Technical Report A

Supplementary marine environment impact assessment

Viva Energy Gas Terminal Project
Supplementary Statement

Technical Report A:

Supplementary Marine Environment Impact Assessment

August 2024

Consulting Environmental Engineers

Foreword - Summary of Supplementary Marine Studies

A full assessment of the potential impacts on the marine environment from the Viva Energy Gas Terminal Project (project) was conducted as part of the Environment Effects Statement (EES) in Technical Report A: *Marine ecology and water quality impact assessment.*

The original Technical Report on marine ecology and water quality concluded that construction and operation of the project is unlikely to have adverse impacts on the chemical and physical attributes of the marine environment, habitat conditions and the ecological character of Corio Bay, including the Point Wilson/Limeburners Bay section of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsular Ramsar site.

In March 2023, after an assessment of the original EES by an independent panel inquiry, the Minister for Planning directed that a Supplementary Statement was required for the Viva Energy Gas Terminal Project in accordance with Sections 5 and 8C (2) of the *Environment Effects Act 1978*, before the Minister could complete the assessment of the project's environmental effects for consideration by statutory decision makers.

The Minister's Directions relevant to the supplementary marine environment study were Recommendations 1 to 8 which required:

- Further survey work to better establish the existing environment and the impacts of existing wastewater discharges from the refinery to enable better understanding of project impacts.
- Further targeted investigations into the effects of existing chlorine discharges from the refinery to confirm likely project impacts resulting from chlorination by-products.
- Refinement of the regional hydrodynamic model.
- Re-running the modelling of wastewater discharge, entrainment and sediment transport using the refined regional hydrodynamic model.
- Further assessment of dredging impacts and confirmation that dredging would not impact the Ramsar site.

In the Supplementary Marine Studies, extensive field surveys were undertaken to measure and assess the existing temperature plume from the refinery discharge points. The temperature measurements were also used to infer chlorine concentrations in the discharge plume. It was determined that the existing temperature and chlorine discharge plumes do not reach the Ramsar site and reach guideline values a short distance from the discharge points.

Extra seagrass mapping was undertaken to further understand the impacts of the existing refinery discharges. Surveys of seagrass cover adjacent to the refinery and at the Ramsar site showed there was no significant difference in seagrass cover in the two zones. This indicated that existing refinery discharges are not having a significant impact on seagrass.

The regional hydrodynamic model was updated to include a greater horizontal and vertical resolution and the FSRU as a barrier. The refined regional hydrodynamic model was peer reviewed and determined to be fit for purpose to assess potential impacts to Corio Bay from the project. The wastewater discharge model, entrainment model and sediment transport model were each re-run using the refined regional hydrodynamic model.

The refined regional hydrodynamic model predicted discharge plumes similar to those measured during the extensive field surveys. The predicted temperature and chlorine discharge plumes from the diffuser were within guideline values and the predicted 20:1 dilution was verified by an independent modelling specialist.

Additional mussels were deployed and analysed for chlorine by-products to further assess the potential impacts of the existing chlorine discharge on marine life in Corio Bay and at the Ramsar site. The mussels were deployed at six sites within the existing discharge plumes and then tested for chlorine by-products. The results showed all chlorine by-product concentrations were very low and below laboratory limits of detection. It is concluded that the existing chlorine discharges present minimal risk to marine life in Corio Bay and at the Ramsar site.

The results of the entrainment modelling indicated that there would be no significant difference in the entrainment of plankton and fish eggs from the Ramsar site during operation of the FSRU in comparison to existing refinery operations. The overall entrainment rates are negligible in comparison to natural processes such as predation and starvation.

The predicted suspended solids plume from dredging activities would not impact seagrass in the Ramsar site. The rate of sediment accretion would have negligible impact on the muddy seabed and the infauna or mobile marine communities that inhabit muddy seabed. No seagrass would be removed during dredging. A small amount (0.5 ha) of seagrass would be removed by the excavation for the sweater transfer pipe. Seagrass in Corio Bay and the Ramsar site would receive sufficient light for growth, indicating that there is a low risk to seagrass during dredging.

The results of the 2023 Supplementary Marine Studies do not change the conclusions reached in the 2022 EES studies and provide extra evidence to support the EES conclusions. The results of the Supplementary Studies are summarised as follows.

Recommendation 1.

Establish existing environment and impacts of existing refinery discharges.

The dominant habitat in the area of the existing refinery discharges of warm seawater is seagrass, with algae epiphytes growing on the seagrass being the next largest habitat. Seagrass is dominant in both the intertidal and subtidal zones, to a depth of 5 m.

Seagrass cover was adopted as the most appropriate indicator of the existing seagrass habitat and was used to establish the effects of the existing discharges. Seagrass cover in the intertidal zone averaged 31 % +/- 6 % in the discharge zone (average plus or minus standard deviation of seagrass cover measurements) and 30 % +/- 9 % in the Ramsar site.

Seagrass cover in the subtidal zone averaged 72 % +/- 4 % in the discharge zone and 68 % +/- 6 % in the Ramsar site. It is concluded that there are no detectible impacts of the existing discharges on seagrass cover or seagrass habitat.

Update seagrass mapping to include the intertidal zone and information on the different seagrass species.

Extensive surveys were carried out to define the extent of the three main species of seagrass in northern Corio Bay – *Nanozostera Muelleri* in the intertidal zone and *Heterozostera nigricaulis* and *Halophila australis* in the subtidal zone. Seagrass species are mixed together in Corio Bay and the proportion of different species varies over time. An updated map showing the extent of the different seagrass species in Corio Bay was prepared.

Recommendation 2. *Refine calibration of the regional hydrodynamic model so that it more accurately reproduces observed water levels, currents, tidal range, and tidal exchange in Corio Bay. Peer review of the model calibration.* The regional hydrodynamic model was upgraded by refining the horizontal grid to 20 m by 20 m cells; refining the vertical grid to 0.5 m layers, improving the resolution of tides and other sea level variations at the model boundary in Port Phillip Bay and representing a fully-loaded FSRU as a blockage to current flow. The refinements led to a small improvement in the prediction of tide heights and currents. The predicted plume dilution and extent remained much the same as shown in the EES.
Recommendation 3. *Re-run the wastewater discharge modelling with revised inputs based on the refined hydrodynamic model.* Future temperature and chlorine discharges from the existing discharges and the FSRU were predicted using the refined regional hydrodynamic model. *Revise the near-field modelling of discharges from the diffuser, noting the revised chlorine default guideline values (DGV) for chlorine.* The near field modelling of dilution from the discharge of the proposed diffuser beneath the refinery pier was repeated by an independent specialist. The same dilution of 20:1 was predicted, matching the dilution predictions in the EES. The effect of the FSRU on dilution of the flow on the seabed under the FSRU was explored and found to be not significant.
Recommendation 4. *Further targeted investigations to confirm potential project impacts resulting from chlorination by-products.* A further six sets of fresh mussels were deployed in the discharge zone. The mussels were collected and analysed for a wide range of chlorinated and brominated compounds. All compounds analysed were at very low concentrations – below the level of laboratory detection and therefore well below Australian water quality guideline limits. The results of the two sets of mussel tests indicate negligible contamination of CBP in Corio Bay.
Recommendation 5. *Re-run the entrainment model with revised inputs based on the refined hydrodynamic model*. The entrainment modelling was repeated using the refined hydrodynamic model. For particles released in the seagrass of the Ramsar site, the same percentage of particles (0.12 %) were entrained in the existing refinery inlet and at a future FSRU intake. This is the same result as established in the 2022 EES and indicates no significant change in entrainment rate with operation of the FSRU.

Recommendation 6.

Re-run the sediment transport model with revised inputs based on the refined hydrodynamic model. Consider including a 'worst-case' scenario for sediment fractions and settling rates.

The sediment size fractions and settling velocities were refined on the basis of data from additional boreholes, settling tests and published data on clay floc settling rates. Suspended solids concentrations were predicted for sites on the outer edge of the Ramsar site. The predicted concentrations varied over the proposed 8-week dredging program, with the concentration at the highest site averaging 3 mg/L.

The revised concentrations matched the concentrations measured in an earlier dredging project in Corio Bay, and also matched the concentrations predicted using the sediment size fractions and settling velocities adopted by previous consultants to verify the measured concentrations. There is no significant change from the suspended solids predictions in the 2022 EES. The results indicate low risk to seagrass health.

Recommendation 7.

Undertake further assessment of dredging impacts on seagrass based on the updated sediment transport modelling and light thresholds of 20 percent surface irradiance for the Ramsar site and 10 percent irradiance for the rest of Corio Bay.

Calculations of available light in the Ramsar site show that, for the highest 14-day suspended solids level, seagrass in the Ramsar site will receive more than 20% of the incident light during the dredging program and the rest of the seagrass areas will receive over 10% light. This meets the light threshold suggested by the IAC and indicates very low risk to seagrass growth.

The installation of the seawater transfer pipe would potentially require the removal of a small (approximately 0.5 ha) area of seagrass. Seagrass surveys in the area show that the main seagrass species present is Halophila with some H. nigricaulis.

Recommendation 8.

Confirm the EES conclusion that dredging will not impact the Ramsar site.

After considering (1) the revised marine modelling of the sediment plumes; and (2) the revised assessment of dredging impacts on seagrass, it is considered that the dredging will not have any impact on seagrass. There is no change from the EES conclusions.

Contents

Figures

Tables

Cover Image

The cover image shows the study area of north Corio Bay, showing the coastline, Geelong refinery, Refinery Pier, with the industrial zone of Geelong in the background and the seagrass habitat in the foreground. The patchiness of the seagrass meadows is evident in the image.

Limitations and Assumptions

The focus of this supplementary studies report is to describe the work undertaken and the findings in response to the Minister’s Directions on eight specific recommendations for further studies. While some sections of the original EES are summarized in this report, the supplementary studies are not a replacement for the original EES.

The EES reported on field work undertaken in 2022 while the field work for the supplementary studies was carried out in 2023. The findings, therefore, are limited to the observable conditions in those periods. It is assumed that the physical environmental conditions in those years is representative of typical conditions in other years.

Field work was constrained by weather, ship movements at the port and limits set by Avalon Airport. Nonetheless, by taking drone images, it is assumed that representative measures of seagrass cover were obtained. Analysis of sediment characteristics was based on the results of borehole cores, which were extensive but necessarily limited to specific locations and there will be some variation in sediment conditions between boreholes. Nonetheless, by analysis of all available sediment data, it is assumed that representative sediment characteristics were derived.

Glossary

Term	Definition
Bathymetry	Bathymetry is the study of underwater depth of ocean floors, lake floors, or river floors. In other words, bathymetry is the underwater equivalent to hypsometry or topography.
Entrainment	Entrainment is the entrapment of one substance by another. Operation of the FSRU would result in some entrainment of plankton, larvae and other small organisms as a result seawater being drawn into the FSRU which has the potential to result in adverse effects on populations and productivity.
Hydrodynamic model	Hydrodynamic modelling is the study of fluids, such as seawater, in motion. Near-field and regional hydrodynamic models were developed for the project and used to: Simulate the existing currents, temperatures, and salinities in Corio Bay. Predict the fate and transport of fine sediments (clay and silt) that are likely to be mobilised during dredging and dredge spoil disposal. Predict the path and dispersion of the discharge plumes, including cooled or warmed chlorinated discharges from the Geelong Refinery and the FSRU. Simulate the potential transport and dispersion of plankton and larvae from different regions of the Bay and predict the entrainment of plankton in the seawater intakes during operation of the FSRU.
Hydraulic jump	A hydraulic jump is a phenomenon in the science of hydraulics which is frequently observed in open channel flow such as rivers and spillways. When liquid at high velocity discharges into a zone of lower velocity, a rather abrupt rise occurs in the liquid surface.
Intertidal zone	The intertidal zone or foreshore is the area above water level at low tide and underwater at high tide: in other words, the part of the littoral zone within the tidal range.
Littoral zone	The littoral zone, also called littoral or nearshore, is the part of a sea, lake, or river that is close to the shore. In coastal ecology, the littoral zone includes the intertidal zone extending from the high water mark, to coastal areas that are permanently submerged — known as the foreshore — and the terms are often used interchangeably.
Marine EES study	Technical Report A: *Marine ecology and water quality impact assessment*, hereafter referred to as the marine EES study (CEE, 2022)
Plumes	In hydrodynamics, a plume or a column is a vertical body of one fluid moving through another.
Ramsar site	A Ramsar site is a wetland site designated to be of international importance under the Ramsar Convention, also known as "The Convention on Wetlands", an international environmental treaty signed on 2 February 1971 in Ramsar, Iran, under the auspices of UNESCO.
Subtidal zone	The subtidal zone is the region of the ocean that is always underwater, even during low tide1

Abbreviations

Abbreviation	Definition
ADCP	Acoustic Doppler Current Profiler
AECOM	AECOM Australia Pty Ltd
ANZECC	Australian and New Zealand Environment and Conservation Council
ANZG	Australian and New Zealand Guidelines
BoM	Bureau of Meteorology
CBP	Chlorinated by-products
CEE	Consulting Environmental Engineers Pty Ltd
CPB	Chlorination-produced by-products
CPO	Chlorine-produced oxidants
DGV	Default guideline values
DTP	Department of Transport and Planning
EES	Environment Effects Statement
EPA	Environment Protection Authority
ERS	Environment Reference Standard
FFG Act	Flora and Fauna Guarantee Act 1988
FSRU	Floating storage and regasification unit
IAC	Inquiry and Advisory Committee
L&T	Lawson and Treloar
LNG	Liquefied natural gas
MPB	Microphytobenthos
NATA	National Association of Testing Authorities
NTU	Nephelometric Turbidity Unit
PAR	Photosynthetically active radiation
SEES	Supplementary Environment Effects Statement
SS	Suspended solids
TBP	Tribromophenol
THM	Trihalomethanes
TUC	Towed underwater camera
UV	Ultraviolet
Viva Energy	Viva Energy Gas Australia Pty Ltd

1. Introduction

This technical report provides the procedures, results and findings of the supplementary marine environment study in response to Recommendation 1 to Recommendation 8 in Table 1 of the Minister for Planning's Directions (Minister's Directions) for the Viva Energy Gas Terminal Project (the Project) Supplementary Statement.

Viva Energy Gas Australia Pty Ltd (Viva Energy) is planning to develop a gas terminal using a ship known as a floating storage and regasification unit (FSRU), which would be continuously moored at Refinery Pier in Corio Bay, Geelong. The key objective of the project is to facilitate supply of a new source of gas for the south-east Australian gas market where there is a projected supply shortfall in coming years. This project would support the community's energy needs as the energy market transitions to lower emissions alternatives.

The FSRU would store liquefied natural gas (LNG) received from visiting LNG carriers (that would moor directly adjacent to the FSRU) and would convert LNG back into a gaseous state by heating the LNG using seawater (a process known as regasification) as required to meet industrial, commercial, and residential customer demand. A 7-kilometre gas transmission pipeline would transfer the gas from the FSRU to the Victorian Transmission System (VTS) at Lara.

The project would be situated adjacent to, and on, Viva Energy's Geelong Refinery, within a heavily developed port and industrial area on the western shores of Corio Bay between the Geelong suburbs of Corio and North Shore. Co-locating the project with the existing Geelong Refinery and within the Port of Geelong offers significant opportunity to minimise potential environmental effects and use the attributes that come with the port and industrial setting.

In March 2023, the Victorian Minister for Planning determined that the project Environment Effects Statement (EES) requires a Supplementary Statement to be prepared by Viva Energy Gas Australia Pty Ltd (Viva Energy), in accordance with sections 5 and 8C(2) of the *Environment Effects Act 1978 (Vic)*. The Supplementary Statement is required to complete the assessment of the project's environmental effects on the marine environment, noise, air quality and Aboriginal cultural heritage in accordance with the Minister's Directions and inform decision making.

1.1 Background

A full assessment was completed of the potential impacts on the marine environment from the project as part of the EES (Technical Report A: *Marine ecology and water quality impact assessment*).

The original marine EES study concluded that construction and operation of the project is unlikely to have adverse impacts on the chemical and physical attributes of the marine environment, habitat conditions and the ecological character of Corio Bay, including the Point Wilson/Limeburners Bay section of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsular Ramsar site.

The Inquiry and Advisory Committee (IAC) wrote that the four existing discharges from the refinery have been operating for over 60 years and that there would be no change in the flow rates or chlorine concentrations in the discharges, whether or not the project proceeds. However, the IAC concluded that it is "difficult to conclusively determine that existing Refinery discharges are having acceptable impacts". The IAC recommended that "a monitoring program should be established to assess the existing impacts of refinery discharges more rigorously and establish a better baseline for ongoing monitoring of the effects of the project on the marine environment" (IAC Report No. 1, section 7.4 (iii)).

Additionally, the IAC concluded that further work should be undertaken to refine the calibration of the regional hydrodynamic model "so that it more closely reproduces observed tidal range, tidal exchange and currents" to provide "a more reliable basis" on which to assess the project's effects on the marine environment (IAC Report No. 1, section 7.5 (iii)).

Furthermore, because "the regional hydrodynamic model provides key input parameters for the modelling on which the assessment of the project's marine impacts is based" the IAC recommended that the modelling of the discharges and sediment transport be re-run using the refined model (IAC Report No. 1, sections 7.6 (iii) and 8.3 (iv) respectively).

The refinery has been taking in seawater for many years and the volume of seawater extracted will not change whether or not the project proceeds. The IAC findings stated that the impacts of entrainment as a result of the project (when compared to existing conditions) "are likely to be relatively contained, as indicated by the entrainment modelling" but recommended re-running the entrainment modelling using the refined regional hydrodynamic model to confirm this (IAC Report No. 1, section 7.7 (iv)).

The IAC stated that the source-path-receptor approach utilised in the EES to determine the impacts of dredging on seagrass was acceptable but recommended further work to assess potential impacts on seagrass using the revised sediment transport modelling and updated seagrass mapping. The IAC noted that it was appropriate for the EES to adopt a minimum light threshold approach for assessing impacts of dredging on seagrass but recommended adopting 10% and 20% of surface light as thresholds for effects in the further assessment (IAC Report No. 1, section 8.5 (iii)).

Further IAC findings are provided in the overview of each section.

1.2 Purpose

This supplementary marine environment study provides a technical response to Recommendation 1 to Recommendation 8 in Table 1 of the Minister's Directions, integrates the findings of the supplementary study with key outcomes of the original EES marine environment impact assessment and provides an update to the EES marine environment mitigation measures recommended in the original EES where necessary.

The objective of this study is to:

- Better establish the existing environment and the impacts of existing wastewater discharges from the refinery.
- Refine regional hydrodynamic model and re-run modelling.
- Conduct further targeted investigations into the effects of existing chlorine discharges from the refinery to confirm likely project impacts resulting from chlorination by-products.
- Refine the regional hydrodynamic model.
- Re-run the modelling of discharges, entrainment and sediment transport using the refined regional hydrodynamic model.
- Further assess of dredging impacts and confirm that dredging would not impact the Ramsar site.
- Confirm EES conclusions and/or update findings based on revised modelling.

1.3 Project Area

The project would be located adjacent to, and on, the Geelong Refinery and Refinery Pier in the City of Greater Geelong, 75 kilometres (km) south-west of Melbourne. The project area is within a heavily developed port and industrial area on the western shores of Corio Bay between the Geelong suburbs of Corio and North Shore. The Geelong central business district is located approximately 7 km south of the project. The project area is shown in Figure 1-1. Corio Bay is the largest bay in the south-west corner of Port Phillip Bay and is a sheltered, shallow basin at the western end of the Geelong Arm, with an area of 44 square kilometres (km^2). The Point Wilson/Limeburners Bay section of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site is located along the northern shoreline of Corio Bay, approximately one kilometre to the north-east of the project (please refer to Section 1.3.1below for a description of proposed changes to the Ramsar site boundary).

The Port of Geelong has been in operation for over 150 years and is the largest industrial bulk cargo port in Victoria, attracting over 600 ship visits and handling more than 14 million tonnes of product annually. Geelong's shipping channels extend 18 nautical miles through Corio Bay from Point Richards through to Refinery Pier. Ports Victoria manages commercial navigation in the port waters in and around Geelong and is responsible for the safe and efficient movement of shipping, and for maintaining shipping channels and navigation aids.

The seabed and shores of Corio Bay have been substantially modified over the last 170 years. Before the settlement of Geelong, a sandbar across the eastern side of the bay from Point Lillias to Point Henry prevented ships from entering Corio Bay. Channels were dredged through the sand bar between 1853 and 1893, allowing the development of the Port of Geelong and the shoreline for urban Geelong. Since 1853, approximately 20 million cubic metres of material have been dredged to create and maintain shipping channels in Corio Bay, allowing for safe ship access to the Port of Geelong.

Refinery Pier is the principal location within the Port of Geelong for movement of bulk liquids. Vessels up to 265 metres in length currently utilise the four berths at Refinery Pier which service Viva Energy refinery operations. The majority of ship visits to the port are to Refinery Pier, with Viva Energy accounting for over half of the trade through the Port of Geelong.

The Geelong Refinery has been operating since 1954 with both the refinery and the co-located Viva Energy Polymer plant being licensed Major Hazard Facilities (MHFs). A range of industrial activities are situated in the Port environs including wood fibre processing and chemical, fertiliser and cement manufacturing.

To the north of the Geelong Refinery, along the proposed underground pipeline corridor, the area is predominantly rural. There are several other existing Viva Energy-owned underground pipelines running between the refinery and the connection point to the South West Pipeline (SWP) at Lara. The proposed pipeline route follows already disturbed pipeline corridors, where possible, through a mix of land uses.

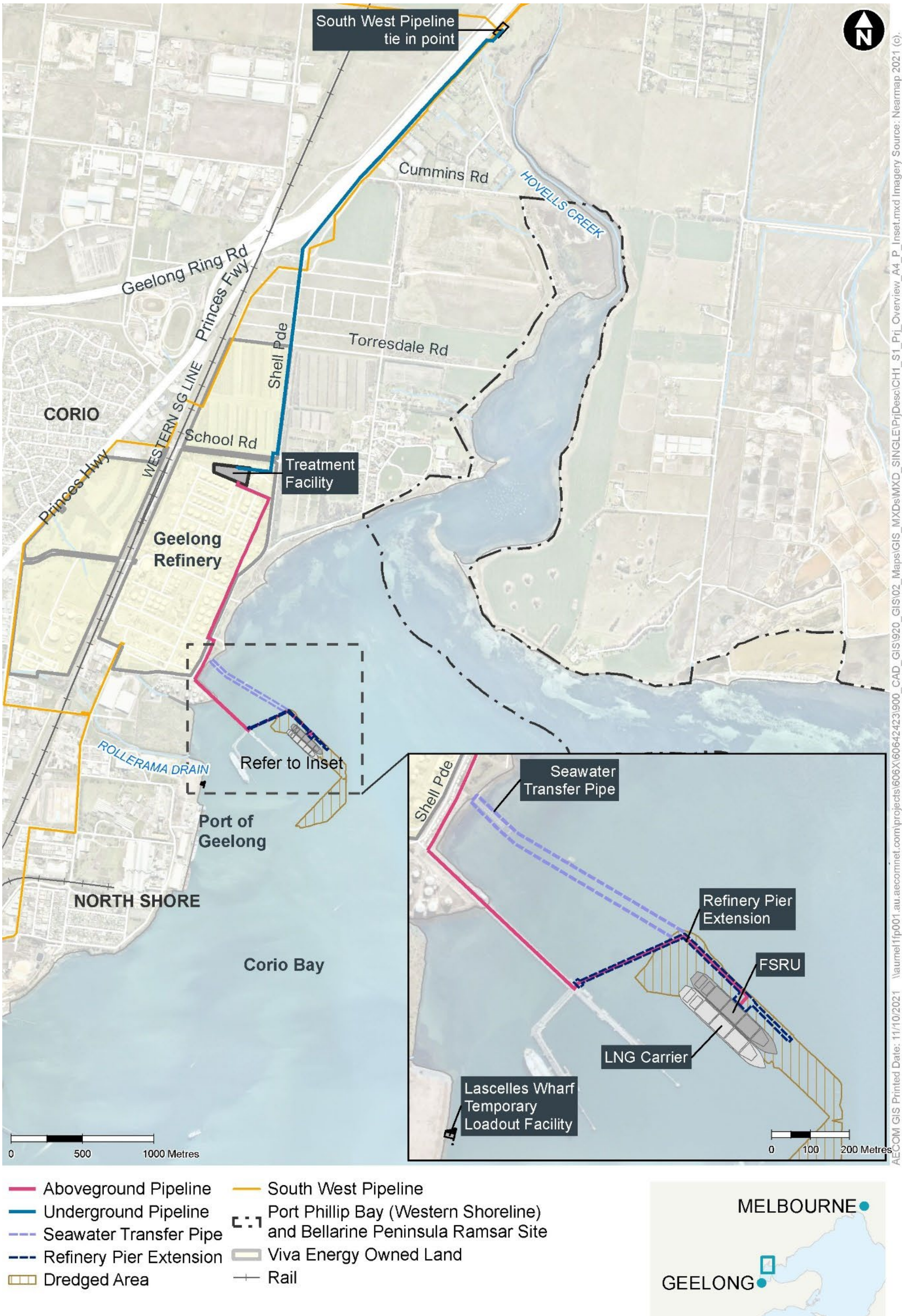


Figure 1-1. Layout of Project

1.3.1 Ramsar Site Boundary

The Department of Energy, Environment and Climate Action are currently undertaking a review of the site boundary of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site to include new additions. The existing Ramsar site currently has six wetland areas, and the plan is to list several new wetlands and extend some of the existing ones.

