galv. steel	275.00	128.00
Poop	7	44.00	Galv. steel	275.00	128.00

10.1.4 Type of shackle Boss Link

10.1.5 Synthetic Tails

	Number	Diameter (Millimetres)	Material	Length (Meters)	Breaking Strength (Tonnes)
Forecastle	11	72.00	High Performance Plyester	11.00	181.40
forward Main Deck	0				
Main Deck	0				
Aft Main Deck	4	72.00	High Performance Plyester	11.00	181.40
Poop	7	72.00	High Performance Plyester	11.00	181.40

10.1.6 Mooring Ropes (on drums)

10.1.7 Other Mooring Lines

	Number	Diameter (Millimetres)	Material	Length (Meters)	Breaking Strength (Tonnes)
forward Main Deck	0				
Main Deck	0				
Aft Main Deck	0				
Poop	0				

10.1.8 Spare Mooring Wires

10.1.9 Spare Mooring Ropes

Storage location	Number	Diameter (Millimetres)	Material	Length (Meters)	MBL (Tonnes)
Fwd Bosun Store	2	72.00	Polyester	220.00	110.00

10.1.10 Spare Mooring Tails

Storage location	Number	Diameter (Millimetres)	Material	Length (Meters)	MBL (Tonnes)
Fwd bosun store	1	72.00	Polyester	11.00	181.00
Aft steering gear room	1	72.00	Polyester	11.00	181.00

10.1.11 Mooring Winches

	Number	Sgl/Dbl drum	Split drum	Motive power	Heaving power (Tonnes)	Brake capacity (Tonnes)	Hauling speed (M/Min)	Type of brake
Forecastle	5	Double Drums	Yes	Electric	30.00	76.80	15.00	
forward Main Deck	0		No					
Main Deck	0		No					
Aft Main Deck	2	Double Drums	Yes	Electric	30.00	76.80	15.00	
Poop	3	Double Drums	Yes	Electric	30.00	76.80	15.00	

10.1.12 What type of winch brakes are fitted? Brake drum and brake band

2 Mooring Bitts

10.2.1	How many sets of mooring bitts are fitted	
1	On forecastle	8
2	On forward main deck	6
3	On aft main deck	2
4	On poop deck	8

10.2.2 Distance of mooring chock for breast/spring lines

1 Forward of centre of manifold

2 Aft of centre of manifold

3 Anchors and Windlass

10.3.1	What is the motive power of the windlass?	Electric
10.3.2	What is the cable diameter?	111.00 Millimetres
10.3.3	Number of Shackles	
1	Port cable	14
2	Starboard cable	13

10.3.4 Are bitter end connections to both cables capable of being slipped? Yes

4 Emergency Towing Arrangements

10.4.1	Is an Emergency Towing Arrangement (ETA) fitted? If not, ignore remainder of this section.	Yes

10.4.2 Details of ETA

	Forward	Aft
Type of System	Emergency towing	Emergency towing winch
Safe Working Load (SWL) of System	204	204
Is pick-up gear provided?	no	yes
Towing pennant length	8	100
Towing pennant diameter	76	80
Type of strong point (e.g. Smit bracket)	Smit	Tankteck.Co / Saejin Intech

Chafing Chain Size	76	
Fairlead size (in format ABCmm x XYZmm)	500x400	500x400
Is a pedestal roller fitter?	yes	yes

10.4.4	How many sets of bitts are fitted in the bow area?	8
10.4.5	What is the height of the bitts in the bow area?	950.00 Millimetres
10.4.6	What is the Safe Working Load (SWL) of the bitts in the bow area?	128.00 Tonnes
10.4.7	What is the distance between bow fairleads and nearest bitts?	5000.00 Millimetres
10.4.8	Is the bow area clear of any obstructions which would hamper towing connections?	Yes

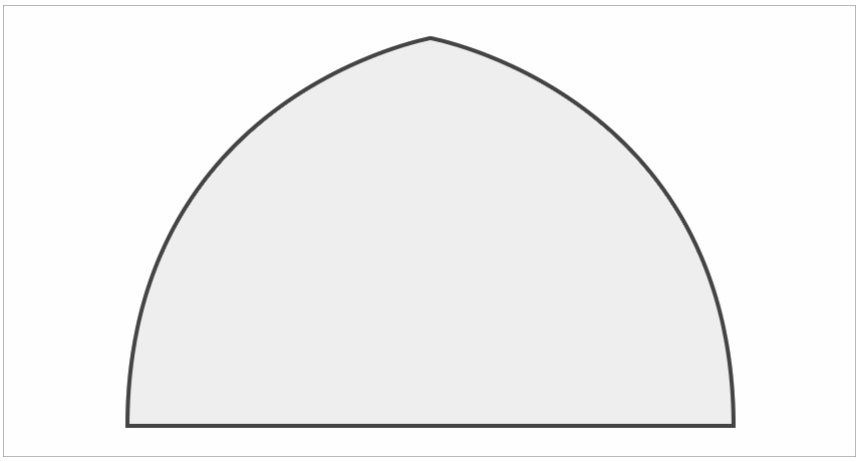
5 Escort Tug

10.5.1	SWL of closed chock on stern	204.00 Tonnes
10.5.2	SWL of bollard on poopdeck suitable for escort tug	204.00 Tonnes
10.5.3	Are stern chock and bollard capable of towing astern to 90 degrees?	Yes

6 Single Point Mooring (SPM) Equipment

10.6.1	Does the ship meet the recommendations contained in the latest edition of OCIMF 'Recommendations for Equipment Employed in the Bow Mooring of Conventional Tankers at Single Point Moorings'?	Yes
10.6.2	Bow chain stoppers	
1	Are bow chain stoppers fitted?	Yes
2	If Yes, how many?	1
3	If Yes, state type	Smit
4	If Yes, what is the Safe Working Load (SWL)?	204.00 Tonnes
5	What is the maximum size chain diameter the bow stopper(s) can handle?	76.00 Millimetres
10.6.3	Closed fairleads	
1	Are closed fairleads of OCIMF recommended size (600mm x 450mm)?	Yes
2	If not, give details of size (in format ABCmm x XYZmm)	
10.6.4	If two forward bow fairleads are fitted give distance between them	
10.6.5	What is the distance between the bow fairlead and stopper/bracket?	3200.00 Meters
10.6.6	What is the distance from the stopper bracket to roller lead/winch drum?	12300.00 Meters
10.6.7	Is there a direct lead from the bow stopper to the winch drum (not the warping end)?	Yes
10.6.8	Is the winch storage drum capable of safely accommodating 150m X 80mm fibre pick up rope?	Yes
10.6.9	Is the winch storage drum capable of safely accommodating 200m X 80mm fibre pick up rope?	No

7 Bow mooring arrangement diagram



10.7.1	Bow mooring arrangement diagram	

8 Manifold arrangement

10.8.1	Manifold Arrangement Diagram	L-L-V-L-L
10.8.2	Distance K end of drip tray to center line of deck cleat	
10.8.3	Distance L spill tray to centre line of bollard	
10.8.4	Distance M length of bollard	

9 Lifting equipment

10.9.1	Cargo handling derricks	
1	How many derricks are fitted?	
2	What is their safe working load (SWL)?	
3	Date last tested	01 January 1900
10.9.2	Cargo handling cranes	
1	If cranes are fitted, how many?	2
2	What is their safe working load (SWL)?	10.00 Tonnes
3	Date last tested	27 April 2017
10.9.3	Other derricks or cranes	
1	If cranes are fitted, how many?	3
2	What is their safe working load (SWL)?	

3	Date last tested	27 April 2017
10.9.4	Is Safe Working Load (SWL) clearly marked on all lifting equipment?	Yes
10.9.5	Can the derricks or crane(s) maintain their design SWL when plumbing a point one metre outboard from the ship's side over the full length of the manifold including bunker and vapour connections?	Yes
10.9.6	If the ship is equipped to operate at Single Buoy Moorings (SBMs), does the arrangement at the manifold area for securing submarine hoses meet OCIMF Guidelines?	No

10 Other equipment

10.10.1	Are accommodation ladders arranged to face aft when rigged?	Yes
10.10.2	Is the accommodation ladder well within the parallel mid-body of the ship so boats may come alongside safely at all stages of draft?	Yes
10.10.3	Are Suez Canal boat davits fitted?	No
10.10.4	Is a Suez Canal searchlight fitted?	Yes

11 Communications and Electronics

1 Communications and Electronics

11.1.1	Under what sea area (A1, A2, A3 or A4) does the ship operate?	A3
11.1.2	Is a Long Range Identification and Tracking (LRIT) System fitted?	Yes
11.1.3	Is the vessel equipped with an Automatic Identification System (AIS)	Yes
11.1.4	Is the vessel equipped with a Voyage Data Recorder or Simplified Voyage Data Recorder?	Yes
11.1.5	Does the VDR or S-VDR have clear instructions to bridge watchkeepers relating to the saving of data following an incident?	Yes
11.1.6	Is a Search and Rescue Transponder (SART) fitted?	Yes
11.1.7	Is an Emergency Position-Indicating Radio Beacon (EPIRB) fitted?	Yes
11.1.8	How many VHF radios are fitted on the bridge?	2
11.1.9	Is a VHF radio fitted in the Cargo Control Room?	Yes
11.1.10	Is the CCR connected to the internal communication system?	Yes
11.1.11	How many intrinsically safe walkie talkies are provided for cargo handling?	14
11.1.12	Is an INMARSAT satellite communications system fitted?	Yes
11.1.13	Are at least three survival craft two-way radio telephones provided?	Yes
11.1.14	List any other communications equipment carried	
11.1.15	Can the radio transmit the helicopter homing signal on 410 KHz?	Yes

12 Propulsion

1 Main Propulsion

12.1.1	Means of main propulsion	
1	What is the means of main propulsion	Diesel-Electric
2	If motor state whether two stroke or four stroke	4 Stroke
3	If four stroke, state how many engines fitted	4
12.1.2	How many propellers are fitted?	Single
12.1.3	Is a controllable pitch propeller fitted?	Fixed
12.1.4	Boilers	
1	How many boilers are fitted?	1
2	What is rated output of boilers?	65.00 Tonnes/Hour
3	Are the boilers equipped to operate on low sulphur fuel when the vessel is operating in Emission Control Areas	No
12.1.5	Low sulphur fuel requirements	
1	Is equipment fitted and are procedures in place to changeover main propulsion fuels to meet low sulphur fuel requirements?	Yes
2	Is equipment fitted and are procedures in place to changeover auxiliary equipment fuels to meet low sulphur fuel requirements?	Yes
12.1.6	What type of fuel is used for main propulsion?	HFO / MGO / LNG
12.1.7	Are pressurised fuel pipes double sheathed?	Yes
12.1.8	When moored at SBM, is main engine capable of being run astern at low revolutions for extended periods (up to 24 hours continuously)?	No
12.1.9	Can a speed of less than 5kts be maintained?	Yes
12.1.10	Is the ship certified for Unmanned Machinery Space (UMS) operation?	Yes
12.1.11	Is the machinery space operated in unmanned mode?	Yes

2 Thrusters

12.2.1	Bow thruster	
1	Is a bow thruster fitted?	No
2	If Yes, give Brake Horse Power	0.00 BHP
12.2.2	Stern thruster	
1	Is a stern thruster fitted?	No
2	If Yes, give Brake Horse Power	0.00 BHP
12.2.3	High angle rudder	
1	Is a high angle rudder fitted?	No
2	Number fitted	0
3	What type	

3 Generators

12.3.1	How many power generators are fitted?	4
12.3.2	What is the design power output of the generators?	20000kw
12.3.3	What type of fuel is used in the generating plant?	Gas og fuel

12.3.4	Is an Emergency Generator or batteries fitted?	Yes

4 Main engine air start compressors

12.4.1	Number of main engine start compressors	2
12.4.2	Operating pressure	30.00 Bar
12.4.3	Motive power of emergency compressor	25.00 Cu Meters/Hour

5 Bunkers

12.5.1 Fuel oil tank capacities

Tank name	Capacity	(Cu Meters)
HFO Bunker Tank Port	687.20	
HFO Bunker Tank Stb	495.50	
HFO Service Tank Stb	235.70	
Fwd HFO Tank Port	1815.50	
Fwd HFO Tank Stb	1789.20	

12.5.2 Diesel oil tank capacities

12.5.3 Gas oil tank capacities

Tank name	Capacity	(Cu Meters)
MGO Service Tank stb	166.10	
No 2.MGO Storage Tank stb	297.30	
No 1.MGO Storage Tank stb	198.20	

6 Steering gear

12.6.1	What type of steering gear is fitted?	Ram type hydrolic
12.6.2	How many motorized hydraulic pumps or motors fitted?	2
12.6.3	How many telemotors fitted?	2
12.6.4	Is an emergency rudder arrest/rudder control fitted?	No

7 Anti-pollution

12.7.1	Is an engine-room bilge high level alarm fitted?	Yes
12.7.2	Is a pump room bilge high level alarm fitted?	Yes
12.7.3	Is there a permanently installed system for the disposal of residues from the machinery space sludge tank to shore?	Yes
12.7.4	Are there facilities on board to incinerate machinery space sludge?	Yes

13 Ship to Ship Transfer

1 Ship to Ship Transfer

13.1.1	Does vessel comply with recommendations contained in OCIMF/ICS/CDI/SIGTTO "Ship To Ship Transfer Guide for Petroleum, Chemicals and Liquefied Gases?	Yes
13.1.2	Are at least 7 ratings available to assist with mooring operations?	Yes
13.1.3	What is Safe Working Load (SWL) of bitts in the manifold area?	128.00 Tonnes
13.1.4	Are manifold bitts at least 35 metres away from the breastlines leading fore and aft?	Yes
13.1.5	What is the maximum outreach of the derricks within their designed SWL?	20.00 Meters
13.1.6	Does the Operator's SMS provide instructions regarding the transfer of personnel using derricks or cranes?	Yes
13.1.7	If cranes are fitted, are they certified for personnel transfer?	Yes
13.1.8	Are personnel who will operate cranes for personnel transfer properly trained?	Yes
13.1.9	Are four (4) 200m x 40mm messenger lines available for Ship-To-Ship (STS) mooring operations?	Yes
13.1.10	Are there two (2) closed chocks with associated bollards and leads to winches located within 35 metres forward and aft of the centre of the cargo manifold?	Yes

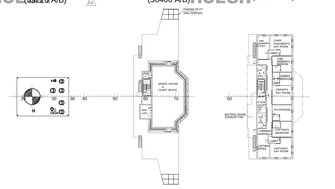
14 Combination Carriers

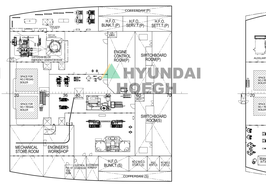
1 Combination Carriers

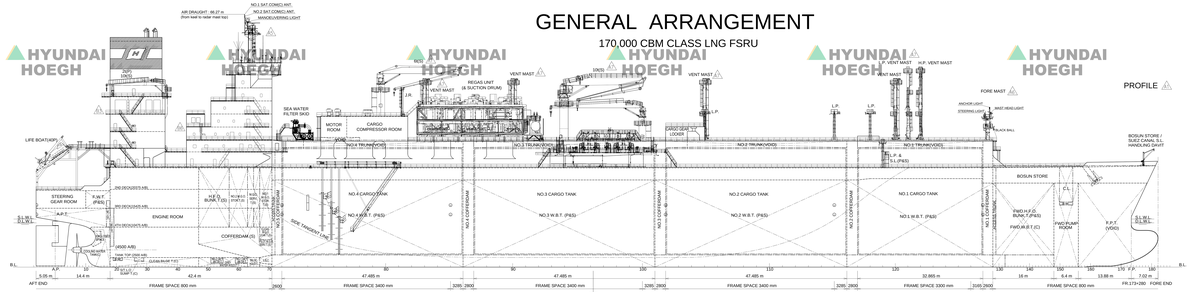
14.1.1	State design of hatches	
14.1.2	State type of hatches	
14.1.3	State if hatches fitted with single or double seals in hatch coaming	
14.1.4	Last date cargo holds/tanks were tested to normal working pressure (min.500mm wg) to prove gas tightness of hatches	01 January 1900
14.1.5	Were the hatches proven to be gas tight?	No

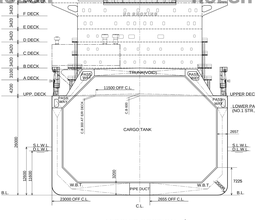
GENERAL ARRANGEMENT

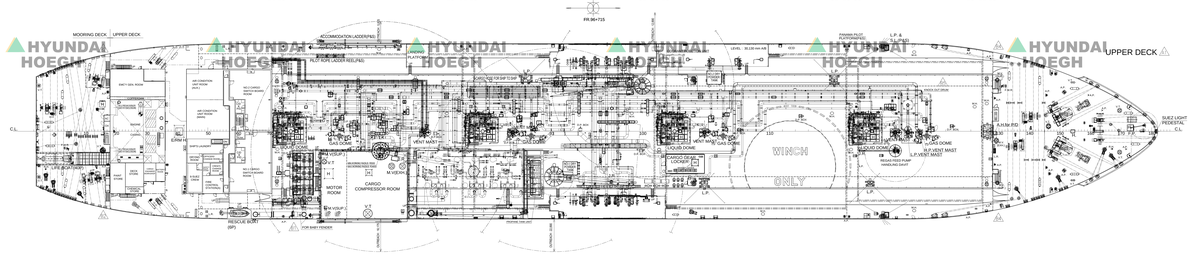
170,000 CBM CLASS LNG FSRU

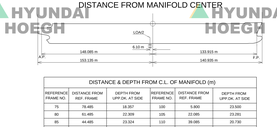












DISTANCE & DEPTH FROM C.L. OF MANIFOLD (m)

REFERENCE FRAME NO.	DISTANCE FROM REF. FRAME	DEPTH FROM UPP.DK. AT SIDE	REFERENCE FRAME NO.	DISTANCE FROM REF. FRAME	DEPTH FROM UPP.DK. AT SIDE
75	78.485	18.357	100	5.800	23.555
80	61.485	20.309	105	22.085	23.291
85	44.485	23.324	110	39.085	20.730
90	26.290	23.500	115	56.085	13.560

PRINCIPAL DIMENSIONS

LENGTH O. A.	294.07	m
LENGTH B. P.	282.00	m
BREADTH MLD.	46.00	m
DEPTH MLD.	26.00	m
DEPTH (TRUNK) MLD.	33.00	m
DRAUGHT (DESIGN) MLD.	11.60	m
DRAUGHT (SCANT.) MLD.	12.60	m

FLAG : MARSHALL ISLANDS
CLASS & NOTATION : DNV-GL,
+1A1, Tanker for Liquefied Gas, Ship Type 2G (-163˚C, 500 kg/m³, Ship), MA-PTO,(Schiffsmaschinenanlage, REGAS), ES, SH, SPM, TCM, VCS, COAT-IP(PSPC-WBT), Recyclable, GAS-FUELED, TWCN

* FSRU mode : Ship Type 2G (-163˚C, 500 kg/m, Ship)

FREEBOARD : "A" TYPE
MAXIMUM PROPULSION POWER : 20,600 kw x 76.8 rpm
MAIN DIESEL GENERATOR ENGINE : 7HiMaD, WARTSILA HYUNDAI 8L50DF
One(1), WARTSILA-HYUNDAI 8L50DF
COMPLEMENT : 39 + 6 (Over) crew) PERSONS
DEADWEIGHT : 81,843 t (at Design Draft, Preliminary)
SPOTS TONNAGE : 159,844 (Preliminary)
NET TONNAGE : 76,130 (Preliminary)
SERVICE SPEED : 19.00 knots (at Design Draught with 21% S.M., Preliminary)

ABBREVIATION

- A.P. : AIR PIPE
- A.H. : ACCESS HATCH
- B.W. : BILGE WELL
- D.P.BOX : DRY POWDER BOX
- J.R. : JIB REST
- L.P. : LIGHTING POST
- L.R. : LIFE RAFT
- M.H. : MANHOLE
- H. : HATCH
- R.H. : ROPE HATCH
- M.V. : MECHANICAL VENTILATION
- V.T. : VENTILATION

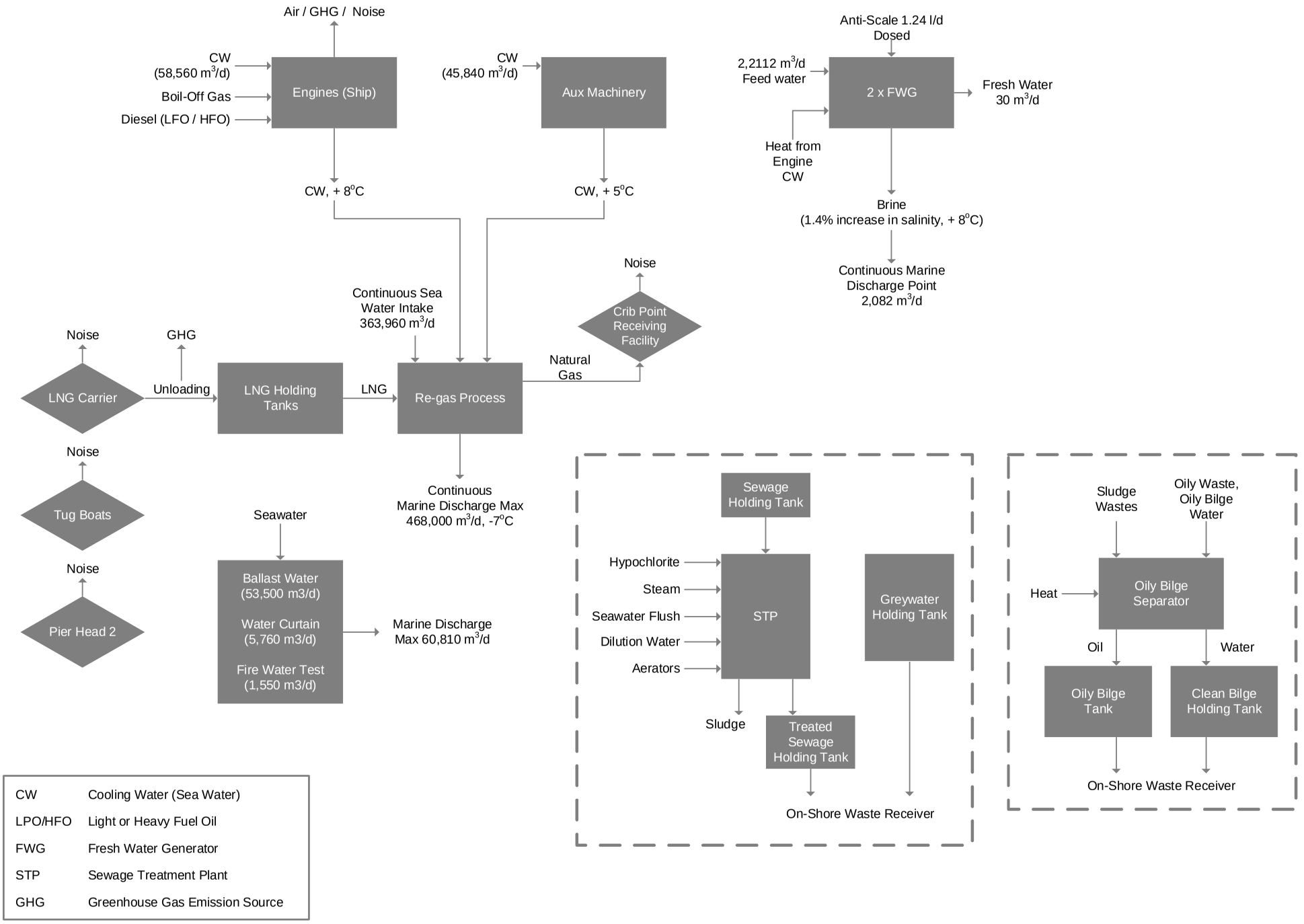
PLAN HISTORY

REV. NO.	DATE (MM/DD/YY)	MARK	DESCRIPTION	CHECKED BY	APPROVED BY
ORI.	04.02.21		ORIGINALLY PREPARED FOR THE CONTRACT.	J. S. YANG	K. S. LEE
189	08.05.25	A1	UPDATED ACCORDING TO FOLLOWING DRAWINGS - HEAD TANK DRAWING (DWG NO. 2552-0001-00-0000-100) - AIRPIPE DRAWING (DWG NO. 2552-0001-00-0000-200) - AIRPIPE OF SLOP TANK (DWG NO. 2552-0001-00-0000-210) - AIRPIPE OF SLOP TANK (DWG NO. 2552-0001-00-0000-220) - AIRPIPE OF LIFT BOAT HANDLING (DWG NO.2-0012-0000)		
		A2	NEWLY SHOWN BY 3RD, 3RD, 4TH DECK AND FLATFORM PLAN - ACCESS HATCH (DWG NO. 2552-0001-00-0000-400) IN STORAGE ROOM (DWG NO. 2R-1000-002)	H. B. CHOI	J. S. YANG
		A3	NEWLY SHOWN ACCOMMODATION PLAN ACCORDING TO - ACCESS HATCH (DWG NO. 2552-0001-00-0000-400)		
		A4	NEWLY SHOWN WEATHER SHIELD PLAN AND ENG. GAS PIPE ACCORDING TO DWG NO. - ACCESS HATCH (DWG NO. 2552-0001-00-0000-400)		
		A5	MODIFIED BASIN MAST ACCORDING TO - TRUSS MAST CONSTRUCTION (DWG NO. S-5143-B01)*		
		A6	MODIFIED MAST ACCORDING TO - HOSE MAST (DWG NO. A2-0012-0001-00-0000-100)*		
		A7	MODIFIED FWD MAST, VENT MAST AND LIGHTING POST - MAST ARRANGEMENT (DWG NO. 2552-0001-00-0000-100)		
		A8	ADDED THE ABBREVIATIONS.		
209	16.07.25	B1	ADDED THE BOLLARD AND SET FOR BARY FENDER		
		B2	MODIFIED THE ACCESS LADDERS FROM SUNKEN DECK TO UPPER DECK		
		B3	ADDED THE PLATFORM FOR VENT LOUVER ON EC C DECK.		
		B4	UPDATED THE SPRING LINE ON FWD MOORING DECK.	H. B. CHOI	J. S. YANG
		B5	ADDED THE RACKS OUT DRUM FOR LP. VENT SYSTEM.		
		B6	ADDED THE VERTICAL LADDER ON B DECK AND C DECK.		

SHIP NO. / NB SHIP IDENTIFICATION NO.		CAUTION	
2552	NB1183(NA)	THIS DRAWING IS PROPRIETARY AND CONFIDENTIAL PROPRIETARY INFORMATION. HEREIN, THE REPRODUCTION, TRANSFER AND/OR UTILIZATION IN WHOLE OR IN PART ARE PROHIBITED WITHOUT THE EXPRESS PERMISSION OF HYUNDAI HEAVY INDUSTRIES CO., LTD.	
PRT. NO. / SHIP DESIGN OFFICE		170,000 CBM CLASS LNG FSRU	
C100	DESIGN COORDINATION DEPT.	(MARK III MEMB., DFDE)	
TEL NO. / SHIP NO.		SHIP NAME	
052-202-7447	2552	HÖEGH GIANT	
DATE	NAME OF DRAWING		
APPROVED	J.S.Yang	GENERAL ARRANGEMENT	
CHECKED	H.B.Choi		
DRAWN	Tobe Mun	SCALE 1/250	DRAWING NO. 1G-7000-201-200
HYUNDAI HEAVY INDUSTRIES CO.,LTD		CONSOLIDATED NO.	FG-3

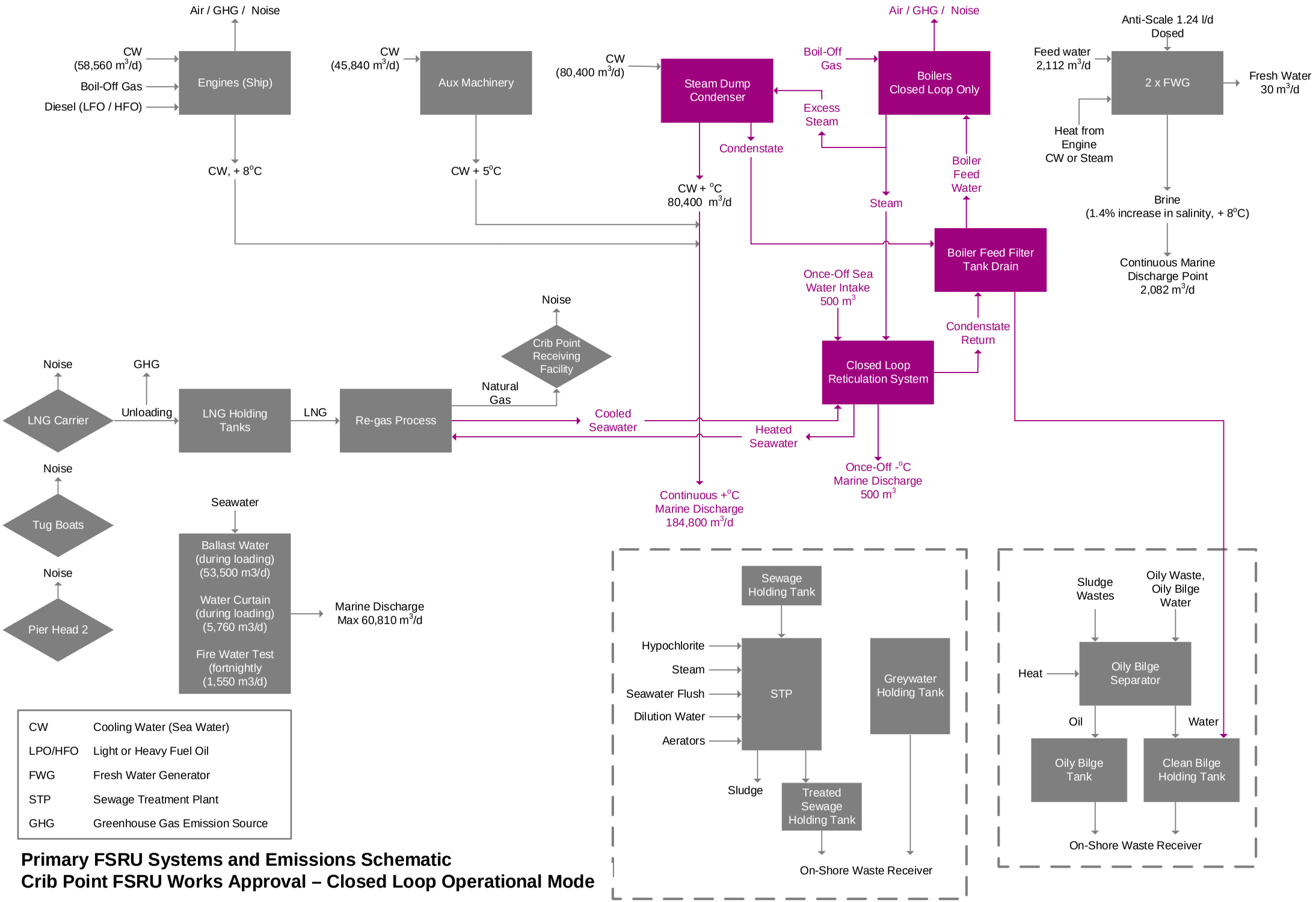
Appendix D

FSRU Systems and Emissions Schematic



CW	Cooling Water (Sea Water)
LPO/HFO	Light or Heavy Fuel Oil
FWG	Fresh Water Generator
STP	Sewage Treatment Plant
GHG	Greenhouse Gas Emission Source

Primary FSRU Systems and Emissions Schematic
Crib Point FSRU Works Approval – Open Loop Operational Mode



CW	Cooling Water (Sea Water)
LPO/HFO	Light or Heavy Fuel Oil
FWG	Fresh Water Generator
STP	Sewage Treatment Plant
GHG	Greenhouse Gas Emission Source

Primary FSRU Systems and Emissions Schematic
Crib Point FSRU Works Approval – Closed Loop Operational Mode

Appendix E

Energy use and greenhouse gas emissions calculations

Appendix E Energy use and greenhouse gas emissions calculations

Greenhouse gas (GHG) emissions were estimated in accordance with the principles of the internationally accepted GHG Protocol. According to the GHG Protocol, greenhouse gas emissions are split into three categories, known as 'Scopes'. Scope 1, Scope 2 and Scope 3 are defined by the GHG Protocol as:

- Scope 1 – Direct emissions of greenhouse gas from sources that are owned or operated by a reporting organisation (examples include combustion of diesel in company-owned vehicles or used in on-site plant and equipment)
- Scope 2 – Indirect emissions associated with the import of energy from another source (examples include import of electricity from the grid, or heat)
- Scope 3 – Other indirect emissions, other than energy imports (above) which are a direct result of the operations of the organisation, but from sources not owned or operated by them and due to upstream or downstream activities (examples include indirect upstream emissions associated with the extraction, production and transport of purchased construction materials; and business travel (by ship, air or rail)).