Figure 1-2 below shows the existing wetlands (yellow) and the proposed additions (blue). Near Corio Bay there are two new additions including an extension around Avalon Beach and the old Moolap Saltworks south of Stingaree Bay.

In both cases, the proposed changes to the Ramsar site boundary are well away from the project area and thus, do not impact the conclusions of the EES or Supplementary Statement.

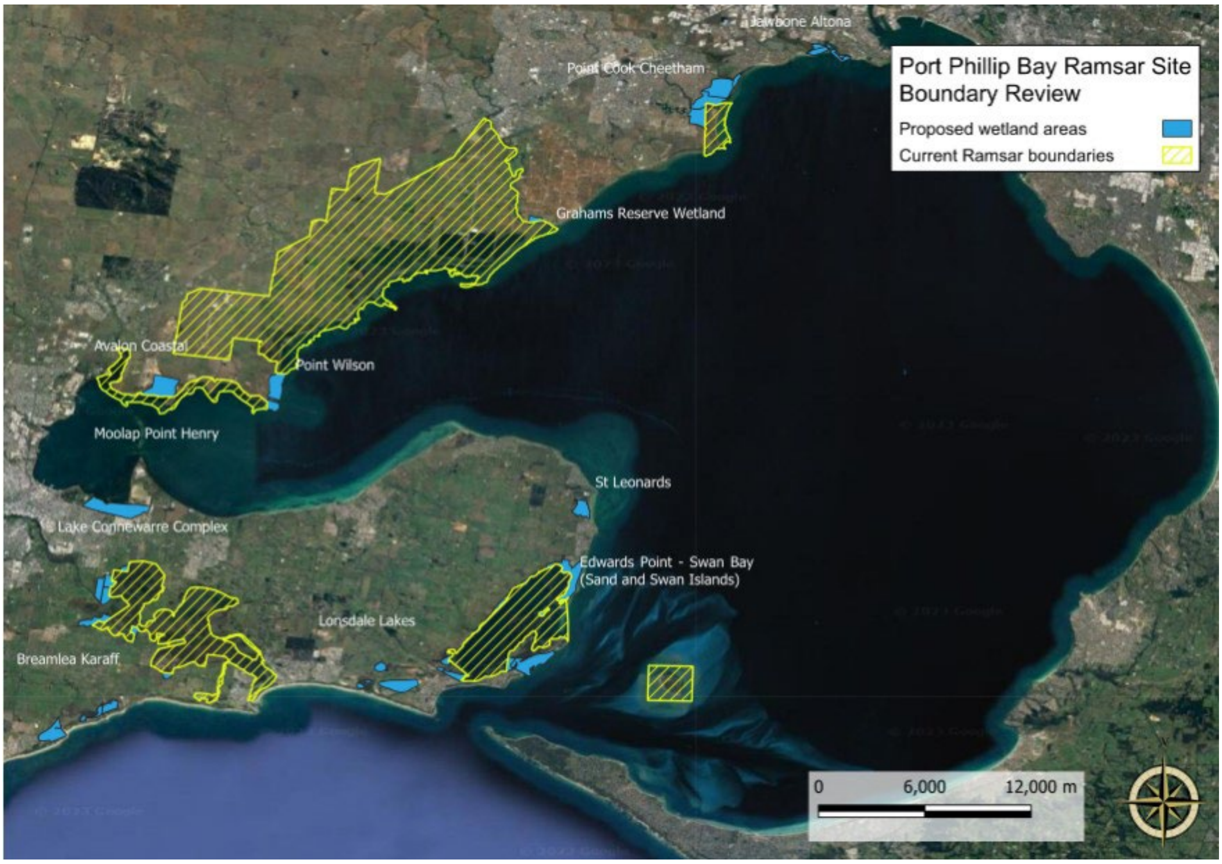


Figure 1-2. Review of Ramsar Site Boundary

(Source: Engage Victoria Website, 2024)

1.4 Project Description

Key components of the project include:

- Extension of the existing Refinery Pier with an approximately 570 metre (m) long angled pier arm, new berth and ancillary pier infrastructure including high pressure gas marine loading arms (MLAs) and a transfer line connecting the seawater discharge points on the FSRU to the refinery seawater intake
- Continuous mooring of an FSRU at the new Refinery Pier berth to store and convert LNG into natural gas. LNG carriers would moor alongside the FSRU and unload the LNG
- Construction and operation of approximately 3km of aboveground gas pipeline on the pier and within the refinery site connecting the FSRU to the new treatment facility
- Construction and operation of a treatment facility on refinery premises including injection of nitrogen and odorant (if required)
- Construction and operation of an underground gas transmission pipeline, approximately 4km in length, connecting to the SWP at Lara.

The Refinery Pier extension would be located to the north-east of Refinery Pier No. 1. The new pier arm would be positioned to allow for sufficient clearance between an LNG carrier berthed alongside the FSRU and a vessel berthed at the existing Refinery Pier berth No. 1. Dredging of approximately 490,000 cubic metres of seabed sediment would be required to allow for the new berth pocket and swing basin.

The FSRU vessel would be up to 300 m in length and 50 m in breadth, with the capacity to store approximately 170,000 cubic metres (m^3) of LNG. The FSRU would receive LNG from visiting LNG carriers and store it onboard in cryogenic storage tanks at about -160 °C.

The FSRU would receive up to 160 PJ per annum (approximately 45 LNG carriers) depending on demand. The number of LNG carriers would also depend on their storage capacity, which could vary from 140,000 to 170,000 m^3.

When gas is needed, the FSRU would convert the LNG back into a gaseous state by heating the LNG using seawater (a process known as regasification). The natural gas would then be transferred through the aboveground pipeline from the FSRU to the treatment facility where odorant and nitrogen would be added, where required, to meet Victorian Transmission System (VTS) gas quality specifications. Nitrogen injection would occur when any given gas cargo needs to be adjusted (diluted) to meet local specifications. Odorant (mercaptan) is added as a safety requirement so that the normally odourless gas can be smelt when in use. From the treatment facility, the underground section of the pipeline would transfer the natural gas to the tie-in point to the SWP at Lara.

1.4.1 Key Construction Activities

Construction of the project would occur over a period of up to 18 months. The key construction activities relate to:

- dredging of seabed sediments to enable the FSRU and LNG carriers to berth at Refinery Pier and excavation of a shallow trench for the seawater transfer pipe
- construction of a temporary loadout facility at Lascelles Wharf
- construction of the new pier arm and berthing infrastructure, seawater transfer pipe, and aboveground pipeline along Refinery Pier and through the refinery
- construction of a gas treatment facility on a laydown area at the northern boundary of the refinery site
- construction of the buried pipeline to a tie-in point to the SWP at Lara.

1.4.1.1 FSRU

There are no local construction activities required for the FSRU. The vessel would be built, commissioned and all production and safety systems verified prior to it being brought to site.

1.4.1.2 Proposed Dredging

An estimated 490,000 cubic metres (m^3) of dredging would be required, over an area of approximately 12 hectares (ha), adjacent to the existing shipping channel to provide sufficient water depth at the new berth and within the swing basin for visiting LNG carriers to turn. Dredging within the new berth would be undertaken to a depth of 13.1 metres and the swing basin would be dredged to a depth of 12.7 metres. The dredging footprint is shown in Figure 1-3.

The dredging is expected to take approximately 8 weeks, depending on the size of the dredge.

1.4.1.3 Seawater Transfer Pipe

Shallow trenching, involving excavation of approximately 8,800 m^3 of sediment, would be required to install the seawater transfer pipe. The excavated sediment would be placed next to the trench temporarily. Once installed, the pipe would be covered with the excavated sediment.

1.4.1.4 Temporary Loadout Facility

The temporary loadout facility at Lascelles Wharf would be the first construction activity to take place in order to facilitate the Refinery Pier extension. This would involve the installation of 10 piles using hydraulic hammers.

1.4.1.5 Proposed New Pier Arm

Construction of the pier arm would be carried out once dredging was complete, primarily from the water using barge-mounted cranes. Steel piles would be driven into the seabed by cranes mounted on floating barges and pre-cast concrete and pre-fabricated steel components would be transported to site by barge and lifted into position. The installation of pier infrastructure such as the marine loading arms (MLAs), piping from the FSRU to the existing refinery seawater intake (SWI) and aboveground pipeline would also be undertaken from the water using barge-mounted cranes.

The pier arm construction, and diffuser and seawater transfer pipe installation are expected to take approximately 12 months.

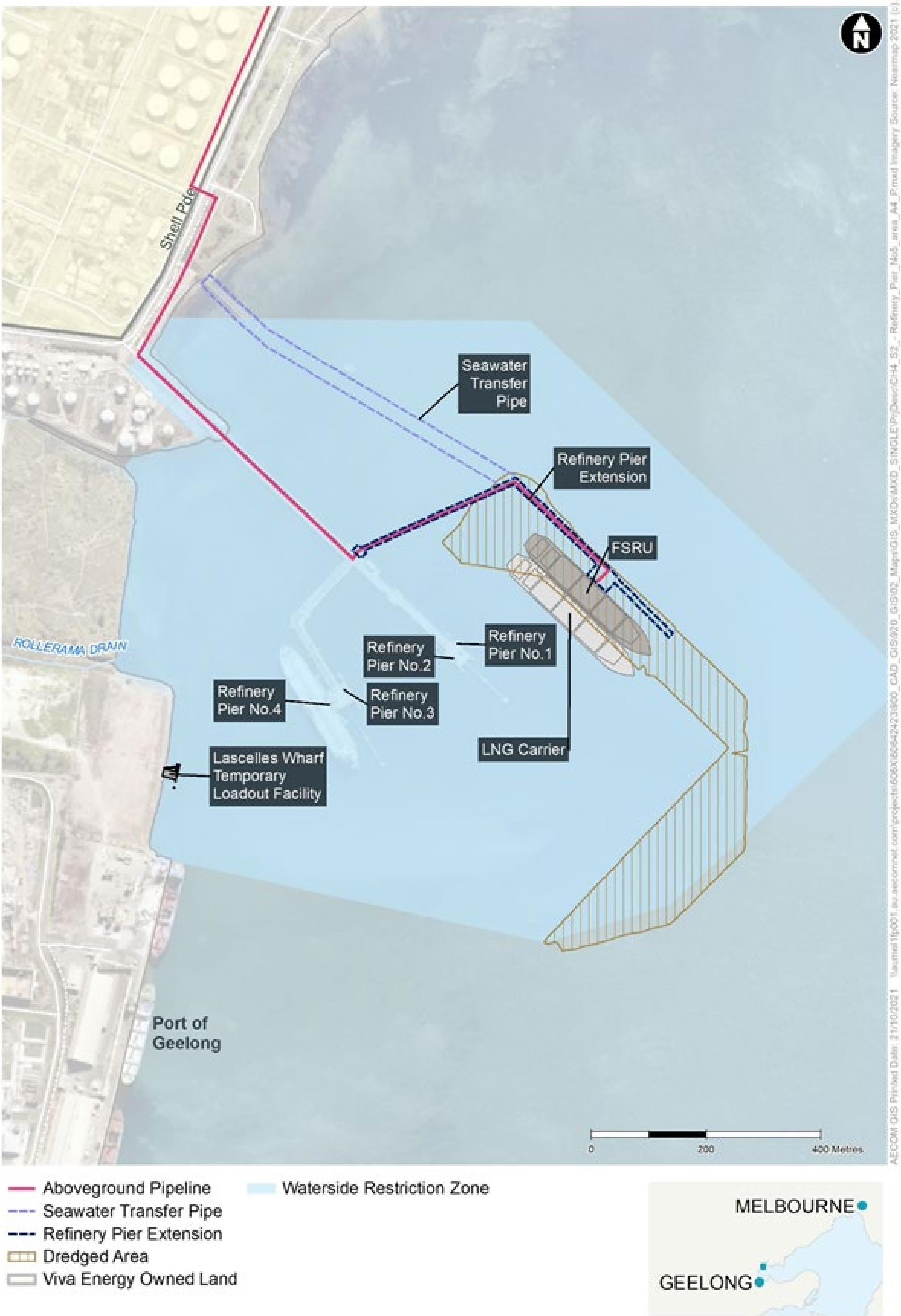


Figure 1-3. Dredging Footprint.

1.4.1.6 Proposed Placement of Dredge Spoil

It is planned to deposit the dredged material within Ports Victoria's existing dredged material ground (DMG) in Port Phillip Bay to the east of Point Wilson, approximately 26 km from Refinery Pier.

Approximately 30 million m^3 of sediment has been dredged in Corio Bay over the last 150 years to make shipping channels. Much of this sediment has been deposited in the defined spoil disposal site to the east of Point Wilson. It has assumed that the dredging spoil from this project also would be deposited in the Point Wilson site unless there is an environmental constraint or there is a better disposal option.

Sediments throughout Corio Bay are slightly contaminated with metals, some reflecting elevated natural concentrations (e.g., arsenic, nickel) and some from urban and industrial sources (e.g., cadmium, chromium, copper, zinc) along the western shore. Metal inputs from the northern catchment via Hovells Creek also are apparent (e.g., cadmium, cobalt and vanadium) in Corio Bay sediments.

Sediments previously placed in the Point Wilson spoil disposal site have the same level of contamination as the proposed dredged material (as demonstrated in the 2020-2021 sampling program). The most recent material placed in the spoil disposal site came from dredging near Refinery Pier No. 4 and the eastern side of Corio Channel – total of 400,000 m^3 of dredged sediment, which is a similar volume to the 490,000 m^3 proposed in the project with a similar metal composition. Thus, adding new sediment will not change the situation in the spoil disposal site.

Extensive sampling and testing of sediments from the proposed dredging area and the spoil disposal site were conducted as part of EES Technical Report B: *Dredged Spoil Disposal Options Assessment* (AECOM, 2022c). The results identified no potential adverse impacts on ecological receptors at either the dredging site or the spoil disposal site. On the basis of the sediment quality assessment undertaken by AECOM in accordance with the National Assessment Guidelines for Dredging (2009), it was concluded that the sediments proposed to be dredged are suitable for offshore disposal at the Point Wilson Disposal Ground.

1.4.1.7 Alternative Dredge Spoil Disposal Sites

Other spoil disposal sites are possibly available in Port Phillip Bay. However, travelling further would use more fuel, generate more greenhouse gas, and prolong the dredging period, for no environmental benefit. Containment of Corio Bay sediments in the Point Wilson spoil disposal site has not been used previously and is not indicated as required. Containment under a clay cover has been used for disposal of more contaminated sediments from Hobsons Bay and the Port of Melbourne.

Disposal on land is an option but the Ramsar Site precludes use of the northern coast and urbanisation precludes use of the western and southern coasts. Filling the seabed (sometimes termed land reclamation) to create new land on the coast of Corio Bay is not favoured. There is no nearby location identified for land reclamation.

In summary, as the extensive testing and risk assessments did not identify adverse impacts to ecological receptors at either the dredging site or the spoil disposal site, the Point Wilson site was adopted as the preferred spoil disposal site.

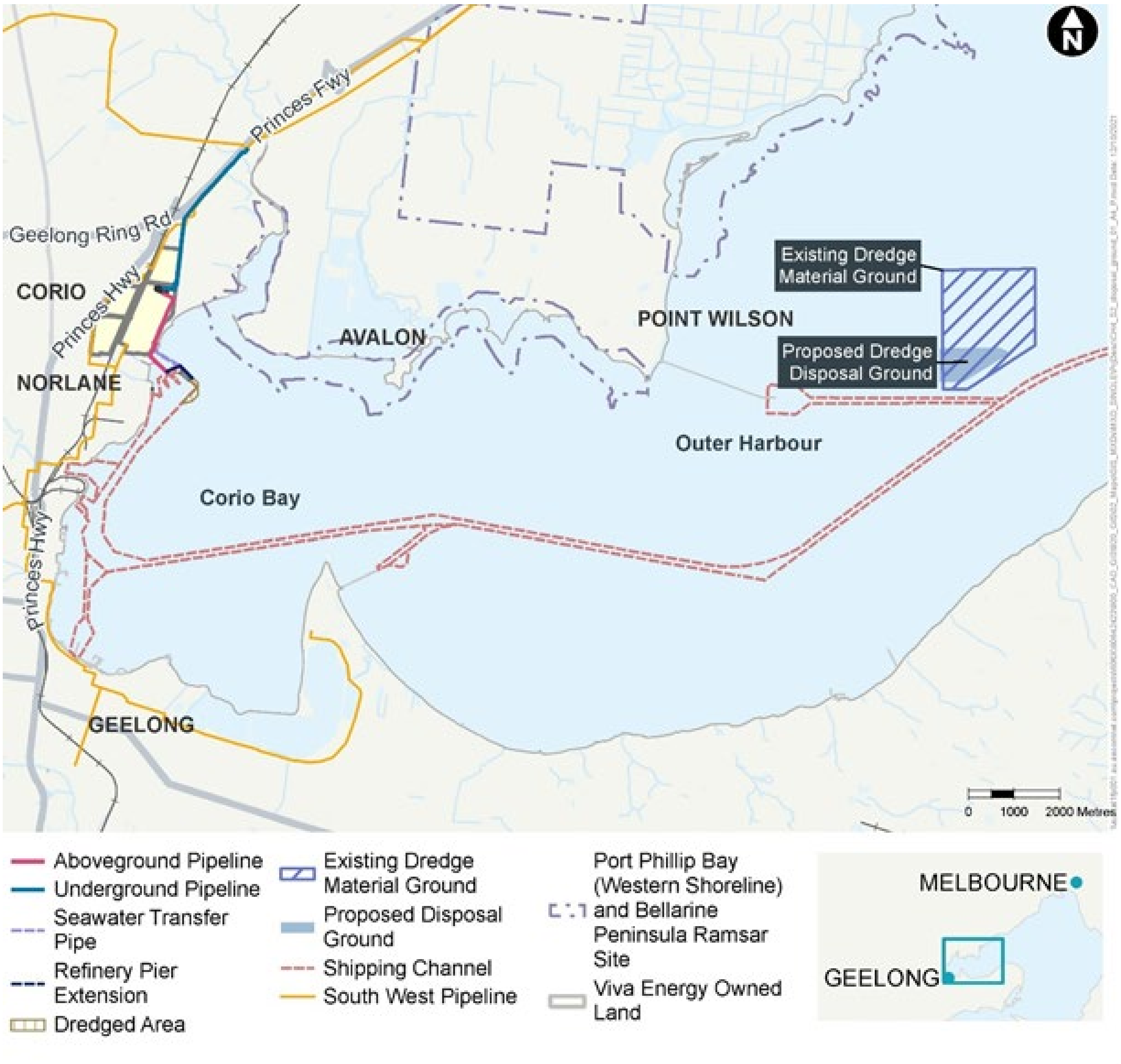


Figure 1-4. Proposed Dredge Material Disposal Ground.

1.4.2 Key Operations Activities

The project is expected to be in operation for approximately 20 years. Key activities relating to project operation include:

- Arrival of up to 45 LNG carriers each year at Refinery Pier – the number and frequency of LNG carriers arriving each year would depend on their storage capacity and gas demand
- Regasification of LNG onboard the FSRU using seawater as a heat source, which would then be reused within the refinery as cooling water
- Injection of nitrogen and odorant into the gas prior to distribution via the VTS
- Monitoring and maintenance of the land pipeline easement.

The first two activities have implications for the marine environment.

LNG carriers would moor next to the FSRU to transfer LNG from the carriers to storage tanks on the FSRU. The transfer would take up to 36 hours. The number of LNG carriers is anticipated to be up to 45 per year depending on gas demand, and the carrier capacity.

The heat required to return the LNG (liquid) to a gas would be obtained from seawater passing through heat exchangers onboard the FSRU. The seawater would be drawn from Corio Bay into the FSRU through sea chests or dedicated water inlets in the hull and circulated through heat exchangers where the liquid LNG would vaporise to a gas. The daily seawater intake would depend on gas production, and would range from 148 ML/d (million litres per day) to 300 ML/d with a maximum day of 350 ML/d. The Geelong Refinery currently uses up to 350 ML/d of seawater for cooling purposes. Cooled seawater (7 °C below ambient seawater temperature) from the FSRU regasification system would be transferred by pipe to the refinery seawater intake for reuse within the refinery and would replace the seawater currently pumped in by the refinery.

To prevent marine growth in the heat exchangers, the seawater drawn into the FSRU would be chlorinated using an electrolysis process. Seawater discharged from the FSRU to the refinery after it has been used in the regasification process would contain short-lived residual chlorine. The refinery has for many years chlorinated the seawater extracted from Corio Bay for use in the cooling water system. Thus, the residual chlorine in the seawater transferred from the FSRU would reduce the need for the addition of chlorine at the refinery. There would be no change in the chlorine concentration in the refinery discharges to Corio Bay.

Any seawater from the FSRU regasification system that exceeds the intake requirements for the refinery (e.g., if parts of the refinery are shut for maintenance) would be discharged to Corio Bay through a diffuser located under the new pier arm. As an indication of planned future operations, it is expected that under current refinery operations there would be full reuse of the seawater from the FSRU on about 344 days per year (94 % of the time) and partial to full reuse on about 21 days per year (6 % of the time).

1.4.2.1 Operating Modes for FSRU

The usual operating mode, or regasification mode, of the FSRU for this project would involve open loop operation with the transfer of seawater from the FSRU by a pipe to the refinery intake as described in the previous section.

With the project, the FSRU intake would replace some or all of the existing seawater intake of the refinery from Corio Bay, the amount of replacement being determined by the production rate of the FSRU at any given time. For example, there would be days where seawater discharge from the FSRU is lower than the normal approximate 350 ML intake requirements of the refinery (e.g., when the production rate for the FSRU is low due to reduced gas demand). In this situation, the refinery would draw the remaining volume of seawater required for cooling through the existing refinery seawater intake, as is done at present.

The refinery cooling water would be discharged from the existing refinery discharge points with the same residual chlorine content as the current refinery discharge but at a lower temperature, closer to ambient temperature conditions in Corio Bay than the current warm refinery discharge.

1.4.2.2 Backup Discharge Arrangements

The backup discharge arrangement for the project would involve direct discharge of some, or all, of the FSRU discharge water into Corio Bay via a diffuser located under the Refinery Pier extension. The diffuser would be used during periodic refinery maintenance periods when the rate of FSRU discharge could exceed the refinery demand for seawater.

The project assessed in the EES, and subsequently this supplementary statement, provides for open loop operation with discharge of FSRU water through the refinery or via the diffuser. The impacts of both of these discharge modes have been assessed, and both form part of the project put forward for regulatory approvals subject to the outcomes of the supplementary statement.

The refinery conducts significant maintenance shutdowns every second year where up to half of the refinery is taken offline for 2 to 3 months. During these periods, cooling water is still required for the operational part of the refinery and is in the range of 200 to 250 ML/day.

Based on the projected seasonal FSRU production rates shown in Table 1-1, the FSRU would still be the principal source of cooling water for the refinery during refinery maintenance. Discharge via the diffuser would also be used in the event that the refinery was permanently decommissioned in the future and the option for reuse of the FSRU discharge water in the refinery was no longer available.

1.4.2.3 Backup FSRU Operating Arrangement

The project assessed in the EES, and subsequently this supplementary statement, also includes the use of the FSRU in closed loop mode. Closed loop operating mode would only be used in the event that the FSRU was unable to transfer seawater through the transfer pipe to the refinery, for example, during FSRU maintenance or due to a pump or pipe failure. Closed loop is not preferred to the usual open loop operation as it uses up to 2.5% of the LNG cargo to heat the LNG and has higher greenhouse gas emissions than open loop operation. Notwithstanding this, closed loop operation also forms part of the project being put forward for regulatory approval.

1.4.2.4 Gas Production Profile

The estimated gas production profile for the project is shown in Table 1-1. This indicative profile is based on typical gas demand rates throughout the year. The FSRU is anticipated to produce a maximum of 500 TJ/day of gas which would require about 300 ML/d of seawater for the regasification process. On a limited number of peak demand days, the gas production rate would fluctuate throughout the day, but the maximum daily flowrate of seawater would be 350 ML/day.

Table 1-1. Indicative FSRU Gas Production and Seawater Use

Season	Estimated gas production (TJ/day)	Seawater use (ML/day)
Summer (Dec – Feb)	250	148
Autumn (Mar – May)	350	208
Winter (Jun – Aug)	500	300
Spring (Sept – Nov)	350	208

The major, planned Refinery shutdowns are generally conducted during spring or autumn. In all cases, the seawater used by the FSRU, and the associated seawater discharge would be no more than 350 ML/day which is the worst-case scenario adopted for the marine water quality modelling and environmental impact assessment, and consistent with the current discharge and operating licence for the refinery.

1.4.2.5 Base Case

The base case, which is the “no project alternative”, would involve continued operation of the refinery drawing in 350 ML/d of seawater from Corio Bay through the existing intake channel, and discharge of 350 ML/d through the four existing licensed discharge points along the shore of Corio Bay.

1.4.2.6 Project Case

The assessment of impacts generally examines the change in impacts between the project and the base case. For the usual proposed mode of operation, this would involve no change in the seawater withdrawal rate of 350 ML/d, no change in the discharge rate of 350 ML/d, no change in the chlorine concentration at the four existing discharge points and a reduction in the temperature rise of the discharge plumes.

1.4.2.7 Backup Discharge Arrangements

As described above, there are backup discharge arrangements included in the proposal, and these have been assessed as part of the project as though operational for a full year.

In practice, Viva Energy will seek to maximise use of open loop operation with transfer of the cooled FSRU water to the refinery intake as, in addition to the environmental benefit described in the Base Case, this arrangement would increase the heat transfer efficiency of the cooling water system in the refinery, with an economic benefit to the refinery. Viva Energy will seek to minimise closed loop operations.

1.4.2.8 Seawater Use

The seawater use involved in operating the project is as follows:

- Extraction of seawater for regasification and refinery operations will be limited to 350 ML/d;
- Discharge of seawater for regasification and refinery operations will be limited to 350 ML/d;
- Periodically, extra seawater will be used for ballast water and firefighting exercises and discharged to Corio Bay;

The refinery intake of seawater will always exceed the FSRU transfer of seawater, so there will be no discharge of excess seawater to Corio Bay through the refinery intake channel.

1.4.3 Key Decommissioning Activities

The FSRU, which continues to be an ocean-going vessel throughout the operation of the project, would leave Corio Bay on completion of the project life to be used elsewhere.

It is anticipated that the Refinery Pier berth and facilities would be retained for other port related uses.

Decommissioning activities may be subject to change, subject to legislative requirements at the time and potential repurposing of the infrastructure at the end of the project.

1.4.4 Project Activities Relevant to the Supplementary Study

The following project activities are relevant to this supplementary marine environment study:

- Dredging of 490,000 m^3 of sediment for the new berth and swing basin, and excavation of a shallow trench for seawater transfer pipe.
- Construction of the new pier arm and ancillary infrastructure, a diffuser under the new pier arm and pipeline along Refinery Pier.
- Construction of the seawater transfer pipe.
- Up to 45 LNG carriers visiting Refinery Pier each year to supply the FSRU.
- Regasification of LNG onboard the FSRU using seawater as a heat source, which would then be reused within the refinery as cooling water.
- Continued discharge from the four existing refinery outlets at the same chlorine concentrations as now and generally with lower temperatures as now, unless the FSRU is not operating.
- Periodic discharge of cooler seawater from the FSRU via the proposed diffuser under the new pier arm, at times if the refinery is not operating.
- Occasional discharge of warmer seawater from the ports on the FSRU if it needs to operate in closed loop mode, up to a maximum of 350 ML/d.
- Discharge of ballast water from the FSRU when it loads LNG.

1.5 Stakeholder and Community Engagement

In accordance with the Minister's Directions, a Technical Reference Group (TRG) has been convened and is chaired by Department of Transport and Planning, Impact Assessment Unit on behalf of the Minister for Planning. The TRG has provided input to Viva Energy's Study Program for the Supplementary Studies and throughout the Supplementary Statement extended assessment process.

Engagement and consultation to support the assessment of the environmental effects of the project on the marine environment, with respect to the recommendations in Table 1 of the Minister's Directions, has been undertaken in accordance with Viva Energy's Supplementary Statement Consultation Activities Plan. The approach, as described in the Supplementary Statement Consultation Activities Plan, has been updated taking on board feedback from stakeholders and the Inquiry and Advisory Committee (IAC). Activities were focused on stakeholder involvement in the extended assessment process and providing opportunities for meaningful engagement on the further work required by the Minister's Directions.

1.6 Linkages to EES Studies and Other Supplementary Studies

This marine environment supplementary study should be read in conjunction with Supplementary Statement Technical Report B: *Supplementary threatened and migratory birds impact assessment (*AECOM 2024).

This marine environment supplementary study references sections of Technical Report A: *Marine ecology and water quality impact assessment* (CEE, 2022) and Technical Report D: *Terrestrial ecology impact assessment* (AECOM 2022) where relevant.

1.6.1 Summary of Fieldwork

Table 1-2 provides a summary of all of the fieldwork that has been undertaken in both the original EES and as part of the Supplementary Statement. Extensive fieldwork has been completed by experienced biologists and engineers to provide accurate results.

Table 1-2. Summary of Fieldwork in the EES and Supplementary Statement

Field Study	Reason for Study	Section Addressed
2021/2022 (EES) – Refer to EES Technical Report A		
Plankton sampling (including phytoplankton, zooplankton and ichthyoplankton).	Plankton was sampled monthly to understand the abundances of plankton species over a year and how the communities change seasonally.	5.9, 5.10 & 5.12
Water quality sampling	Water quality was sampled monthly to see how temperature, salinity and dissolved oxygen change seasonally	5.5
Water temperature recording	Water temperature was recorded by two temperature loggers at various depths. The results were used to see how temperature changed hourly and daily and the temperature variations that biota are normally exposed to under existing conditions.	5.5
Light attenuation recording	Two PAR loggers measured underwater light for a period of 3 months. The data were used to calculate light attenuation in the water column.	5.5

Field Study	Reason for Study	Section Addressed
2021/2022 (EES) – Refer to EES Technical Report A		
Current recording	Currents were recorded for 1 month by an ADCP to the north of Refinery Pier. Current data were used to calibrate the regional hydrodynamic model and to understand how far water moved during tidal cycles and due to wind..	5.4
Seabed video tows	Video tows of the seabed were conducted at sites throughout Corio Bay focusing on the project area of north Corio Bay. The video tows assessed the seabed habitats and confirmed the boundaries of important biotopes.	5.15 & 5.17
Mussel sampling	Mussels were sampled at several places in Corio Bay. The mussels were analysed for a wide range of chlorine residuals including trihalomethanes (THMs), haloacetic acids and bromophenols.	9.12
Infauna sampling	Infauna sampling was conducted at several sites throughout the Bay using a ponar grab. The samples were analysed to assess the composition and richness of infauna communities.	5.16
2023 (Supplementary Statement)		
Seabed video tows	Towed camera surveys were conducted through the shallow water along the refinery shoreline and in the Ramsar site. In winter, spring and summer.	3.4.3
Drone images	Monthly drone images of the intertidal and shallow subtidal zone at low tide were used to assess seagrass habitats. The drone images were used to analyse and categorise seagrass habitats and density of cover.	3.4.4
Mussel sampling	Mussels were deployed at six sites in Corio Bay for 4 weeks. The mussels were analysed for a wide range of chlorine residuals including trihalomethanes (THMs), haloacetic acids and bromophenols.	6.3.2
Seawater temperature Recording	Seawater temperature in the bay was measured at multiple points in the plumes from the existing discharges to measure mixing and the extent of the dispersing plumes. Measurements were made were taken monthly at hundreds of points using a sensitive temperature probe on a range of tide conditions.	3.3.2
Temperature profiles	A sensitive temperature probe was deployed at several points near the refinery discharges to record depth profiles in the dispersing plumes.	3.3.2
Suspended Solids Sampling	Seawater samples were collected in the Ramsar Site and analysed for suspended solids to provide for a background baseline.	8.3.9

2. Minister's Directions

The Minister's Directions require Viva Energy to prepare a Supplementary Statement to provide an assessment of the environmental effects of the project on the marine environment, noise, air quality and Aboriginal cultural heritage with respect to the consolidated recommendations of the IAC for further work. Table 1 of the Minister's Directions presents the IAC's consolidated recommendations for further work.

Recommendation 1 to 8 in Table 1 of the Minister's Directions relate to the marine environment and are provided in the tabulation below.

Table 2-1. Summary of Minister's Directions

Recommendation	Description	Section addressed
Recommendation 1	Undertake further survey work to better establish the existing environment and the impacts of existing wastewater discharges from the refinery to enable better understanding of Project impacts. The survey work should: a) Cover intertidal, littoral and subtidal habitats that could potentially be affected by the project, including the Ramsar site. b) Update seagrass mapping to include the intertidal zone and information on the different seagrass species. c) Be carried out over a period of at least 12 months before construction or dredging starts, with a minimum of four sampling runs (one in each season) to address seasonal variability. d) Establish a better baseline for monitoring during and after the project to confirm predicted outcomes on shoreline and benthic communities, including seagrasses and macroalgae.	Section 3
Recommendation 2	Refine calibration of the regional hydrodynamic model so that it more accurately reproduces observed water levels, currents, tidal range, and tidal exchange in Corio Bay. Consider: a) The selection of the most appropriate wind data. b) More detailed horizontal resolution to represent the Hopetoun and North Channels more accurately. c) More detailed vertical resolution to represent discharge plumes in shallow waters more accurately. d) The effects of the presence of the Floating Storage Regasification Unit (FSRU) on currents. e) Peer review of the model calibration.	Section 4
Recommendation 3	Re-run the wastewater discharge modelling with revised inputs based on the refined hydrodynamic model. Consider: a) Revising the nearfield modelling of discharges from the diffuser to address the matters raised by Dr McCowan in his written evidence (D75). b) The Inquiry and Advisory Committee's (IAC) recommended default guideline values (DGV) for chlorine discharges (7.2 microgram per litre in Corio Bay generally, including the Project area; 2.2 microgram per litre at the Ramsar site).	Section 5

Recommendation	Description	Section addressed
Recommendation 4	Consider undertaking further targeted investigations into the effects of existing chlorine discharges from the refinery to confirm likely project impacts resulting from chlorination by-products, including measurement of chlorination by-product concentrations in: a) Seawater. b) Biota that have high susceptibility to contamination.	Section 6
Recommendation 5	Re-run the entrainment modelling with revised inputs based on the refined hydrodynamic model.	Section 7
Recommendation 6	Re-run the sediment transport modelling with revised inputs based on the refined hydrodynamic model. Consider including a 'worst-case' scenario for sediment fractions and settling rates which includes the largest expected proportions of fine and very fine materials that have the slowest expected settling velocities.	Section 8
Recommendation 7	Undertake further assessment of dredging impacts on seagrass based on: a) The revised sediment transport modelling. b) Revised light thresholds of 10 percent to 20 percent surface irradiance (20 percent surface irradiance should be applied to any sediment plumes that extend to the Port Phillip Bay (western shoreline) and Bellarine Peninsular Ramsar Site). c) The updated seagrass mapping (Rec. 1b).	Section 9 (Section 8 also relevant)
Recommendation 8	Confirm the EES conclusion that dredging will not impact the Ramsar site after considering: a) The revised marine modelling. b) The revised assessment of impacts on seagrass.	Section 10 (Section 8 and Section 9 also relevant)

The following sections of this marine supplementary studies report provide details on each Minister's Direction, the methodology adopted to satisfy the Direction, the study findings and discussion of the findings in the context of the original EES findings.

3. Recommendation 1 – Impacts of Existing Discharges

3.1 Summary of Original EES Findings

The usual operating mode of the FSRU is open loop. With open loop operation, seawater is taken into the FSRU, cooled during the regasification process (approximately 7°C below ambient temperature) and piped to the existing refinery seawater intake for reuse in the refinery, where it would be heated.

The refinery currently uses approximately 350 ML/day of seawater and heats the seawater to approximately 10°C above the entry water temperature. Reuse of the FSRU discharge as refinery cooling water would reduce the temperature rise of the discharged seawater to approximately 2°C above the entry temperature when the discharge rate is 350 ML/day.

The FSRU discharge would replace some or all of the seawater intake from Corio Bay by the refinery. If the FSRU seawater use is less than the refinery use on any given day, the refinery would draw the remaining volume of seawater through the existing refinery seawater intake.

Following reuse, the seawater from the refinery would be discharged via the four existing refinery discharge outlets.

EES Technical report A: *Marine ecology and water quality impact assessment* (CEE 2022) assessed the seawater discharges from the existing refinery. The results are presented in Section 8.4 and 9.7 of EES Technical report A: *Marine ecology and water quality impact assessment* (CEE 2022).

The regional hydrodynamic model was used to predict the potential temperature and chlorine plumes during operation of the project in the EES. The EES modelled the existing plumes from the refinery and showed that they normally travel to the north along the coast. Due to mixing and temperature loss to the atmosphere, the temperature rise is around 1°C above ambient at the boundary of the Ramsar Site.

The existing chlorine plumes are small and below 3.6 µg/L within 200 m of the discharge points and do not extend to the Ramsar site.

Combined use of seawater in the FSRU and the refinery would reduce the existing temperature rise in the current discharges (from a discharge temperature around 10°C above ambient to 1-3°C above ambient) and there would be a smaller temperature plume along the shoreline.

The extent and concentrations of the chlorine plumes with the project would essentially be the same as the existing situation as the same volume of seawater and concentration of residual chlorine would be discharged, with a minor effect of reduced spreading due to the lower temperature of the discharge plumes than existing.

As the proposed discharge of cooled seawater from the FSRU through the refinery does not result in a substantial change in concentration of chlorine from the existing refinery discharge plumes, and a reduction in the extent of the temperature plumes, the project is unlikely to impact the extent of seagrass in Corio Bay or food resources for migratory shorebirds. Therefore, the EES determined that reuse of seawater from the FSRU through the refinery would not have a significant impact on the existing environment or the ecological character of the Ramsar site.

The EES noted that seagrass was mapped in the northern end of Corio Bay and Limeburners Bay in 2001 by Blake and Ball and extra mapping during the EES confirmed and refined the extent of seagrass. The offshore seabed of Corio Bay is dominated by *H. nigricaulis* with a mixture of sparse to medium *H. nigricaulis* and *Halophila* in deeper water. *Halophila* is normally patchy with areas of sediments between plants, whereas *H. nigricaulis* is typically found in shallower water with medium to dense seagrass meadows.

To further understand the existing seabed habitat, seabed video tows were conducted at sites throughout Corio Bay. The results of the seabed video tows are presented in Section 5.17 and 9.10 of EES Technical report A: *Marine ecology and water quality impact assessment* (CEE 2022). Seagrass extent was mapped mapping following the seagrass surveys.

The results of the investigations and mapping showed that no seagrass would be removed as a result of the proposed dredging as the waters proposed to be dredged are deeper than the extent of seagrass.

3.2 Overview

The four existing discharges from the refinery have been operating for many years and , whether or not the project proceeds, there would be no change in the flow rates or chlorine concentrations in the discharges. The IAC concluded that *"it is difficult to conclusively determine that existing Refinery discharges are having acceptable impacts"*. The IAC recommended that *"a monitoring program should be established to assess the existing impacts of refinery discharges more rigorously and establish a better baseline for ongoing monitoring of the effects of the project on the marine environment."*

Recommendation 1 of the Minister's Directions is related to this conclusion and was as follows:

Undertake further survey work to better establish the existing environment and the impacts of existing wastewater discharges from the refinery to enable better understanding of Project impacts. The survey work should:

a) Cover intertidal, littoral, and subtidal habitats that could potentially be affected by the project, including the Ramsar site.

b) Update seagrass mapping to include the intertidal zone and information on the different seagrass species.

c) Be carried out over a period of at least 12 months before construction or dredging starts, with a minimum of four sampling runs (one in each season) to address seasonal variability.

d) Establish a better baseline for monitoring during and after the project to confirm predicted outcomes on shoreline and benthic communities, including seagrasses and macroalgae.

3.3 Summary of Tasks

A number of tasks were undertaken as per the study program developed for the Supplementary Statement to address Recommendation 1 of the Minister's Directions. An overview of these tasks and their objectives is provided below.

<u>Task 1a: Further monitor the extent of the existing refinery plumes in the intertidal, littoral, and subtidal zones.</u>

- Additional sampling, and analysis of measurements of temperature and chlorine in the four refinery wastewater discharges was undertaken in 2022-23.
- Sensitive temperature/salinity sensors (Castaway CDT and a YSI Exo Multi-parameter Water Quality Sonde) were deployed from shallow draft vessels each month from July 2023 to January 2024 to measure seawater temperature at hundreds of points in the plumes and establish the contours of temperature in the existing discharge plumes. The temperature measurements from the vessel were supplemented by measurements taken using the Castaway CDT deployed from a drone.

As the chlorine levels in the existing refinery discharge plumes are below the level of detection, chlorine levels in the plumes were calculated using the measured temperature rise relative to ambient seawater, the known ratio of chlorine to temperature in the discharges and the known decay rates of chlorine and temperature with time.

- Contours showing the distribution of temperature and chlorine in the existing plumes and the extent of the existing combined refinery plumes were plotted.

Further detail about Task 1a is provided in Section 3.4 of this report.

<u>Task 1b: Update the seagrass mapping in the intertidal, littoral, and subtidal zones of the existing discharge plumes and at suitable reference sites in the Ramsar site</u>

- Photographs of the intertidal and subtidal seagrass were made using low-level drones and towed camera surveys in winter, spring, and summer. Seagrass was inspected visually to ground-truth and classify images.
- Maps of the species and distribution of seagrass were prepared. The maps were compared with maps from previous years to understand short-term and long-term variation in seagrass meadows in the study area.
- The seagrass cover at many points along transect lines in the discharge zone and in the Ramsar Site were measured in winter, spring and summer in 2023/2024.
- A statistical analysis was undertaken using the two sided t-test to examine whether there is a difference in seagrass cover in the area of the discharge plumes compared to seagrass cover in the Ramsar site.

Further detail about Task 1b is provided in Section 3.5 of this report.

<u>Task 1c/1d: Provide a baseline for monitoring during and after project construction to confirm predicted environmental outcomes</u>

- As per the approved study program, this task will not form part of the Supplementary Statement. Because of the variation in seagrass cover and proportions of different species from year to year, this task needs to be carried out in the 12-months prior to the commencement of dredging to provide the most accurate and representative baseline for project monitoring before, during and after dredging and jetty construction. This task would form part of the secondary approvals process (*Marine and Coastal Act Consent*).

Further detail about Task 1c and the methodology that is proposed for this task is provided in Section 3.6 of this report.

3.4 Task 1a: Monitor Extent of Existing Refinery Plumes

3.4.1 Background to EES

As described in detail in Section 1.4.2 of Technical Report A: *Marine environment impact assessment* of the EES (CEE 2022) and in Section 1 of this report, the Geelong refinery uses seawater from Corio Bay for cooling and has been doing so for over 60 years. The temperature of three of the refinery discharges is elevated at 10 ^{o}C to 11^{o}C above ambient seawater temperature; the other discharge is small and at ambient temperature. Chlorine is added to the intake seawater to control biofouling in equipment within the refinery.

To establish the existing environment and the impacts of existing discharges from the refinery, CEE undertook over 12 months of field investigations during the development of the EES in 2020 and 2021.

Field investigations included current, temperature and water quality monitoring, measurement of bathymetry, surveys of seagrass and other seabed habitat, and plankton and larvae surveys.

The seabed and shoreline of Corio Bay have been substantially modified over the last 170 years with shipping channels being dredged, the western shoreline being developed for industrial uses, the Port of Geelong being developed, and seawalls, marinas and jetties constructed as part of Geelong's urbanisation.

Despite these developments, field investigations indicate that Corio Bay has good water quality and a diverse range of marine life that has adapted to the existing conditions of the Bay. Corio Bay has a dynamic and self-sustaining ecosystem which includes approximately 1,000 species of plants and animals.

3.4.2 Methodology in Supplementary Study

To address Recommendation 1a of the Minister's Direction, additional sampling, and analysis of measurements of the temperature and chlorine in the four refinery wastewater discharges was undertaken for the supplementary study. Figure 3-1 shows the location of the four existing discharge points, from W1 (in the south) to W5 (in the north), with the EPA licence mixing zones. Note that there is no W2 discharge. Viva Energy takes measurements of temperature and chlorine levels in each discharge daily or weekly and the data (1/1/2022 to 18/7/2024) was used to confirm that the temperature and chlorine increment was consistent with the measurement in 2021.

It is noted that the discharge conditions in 2022-23 are the same as those measured in 2020-21 and reported in Table 5-23 of Technical Report A: *Marine ecology and water quality impact* assessment (CEE 2022).

Table 3-1. Temperature Rise and Chlorine Level in Existing Refinery Discharges

Discharge	Discharge	Temperature Rise, deg C		Chlorine, µg/L	
	m^3/s	95 percentile	75 percentile	95 percentile	75 percentile
W1	2.64	+10	+8.5	20	20
W3	0.02	+0.2	+0.2	18	14
W4	0.41	+11	+10	40	30
W5	0.98	+10	+9	40	20

The categories of observed seagrass cover were converted to percentage cover using the ranges defined by Blake and Ball (2001). The average seagrass cover on each line was calculated. Taking each line as a measure, the mean intertidal and subtidal seagrass cover in the discharge zone and in the Ramsar site was calculated, together with the corresponding standard deviations. The two-sided t-test was used at the 0.05 significance level to examine whether there was a significant difference in seagrass cover in the two areas.

Figure 3-1. Location of Existing Refinery Discharges with Mixing Zones.

The temperature rise in the existing plumes formed by the refinery discharges was measured at hundreds of points along and adjacent to the plumes each month from July 2023 to January 2024 for this supplementary study. The measurements were made in various tide and wind conditions including incoming and outgoing tides and at slack water, but not neap or king tides.

Plume modelling conducted in 2022 (refer to Section 8 of Technical Report A: *Marine environment impact* assessment (CEE 2022) informed timing of the plume measurements and showed faster dispersion and shorter plumes with stronger winds.

Water temperature in Corio Bay was measured using a sensitive temperature/salinity sensor (Castaway CDT) and the sensors in a YSI Exo Multi-parameter Water Quality Sonde. In each case, the instruments were calibrated the day before use and the accuracy of temperature measurements was better than +/-0.1°C. Northern Corio Bay has very shallow sections making water monitoring close to the discharges and within the Ramsar site (background) difficult. Thus, a range of methods were used including deployment from drones, boats, kayak and by personnel wading in shallow water, and the measurements from each method were cross-calibrated.

In each sampling occasion water temperature measurements were taken both within and outside of the dispersing plumes to obtain the increment above background.

3.4.2.1 Design Guideline Values for Temperature and Chlorine

DGV for temperature

The *Australian and New Zealand Guidelines (ANZG) for Fresh and Marine Water Quality* provides guidance on water quality (ANZG, 2000, 2018, 2020). These include default guideline values (DGV) for water quality and a framework for deriving guideline values.

The ANZECC 2000 Guidelines define a DGV for temperature based the natural 50 and 80 percentile temperature:

- *Warm discharges should not increase the median temperature above the 80-percentile temperature, based on the seasonal distribution of seawater temperature data.*

The annual variation in seawater temperature in Corio Bay is from 11°C to 22°C. On an annual basis, the 50 to 80 percentile temperature range is 3.3°C. This data is based off of model outputs from HydroNumerics and verified against temperature monitoring done over a 6-to-12-month period in Corio Bay by CEE during the EES (CEE 2022). The adopted DGV for temperature change in waters of Corio Bay is 3°C. As shown in Figure 3-2, there is evidence that natural variations involve larger temperature variations in shorter time scales, so this is a reasonable and conservative DGV.

A more stringent temperature DGV of 2°C is adopted for the Ramsar site which at the closest point is 830 m north-east of the W5 discharge, although it is noted that natural temperature variations in the Ramsar site, particularly Limeburners Bay, are larger than in Corio Bay.

A less stringent temperature DGV of 5°C is defined for the intertidal zone based on the natural variations in atmospheric temperature that intertidal seagrass experiences.