The sources of GHG emissions included in the construction and operation phase of the Floating Storage Regasification Unit (FSRU) are provided in **Table 56**. A 'tick' (✓) denotes the emission source has been included in the assessment, whilst a 'cross' (x) denotes the emission source has been excluded. A 'dot' (•) denotes whether the emission is Scope 1, Scope 2 or Scope 3.

Table 56 A summary of construction and operation GHG emissions relevant to the FSRU

Source of GHG emission	Activity	Included in assessment?	Direct	Indirect	
			Scope 1	Scope 2	Scope 3
Construction					
Transport fuel	Fuel used in the transportation of the FSRU	✓	•		
Landfill	Construction waste disposed in landfill	x			•
Operation					
Stationary fuel	Fuel consumed by onsite plant and equipment (including the FSRU)	✓	•		•
	Fuel consumed by offsite plant and equipment	x			•
	Natural gas consumed by end users in the VTS (i.e. commercial and residential properties)	x			•
Fugitive emissions	Operational waste disposed at landfill	x			•
	Fugitive emissions from plant and pipeline operations	✓	•		
	Emissions from the disposal of municipal solid waste	x			•
	Emissions from liquid waste products, sewage	x			•

B1 Construction

The GHG emissions associated with the FSRU during construction include emissions related to the following activities:

- Mobilisation of the FSRU (i.e. Transportation of vessel from an assumed port (Korea) to Crib Point).

A number of inputs were used for calculating transport fuel emissions associated with the FSRU during construction. The details of these inputs are presented in **Table 57**.

Table 57 A summary of inputs related to fuel consumed for FSRU vessel transportation to Crib Point

Input	Units	Value	Source
Shipping distance from Korea to Crib Point (round trip)	nautical miles	10,282	Distance sourced from sea-distances.org
	km	19,042	Conversion to metric units
Shipping speed	knots	18	Assumption based on discussions with Poten Partners
	km/h	33	Conversion to metric units
Days to transport	days	23.8	Calculated based on shipping distance and shipping speed
Type of fuel consumed by FSRU	-	Fuel oil	
Average fuel consumption of FSRU	t/day	103.2	Hoegh specifications
Energy content of fuel oil	GJ/t	40.66	Energy content sourced from Department for Environment, Food and Rural Affairs (DEFRA) 2019
Emission factor	Kilogram (kg) Carbon dioxide equivalent (Co_2-e) /GJ	80.2185	Emission factor for Ocean Tanker Bunker fuel sourced from American Petroleum Institute – LNG Operations Consistent Methodology for Estimating GHG Emissions

Section 2.2 of the National Greenhouse and Energy Reporting (NGER) National Greenhouse Account Factors sets out the methodology for calculation of direct (Scope 1) GHG emissions from fuels used for transport purposes using designated emission factors. The following formula was used to estimate GHG emissions:

$$E_i = \frac{Q_i \times EC_i \times EF_i}{1000}$$

where:

E_i is the emission from fuel type (i) (tonnes (t) CO_2-e)

Q_i is the quantity of fuel type (i) (GJ) combusted for transport energy purposes

EC_i is the energy content factor of fuel type (i) (if Q_i is measured in GJ, then EC_i is 1)

EF_i is the emission factor for fuel type (i) (kg CO_2-e) used for transport energy purposes

The following calculations were made:

Total scope 1 transport fuel GHG emissions during construction

$= ((23.8 \times 103.2 \times 40.66) \times 1 \times 80.2185)/1000$

$= 8{,}012\ \mathrm{t\ CO_2 - e}$

B2 Operation

The GHG emissions associated with the FSRU during operation include emissions related to the following activities:

- Stationary fuel emissions during operation of the FSRU; and
- Fugitive emissions during unloading from LNG carriers to the FSRU.

The GHG emissions associated with the FSRU during operation have been assessed based on two possible regasification modes which include closed loop mode and open loop mode. Calculations for all modes of operation assumes supplying natural gas at 387 Million standard cubic feet per day (mmscf/d) for 213 days, 500 mmscf/d for 122 days per year and 750 mmscf/d for 30 days per year, delivering a total of 40 cargos of LNG into the VTS. This equates to approximately 160 Petajoule (PJ) of natural gas delivery per annum.

Operational inputs and assumptions for scope 1 emission calculations relating to stationary fuel combustion for the FSRU are presented in **Table 58**.

Table 58 Inputs used in calculating stationary fuel emissions during operations

Input	Units	Value	Source
LNG cargo delivery globally to Crib Point			
Total natural gas delivery[4]	PJ	160	AGL
Total LNG cargos	per annum	40	AGL
Cargo volume	m^3 of LNG	160,000	AGL
Time to transfer one cargo	Hours (hrs)	36	AGL
Cargos received at FSRU at 387 mmscf/d send out rate	#	20	AGL
Cargos received at FSRU at 500 mmscf/d send out rate	#	16	AGL
Cargos received at FSRU at 750 mmscf/d send out rate	#	4	AGL
FSRU demand whilst LNGC unloading; closed loop			
387 mmscf/d send out rate	tonne/hr	10.42	AGL
500 mmscf/d send out rate	tonne/hr	10.42	AGL
750 mmscf/d send out rate	tonne/hr	15.18	AGL
FSRU demand whilst LNGC not unloading; closed loop			
387 mmscf/d send out rate	tonne/hr	10.21	AGL
500 mmscf/d send out rate	tonne/hr	10.21	AGL
750 mmscf/d send out rate	tonne/hr	14.97	AGL
FSRU demand whilst LNGC unloading; open loop			
387 mmscf/d send out rate	tonne/hr	2.61	AGL
500 mmscf/d send out rate	tonne/hr	2.61	AGL

[4] It is recognised that the operation of the FSRU consumes a portion of the total gas delivered to the project. Based on the methodology applied within this assessment:

- approximately 0.8% of total gas delivered is consumed in the project operations when the FSRU is operating in open loop mode; and
- approximately 3.0% of the total gas delivered is consumed in the project operations when the FSRU is operating in closed loop mode.

Input	Units	Value	Source
750 mmscf/d send out rate	tonne/hr	3.33	AGL
FSRU demand whilst LNGC not unloading; open loop			
387 mmscf/d send out rate	tonne/hr	2.40	AGL
500 mmscf/d send out rate	tonne/hr	2.40	AGL
750 mmscf/d send out rate	tonne/hr	3.26	AGL
Other			
Gas density – LNG (at Standard Temperature and Pressure (STP))	kg/m^3	0.799	Density sourced from www.unitrove.com
Gas energy content – LNG	GJ/m^3	0.0393	NGER National Greenhouse Account Factors *Table 2: Emission factors for the consumption of natural gas*
Emission factor	Kg Co_2-e /GJ	51.53	NGER National Greenhouse Account Factors *Table 2: Emission factors for the consumption of natural gas*

Section 2.1.2 of the NGER National Greenhouse Account Factors sets out the methodology for calculation of direct (Scope 1) GHG emissions from gaseous fuels used for stationary use (non-transport related) using designated emission factors. The following formula was used to estimate GHG emissions:

$$E_i = \frac{Q_i \times EC_i \times EF_i}{1000}$$

where:

E_i is the emission from fuel type (i) (t CO_2-e)

Q_i is the quantity of fuel type (i) (GJ) combusted for transport energy purposes

EC_i is the energy content factor of fuel type (i) (if Q_i is measured in GJ, then EC_i is 1)

EF_i is the emission factor for fuel type (i) (kg CO_2-e) used for transport energy purposes

The following calculations were made:

B2.1 Closed loop system

Send out rate: 387 mmscf/d

Annual time unloading:

$$= \frac{\text{total LNG cargos} \times \text{time to unload}}{24} = \frac{20 \times 36}{24} = 30 \text{ days/annum}$$

Annual time not unloading:

$$= \text{operational days} - \text{annual time unloading} = 213 - 30 = 183 \text{ days/annum}$$

Total fuel demand while unloading:

$$= \text{annual time unloading} \times \text{operational hours} \times \text{fuel demand while unloading} \times 1000$$

$$= 30 \times 24 \times 10.42 \times 1000 = 7{,}502{,}400 \text{ kg/annum}$$

Convert to volumetric flowrate by using gas density

$$= \text{mass flowrate} \times \frac{1}{\text{gas density}} = 7{,}502{,}400 \times \frac{1}{0.799} = 9{,}389{,}737\ \text{m}^3/\text{annum}$$

Total fuel demand while not unloading:

$$= \text{annual time not unloading} \times \text{operational hours} \times \text{fuel demand while not unloading} \times 1000$$

$$= 183 \times 24 \times 10.21 \times 1000 = 44{,}842{,}320\ \text{kg/annum}$$

$$= 44{,}842{,}320 \times \frac{1}{0.799} = 56{,}123{,}054\ \text{m}^3/\text{annum}$$

Gas consumed per annum:

$$= (\text{total fuel demand while unloading} + \text{total fuel demand while not unloading}) \times \text{gas energy content}$$

$$= (9{,}389{,}737 + 56{,}123{,}054) \times 0.0393 = 2{,}574{,}653\ \text{GJ/annum}$$

Send out rate: 500 mmscf/d

Gas consumed per annum:

$1{,}476{,}374\ \text{GJ/annum}$

Send out rate: 750 mmscf/d

Gas consumed per annum (maximum):

$531{,}639\ \text{GJ/annum}$

Annual total scope 1 stationary fuel GHG emissions during closed loop system operation

$$= \text{E}_\text{i}(387\ mmscf/d) + E_i(500\ mmscf/d) + E_i(750\ mmscf/d)$$

$$= \frac{2{,}574{,}653 \times 1 \times 51.53}{1000} + \frac{1{,}476{,}374 \times 1 \times 51.53}{1000} + \frac{531{,}639 \times 1 \times 51.53}{1000}$$

$$= 132{,}672 + 76{,}078 + 27{,}395$$

$$= 236{,}145\ \text{t}\ \text{CO}_2 - \text{e}$$

B2.2 Open loop system

Repeating the steps outlined in B2.1 above for the closed loop system, annual total scope 1 stationary fuel GHG emissions during open loop system operation are:

$$= 55{,}572\ \text{t}\ \text{CO}_2 - \text{e}$$

B3 Fugitive emissions - operations

Operational inputs and assumptions for scope 1 emission calculations relating to fugitive emissions are presented in **Table 59**.

Table 59 Inputs used in calculating fugitive emissions during operations

Input	Units	Value	Source
Unloading of LNG to FSRU			
Number of flanged connections	#	12	4 unloading and 2 return hoses – AGL
Hours of operation	per annum	1,440	Based on 40 cargos
Transfer of natural gas from FSRU to Crib Point Receiving Facility			
Pipeline length	km	1.8	AGL documentation
Hours of operation	per annum	8,760	AGL
Other			
Emission factor - connectors, flanges, threaded fittings	t CO_2-e/hr/ component	0.1089	Emission factor sourced from American Petroleum Institute – LNG Operations Consistent Methodology for Estimating GHG Emissions *Table 13 Default Methane Emission Factor per Component Population for LNG Storage and Import/Export Terminals*
Emission factor – gas transmission pipeline	t CO_2-e /km/hr	3.03E-05	American Petroleum Institute Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Natural Gas Industry *Table 6-6. Fugitive emissions factors for natural gas transmission and storage equipment*

Section 2.4.2.6 of the NGER National Greenhouse Account Factors sets out the methodology for calculation of fugitive emissions related to natural gas production and processing (other than emissions that are vented or flared).

The following calculations were made:

Fugitive emissions – transfer of LNG from carrier to FSRU

$$= \text{Annual unloading time} \times \text{total connections} \times \text{emission factor for methane}$$

$$= 1{,}440 \times 12 \times 0.1089 = 1{,}882 \text{ t } CO_2 - \text{e}$$

Fugitive emissions – transfer of natural gas from FSRU to Crib Point Receiving Facility

$$= (\text{hours of operation} \times \text{pipeline length} \times \text{emission factor})$$

$$= (8{,}760 \times 1.8 \times 0.0000303) = 0.5 \text{ t } CO_2 - \text{e}$$

AGL Gas Import Jetty Project

Transport Fuel Emissions - Construction

Date	1/15/2020
Revision	R05
Completed By	DM
Checked By	AK, JH

FSRU Transport from Korea to Crib Point		
Liquified Natural Gas		
S1	S2	S3
tCO2-e		
8,011.53	-	-

FSRU Transport from Korea to Crib Point							
Number of Cargos	Nautical Miles round trip	Transport Distance	Shipping Speed	Average Ship Speed	Days to transport	Fuel consumption (Fuel Oil)	Total Energy
#		km	knots	km/h	days	t/day	GJ
1	10,282	19,042	18	33	23.8	103.2	99,871.4

NOTE: this assumes return of vessel at end of operating life

AGL Gas Import Jetty Project

Stationary Fuel Emissions - Operations

Date 1/15/2020
Revision R05
Completed By DM
Checked By AK, JH

		Total FSRU Operations			FSRU Reciprocating Engines & Boilers			Operation									Ship Demand										
		Fuel Gas			Fuel Gas												While unloading	Not unloading	Gas Data		While unloading		Not unloading		Gas consumed per annum	Gas consumed per day	Adjusted Gas Consumption
Scenario (Send out rates)	Operation	S1	S2	S3	S1	S2	S3	Send Out rate	Total LNG Cargos	Time to unload 1 cargo	Annual time unloading	Annual time not unloading	Operational Days	Operational Hours	Lean LNG Cargos	Rich LNG Cargos											
																	Fuel demand - FSRU engine and boiler	Fuel demand - FSRU engine and boiler	Gas Density - LNG	Gas Energy Content - LNG	Total Fuel Demand - LNG		Total Fuel Demand - LNG				
Closed Loop		tCO2-e			tCO2-e			#	#	hrs	days/annum	days/annum	days/annum	hrs/day	#	#	tonnes/h	tonnes/h	kg/m3	GJ/m3	kg/annum	m3/annum	kg/annum	m3/annum	GJ/annum	GJ/operational day	GJ/annum
387	Closed Loop	132,672	-	-	132,672	-	-	387	20	36	30.00	183.00	213	24	20	-	**10.42**	**10.21**	0.799	0.0393	7,502,400	9,389,737	44,842,320	56,123,054	2,574,653	12,088	2,574,653
500	Closed Loop	76,078	-	-	76,078	-	-	500	16.0	36	24.00	98.00	122	24	11	5	**10.42**	**10.21**	0.799	0.0393	6,001,920	7,511,790	24,013,920	30,054,969	1,476,374	12,101	1,476,374
750	Closed Loop	27,395	-	-	27,395	-	-	750	4.0	36	6.00	24.00	30	24	3	1	**15.18**	**14.97**	0.799	0.0393	2,185,920	2,735,820	8,622,720	10,791,890	531,639	17,721	531,639
Open Loop		**236,145**	**-**	**-**																							**4,582,665**
387	Open Loop	31,479	-	-	31,479	-	-	387	20	36	30.00	183.00	213	24	20	-	**2.61**	**2.4**	0.799	0.0393	1,879,200	2,351,940	10,540,800	13,192,491	610,896	2,868	610,896
500	Open Loop	18,118	-	-	18,118	-	-	500	16.0	36	24.00	98.00	122	24	11	5	**2.61**	**2.4**	0.799	0.0393	1,503,360	1,881,552	5,644,800	7,064,831	351,593	2,882	351,593
750	Open Loop	5,975	-	-	5,975	-	-	750	4.0	36	6.00	24.00	30	24	3	1	**3.33**	**3.26**	0.799	0.0393	479,520	600,150	1,877,760	2,350,138	115,946	3,865	115,946
		55,572	**-**	**-**																			Per closed	Per open			**1,078,435**

CLOSED

OPEN

AGL Gas Import Jetty Project

Fugitive Emissions - Operations

Date 1/15/2020
Revision R05
Completed By DM
Checked By AK, JH

LNGC to FSRU unloadinging			Topside Jetty Infrastructure			Crib Point Metering & Odorant Plant		
Fugitive			Fugitive			Fugitive		
S1	S2	S3	S1	S2	S3	S1	S2	S3
tCO2-e			tCO2-e			tCO2-e		
1,882.0	**-**	**-**	**0.5**	**-**	**-**	**29**	**-**	**-**

LNGC to FSRU unloadinging				
Total LNG Cargos	Annual unloading time	Unloading hoses	Return hoses	Total connections
#	hrs/annum	#	#	#
40	**1,440.00**	**4.00**	**2.00**	**12.00**

FSRU Plant
Operational Hours
hrs
8,760.00

Appendix F

Air emissions – meteorology and climate data

Appendix F Air emissions – meteorology and climate data

The closest BoM Station to the Gas Import Jetty Works is located at Cerberus (Station number 086361), approximately five kilometres to the south-west of the Crib Point site. Cerberus is situated in similar terrain to the FSRU location and is near enough to provide an indication of meteorology. The surface data file for AERMOD is based on BoM Cerberus observations, with the exception of solar radiation and cloud data which was generated from TAPM (refer to **Table 61**).

Long-term climate data has been recorded at the Cerberus BoM site between 1986 and 2019. Temperature (1991–2019), precipitation (1986–2019), humidity, wind speeds and wind direction (1991–2010) records are summarised in **Table 60**.

As shown in **Table 60** the warmest temperatures occur during the summer months, with the highest mean maximum temperature (25ºC) occurring in February. July is the coldest month, with a recorded mean minimum temperature of 6.4ºC. The annual mean rainfall is 720 millimetres over 106 days per year. August is the wettest month, with a mean rainfall of 75 millimetres, while January is the driest month with a mean rainfall of 37 millimetres. Humidity follows a diurnal cycle, with higher humidity in the morning compared to the afternoon.

Table 60 BoM climate average statistics at Cerberus station (1986 to 2019)

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean maximum temperature (°C)	24.6	25	23.1	19.9	16.6	14.2	13.7	14.6	16.5	18.6	20.6	22.5	19.2
Mean minimum temperature (°C)	13.9	14.3	12.6	10	8.5	6.8	6.4	6.6	7.6	8.8	10.7	12	9.8
Mean rainfall (mm)	37.1	38.1	44.9	61.1	69.6	71.6	72.2	75.1	66.6	65.6	54.9	55.1	719.8
Decile 5 (median) rainfall (mm)	32.8	30.6	41.6	56.2	64.4	60.1	67.2	71.6	63	56.4	41.3	44.2	725.4
Mean number of days of rain ≥ 1 mm	4.9	4.3	6.3	8.3	11.4	10.9	11.6	12.4	10.8	10.3	7.7	6.7	105.6
Mean 9am temperature (°C)	18.3	18.3	16.5	14.7	12.1	9.8	9.2	10.2	12	13.8	15.2	16.9	13.9
Mean 9am relative humidity (%)	72	76	79	79	86	86	85	81	77	73	74	72	78
Mean 9am wind speed (km/h)	16.2	14.4	13.1	13.9	12.4	14.1	14.5	16.4	17.9	17.4	15.9	16.6	15.2
Mean 3pm temperature (°C)	22.3	23	21.2	18.2	15.4	13.1	12.6	13.5	14.9	16.5	18.5	20.4	17.5
Mean 3pm relative humidity (%)	58	56	57	60	68	72	69	64	63	61	62	59	62
Mean 3pm wind speed (km/h)	22.3	20.9	20.2	17.8	15.9	17	17.9	19.6	20.3	20.5	20.6	21.8	19.6
Latitude: 38°36"S Longitude: 145°18"E, Elevation: 13 m, Commenced: 1986 Status: Open, Latest available data: 13 Feb 2019													

In addition to the BoM monitoring data, prognostic data from the TAPM model has been used to generate the profile data file for AERMOD. TAPM is a prognostic meteorological and air pollution model developed by CSIRO. The model can be used to predict three-dimensional meteorology, including terrain-induced circulations and is connected to databases of terrain, vegetation and soil type, leaf area index, sea-surface temperature, and synoptic scale meteorological analysis. TAPM prognostic meteorological data was extracted at a point close to the FSRU location.

TAPM meteorological modelling undertaken for the project was set up in accordance with Section 1.3 of the EPA guidance document (EPA 2013a). Some of the key input parameters are described in **Table 61**.

Table 61 Summary of TAPM modelling parameters

Modelling Parameter	Input
Horizontal Grid Points	41 x 41 grid points
Outer Grid Resolution	10,000 m
Nested Grids	Three nested grids. Resolution of 3,000m 1,000m and 300m.
Grid centre coordinates (mX, mY)	344169, 5753846
Vertical levels	25 vertical levels
Land use data	Default TAPM database
Simulation length	Five years with 1 spin up day. 31 December 2013 – 31 December 2018

Winds

Wind predictions have been extracted from AERMOD for the FSRU location (hereafter referred to as AERMOD Crib Point) for reference against regional observations. **Table 62** presents a summary of the yearly wind speed statistics for AERMOD Crib Point. **Figure 52** to **Figure 54** present wind roses for AERMOD Crib Point, with a comparison to BoM Cerberus presented in **Figure 52**.

The wind speed statistics in **Table 62** suggest that the AERMOD Crib Point data show similarities between years, with a minor variation in both average and maximum wind speed. The greatest percentage of calm winds occurred in 2015 and 2016.

Table 62 Yearly AERMOD Crib Point wind statistics 2014 –2018

Wind Parameters	2014	2015	2016	2017	2018
Average (m/s)	3.06	2.82	2.99	2.95	3.19
Maximum (m/s)	13.3	11.4	12.2	11.4	12.8
Calms (%) (<0.5m/s)	6.5	20.2	20.1	7.1	6.9

AERMOD Crib Point wind data is presented as annual wind roses for the years 2014 to 2018 in **Figure 52**. Annual 9 am and 3 pm wind distribution patterns are similar to BoM Cerberus data with the dominant winds from the north to northwest in the morning and southwest in the afternoon. AERMOD Crib Point wind speeds were slightly lower than BoM historical data with 9 am averaging 11.2 kilometres per hour (km/h) (BoM 13.9 km/h) and 3 pm wind speeds averaging 15.9 km/h (BoM 19.6 km/h).

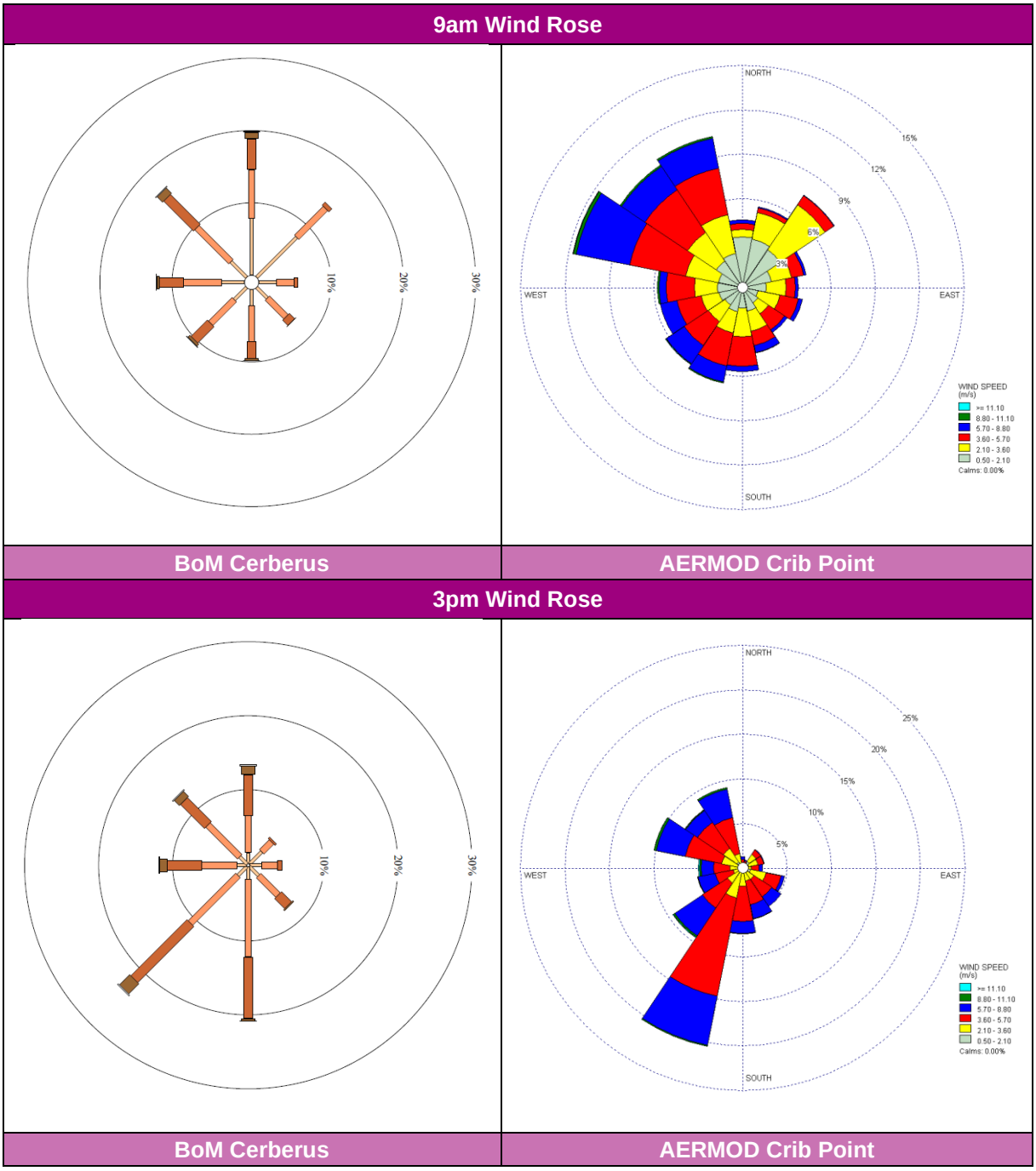


Figure 52 9am and 3pm wind rose comparison AERMOD Crib Point 2014 –2018 to long-term BoM Cerberus

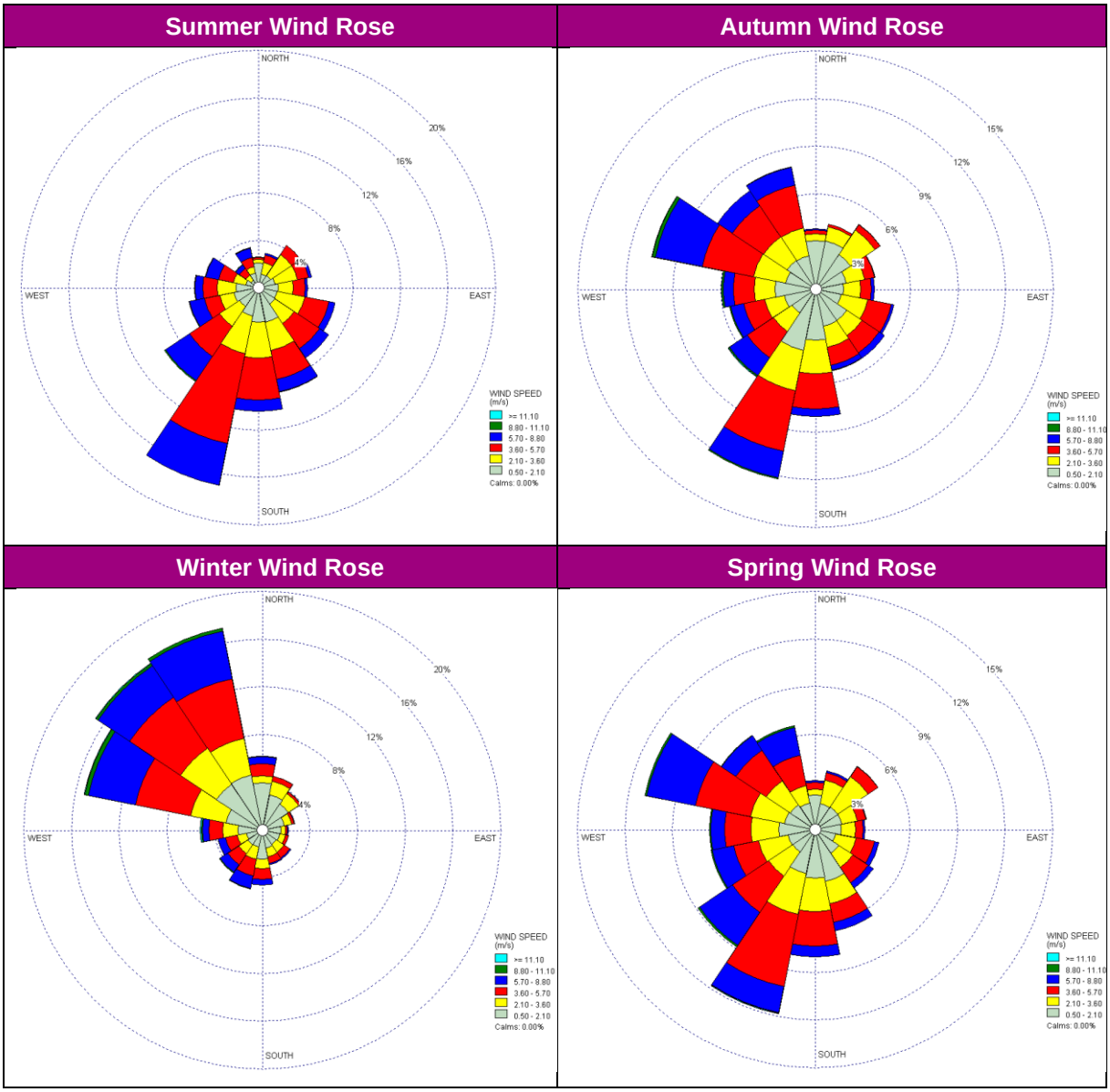


Figure 53 AERMOD Crib Point seasonal wind rose, 2014-2018

The seasonal wind data in **Figure 53** show north-west and south-west portions for autumn and spring, whilst winter is dominated from the north-west and summer from the south-west. The seasonal trends generally match the annual wind trend with northwest and southwest portions dominating.