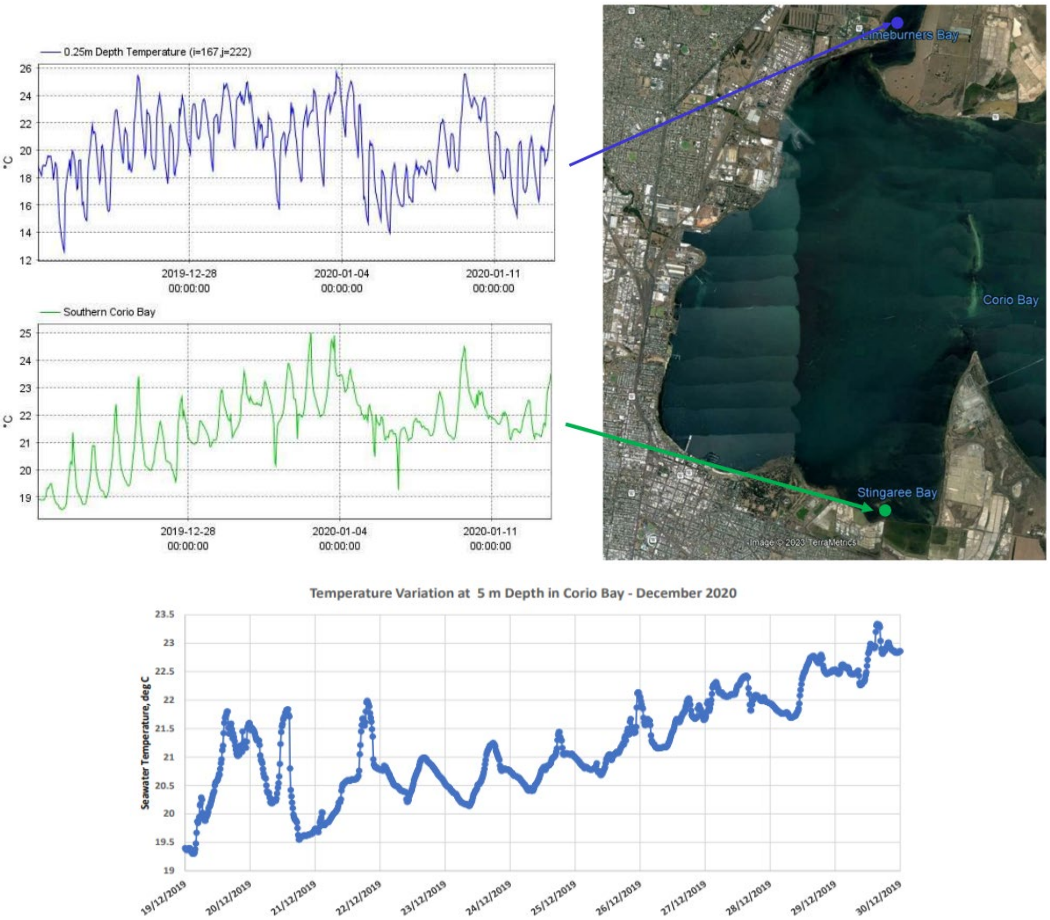


Figure 3-2. Examples of Temperature Variations in Corio Bay (HydroNumerics Model)

DGV for Chlorine

In the *Environmental Reference Standard* (EPA, 2021), the Geelong Arm of Port Phillip Bay is defined as a “slightly to moderately modified” ecosystem. Thus, the 95% level of species protection applies to Corio Bay *(EPA, 2021, Table 5-13*). The IAC recommended a higher level of species protection (99%) for the Ramsar site across the north of Corio Bay.

Updated DGV (or water quality design value) for chlorine-producing oxidants in marine waters were provided by the EPA in July 2023 via the TRG comments as follows:

- 95% protection (Corio Bay) CPO = 10 μg/L.
- 99% protection (Ramsar site) CPO = 4.3 μg/L

Note that these updated DGV differ from the chlorine DGV used in Section 9.5.3 of *Technical Report A: Marine environment impact assessment* (CEE 2022) of the EES.

ANZG DGVs are derived according to risk assessment principles and represent the current best estimates of the concentrations of toxicants (such as chlorine) that should have no significant adverse effects on the aquatic ecosystem. The DGV are derived from all reliable data on the effects of a toxicant on at least five species from at least four taxonomic groups as summarised in a species sensitivity curve (Warne et al, 2018). As a result, the derived DGV apply to all marine species.

3.4.3 Extent of Temperature Rise in Discharge Plumes

Temperature rise was used as the indicator of the extent of the existing discharge plumes because it can be measured directly in the field and excess temperature lasts longer than chlorine, which decays quickly and cannot be measured in the field. As shown in Table 3-1 above, the three main cooling water discharges from the refinery are 10°C to 11°C above ambient seawater temperature at the point of discharge. The temperature in the plumes decreases with time and distance due to mixing and temperature loss to the atmosphere.

Surveys were run on a monthly basis on the following dates: 26 July 2023, 15 August 2023, 27 September 2023, 18 October 2023, 2 November 2023, 15 December 2023 and 17 January 2024. An envelope showing the maximum extent of the temperature contours was prepared by combining the monthly plots.

Figure 3-3 shows the outer envelope of temperature increments from the six sets of plume temperature measurements. The following observations were made:

- The W1 discharge comes from a channel that is 11 m wide and 0.25 m deep. The plume slows on leaving the channel and spreads to a surface layer about 0.5 m thick. In calm conditions, the plume spreads laterally and forms a surface layer around 0.5 m to 1 m deep. Mostly, the plume travelled to the north, under Refinery Pier.
- The W3 discharge is small (see Table 3-1. The discharge from W3 comes from backwashing the inlet screens and is at the same temperature as the incoming water from Corio Bay. Thus, the discharge from W3 mixes and disperses rapidly.
- The W4 discharge is from the open-end of a 0.9 m diameter pipe and it forms a plume about 0.3 m thick that gradually deepens and increases in width. Mostly, the plume travelled to the north along the shore, with the inner edge of the plume at the beach.
- The W5 discharge is from a channel that is 4 m wide, and the flow is 0.25 m deep. The plume extends out approximately 40 m or so from the channel and gradually deepens to around 0.5 m. The plume generally turns to the north and spreads with the inner edge at the beach.

W1 Plume

The +5°C contour envelope (which is the DGV for temperature change defined for the intertidal zone) for the W1 plume extends for 250 m north under Refinery Pier and for 150 m to the south and 250 m to the north. Seagrass is growing in patches under the plume at the mouth of the creek from which the discharge flows. At low tide, this seagrass is within the zone of elevated temperature. The intertidal area near W1 is a rock boulder wall without intertidal seagrass.

The +3°C contour envelope (which is the DGV for temperature change defined for Corio Bay) for the W1 plume extends for 500 m to the north towards and just past the seawater intake. There is much less flow to the south and the plume extends for approximately 200 m south. To the north, the W1 plume is partly captured by the refinery seawater intake.

W3 Plume

The W3 discharge has the same temperature as ambient seawater and so there is no temperature plume from this discharge.

Combined W4 and W5 Plume

The W4 and W5 plumes were sometimes separate and sometimes combined. The combined temperature plume envelope shows the two plumes connected. The +5°C contour has a north-to-south extent of 440 m and extends for 175 m offshore. The +3°C contour has a north-to-south extent of 950 m and extends for a maximum of 430 m offshore. Intertidal and subtidal seagrass is present under both of these plumes. The intertidal seagrass under the plume is usually within the zone of elevated temperature and the subtidal seagrass is in the zone of elevated temperature at low tide.

The +2°C contour envelope (which is the DGV for temperature change defined for the Ramsar site) for the combined W4 and W5 plumes extends for 650 m to the north. At the furthest extent of the measured plumes, the +2°C contour is separated by 200 m from the closest point of the Ramsar site.

Summary on Extent of Existing Plumes

In summary, seawater temperature in the existing refinery plumes has been measured monthly at many sites (typically 3,000 to 5,000 temperature readings each month) in and adjacent to the plumes at monthly intervals to establish the contours of temperature rise above ambient at monthly intervals, in various tide conditions.

The +5°C contour encompasses a small area of intertidal seagrass, extending for 150 m to the north of W5.

The +3°C contour extends along the shore for 560 m north from the W5 discharge. The +2°C contour extends a further 90 m north but does not reach the Ramsar site.

The temperature rise in the existing refinery discharges has declined to within the DGV for temperature change before the Ramsar site is reached. It can be concluded that there is no impact of temperature on marine organisms in the Ramsar site from the existing discharges.

Thickness of Plumes

As the discharge plumes are warmer than the adjacent seawater, they are buoyant and form a shallow layer on the surface of the Bay.

Vertical temperature profiles were measured at many points in the plumes. The discharge from W1 is about 1.2 m deep near the mouth of the creek but further away the plume thickness decreases to 0.5 to 1.0 m as the plume spreads out. On a calm day, the plume spreading can reduce the thickness of the plume from W1 to approximately 0.25 m at 500 m.

Figure 3-3. Envelope of Extent of Measured Temperature Plumes

Note: The envelope of all measured plumes is not the outline of an instantaneous plume but the extent of all plumes in all directions based on six surveys of plume temperature. The plumes at any time occupy about 50 % of the area of the envelope of all measured plumes.

The discharge from W3 and W4 is around 0.25 to 0.3 m deep at the discharge points and the plumes spread and mix downwards as they are carried away by the ambient currents. At times of weaker currents and winds, the plume thickness is approximately 0.5 m.

When there are stronger winds, the plumes mix vertically to a thickness of around 1.0 m, with a maximum thickness of 1.2 m measured.

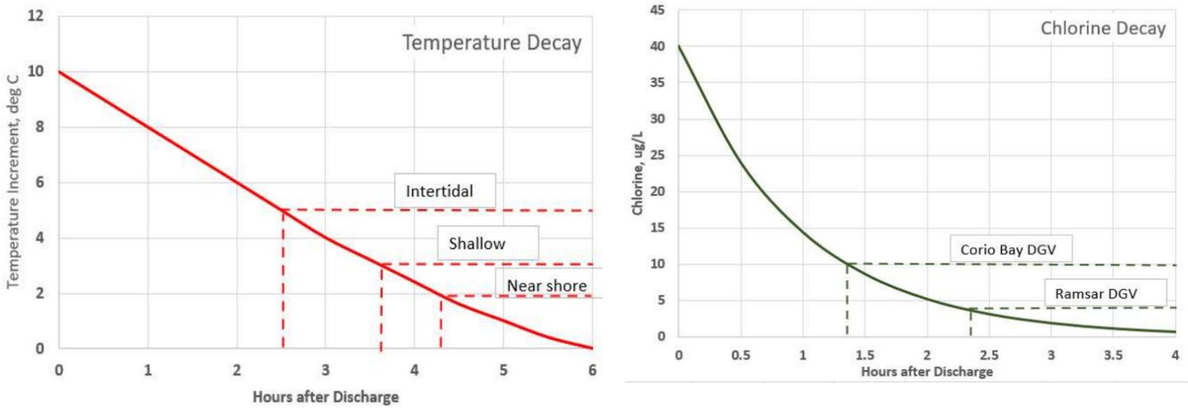
As the plumes are generally in the top 2 m of water, the biota that could potentially be affected by the discharges are (1) in the intertidal zone, (2) on the seabed of the subtidal zone to a depth of 2 m below low tide, and (3) the top of the seagrass of the subtidal zone growing upwards from a depth of 2 m.

3.4.3.1 Extent of Chlorine in Existing Discharge Plumes

It is not possible to measure chlorine in seawater at low concentrations of chlorine and on a boat, as the sample must be tested within 1 minute to comply with NATA standards. Thus, the method used to establish chlorine concentrations in the refinery plumes was to develop a correlation between temperature and residual chlorine concentration and use it to convert the measured temperature contours into equivalent chlorine contours.

The relationship between excess temperature and residual chlorine was developed using a large volume of the W5 discharge held in a tank on the shore and measuring the decay of temperature and chlorine with time. The results of the experiments are shown in Figure 3-4.

The initial temperature was 10 degrees above ambient and the initial chlorine concentration was 0.04 mg/L or 40 µg/L chlorine. The temperature declined with time and 8°C temperature excess temperature was reached 1 hour after discharge, at which time the chlorine concentration was 15 µg/L. The 6°C excess temperature was reached 2 hours after discharge, at which time the residual chlorine concentration was 5 µg/L chlorine. Using the two decay curves, temperature contours can be converted into chlorine contours, noting that there is equal dilution with time of both temperature and chlorine in the discharge plumes.



3 °C reached after 3.6 hours – Approx. 650 m travel (without accounting for dilution)

10 µg/L reached after 1.4 hours – Approx. 300 m travel (without accounting for dilution)

Figure 3-4. Results of Experiments of Temperature Decay and Chlorine Decay.

The plume temperature survey results were processed to determine the shape and extent of the chlorine plumes and define the 10 µg/L and 4.3 µg/L chorine contours (corresponding to the DGV for chlorine in Corio Bay and the Ramsar site).

The inferred chlorine plumes are shown in Figure 3-5. The 10 µg/L contour extends from the W1 discharge along the rock wall shoreline for approximately 150 m. There is only a very small zone of chlorine above 10 µg/L at W3. The 10 µg/L chlorine contour from the W5 discharge extends in the plume for approximately 100 m.

For all discharges, the inferred 10 µg/L chlorine contour is within the existing defined EPA mixing zone in the refinery operating licence.

The inferred 4.3 µg/L chlorine level, which applies only in the Ramsar site, extends for approximately 200 m from W1 and for about 160 m from W5. The chlorine level in the plumes is less than 4.3 µg/L well before the Ramsar site (approximately 800 m away). Thus, there is no risk of chlorine extending to the Ramsar site at any detectible or significant concentration and would have no impact on Ramsar values.

Figure 3-5. Inferred Chlorine Contours in Existing Plumes

3.5 Task 1b: Update Seagrass Mapping

3.5.1 Background to EES

As described in detail in the EES Technical Report A: *Marine environment impact assessment* (CEE 2022), CEE undertook over 12 months of field investigations in 2020 and 2021 to establish the existing environment. This included extensive surveys of seagrass focussing on the seagrass beds which dominate the coast by the refinery and in the Ramsar Site.

Species of Seagrass

There are around 30 species of **seagrass** in Australia. Following extensive desktop and field investigations it was concluded that five species occur in northern Corio Bay, growing on muddy to fine sandy intertidal to shallow subtidal seabed:

1. *Nanozostera muelleri* (*N muelleri*) - a short grass-like seagrass growing mostly in intertidal or shallow water;

2. *Heterozostera nigricaulis (H nigricaulis)* - a tall grass-like seagrass with black stems growing in shallow water;
3. *Halophila australis (Halophila)*– a paddle shaped seagrass growing in deeper water;
4. *Althenia marina (Althenia)* – wiry and bushy in occasional patches in shallow water;
5. *Ruppia tuberosa (Ruppia)* – also wiry and bushy in occasional patches in shallow water.

Althenia marina (Althenia) and *Ruppia tuberosa* (Ruppia) are not unanimously recognised as "seagrasses" by seagrass scientists as these plants reproduce in saline terrestrial conditions. NSW Flora Online describes *Ruppia tuberosa* is a "*perennial herb that grows in small brackish swamps, saline lakes and marshes, or on tidal flats of sheltered bays*". *Althenia* and *Ruppia* often grow together and occupy only a small area of the seabed in Corio Bay.

Excluding *Althenia* and *Ruppia,* there are only three species of seagrass in Corio Bay. *N muelleri* is dominant in the intertidal zone, *H nigricaulis* is dominant in the shallow subtidal zone and *Halophila* is dominant in deeper water.

The seagrass and algae species can be identified by direct examination of samples and with some confidence from underwater camera images. Water depth, seawater turbidity and the amount and patchiness of ephemeral epiphytes may change the apparent colour and 'texture' of seagrass in aerial images so ground-truthing is required.

Seaweeds, or algae, may be present at times growing in varying amounts either as epiphytes on the leaves of *H nigricaulis* or lying loosely over the canopy of *H nigricaulis* or *Halophila*. There also are small patches of shoreline algae growing in or just above the intertidal zone.

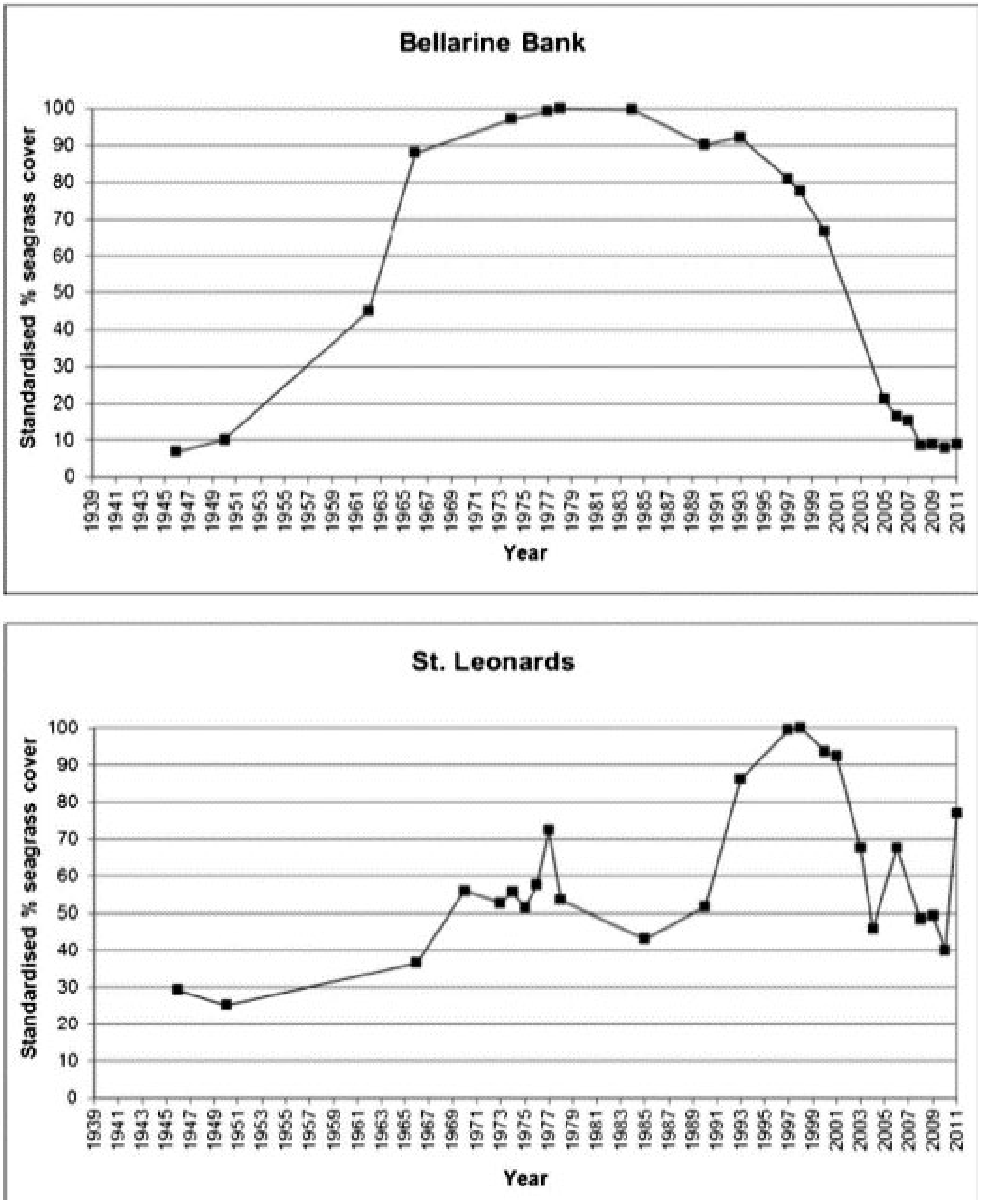
Spatial and Temporal Variability

Seagrass species are mixed together in Corio Bay and the proportion of different species in the mixtures varies over time. These factors add complexity to categorizing and mapping seagrass vegetation into consistent areas. Hence, large-scale maps or models of seagrass distribution in Port Phillip and Corio Bay often combine species into vegetation groups, ecological communities or habitat categories (Blake and Ball 2001, Sinclair 2010, Mazor et al 2021).

As part of the Channel Deepening Program, the Dept of Primary Industries reported on seagrass monitoring surveys throughout Port Phillip Bay. The reports emphasized that historical aerial photographs indicated that seagrass cover in Port Phillip Bay varies on the scale of decades, with several sites showing a peak in seagrass cover in the 1990s followed by a period of decrease to 2011 (see Figure 3-6). This was attributed to long term variation in rainfall patterns, which influenced long term cycles in nutrient inputs to Port Phillip Bay. Other causes of variability in seagrass cover include climatic conditions, nutrients, sediment transport and erosion due to wave action (Blake and Ball 2001, Sinclair 2010).

The extent of the seagrass meadows is limited by the availability of light (depth limitation), exposure to wave action and sediment movement. Areas that are protected from strong currents and wave exposure, and relatively isolated from land catchments, such as in Corio Bay, have a relatively stable cover of seagrass over time ('persistent' seagrass beds). The seagrasses grow in fine, muddy sediments, and most of their nutrients come from internal breakdown and recycling of detritus (Jenkins et al, 2015).

Even though the seagrasses in Corio Bay are persistent, there are variations at a local scale from year to year, or even within years. Figure 3-6 shows an example at St Leonards and Bellarine Park (Port Phillip Bay) both of which are in the vicinity of Corio Bay and consist of the same species of seagrass as the project area. The figure shows there has been a significant change in seagrass cover over years.



Source: Ball et al (2014)

Figure 3-6. Year to Year Variation in Seagrass Distribution in Port Phillip Bay

3.5.2 Methodology of Seagrass Surveys

Seagrass mapping was completed using a range of methods including towed underwater camera, inspection by biologist-divers, high resolution drone imagery and direct in person ground truthing in intertidal areas.

To understand the spatial distribution of seagrass species and cover, towed underwater camera transects were run throughout northern Corio Bay with a total of around 11,300 images analysed. A map of the seagrass species and the distribution of seagrass in north Corio Bay was prepared. The 2023 map was compared with maps from previous years to understand short-term and long-term variation in seagrass meadows in the study area. The seagrass distribution results are shown in Section 3.5.3.

Seagrass Cover Surveys

To establish the potential impact on seagrass due to the existing discharges, a comparison was made of seagrass cover along transects parallel to the shoreline around the existing discharges (Discharge Area) and in the Ramsar site (Reference Area). The comparison surveys were conducted on three occasions in the supplementary study.

The methodology for the comparison of seagrass cover is set out below.

The seagrass mapping (see Section 3.5.3) showed that seagrass cover varies from site to site and month to month. Therefore, seagrass cover surveys need to sample a relatively large area of seagrass to obtain a representative measure of the average seagrass cover in the area. This was achieved by defining transects parallel to the coast that extended for 300 m to 600 m along the shore at fixed elevations relative to mean sea level. There were two intertidal transects and two subtidal transects.

Within the Discharge Area, the transects extended across the existing refinery discharges (W1, W3, W4 and W5). In the Reference Area, the transects extended along two reference sites. The transects were parallel to the coast, two in the intertidal zone (at elevations of 0.2 m above mean sea level and 0.2 m below mean sea level) and two in the subtidal zone (elevations of approximately 0.4 m and 0.6 m below mean sea level).

Sampling sites, each 2 m by 2 m in area, were defined at 15 m intervals along each transect. Three surveys at 10-week intervals were made to obtain replicate observations of seagrass cover at each site on each transect. Seagrass cover was assessed using standard procedures, as described below, and the average seagrass cover was calculated on each transect for each sampling time. Bare sediment or seagrass wrack meant a cover score of zero.

Seagrass cover was assessed using categories of “Sparse”, “Medium” and “Dense”, using the classifications of Blake and Ball (2001):

For *H nigricaulis*:

- Dense: Thick enough to hide the sediment underneath from view.
- Medium: Thick enough for leaves to touch but sediment could be discerned beneath.
- Sparse: When plants are present but of a density where leaves from individual plants essentially do not touch each other.

For *Halophila*:

- Dense: The base sediment could always be seen, but the leaves were within touching distance of each other.
- Medium: Present but leaves do not touch although within proximity of each other.
- Sparse: Leaves do not touch, and individual plants clearly dispersed.

To measure seagrass cover, photographs of the intertidal and shallow water seagrass at each site were captured using low-level drones at low tide. These were supplemented in deeper subtidal areas with images obtained using a video camera towed by a boat. The seagrass cover was then assessed by experienced marine scientists at each 2 m by 2 m sampling site and plotted to show the variation in seagrass cover with distance along each transect line. To assist in the analysis of seagrass cover, ground-truthing was achieved by CEE marine biologists by visual inspection of intertidal areas, further towed camera imagery and diver inspection of subtidal areas.

The same procedure was followed for all transects at each of the survey sites in the Discharge Area and Reference Area.

The assessment involved over 10,000 high resolution drone images stitched into orthometric maps from winter to summer 2023, analysis of over 11,300 underwater images taken along 15 kms of transects across the discharge area and Ramsar zone over a period of six month and ground truthing of seagrass images by marine biologists.

Because of the spatial variation in seagrass cover, a large number of sites on each transect was required to obtain representative values of average seagrass cover. The assessment of seagrass cover corresponds to about 100 m^2 to 160 m^2 per transect. Overall, seagrass cover was assessed and recorded on approximately 2800 m^2 in the discharge zone and the same area in the Ramsar site.

A statistical analysis was undertaken using the two sided t-test to examine whether there is a difference in seagrass cover in the area of the discharge plumes compared to seagrass cover in the Ramsar site.

3.5.2.1 Use of Seagrass Cover as an Indicator

Previous studies of seagrass in Port Phillip Bay and Corio Bay have used seagrass cover as a metric to describe the condition of seagrass.

The *Port Phillip Bay - Environmental Study* (CSIRO, 1996) mapped the extent of various benthic habitats, including seagrass, using airborne multispectral scanners.

The later *Historical Mapping of Seagrass in Port Phillip Bay* mapped seagrass at three sites in Port Phillip Bay between 1939 and 2011 and reviewed possible influences on changes in seagrass cover (Ball et al, 2014). Historical aerial photographs were digitally scanned and orthorectified to map seagrass cover in a GIS system.

Variations in seagrass cover were related to long period weather patterns, with sustained seagrass expansion during wet decades and decline in seagrass during prolonged droughts. The declines were not consistent between sites as some sites (notably in Corio Bay) were more stable during droughts. Sites with large declines in seagrass were all subject to large sediment movement.

The Marine Science and Ecology Report (MSE, 2006) on monitoring the impacts of dredging in the Corio Bay Channel Deepening Program concluded that there was no impact of that extensive dredging program based on measurements of the percentage cover of seagrass. The cover was measured by quantitative photographic and video monitoring of seagrass at eight sites, supported by ground-truthing by divers. Some morphological measurements of seagrass characteristics were made but were not used in making conclusions.

The DELWP report on Marine and Coastal Ecosystem Accounting (Eigenraam et al, 2016) used hectares of seagrass cover (and other ecosystem descriptors) in Corio Bay to assess environmental services and values.

The extensive seagrass monitoring conducted for the Port Phillip Channel Deepening Program (CDP) involved surveys over three years at multiple sites (Vic Auditor General, 2012). Seagrass monitoring measured seagrass cover in mapping areas of 30 to 100 ha at 30 sites and morphological changes in ten plots of 4 m^2. Seagrass cover was plotted from aerial photography in April each year. The plots were sampled twice a year (Hirst et al, 2012).

The CDP study concluded that the health of seagrass at intertidal plots was consistent with past seasonal trends. Intertidal seagrass cover, length and shoot density remained high at Mud Islands, St Leonards and Swan Bay, and low at Point Richards.

Subtidal seagrass health varied widely between plots but was either higher or consistent with past seasonal trends. The Office of Environmental Monitor concluded that there was no observable impact on seagrass due to the dredging (Vic Auditor General, 2012).

Principal Components Analysis (PCA) of the measurements showed that a single principal component summarized variance in seagrass cover, length and stem/shoot density from 2008 to 2011, because these variables are highly correlated. "All three variables measure aspects of seagrass canopy structure and are therefore interrelated. The outcomes of the PCA show there is a high degree of redundant information obtained by measuring all the variables, and that a single variable (seagrass cover) may function as a useful proxy for all three variables" (Hirst et al, 2012).

Hirst et al. (2012) state that percent cover may be the most useful proxy for seagrass health under a range of circumstances because it is strongly correlated with the first PCA axis, is the simplest variable to measure in the field and provides most data for the expenditure.

Seagrass cover is a robust measure of seagrass condition in Corio Bay. Its use allows increased replication and collection of data over a large spatial area (900 sites each with an area of 4 m^2). Seagrass presence and abundance mapping using seagrass cover from photographs is considered the most appropriate method to assess a change in seagrass conditions due to the refinery discharges.

3.5.3 Results

3.5.3.1 Seagrass Distribution in Corio Bay

Seagrass distribution and cover was measured throughout northern Corio Bay in many surveys conducted during 2021 to 2023 using a towed underwater camera (TUC) and composite drone images. The distribution of seagrass in the area was mapped using a combination of the TUC images, NearMap images and seasonal drone photographs. Ground truthing was achieved by direct observation at low tide for intertidal areas and diver observation (at points) and from towed video camera images at deeper sites. The extent of seagrass increased from 2021 to 2023. Cover of medium and dense seagrass was about 60 % in 2021 and increased to about 75% in 2023.

The camera tows showed that the main seagrass species in the bay are a combination of *N. muelleri* in the intertidal zone and *H. nigricaulis* and *Halophila* in the subtidal zone. A small area of *N. muelleri* with a broad leaf was observed in shallow water at the entrance to Limeburners Bay.

Figure 3-7 shows a map of seagrass zones in Corio Bay based on the species found in each zone. Starting at the high water line, the orange zone shows the intertidal area which is dominated by *N. muelleri* as well as some intertidal green algae which can be observed at several points along the shore.

Further offshore, the yellow zone represents the transition zone from intertidal seagrass to subtidal seagrass and includes a combination of *N muelleri* and *H nigricaulis*.

The light blue zone represents the shallow subtidal area that contains a combination of *H nigricaulis* and *the broad-leaf muelleri*, although is dominated by *H nigricaulis*. This zone goes down to around the 2 m depth contour.

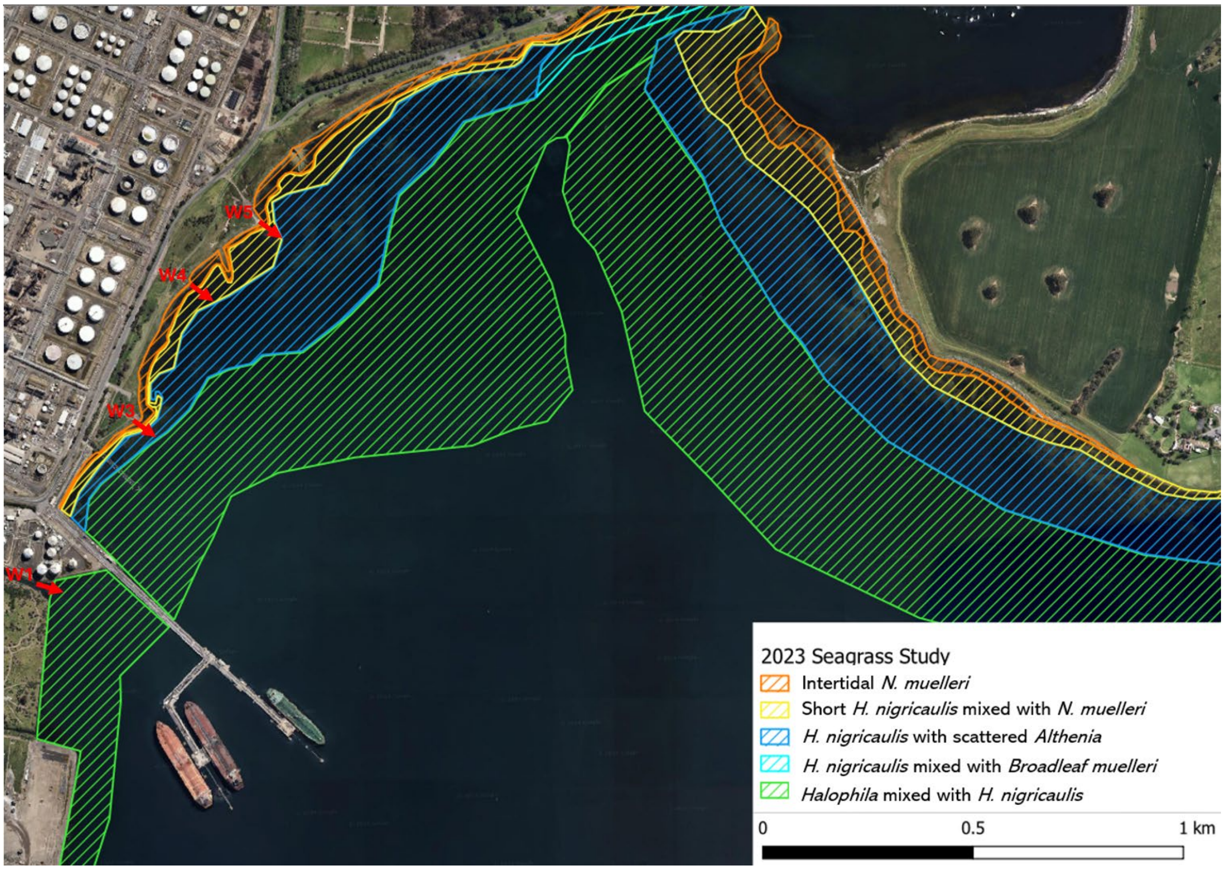


Figure 3-7. Map of Seagrass Distribution in Northern Corio Bay.

The green zone starts at around the 2 m depth contour and represents the deeper subtidal area with a combination of *H nigricaulis* and *Halophila*. The shallower part of this zone is typically dominated by *H nigricaulis*. At greater depth, *Halophila* is more dominant.

At around 5 m below mean sea level, there is insufficient available light to support seagrass growth and so the seabed at depths below 5 m is bare sand and mud that is covered in microphytobenthos (MPB) with bioturbidity organisms as found in the EES studies (CEE, 2022).

N muelleri in the intertidal and shallow subtidal zones in the vicinity of the W3 to W5 discharges is routinely exposed to the discharges. As described in Section 3.4, the refinery discharge plumes often extend to 2 m below the surface, so *H nigricaulis* and A*lthenia* are also routinely exposed to the discharges close to the discharge sites, and regularly in shallow water along the path of the plume.

Because the plume is always at the surface, seagrass that is more than 2 m below mean sea level is seldom exposed to the discharges as the plume occupies the layer of water above the seagrass. *Halophila* is a short plant and as described above, generally grows in waters below the 2 m depth contour. Thus, it grows too deep to be exposed to the discharge plumes. However the other species mentioned above are at depths which could be exposed to the plume at various tide heights.

3.5.3.2 Algae and Epiphyte Cover

The images from the long video survey were analysed for algal and epiphyte cover. The analysis showed that algae cover was episodic, with more algae covering some *H nigricaulis* plants in deeper sites and more epiphyte growth in shallower sites. Overall, the algal and epiphyte cover was reasonably consistent on the seagrass in both the existing discharge area and the Ramsar site.

3.5.3.3 Regional Scale Seagrass Distribution

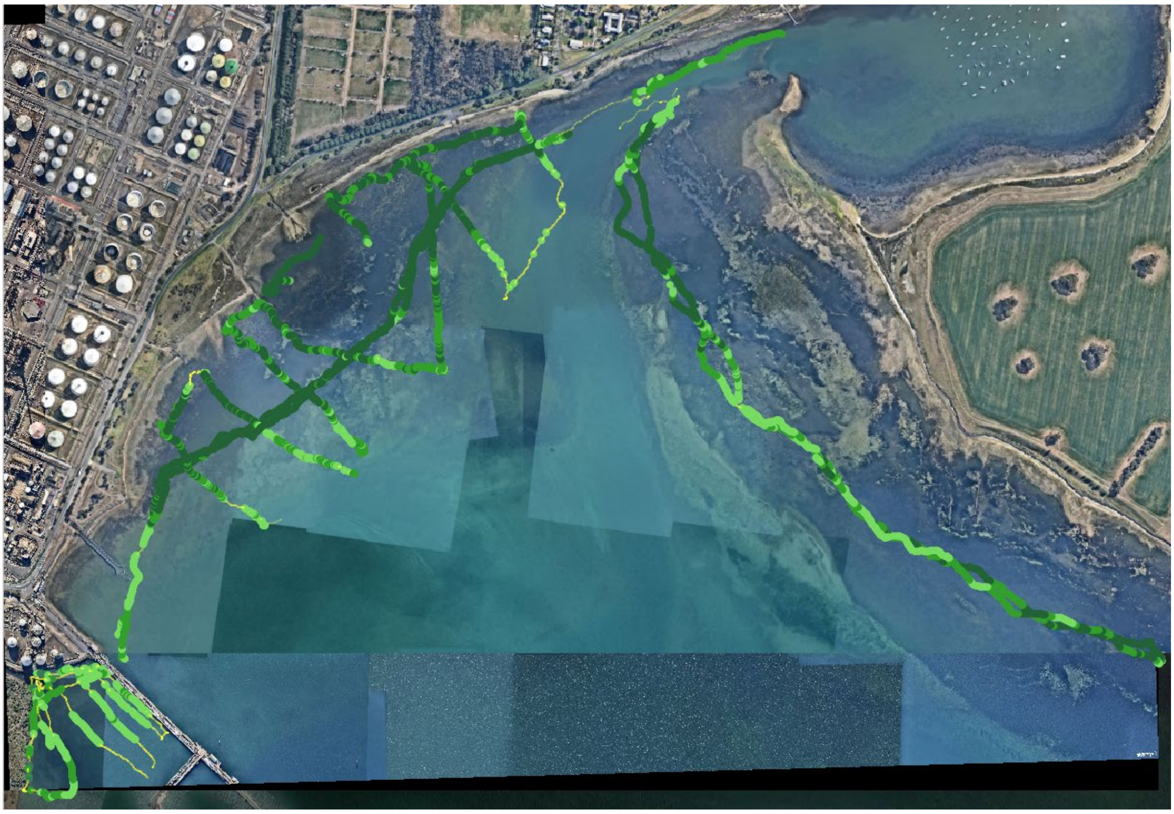
Seagrass distribution and cover also was measured at a regional scale along several transects through northern Corio Bay to supplement the extensive surveys carried out in 2020 and 2021 for the original EES, as detailed in Section 5 of Technical Report A: *Marine environment impact assessment* (CEE 2022). This included transects perpendicular to shore, from deep to shallow water, and a 3 km long transect on the 2 m depth contour along the boundary of the Ramsar site and the northern shore using an underwater camera.

The 3 km long camera survey was conducted in winter 2023 and repeated in summer 2023/2024 to assess existing conditions at those two times and changes over the intervening six months. Tows completed in the 2021 EES were repeated in 2023, specifically around the W1 discharge.

As previously noted, the main subtidal seagrass species in the bay are a combination of *H. nigricaulis* and *Halophila* in the deeper subtidal zone. Figure 3-8 shows the results of the underwater camera tows for the presence and density of cover of *H. nigricaulis* in all the tows including those in winter, spring and summer. The map shows *H nigricaulis* is the dominant species of subtidal seagrass in Corio Bay through all months and is found growing densely around the discharges and in the Ramsar site.

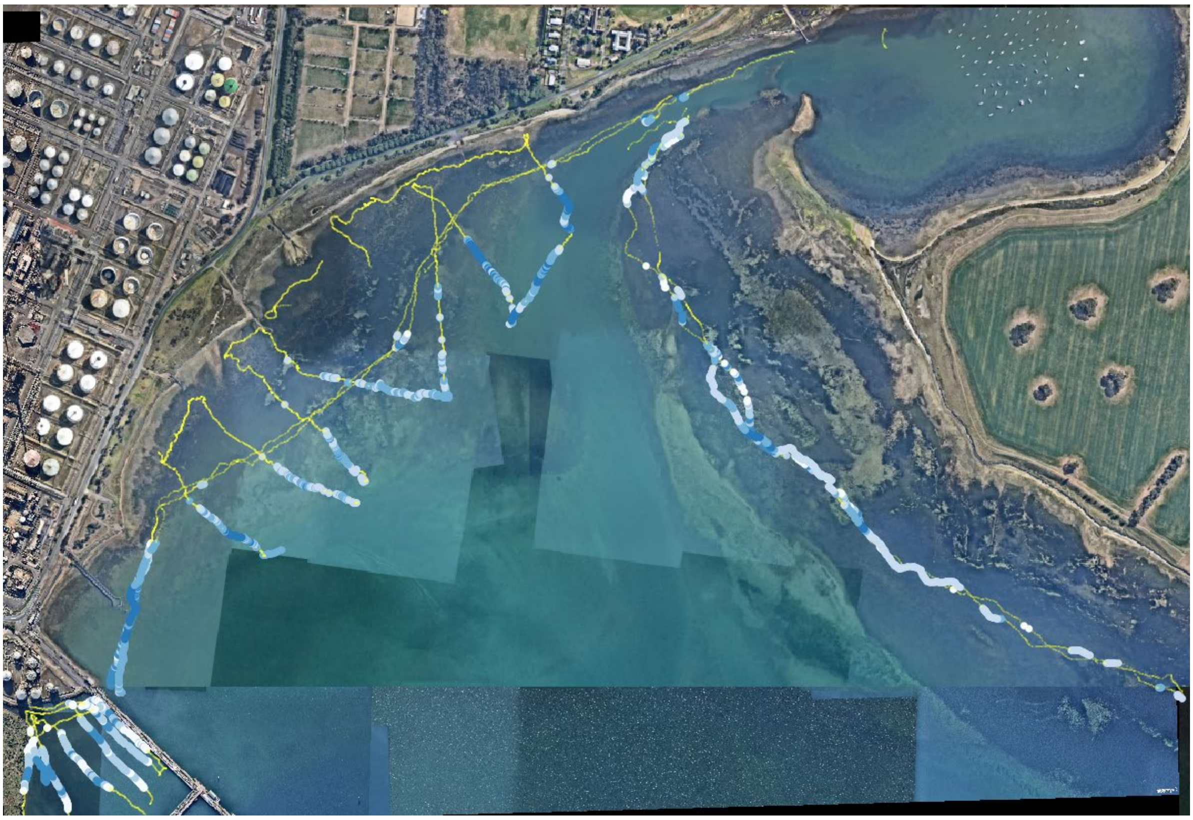
Figure 3-9 shows the results of the underwater camera tows for the presence and density of cover for *Halophila*. It was seen that *Halophila* generally grows in deeper water than the denser *H nigricaulis* and is therefore found further offshore. No *Halophila* was observed in close proximity to the discharges.

Figure 3-10 shows a small band of broadleaf *N. muelleri* seen in the entrance to Limeburners Bay. This seagrass species is the same species as *N. muelleri,* however in the shallow subtidal zone, it has broader leaves.



Legend: Density of *H nigricaulis:* light green = sparse; dark green = dense

Figure 3-8. Results of Seagrass Mapping – *H nigricaulis*



Legend: Density of *Halophila australis:* light blue = sparse; dark blue = dense

Figure 3-9. Results of Seagrass Mapping - *Halophila*

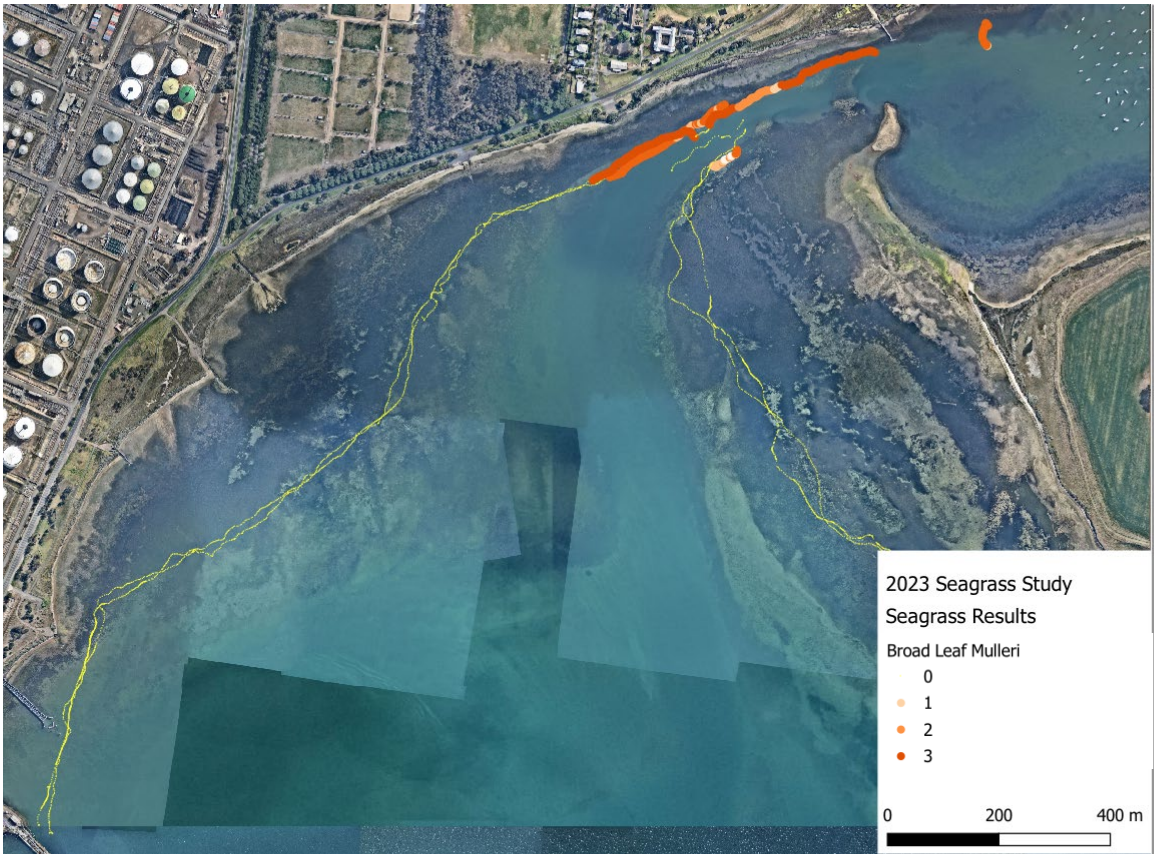


Figure 3-10. Results of Seagrass Mapping – Broadleaf Muelleri

3.5.3.4 Sea Urchin Survey Results

Sea urchins *Heliocidaris erythrogramma* are native to Port Phillip Bay and Corio Bay. The population of the sea urchins appear to have increased significantly in the last decade, including in Corio Bay (Carnell and Keough 2019). A high population of sea urchins results in overgrazing of seagrass which leads to bare patches or "urchin barrens".

While sea urchins feed on seagrass beds and other macrophytes with little effect on seagrass abundance, areas with a continued high recruitment of juvenile urchins can extend barrens and reduce the numbers of other species that would usually be expected in the habitat and water depth (Ling et al 2019).

During the 2021 survey in Corio Bay, a large number of sea urchins was recorded offshore of the discharges near W4 and W5 (see Section 5.17.1 of Technical Report A: *Marine environment impact assessment*) (2022). The 2023 surveys found that the numbers of sea urchins near the discharges had reduced substantially. However, a large patch of urchins was seen in the Ramsar site offshore from Avalon College in 2023 and a few urchins were observed during video tows offshore from W4.

In summary, over the period from 2021 to 2023 there has been a decrease in the number of sea urchins in the seagrass areas of north Corio Bay, particularly near the discharge sites. The changes in sea urchin populations are most likely natural, however there is a program to cull sea urchins in the Jawbone and Ricketts Point Marine Sanctuaries (Nature Conservancy, 2015).

3.5.4 Impact of Existing Discharges on Seagrass

Seagrass meadows are a major source of productivity in Corio Bay and dominate the seabed around the perimeter of Corio Bay. Seagrass habitats are highly productive ecosystems providing food and shelter for a rich assemblage of marine life and fulfil a range of other beneficial functions including carbon sequestration, sediment stabilisation, nutrient cycling and habitat for fish (Ball et al, 2014).

Figure 3-11 shows the locations of the two intertidal transects and two subtidal transects across discharge points W1, W3, W4 and W5 and two reference sites. At the reference sites, the same two intertidal and two subtidal transects were defined in the Ramsar site well away from the refinery discharges (blue lines in Figure 3-11). The shoreline along the Ramsar Site is very similar to the shoreline at the discharges and so the locations of the reference sites were chosen randomly, however were influenced by where the shoreline could be accessed. Reference site 1 is near Avalon Village and reference site 2 is near Avalon College. This experimental design with multiple transects and multiple areas ensures there is not pseudo-replication.

As the three dominant seagrass species are intermingled, seagrass cover is the most appropriate indicator of the impact of the existing discharges on the productivity, health and condition of seagrass in north Corio Bay. Changes in seagrass cover are correlated to changes in three environmental functions of seagrass: (1) primary production; (2) provision of habitat; and (3) stabilisation of sediments.

Additional environmental indicators of impact considered are alga cover (although alga distribution is related more to storm activity than refinery discharges), epiphytes and seagrass grazing (although seagrass cover reflects their effects) and the distribution of bare sediment patches (also incorporated in seagrass cover).

Figure 3-11. Location of Intertidal and Subtidal Transects

3.5.4.1 Intertidal Seagrass Cover

Winter

Figure 3-12 shows the intertidal and subtidal survey points near W4 and W5. Figure 3-13 shows an example of the assessed winter seagrass cover at the survey points along Line 2 (lower intertidal).