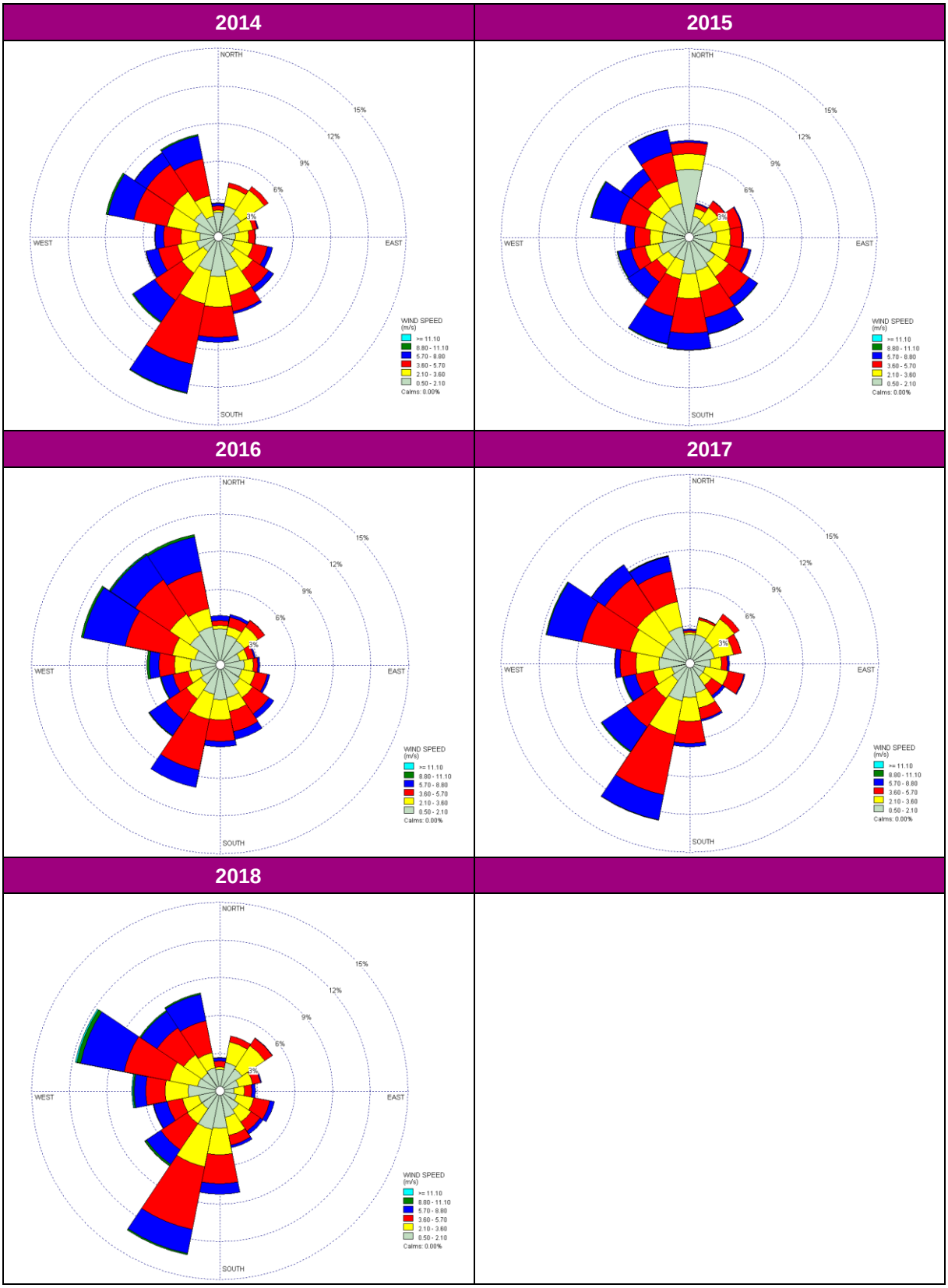


Figure 54 AERMOD Crib Point individual annual wind rose comparison 2014-2018

The annual wind roses in **Figure 54** prepared for the five model years show some consistency between years, with northwest and southwest winds dominating. All years show minimal winds from the east.

Meteorology conclusion

A five-year meteorological dataset was prepared for the FSRU location using TAPM and local observations from the BoM Cerberus station. Data was evaluated using hourly observation data and shows reasonable correlation with long-term and expected trends. The predicted meteorology is considered to be acceptable for use in modelling of air emissions from the FSRU location.

Terrain and land use

The terrain in the immediate area surrounding the FSRU location is predominantly flat and approximately 30 kilometres north-east of open waters. A small mountain range, 15 kilometres from Crib Point, runs north-south on the Mornington Peninsula with elevations up to approximately 200 metres above mean sea level, which may influence the local meteorology. Land use categories used in the AERMOD dispersion model were assigned using satellite imagery in accordance with the U.S. Geological Survey (USGS) Land Use and Land Classification System. Terrain elevations of the model grid are presented in **Figure 55**.

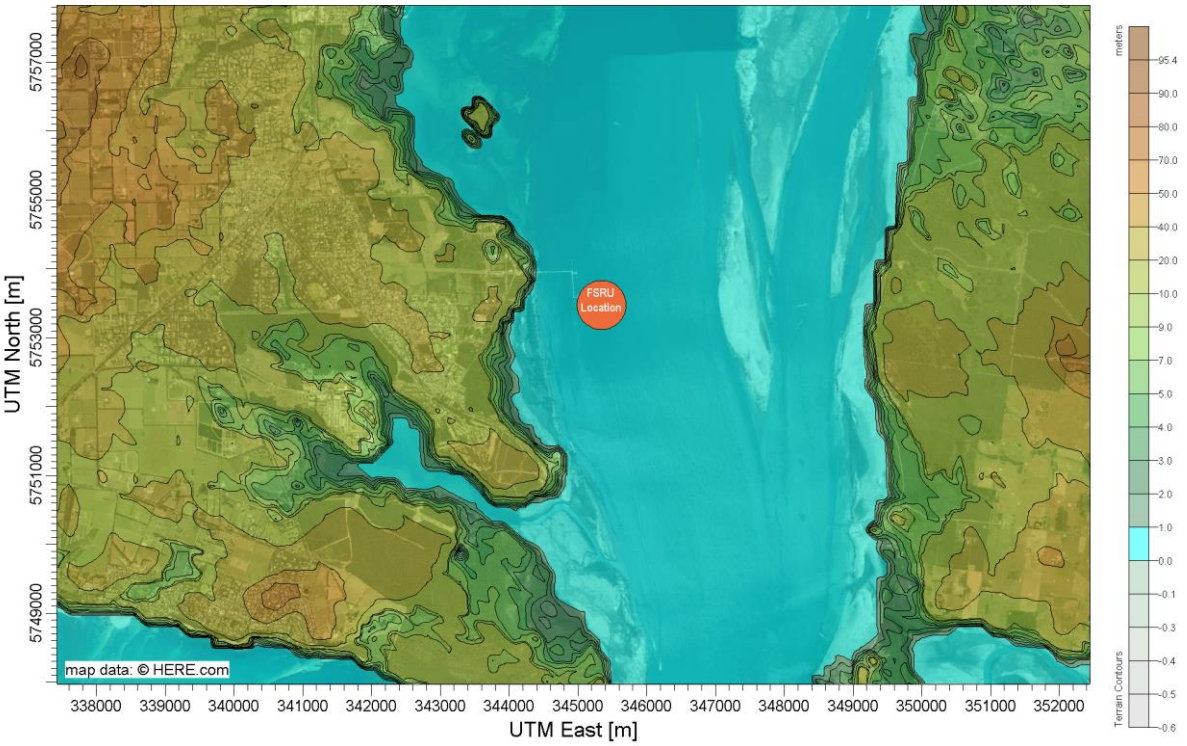


Figure 55 Terrain elevations of model grid

Appendix G

Air emissions - manufacturer emissions specifications

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.

EXHAUST GAS EMISSION DATA FOR MARINE ENGINES

Back-up fuel operation Wärtsilä 50DF, constant speed: 500 and 514 rpm

Typical exhaust gas emission data at different load points and nominal receiver temperatures.

IMO Tier 2 NOx limit is fulfilled.
NOx limits are:

10.54 g/kWh for nominal speed of 500 rpm
10.47 g/kWh for nominal speed of 514 rpm

Emissions (Note 1)

Load	[%]	100	75	50	25
NOx (as NO2) (Note5)	g/kWh	10,2	10,2	10,2	10,2
CO	g/kWh	0,6	0,7	1,3	2,9
THC (as C)	g/kWh	0,21	0,42	0,71	1,02
particles, LFO (Notes 2a,b)	g/kWh	0,2	0,2	0,2	0,3
particles, HFO (Notes 2a,c)	g/kWh	0,6	0,6	0,6	0,7
SO2, LFO (Notes 3a,b)	g/kWh	0,8	-	-	-
SO2, HFO (Notes 3a,c)	g/kWh	8,0	-	-	-
Typical CO2 (Note 4)	g/kWh	633	-	-	-

Back-up fuel operation Wärtsilä 50DF, FPP curve from 500 and 514 rpm

Load	[%]	100	75	50	25
NOx (as NO2) (Note 6)	g/kWh	10,2	10,6	10,4	10,4
CO	g/kWh	0,6	0,7	1,3	2,9
THC (as C)	g/kWh	0,21	0,42	0,71	1,02
particles, LFO (Notes 2a,b)	g/kWh	0,2	0,2	0,2	0,3
particles, HFO (Notes 2a,c)	g/kWh	0,6	0,6	0,6	0,7
SO2, LFO (Notes 3a,b)	g/kWh	0,8	-	-	-
SO2, HFO (Notes 3a,c)	g/kWh	8,0	-	-	-
Typical CO2 (Note 4)	g/kWh	633	-	-	-

NOTE 1. Conditions according to ISO 8178 standard reference conditions. Tolerances are included.

NOTE 2a. Particles measured as "dry dust" according to ISO 9096-03 or alternatively EPA method 17 measurement standards under steady state conditions.
The use of quartz fibre filter material is required (only HFO operation).
Particles emissions are affected by the fuel ash and sulphur content.

NOTE 2b. The values are valid for the fuel ash content < 0.01%-weight and fuel sulphur content < 0.2%-weight and LHV 42.7 MJ/kg.

NOTE 2c. The values are valid for the fuel ash content < 0.1%-weight and fuel sulphur content < 2.0%-weight and LHV 42.7 MJ/kg.

NOTE 3a. SO2 emissions depend on the fuel sulphur content and can be calculated as follows:
SO2 [g/kWh] = ((SFOC [g/kWh])*42.7MJ/kg)/(LHV,real [MJ/kg])*(fuel sulphur content [w-%])/100*64/32.

NOTE 3b. The values are valid for the fuel sulphur content < 0.2%-weight and LHV 42.7 MJ/kg.

NOTE 3c. The values are valid for the fuel sulphur content < 2.0%-weight and LHV 42.7 MJ/kg.

NOTE 4. CO2 emissions depend on engine efficiency and fuel carbon content and can be calculated as follows:
((SFOC [g/kWh])*42.7MJ/kg)/(LHV,real [MJ/kg])*(fuel carbon content [w-%])/100*44/12.

NOTE 5. Tier 2 is guaranteed, specific load NOx values are given for indication only.

NOTE 6 Expected NOx on FPP curve. E3 weighted NOx is not guaranteed

1. AUX. BOILER PERFORMANCE DATA & CURVE

MAC-90BF BOILER EXPECTED PERFORMANCE DATA FOR GAS FIRING

- **Fuel** :GAS
- **Economizer** :APPLIED
- **Fuel Gas Recirculation** :APPLIED (GR%=Max.30%)

LOAD			25%	50%	75%	100%
EVAPORATION		kg/h	22,500	45,000	67,500	90,000
DRUM PRESSURE		MPag	1.5	1.5	1.5	1.5
FEED WATER TEMP.		deg.C	80	80	80	80
SATURATED STEAM TEMP.		deg.C	200.4	200.4	200.4	200.4
BOILER EFFICIENCY (LHV BASE)		%	93.5	94.9	95.0	95.0
CALORIFIC VALUE	HHV	kcal/kg	12,910	12,910	12,910	12,910
	LHV	kcal/kg	11,670	11,670	11,670	11,670
FUEL GAS CONSUMPTION		kg/h	1,209	2,382	3,570	4,760
EXCESS AIR RATE		%	27	15	10	10
O2 RATE		%	4.5	2.8	2.0	2.0
COMBUSTION AIR FLOW		kg/h	26,114	46,596	66,784	89,046
FLUE GAS RECIRCULATION RATIO		%	30	30	30	30
NOx CONCENTRATION(@3%O2)		mg/Nm^3	53	77	72	90
FLUE GAS FLOW		kg/h	35,157	62,957	90,389	120,519
AMBIENT AIR TEMP.		deg.C	45	45	45	45

Note)
- Flue gas flow of volume base is actual condition volume flow at boiler outlet, not standard condition volume flow.
- Maximum flue gas temperature is about 450 degree-C.

Fuel Gas :
Chemical composition

Nitrogen (N2)	: 0.69%	Ethane (C2H6)	: 6.32%
Carbon dioxide (CO2)	: 0.0%	Propane (C3H8)	: 2.16%
Methane (CH4)	: 89.63%	Butane (C4H10)	: 1.2%
		Pentane (C5H12)	: 0.0%

Technical Data and Design Data for DF Generator and Economizer

Technical data for the 6L50DF and 8L50DF generators installed onboard Giant and Esperanza is given below, as taken from the Wartsila product documentation

Wärtsilä 6L50DF		**Mode of operation**	
		Gas	**Diesel**
Engine speed	rpm	514	
Engine output	kW	5850	
Cylinder bore	mm	500	
Stroke	mm	580	
Mean effective pressure	MPa (bar)	2.0 (20.0)	
Mean piston speed	m/s	9.9	
Exhaust gas system			
Flow at 100% load	kg/s	9.4	11.6
Flow at 75% load	kg/s	7.1	9.0
Flow at 50% load	kg/s	5.4	6.3
Temperature after turbocharger at 100% load (TE 517)	°C	373	343
Temperature after turbocharger at 75% load (TE 517)	°C	424	351
Temperature after turbocharger at 50% load (TE 517)	°C	426	385
Backpressure, max.	kPa (bar)	4 (0.04)	
Calculated pipe diameter for 35 m/s	mm	789	856

Wärtsilä 8L50DF		**Mode of operation**	
		Gas	**Diesel**
Engine speed	rpm	514	
Engine output	kW	7800	
Cylinder bore	mm	500	
Stroke	mm	580	
Mean effective pressure	MPa (bar)	2.0 (20.0)	
Mean piston speed	m/s	9.9	

Wärtsilä 8L50DF		Mode of operation	
		Gas	Diesel
Exhaust gas system			
Flow at 100% load	kg/s	12.5	15.4
Flow at 75% load	kg/s	9.5	11.9
Flow at 50% load	kg/s	7.2	8.4
Temperature after turbocharger at 100% load (TE 517)	°C	373	343
Temperature after turbocharger at 75% load (TE 517)	°C	424	351
Temperature after turbocharger at 50% load (TE 517)	°C	426	385
Backpressure, max.	kPa (bar)	4 (0.04)	
Calculated pipe diameter for 35 m/s	mm	910	986

Calculated performance data for the Economizer installed onboard Giant (HN2552). Please note that the capacity of the Economizer is slightly increased on Esperanza compared to Giant.

4.EXPECTED EVAPORATION ON EACH M/E LOAD (Wartsila-Hyundai 8L50DF ×3sets)

Season	-	ISO				Tropical				Winter			
M/E fuel	-	Diesel	Diesel	Gas	Gas	Diesel	Diesel	Gas	Gas	Diesel	Diesel	Gas	Gas
M/E load	%	100%	85%	100%	85%	100%	85%	100%	85%	100%	85%	100%	85%
Evaporation	kg/h	818	750	881	906	983	906	887	910	671	612	902	925
Feed Water Flow	kg/h	818	750	881	906	983	906	887	910	671	612	902	925
Drum Steam Press.	MPa	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Inlet F.W.P	MPa	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Inlet Gas Flow	kg/h	55,440	47,880	45,000	38,880	52,200	45,360	45,000	38,880	58,680	50,400	45,000	38,880
Feed Water Temp.	℃	80	80	80	80	80	80	80	80	80	80	80	80
Steam Temp.	℃	175	175	175	175	175	175	175	175	175	175	175	175
Inlet Gas Temp	℃	338	337	368	388	373	372	369	389	308	307	372	392
Outlet Gas Temp	℃	301	297	319	330	326	322	320	331	278	275	322	333
Draft Loss	kPa	0.79	0.60	0.57	0.45	0.75	0.58	0.57	0.45	0.83	0.63	0.57	0.45
			DESIGN										

4.EXPECTED EVAPORATION ON EACH M/E LOAD (Wartsila-Hyundai 6L50DF ×1set)

Season	-	ISO				Tropical				Winter			
M/E fuel	-	Diesel	Diesel	Gas	Gas	Diesel	Diesel	Gas	Gas	Diesel	Diesel	Gas	Gas
M/E load	%	100%	85%	100%	85%	100%	85%	100%	85%	100%	85%	100%	85%
Evaporation	kg/h	823	750	879	890	991	900	884	895	674	616	900	909
Feed Water Flow	kg/h	823	750	879	890	991	900	884	895	674	616	900	909
Drum Steam Press.	MPa	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Inlet F.W.P	MPa	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Inlet Gas Flow	kg/h	41,760	36,000	33,840	28,800	39,600	33,840	33,840	28,800	43,920	38,160	33,840	28,800
Feed Water Temp.	℃	80	80	80	80	80	80	80	80	80	80	80	80
Steam Temp.	℃	175	175	175	175	175	175	175	175	175	175	175	175
Inlet Gas Temp	℃	338	337	368	388	373	372	369	389	308	307	372	392
Outlet Gas Temp	℃	288	284	303	311	311	305	303	311	268	265	305	313
Draft Loss	kPa	0.88	0.67	0.63	0.48	0.85	0.63	0.63	0.49	0.92	0.71	0.63	0.49
			DESIGN										

Appendix H

Air emissions – modelling predictions

Appendix H Air emissions – modelling predictions

Gas-fuelled FSRU open loop modelling predictions

Table 63 presents the results of the gas-fuelled FSRU in open loop mode, at each of the 38 sensitive receptor locations.

Table 63 Gas-fuelled FSRU, open loop scenario, pollutant concentration results at sensitive receptor locations, 99.9th percentile including background (µg/m³)

Receptor	NO_2 (1 h)	CO (1 h)	VOC (3 min)	PM_{10} (1 h)	$PM_{2.5}$ (1 h)	PAH (3 min)	Benzene (3 min)	Formaldehyde (3 min)
Background	54.7	1360	-	44.6	19.3	-	-	-
R01	57.8	1368	7.8	45.2	19.8	0.000011	0.029	3.6
R02	57.2	1366	6.3	45.0	19.7	0.000009	0.023	2.9
R03	57.7	1368	7.5	45.1	19.7	0.000011	0.028	3.5
R04	57.5	1367	7.0	45.1	19.7	0.000010	0.026	3.3
R05	57.6	1367	7.1	45.1	19.7	0.000010	0.027	3.3
R06	58.0	1368	8.3	45.2	19.8	0.000012	0.031	3.9
R07	57.3	1366	6.4	45.1	19.7	0.000009	0.024	3.0
R08	57.5	1367	7.0	45.1	19.7	0.000010	0.026	3.3
R09	57.6	1367	7.1	45.1	19.7	0.000010	0.026	3.3
R10	58.2	1369	8.6	45.2	19.8	0.000013	0.032	4.1
R11	57.5	1367	7.0	45.1	19.7	0.000010	0.026	3.3
R12	57.5	1367	6.8	45.1	19.7	0.000010	0.025	3.2
R13	57.7	1367	7.3	45.1	19.7	0.000011	0.027	3.4
R14	63.2	1381	21.1	46.1	20.6	0.000031	0.079	9.9
R15	61.4	1377	16.7	45.8	20.3	0.000024	0.062	7.8
R16	57.8	1368	7.6	45.1	19.8	0.000011	0.028	3.6
R17	57.3	1366	6.4	45.1	19.7	0.000009	0.024	3.0
R18	57.1	1366	5.9	45.0	19.7	0.000009	0.022	2.8
R19	57.1	1366	5.9	45.0	19.7	0.000009	0.022	2.8
R20	57.1	1366	6.0	45.0	19.7	0.000009	0.022	2.8
R21	57.0	1366	5.8	45.0	19.6	0.000008	0.022	2.7
R22	57.3	1366	6.3	45.1	19.7	0.000009	0.024	3.0
R23	57.8	1368	7.8	45.2	19.8	0.000011	0.029	3.7
R24	58.0	1368	8.1	45.2	19.8	0.000012	0.030	3.8
R25	56.9	1366	5.5	45.0	19.6	0.000008	0.021	2.6
R26	56.9	1365	5.3	45.0	19.6	0.000008	0.020	2.5
R27	57.7	1368	7.5	45.1	19.8	0.000011	0.028	3.5
R28	57.7	1368	7.4	45.1	19.7	0.000011	0.028	3.5
R29	57.7	1368	7.5	45.1	19.8	0.000011	0.028	3.5
R30	58.4	1369	9.2	45.3	19.9	0.000013	0.034	4.3
R31	63.5	1382	21.7	46.2	20.6	0.000032	0.081	10.2
R32	63.7	1382	22.2	46.2	20.6	0.000032	0.083	10.4
R33	69.2	1396	35.9	47.2	21.5	0.000052	0.134	16.9
R34	65.9	1388	27.8	46.6	21.0	0.000041	0.104	13.1
R35	56.7	1365	4.9	44.9	19.6	0.000007	0.018	2.3
R36	56.7	1365	5.0	45.0	19.6	0.000007	0.018	2.3
R37	56.7	1365	4.9	45.0	19.6	0.000007	0.018	2.3

Receptor	NO_2 (1 h)	CO (1 h)	VOC (3 min)	PM_{10} (1 h)	$PM_{2.5}$ (1 h)	PAH (3 min)	Benzene (3 min)	Formaldehyde (3 min)
R38	56.6	1365	4.8	44.9	19.6	0.000007	0.018	2.2
Max	**69.2**	**1396**	**35.9**	**47.2**	**21.5**	**0.000052**	**0.134**	**16.9**
Criteria	**190**	**29000**	**-**	**80**	**50**	**0.73**	**53**	**40**

Gas-fuelled FSRU closed loop (two boilers)

Table 64 presents the results of the gas-fuelled FSRU in closed loop mode with two boilers, at each of the 38 sensitive receptor locations.

Table 64 Gas-fuelled FSRU, two boiler scenario, pollutant concentration results at sensitive receptor locations, 99.9th percentile including background (µg/m³)

Receptor	NO_2 (1 h)	CO (1 h)	VOC (3 min)	PM_{10} (1 h)	$PM_{2.5}$ (1 h)	PAH (3 min)	Benzene (3 min)	Formaldehyde (3 min)
Background	**54.7**	**1360**	**-**	**44.6**	**19.3**	**-**	**-**	**-**
R01	58.6	1370	7.9	45.3	19.9	0.000012	0.030	3.7
R02	58.0	1368	6.5	45.2	19.8	0.000009	0.024	3.0
R03	58.4	1370	7.6	45.3	19.9	0.000011	0.028	3.6
R04	58.0	1368	7.2	45.2	19.8	0.000011	0.027	3.4
R05	58.1	1369	7.3	45.3	19.9	0.000011	0.027	3.4
R06	58.8	1371	8.4	45.4	20.0	0.000012	0.031	4.0
R07	57.8	1368	6.6	45.2	19.8	0.000010	0.024	3.1
R08	58.1	1369	7.2	45.3	19.8	0.000010	0.027	3.4
R09	58.4	1370	7.4	45.3	19.9	0.000011	0.028	3.5
R10	58.7	1370	8.8	45.4	19.9	0.000013	0.033	4.1
R11	58.1	1369	7.2	45.3	19.8	0.000010	0.027	3.4
R12	58.3	1369	7.0	45.3	19.9	0.000010	0.026	3.3
R13	58.4	1369	7.6	45.3	19.9	0.000011	0.028	3.6
R14	63.9	1383	21.3	46.3	20.7	0.000031	0.079	10.0
R15	61.8	1378	16.9	45.9	20.4	0.000025	0.063	7.9
R16	58.6	1370	7.8	45.3	19.9	0.000011	0.029	3.7
R17	57.9	1368	6.6	45.2	19.8	0.000010	0.024	3.1
R18	57.4	1367	6.0	45.1	19.8	0.000009	0.022	2.8
R19	57.5	1367	6.0	45.1	19.7	0.000009	0.022	2.8
R20	57.5	1367	6.1	45.2	19.8	0.000009	0.023	2.9
R21	57.5	1367	6.0	45.1	19.8	0.000009	0.022	2.8
R22	57.7	1368	6.4	45.2	19.8	0.000009	0.024	3.0
R23	58.8	1370	8.2	45.4	20.0	0.000012	0.031	3.9
R24	58.4	1370	8.2	45.3	19.9	0.000012	0.030	3.8
R25	57.4	1367	5.7	45.1	19.7	0.000008	0.021	2.7
R26	57.4	1367	5.5	45.1	19.7	0.000008	0.020	2.6
R27	58.6	1370	7.8	45.3	19.9	0.000011	0.029	3.6
R28	58.4	1370	7.6	45.3	19.9	0.000011	0.028	3.6
R29	58.5	1370	7.6	45.3	19.9	0.000011	0.028	3.6
R30	59.3	1372	9.7	45.5	20.1	0.000014	0.036	4.6
R31	63.9	1383	21.9	46.3	20.7	0.000032	0.081	10.3
R32	64.0	1383	22.3	46.3	20.7	0.000033	0.083	10.5
R33	70.9	1401	36.5	47.6	21.8	0.000053	0.136	17.1

Receptor	NO_2 (1 h)	CO (1 h)	VOC (3 min)	PM_{10} (1 h)	$PM_{2.5}$ (1 h)	PAH (3 min)	Benzene (3 min)	Formaldehyde (3 min)
R34	67.0	1391	28.2	46.9	21.2	0.000041	0.105	13.2
R35	57.1	1366	5.0	45.1	19.7	0.000007	0.019	2.4
R36	57.2	1366	5.1	45.1	19.7	0.000007	0.019	2.4
R37	57.1	1366	5.0	45.1	19.7	0.000007	0.019	2.4
R38	57.0	1366	4.8	45.0	19.7	0.000007	0.018	2.3
Max	**70.9**	**1401**	**36.5**	**47.6**	**21.8**	**0.000053**	**0.136**	**17.1**
Criteria	**190**	**29000**	**-**	**80**	**50**	**0.73**	**53**	**40**

Gas-fuelled FSRU closed loop (three boilers)

Table 65 presents the results of the gas-fuelled FSRU in closed loop mode with three boilers, at each of the 38 sensitive receptor locations.

Table 65 Gas-fuelled FSRU, three boiler scenario, pollutant concentration results at sensitive receptor locations, 99.9th percentile including background (µg/m³)

Receptor	NO_2 (1 h)	CO (1 h)	VOC (3 min)	PM_{10} (1 h)	$PM_{2.5}$ (1 h)	PAH (3 min)	Benzene (3 min)	Formaldehyde (3 min)
Background	**54.7**	**1360**	**-**	**44.6**	**19.3**	**-**	**-**	**-**
R01	58.8	1371	8.0	45.4	20.0	0.000012	0.030	3.8
R02	58.4	1370	6.6	45.4	19.9	0.000010	0.025	3.1
R03	58.8	1370	7.8	45.4	20.0	0.000011	0.029	3.6
R04	58.3	1369	7.3	45.3	19.9	0.000011	0.027	3.4
R05	58.5	1370	7.4	45.4	19.9	0.000011	0.028	3.5
R06	59.3	1372	8.6	45.5	20.1	0.000013	0.032	4.0
R07	58.2	1369	6.6	45.3	19.9	0.000010	0.025	3.1
R08	58.5	1370	7.2	45.4	19.9	0.000011	0.027	3.4
R09	58.8	1371	7.5	45.4	20.0	0.000011	0.028	3.5
R10	59.1	1371	8.9	45.4	20.0	0.000013	0.033	4.2
R11	58.5	1370	7.2	45.4	19.9	0.000011	0.027	3.4
R12	58.6	1370	7.0	45.4	20.0	0.000010	0.026	3.3
R13	58.8	1370	7.8	45.4	20.0	0.000011	0.029	3.7
R14	64.3	1384	21.5	46.4	20.8	0.000031	0.080	10.1
R15	62.0	1379	17.0	45.9	20.4	0.000025	0.063	8.0
R16	59.0	1371	8.0	45.4	20.0	0.000012	0.030	3.8
R17	58.2	1369	6.7	45.3	19.9	0.000010	0.025	3.1
R18	57.8	1368	6.0	45.2	19.8	0.000009	0.022	2.8
R19	57.8	1368	6.1	45.2	19.8	0.000009	0.023	2.9
R20	57.9	1368	6.2	45.2	19.8	0.000009	0.023	2.9
R21	57.8	1368	6.1	45.2	19.8	0.000009	0.023	2.9
R22	58.0	1368	6.6	45.2	19.8	0.000010	0.024	3.1
R23	59.3	1372	8.4	45.5	20.1	0.000012	0.031	3.9
R24	58.8	1371	8.2	45.4	20.0	0.000012	0.030	3.8
R25	57.7	1368	5.8	45.2	19.8	0.000008	0.022	2.7
R26	57.7	1368	5.5	45.2	19.8	0.000008	0.021	2.6
R27	59.0	1371	7.9	45.4	20.0	0.000011	0.029	3.7
R28	58.8	1370	7.6	45.4	20.0	0.000011	0.028	3.6
R29	58.8	1371	7.7	45.4	20.0	0.000011	0.029	3.6

Receptor	NO_2 (1 h)	CO (1 h)	VOC (3 min)	PM_{10} (1 h)	$PM_{2.5}$ (1 h)	PAH (3 min)	Benzene (3 min)	Formaldehyde (3 min)
R30	59.9	1374	9.9	45.7	20.2	0.000014	0.037	4.6
R31	64.1	1384	21.9	46.3	20.7	0.000032	0.082	10.3
R32	64.1	1384	22.4	46.3	20.7	0.000033	0.083	10.5
R33	71.9	1404	36.8	47.9	22.0	0.000054	0.137	17.3
R34	67.6	1393	28.3	47.0	21.3	0.000041	0.105	13.3
R35	57.4	1367	5.1	45.1	19.7	0.000007	0.019	2.4
R36	57.4	1367	5.2	45.1	19.7	0.000008	0.019	2.4
R37	57.4	1367	5.1	45.1	19.7	0.000007	0.019	2.4
R38	57.2	1366	4.9	45.1	19.7	0.000007	0.018	2.3
Max	**71.9**	**1404**	**36.8**	**47.9**	**22.0**	**0.000054**	**0.137**	**17.3**
Criteria	**190**	**29000**	**-**	**80**	**50**	**0.73**	**53**	**40**

Liquid-fuelled FSRU

The FSRU will use gas fuel (boil-off gas) for combustion in the reciprocating engines. Liquid fuel (diesel) will be used only when a back-up fuel source is needed such as during emergency, maintenance or start-up. The maximum diesel usage predicted is 14.6 tonnes per day and has been included in the modelling of potential operational air quality impacts for completeness.