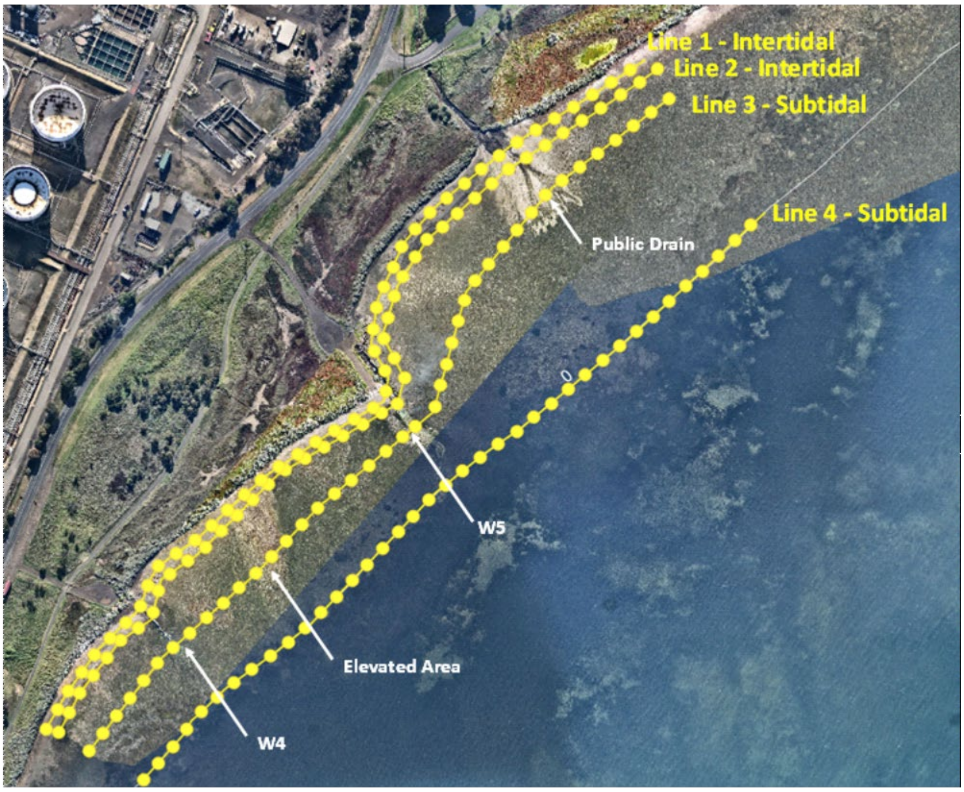
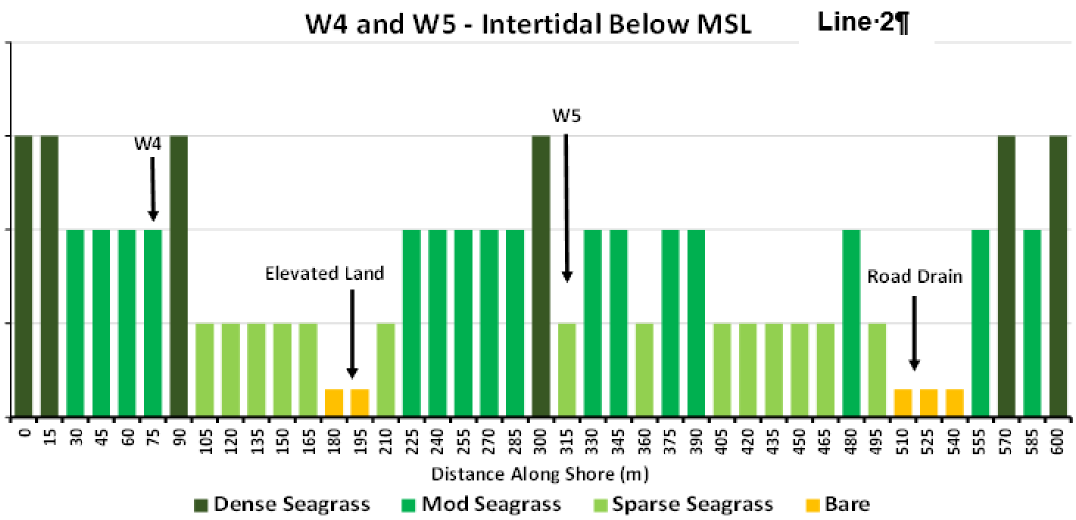


Figure 3-12. Transects and Survey Points for W4 and W5



Searass cover observed in 2x2 m area for each point

Figure 3-13. Seagrass Cover Along Intertidal Line 2 for W4 and W5 - Winter

Figure 3-13 shows the seagrass cover on 41 points along Line 2, which extends along the intertidal zone just below mean sea level. The legend for seagrass cover is shown on the figure, with high, dark green columns representing dense seagrass, medium height and colour green representing moderate seagrass cover and short light green columns representing sparse seagrass cover. Bare patches are depicted as very short orange columns.

On Line 2 through existing discharge points W4 and W5, there are 6 sites with dense seagrass, 16 sites with moderate seagrass, 14 sites with sparse seagrass and 5 sites with no seagrass. The bare patches are where sandy sediment has washed into the intertidal zone in a road drain, or elevated land. There are patches of dense and moderate seagrass adjacent to W4 and W5.

Line 1, higher in the intertidal zone, has mostly sparse patches of *N muelleri* but with a patch of dense seagrass at and adjacent to W3. The intertidal seagrass *N muelleri* is a short plant with stems being typically around 5 to 10 cm in height and favours a muddy rather than sandy seabed.

The total seagrass cover along each transect was calculated assuming:

- dense = 95 % seagrass.
- moderate = 50 % seagrass; and
- sparse = 10 % seagrass;
- bare sediment = no seagrass;

The cover results for the survey lines are averaged and summarised in Table 3-2 for intertidal seagrass (lines 1 and 2). In the intertidal area, there was lower seagrass cover observed around the W3 discharge compared to W4 and W5, and also the Ramsar site. There is no intertidal transect for the W1 site, as the bay around W1 is heavily modified with the jetties, wharfs and dredging, with rock banks on the sides.

For all winter intertidal transects, the average seagrass cover at the discharge zones (27%) was similar to the average cover at the reference sites in the Ramsar site (32%). A t-test was used to determine if there is a statistically significant difference between the means of seagrass cover on the transects at the discharge site and at the reference sites. There is no statistically significant difference between the means.

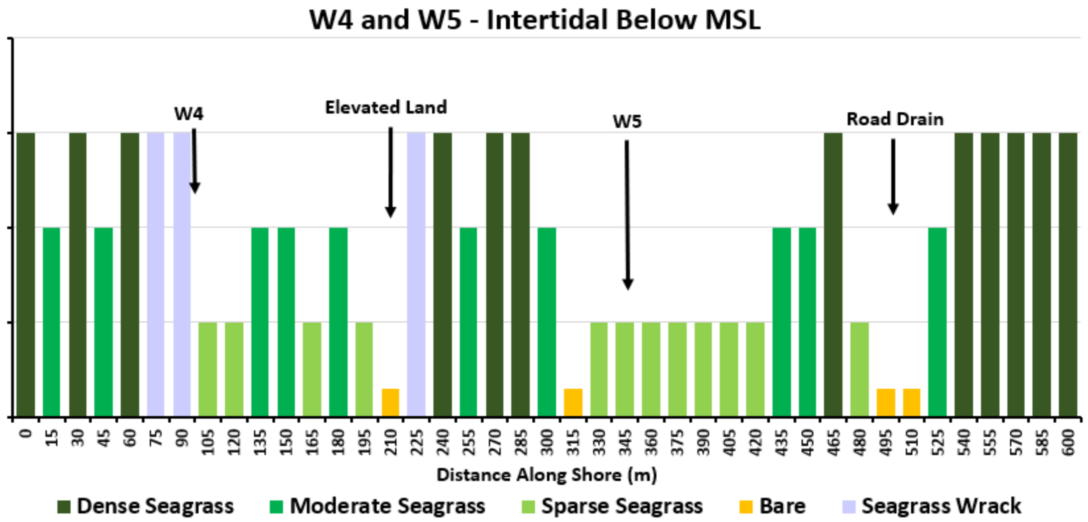
Table 3-2. Intertidal Seagrass Cover Results - Winter

Intertidal Seagrass Cover							
Cover	**W3**	**W4-W5**	**Average**	**Ref 1**	**Ref 2**	**Average**	**Std Dev**
Bare	33%	16%	**25%**	23%	7%	**15%**	11%
Sparse	30%	35%	**33%**	28%	59%	**43%**	15%
Moderate	23%	34%	**29%**	23%	15%	**19%**	8%
Dense	7%	12%	**9%**	20%	19%	**20%**	6%
AVERAGE	**21%**	**32%**	**27%**	**33%**	**31%**	**32%**	**6%**

Note: Algae cover not included in seagrass cover totals

Spring

A second analysis of intertidal seagrass cover was completed over the spring months using drone imagery and ground truthing to establish the extent of seagrass on the same four transects at the discharge points and the same four transects in the Ramsar site. Figure 3-14 shows the assessed spring seagrass cover at the survey points along Line 2 (intertidal). There are seven additional plots of seagrass cover documented in Technical Report No 5.



Searass cover observed in 2x2 m area for each point

Figure 3-14. Seagrass Cover at Intertidal Line 2 for W4 and W5 - Spring

There were changes in seagrass cover between winter and spring, with more cover at some sites (change from sparse to medium, or medium to dense). The purple columns represent the large patches of washed-up seagrass wrack along the shoreline which buried the seagrass. In between the wrack there were patches of sparse to dense seagrass. There is no seagrass on the section of elevated land between W4 and W5 or at the road drain. The area around W5 had slightly less seagrass compared to the winter survey.

The cover results for the survey lines are averaged and summarised in Table 3-3 for intertidal seagrass (lines 1 and 2) and Table 3-6 for subtidal seagrass (lines 3 and 4). There is no intertidal transect for the W1 site, as the bay around W1 is heavily modified with the jetties, wharfs and dredging with rock banks on the sides.

In the intertidal area there was lower seagrass cover around the W3 discharge compared to W4 and W5, and also in the Ramsar site, particularly at Reference site 2 where the cover decreased from 31 % to 18 %. As a result, the overall average seagrass cover in the intertidal zone near the discharge sites was higher (36%) than in the Ramsar site (24 %).

Table 3-3. Intertidal Seagrass Cover Results - Spring

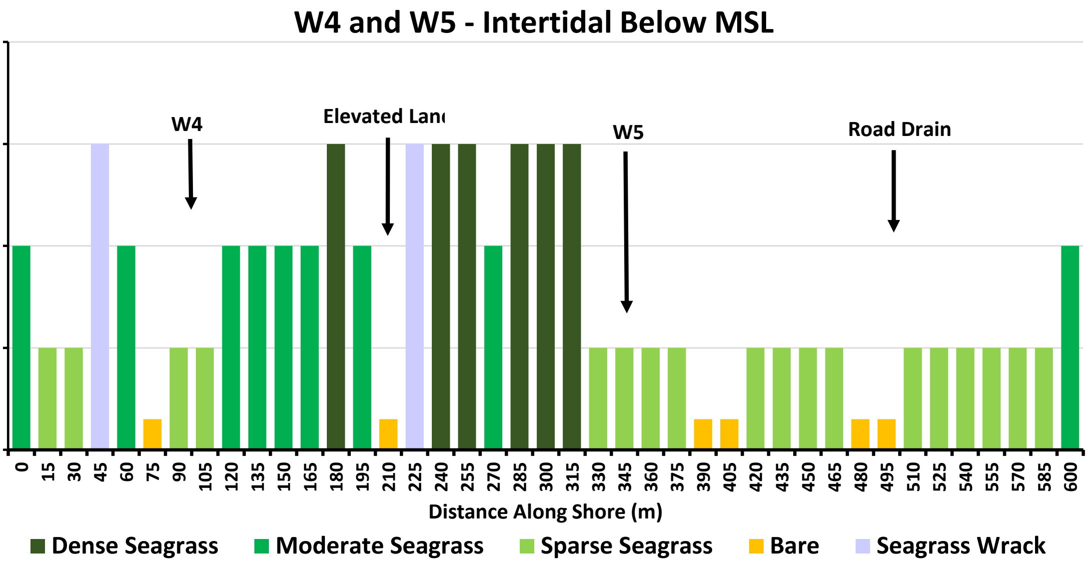
Intertidal Seagrass Cover							
Cover	**W3**	**W4-W5**	**Average**	**Ref 1**	**Ref 2**	**Average**	**Std Dev**
Bare	43%	14%	**29%**	17%	54%	**36%**	20%
Sparse	13%	38%	**26%**	39%	15%	**28%**	15%
Moderate	22%	24%	**23%**	34%	29%	**32%**	6%
Dense	22%	24%	**23%**	10%	2%	**6%**	10%
AVERAGE	**33%**	**39%**	**36%**	**31%**	**18%**	**24%**	**9%**

Summer

The third seasonal survey of intertidal seagrass cover was completed over summer months using drone imagery and ground truthing.

Figure 3-15 shows the summer seagrass cover at the survey points along Line 2 (intertidal).

There was more intertidal seagrass between the W4 and W5 discharge sites compared to spring. There were still patches of seagrass wrack along the shoreline, but less than in spring, with more intertidal seagrass evident.



Searass cover observed in 2x2 m area for each point

Figure 3-15. Seagrass Cover Along Intertidal Line 2 for W4 and W5 – Summer

Table 3-4 lists the seagrass cover in summer for intertidal seagrass (lines 1 and 2) and Table 3-7 for subtidal seagrass (lines 3 and 4). After accounting for the wrack, the intertidal seagrass cover at the discharge sites (30 %) is not significantly different from the intertidal seagrass cover at the Reference sites (34 %).

Table 3-4. Intertidal Seagrass Cover Results - Summer

Intertidal Seagrass Cover							
Cover	**W3**	**W4-W5**	**Average**	**Ref-1**	**Ref-2**	**Average**	**Std Dev**
Bare	23%	22%	**23%**	0%	37%	**26%**	21%
Sparse	38%	44%	**41%**	30%	28%	**22%**	13%
Moderate	15%	21%	**18%**	55%	30%	**43%**	18%
Dense	23%	12%	**18%**	15%	5%	**10%**	7%
AVERAGE	**33%**	**26%**	**30%**	**45%**	**23%**	**34%**	**10%**

3.5.4.2 Subtidal Seagrass Cover

Winter

The same procedure was followed to assess seagrass cover on the subtidal transects in the three seasons. High quality images were obtained using low-flying drones of the intertidal and shallow subtidal areas or, in deeper water, by underwater camera images.

Line 3, in the shallow subtidal zone, shows equal amounts of dense, moderate and sparse seagrass cover, with one bare patch. Line 4, in deeper water, shows mostly dense seagrass, including just south of the W3 discharge, with moderate seagrass on each side of W3.

Similar seagrass cover patterns were measured in the Ramsar Site. For example, Line 3 in the reference site shows approximately equal amounts of dense, moderate and sparse seagrass cover, with one bare patch. Line 4 in the reference site shows mostly dense seagrass, with one site of moderate seagrass.

The Line 3 and Line 4 transects, and corresponding measurement points were used and the seagrass cover was quantified using the same definitions. Over the three seasons, subtidal seagrass cover was assessed at 450 sites in the discharge zone and 450 points in the reference zone.

Generally, there was much more seagrass cover in the subtidal zone with the cover increasing with depth. The average subtidal seagrass cover was 66 % near W3 and 69 % near W4 and W5, with an overall average cover in the discharge zone of 67 %. The subtidal seagrass cover was more variable in the reference zone, with an average of 62 % at Reference site 1 and 77 % at Reference site 2. The overall average seagrass cover in the reference sites was 69 %, almost the same in the discharge zone (67 %). There is no statistically significant difference.

Table 3-5. Subtidal Seagrass Results - Winter

Subtidal							
Cover	**W3**	**W4-W5**	**Average**	**Ref-1**	**Ref-2**	**Average**	**Std Dev**
Bare	3%	4%	**4%**	11%	4%	**8%**	4%
Sparse	17%	6%	**12%**	11%	7%	**9%**	5%
Moderate	27%	38%	**32%**	30%	19%	**24%**	14%
Dense	53%	52%	**52%**	48%	70%	**59%**	12%
AVERAGE	**66%**	**69%**	**67%**	**62%**	**77%**	**69%**	**6%**

Spring

The subtidal seagrass cover analysis showed very similar seagrass cover along each of the transects in the discharge area and the reference zones. The overall average for the discharge areas (74%) was very similar to the Ramsar site (72%). There is no statistically significant difference.

Table 3-6. Subtidal Seagrass Cover Results - Spring

Subtidal Seagrass Cover							
Cover	**W3**	**W4-W5**	**Average**	**Ref-1**	**Ref-2**	**Average**	**Std Dev**
Bare	3%	4%	**4%**	2%	5%	3%	1%
Sparse	7%	10%	**9%**	17%	4%	10%	6%
Moderate	30%	18%	**24%**	29%	19%	24%	7%
Dense	60%	68%	**64%**	52%	72%	62%	9%
AVERAGE	**73%**	**75%**	**74%**	**66%**	**78%**	**72%**	**5%**

Summer

Table 3-7 shows that most of the subtidal survey points had moderate to dense seagrass by summer. Moderate seagrass was assessed at 22 % of the discharge points and 21 % of the reference points. The proportion of dense seagrass was higher at the discharge sites than at the reference sites, but overall, there is not a significant difference in the proportion of seagrass cover at the discharge sites (73 %) compared to the proportion at the reference sites (67 %).

Table 3-7. Subtidal Seagrass Results - Summer

Subtidal Seagrass Cover							
Cover	**W3**	**W4-W5**	**Average**	**Ref 1**	**Ref 2**	**Average**	**Std Dev**
Bare	0%	2%	**1%**	2%	6%	**4%**	3%
Sparse	17%	9%	**13%**	21%	13%	**17%**	5%
Moderate	24%	19%	**22%**	17%	25%	**21%**	4%
Dense	59%	70%	**64%**	60%	56%	**58%**	6%
AVERAGE	**70%**	**77%**	**73%**	**68%**	**67%**	**67%**	**3%**

3.5.4.3 Subtidal Seagrass Cover

Figure 3-16 shows the seagrass cover at W4 and W5 with increasing depth. The results show the increase of seagrass between below low tide and LAT, increasing from 39 % in winter to 90 % in spring. There was slightly less cover on the transect below LAT (86 %) where some patches of sparser seagrass were observed.

Overall, this analysis of seagrass cover shows that seagrass is persistent in the area of the discharges however, there is increased seagrass at depth which is expected due to greater water depth with sufficient available light.

There is a lot of spatial variability on a local scale as patches of seagrass can come and go with natural changes to conditions due to storms, sediment movement, swan and sea urchin grazing, disease and other factors.

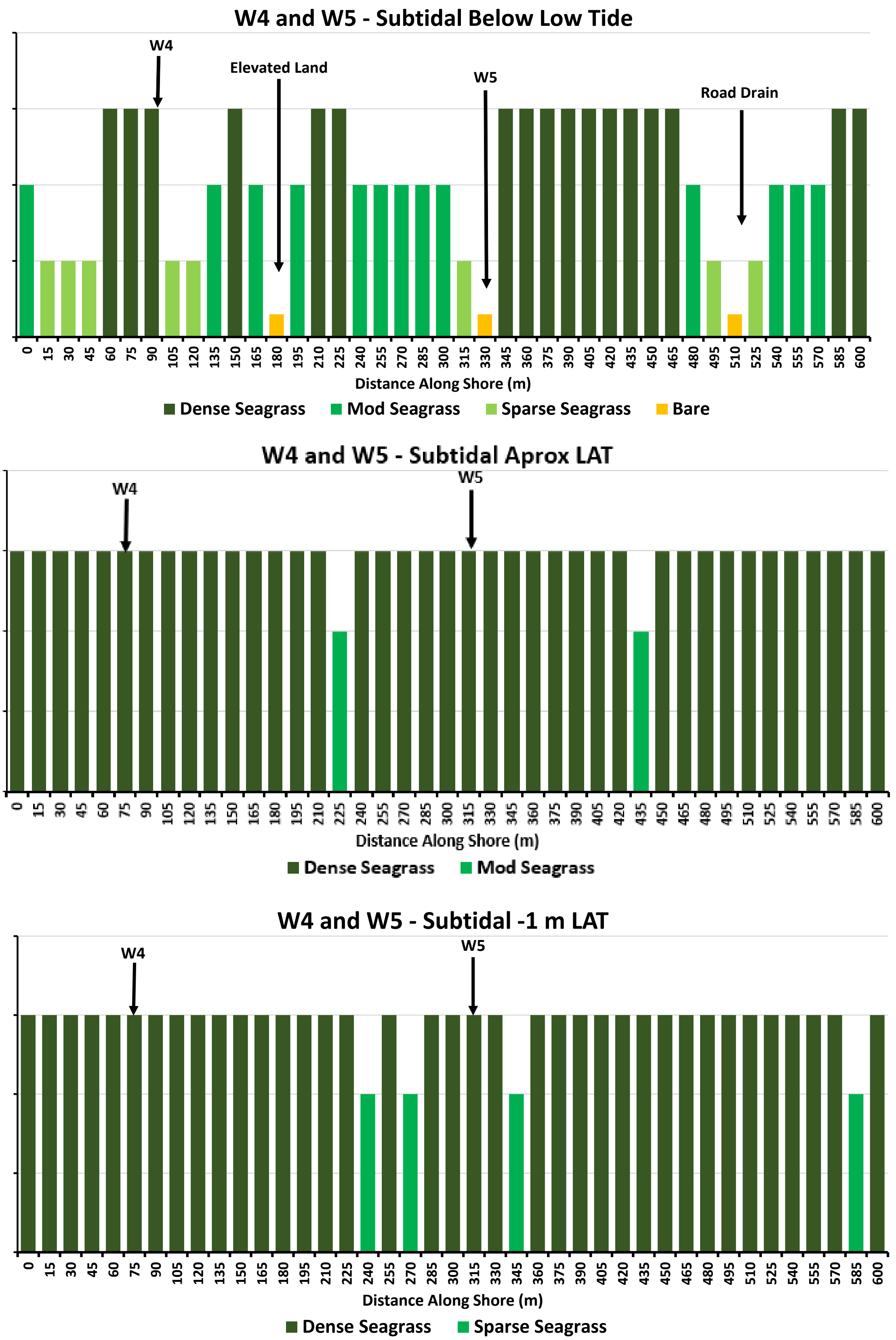


Figure 3-16. Seagrass Cover in 2x2 m Area Along Subtidal Lines at W4 and W5

3.5.4.4 Assessment of Seagrass Cover at Impact Sites vs Reference Sites

Intertidal Sites (2023)

Figure 3-17 shows the data for the average intertidal seagrass cover measured in the discharge zone (blue columns) and the average intertidal seagrass cover measured in the reference zone (green columns). Over the three period from winter to summer, the average seagrass cover in the discharge zone of 31 % was about the same as the average seagrass cover in the reference zone of 30 %.

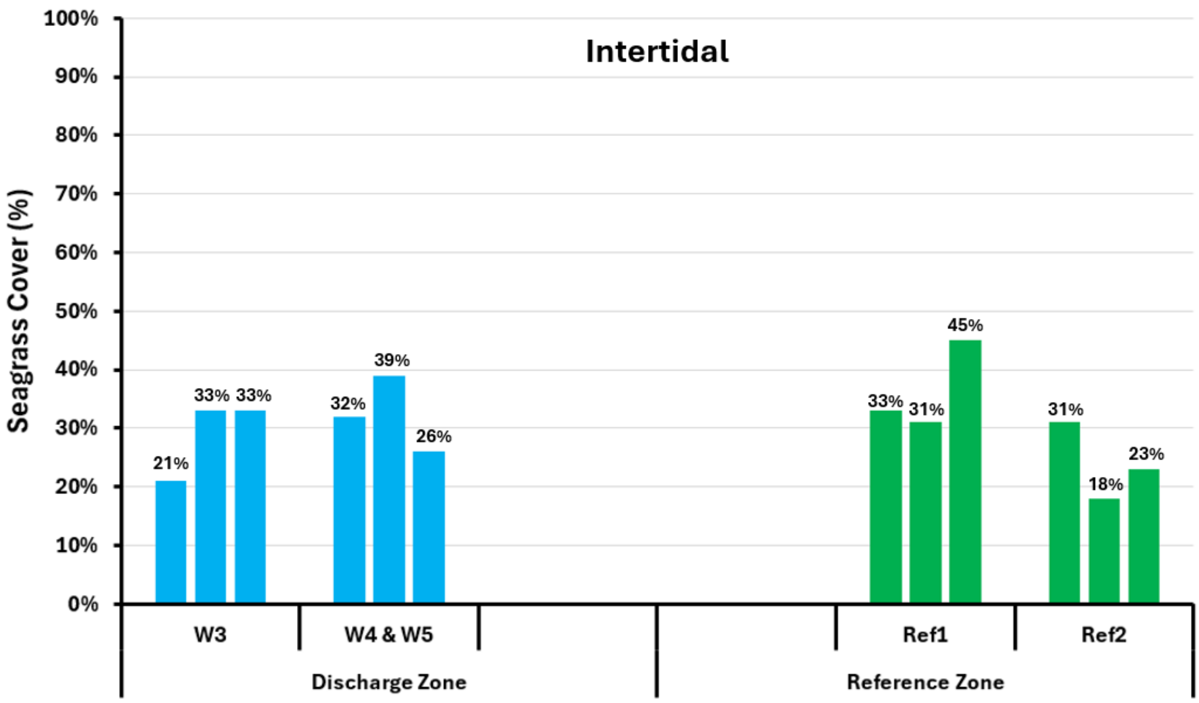


Figure 3-17. Comparison of Cover in Intertidal Discharge and Reference Sites

The two-sided t-test is used to determine whether there is a significant difference between the seagrass cover in the two zones. The 6 cover measurements in the discharge zone (Mean = 31, SD = 6.3) compared closely to the 6 cover measurements in the reference zone (Mean = 30, SD = 9.3). The two-sided t value is 0.11. The p-value is 0.92. Degrees of freedom = 10. The difference in seagrass cover is not significant at $p < .05$.