Table 66 presents the results of the gas-fuelled FSRU in closed loop mode with three boilers, at each of the 38 sensitive receptor locations.

Table 66 Liquid- fuelled FSRU pollutant concentration results at sensitive receptor locations, 99.9th percentile including background (µg/m³)

Receptor	NO_2 (1 h)	CO (1 h)	VOC (3 min)	PM_{10} (1 h)	$PM_{2.5}$ (1 h)	SO_2 (1 h)	PAH (3 min)	Benzene (3 min)	Formaldehyde (3 min)
Background	**54.7**	**1360**	**-**	**44.6**	**19.3**	**16.9**	**-**	**-**	**-**
R01	59.0	1364	13.0	45.0	19.6	18.0	0.0000019	0.13	0.013
R02	58.2	1363	8.3	44.9	19.6	17.8	0.0000012	0.08	0.008
R03	58.8	1364	12.5	45.0	19.6	18.0	0.0000018	0.13	0.013
R04	58.7	1364	12.4	45.0	19.6	17.9	0.0000018	0.12	0.012
R05	58.6	1364	9.8	45.0	19.6	17.9	0.0000014	0.10	0.010
R06	59.4	1364	16.2	45.0	19.7	18.1	0.0000024	0.16	0.016
R07	58.1	1363	11.0	44.9	19.6	17.8	0.0000016	0.11	0.011
R08	58.6	1364	13.8	45.0	19.6	17.9	0.0000020	0.14	0.014
R09	58.9	1364	14.5	45.0	19.6	18.0	0.0000021	0.14	0.014
R10	59.8	1365	16.4	45.1	19.7	18.2	0.0000024	0.16	0.016
R11	58.6	1364	13.8	45.0	19.6	17.9	0.0000020	0.14	0.014
R12	58.3	1363	9.6	44.9	19.6	17.8	0.0000014	0.10	0.010
R13	58.6	1364	10.6	45.0	19.6	17.9	0.0000016	0.11	0.011
R14	67.7	1372	19.9	45.9	20.3	20.2	0.0000029	0.20	0.020
R15	65.0	1370	17.1	45.6	20.1	19.5	0.0000025	0.17	0.017
R16	58.8	1364	14.0	45.0	19.6	18.0	0.0000021	0.14	0.014
R17	58.2	1363	11.1	44.9	19.6	17.8	0.0000016	0.11	0.011
R18	57.9	1363	10.7	44.9	19.6	17.7	0.0000016	0.11	0.011
R19	57.8	1363	10.2	44.9	19.6	17.7	0.0000015	0.10	0.010
R20	57.9	1363	8.5	44.9	19.6	17.7	0.0000012	0.08	0.008

Receptor	NO_2 (1 h)	CO (1 h)	VOC (3 min)	PM_{10} (1 h)	$PM_{2.5}$ (1 h)	SO_2 (1 h)	PAH (3 min)	Benzene (3 min)	Formaldehyde (3 min)
R21	57.8	1363	7.7	44.9	19.6	17.7	0.0000011	0.08	0.008
R22	58.3	1363	9.1	44.9	19.6	17.8	0.0000013	0.09	0.009
R23	58.8	1364	13.9	45.0	19.6	18.0	0.0000020	0.14	0.014
R24	60.2	1365	12.6	45.1	19.7	18.3	0.0000018	0.13	0.013
R25	57.7	1363	8.1	44.9	19.5	17.7	0.0000012	0.08	0.008
R26	57.6	1363	7.8	44.9	19.5	17.7	0.0000011	0.08	0.008
R27	59.2	1364	16.4	45.0	19.7	18.0	0.0000024	0.16	0.016
R28	59.1	1364	15.1	45.0	19.7	18.0	0.0000022	0.15	0.015
R29	59.6	1365	15.7	45.1	19.7	18.2	0.0000023	0.16	0.016
R30	64.6	1369	15.3	45.6	20.1	19.4	0.0000022	0.15	0.015
R31	71.8	1376	16.4	46.2	20.7	21.3	0.0000024	0.16	0.016
R32	72.4	1376	15.6	46.3	20.7	21.4	0.0000023	0.16	0.016
R33	79.4	1383	16.1	47.0	21.3	23.2	0.0000023	0.16	0.016
R34	72.9	1377	11.3	46.4	20.8	21.6	0.0000016	0.11	0.011
R35	57.4	1363	6.0	44.9	19.5	17.6	0.0000009	0.06	0.006
R36	57.6	1363	6.2	44.9	19.5	17.6	0.0000009	0.06	0.006
R37	57.5	1363	3.7	44.9	19.5	17.6	0.0000005	0.04	0.004
R38	57.3	1362	4.8	44.8	19.5	17.6	0.0000007	0.05	0.005
Max	**79.4**	**1383**	**19.9**	**47.0**	**21.3**	**23.2**	**0.0000029**	**0.20**	**0.020**
Criteria	**190**	**29000**	**-**	**80**	**80**	**450**	**0.73**	**53**	**40**

Appendix I

Air emissions - Human Health Risk Assessment (HHRA)

Appendix I Air emissions - Human Health Risk Assessment (HHRA)

Formaldehyde is listed in the State Environment Protection Policy (SEPP) (Air Quality Management (AQM)) as Class 2 indicator and is derived from the current Worksafe Australia Occupational Health and Safety Time Weighted Average (TWA) value of 1,200 µg/m^3 divided by a safety factor of 30 (Safe Work Australia 2013). This safety factor accounts for extrapolation from a healthy adult exposed over their working life (eight hours a day, five days a week) to the general population potentially exposed over a lifetime and takes into account the protection of sensitive groups including the elderly and children. In addition, this extrapolation does not take into account relevant epidemiological data in the exposure of humans to formaldehyde emissions.

Where significant quantities of toxic air pollutants are emitted and the predicted concentrations are approaching or exceeding the SEPP criteria (which are as discussed above indicator criteria based on work health and safety criteria), it is recommended to undertake further analysis of the modelling results against health based toxicological criteria for use within a human health risk assessment (HHRA).

In accordance with the Assessment of Site Contamination (ASC) National Environment Protection Measure (NEPM) (2013), the HHRA process is generally undertaken in 'tiers' involving processing more detailed levels of data collection and analysis. It is noted that that the ASC NEPM (2013) methodology is specifically for the assessment of contaminated sites but is generic in its approach and applicable to this assessment.

The first tier (Tier 1) comprises a screening level assessment where predicted pollutant levels are compared to published human health screening criteria to determine whether further assessment is required. Exceedance of Tier 1 criteria is used to define the pollutants that require more detailed assessment by the development of site-specific criteria. An exceedance of health screening criteria does not mean that significant health risk is likely to be present; rather it is a trigger for a more detailed consideration of potential risks to human health.

Depending on the likely or predicted exposure period, acute (short-term) and chronic (long-term) screening criteria can be considered in a Tier 1 assessment. As the FSRU is expected to operate at peak capacity in short durations for only 10 per cent of the year, the Acute 1-hour Criteria has been considered for the purpose of screening formaldehyde emissions from the FSRU. The Protective Action Criteria (PAC), was developed in May 2016 by the U.S. Department of Energy (USDOE 2016) to combine the following:

- Acute Exposure Guideline Levels (AEGLs) developed by the National Advisory Committee on Acute Exposure Guideline Levels for Hazardous Substances (NAC/AEGL Committee) and available from the United States Environmental Protection Agency (US EPA). In general, three levels of AEGLs: AEGL 1, AEGL 2 and AEGL 3, have been developed for five exposure periods i.e. 10 minutes, 30 minutes, 1-hour, 4-hours and 8-hours.
- Emergency Response Planning Guidelines (ERPGs) developed by the American Industrial Hygiene Association (AIHA) and Subcommittee on Consequence Assessment and Protective Actions (SCAPA).
- Temporary Emergency Exposure Limits (TEELs) developed by SCAPA as temporary limits for chemicals until AEGLs or ERPGs are developed. This also includes Threshold Limit Values (TLV) - Short-Term Exposure Limit (STEL). STEL refers to the time-weighted average maximum airborne concentration of a substance calculated over a 15-minute period.

The acute screening criteria for formaldehyde are shown below in **Table 67**.

Table 67 Formaldehyde Acute Exposure Screening Criteria

Chemical	Concentration (µg/m^3)	Source
Formaldehyde	PAC-1 (1 hour): 1,190	AEGL-1 - converted from 0.90 ppm[1]
	PAC-2 (1 hour): 18,500	AEGL-2 - converted from 14 ppm[1]
	PAC-3 (1-hour): 74,000	AEGL-3 - converted from 56 ppm[1]

[1] Based on a molecular weight of 30.031g/mol

The maximum predicted 1-hour and 3-minute formaldehyde concentrations for the gas-fuelled, three boiler scenario is 178 µg/m^3 and 324 µg/m^3, respectively. The 99.9th percentile 1-hour and 3-minute average concentrations are 123 µg/m^3 and 223 µg/m^3, respectively. Refer to **Figure 56** for 99.9th percentile 3-minute concentration contours.

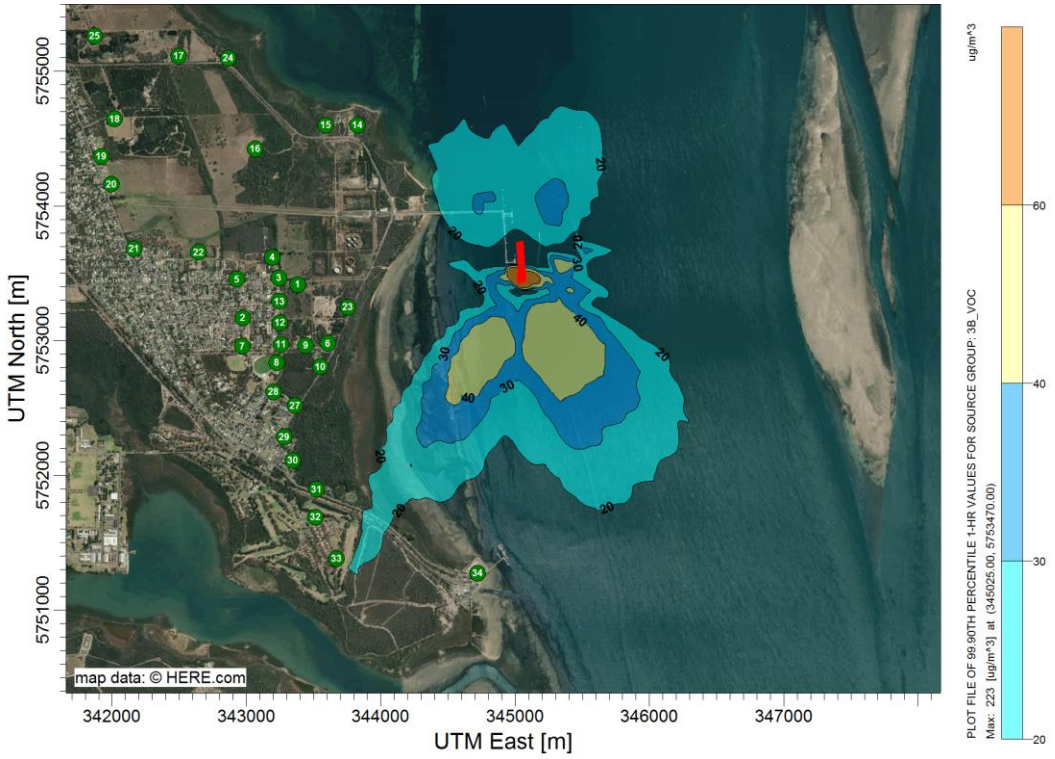


Figure 56 Gas-fuelled FSRU, three boiler scenario, Formaldehyde concentration results, 99.9th percentile, no background (µg/m^3)

The following is noted in terms of compliance with the criteria for workers health and general compliance with acute exposure criteria:

- Predicted maximum 1-hour average concentration (178 µg/m^3) represents approximately 15 per cent of the TWA criterion (1,200 µg/m^3) and PAC-1 criterion (1,190 µg/m^3)

Modelling results demonstrate that formaldehyde concentrations will be much less than the TWA and PAC-1 criteria, indicating that from an acute health risk perspective, there are no adverse health impacts expected for workers or receptors in the vicinity of the FSRU.

Modelling was based on five years of meteorology data to ensure the worst-case conditions have been considered. Worst case scenarios, with the FSRU operating at peak capacity are only expected to occur for ten per cent of the year over short durations. For elevated concentrations to occur on land,

worst case meteorology would need to occur at the same time as the FSRU is operating at 100 per cent load. For the remainder of the year, emissions from the FSRU are expected to be much less, implying further compliance with the criterion at lower predicted concentrations.

In the atmosphere, formaldehyde has a half-life of 1.6–19 hours, decomposing into hydrogen gas and carbon monoxide (USEPA 2019). AERMOD assumes that pollutants are inert gases; i.e. the model does not account for any chemical transformations. Given this known decomposition of formaldehyde, it is expected that ambient concentrations will be lower than those predicted by AERMOD.

An analysis on the frequency of occurrence for the predicted formaldehyde impacts was undertaken by choosing eight locations within the 40 µg/m^3 99.9th percentile 3-minute formaldehyde contour of the three boiler gas-fuelled scenario. Locations are summarised below and presented in **Figure 57**:

- Locations 1 and 2 approximately 60 metres from the FSRU
- Locations 3 and 4 approximately 275 metres from the FSRU
- Locations 5 and 6 approximately 530 metres from the FSRU
- Locations 7 and 8 approximately 800 metres from the FSRU.

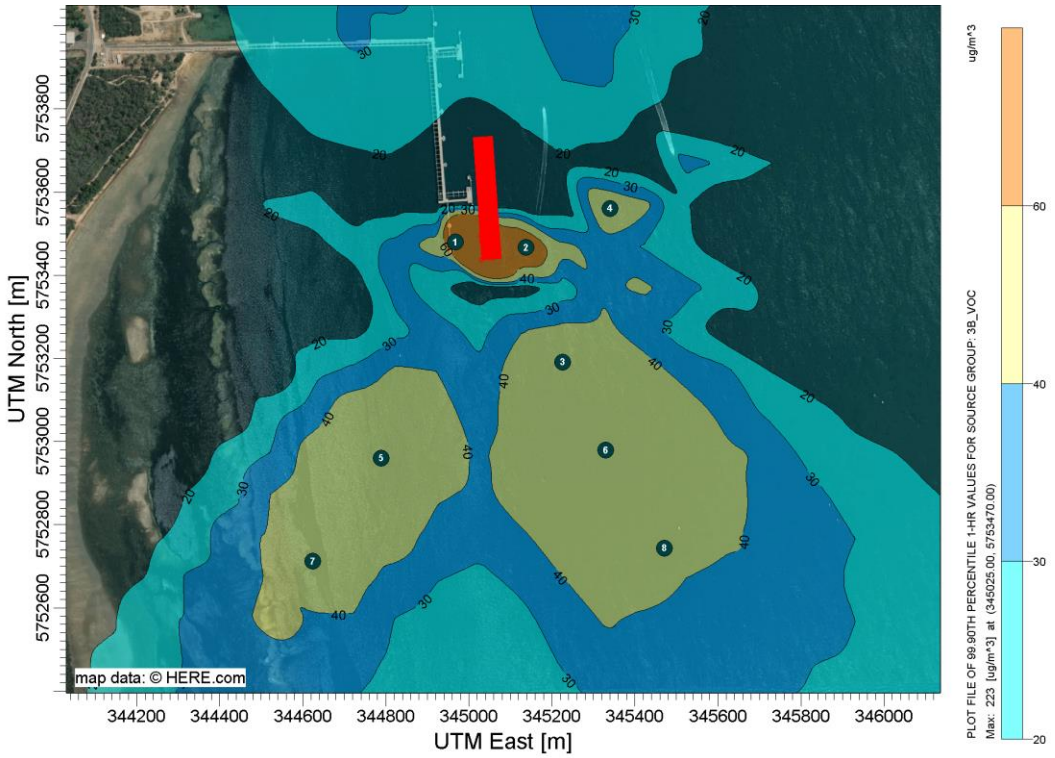


Figure 57 The eight locations chosen for frequency of occurrence analysis, Gas-fuelled FSRU, three boiler scenario, Formaldehyde concentration results, 99.9th percentile, no background (µg/m^3)

Modelling was undertaken using five years of meteorology which outputs a total of 43,824 1-hour average formaldehyde concentrations for each of the eight locations shown in **Figure 57**. Concentrations were then converted to 3-minute averages by multiplying by 1.82 for comparison to the SEPP (AQM) design criterion. **Table 68** presents the frequency of occurrence results within the selected concentration ranges.

Table 68 Frequency of occurrence, three boiler scenario, formaldehyde concentration results

Location	1	2	3	4	5	6	7	8
Formaldehyde concentration (µg/m³)	Percentage of Hours							
Less than 5	98.8%	97.9%	90.7%	96.2%	96.3%	91.7%	97.9%	95.0%
5 - 10	0.5%	0.4%	3.1%	2.1%	1.9%	3.8%	0.7%	2.9%
10 - 15	0.1%	0.3%	2.2%	0.7%	0.4%	1.9%	0.2%	0.5%
15 - 20	0.1%	0.2%	1.5%	0.1%	0.2%	0.7%	0.3%	0.4%
20 - 25	0.0%	0.2%	1.2%	0.2%	0.3%	0.4%	0.3%	0.5%
25 - 30	0.1%	0.1%	0.4%	0.0%	0.3%	0.5%	0.2%	0.3%
30 - 35	0.0%	0.0%	0.3%	0.0%	0.2%	0.3%	0.1%	0.2%
35 - 40	0.0%	0.0%	0.3%	0.1%	0.1%	0.3%	0.0%	0.0%
Greater than 40	0.3%	0.8%	0.3%	0.5%	0.4%	0.4%	0.2%	0.1%

Frequency of occurrence results illustrate that the 99.9th percentile ground level concentrations are extreme values, with 3-minute ground level formaldehyde concentrations predicted to be:

- below 5 µg/m^3 at Locations 1, 2, 4, 5, 7 and 8 for at least 95.0 per cent of the year
- below 5 µg/m^3 at Locations 3 and 6 for approximately 91 per cent of the year
- below the criterion (40 µg/m^3) for at least 99 per cent of the year at all eight Locations .

The air modelling assessment and HHRA demonstrates that there is a low risk of air quality impacts from the FSRU operations and emissions are unlikely to have regionally or State significant effects on the air environment. An air quality monitoring programme will be designed and implemented to confirm FSRU emission rates comply with design specifications.

Appendix J

Noise – operational noise criteria

Appendix J Noise – operational noise criteria

The following method was used to determine the recommended maximum noise levels (compliance criteria) at the Gas Import Facility.

SEPP N-1 method: 103 The Esplanade, 132 The Esplanade, 43 Disney Street

1. Zoning Levels

The SEPP N-1 Zoning Level for each period was calculated in accordance with Schedule B2 of SEPP N-1 for the noise-sensitive receptor which are close to the site, and within the Major Urban Area.

The calculated Zoning Levels are presented below.

SEPP N-1 Zoning Levels	Day	Evening	Night
103 The Esplanade	52 dB(A)	46 dB(A)	41 dB(A)
43 Disney Street	56 dB(A)	50 dB(A)	45 dB(A)
132 The Esplanade	50 dB(A)	44 dB(A)	39 dB(A)

2. Background Noise Levels

The background noise monitoring results were compared to the Zoning Levels to determine whether the background level is low, neutral or high. If the background level is not neutral, then the noise limit is based on the background level. SEPP N-1 provides formulas for calculating limits based on high or low background levels.

At 103 The Esplanade and 43 Disney Street the background levels were low in comparison to Zoning Levels during the day, evening and night. At 132 The Esplanade, the background levels were low in comparison to Zoning Levels during the day and night and neutral in the evening.

3. SEPP N-1 Noise Limits

A summary of SEPP N-1 noise limits is shown below.

Noise-Sensitive Receptor	Recommended Noise Levels ($L_{Aeq,30min}$)		
	Day	Evening	Night
103 The Esplanade	47dB(A)	42 dB(A)	35 dB(A)
43 Disney Street	48 dB(A)	43 dB(A)	36 dB(A)
132 The Esplanade	45 dB(A)	42 dB(A)	35 dB(A)

NIRV: French Island Receptors

1. Zone Levels

NIRV prescribes different ‘zone levels’ depending on the zoning of the land at the noise-emitting premises, and at the noise sensitive receptors, to provide a basis for the resultant recommended noise levels.

Table 1 of the NIRV is used in conjunction with the planning scheme for the subject site to determine the applicable zone levels.

Under the Mornington Peninsula and French-Elisabeth-Sandstone Islands Planning Schemes, the site is located in Public Use Zone 7 (PUZ7) and the French island residential properties are positioned in Rural Conservation Zone (RCZ). The Crib Point zoning map is shown in **Figure A** below.

The zone levels applicable to the Gas Import Facility site are presented below.

Residential Zoning	Day	Evening	Night
RCZ	45 dB(A)	40 dB(A)	35 dB(A)

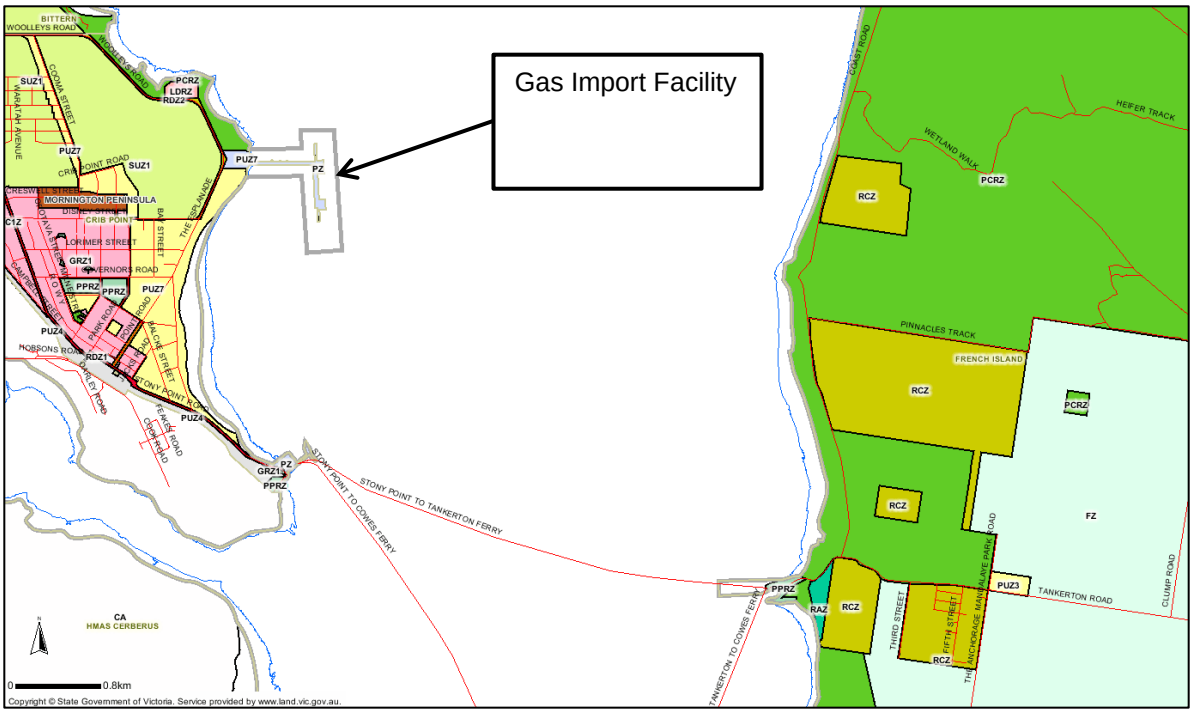


Figure A Crib Point zoning map

2. Distance Adjustment

NIRV states that distance adjustments are to be made to the zone levels where the noise-emitting premises and the noise-sensitive receptors are not within the same zone classification or are separated by another zone type (other than road or railway line). The distance adjustment is based on the distance between the receptor and the boundary of the zone in which the noise-emitting premises is located.

The adjustment to the zone levels for distance is a subtraction of one decibel for every 100 metres from the receptor to the boundary of the land use zone in which the noise emitter is located. The distance adjustment shall be made up to a maximum subtraction of nine decibels.

The distance adjustment is shown in below.

Residential Zoning	Distance Adjustment
RCZ	One decibel for every 100 metres of distance between PUZ7 and the receptor.

As the receptors are separated by a significant distance (~5km) form PUZ7, the base noise level check sets the recommended levels.

3. Base Noise Level Check

NIRV stipulates ‘base noise levels’, which place lower limits on the distance-adjusted levels, to ensure that the levels are not lower than necessary to provide reasonable protection to noise-sensitive areas. The base noise levels are shown below.

NIRV Levels	Day	Evening	Night
Base Noise Level Check	45 dB(A)	37 dB(A)	32 dB(A)

4. NIRV Recommended Noise Levels

Recommended levels(Compliance Criteria) determined for the French Island residential locations are shown below.

Noise-Sensitive Receptor	NIRV Recommended Maximum Noise Levels ($L_{Aeq,30min}$)		
	Day	Evening	Night
French Island Receptors	45 dB(A)	37 dB(A)	32 dB(A)

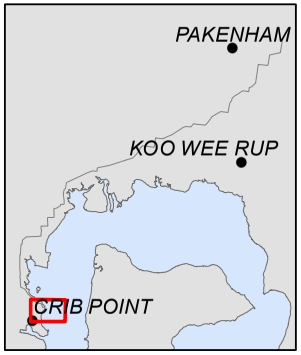
Appendix K

Noise – operational noise maps

N

Meters
0 50 100 150 200 250 300

Operational Noise Contours
Mapsheet 1 (of 5)



Legend

- Buildings and Structures
- Crib Point Receiving Facility
- FSRU
- LNG Carrier Ship
- Tug Boats

Predicted Noise Level, $L_{Aeq,30min}$ dB

- Below 30 dBA
- 30 dBA to 33 dBA
- 33 dBA to 36 dBA
- 36 dBA to 39 dBA
- 39 dBA to 42 dBA
- 42 dBA to 45 dBA
- Above 45 dBA

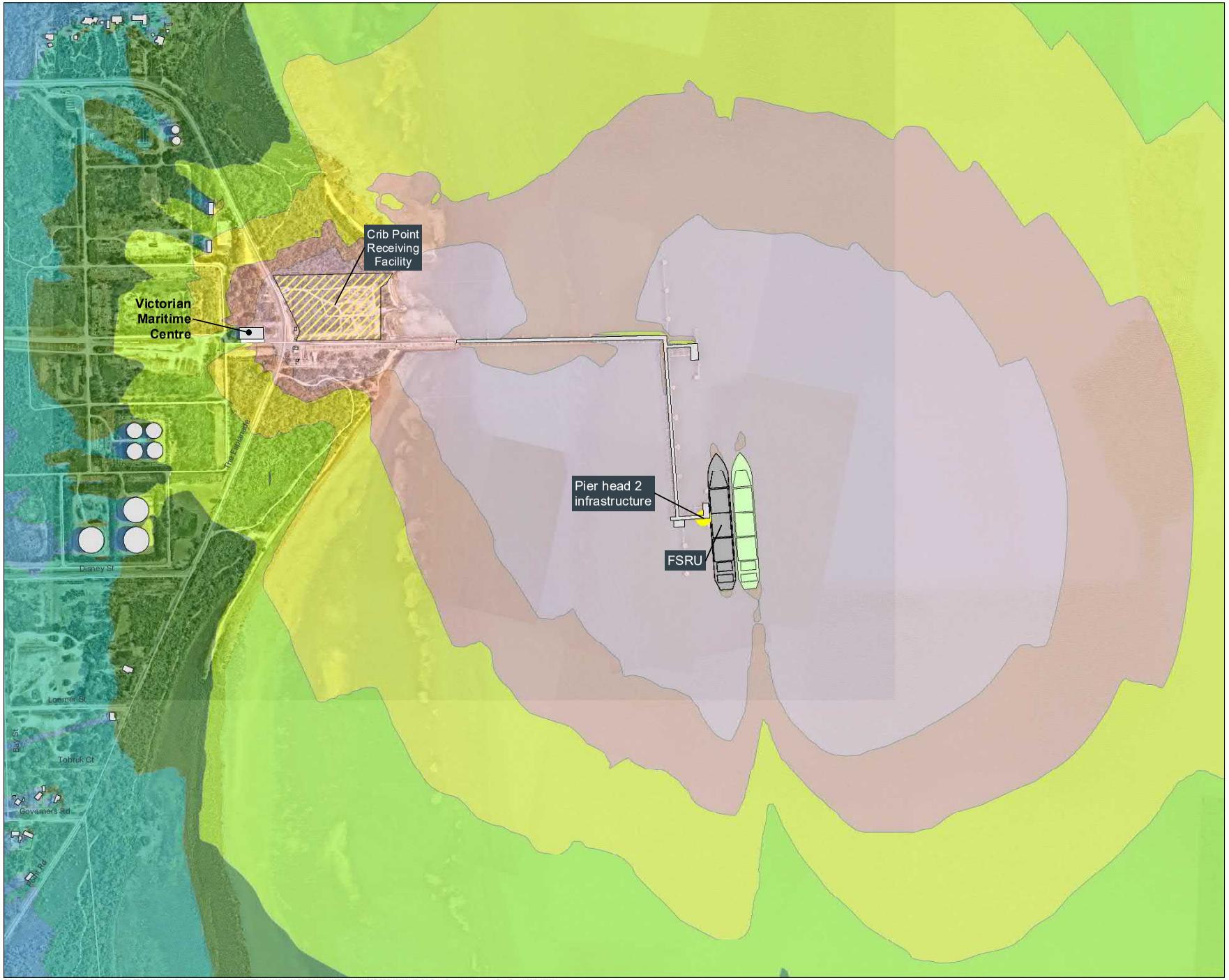
Predicted Operation Levels Scenario 1 - LNG carrier berthing with mitigation (NV10): Closed loop

Noise and Vibration Impact

AECOM does not warrant the accuracy or completeness of information displayed in this map and any person using it does so at their own risk. AECOM shall bear no responsibility or liability for any errors, faults, defects, or omissions in the information.

Source: Vicmap 2019 (c), Imagery - Nearmap 2019 (c).