Even though the intertidal seagrass in the discharge zone in immersed in the discharge plumes during most high tides, there is no significant effect on seagrass cover – with neither extra seagrass or less seagrass. It is concluded that the presence of the discharge plumes does not have a significant impact on intertidal seagrass cover.

Seagrass Directly Under Plumes

Seagrass was observed growing directly in the W1, W4 and W5 discharge plumes. The seagrass was inspected by marine biologists and observed to have the same leaf colour, leaf height, low epiphyte count, and density as the adjacent seagrass (Crockett, 2022, Chidgey, 2024).

Subtidal Sites (2023)

Figure 3-18 shows the data for the average subtidal seagrass cover measured in the discharge zone (blue columns) and to the average subtidal seagrass cover measured in the reference zone (green columns). The average seagrass cover in the discharge zone of 72 % is slightly higher than the average seagrass cover in the reference zone of 68 %.

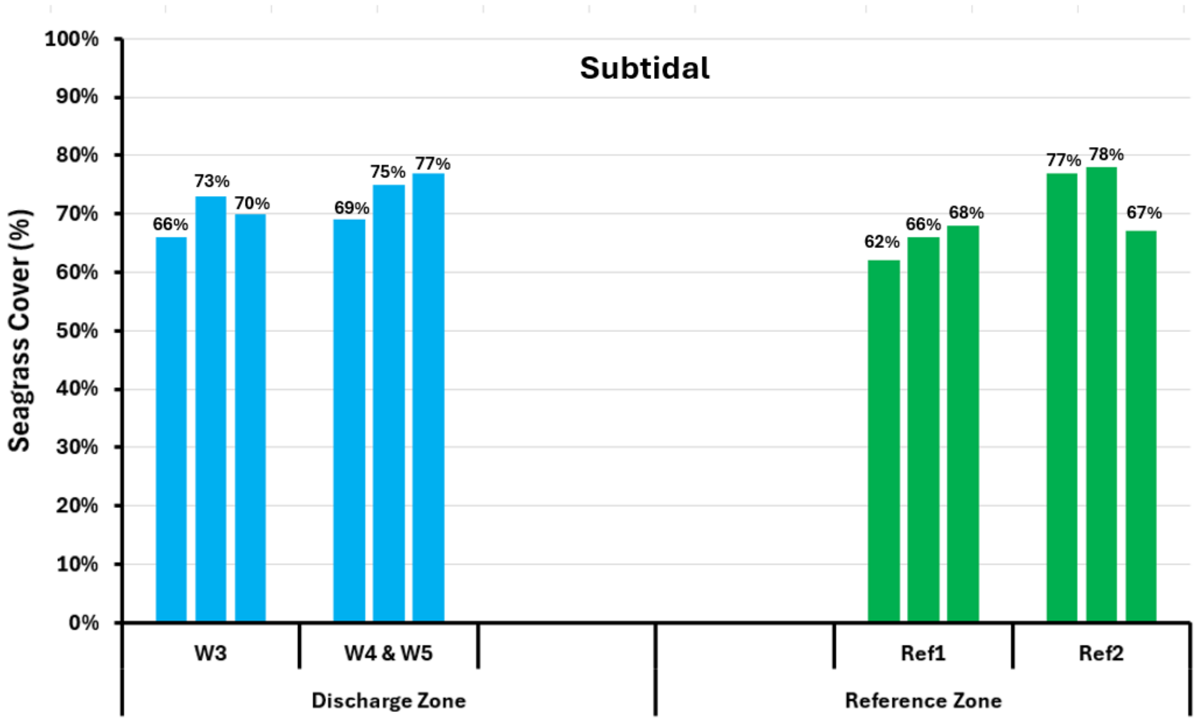


Figure 3-18. Comparison of Cover in Subtidal Discharge and Reference Sites

The two-sided t-test is used to determine whether there is a significant difference between the seagrass cover in the two zones. The 6 cover measurements in the discharge zone (Mean = 72, SD = 4.1) are similar to the 6 cover measurements in the reference zone (Mean = 68, SD = 5.7). The two-sided t value is 1.22. Degrees of freedom = 10. The p-value is 0.25. The difference in seagrass cover is not significant at $p < .05$.

Even though the subtidal seagrass in the discharge zone in or under the discharge plumes most of the time, there is no significant effect on seagrass cover – with neither extra seagrass or less seagrass. It is concluded that the presence of the discharge plumes does not have a significant impact on subtidal seagrass cover.

As discussed in Section 3.5.2.1, Hirst et al. (2012) state that seagrass cover may be the most useful proxy for seagrass health under a range of circumstances because it is strongly correlated with seagrass length, stem/shoot density and canopy structure.

3.5.5 Year to Year Variation in Seagrass Cover

Even though the seagrasses in Corio Bay are persistent, there are variations at a local scale from year to year, or even within years. However, the data show no detectable gradient in change with distance from the discharge points.

The seagrass cover at the W5 discharge varied considerably over time. In May 2021 and June 2023, the channel had noticeable seagrass around the exit whereas in April 2022 and August and November 2023 there was little seagrass in the channel. December 2023 showed a decrease in seagrass all around the outlet.

Patches of seagrass in Port Phillip Bay and Corio Bay can vary in size and density in short time periods. Some of this change is seasonal but other changes are caused by variations in environmental conditions and grazing (Jenkins et al, 2015). Figure 3-19 shows the variation in *H nigricaulis* cover at several sites in Port Phillip Bay between 2008 and 2011.

Overall, the time series images show that patches of seagrass in Corio Bay come and go with seasonal changes as well as other factors including sea urchins (which feed on seagrass), nutrient availability and seabed characteristics.

The key services provided by seagrass in Corio Bay are (1) primary productivity; (2) habitat and (3) food supply. The methodology used to quantify seagrass cover provided a suitable description of these outcomes and showed that the same level of services are provided by seagrass in the discharge zone as in the Ramsar site, as the seagrass cover is the same in both areas.

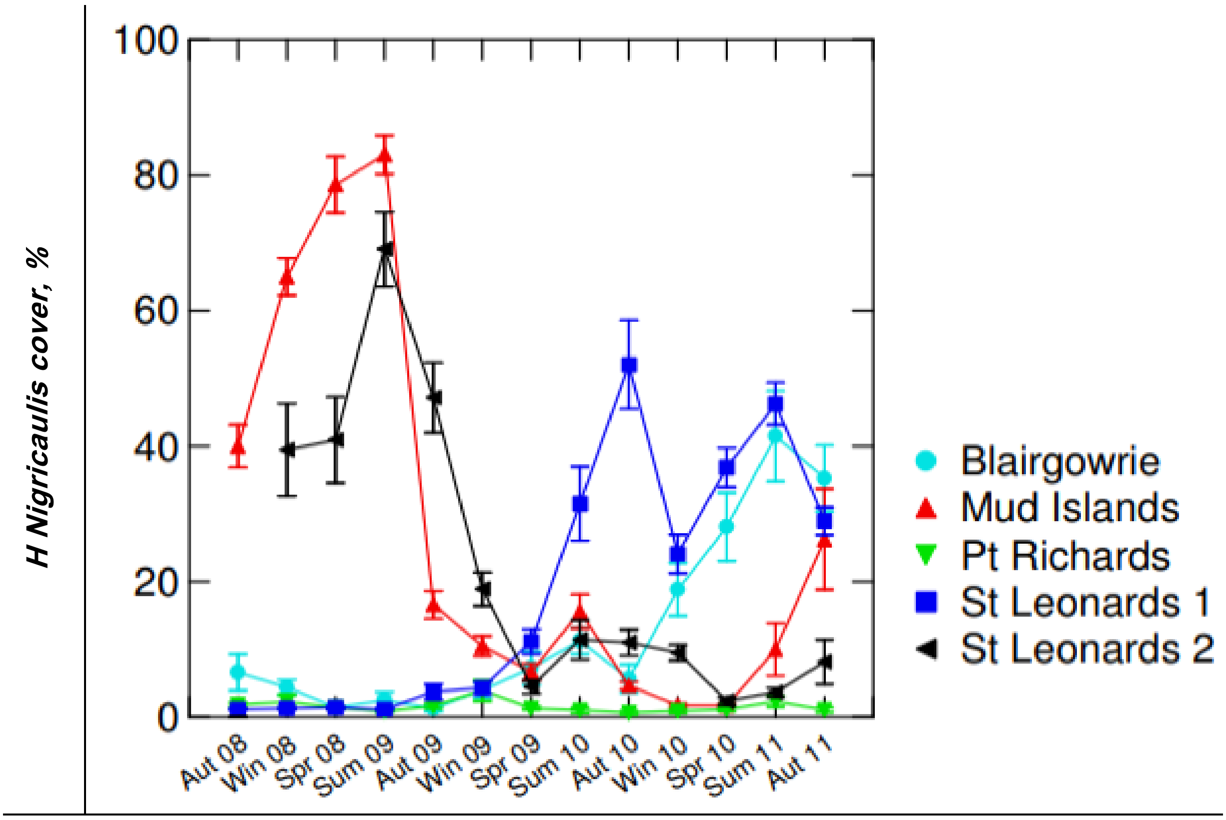


Figure 3-19. Variation in Seagrass Cover in Port Phillip Bay

3.6 Task 1c/d Proposed Baseline Surveys Prior to Dredging

3.6.1 Requirement for Baseline Study

A marine ecological survey is required to establish baseline environmental conditions in the 12-month period prior to commencing dredging works and construction at Refinery Pier. The purpose of the program is to define the condition of the existing environment and determine if dredging causes any negative impacts outside of the natural variation. The seagrass studies have demonstrated that there is a significant year to year variation in seagrass and therefore the baseline monitoring of seagrass to detect the impacts of dredging should be scheduled for the year just before the dredging.

The baseline survey needs to be carried out 12-months prior to the commencement of dredging or construction to provide the most accurate and representative baseline for project monitoring during and after construction. This task will form part of the secondary approvals process (*Marine and Coastal Act Consent*) and this task will not form part of the Supplementary Statement.

This longer and more extensive survey will be carried out over the period of 12 months before construction or dredging starts, with a minimum of four sampling runs (one in each season) to address seasonal variability.

3.6.2 Reference Documents

Key reference documents used for developing the proposed baseline survey methodology are:

- EPA Victoria, (2001), "*Guidelines for Dredging",* Publication 691
- EPA Western Australia (2021) "*Environmental Impact Assessment of Marine Dredging Proposals",* Technical Guidance
- G Jenkins, M Keough, D Ball, P Cook, A Ferguson, J Gay, A Hurst, R Lee, A Longmore, P Macreadie, S Nayer, C Sherman, T Smith, J Ross and P York (2015), *"Seagrass Resilience in Port Phillip Bay",* Final Report, DELWP.
- Marine Science & Ecology (2006), *Review of Impacts of Dredging Turbidity Plumes on Seagrass in the Geelong Arm Channel Improvement Program, 1997",* Report to Victorian Regional Channel Authority.

Victorian Dredging Guidelines

The EPA Victorian Dredging Guidelines state that longer-term monitoring is required to improve future dredging by better assessment of impacts, where they may be significant, but their duration or extent are poorly documented, and to confirm predictions in larger projects.

In developing forward-looking monitoring plans the following issues need to be considered:

- Assessment of impacts can usually be undertaken much more efficiently by thoroughly monitoring particular proposals rather than inadequately monitoring each proposal,
- Some impacts are better assessed by targeted research than by routine monitoring,
- Monitoring programs should be integrated with regional monitoring programs where possible.

The *Victorian Dredging Guidelines* note that the costs of monitoring small and large dredging projects are similar, and so monitoring is done predominantly on large projects. Even there, monitoring should address specific objectives, either contributing to ongoing improvement of dredging methods or providing reassurance to the public through accurate information on measurable impacts. Where adequate information already exists on the extent, duration or cause of dredging impacts, further monitoring should not be required.

The Victorian Dredging Guidelines emphasise the importance of monitoring photosynthetically available radiation (PAR) which is the light available for seagrass, algae and phytoplankton to photosynthesise. Appendix 5 of the Dredging Guidelines describe the relationship between light attenuation and turbidity in Corio Bay, suspended solids and turbidity in Corio Bay, turbidity limits used in previous dredging programs in Corio Bay, light requirements of seagrass and suggested limits on NTU for dredging in Corio Bay. The baseline monitoring must focus on measurement of background turbidity and light levels.

WA EPA Technical Guidance

The *WA EPA Technical Guidance* (EPA, 2021) is the latest version including the findings of the research program undertaken by the Dredging Science Node of the Western Australian Marine Science Institution (WAMSI). The WAMSI findings are available through the publication of nearly 100 scientific reports including 53 peer-reviewed journal articles and have significantly increased the understanding of dredging pressures, and the tolerance of marine biota to those pressures.

The Technical Guidance is structured in three areas which provide up-to-date and valuable guidance:

A. Guidelines to predict and manage the impacts of dredging;

B: Windows of environmental sensitivity;

C: Dredge-related environmental surveys, monitoring and management.

The WA EPA Guidelines recommend characterising the physical environment (light and turbidity) and the biological environment (focussing on seagrass, corals and sponges). Note that corals and sponges are very uncommon in Corio Bay because the seabed is soft mud (suitable for seagrass) and not rock (suitable for corals and sponges).

The WA EPA Guidelines recommend the key water quality parameters to measure are seabed light measured as photosynthetically active radiation (PAR) used to derive benthic daily light integral (DLI), turbidity as NTU and total suspended sediments (TSS).

3.6.3 Previous Monitoring of Dredging Impacts in Corio Bay

In planning the baseline studies for the proposed dredging program, it is appropriate to refer back to previous dredging programs in Corio Bay, to assess what impacts were identified and what monitoring programs were implemented successfully.

For comparison, the proposed dredging program involves the excavation of 490,000 m^3 of sediment to make a new berth and turning basin at Refinery Pier. Dredging is proposed for a period of 8 weeks using a backhoe dredging operating at similar production rates as previous dredging programs in Corio Bay and Port Phillip Bay. The modelling of suspended solids concentrations carried out for the supplementary studies shows that, at the site with the highest concentrations, suspended sediment will exceed 10 mg/L for only 24 hours in daylight and exceed 5 mg/L for 114 hours in daylight (less than 10 days). These predictions suggest the impacts on seagrass may be mild and difficult to discern in relation to other factors.

Shipping channels for the Port of Geelong have been progressively enlarged and modified over a period of approximately 150 years to allow for safe ship access to the port (Worley Parsons 2011) with approximately 20 million m^3 of material dredged to create and maintain the shipping channels between 1854 and 1997. For context, this is forty times the volume of the proposed dredging program. The volume of dredging in historical dredging programs is shown in Figure 3-20. In the figure, the proposed dredging (490,000 m^3) in this project is shown as the final red column. The proposed dredging could be classed as a small to medium dredging project. Nonetheless, it is important to develop a baseline so that any impacts of dredging can be determined.

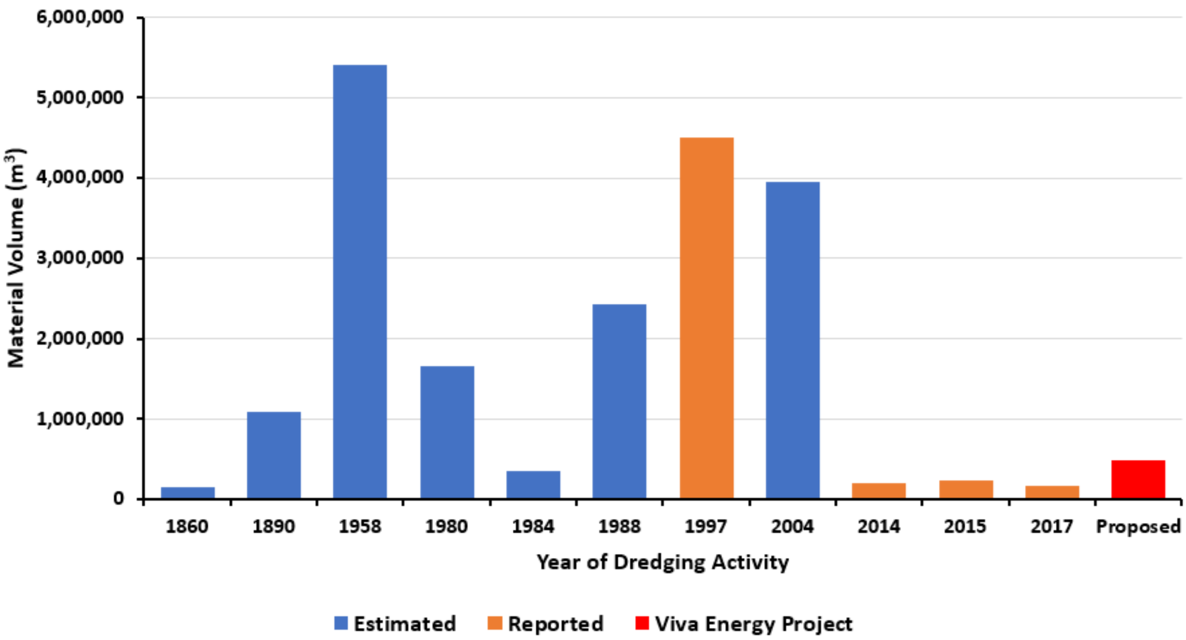


Figure 3-20. Comparison of Dredging Programs in Corio Bay

The 1996-1997 dredging program could be classed as a large dredging project as it involved dredging 4.5 million m^3 of sediments at the Grain Pier, Lascelles Wharf and Refinery Pier and Point Henry, mostly areas close to the proposed dredging at Refinery Pier and involving the same sediment characteristics. There was extensive monitoring of turbidity generated by the dredging in Corio Bay, and the effects on seagrass and algae, as summarised below.

Turbidity monitoring by Lawson and Treloar (1998) for the 1996-1997 Channel Improvement Program showed the following results for average turbidity in Corio Bay:

- Pre-dredging turbidity = 0.4 to 1.2 NTU (23 surveys);
- During dredging turbidity = 0.5 to 2.5 NTU (19 surveys);
- Post-dredging turbidity = 0.4 to 1.0 NTU (7 surveys).

There was a small increase in turbidity during the dredging period of 14 months, with a rapid return to baseline conditions when the dredging was completed.

Marine Sciences & Ecology (2006) conducted a study on the effects on seagrass between Avalon and Pt Wilson of the 1997 dredging program. Monthly surveys of seagrass cover and biomass were undertaken – 14 surveys prior to dredging; 14 surveys during dredging and 3 surveys after dredging. The surveys involved quantitative photographic and video monitoring supported by qualitative in situ observations and estimation of biomass in 0.25 m^2 sample areas by harvesting seagrass and algae.

The MSE monitoring demonstrated that both the cover and biomass (standing crop) of *H. nigricaulis* was unaffected by turbidity generated during the dredging program.

The MSE surveys established that the biomass of filamentous algae covering a small proportion of the seagrass declined with the reduction in incident light due to turbidity, allowing some extra growth of the seagrass that had been shaded by algae (MSE, 2006).

3.6.4 Conceptual Ecological Model of Corio Bay

Figure 3-21 shows a Conceptual Ecological Model of Corio Bay prepared by CEE to illustrate the key ecological components in the intertidal and subtidal areas. As explained by Jenkins et al (2015), seagrass in the dominant component of the intertidal and shallow subtidal waters. Swans feed on the seagrass in shallow water and the bare patches contain a range of infauna and burrowing organisms. Shore birds feed in the intertidal area and on small animals in seagrass wrack.

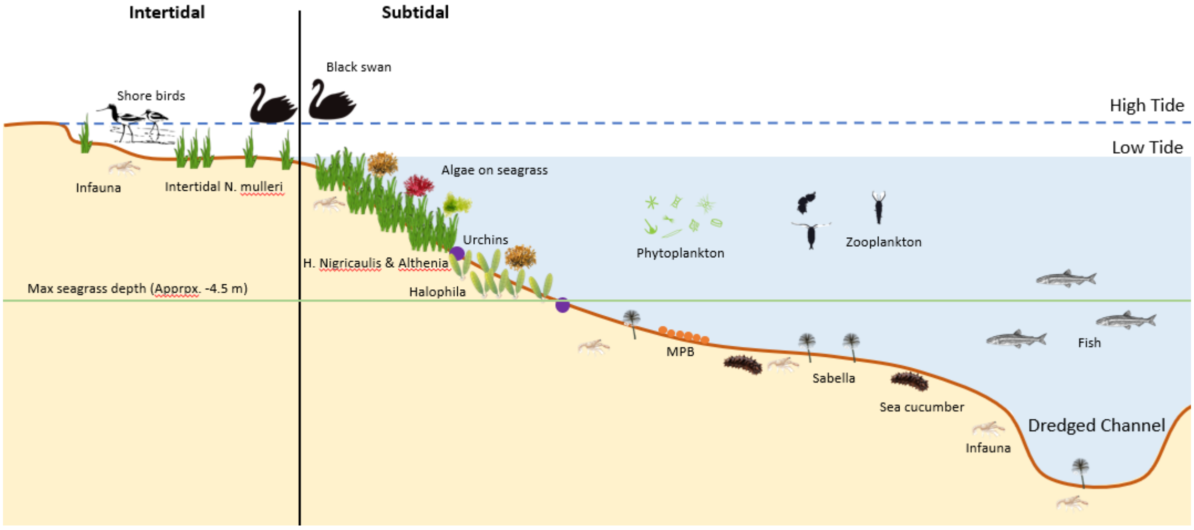


Figure 3-21. Conceptual Model of Corio Bay Ecosystem

Seagrass habitats and the potential impacts of the project on seagrass habitats have been a major focus of the EES and supplementary studies. The importance of seagrasses as primary producers, oxygen suppliers, biotic habitat and seascape features is recognised. A range wide range of marine species are associated with habitat created by seagrasses.

The distribution of *H nigricaulis* ('black-stemmed' seagrass) in northern Corio Bay is well-understood from historical studies of seagrass in Port Phillip Bay, the EES studies and the supplementary marine studies. Meadows are persistent at locations extending from the low tide mark to around 4 m, although meadow boundaries and condition vary from year to year according to variations in natural parameters.

Althenia marina (previously *Lepilaena marina*) is distributed in sheltered brackish to hypersaline habitat (lagoons and estuaries) from eastern Victoria to southern West Australia and around Tasmania. It is an annual plant, only occurring during spring and summer. It is growing occasionally and patchily in the lower intertidal/upper subtidal area along the refinery shoreline of Corio Bay among *H nigricaulis*. The refinery coastline represents marginal habitat for *Althenia*, which prefers calmer conditions such as in Limeburners Bay and Swan Bay.

The size, depth and extent of the existing temperature and chlorine plumes have been measured. The plumes are shallow and on the surface, mostly above the dense seagrass meadows, so there is little or no direct effect on *H nigricaulis* and *Althenia.* The seagrass cover assessment showed no change in seagrass cover in the discharge zone compared to seagrass cover in the Ramsar site.

The chlorine plumes are small and will not change with (or without) the project. The temperature plumes will become smaller with the project, as illustrated in Section 5.5.2.

Dredging will not, on average over the 8-week dredging period, cause a significant reduction in light available for seagrass growth (see Section 10). There will be short term pulses of high turbidity which will be monitored and managed (by, for example, reducing the duration of barge overflow and slowing the rate of dredging). Thus, dredging will be managed to avoid or minimise potential impacts of light reduction on both species of marine seagrass.

3.6.4.1 Threatened Species

The Flora and Fauna Guarantee Act (FFG Act) 1988 February 2024 threatened species list includes 14 marine invertebrate species. These species have been rarely collected in Victoria. While a few may be associated with seagrass habitat, others are not likely to be associated with seagrass or found in the particular environmental conditions of Corio Bay.