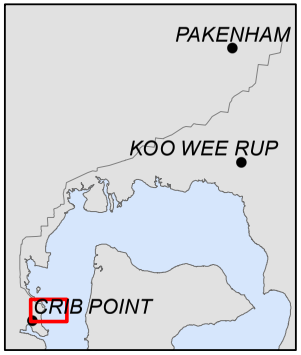
C:\Users\evanst2\Documents\ArcGIS\Packages\CPT_DDP_20200117_Crib Point OperationMaps_DFE5FA6A-5A8B-4486-B36F-610213B0ED26\v106\CPT_DDP_20200117_Crib Point OperationMaps.mxd Date Saved: 26/04/2020



N

Meters
0 50 100 150 200 250 300

Operational Noise Contours
Mapsheet 2 (of 5)



Legend

- Buildings and Structures
- Crib Point Receiving Facility
- FSRU
- LNG Carrier Ship

Predicted Noise Level, $L_{Aeq,30min}$ dB

- Below 30 dBA
- 30 dBA to 33 dBA
- 33 dBA to 36 dBA
- 36 dBA to 39 dBA
- 39 dBA to 42 dBA
- 42 dBA to 45 dBA
- Above 45 dBA

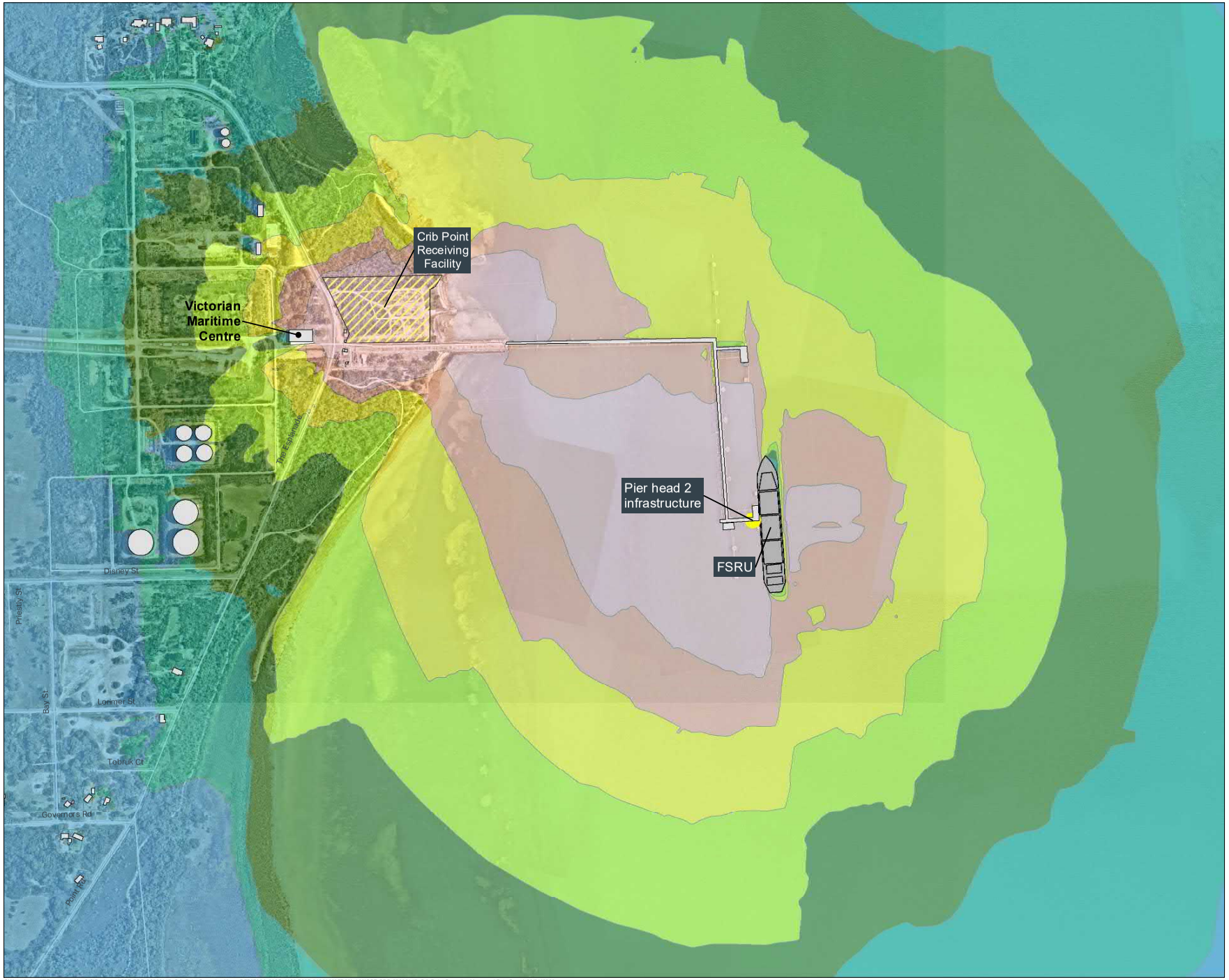
Predicted Operation Levels Scenario 2 - LNG carrier berthed with mitigation (NV10): Closed loop

Noise and Vibration Impact

AECOM does not warrant the accuracy or completeness of information displayed in this map and any person using it does so at their own risk. AECOM shall bear no responsibility or liability for any errors, faults, defects, or omissions in the information.

Source: Vicmap 2019 (c), Imagery - Nearmap 2019 (c).

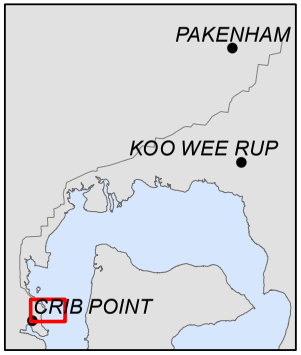
C:\Users\levanst2\Documents\ArcGIS\Packages\CPT_DDP_20200117_Crib Point OperationMaps_DFE5FA6A-5A89-4486-B36F-610213606ED2\v106\CPT_DDP_20200117_Crib Point OperationMaps.mxd Date Saved: 26/04/2020



N

Meters
0 50 100 150 200 250 300

Operational Noise Contours
Mapsheet 3 (of 5)



Legend

- Buildings and Structures
- Crib Point Receiving Facility
- FSRU

Predicted Noise Level, $L_{Aeq,30min}$ dB

- Below 30 dBA
- 30 dBA to 33 dBA
- 33 dBA to 36 dBA
- 36 dBA to 39 dBA
- 39 dBA to 42 dBA
- 42 dBA to 45 dBA
- Above 45 dBA

Predicted Operation Levels Scenario 3 - FSRU operation after mitigation (NV10): Closed loop

Noise and Vibration Impact

AECOM does not warrant the accuracy or completeness of information displayed in this map and any person using it does so at their own risk. AECOM shall bear no responsibility or liability for any errors, faults, defects, or omissions in the information.

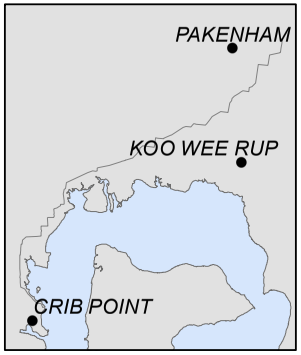
Source: Vicmap 2019 (c), Imagery - Nearmap 2019 (c).

C:\Users\evanst2\Documents\ArcGIS\Packages\CPT_DDP_20200117_Crib Point OperationMaps_DFE5FA6A-5A8B-4486-B36F-610213B0ED26\v106\CPT_DDP_20200117_Crib Point OperationMaps.mxd Date Saved: 26/04/2020

N

Meters
0 50 100 150 200 250 300

Operational Noise Contours
Mapsheet 4 (of 5)



Legend

- Buildings and Structures
- Crib Point Receiving Facility
- FSRU
- LNG Carrier Ship

Predicted Noise Level, $L_{Aeq,30min}$ dB

- Below 30 dBA
- 30 dBA to 33 dBA
- 33 dBA to 36 dBA
- 36 dBA to 39 dBA
- 39 dBA to 42 dBA
- 42 dBA to 45 dBA
- Above 45 dBA

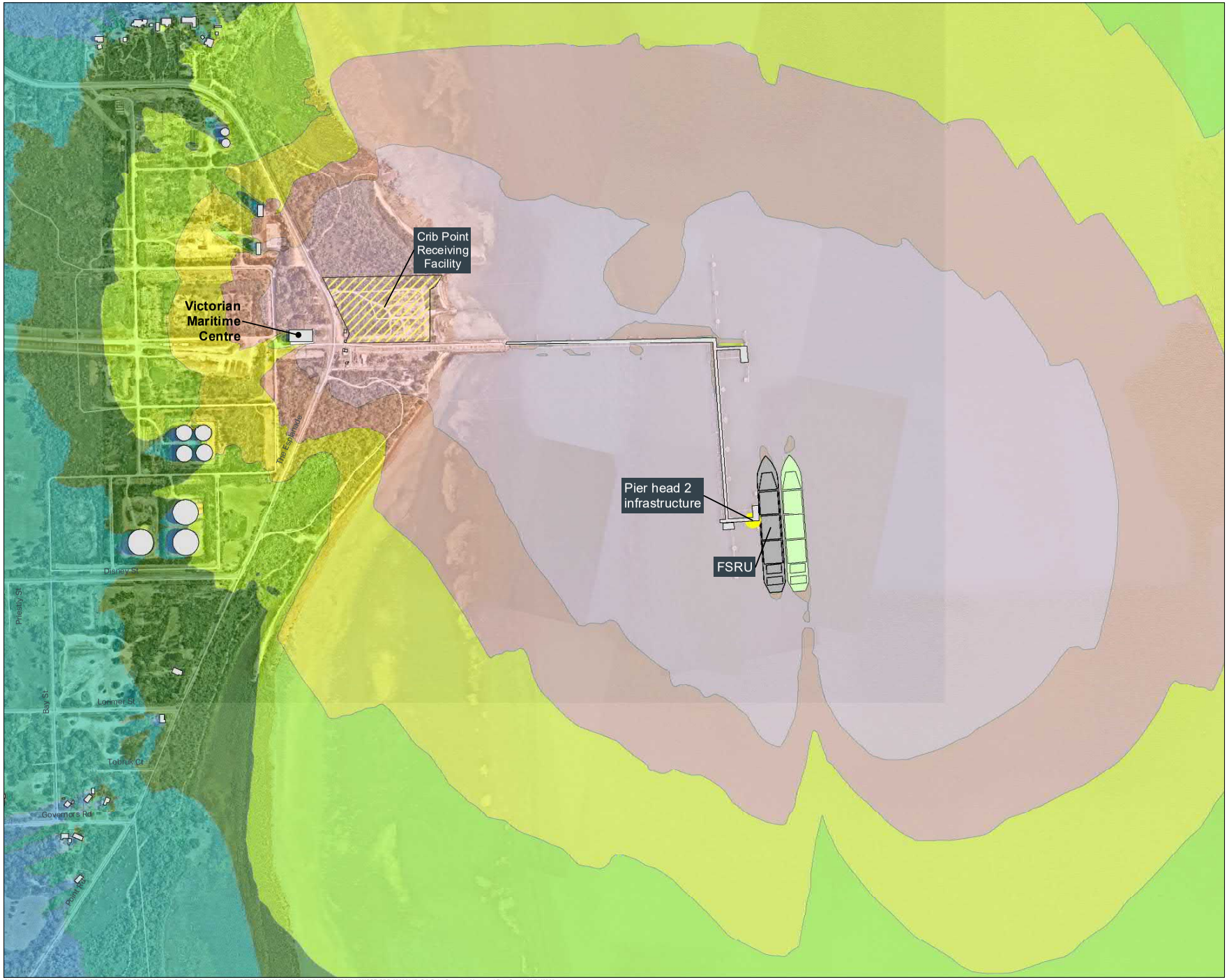
Predicted Operation Levels Scenario 4 - LNG carrier berthed with mitigation (NV10): Open loop

Noise and Vibration Impact

AECOM does not warrant the accuracy or completeness of information displayed in this map and any person using it does so at their own risk. AECOM shall bear no responsibility or liability for any errors, faults, defects, or omissions in the information.

Source: Vicmap 2019 (c), Imagery - Nearmap 2019 (c).

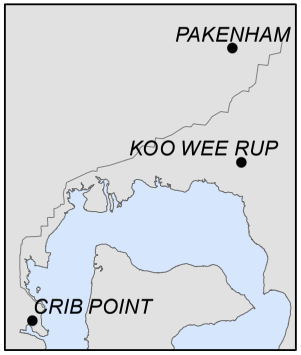
C:\Users\evanst2\Documents\ArcGIS\Packages\CPT_DDP_20200117_Crib Point OperationMaps_DFE5FA6A-5A8B-4486-B36F-610213606ED2\v106\CPT_DDP_20200117_Crib Point OperationMaps.mxd Date Saved: 26/04/2020



N

Meters
0 50 100 150 200 250 300

Operational Noise Contours
Mapsheet 5 (of 5)



Legend

- Buildings and Structures
- Crib Point Receiving Facility
- FSRU
- LNG Carrier Ship

Predicted Noise Level, $L_{Aeq,30min}$ dB

- Below 30 dBA
- 30 dBA to 33 dBA
- 33 dBA to 36 dBA
- 36 dBA to 39 dBA
- 39 dBA to 42 dBA
- 42 dBA to 45 dBA
- Above 45 dBA

Predicted Operation Levels Scenario 5 - LNG carrier berthed and nitrogen offloading with mitigation (NV10): Closed loop

AECOM does not warrant the accuracy or completeness of information displayed in this map and any person using it does so at their own risk. AECOM shall bear no responsibility or liability for any errors, faults, defects, or omissions in the information.

Source: Vicmap 2019 (c), Imagery - Nearmap 2019 (c).

C:\Users\evanst2\Documents\ArcGIS\Packages\CPT_DDP_20200117_Crib Point OperationMaps_DFE5FA6A-5A8B-4486-B36F-610213B0ED26\v106\CPT_DDP_20200117_Crib Point OperationMaps.mxd Date Saved: 26/04/2020

Appendix L

Water - risk assessment

Appendix L Water - risk assessment

The EES scoping requirements for the project require that a risk-based approach be adopted for assessment of the potential impacts of the operation of the Floating Storage Regasification Unit (FSRU). A risk assessment has been carried out using an approach that is consistent with the AS/NZS ISO 31000:2018 *Risk Management Process* and EPA Victoria Publication 1287 – Guideline for Risk Assessment of Wastewater Discharge to Waterways to determine the risk of identified impacts associated with discharge to surface water.

The risk assessment process provides a method for:

- facilitating a consistent approach to risk assessment across the various specialist studies in the EES
- identifying key project risks that require detailed investigation;
- ensuring that the level of investigation is proportionate to the relative environmental risk; and
- assessing the effectiveness of proposed mitigation measures and whether additional measures may be required.

Risk can be defined as a combination of:

- the magnitude of potential consequences of the event; and
- the likelihood of an event occurring.

The risk assessment process developed for the project involved the assignment of consequence and likelihood ratings which then combines to give an overall risk level for each identified impact associated with discharge to surface water.

Assigning consequence of risks

The consequence rating criteria used in the risk assessment for risks relating to benthic habitats and communities as well as the consequence rating criteria used in the risk assessment for risks relating to entrainment is show in **Table 69**.

The consequence criteria in the risk assessment extend across a scale of magnitude from ‘negligible’ to ‘severe’, which is related to the size of the impact, the spatial area affected, and the expected recovery time of the environmental system(s) affected. For example, where a minimal impact was indicated over a local area only and with a recovery time within the range of normal variability, the consequence of the event is ‘minor’ (towards the ‘negligible’ end of the scale). Conversely, a ‘major’ consequence describes scenarios involving a very high magnitude event, affecting a very large area or requiring many years to recover.

The consequence ratings for benthic habitats were developed taking into consideration:

- the area of channel in North Arm at low tide is about 6,900 hectares (ha)
- the area of the Port of Hastings that is dredged to maintain the access channels and turning basin for the Crib Point Jetty berths is about 90 ha
- the area that would be occupied by the FSRU and LNG carrier is about 3 ha.

The process of developing consequence ratings for entrainment is described in the EES Technical Report A: *Marine impact assessment* (refer to **Appendix B**). The consequence ratings for entrainment were developed taking into consideration:

- natural mortality and flushing rates
- that the effects of entrainment can be:
    - to reduce primary productivity in North Arm
    - reduce plankton and fish larvae

As shown in **Table 69**, a more stringent consequence was defined for the fish breeding months in spring and summer with a less stringent consequence for months outside the principal fish breeding season.

Table 69 Consequence rating criteria

Consequence rating	Description – benthic habitats and communities	Description - Entrainment
Negligible	Impacts not detectable against natural variability or detectable impacts within 9 ha zone around FSRU. Recovery within 1 year	Impacts not detectable against natural variability
Minor	Detectable impact up to 45 ha around FSRU	Change in population up to 0.2 per cent (Spring/Summer) Change in population up to 0.3 per cent (Autumn/Winter)
Moderate	Detectable impact up to 250 ha around FSRU	Change in population of 0.2 to 0.4 per cent (Spring/Summer) Change in population of 0.3 to 0.6 per cent (Autumn/Winter)
Major	Detectable impact more than 250 ha around FSRU	Change in population of 0.4 to 1 per cent (Spring/Summer) Change in population of 0.6 to 1 per cent (Autumn/Winter)
Severe	Detectable impact over North Arm	Change in population of more than 1 per cent

Assigning likelihood of risks

A likelihood rating has been assigned for each identified risk pathway using the guide in **Table 70**. The likelihood criteria in the risk assessment range from ‘almost certain’ where ‘the event is expected to occur in most circumstances or is planned to occur’ to ‘rare’ where ‘the event may occur only in exceptional circumstances.’

Table 70 Likelihood rating criteria

Likelihood rating	Description
Rare	The event may occur only in exceptional circumstances
Unlikely	The event could occur but is not expected
Possible	The event could occur
Likely	The event will probably occur in most circumstances
Almost certain	The event is expected to occur in most circumstances or is planned to occur

Risk assessment matrix and risk rating

Together the consequence and likelihood have been combined to arrive at a risk rating, using the matrix shown in **Table 71**.

Table 71 Risk assessment matrix

		Consequence ratings				
		Negligible	Minor	Moderate	Major	Severe
Likelihood rating	Rare	Very low	Very low	Low	Medium	Medium
	Unlikely	Very low	Low	Low	Medium	High
	Possible	Low	Low	Medium	High	High
	Likely	Low	Medium	Medium	High	Very high
	Almost certain	Low	Medium	High	Very high	Very high

Appendix M

Water – Chlorine guideline value

Appendix M Water – Chlorine guideline value

The maximum acceptable chlorine level or Guideline Limit is obtained by consideration of the *State Environment Protection Policy (Waters) 2018* (SEPP (Waters)), ANZECC Guidelines and a CSIRO report specifically addressing the chlorine limit in marine waters.

SEPP (Waters)

Discharges from Scheduled Premises to the aquatic environment in Victoria are currently regulated by the Environment Protection Authority (EPA) under SEPP (Waters). The Policy lists Environmental Quality Indicators and Objectives that are required to be met to protect 'Beneficial Uses' of Victoria's aquatic environments and assigns levels of protection for various water bodies depending on their natural characteristics.

The Policy lists Western Port as a sub-Segment of Victoria's Marine and Estuarine segment. The Policy further divides the Western Port sub-Segment into:

- Entrances and North Arm, where the FSRU would be sited, which are considered largely unmodified; and
- East Arm which is considered slightly to moderately modified.

The Policy also refers to the ANZECC Guidelines for Fresh and Marine Water Quality (2000) for levels of potential toxicants that are considered appropriate to protect aquatic ecosystems at the level assigned to that water body.

ANZECC Guideline for Chlorine

The ANZECC Guidelines have been developed and refined over years of scientifically rigorous processes, review and consultation. The Guidelines provide generic trigger values and procedures to develop site-specific Guideline Values for the protection of aquatic ecosystems.

Further, the Guidelines and a recent associated document (Technical rationale for changes to the method for deriving Australian and New Zealand water quality guideline values for toxicants 2018) define the procedure to develop Guideline Values (GV) for protection of ecosystems based on all available toxicity test results for any particular chemical. This procedure is based on the use of species sensitivity distributions of chronic toxicity data for at least five species and is applicable to developing short-term GVs for the possible short-term discharge of chlorine oxidants to the marine environment at Western Port.

The ANZECC Guidelines have a chronic Guideline Value for chlorine in freshwater of 3 µg/L.

CSIRO Report on Chlorine Guideline Value

To develop an up-to-date Guideline Value for marine waters, the CSIRO was contracted to review all available toxicity data for chlorine and develop a Guideline Value applicable to marine waters in Western Port for that provided 99 % species protection.

The conclusions of the CSIRO review can be summarised as follows:

- For 99 % species protection and continuous exposure, the short-term Guideline value for chlorine (CPO) is 2 µg/L where the concentration zone is relatively consistent over time.
- For 99 % species protection and where the concentration is intermittent or variable over time, such as the tidally varying conditions in the North Arm of Western Port, the short-term Guideline Value is 6 µg/L.

Hence, for this assessment, a Guideline Value of 6 µg/L is used for chlorine, based on averaging chlorine exposure over a 12-hour tidal cycle.

The tidal excursion of waters on North Arm ranges from 4.3 km on the average neap tide to 7.2 km on the average spring tide. Thus, all sites in the tidal channels of North Arm are considered to experience intermittent chlorine exposure and the Guideline Value of 6 µg/L applies to the average chlorine exposure over a 12-hour tidal cycle. The CSIRO report is provided in this appendix.

www.csiro.au

Behaviour and regulation of chlorine in waters associated with the AGL Gas Import Jetty Project

Graeme Batley and Stuart Simpson

March, 2019

CSIRO Report No. EP192435

Prepared for CEE Pty Ltd

Commercial-in-confidence

Citation

Batley GE and Simpson SL. (2019). Behaviour and regulation of chlorine in waters associated with the AGL Gas Import Jetty Project. CSIRO Land and Water Report EP192345, Lucas Heights, NSW, Australia, 22 pp.

Copyright

© Commonwealth Scientific and Industrial Research Organisation 2019. To the extent permitted by law, all rights are reserved and no part of this publication covered by copyright may be reproduced or copied in any form or by any means except with the written permission of CSIRO.

Important disclaimer

CSIRO advises that the information contained in this publication comprises general statements based on scientific research. The reader is advised and needs to be aware that such information may be incomplete or unable to be used in any specific situation. No reliance or actions must therefore be made on that information without seeking prior expert professional, scientific and technical advice. To the extent permitted by law, CSIRO (including its employees and consultants) excludes all liability to any person for any consequences, including but not limited to all losses, damages, costs, expenses and any other compensation, arising directly or indirectly from using this publication (in part or in whole) and any information or material contained in it.

Table of Contents

Executive summary
.....iv

1 Introduction 1

2 Behaviour of chlorine in seawater..... 2

2.1 Chlorine chemistry 2

2.2 Rates of reaction..... 3

3 Toxicity of chlorine and its reaction products 4

3.1 Toxicity testing..... 4

3.2 Water quality guideline values for chlorine in marine waters 9

3.3 Process for developing an Australian marine chlorine default GV (DGV) for chlorine..... 9

4 Application of chlorine GVs to marine mixing zones 14

4.1 GVs for marine mixing zone boundaries 15

5 Monitoring of chlorine 16

6 Conclusions 18

7 References 19

Figures

Figure 1. Species sensitivity distribution of all acute toxicity test data (flow-through plus static) from 11

Figure 2. Species sensitivity distribution of all flow-through LC50 data plus only 15-min static toxicity test data from Table 1.....12

Tables

Table 1. Toxicity data for CPOs in seawater with salinity ≥25‰.....6

Table 2. Summary of short-term toxicity values derived from different data combinations.....11

Table 3. Analytical methods for chlorine produced oxidants.....14

Executive summary

AGL Wholesale Gas Limited (AGL) is proposing to develop a liquefied natural gas (LNG) import facility at Crib Point in Western Port, Victoria. The facility will receive LNG carriers, store the LNG and re-gasify it as required to meet demand for high pressure pipeline gas. Re-gasification involves the heating of cold LNG via heat exchangers using the ambient heat of seawater from Western Port. Biofouling of the heat exchanger pipes can occur from a range of marine biota and propagules that can attach to the pipes and grow into larger individuals.

The proposed use of chlorine as a biocide in heat exchanger pipes and the subsequent discharge of chlorine-containing seawater to a high conservation value ecosystem requires a range of regulatory considerations, including comparing predicted chlorine concentrations in the discharge with accepted guideline values that protect marine ecosystem values. Unlike most other toxicants, chlorine and the hypochlorite ion synthesised by the electrolysis of seawater are highly reactive, first reacting with natural bromide in seawater to form hypobromite ion that further reacts with organic matter such that, within hours, the original oxidants have chemically reacted and the toxic concentration is significantly reduced. This has consequences for the potential impacts of chlorine and other chlorine produced oxidants (CPOs) as toxicants on aquatic biota.

Regulation of persistent toxicants in seawater is typically based on chronic toxicity data used in a species sensitivity distribution (SSD) to derive a default guideline value (DGV) that is considered to be protective of a given percentage of species. The constant exposure durations for these toxicity tests range from 3 to 7 days. This duration is inappropriate for testing of a toxicant which has significantly decomposed within this period, so to account for effects over shorter durations, short-term GVs are more appropriate. These use acute toxicity data with endpoints based on lethality to 50% of the test species (LC50 values).

Canada derived a short-term GV of 0.5 µg Cl/L by applying an 'application factor' to the lowest toxicity data. In the UK, a short-term predicted no-effect concentration of 0.05 µg/L was derived also using the low reliability assessment factor approach. In Australia and New Zealand, in the absence of sufficient chlorine toxicity data for marine species, a low reliability environmental concern value of 3 µg Cl/L was adopted in 2000.

A review of available toxicity data for chlorine indicated a large database (24 points) of acute toxicity data and very few chronic data. The majority of the tests used flow-through systems to avoid the reduction in chlorine concentration due to its reaction, while a limited number of tests used static exposure conditions, with solution renewal, usually every 24 h. Using all of the acute LC50 data in an SSD, short-term toxicity values of 3.0 and 11 µg Cl/L were derived for 99 and 95% species protection respectively. Because this is based on LC50 data, and the preferred ANZG (2018) approach is to use LC10 data, a factor of 1.5 (experimentally derived) was used to convert these to short-term toxicity values of 2.0 and 7.3 µg Cl/L respectively, based on LC10 values. These are termed very high reliability compared to the lesser reliability of the Canadian and UK GVs.

We recommend that:

- 99 and 95% species protection short-term GVs of 2.0 and 7.3 µg Cl/L apply to CPO concentrations at and beyond the boundary of a mixing zone in situations where the concentration at the boundary of a mixing zone is relatively consistent over time.

- 99% species protection short-term GV of 6.0 Cl/L apply to CPO concentration at and beyond the boundary of a mixing zone where concentration at the boundary of a mixing zone is intermittent or variable over time such as North Arm of Western Port.
- These water quality objectives may not be met within a mixing zone.

Analytical methods for CPOs were reviewed and the two most sensitive were an amperometric and an iodometric method. Both of these will require some effort to reliably detect compliance with the 2 µg/L value.

1 Introduction

AGL Wholesale Gas Limited (AGL) is proposing to develop a liquefied natural gas (LNG) import facility at Crib Point in Western Port, Victoria. The facility will use a Floating Storage and Regasification Unit (FSRU) that will be continuously moored at the existing Crib Point Jetty and will receive LNG carriers of approximately 300 m in length. The FSRU will receive LNG cargos from visiting carriers, store the LNG and re-gasify it as required to meet demand for high pressure pipeline gas. Re-gasification involves the heating of the cold LNG via heat exchangers using the ambient heat of seawater from Western Port. Biofouling of the heat exchanger pipes can occur from the range of marine biota and propagules that can attach to the pipes and grow into larger individuals. Chlorine is an effective biocide that has been used to prevent biofouling (Nguyen et al., 2012; Rajagopal, 2012). It is easily generated by seawater electrolysis and introduced at the intake to the heat exchanger system (Apetroaei et al., 2018). A consequence of this is the potential, after discharge, for residual chlorine to affect the health of the receiving water ecosystem (Khalanski and Jenner, 2012).

AGL has been required to prepare an Environmental Effects Statement (EES) under the Victorian Environment Effects Act. This is being managed by AECOM, who have contracted CEE Pty Ltd to assist with marine environmental matters. CEE Pty Ltd has asked CSIRO to provide a technical assessment of the recommended safe guideline values (GVs) for chlorine in the marine environment.

The study was to specifically investigate:

1. The behaviour of chlorine including its likely reactions and transformations as it is generated by electrolysis and as it travels from the intake, as it cools through the heat exchanger to the point of discharge and in the seawater as the discharged water mixes with seawater and disperses;
2. The processes and conservatism in establishing a GV for chlorine in the marine environment;
3. The present status and GV for chlorine (total residual chlorine (TRC) or total residual oxidants (TRO)) in the marine environment that is likely to be suitable for North Arm of Western Port, a Ramsar-listed Wetland of International Importance classified as an “Area of high conservation value” in Schedule 5 of Victoria’s State Environment Protection Policy Waters, 2018. The Policy also classifies the ecosystems of the management segment as “largely unmodified”. Consequently, the Policy requires 99% species protection with respect to environmental indicators and objectives including ANZECC/ARMCANZ (2000) guidelines (ANZG, 2018a).
4. The practicality of monitoring chlorine concentrations in the marine environment and likely detection limits.

2 Behaviour of chlorine in seawater

2.1 Chlorine chemistry

Chlorination remains one of the most effective approaches for the control of biofouling organisms in seawater. It can be undertaken by the addition of sodium hypochlorite (NaOCl) or more usually by electrolysis of seawater. Electrolysis produces chlorine and hydrogen according to the reaction:

$$2Cl^- + 2H_2O \longrightarrow Cl_2 + H_2 + 2OH^- \quad (1)$$

Chlorine is soluble in seawater and rapidly hydrolyses to produce hypochlorous acid (HOCl) and its dissociation product, the hypochlorite ion (OCl^-). At the pH of seawater, HOCl is 80% dissociated to hypochlorite (pKa = 7.54). The term *free chlorine* refers to Cl_2, HOCl and hypochlorite ion OCl- in equilibrium.

$$Cl_2 + 2OH^- \longrightarrow OCl^- + Cl^- + H_20 \quad (2)$$

Both chlorine and the hypochlorite ion are powerful oxidants. *Residual chlorine* is the term given to the concentration of chlorine and its reaction product (hypochlorite ion) that remain in solution.

Bromide ion, present in seawater at a high concentration near 65 mg/L, is rapidly oxidised by hypochlorite to form hypobromous acid (pKa = 8.6) which is only some 20% dissociated to hypobromite ion at the pH of seawater (8.1). This reaction is 99% complete in 10 s (Jenner et al., 1997).

$$OCl^- + Br^- \longrightarrow OBr^- + Cl^- \quad (3)$$

Hypobromous acid is still a good oxidant, although a weaker oxidant that hypochlorite. The antifouling and oxidative capacity of electrolysed seawater is therefore largely due to hypobromite rather than hypochlorite. Total residual chlorine (TRC) in seawater is commonly taken as comprising all chlorine-produced oxidants in seawater and expressed as mg Cl/L (ANZECC/ARMCANZ, 2000). This would include hypobromous acid and would in fact be mostly bromine-based. The use of TRC is more usually used in reference to fresh waters, whereas in marine waters, the equivalent term is chlorine-produced oxidants (CPO).

In waters where ammonia is present at elevated concentrations, the formation of chloramines (and bromamines) is also a possibility:

e.g. $$HOCl + NH_3 \longrightarrow NH_2Cl + H_2O \quad (4)$$

$$HOBr + NH_3 \longrightarrow NH_2Br + H_2O \quad (5)$$

It was estimated that for these to be significant, ammonia concentrations would need to exceed 10 µg/L for chlorination at 1 mg/L (Sugam and Helz, 1977). Ammonia concentrations in Western Port seawater are typically <10 µg/L, so there is negligible potential for formation of significant quantities of chloramines or bromamines as chlorination reaction products (Chidgey, 2018), and measured concentrations in Western Port seawater are reportedly below this value (Chidgey, 2018).

Because the majority of hypochlorous and hypobromous acids are consumed by reaction with organic compounds, the main products are a diverse range of halogenated organics, in particular trihalomethanes. Jenner et al. (1997) found that bromoform was the major product in a power station seawater cooling water discharge at 16 µg/L for a mean chlorine dosage of 0.5-1.5 mg/L as Cl_2. The high volatility of such compounds means that they are reasonably rapidly lost. The half-life of bromoform varies from 16.9 h at 1 m depth to

85 h at 5 m (Abarnou and Miossec, 1992), considerably longer than the half-life for chloroform of near 30 minutes.

2.2 Rates of reaction

In assessing the ecological impacts of residual chlorine resulting from cooling seawater discharges, the rates at which chlorine and hypochlorite species react initially to form hypobromite species and further with other receiving water constituents such as ammonia or natural dissolved organic matter (DOM), will be critical. Very few studies have examined this in any detail. Zeng et al. (2009) showed that at 15°C, an initial residual chlorine concentration of 2.35 mg Cl/L reduced to around 0.8 mg Cl/L in less than 1 minute. This reduction resulted from the oxidation of bromide to hypobromous acid (Equation 3) which is literally too fast to measure. This is followed by a slower first-order decomposition over 15 minutes to 0.5 mg/L and almost to completion in 30-40 minutes. The higher the water temperature, the faster the reactions and the reduction in chlorine concentration. They noted that in summer, the CPO had fully decayed before discharge, whereas in winter, the CPO decomposition was slower and might be incomplete. In Western Port, seawater temperatures (inlet cooling water) are in the range 11-22°C and the temperature of the discharge water after giving up heat in the heat exchanger, is typically a further 7°C lower than the inlet water (i.e. 4-15°C range). No studies have published useful CPO decay rate data for temperatures lower than 10°C, but the rates of decomposition of CPO appear similar at 10 and 15°C, and likely to be not too dissimilar at 5°C.

At Cribb Point, conservative estimates of the decomposition of CPO can be obtained using water temperatures of 10°C within the heat exchanger and discharge environment. Based on CPO decomposition data and models from the literature (Wang et al., 2008; Saeed et al., 1015), a CPO concentration of 100 µg Cl/L is predicted to decay to 50 µg/L within 2 h (~50%), and 25 µg/L within 24 h (~75%) in a 5-15°C receiving seawater environment. In a 24-h trial of CPO decomposition using Crib Point seawater at 12°C (Chidgey, 2018), an initial CPO concentration of 500 µg Cl/L decayed to approximately 400 µg/L within 0.5 h (~20%), 300 µg/L within 4 h (~40%), and 160 µg/L within 24 h (~68%). For an initial CPO concentration of 1000 µg/L the decay was ~7% in 0.5 h, ~19% within 4 h, and ~42% within 24 h, potentially indicating faster CPO decay at lower concentrations. The Cribb Point test results indicate a slower CPO decomposition rate over the first several hours, but, over 24 h, is similar to that of the literature models.

The CPO decomposition is slower at salinities lower than 35‰. The rate of reaction with DOM is slower than the reaction with bromide and increases with increasing DOM concentrations (Wang et al., 2008). Similar findings were obtained by Saeed et al. (2015).

The above findings are relevant to how the toxicity testing data might be interpreted and applied in order to protect the receiving environment. In tests using continuous flow hypochlorite addition, reaction with bromide would be presumed to have occurred (available bromide reacts rapidly), whereas in static tests, depending on the duration, further oxidative reactions might have progressed (slower reactions with DOM). Applying toxicity data derived in this way will need to take into account the time of exposure required to elicit ether acute or chronic toxicity to determine the nature of the impact, if any.

3 Toxicity of chlorine and its reaction products

3.1 Toxicity testing

Because the half-lives of chlorine and its toxic reaction products are short in marine waters, it is usual for toxicity tests to be flow-through, resulting in continuous renewal of the test water and maintenance of a near-constant chlorine exposure to the test organisms. Concentrations of chlorine-produced oxidants (CPOs) must be measured frequently to demonstrate that substantial reduction in concentration is not occurring. The analytical method must measure all CPOs and not only one or more of the components.

Table 1 is a composite of the available toxicity data from Chariton and Stauber (2008), CCME (1999), USEPA (1985) and more recent literature data that have been quality assessed to meet the latest ANZG (2018) criteria as documented by Warne et al. (2018). Application of the revised quality assessment method led to the elimination of many data in estuarine waters where the salinity was below the 25‰ criterion.

As expected, the majority of the tests used flow-through systems containing continually added hypochlorite in seawater, rather than static tests where the test hypochlorite-containing seawater was replaced regularly (usually daily). The latter resulted in the test organisms being exposed to fluctuating concentrations. In static laboratory tests, it was usual to renew the test solutions regularly (usually every 24 h), but as a consequence, the exposure was to rapidly decaying hypochlorite concentrations. Not surprisingly the LC50 values (50% lethal effect concentration) from such tests were generally higher than those for flow-through tests. For example, a 0.5 h flow-through test with the rotifer *Brachionus plicatilis* had an LC50 of 90 µg Cl/L (Capuzzo et al., 1976) compared to a 24-h static test LC50 of 586 µg Cl/L (Lopez-Galindo et al., 2010). The flow-through test value only was used in the species sensitivity distribution (SSD) used to derive a guideline value (GV).

Nearly all of the reported bioassays were classified as acute tests, where a lethal or adverse sub-lethal effect occurs after exposure to a chemical for a short period relative to the organism's life span (acute test durations are organism specific as defined by Warne et al. (2019)). Chronic tests by comparison are ones where a lethal or adverse sub-lethal effect occurs after exposure to a chemical for a period of time that is a substantial portion of the organism's life span or an adverse effect on a sensitive early life stage. The only chronic data reported were for 72-h algal bioassays which by definition are considered as chronic tests (Warne et al., 2018), and for one 8-day fish test (Alderson, 1970).

The most sensitive species were sea urchins, with impacts on fertilisation being seen at near 6 µg Cl/L as CPO. Sperm were pre-exposed to the hypochlorite in seawater for 15 min with no effect on viability, while a time from 1 to 60 min of pre-exposure of eggs before adding sperm did not affect the result, for the sand dollar, *Dendrastur excentricus*. LC50 values for 15-min sperm plus egg exposures following a 1, 1, 1, 5, 6, and 60 min pre-exposure, were 2, 10, 13, 7, 6 and 8 µg/L respectively, so the geometric mean of the three 1 min pre-exposures, 6.4 µg Cl/L, was used. For the sea urchin, *Strongylocentrotus droebachiensis*, an experiment where the hypochlorite and seawater were pre-mixed for 24 or 48 h before exposure did not affect the toxicity to sperm fertilisation, suggesting that reaction products other than CPOs were causing toxicity. As the exposure time of sperm and eggs was only 15 min in these fertilisation experiments, the tests are classified as acute (Warne et al., 2018); chronic tests with this species require ≥1 h exposure (Dinnel et al., 1981).

The next most sensitive species were fish, with plaice (*Pleuronectes platessa*) having an LC50 of 24 µg/L (Alderson, 1970), although data for water of salinity <25‰ indicate LC50 values as low as 5 µg CPO/L for copepods and oyster and clam larvae (Bellanca and Bailey, 1977).

There were results for only two algal species, *Isochrysis galbana* and *Dunaliella salina* (Lopez-Galindo et al., 2010), and these were not particularly sensitive, with chronic EC10 values for two species of 119 and 381 µg Cl/L respectively. These were, however, based on 96-h static exposures, and that might explain the lower sensitivity. Their respective EC50 values of 2910 and 1730 µg Cl/L were the highest of any tests reported (Table 1).

There have been few studies that have examined the toxicity of reaction products. The oxidation products from bromine were found to be less toxic than those from chlorine (Dinnel et al., 1981), while the toxicity of chloroform and bromoform produced by reactions with organics has been described as 'moderate to high', although a recent review showed that, at least for chloroform, effects on algae and fish are typically seen at mg/L concentrations, orders of magnitude above those for hypochlorite toxicity (UK Marine SAC, 2019).

Table 1. Toxicity data for CPOs in seawater with salinity ≥25‰

Species	Life stage	Exposure duration (h)	Acute / Chronic	Test type	Toxicity measure	Test medium	Temp (°C)	Conc. (µg/L)	Reference	Comments
Algae (Chronic)										
Alga *(Isochrysis galbana)*		96	Chronic	Static	Growth (EC10)	Synthetic seawater	20	119	Lopez-Galindo et al. (2010)	CPO every 30 min. IC50 2910 µg/L
Alga (*Dunaliella salina)*		96	Chronic	Static	Growth (EC10)	Synthetic seawater	20	381	Lopez-Galindo et al. (2010)	Daily biomass measurements. IC50 1730 µg/L
Invertebrates (Acute)										
American oyster (*Crassostrea virginica*)	Larvae	0.5	Acute	Flow through	Mortality (LC50)	Seawater	25	80	Capuzzo, 1979	Acceptable quality
Copepod *(Acartia tonsa)*		0.5	Acute	Flow through	Mortality (LC50)	Seawater	20	820	Capuzzo, 1979	Acceptable quality
Rotifer (*Brachionus plicatilis*)		0.5	Acute	Flow through	Mortality (LC50)	Seawater	25	90	Capuzzo, 1979	Acceptable quality
Rotifer (*Brachionus plicatilis*)	0.5 h old	24	Acute	Static	Mortality (LC50)	Synthetic seawater	20	586 (LC50), 438 (LC10)	Lopez-Galindo et al., 2010	Measured in 0.3 mL well plates
Amphipod (*Hyale barbicornis*)	Juveniles	96	Acute	24-h renewal	Mortality (LC50)	Seawater	20	2200	Anasco et al., 2008	Conc decayed rapidly Nominal for 24-h, measured for others
Amphipod (*Hyale barbicornis*)	Juveniles	96	Acute	24-h renewal	Body length (EC50)	Seawater	20	1100	Anasco et al., 2008	Conc decayed rapidly Nominal for 24-h, measured for others
Coon stripe shrimp *(Pandalus danae)*	Juvenile and adult	96	Acute	Flow through	Mortality (LC50)	Seawater	15	178	Gibson et al., 1975 and Thatcher, 1978	Acceptable quality
Sea urchin (*Strongylocentrotus droebachiensis)*	Sperm	15 min	Acute	Static	Fertilisation (EC50)	Seawater	14	<5, <6	Dinnel et al., 1981	Sperm exposed for 15 mins, eggs exposed pre-test for 24 or 48 h.
Sand dollar (*Dendrastur excentricus)*	Sperm	15 min	Acute	Static	Fertilisation (EC50)	Seawater	14	6.4 (geomean of 3 shortest pre-exposure times)	Dinnel et al., 1981	Sperm exposed 15 min before adding to eggs. Pre-exposure of eggs for 1-60 min did not affect toxicity.

Table 1. Toxicity data for CPOs in seawater with salinity ≥25‰ (continued)

Species	Life stage	Exposure duration (h)	Acute / Chronic	Test type	Toxicity measure	Test medium	Temp (°C)	Conc. (µg Cl/L as CPO)	Reference	Comments
Lobster (*Homarus americanus)*	Larvae	1	Acute	Flow through	Mortality (LC50)	Seawater	na	2890	Capuzzo et al. 1976	Seawater and toxicant mixed for 14 h before larvae addition. Flow through system. After 60 min exposure LC50 was 16300 based on applied conc and 2890 µg Cl/L (calculated from a decay equation) based on the residual. Used ACR of 4.5 for crustaceans.
Mysid (*Neomysis* sp)	Adult	96	Acute	Flow through	Mortality (LC50)	Seawater (28‰)	15	162	Thatcher, 1978	Acceptable quality
Amphipod (*Pontogeneia* sp)	Adult	96	Acute	Flow through	Mortality (LC50)	Seawater (28‰)	15	687	Thatcher, 1978	Acceptable quality
Amphipod (*Anonyx* sp)	Adult	96	Acute	Flow through	Mortality (LC50)	Seawater (28‰)	15	145	Thatcher, 1978	Acceptable quality
Shrimp (*Pandalus goniurus*)	Adult	96	Acute	Flow through	Mortality (LC50)	Seawater (28‰)	15	90	Thatcher, 1978	Acceptable quality
Shrimp (*Crangon nigricauda*)	Adult	96	Acute	Flow through	Mortality (LC50)	Seawater (28‰)	15	134	Thatcher, 1978	Acceptable quality
Shore crab (*Hemigrapsus nudus* and *H. oregonensis*	Juvenile and adult	96	Acute	Flow through	Mortality (LC50)	Seawater (28‰)	15	1418	Thatcher, 1978	Acceptable quality
Fish (Acute)										
Tidewater silverside juvenile (*Menidia peninsulae*)	Fry	96	Acute	Flow through	Mortality (LC50)	Seawater (22-27‰)	25	54	Goodman et al., 1983	Acceptable quality
Fish (*Oryzias javanicus*)	Larvae	96	Acute	24-h renewal	Mortality (LC50)	Seawater	26	190	Anasco et al., 2008	Conc decayed rapidly. Nominal for 24-h, measured for others
Fish (*Oryzias javanicus*)	Larvae	24	Acute	24-h renewal	Mortality (LC50)	Seawater	26	320	Anasco et al., 2008	Fish died immediately after exposure. To 50 µg Cl/L based on averages of measured initial concentration.

Table 1. Toxicity data for CPOs in seawater with salinity ≥25‰ (continued)

Species	Life stage	Exposure duration (h)	Acute / Chronic	Test type	Toxicity measure	Test medium	Temp (°C)	Conc. (µg/L)	Reference	Comments
Plaice (*Pleuronectes platessa*)	Larvae	96	Acute	Flow through	Mortality (LC50)	Seawater	8	24	Alderson et al., 1970	Low temperature
Coho salmon (*Oncorhynchus kisutch*)	Juvenile	96	Acute	Flow through	Mortality (LC50)	Seawater (28‰)	15	32	Thatcher, 1978	Acceptable quality
Pacific herring (*Clupea harengus pailasi*)	Juvenile	96	Acute	Flow through	Mortality (LC50)	Seawater (28‰)	15	65	Thatcher, 1978	Acceptable quality
Threespine stickleback (*Gasterosteus aculeatus)*	Juvenile and adult	96	Acute	Flow through	Mortality (LC50)	Seawater (28‰)	15	167	Thatcher, 1978	Acceptable quality
Shiner perch (*Cymatogaster aggregata*)	Juvenile and adult	96	Acute	Flow through	Mortality (LC50)	Seawater (28‰)	15	71	Thatcher, 1978	Acceptable quality
Pacific sand lance (*Ammodytes hexapterus*)	Juvenile and adult	96	Acute	Flow through	Mortality (LC50)	Seawater (28‰)	15	82	Thatcher, 1978	Acceptable quality
English sole (*Parophrys vetulus*)	Juvenile	96	Acute	Flow through	Mortality (LC50)	Seawater (28‰)	15	73	Thatcher, 1978	Acceptable quality
Fish (Chronic)										
Plaice (*Pleuronectes platessa*)	Eggs	8 days	Chronic	Flow through	Mortality (LC50)	Seawater	8	120	Alderson, 1970	Low temperature

3.2 Water quality guideline values for chlorine in marine waters

The derivation of guideline values (GVs) for chlorine and its reaction products has been dealt with by a number of jurisdictions (USEPA, 1985; CCME, 1999; ANZECC/ARMCANZ, 2000; Sorokin et al., 2007). The USEPA (1985) recommended that, "except possibly where a locally important species is very sensitive, saltwater aquatic organisms and their uses should not be affected unacceptably if the four-day average concentration of chlorine-produced oxidants does not exceed 7.5 µg/L more than once every three years on the average and if the one-hour average concentration does not exceed 13 µg/L more than once every three years on the average".

Environment Canada (CCME, 1999) noted that the four most sensitive species endpoints in their database were reduced egg fertilisation successes for sand dollars and green sea urchins at 2 and 5 µg Cl/L as CPO, respectively (Dinnel et al., 1981), the 48-h LC50 for the eastern oyster larvae of 5 µg/L and the 48-h EC50 for hard clam larvae of 6 µg/L (Roberts et al., 1975), were not considered acceptable due to reservations with respect to the analytical methodologies and testing protocols. Their default acute GV, termed a short-term GV, was derived by applying an 'application factor' of 0.05 to the 10 µg/L LC50 for the next most sensitive species, blue crabs (Patrick and McLean 1971), American oysters (Capuzzo, 1979), the rotifer *Brachionus plicatilis* (Capuzzo, 1976), and phytoplankton (Eppley et al., 1976), giving a value of 0.5 µg/L.

A risk assessment report for the UK Environment Agency (Sorokin et al., 2007) identified the lowest reliable short-term toxicity data point as a 24-h LC50 of 5 µg Cl/L as free available chlorine for a freshwater species, the crustacean *Ceriodaphnia dubia*. A standard assessment factor of 100 was applied resulting in a predicted no-effect concentration (PNEC) in saltwater of 0.05 µg Cl/L. This was recommended as a replacement for the existing environment quality standard (EQS) as part of the European Water Framework Directive. The existing EQS (Lewis et al., 1994) was based on an assessment factor of ~2 applied to an acute LC50 value of 28 µg/L for both plaice and sole for total residual oxidants (TRO). This resulted in an EQS of 10 µg/L, substantially higher than the proposed PNEC in saltwater.

In Australia and New Zealand, the absence of sufficient toxicity data for marine species, led to the adoption in 2000 of a moderate reliability freshwater chronic GV of 3 µg Cl/L as a low reliability environmental concern value for marine waters (ANZECC/ARMCANZ, 2000). It was noted that although the chlorine figure for 95% species protection was relatively close to the acute toxicity value for the most sensitive species, this was considered sufficiently protective, due to its decomposition rate in seawater, the narrow difference between acute and chronic toxicity and the lesser sensitivity of other data for this species (ANZECC/ARMCANZ, 2000).

A revision of the marine chlorine default GV (DGV) for Australia and New Zealand was identified as a priority as part of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018).

3.3 Process for developing an Australian marine chlorine default GV (DGV) for chlorine

An initial draft DGV for chlorine for the ANZG was prepared under contract in 2016. The resulting draft technical report and unpublished chronic DGV for 95% species protection was 0.9 µg/L (the 99% protection value was 0.03 µg C/L). Closer scrutiny of the draft report by independent specialist reviewers, showed that many of the data used in the 2016 analysis did not meet the acceptance criteria as discussed below. It was concluded that a more comprehensive analysis was required using the most recent data acceptance criteria and procedures (Warne et al., 2018; Batley et al., 2018).

The most recently accepted method for deriving GVs for toxicants in water provides the following advice on the use of short-term (acute) toxicity data in deriving GVs for particular chemicals where there are sound test data that show that effects over short times are environmentally relevant: “Such tests usually (but not necessarily) measure lethality and might be appropriate in cases of a spill event, or pulse exposures as can occur with pesticides in rivers, or where contaminants are short-lived and non-persistent due to dispersion, volatilisation or degradation. The minimum exposure period is generally 96 h, but there might be circumstances where a lesser exposure time is relevant. The types of tests considered to measure acute responses are detailed in Table 1” (Batley et al., 2018).

“If a short-term GV is required for a site-specific application, it can be derived using a species sensitivity distribution (SSD) applied to acute toxicity data. The preferred data order is: acute NEC, EC/IC/LC10, BEC10, EC/IC/LC15-20, and lastly NOEC data. However, if there are insufficient of those data then acute LC50/IC50/EC50, LOEC and MATC values should be divided by 5, 2.5 and 2, respectively, and used to estimate acute EC/IC/LC10 or NOEC values. If short-term GVs are to be used for non-guideline purposes such as setting licence conditions or in prosecutions, then the data preferences may change to reflect the purpose of the GV. No acute to chronic ratio (ACR) or default assessment factors (AFs) are applied to the acute data to derive short-term GVs, except for those used to convert the acute data to EC/IC/LC10 data. Apart from the use of acute toxicity data, the derivation process should follow the GV derivation method described in Warne et al. (2018)” (Batley et al., 2018).

On the basis of the above, it was clear that the behaviour of chlorine in seawater justified the derivation of a short-term GV. For this purpose, the Chariton and Stauber (2008) data were first re-evaluated using the latest Australian and New Zealand method for GV derivation (Warne et al., 2018). They had used 32 acute marine invertebrate and fish data in an SSD, and with the original Burrlioz 1.0 software derived an acute GV of 13 µg/L for 95% species protection and 5.6 µg/L for 99% species protection. Using an acute to chronic ratio of 2.4 (the geometric mean of the ACRs of 3.71 and 1.5 found by Fisher et al. (1999)), gave chronic GVs of 2.3 and 5.4 µg/L, respectively, for 99 and 95% species protection.

The 2018 screening procedure eliminated some 23 data points from the Chariton and Stauber list, the majority on the basis that the salinity was below 25‰, including the studies of Roberts et al. (1975) and Patrick and McLean (1971) that were used by Canada, as discussed above. The data were supplemented with other more recent literature data and the data referred to in the USEPA, Canadian and UK guidance. The final database was selected from Table 1. Only acute toxicity data from this table, from both flow-through and static tests were used to derive GVs using a species sensitivity distribution (SSD) according to the revised derivation method (Warne et al., 2018). The resulting SSD is shown in Figure 1. This first derivation of short-term toxicity values gave 3, 11 and 20 µg Cl/L respectively for 99, 95 and 90% species protection in Column 2, Table 2.

Table 2. Summary of short-term toxicity values derived from different data combinations

Level of protection (% species)	All acute LC50 data (flow-through and static)	All acute LC50 data plus algal EC50s	Flow-through acute LC50 data only	All flow-through LC50 data plus only 15 min static LC50 data	All acute LC50 data converted to LC10s **RECOMMENDED DGV**
			µg Cl/L as CPO		
99	3.0	3.2	19	2.2	**2.0**
95	11	12	31	8.5	**7.3**
90	20	21	41	16	**13**
Reliability			Very high		

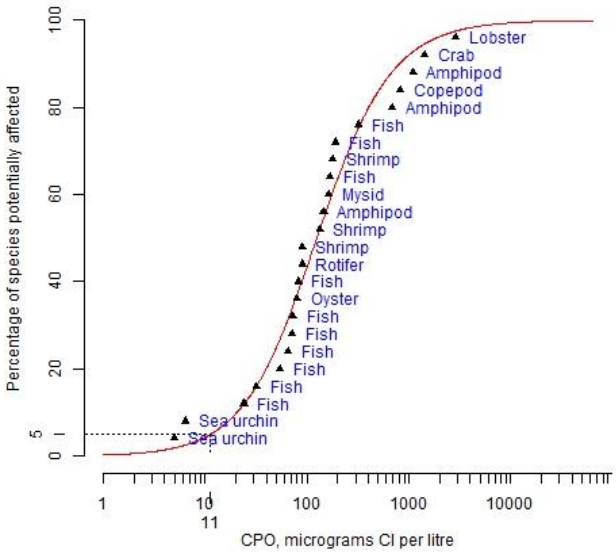


Figure 1. Species sensitivity distribution of all acute toxicity test data (flow-through plus static) from Table 1

Note that there were no data for toxicity to algae in this derivation. The European Chemicals Bureau (2002) recommend using the 72-h (or longer) algal EC50 values as equivalent to a short-term result, with the EC10 being the long-term result. Using these EC50 values from static tests that were very insensitive, the second derivation of protection levels were only marginally altered to 3.2, 12 and 21 µg Cl/L respectively (Column 5, Table 2).

Because of the high reactivity of chlorine, and with the lifetime of the reaction products being of the order of several hours at most, it would be appropriate for management purposes to apply guidelines that are

protective against short-term effects. Any toxicity tests that use flow-through systems in an attempt to prolong the exposure period will result in greater effects than tests undertaken with exposure conditions that mimic the field situation, and so the GV derived using such data will be overly conservative. For static tests, it is the renewal frequency in the context of reaction rate that is important, hence 1-15 min static exposures cannot be treated as analogous to 24+ h static tests. If all data from non-flow-through tests were omitted, the values for 99 and 95% species protection increased to 19 and 31 µg Cl/L respectively for this third derivation (Column 3, Table 3), largely due to the removal of the most sensitive endpoints, which were static tests, although the minimum reaction time was only 15 min before each test plus 1-10 mins during fertilisation, which is a lot shorter than the other static tests. Leaving these data in gave the fourth derivation of 2.2 and 8.5 µg Cl/L respectively (Column 4, Table 3) (see Figure 2).

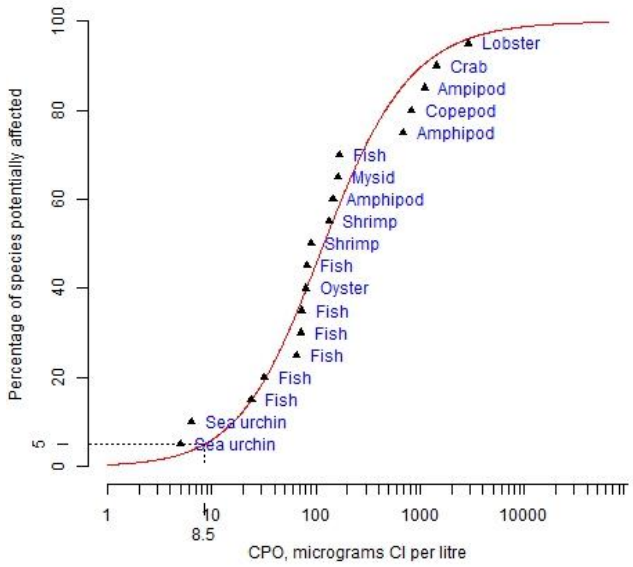


Figure 2. Species sensitivity distribution of all flow-through LC50 data plus only 15-min static toxicity test data from Table 1

It could be argued that chronic tests that last longer than 6 h to show an effect, should not be included in the derivation, assuming that the products of the reactions are less toxic than the starting materials. That this is the case for chloroform and bromoform has been shown by Stewart et al. (1979). LC50 values for larval survival for the oyster, *Crassostrea virginica*, estimated from the published dose-response curves, of 2, 1 and 0.1 mg/L respectively for chloroform, bromoform and bromate. They noted that chloroform and bromoform are both lost from solution by volatilisation. Not considered was the toxicity of chloramine and bromamine products only formed where ammonia concentrations are elevated in the seawater.

From a regulatory context, the application of a short-term GV makes sense, however, not necessarily one based on effects to 50% of the test population, i.e. LC50 values, but rather one based on a 10% effect, i.e. LC10, as we apply to chronic tests that use EC10 values. In some instances, however, regulations have stipulated an acute LC50/EC50-based GV not to be exceeded in mixing zones.

Unfortunately, very few papers either report LC10 values or publish dose-response curves from which the values could be estimated. For example, Lopez-Galindo et al. (2011) reported an LC50/LC10 ratio of 1.33 for NaOCl toxicity to *Brachionus plicatilis* and ratios in excess of 5 for the algae *Isochrysis galena* and *Dunaliella salina.* The normally accepted default ratio would be 5 (Warne et al., 2018), but based on the lower

observed value above, a value of 1.5 is suggested. On this basis, the recommended values for 99 and 95% species protection would be 2.0 and 7.3 µg Cl/L (Column 6, Table 3) obtained by dividing the values in Column 2 of Table 2 by 1.5. The values are additionally conservative because the concentrations are decaying in the field whereas they were not in the flow-through laboratory tests. Note that this value has yet to be proposed and adopted as an official GV.

Northwestern and eastern Western Port is a Ramsar listed Wetland of International Significance, hence, the Waters State Environment Protection Policy Legal lists the Ramsar part of Western Port, which includes the Crib Point in North Arm, as an area of high conservation value with 99% species protection. It might be argued that areas within Port limits and in the planning regulations as a Port Zone around Crib Point jetty could be altered to requiring only 95% species protection. Noting, however, that since two apparently sensitive northern Pacific Ocean sea urchin species used in the SSD would not be protected by the 95% protection value (Figure 1), it would be additionally appropriate to recommend the 99% protection value.

4 Application of chlorine GVs to marine mixing zones

The regulation of contaminants being released to a water body from a point source requires consideration of a mixing zone. This is discussed in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018) (http://www.waterquality.gov.au/anz-guidelines/resources/key-concepts/mixing-zones):

"We can define a mixing zone as an explicitly defined area around an effluent discharge where some, or all, water quality objectives may not be met.

Under some circumstances, it is an accepted practice to apply the concept of a mixing zone. As a consequence, some community values of the water body may not be protected.

The size of a mixing zone — and the environmental conditions within it — are important concerns, particularly because degraded areas around effluent discharges compromise community values.

How to apply a mixing zone

If mixing zones are to be applied, then they should be as small as practicable. Water quality management should ensure that the agreed and designated community values and management goals of the broader waterway outside the mixing zone are not compromised.

If a mixing zone is applied to a river or estuarine waterway, then it is essential to ensure it does not extend across the entire width of the waterway and impact on biota migration pathways.

Mixing zones are regulated at the state or territory level in Australia and the regional council level in New Zealand. You should seek specific guidance on mixing zones from your relevant local jurisdiction."

In the case of the discharge of seawater containing chlorine-produced oxidants (CPOs), the species protection GV would apply at and beyond the boundary of a mixing zone.

The above discussion shows that the recommended GVs for 99 and 95% species protection for chlorine in the marine environment is 2.0 µg Cl/L and 7.3 µg Cl/L, respectively. These values were derived from experiments designed to maintain constant concentration over the period of exposure of the test biota. Hence, the derived GVs would apply where CPO concentration was relatively constant at the boundary of a mixing zone at some point along the dispersion pathway. However, dispersal of discharges to the marine environment are seldom consistently in a single direction and therefore concentration of a released constituent at a particular distance and direction from the release point will vary over time. Reversals in tidal currents every 6 h will result in variable 'exposure' to fixed benthic species close to the discharge, while planktonic species will have short exposure as they may be carried into the area affected and carried out as the chlorine concentration reduces by dilution and chemical reaction. This creates a complex exposure scenario, which is usual for the marine environment and fits the above discussion of pulses. The present approach has been to estimate a 'worst case scenario', which is the area over which the chlorine concentration calculated by dilution alone exceeds the GV at any time. This is a very conservative starting point and applies lines of logic (chemical decomposition, variable exposure, etc) to provide a more realistic estimate of the area of effect. In other cases, it has been suggested that the regulatory mixing zones for toxicity, nutrient effect, suspended solids or organic general enrichment be set at the worst-case boundary and be monitored to refine the dimensions over periods of licence review.

In considering the fact that this CPOs chemically decompose, our recent work (Angel et al., 2015) (and that of others) on pulsed exposures indicates that, while there might be an impact from the initial exposure, the use of a time-averaged concentration over the exposure period better reflects the exposure concentration. On that basis, a time-averaged concentration could be estimated from some of the published reaction rate data to estimate exposure in a tidal situation and compared to the time-averaged exposure concentration in a flow-through test, over the time interval for the dispersion and decay post discharge. Using this ratio, the GV could be accordingly increased. In a strongly tidal situation like North Arm of Western Port, this might add a factor of 2 to 3 to the recommended GV, making a value of near 6 µg Cl/L for 99% species protection more reasonable for assessing potential impacts in situations of intermittent exposure in situations of strong tidal reversals in dispersion.

4.1 GVs for marine mixing zone boundaries

From the above discussion it is apparent that the recommended values for 99 and 95% species protection of 2.0 and 7.3 µg Cl/L as short-term GVs would apply to CPO concentration at the boundary of a mixing zone where concentration was relatively consistent over time. We recommend that time-averaged or time-averaged GVs apply at the boundary of a mixing zone in areas affected by tidal reversals, where concentration varies between a maximum and near background over periods of minutes to hours. This would add a factor of 2 to 3 to the recommended GV exposure in such situations.

Hence, we recommend:

- 99 and 95% species protection short-term GVs of 2.0 and 7.3 µg Cl/L apply to CPO concentration at and beyond the boundary of a mixing zone where concentration is relatively consistent over time.
- 99% species protection short-term GVs of 6.0 Cl/L apply to CPO concentration at and beyond the boundary of a mixing zone where concentration is intermittent or variable over time such as North Arm of Western Port.
- These water quality objectives may not be met within a mixing zone

The 99 and 95% species protection short-term GVs of 2.0 and 7.3 µg Cl/L will be proposed for inclusion in the Australia New Zealand Water Quality Guidelines (ANZG, 2018) for situations of constant exposure with a recommendation that time-averaged concentrations measured at and beyond the mixing zone boundary be used in situations of variable exposure to assess GV compliance.

5 Monitoring of chlorine

A number of methods are available for the analysis of CPO (or TRC) in seawater as shown in Table 3, however, few have detection limits suitable for assessing compliance with a 2 to 6 µg/L GV. Three methods come close to these limits: (i) using amperometric titration, (ii) using an ion selective electrode to detect iodide, and (iii) an iodine colorimetric method.

Table 3. Analytical methods for chlorine produced oxidants

Analytical method	Detection limit (µg Cl/L as CPO)	Reference
Iodometric 4500-Cl B and 4500-Cl C	100	APHA, 2017;
Amperometric titration 4500-Cl D	15	APHA, 2017; Fisher et al., 1999;
Low-level amperometric titration 4500-Cl E	1	APHA, 2017; Dinnel et al., 1981
DPD[a] ferrous titrimetric 4500-Cl F	18	APHA, 2017
DPD colorimetric 4500-Cl G	10	APHA, 2017; Lopez-Galindo et al., 2010; Anasco et al., 2008
Syringaldazine (FACTS) 4500-Cl H	100	APHA, 2017
Iodine colorimetric method	4	Wang et al., 2008; Sugita et al., 1992
Iodometric electrode 4500-Cl I	1	APHA, 2017, Jenkins and Baird, 1979; Rigdon et al., 1978; Dimmock and Midgely, 1982

[a] DPD = N, N-diethyl-p-phenylenediamine

Dinnel et al. (1981) used a commercial amperometric titrator and the amperometric detection iodometric method to achieve a lower limit of detection in sewage of 50 µg Cl/L mg/L as CPO, however, using a dual platinum electrode amperometric titrator (Andrew and Glass, 1974) with addition of the titrant with a microburette, enabled detection of 1µg/L.

The iodometric electrode method described in APHA (2017) appears to offer the best detection limits. Dimmock and Midgely (1982) investigated the use of an Orion Residual Chlorine electrode for chlorine oxidants in cooling waters. This electrode consists of an iodide electrode and a platinum electrode mounted together. Iodide is added to the test solutions which reacts with the chlorine oxidants to form iodine. The electrode senses the difference in iodide concentrations, so for low CPO concentrations it will be important to use low concentrations of added potassium iodide. Reaction is fastest at pH 4, so the seawater pH first needs to be adjusted by the addition of acetate.

Wang et al. (2008) used an iodine colorimetric method, where potassium iodide is added to the test where it reacts with oxidants to form the triiodide ion, which can be determined spectrophotometrically at 352 nm. Unlike the DPD colorimetric method, which needs to be undertaken rapidly, with the iodine method, samples can be spiked with iodine reagent in the field (or laboratory) and safely analysed at a later time (Wang et al., 2008). The method is detailed in a paper by Sugita et al. (1992). The detection limit is, however, only 4 µg Cl/L.

This iodometric electrode method appears to be one of the best, however, for all three methods, detecting compliance against GVs will be pushing the method to its lower limits. Considerable effort will be required to master whatever method is applied and to get it to perform at low µg/L concentrations.

6 Conclusions

The use of chlorine as a biocide in heat exchanger pipes and the subsequent discharge of chlorine-containing seawater to a high conservation value ecosystem presents a range of regulatory considerations. Unlike most other toxicants, chlorine and the hypochlorite ion formed in seawater are highly reactive, first reacting with natural bromide in seawater to form hypobromite ion that further reacts with organic matter such that, within hours, the original concentration is significantly reduced. This has consequences for the potential impacts of chlorine and other chlorine produced oxidants (CPOs) on aquatic biota.

Regulation of persistent toxicants in seawater uses chronic toxicity data in an SSD to derive a DGV that is protective of a given percentage of species. The exposure durations for these toxicity tests range from 3 to 7 days. This duration is inappropriate for testing of a toxicant where the concentration has significantly decayed within this period, so to account for effects over shorter durations, short-term GVs are more appropriate.

We recommend that:

- 99 and 95% species protection short-term GVs of 2.0 and 7.3 µg Cl/L apply to CPO concentrations at and beyond the boundary of a mixing zone in situations where the concentration at the boundary of a mixing zone is relatively consistent over time.
- 99% species protection short-term GV of 6.0 Cl/L apply to CPO concentration at and beyond the boundary of a mixing zone where concentration at the boundary of a mixing zone is intermittent or variable over time such as North Arm of Western Port.
- These water quality objectives may not be met within a mixing zone.
- The 99 and 95% species protection short-term GVs of 2.0 and 7.3 µg Cl/L will be proposed for inclusion in the Australia New Zealand Water Quality Guidelines (ANZG, 2018a) for situations of constant exposure with a recommendation that time-averaged concentrations measured at and beyond the mixing zone boundary be used in situations of variable exposure to assess GV compliance.

Analytical detection at this concentration will require either an amperometric or an iodometric method whose detection limits have been reported as 1 µg Cl/L.

7 References

Abarnou, A. and Miossec, L. (1992). Chlorinated waters discharged to the marine environment chemistry and environmental impact: an overview. Science of the Total Environment, 126, 173-197.

Alderson, R. (1970). Effects of low concentrations of free chlorine on eggs and larvae of plaice (*Pleuronectes platessa* L.). In: Marine Pollution and Sea Life. M. Riuvo, ed., FAO, Fishing News (Books) Ltd., Surrey, England.

Anasco, N., Koyama, J., Imai, S. and Nakamura, K. (2008). Toxicity of residual chlorines from hypochlorite treated seawater to marine amphipod *Hyale barbicornis* and estuarine fish *Oryzias javanicus*. Water Air and Soil Pollution, 195, 129-136.

Andrew, R.W. and Glass, G.E. (1974). Amperometric titration methods for total residual chlorine, ozone, and sulfite (Tentative Methods – Not for Publication) US EPA Environmental Research Laboratory, Duluth, MN, USA.

Angel, B.M., Simpson, S.L., Chariton, A.A., Stauber, J.L. and Jolley, D.F. (2015). Time-averaged concentrations of copper from continuous exposures conservatively predict pulsed exposure toxicity to the marine diatom, *Phaeodactylum tricornutum*: Importance of uptake and elimination. Aquatic Toxicology, 164, 1–9.

ANZECC/ARMCANZ (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, ACT, Australia.

ANZG (2018a). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines

ANZG (2018b). Default guideline values for toxicants: Chlorine – Marine (Draft). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia, 12 pp.

Apetroaei, M.R., Atodiresei, D.V. Rău, I., Apetroaei, G.M., Lilios, G., Schroder, V. (2018). Overview on the practical methods of ballast water treatment. IOP Conf. Series: Journal of Physics: Conf. Series 1122, 1-8.

APHA (2017). Standard Methods for the Examination of Water and Wastewater, 23rd Edition. America Public Health Association/American Water Works Association/Water Environment Federation, Washington, DC, USA.

Batley, G.E., van Dam, R.A., Warne, M.St.J., Chapman, J.C., Fox, D.R., Hickey C.W. and Stauber, J.L. (2018). Technical rationale for changes to the method for deriving Australian and New Zealand water quality guideline values for toxicants– update of 2014 version. Prepared for the revision of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra, 43 pp.

Bellanca, M.A. and Bailey, D.S. (1977). Effects of chlorinated effluents on aquatic ecosystems in the lower James River. Journal of the Water Pollution Control Federation, 49, 639-645.

Capuzzo, J.M. (1979). The effect of temperature on the toxicity of chlorinated cooling waters to marine animals – a preliminary review. Marine Pollution Bulletin, 10, 45-47.

Capuzzo, J.M., Lawrence, S.A. and Davidson, J.A. (1976). Combined toxicity of free chlorine, chloramine and temperature to Stage I larvae of the American lobster *Homarus americanus*. Water Research, 10, 1093-1099.

CCME (1999). Canadian water quality guidelines for the protection of aquatic life: Reactive chlorine. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg, Manitoba, 9 pp.

Chariton, A.A. and Stauber, J.L. (2008). Toxicity of chlorine and its major by-products in seawater: a literature review. CSIRO Land and Water Science Restricted Report No. 54/08, Lucas Heights, NSW, 19 pp.

Chidgey, S. (2018). Chlorine in seawater heat exchange process at Crib Point. Technical Report to Jacobs Group Australia. CEEPty Ltd, Cheltenham, Vic, 31 pp.

Deborde, M. and von Gunten, U. (2008). Reactions of chlorine with inorganic and organic compounds during water treatment—Kinetics and mechanisms: A critical review. Water Research, 42, 13-52.

Dimmock, N.A. and Midgley, D. (1982). Performance of the Orion 97–70 total residual chlorine electrode at low concentrations and its application to the analysis of cooling waters. Talanta, 29, 557-567.

Dinnel, P.A., Stober, Q.J. and DiJulio, D.H. (1981). Sea urchin sperm bioassay for sewage and chlorinated seawater and its relation to fish bioassays. Marine Environmental Research, 5, 29-39.

ECB (2002). Technical guidance document on risk assessment. Part II. European Chemicals Bureau Report No. EUR 20418 EN/2. Available at: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC23785/EUR%2020418%20EN-2.pdf, accessed April 17, 2019.

Eppley, R.W., Renger, E.H. and Williams, P.M. (1976). Chlorine reactions with sea-water constituents and the inhibition of photosynthesis of natural marine phytoplankton. Estuarine Coastal and Marine Science, 4, 147-161.

Fisher, D.J., Burton, D.J., Yonkos, L.T., Turley, S.D. and Ziegler, G.P. (1999). The relative acute toxicity of continuous and Intermittent exposures of chlorine and bromine to aquatic organisms in the presence and absence of ammonia. Water Research, 33, 760-779.

Gibson, C.I., Thatcher, T.O. and Apts, C.W. (1975). Some effects of temperature, chlorine and copper on the survival and growth of the coon stripe shrimp, *Pandalus danae.* Battelle Northwest Report No. BNWL-SA-5344, Richland, Washington, USA.

Goodman, L., Douglas, P., Middaugh, D.J., Hansen, P.J., Higdon, P.K. and Cripe, G.M. (1983). Early life-stage toxicity test with tidewater silversides (*Menidia peninsulae*) and chlorine-produced oxidants. Environmental Toxicology and Chemistry, 2, 337– 342.

Jenkins, R.L. and Baird, R.B. (1979) Deteemination of total chlorine residual in treated wastewaters by electrode. Analytical Letters, 12, 125-141.

Jenner, H.A., Taylor, C.J.L., van Donk, M. and Khalanski, M. (1997). Chlorination by-products in chlorinated cooling water of some European coastal power stations. Marine Environmental Research, 43, 279-293.

Khalanski, M. and Jenner, H.A. (2011). Chlorination chemistry and ecotoxicology of the marine cooling water systems. In: Operational and Environmental Consequences of Large Industrial Cooling Water Systems, Rajagopal, S., Jenner, H.A. and Venugopalan, V.P., eds, Springer, New York, USA, pp. 183-226.

Khalanski, M., Jenner, H.A. (2012). Chapter 9. Chlorination chemistry and ecotoxicology of the marine cooling water systems. In: Rajagopal, S.,Jenner, H.A., Venugopalan, V.P. (eds.), Operational and Environmental Consequences of Large Industrial Cooling Water Systems, Springer, pp. 183-226.

Lewis, S., Cartwright, N.G., Jerman, E., Tynan, P., Sims, I. R. and Wellstein, N. (1994). Proposed Environmental Quality Standards for chlorine in fresh and marine waters. Water Research Centre, WRc, Report, Medmenham, UK.

Lopez-Galindo, C., Garrido, M.C., Casanueva, J.F. and Nebot, E. (2010). Degradation models and ecotoxicity in marine waters of two antifouling compounds: sodium hypochlorite and an alkylamine surfactant. Science of the Total Environment, 408, 1779-1785.

Nguyen,T., Roddick, F.A., Fan, L. (2012). Biofouling of water treatment membranes: a review of the underlying causes, monitoring techniques and control measures. Membranes, 2, 804–840.

Patrick, R., and McLean, R. (1971). Entrainment simulation studies on some estuarine organisms for the Potomac Electric Power Company. Academy of Natural Sciences, Philadelphia, Department of Limnology, Philadelphia, USA

Sugita, H., Hayashi, K., Asai, T., Mitsuya, T., Amanuma, K., Maruyama, C. and Deguchi, Y. (1992). Spectrophotometric method for determination of total residual oxidants in seawater. Suisanzoshoku, 40, 45-49.

Rajagopal, S. (2011). Chlorination and biofouling control in industrial cooling water systems. In**:** Operational and Environmental Consequences of Large Industrial Cooling Water Systems, Rajagopal, S., Jenner, H.A. and Venugopalan, V.P, eds, Springer, New York, USA, pp. 163-182.

Rigdon, L.P., Moody, G.J. and Frazer, J.W. (1978). Determination of residual chlorine in water with computer automation and a residual-chlorine electrode. Analytical Chemistry, 50, 465-469.

Roberts, M.H., Diaz, R.J., Bender, M.E. and Huggett, R.J. (1975). Acute toxicity of chlorine to selected estuarine species. Journal of the Fisheries Research Board of Canada, 32, 2525–2528.

Saeed, S., Prakash, S., Deb, N., Campbell, R., Kolluru, V., Febbo, E. and Dupont, J. (2015). Development of a site-specific kinetic model for chlorine decay and the formation of chlorination by-products in seawater. Journal of Marine Science and Engineering, 3, 772-792.

Sorokin, N., Atkinson, C., Aldous, E., Rule, K. and Comber, S. (2007). Proposed EQS for Water Framework Directive Annex VIII substances: chlorine (free available). Environment Agency Science Report No. SC040038/SR4, Bristol, U.K., 69 pp.

Stewart, M.E. Blogoslawski, W.J., Hsu, R.Y. and Helz, G.R. (1979). By-products of oxidative biocides: toxicity to oyster larvae. Marine Pollution Bulletin, 10, 166-169.

Sugam, R. and Helz, G.R. (1977). Speciation of chlorine produced oxidants in marine waters. Chesapeake Science 18, 113-115.

Sugita, H., Hayashi, K., Asai, T., Mitsuya, T., Amanuma, K., Maruyama, C. and Deguchi, Y. (1992). Spectrophotometric method for determination of total residual oxidants in seawater. Suisanzoshoku, 40, 45-49.

Thatcher, T.O. 1978. The relative sensitivity of Pacific Northwest fishes and invertebrates co chlorinated sea water. In: Water Chlorination: Environmental Impact and Health Effects, Vol. 2, R.L. Jolley, H. Gorchev, and D.H. Hamilton, eds, Ann Arbor Science Publishers, Ann Arbor, MI, USA, p. 341.

UK Marine SAC (2019). Biocides used in cooling water disinfection. UK Marine Special Areas of Conservation web site, accessed April 15, 2019, http://www.ukmarinesac.org.uk/activities/water-quality/wq8_28.htm

USEPA (1985). Ambient water quality criteria for chlorine – 1984. United States Environmental Protection Agency Report No. EPA 440/5-84-030, Office of Water, Washington, DC, USA, 57 pp.

Wang, J-T., Chen, M-H., Lee, H-J., Chang, W-B., Chen, C-C., Pai, S-C. and Meng, P-J. (2008). A model to predict total chlorine residue in the cooling seawater of a power plant using iodine colorimetric method. International Journal of Molecular Sciences, 9, 542-553.

Warne, M., Batley, G.E., van Dam, R.A., Chapman, J.C., Fox, D.R., Hickey, C.W. and Stauber, J.L. (2018). Revised Method for Deriving Australian and New Zealand Water Quality Guideline Values for Toxicants – update of 2015 version. Prepared for the revision of the Australian and New Zealand

Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra, 48 pp.

Zeng, J., Jiang, Z., Chen, Q., Zheng, P. and Huang, Y. (2009). The decay kinetics of residual chlorine in cooling seawater simulation experiments. Acta Oceanologica Sinica, 28, 54-59.

CONTACT US

t 1300 363 400

e enquiries@csiro.au

w www.csiro.au

At CSIRO we shape the future

We do this by using science to solve real issues. Our research makes a difference to industry, people and the planet.

As Australia's national science agency, we've been pushing the edge of what's possible for over 85 years. Today we have more than 5,000 talented people working out of 50-plus centres in Australia and internationally. Our people work closely with industry and communities to leave a lasting legacy. Collectively, our innovation and excellence places us in the top ten applied research agencies in the world.

WE ASK, WE SEEK AND WE SOLVE

For further information

CSIRO

Graeme Batley

t **+61 2 9710 6830**

e **Graeme.batley@csiro.au**

w www.csiro.au

Appendix N

Water - Toxicity test report

Toxicity Assessment of Free Chlorine in Crib Point Seawater

CEE Pty Ltd

October 2019

T +61 2 9420 9481
Unit 27, 2 Chaplin Drive
Lane Cove NSW 2066 Australia
www.ecotox.com.au
ECOTOX SERVICES AUSTRALIA PTY LIMITED
ABN 95 619 426 201

Toxicity Test Report: TR1861/1

Client:	CEE	**ESA Job #:**	PR1861
	Unit 4, 150 Chesterville Rd	**Date Sampled:**	13 August 2019
	Cheltenham VIC 3192	**Date Received:**	14 August 2019
Attention:	Scott Chidgey	**Sampled By:**	Not applicable
Client Ref:	Not Supplied	**ESA Quote #:**	PL1861_q01

Lab ID No.:	Sample Name:	Sample Description:
9261	Crib Point (Diluent)	Aqueous sample, pH 8.2, salinity 33.8‰, total ammonia <2.0mg/L. Sample received at 13ºC in apparent good condition.
1901*	Sodium Hypochlorite	12.5%w/v, GLR (General Laboratory grade), 5L, Rowe Scientific, Batch CN270315

*ESA Chemical Inventory number, for all ESA laboratory reagents.

Test Performed:	96-hr fish imbalance toxicity test using barramundi *Lates calcarifer*
Test Protocol:	ESA SOP 117 (ESA 2017), based on USEPA (2002)
Test Temperature:	The test was performed at 25±2°C.
Deviations from Protocol:	Nil
Comments on Solution Preparation:	The nominal test dilutions were prepared by the direct addition of sodium hypochlorite reagent to Crib Point seawater at the prescribed dosing rates using 2L volumetric flasks, with gentle inverting to minimise volatilisation of chlorine into the headspace. A FSW control and a Crib Point Diluent control were tested concurrently with the sample. Free chlorine were determined using the Merck Spectroquant kit (SKU 1.00599.0001) range 0.010-6.00mg/L to provide measured concentrations for each test treatment.
Source of Test Organisms:	Hatchery reared, SA
Test Initiated:	04 October 2019 at 1800h

Sample 9261 +Cl_2: *Crib Point +Cl_2*

Nominal Concentration (mg Free Cl_2/L)	**% Unaffected (Mean ± SD)**
FSW Control	100 ± 0.0
Diluent Control	100 ± 0.0
0.006	100 ± 0.0
0.013	100 ± 0.0
0.025	100 ± 0.0
0.05	100 ± 0.0
0.1	100 ± 0.0
0.2	100 ± 0.0
0.5	100 ± 0.0
1.0	100 ± 0.0

96-hr EC10 = >1mg Free Cl_2/L
96-hr EC50 = >1mg Free Cl_2/L
NOEC = 1mg Free Cl_2/L
LOEC = >1mg Free Cl_2/L

Sample 9261 +Cl_2: *Crib Point +Cl_2*

Measured Concentration (mg Free Cl_2/L @t=0)	**% Unaffected (Mean ± SD)**
FSW Control	100 ± 0.0
Diluent Control	100 ± 0.0
0	100 ± 0.0
0	100 ± 0.0
0	100 ± 0.0
0	100 ± 0.0
0.09	100 ± 0.0
0.19	100 ± 0.0
0.49	100 ± 0.0
0.98	100 ± 0.0

96-hr EC10 = >0.98mg Free Cl_2/L
96-hr EC50 = >0.98mg Free Cl_2/L
NOEC = 0.98mg Free Cl_2/L
LOEC = >0.98mg Free Cl_2/L

Vacant

T +61 2 9420 9481
Unit 27, 2 Chaplin Drive
Lane Cove NSW 2066 Australia
www.ecotox.com.au
ECOTOX SERVICES AUSTRALIA PTY LIMITED
ABN 95 619 426 201

Toxicity Test Report: TR1861/1

QA/QC Parameter	Criterion	This Test	Criterion met?
Control mean % unaffected	≥80.0%	100%	Yes
Reference Toxicant within cusum chart limits	9.7-118.0mg NH_4^+/L	42.6mg NH_4^+/L	Yes

Test Report Authorised by: Dr Rick Krassoi, Director on 11 October 2019

Results are based on the samples in the condition as received by ESA.
This document shall not be reproduced except in full.

Citations:

ESA (2017) SOP 117 –*Freshwater and Marine Fish Imbalance Test*. Issue No 6. Ecotox Services Australasia, Sydney, NSW

USEPA (2002) Methods for measuring the acute toxicity of effluents and receiving waters to freshwater and marine organisms. Fifth edition EPA-821-R-02-012. United States Environmental Protection Agency, Office of Research and Development, Washington FC, USA

T +61 2 9420 9481
Unit 27, 2 Chaplin Drive
Lane Cove NSW 2066 Australia
www.ecotox.com.au
ECOTOX SERVICES AUSTRALIA PTY LIMITED
ABN 95 619 426 201

Toxicity Test Report: TR1861/2

Client:	CEE	**ESA Job #:**	PR1861
	Unit 4, 150 Chesterville Rd	**Date Sampled:**	13 August 2019
	Cheltenham VIC 3192	**Date Received:**	14 August 2019
Attention:	Scott Chidgey	**Sampled By:**	Not applicable
Client Ref:	Not Supplied	**ESA Quote #:**	PL1861_q01

Lab ID No.:	**Sample Name:**	**Sample Description:**
9261	Crib Point (Diluent)	Aqueous sample, pH 8.2, salinity 33.8‰, total ammonia <2.0mg/L. Sample received at 13ºC in apparent good condition.
1901*	Sodium Hypochlorite	12.5%w/v, GLR (General Laboratory grade), 5L, Rowe Scientific, Batch CN270315

*ESA Chemical Inventory number, for all ESA laboratory reagents.

Test Performed:	96-hr acute toxicity test using the amphipod *Allorchestes compressa*
Test Protocol:	ESA SOP 108 (ESA 2017), based on USEPA (2002) and Department of Transport and Communications (1990)
Test Temperature:	The test was performed at 20±1°C.
Deviations from Protocol:	Nil
Comments on Solution Preparation:	The nominal test dilutions were prepared by the direct addition of sodium hypochlorite reagent to Crib Point seawater at the prescribed dosing rates using 2L volumetric flasks, with gentle inverting to minimise volatilisation of chlorine into the headspace. A FSW control and a Crib Point Diluent control were tested concurrently with the sample. Free chlorine were determined using the Merck Spectroquant kit (SKU 1.00599.0001) range 0.010-6.00mg/L to provide measured concentrations for each test treatment.
Source of Test Organisms:	In-house culture, originally sourced from Queenscliff, VIC
Test Initiated:	04 October 2019 at 1830h

Sample 9261 +Cl_2: *Crib Point +Cl_2*		Sample 9261 +Cl_2: *Crib Point +Cl_2*		*Vacant*
Nominal Concentration (mg Free Cl_2/L)	**% Unaffected (Mean ± SD)**	**Nominal Concentration (mg Free Cl_2/L @ t=0)**	**% Unaffected (Mean ± SD)**	
FSW Control	100 ± 0.0	FSW Control	100 ± 0.0	
Diluent Control	100 ± 0.0	Diluent Control	100 ± 0.0	
0.006	100 ± 0.0	0.006	100 ± 0.0	
0.013	100 ± 0.0	0.013	100 ± 0.0	
0.025	100 ± 0.0	0.025	100 ± 0.0	
0.05	100 ± 0.0	0.05	100 ± 0.0	
0.1	100 ± 0.0	0.1	100 ± 0.0	
0.2	100 ± 0.0	0.2	100 ± 0.0	
0.5	100 ± 0.0	0.5	100 ± 0.0	
1.0	100 ± 0.0	1.0	100 ± 0.0	
96-hr EC10 = >1mg Free Cl_2/L		**96-hr EC10 = >1mg Free Cl_2/L**		
96-hr EC50 = >1mg Free Cl_2/L		**96-hr EC50 = >1mg Free Cl_2/L**		
NOEC = 1mg Free Cl_2/L		**NOEC = 1mg Free Cl_2/L**		
LOEC = >1mg Free Cl_2/L		**LOEC = >1mg Free Cl_2/L**		

T +61 2 9420 9481
Unit 27, 2 Chaplin Drive
Lane Cove NSW 2066 Australia
www.ecotox.com.au
ECOTOX SERVICES AUSTRALIA PTY LIMITED
ABN 95 619 426 201

Toxicity Test Report: TR1861/2

QA/QC Parameter	Criterion	This Test	Criterion met?
Control mean % unaffected	≥90.0%	100%	Yes
Reference Toxicant within cusum chart limits	0.54-8.63mg SDS/L	3.3mgSDS/L	Yes

Test Report Authorised by: Dr Rick Krassoi, Director on 11 October 2019

Results are based on the samples in the condition as received by ESA.
This document shall not be reproduced except in full.

Citations:

Department of Transport and Communications (1990) Guidelines for Acceptance of Oil Spill Dispersants in Australian Waters. Pollution Prevention Section, Department of Transport and Communications, Canberra ACT.

ESA (2017) SOP 108 – *Amphipod Acute Toxicity Test*. Issue No 10. Ecotox Services Australia, Sydney, NSW.

USEPA (2002) Methods for measuring the acute toxicity of effluents and receiving waters to freshwater and marine organisms. Fifth Edition. United States Environmental Protection Agency, Office of Research and Development, Washington DC, EPA/600/4-90/027F.

NATA WORLD RECOGNISED ACCREDITATION

T +61 2 9420 9481
Unit 27, 2 Chaplin Drive
Lane Cove NSW 2066 Australia
www.ecotox.com.au
ECOTOX SERVICES AUSTRALIA PTY LIMITED
ABN 95 619 426 201

Chain-of-Custody Documentation

Chain-of-Custody / Service Request Form

Datasheet ID: 601.1
Last Revised: 15 July 2014

ecotox SERVICES AUSTRALASIA

Customer: CEE Pty Ltd
Contact Name: Scott Chidgey
Phone: 0395534787 Email: chidgey@cee.com.au (please provide an email address for sample receipt notification)
Sampled by: Peter Crockett

Ship To: Ecotox Services Australasia
Attention: Rick Krassoi

2/2

Sample Date (day/month /year)	Sample Time	Sample Name (exactly as written on the sample vessel)	Sample Method (eg. Grab, composite etc.)	Number and Volume of Containers (eg 2 x 1L)	Tests Requested (See reverse for guidance)	Comments / Instructions
					Diluent for Cl_2 tests	**Note that testing will be delayed if an incomplete chain of custody is received** • Additional treatment of samples (i.e. spiking) • Sub-contracted services (i.e. chemical analyses) • Dilutions required (if different than 100% down to 6.25%) • Sample holding time restriction (if applicable) • Sample used for litigation (if applicable) *Note: An MSDS must be attached if Available* **ESA Project Number: PR** 1852
13/08/2019	13 :00	Crib Point	Grab	4 x 5 L 2	1	Sea Water

1) Released By:	Date:	2) Received By:	Date:	3) Released By:	Date:	4) Received By:	Date:
P. Crockett	13/08/2019		14/8/19				
Of:	Time:	Of:	Time:	Of:	Time:	Of:	Time:
CEE	17:00	ESA	1430				

Note that the chain-of-custody documentation will provide definitive information on the tests to be performed.

Ecotox Services Australasia . Unit 27, 2 Chaplin Drive, Lane Cove NSW 2066 AUSTRALIA
Phone: 61 2 9420-9481 Fax 61 2 9420-9484 info@ecotox.com.au

Chain-of-Custody / Service Request Form

Datasheet ID: 601.1
Last Revised: 15 July 2014

ecotox SERVICES AUSTRALASIA

1/2

Customer: CEE Pty Ltd
Contact Name: Scott Chidgey
Phone: 0395534787 Email: chidgey@cee.com.au (please provide an email address for sample receipt notification)
Sampled by: Peter Crockett

Ship To: Ecotox Services Australasia
Attention: Rick Krassoi

13.c

Sample Date (day/month /year)	Sample Time	Sample Name (exactly as written on the sample vessel)	Sample Method (eg. Grab, composite etc.)	Number and Volume of Containers (eg 2 x 1L)	Tests Requested (See reverse for guidance)						Comments / Instructions
					Diluent for Cl_2 tests.						**Note that testing will be delayed if an incomplete chain of custody is received** • Additional treatment of samples (i.e. spiking) • Sub-contracted services (i.e. chemical analyses) • Dilutions required (if different than 100% down to 6.25%) • Sample holding time restriction (if applicable) • Sample used for litigation (if applicable) *Note: An MSDS must be attached if Available* **ESA Project Number: PR** 1852
9261 13/08/2019	13 :00	Crib Point	Grab	4 x 5 L 2 P	1						Sea Water

1) Released By:	Date:	2) Received By:	Date:	3) Released By:	Date:	4) Received By:	Date:
P. Crockett	13/08/2019		14/8/19				
Of: CEE	Time: 17:00	Of: ESA	Time: 1430	Of:	Time:	Of:	Time:

Note that the chain-of-custody documentation will provide definitive information on the tests to be performed.

Ecotox Services Australasia . Unit 27, 2 Chaplin Drive, Lane Cove NSW 2066 AUSTRALIA
Phone: 61 2 9420-9481 Fax 61 2 9420-9484 info@ecotox.com.au

Statistical Printouts for the Larval Fish Imbalance Tests

Fish Imbalance Test-96 hr Unaffected

Start Date:	4/10/2019 18:00	Test ID:	PR1861/01	Sample ID:	Crib Point + Cl2
End Date:	8/10/2019 18:00	Lab ID:	9261 +Cl2	Sample Type:	CP-Chemical product
Sample Date:		Protocol:	ESA 117	Test Species:	LT-Lates calcarifer
Comments:					

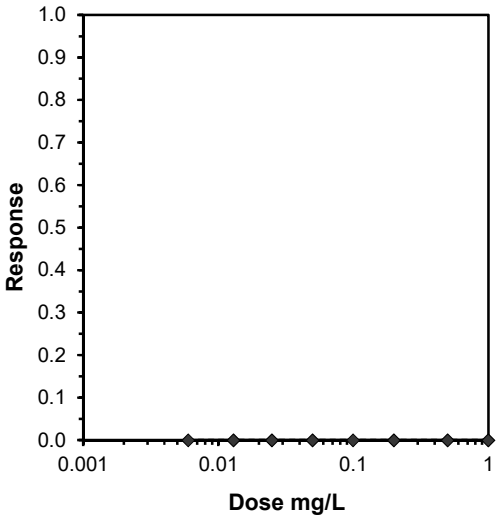
Conc-mg/L	1	2	3	4
FSW Control	1.0000	1.0000	1.0000	1.0000
Diluent Control	1.0000	1.0000	1.0000	1.0000
0.006	1.0000	1.0000	1.0000	1.0000
0.013	1.0000	1.0000	1.0000	1.0000
0.025	1.0000	1.0000	1.0000	1.0000
0.05	1.0000	1.0000	1.0000	1.0000
0.1	1.0000	1.0000	1.0000	1.0000
0.2	1.0000	1.0000	1.0000	1.0000
0.5	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000

			Transform: Arcsin Square Root					Isotonic	
Conc-mg/L	Mean	N-Mean	Mean	Min	Max	CV%	N	Mean	N-Mean
FSW Control	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4		
Diluent Control	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000
0.006	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000
0.013	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000
0.025	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000
0.05	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000
0.1	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000
0.2	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000
0.5	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000
1	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)	1	0.935		
Equality of variance cannot be confirmed				
The control means are not significantly different (p = 1.00)	0	2.446912		

Log-Logit Interpolation (200 Resamples)

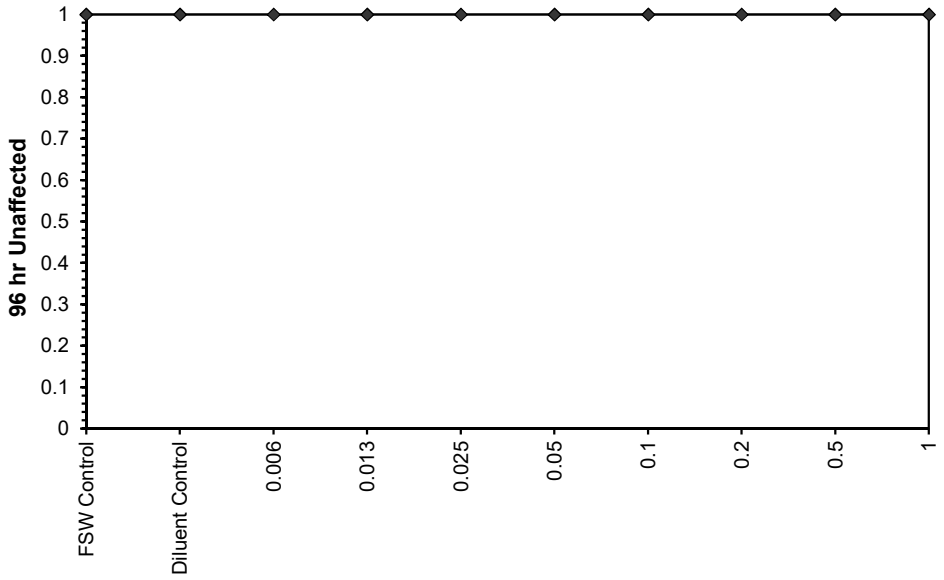
Point	mg/L	SD	95% CL(Exp)	Skew
IC05	>1			
IC10	>1			
IC15	>1			
IC20	>1			
IC25	>1			
IC40	>1			
IC50	>1			



Fish Imbalance Test-96 hr Unaffected

Start Date:	4/10/2019 18:00	Test ID:	PR1861/01	Sample ID:	Crib Point + Cl2
End Date:	8/10/2019 18:00	Lab ID:	9261 +Cl2	Sample Type:	CP-Chemical product
Sample Date:		Protocol:	ESA 117	Test Species:	LT-Lates calcarifer
Comments:					

Dose-Response Plot



Fish Imbalance Test-96 hr Unaffected

Start Date:	4/10/2019 18:00	Test ID:	PR1861/01	Sample ID:	Crib Point + Cl2
End Date:	8/10/2019 18:00	Lab ID:	9261 +Cl2	Sample Type:	CP-Chemical product
Sample Date:		Protocol:	ESA 117	Test Species:	LT-Lates calcarifer
Comments:					

Auxiliary Data Summary

Conc-mg/L	Parameter	Mean	Min	Max	SD	CV%	N
FSW Control	% unaffected	100.00	100.00	100.00	0.00	0.00	4
Diluent Control		100.00	100.00	100.00	0.00	0.00	4
0.006		100.00	100.00	100.00	0.00	0.00	4
0.013		100.00	100.00	100.00	0.00	0.00	4
0.025		100.00	100.00	100.00	0.00	0.00	4
0.05		100.00	100.00	100.00	0.00	0.00	4
0.1		100.00	100.00	100.00	0.00	0.00	4
0.2		100.00	100.00	100.00	0.00	0.00	4
0.5		100.00	100.00	100.00	0.00	0.00	4
1		100.00	100.00	100.00	0.00	0.00	4
FSW Control	pH	8.20	8.20	8.20	0.00	0.00	1
Diluent Control		8.20	8.20	8.20	0.00	0.00	1
0.006		8.20	8.20	8.20	0.00	0.00	1
0.013		8.20	8.20	8.20	0.00	0.00	1
0.025		8.20	8.20	8.20	0.00	0.00	1
0.05		8.20	8.20	8.20	0.00	0.00	1
0.1		8.20	8.20	8.20	0.00	0.00	1
0.2		8.20	8.20	8.20	0.00	0.00	1
0.5		8.20	8.20	8.20	0.00	0.00	1
1		8.20	8.20	8.20	0.00	0.00	1
FSW Control	Salinity ppt	36.00	36.00	36.00	0.00	0.00	1
Diluent Control		33.80	33.80	33.80	0.00	0.00	1
0.006		35.80	35.80	35.80	0.00	0.00	1
0.013		35.80	35.80	35.80	0.00	0.00	1
0.025		35.80	35.80	35.80	0.00	0.00	1
0.05		35.80	35.80	35.80	0.00	0.00	1
0.1		35.80	35.80	35.80	0.00	0.00	1
0.2		35.80	35.80	35.80	0.00	0.00	1
0.5		35.80	35.80	35.80	0.00	0.00	1
1		35.80	35.80	35.80	0.00	0.00	1
FSW Control	DO %	98.90	98.90	98.90	0.00	0.00	1
Diluent Control		99.20	99.20	99.20	0.00	0.00	1
0.006		98.90	98.90	98.90	0.00	0.00	1
0.013		99.10	99.10	99.10	0.00	0.00	1
0.025		99.60	99.60	99.60	0.00	0.00	1
0.05		99.70	99.70	99.70	0.00	0.00	1
0.1		99.40	99.40	99.40	0.00	0.00	1
0.2		98.90	98.90	98.90	0.00	0.00	1
0.5		99.40	99.40	99.40	0.00	0.00	1
1		100.20	100.20	100.20	0.00	0.00	1

Fish Imbalance Test-96 hr Unaffected

Start Date:	4/10/2019 18:00	Test ID:	PR1861/02	Sample ID:	Crib Point + Cl2
End Date:	8/10/2019 18:00	Lab ID:	9261 +Cl2	Sample Type:	CP-Chemical product
Sample Date:		Protocol:	ESA 117	Test Species:	LT-Lates calcarifer
Comments:	Measured Concentration @ t=0				

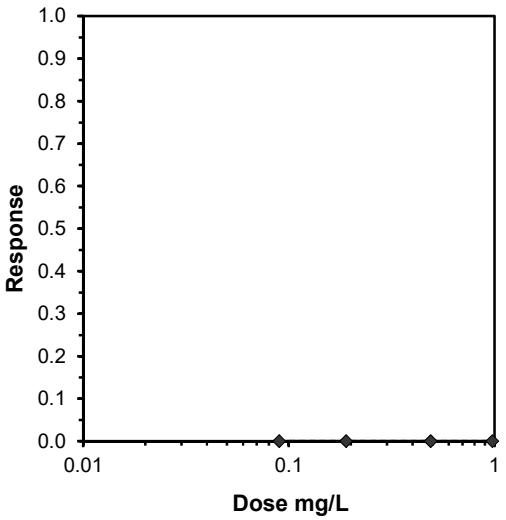
Conc-mg/L	1	2	3	4	5	6	7	8	9	10
FSW Control	1.0000	1.0000	1.0000	1.0000						
Diluent Control	1.0000	1.0000	1.0000	1.0000						
0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000				
0.09	1.0000	1.0000	1.0000	1.0000						
0.19	1.0000	1.0000	1.0000	1.0000						
0.49	1.0000	1.0000	1.0000	1.0000						
0.98	1.0000	1.0000	1.0000	1.0000						

			Transform: Arcsin Square Root					Isotonic	
Conc-mg/L	Mean	N-Mean	Mean	Min	Max	CV%	N	Mean	N-Mean
FSW Control	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4		
Diluent Control	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000
0	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	16	1.0000	1.0000
0.09	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000
0.19	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000
0.49	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000
0.98	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)	1	0.935		
Equality of variance cannot be confirmed				
The control means are not significantly different (p = 1.00)	0	2.446912		

Log-Logit Interpolation (200 Resamples)

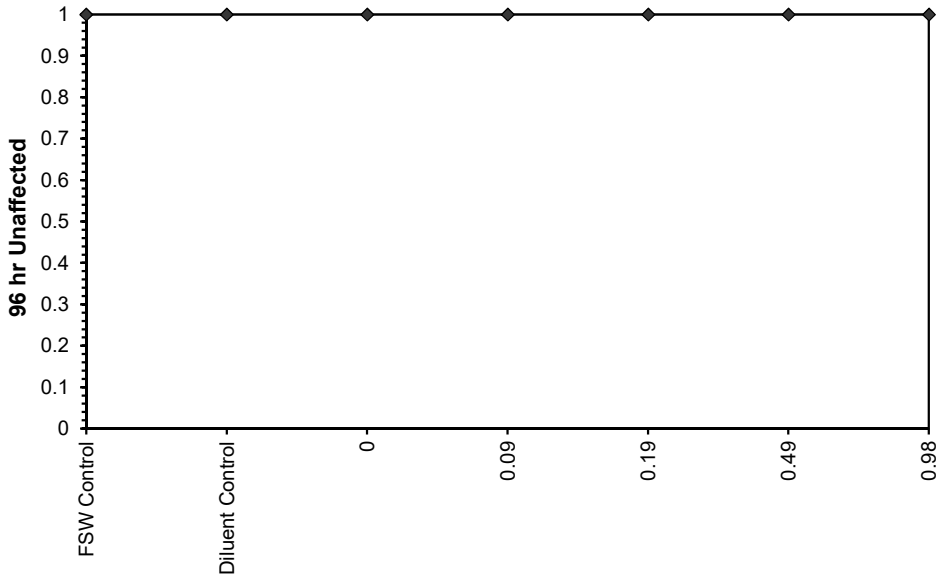
Point	mg/L	SD	95% CL(Exp)	Skew
IC05	>0.98			
IC10	>0.98			
IC15	>0.98			
IC20	>0.98			
IC25	>0.98			
IC40	>0.98			
IC50	>0.98			



Fish Imbalance Test-96 hr Unaffected

Start Date:	4/10/2019 18:00	Test ID:	PR1861/02	Sample ID:	Crib Point + Cl2
End Date:	8/10/2019 18:00	Lab ID:	9261 +Cl2	Sample Type:	CP-Chemical product
Sample Date:		Protocol:	ESA 117	Test Species:	LT-Lates calcarifer
Comments:	Measured Concentration @ t=0				

Dose-Response Plot



Fish Imbalance Test-96 hr Unaffected

Start Date:	4/10/2019 18:00	Test ID:	PR1861/02	Sample ID:	Crib Point + Cl2
End Date:	8/10/2019 18:00	Lab ID:	9261 +Cl2	Sample Type:	CP-Chemical product
Sample Date:		Protocol:	ESA 117	Test Species:	LT-Lates calcarifer
Comments:	Measured Concentration @ t=0				

		Auxiliary Data Summary					
Conc-mg/L	**Parameter**	**Mean**	**Min**	**Max**	**SD**	**CV%**	**N**
FSW Control	% unaffected	100.00	100.00	100.00	0.00	0.00	4
Diluent Control		100.00	100.00	100.00	0.00	0.00	4
0		100.00	100.00	100.00	0.00	0.00	16
0.09		100.00	100.00	100.00	0.00	0.00	4
0.19		100.00	100.00	100.00	0.00	0.00	4
0.49		100.00	100.00	100.00	0.00	0.00	4
0.98		100.00	100.00	100.00	0.00	0.00	4
FSW Control	pH	8.20	8.20	8.20	0.00	0.00	1
Diluent Control		8.20	8.20	8.20	0.00	0.00	1
0		8.20	8.20	8.20	0.00	0.00	4
0.09		8.20	8.20	8.20	0.00	0.00	1
0.19		8.20	8.20	8.20	0.00	0.00	1
0.49		8.20	8.20	8.20	0.00	0.00	1
0.98		8.20	8.20	8.20	0.00	0.00	1
FSW Control	Salinity ppt	36.00	36.00	36.00	0.00	0.00	1
Diluent Control		33.80	33.80	33.80	0.00	0.00	1
0		35.80	35.80	35.80	0.00	0.00	4
0.09		35.80	35.80	35.80	0.00	0.00	1
0.19		35.80	35.80	35.80	0.00	0.00	1
0.49		35.80	35.80	35.80	0.00	0.00	1
0.98		35.80	35.80	35.80	0.00	0.00	1
FSW Control	DO %	98.90	98.90	98.90	0.00	0.00	1
Diluent Control		99.20	99.20	99.20	0.00	0.00	1
0		99.33	98.90	99.70	0.39	0.63	4
0.09		99.40	99.40	99.40	0.00	0.00	1
0.19		98.90	98.90	98.90	0.00	0.00	1
0.49		99.40	99.40	99.40	0.00	0.00	1
0.98		100.20	100.20	100.20	0.00	0.00	1

Statistical Printouts for the Acute *Allorchestes* Toxicity Test

Amphipod Acute Toxicity Test-96hr % Unaffected

Start Date:	4/10/2019 18:30	Test ID:	PR1861/04	Sample ID:	Crib Point + Cl2
End Date:	8/10/2019 18:30	Lab ID:	9261 +Cl2	Sample Type:	CP-Chemical product
Sample Date:		Protocol:	ESA 108	Test Species:	AC-Allorchestes compressa
Comments:	Nominal Concentration				

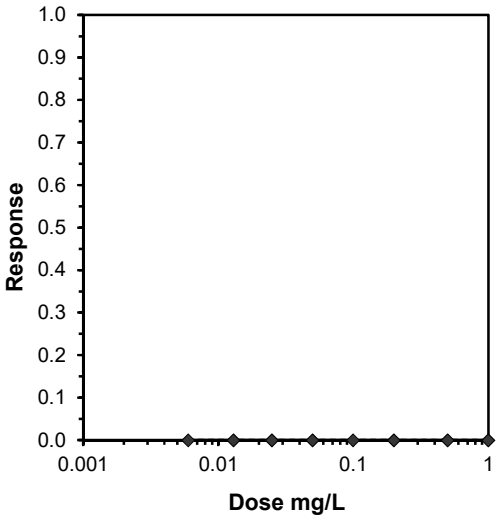
Conc-mg/L	1	2	3	4
FSW Control	1.0000	1.0000	1.0000	1.0000
Diluent Control	1.0000	1.0000	1.0000	1.0000
0.006	1.0000	1.0000	1.0000	1.0000
0.013	1.0000	1.0000	1.0000	1.0000
0.025	1.0000	1.0000	1.0000	1.0000
0.05	1.0000	1.0000	1.0000	1.0000
0.1	1.0000	1.0000	1.0000	1.0000
0.2	1.0000	1.0000	1.0000	1.0000
0.5	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000

			Transform: Arcsin Square Root					Isotonic	
Conc-mg/L	Mean	N-Mean	Mean	Min	Max	CV%	N	Mean	N-Mean
FSW Control	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4		
Diluent Control	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000
0.006	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000
0.013	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000
0.025	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000
0.05	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000
0.1	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000
0.2	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000
0.5	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000
1	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)	1	0.935		
Equality of variance cannot be confirmed				
The control means are not significantly different (p = 1.00)	0	2.446912		

Log-Logit Interpolation (200 Resamples)

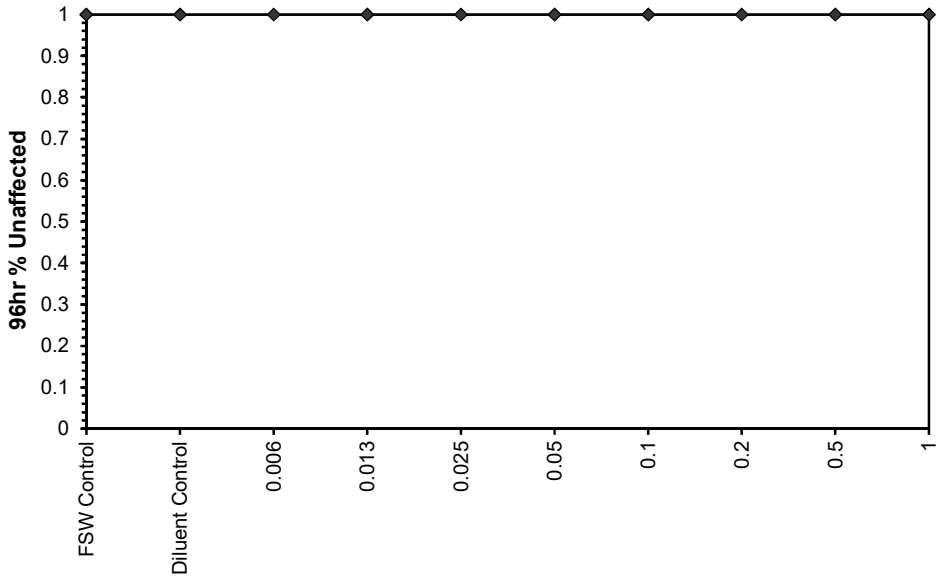
Point	mg/L	SD	95% CL(Exp)	Skew
IC05	>1			
IC10	>1			
IC15	>1			
IC20	>1			
IC25	>1			
IC40	>1			
IC50	>1			



Amphipod Acute Toxicity Test-96hr % Unaffected

Start Date:	4/10/2019 18:30	Test ID:	PR1861/04	Sample ID:	Crib Point + Cl2
End Date:	8/10/2019 18:30	Lab ID:	9261 +Cl2	Sample Type:	CP-Chemical product
Sample Date:		Protocol:	ESA 108	Test Species:	AC-Allorchestes compressa
Comments:	Nominal Concentration				

Dose-Response Plot



Amphipod Acute Toxicity Test-96hr % Unaffected

Start Date:	4/10/2019 18:30	Test ID:	PR1861/04	Sample ID:	Crib Point + Cl2
End Date:	8/10/2019 18:30	Lab ID:	9261 +Cl2	Sample Type:	CP-Chemical product
Sample Date:		Protocol:	ESA 108	Test Species:	AC-Allorchestes compressa
Comments:	Nominal Concentration				

		Auxiliary Data Summary					
Conc-mg/L	**Parameter**	**Mean**	**Min**	**Max**	**SD**	**CV%**	**N**
FSW Control	% Non-immobilised	100.00	100.00	100.00	0.00	0.00	4
Diluent Control		100.00	100.00	100.00	0.00	0.00	4
0.006		100.00	100.00	100.00	0.00	0.00	4
0.013		100.00	100.00	100.00	0.00	0.00	4
0.025		100.00	100.00	100.00	0.00	0.00	4
0.05		100.00	100.00	100.00	0.00	0.00	4
0.1		100.00	100.00	100.00	0.00	0.00	4
0.2		100.00	100.00	100.00	0.00	0.00	4
0.5		100.00	100.00	100.00	0.00	0.00	4
1		100.00	100.00	100.00	0.00	0.00	4
FSW Control	pH	8.20	8.20	8.20	0.00	0.00	1
Diluent Control		8.20	8.20	8.20	0.00	0.00	1
0.006		8.20	8.20	8.20	0.00	0.00	1
0.013		8.20	8.20	8.20	0.00	0.00	1
0.025		8.20	8.20	8.20	0.00	0.00	1
0.05		8.20	8.20	8.20	0.00	0.00	1
0.1		8.20	8.20	8.20	0.00	0.00	1
0.2		8.20	8.20	8.20	0.00	0.00	1
0.5		8.20	8.20	8.20	0.00	0.00	1
1		8.20	8.20	8.20	0.00	0.00	1
FSW Control	DO %	36.00	36.00	36.00	0.00	0.00	1
Diluent Control		33.80	33.80	33.80	0.00	0.00	1
0.006		35.80	35.80	35.80	0.00	0.00	1
0.013		35.80	35.80	35.80	0.00	0.00	1
0.025		35.80	35.80	35.80	0.00	0.00	1
0.05		35.80	35.80	35.80	0.00	0.00	1
0.1		35.80	35.80	35.80	0.00	0.00	1
0.2		35.80	35.80	35.80	0.00	0.00	1
0.5		35.80	35.80	35.80	0.00	0.00	1
1		35.80	35.80	35.80	0.00	0.00	1
FSW Control	Salinity ppt	98.90	98.90	98.90	0.00	0.00	1
Diluent Control		99.20	99.20	99.20	0.00	0.00	1
0.006		98.90	98.90	98.90	0.00	0.00	1
0.013		99.10	99.10	99.10	0.00	0.00	1
0.025		99.60	99.60	99.60	0.00	0.00	1
0.05		99.70	99.70	99.70	0.00	0.00	1
0.1		99.40	99.40	99.40	0.00	0.00	1
0.2		98.90	98.90	98.90	0.00	0.00	1
0.5		99.40	99.40	99.40	0.00	0.00	1
1		100.20	100.20	100.20	0.00	0.00	1

Amphipod Acute Toxicity Test-96hr % Unaffected

Start Date:	4/10/2019 18:30	Test ID:	PR1861/03	Sample ID:	Crib Point + Cl2
End Date:	8/10/2019 18:30	Lab ID:	9261 +Cl2	Sample Type:	CP-Chemical product
Sample Date:		Protocol:	ESA 108	Test Species:	AC-Allorchestes compressa
Comments:	Measured Concentration @ t=0				

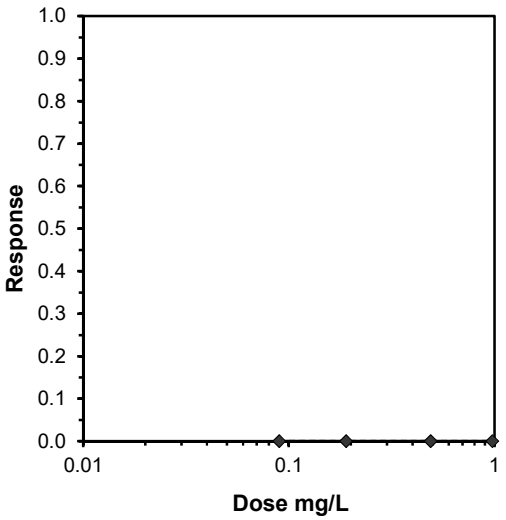
Conc-mg/L	1	2	3	4	5	6	7	8	9	10
FSW Control	1.0000	1.0000	1.0000	1.0000						
Diluent Control	1.0000	1.0000	1.0000	1.0000						
0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000				
0.09	1.0000	1.0000	1.0000	1.0000						
0.19	1.0000	1.0000	1.0000	1.0000						
0.49	1.0000	1.0000	1.0000	1.0000						
0.98	1.0000	1.0000	1.0000	1.0000						

			Transform: Arcsin Square Root					Isotonic	
Conc-mg/L	Mean	N-Mean	Mean	Min	Max	CV%	N	Mean	N-Mean
FSW Control	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4		
Diluent Control	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000
0	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	16	1.0000	1.0000
0.09	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000
0.19	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000
0.49	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000
0.98	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	1.0000	1.0000

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)	1	0.935		
Equality of variance cannot be confirmed				
The control means are not significantly different (p = 1.00)	0	2.446912		

Log-Logit Interpolation (200 Resamples)

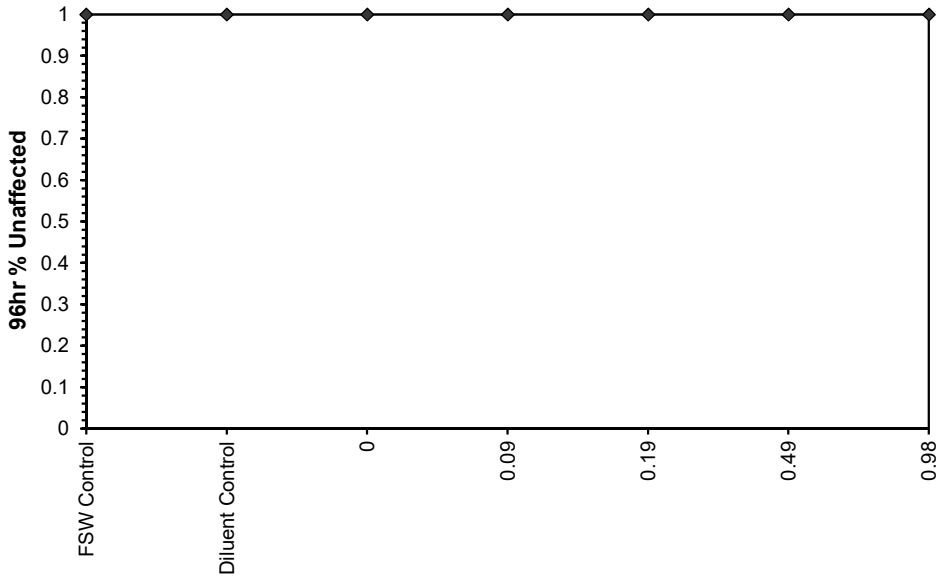
Point	mg/L	SD	95% CL(Exp)	Skew
IC05	>0.98			
IC10	>0.98			
IC15	>0.98			
IC20	>0.98			
IC25	>0.98			
IC40	>0.98			
IC50	>0.98			



Amphipod Acute Toxicity Test-96hr % Unaffected

Start Date:	4/10/2019 18:30	Test ID:	PR1861/03	Sample ID:	Crib Point + Cl2
End Date:	8/10/2019 18:30	Lab ID:	9261 +Cl2	Sample Type:	CP-Chemical product
Sample Date:		Protocol:	ESA 108	Test Species:	AC-Allorchestes compressa
Comments:	Measured Concentration @ t=0				

Dose-Response Plot



Amphipod Acute Toxicity Test-96hr % Unaffected

Start Date:	4/10/2019 18:30	Test ID:	PR1861/03	Sample ID:	Crib Point + Cl2
End Date:	8/10/2019 18:30	Lab ID:	9261 +Cl2	Sample Type:	CP-Chemical product
Sample Date:		Protocol:	ESA 108	Test Species:	AC-Allorchestes compressa
Comments:	Measured Concentration @ t=0				

		Auxiliary Data Summary					
Conc-mg/L	**Parameter**	**Mean**	**Min**	**Max**	**SD**	**CV%**	**N**
FSW Control	% Non-immobilised	100.00	100.00	100.00	0.00	0.00	4
Diluent Control		100.00	100.00	100.00	0.00	0.00	4
0		100.00	100.00	100.00	0.00	0.00	16
0.09		100.00	100.00	100.00	0.00	0.00	4
0.19		100.00	100.00	100.00	0.00	0.00	4
0.49		100.00	100.00	100.00	0.00	0.00	4
0.98		100.00	100.00	100.00	0.00	0.00	4
FSW Control	pH	8.20	8.20	8.20	0.00	0.00	1
Diluent Control		8.20	8.20	8.20	0.00	0.00	1
0		8.20	8.20	8.20	0.00	0.00	4
0.09		8.20	8.20	8.20	0.00	0.00	1
0.19		8.20	8.20	8.20	0.00	0.00	1
0.49		8.20	8.20	8.20	0.00	0.00	1
0.98		8.20	8.20	8.20	0.00	0.00	1
FSW Control	DO %	36.00	36.00	36.00	0.00	0.00	1
Diluent Control		33.80	33.80	33.80	0.00	0.00	1
0		35.80	35.80	35.80	0.00	0.00	4
0.09		35.80	35.80	35.80	0.00	0.00	1
0.19		35.80	35.80	35.80	0.00	0.00	1
0.49		35.80	35.80	35.80	0.00	0.00	1
0.98		35.80	35.80	35.80	0.00	0.00	1
FSW Control	Salinity ppt	98.90	98.90	98.90	0.00	0.00	1
Diluent Control		99.20	99.20	99.20	0.00	0.00	1
0		99.33	98.90	99.70	0.39	0.63	4
0.09		99.40	99.40	99.40	0.00	0.00	1
0.19		98.90	98.90	98.90	0.00	0.00	1
0.49		99.40	99.40	99.40	0.00	0.00	1
0.98		100.20	100.20	100.20	0.00	0.00	1

Gas Import Jetty and Pipeline Project

www.gasimportprojectvictoria.com.au

General and Gas Import Jetty enquiries
1800 039 600
AGLcommunity@agl.com.au

Pipeline enquiries
1800 531 811
cribpointpakenham@apa.com.au