Athanopsis australis is known from collections in "sand, mud and reef" seabed in Port Phillip Bay and Bridgewater Bay in Victoria. It has been collected on a shelly sand seabed near Point Wilson. As a rarely collected species, it has not been collected within seagrass but is possible that it may also be associated with seagrass.

The sea cucumber *Apsolidium handrecki* is found on a wave-affected rocky platform in southern Western Port, and therefore is considered to be unlikely to occur in a seagrass habitat in Corio Bay.

The sea cucumber *Thyone nigra* has been collected from Corio Bay (and the known habitat extends as far as Fremantle in West Australia). Sea cucumbers were collected in some infauna sediment grabs during the EES studies, but none were *Thyone nigra* (Avery pers comm. 2023). It is possible that this small sea cucumber may occur in the vicinity of the project development area, but none have been collected in Victoria since around 1960.

Other listed species that may be associated with seagrass (eg, *Pseudocalliax tooradin* from Western Port) may occur in Corio Bay, but in very scarce abundance.

The proposed dredging would occur in a 12 ha area with a muddy seabed. It will result in a muddy seabed of the same character, but several metres deeper. The infauna studies in the EES show that a similar infauna community will re-establish in the dredged area.

A turbid plume can reduce the light available to primary producers, including seagrass, phytoplankton and MPB. During the 8-week dredging program, there will be reduced visibility for some animals including fish and sea birds, although that is a natural occurrence in Corio Bay from strong winds, turbulent eddies and ship movements.

Dredging and subsequent settlement of suspended solids will lead to removal of infauna and localised burial and clogging.

Mobilisation of nitrogen from pore water in sediments may increase phytoplankton blooms, and the Victorian Dredging Guidelines recommend sampling to assess whether toxic blooms develop.

3.6.5 Proposed Methodology for Baseline Monitoring for Dredging Impacts

A summary of what the baseline surveys could include is provided in this section, noting that the final methodology would be developed in consultation with the relevant government agencies and approved prior to implementation. It is proposed that the baseline monitoring occurs for one year before dredging, during dredging and for one year after dredging.

Light and NTU Monitoring

Monitoring of light (as PAR) and turbidity (as NTU) is the focus of dredging-related monitoring. The 12-month study should establish baseline conditions prior to dredging, record the reductions during the dredging period and monitor the recovery after dredging has been completed. As NTU and light will be directly monitored, TSS monitoring is not required.

Continuous turbidity (NTU) monitors would be deployed at three sites along the outer boundary of the Ramsar site and one site closer to the dredging footprint. Two light (PAR) monitors would be deployed between the NTU monitors along the Ramsar Site. The results would give a good understanding of light conditions for the seagrass in the Ramsar site. The proposed locations of the sensors are shown in Figure 3-22.

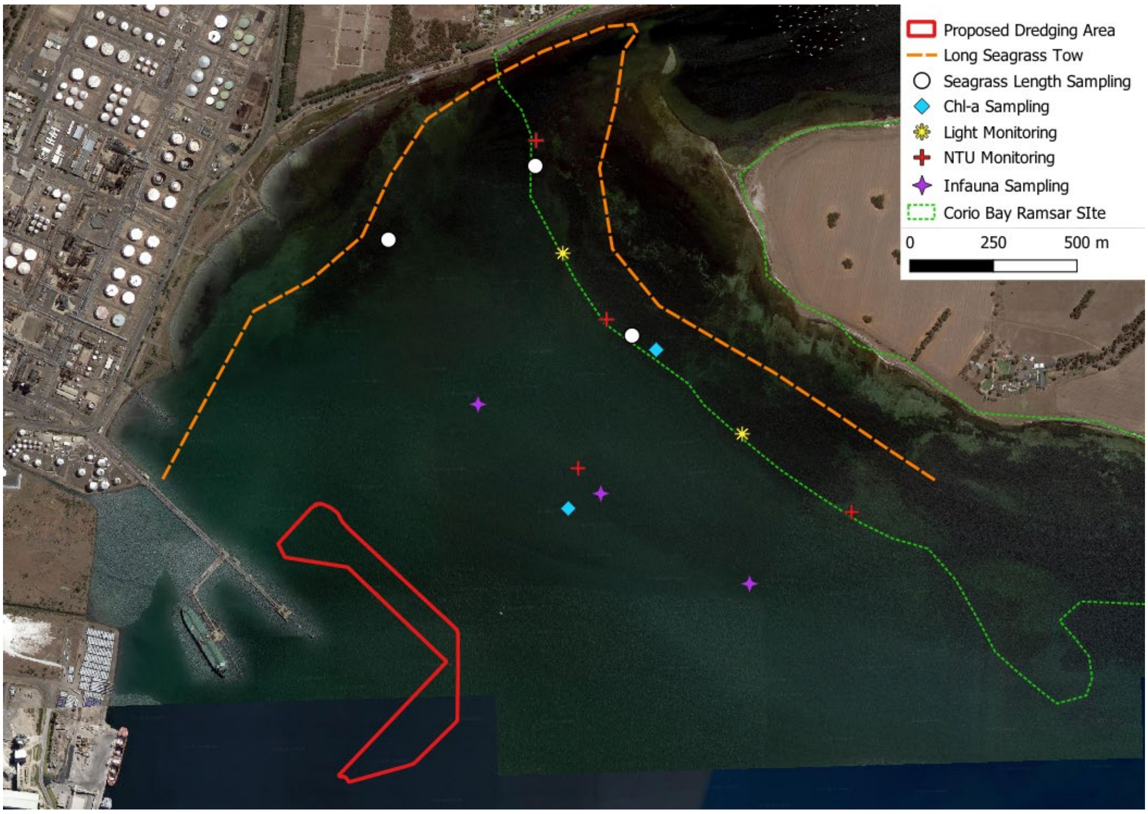


Figure 3-22. Recommended Monitoring Locations for Baseline Study

NTU sensors will record turbidity continuously. The loggers will be deployed at 1.5 m depth, so they measure turbidity at the depth of the densest seagrass meadows. Loggers will be retrieved and maintained regularly during the 12 month baseline program and during dredging. The signals will be transmitted to a recording device (within the refinery site), so the condition of the loggers and the turbidity level is always known. PAR is measured by using two light sensors deployed along the boundary of the Ramsar site plus a reference light sensor nearby on the shore. The sensors will log data continuously and the data retrieved at regular intervals, when the loggers are cleaned and maintained.

Given the potential for biofouling of the instruments, the target is at least 70 % of records each month in the baseline period, and 90 % monitoring during dredging. The instruments should be checked monthly and the loggers should be set at 1 m below low water level.

Primary Production in Corio Bay

Primary production in Corio Bay is by phytoplankton (42 %), seagrass (38 %), MPB (11 %) and macroalgae (seaweeds, 9 %) based on the assessment in Section 10.2 of Technical Report A: *Marine environment impact assessment* (CEE 2022). The extent and health of the primary producers before and after dredging should be measured to determine whether there has been any change in primary producers.

Phytoplankton Monitoring

Extensive phytoplankton monitoring in Corio Bay was carried out in the initial EES studies conducted for the project. Extensive chlorophyll-a measurements are not proposed for the baseline surveys as the Victorian Dredging Guidelines state that: "*phytoplankton populations require less light than seagrass, and are more ephemeral than macroalgae, impacts of turbidity on phytoplankton would not normally be measurable. Given the usual scale of dredging and the rapid dilution and mixing in the water column, impacts on phytoplankton would usually be expected to be smaller than the effects of natural phenomena, such as storms, which impact far larger areas".*

During the dredging program, and for 2 weeks before and afterwards, samples from the sediment in the dredge basin should be collected fortnightly and analysed for toxic dinoflagellates to identify the risk of a toxic algal bloom occurring. Samples of phytoplankton should also be taken at four sites to check for toxic algae that has been released. Sampling sites are shown in Figure 3-23.

Baseline Seagrass Surveys

The EES and supplementary studies have shown the seagrass in Corio Bay varies from year to year. Thus, the baseline studies need must be scheduled in the year just prior to dredging to define the appropriate seagrass baseline.

Seagrass and algae surveys are proposed at quarterly intervals along the same 3 km long transect that was surveyed in winter, spring and summer of 2023. The 2023 surveys measured the cover of seagrass from towed camera images. The same procedure, with quarterly seagrass subtidal surveys is proposed for the baseline surveys. The baseline surveys should classify seagrass cover using the Blake and Ball categories (2001).

Measurement of the length of seagrass will be undertaken at five site – Two along the Ramsar site boundary, one along the refinery foreshore and two at reference sites in south Corio Bay. While it is not likely that there will be a significant morphological change during an 8-week dredging program, particularly as suspended sediments are predicted to average only 3 mg/L and exceed 10 mg/L for only a few hours at a time, changes in seagrass leaf length will be monitored.

Intertidal seagrass surveys are not proposed for the baseline surveys as the intertidal seagrass, *N. muelleri,* experiences high light intensity every time there is a low tide during the day, so changes in light due to turbidity would be insignificant in the intertidal zone.

Regular ground-truthing of the camera images by direct observation is required for the baseline surveys. It is feasible to harvest a small section of representative subtidal seagrass at seabed level (leaving the rhizomes in place) at several sites and make a series of morphological measurements made on the samples (stem height, number of leaf clusters, leaf length). However, as *Heterozostera nigricaulis* and *Althenia marina* are listed species in the *FFG Act* 1988, approval to cut or take seagrass must be obtained and a permit would need to be obtained. It would be better to use non-destructive observations and measurements in the baseline study. The proposed seagrass survey line is shown in Figure 3-23.

Baseline Algal Surveys

The quarterly towed camera images would also be analysed for algal cover using the same classification system as seagrass – Blake and Ball (2001).

Infauna Surveys

Infauna samples would be collected by divers quarterly at the three sites shown in Figure 3-23. Duplicate samples are collected using a grab, preserved and then transported to a lab to be analysed for infauna species and abundance.

Figure 3-23. Recommended Sampling Locations in Corio Bay for Baseline Study.

3.6.5.1 Schedule for Proposed Baseline Monitoring

Table 3-8 sets out the components and frequency of the proposed baseline sampling program.

Table 3-8. Summary of Proposed Baseline Survey Program

Task	Number of Sites	Frequency
Long Seagrass Tow	2	Quarterly
Seagrass length Sampling	5	Quarterly
Chl-a Sampling	4	Quarterly
Light Monitoring	2	Continuous
NTU Monitoring	4	Continuous
Infauna Sampling	3	Quarterly

Time-series data should be collected for key parameters to capture the typical range of conditions across the area that may be influenced by dredging. Particular emphasis should be on the areas of seagrass meadows. The PAR regime at the seabed at potential impact and reference monitoring sites should be characterized through one annual cycle. Water quality parameters should be measured at the site regularly, at least during every logger service, to provide contemporaneous measurement points for related parameters (e.g. NTU).

Table 3-9 sets out an indicative schedule for the baseline monitoring program.

Table 3-9. Schedule for Proposed Baseline Survey Program

Task	Q1		Q2		Q3		Q4	
	Quarterly	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly	Monthly
Long Seagrass Tow	■		■		■		■	
Seagrass length Sampling	■		■		■		■	
Chl-a Sampling	■		■		■		■	
Light Monitoring	■	■	■	■	■	■	■	■
NTU Monitoring	■	■	■	■	■	■	■	■
Infauna Sampling	■		■		■		■	

3.6.5.2 Data Analysis

The baseline survey to detect the impacts of seagrass involves a BDRI philosophy (before, during, reference, impact). The purpose of the baseline study is to establish the background condition and characterise the data which can be used to develop trigger values for an adaptive management program. This will inform the best statistical method for analysis. It is suggested that data be analysed using a combination of Control Charting and PERMANOVA method (permutational multivariate analysis of variance).

3.7 Conclusions for Minister's Recommendation 1

Recommendation 1 of the Minister's Directions required further survey work to better establish the existing environment and the impacts of existing seawater discharges from the refinery.

The refinery plumes were tracked and mapped in this supplementary statement by deploying highly sensitive temperature probe from a vessel and drone over a range of tidal and wind conditions in winter, spring, and summer 2023 (Task 1a). The temperature contours in the plumes were calculated from the readings.

A relationship between temperature and residual chlorine was developed from the results of field tests and inferred chlorine contours were calculated from the measured temperature plumes. From these results, the envelope of excess temperature and chlorine was determined and mapped.

In addition, a series of surveys were undertaken in winter, spring and summer 2023 to update the seagrass mapping in the intertidal, littoral, and subtidal zone of the existing discharge plumes and suitable reference sites in the Ramsar site (Task 1b). This enabled the development of detailed maps showing the spatial patterns of seagrass in the area of the existing refinery plumes and the western Ramsar Site.

The comparison of seagrass cover near the discharge sites, and at reference sites, is based on approximately 450 measurements of seagrass cover at the discharge sites and also at the reference sites, with 900 seagrass cover measurements in total.

The following conclusions are made:

- The +5°C temperature contour encompasses a small area of intertidal seagrass, extending for 150 m to the north of W5. The +3°C temperature contour extends along the shore for 560 m north from the W5 discharge. The +2°C contour extends a further 90 m north but does not reach the Ramsar site.
- The extent of chlorine in the existing refinery plumes was inferred from the measured temperature contours. The 10 µg/L chlorine contour, which represents the DGV that applies to Corio Bay, encompasses only a small area, within the existing EPA licence mixing zones. The 4.3 µg/L chlorine contour, which represents the DGV that applies to the Ramsar site, extends for 150 m from the W1 and W5 discharges, and is well away from the Ramsar site.

- The seagrass surveys that were undertaken showed the intertidal seagrass species in the bay is *N. muelleri;* the main subtidal seagrass species in the bay are a combination of *H. nigricaulis* and *Halophila;* and there are minor amounts of *Althenia* and *Ruppia* near the discharges, and a small strip of broadleaf *Muelleri* in the entrance to Limeburners Bay.
- There was more seagrass cover in 2023 compared to 2021.
- The cover of intertidal seagrass in the discharge zone varied by season from 21 % to 39 %. Dead seagrass (wrack) covered part of the intertidal area in spring and summer.
- For the intertidal zone over all three seasons, there was 31 % seagrass cover in the discharge sites (+/- 6 %) and 30 % seagrass cover in the reference sites(+/- 9 %). There is no significant difference between the average cover values.
- The cover of subtidal seagrass in the discharge zone varied by season from 70 % to 77 %
- For the subtidal zone over all three seasons, there was 72 % (+/- 5 %) seagrass cover at the discharge sites and 68 % (+/- 6 %) seagrass cover at the reference sites. There is no significant difference between the average cover values.
- Seagrass was observed growing directly in the discharge plumes at the same density and health as elsewhere.
- It is concluded that the existing discharges have no measurable effect on seagrass cover.
- Future discharges with the FSRU in operation would have a smaller temperature increase, the same small residual chlorine concentration as the present discharges and the same discharge rates as now. It is considered that the project would have no discernible impact on seagrass cover.
- Over the period from 2021 to 2023 there has been a decrease in the number of sea urchins in the seagrass areas of north Corio Bay, particularly near the discharge sites.

Based on the impact vs reference site assessment, it is concluded that the existing discharges have no measurable effect on seagrass cover. No significant difference in seagrass cover was detected between the discharge sites and Ramsar sites. Seagrass was observed growing directly in the discharge plumes at the same density and health as elsewhere.

Recommendation 1 of the Minister's Directions also requires further survey work to be undertaken to establish a better baseline for monitoring during and after the dredging and construction stages to confirm predicted outcomes on shoreline and benthic communities, including seagrasses and macroalgae. This task will not form part of the Supplementary Statement as it will need to be carried out 12-months prior to the commencement of dredging or construction to provide the most accurate and representative baseline for project monitoring during and after construction. This task will form part of the secondary approvals process *(Marine and Coastal Act Consent)*

A proposed study plan has been developed to be carried out in the 12 months before dredging commences (Task 1c/1d). The plan includes sites for the seasonal monitoring of seagrass height and density, light attenuation, turbidity, microphytobenthos, chlorophyl-a and infauna.

4. Recommendation 2 – Refine Regional Hydrodynamic Model

4.1 Summary of Original EES Model

Regional hydrodynamics and water quality were modelled using the Aquatic Ecosystem Model 3D (AEM3D). This model is a three-dimensional hydrodynamic and water quality model which has been used for a number of assessments in Port Phillip Bay. As part of EES Technical report A: marine ecology and water quality impact assessment, the AEM3D model was adapted to focus on Corio Bay by incorporating a fine 3D grid with cells of 20 metres by 20 metres and 1 metre deep. The hydrodynamics of the bay were represented within this fine scale grid.

Key model inputs included the following:

- Wind data from Geelong Racecourse
- A 1 metre vertical grid.
- A 20 metre by 20 metre horizontal grid within the project area and a 400 metre by 400 metre horizontal grid in the outer regions of the model domain.
- a 400 metre by 20-50 metre horizontal grid In the Hopetoun Channel.
- The regional hydrodynamic model did not include the FSRU.

The verification of regional hydrodynamic model is presented in Section 6.5 of EES Technical report A: *Marine ecology and water quality impact assessment* (CEE 2022). Currents predicted by the model were compared to field measurements collected in Summer 2020 and Autumn 2021. Field measurements showed good agreement with the regional hydrodynamic model.

The regional hydrodynamic model was used to:

- Simulate the existing currents, temperatures, and salinities in Corio Bay
- Predict the fate and transport of fine sediments (clay and silt) that are likely to be mobilised during dredging and dredge spoil disposal.
- Predict the path and dispersion of the discharge plumes, including cooled or warmed chlorinated discharges from the refinery and the FSRU.
- Simulate the potential transport and dispersion of plankton from different regions of the bay and predict the entrainment of plankton during operation of the FSRU.

4.2 Overview

The IAC concluded that because the regional hydrodynamic model underpins the assessment of the project's marine impacts, further work should be undertaken to refine the calibration of the model "so that it more closely reproduces observed tidal range, tidal exchange and currents" to provide "a more reliable basis".

Recommendation 2 of the Minister's Directions is related to this conclusion and was as follows:

Refine calibration of the regional hydrodynamic model so that it more accurately reproduces observed water levels, currents, tidal range, and tidal exchange in Corio Bay. Consider:

a) *The selection of the most appropriate <u>wind data.</u>*

b) *More detailed <u>horizontal resolution</u> to represent the Hopetoun and North Channels more accurately.*

c) *More detailed <u>vertical resolution</u> to represent discharge plumes in shallow waters more accurately.*

d) *The effects of the* <u>*presence of the Floating Storage Regasification Unit*</u> *(FSRU) on currents*

e) <u>*Peer review*</u> *of the model calibration.*

4.3 Summary of Tasks

The tasks were undertaken by Hydronumerics as per the study program developed for the Supplementary Statement to address Recommendation 2 of the Minister's Directions. An overview of these tasks and their objectives and outcomes is provided in this section of the report, and are described in further detail in the subsequent sections of this report.

Recommendation 2a, to select the most appropriate wind data, involved:

- Preparing a wind field for Corio Bay from the Geelong, Avalon and Point Wilson wind data using the Calmet program.
- Comparing predicted plume size and extent against measurements of plume size and extent to select the wind field that best matches the existing plume measurements.

Recommendation 2b, to improve model resolution in the Channels, involved:

- Updating the model grid to a 20 m horizontal resolution to make a more detailed representation of the flow in the Hopetoun and North Channels.

Recommendation 2c, to improve vertical resolution in the model, involved:

- Updating the model grid to a 0.5 m vertical resolution over the top 5 m to represent discharge plumes in shallow waters more accurately;
- Checking that the vertical layers in the model are aligned with observed field conditions and the model correctly reproduces the mixing and transport of a shallow surface layer.

Recommendation 2d, to include the FSRU in the model predictions of currents.

- Representing the FSRU as a solid barrier in the model to observe its effect on currents.

Recommendation 2e was to respond to a peer review of the regional hydrodynamic model. The peer review was by Stantec. Their comments have been received and implemented.

The details and findings of the tasks to refine the regional hydrodynamic model are described in the Hydronumerics report: Hydrodynamics (2024) *"Refinement of Regional Hydrodynamic Model of Corio Bay for Supplementary Marine Studies"*, Report to CEE

4.4 Wind File Selection for Supplementary Studies

The project site is situated in the northwest corner of Corio Bay between two meteorological stations maintained by the Bureau of Meteorology (BoM) and are reliable sources of long-term meteorological data. The Geelong Racecourse site is 9 km to the south of the project site and the Avalon airport site is 9 km to the north of the project site (Figure 4-1). Both these stations were considered for use in describing the wind fields in the model.

Section 6.4.3 and Section 8.9 of Technical Report A: *Marine environment impact assessment* (CEE 2022) and Appendix A of the Hydrodynamic Modelling Report (Hydronumerics 2022a) was noted that the two stations showed similar seasonal wind patterns and the key difference between the meteorological observations at the two stations is the strength of the wind field.

The station at Geelong Racecourse typically has lighter winds when compared to the more exposed site at Avalon Airport. During the 2019 to 2021 period, wind events recorded at Geelong Racecourse were greater than 8 m/s for 5% of the time, compared to 14% of the time at Avalon Airport.

The wind directions at the two sites were comparable, the most frequent winds blowing from the S (10 to 15% of the time) and between W to NW (40 to 45% of the time). The wind rose for the two sites differ only slightly.

Figure 4-1. BoM Meteorological Stations Near Port Phillip Bay

(source: http://www.bom.gov.au/vic/observations/melbournemap.shtml)

The wind speeds at the different sites reflect the extent of sheltering - the Geelong Racecourse wind field is less exposed than Avalon Airport. The winds at Avalon Airport have few obstructions and therefore higher wind speeds. The wind directions at the two sites are similar.

4.4.1 Extra Calmet Wind Field for Supplementary Marine Studies

An additional wind file was generated in the Supplementary Studies for the Corio Bay site using Calmet. This wind model constructs 3-D wind and temperature fields from meteorological measurements, topography and land use data. In addition, Calmet provides 2-D fields of micro-meteorological parameters for atmospheric dispersion simulations (mixing height, friction velocity and convective velocity).

The Calmet wind modelling was initiated with the CSIRO Air Pollution Model (TAPM) to produce regional scale 3-D TAPM meteorology including the effects of terrain, applying databases of terrain, vegetation and soil type, leaf area index, sea surface temperature, and synoptic-scale meteorological analyses for the Victorian region.

The TAPM upper air and BoM surface profile data are then used by Calmet to provide an initial wind field that is adjusted for terrain, channelling, slope flow and kinematic effects. Wind observations at Geelong Racecourse, Geelong Refinery, Avalon Airfield and Point Wilson were incorporated. The output of the Calmet model can be seen as a combination and interpolation of wind and meteorological measurements at Geelong Racecourse, Geelong Refinery, Avalon Airfield and Point Wilson.

As the eastern boundary of the refined grid had been moved into Port Phillip Bay, it was necessary to update tidal conditions for the eastern boundary of the model. A new sea-level boundary condition at the eastern extent of the refined grid was generated from a far-field model that included Port Phillip Bay, Western Port Bay and the central Victorian coast, driven by tide measurements at Lorne and a wind field from the BoM ACCESS 5 km wind grid. The sea-level predictions from the far-field model were then used as boundary conditions for the refined Corio Bay model. This method ensured that both tidal harmonics and low-frequency sea-level oscillations recorded at Lorne tidal gauge are passed into the refined model grid from the far-field model.

Table 4-1 compares the 10, 50 and 90 percentile wind speeds for the three wind files (Geelong, Calmet and Avalon). The wind speeds determined by Calmet are between the Geelong Racecourse and Avalon Airport observations.

Table 4-1. Comparison of Wind Speeds in Alternative Wind Files

Speed percentile	Geelong Racecourse	Calmet Model	Avalon Airport
10 percentile	0.9	1.3	2.0
50 percentile	3.1	4.0	4.6
90 percentile	6.4	7.7	8.8

Wind speed in m/s

4.4.2 Selection of Preferred Wind File

The wind file preferred for use in the Supplementary was selected from a consideration of: (1) predicted versus measured current speeds; and (2) predicted versus measured temperature contours and extent of temperature plumes.

Figure 4-2 compares the predicted current speed distributions with the three wind files with the measured current speeds (dashed green line) for the northern current meter location. The currents predicted using Calmet winds (purple line) show the best fit to the measured current speeds. The currents predicted using the Geelong winds are similar to those for the Calmet winds in the lower half of the range, but slower than the measurements from 3 to 11 cm/s. The currents predicted using the Avalon winds result in current speeds substantially higher than the measured currents.

Note that the difference between the predicted currents and measured currents using the Calmet wind file are within 0.01 m/s of the measured currents – which is within the accuracy of the measurement of the current meter of 0.01 m/s.

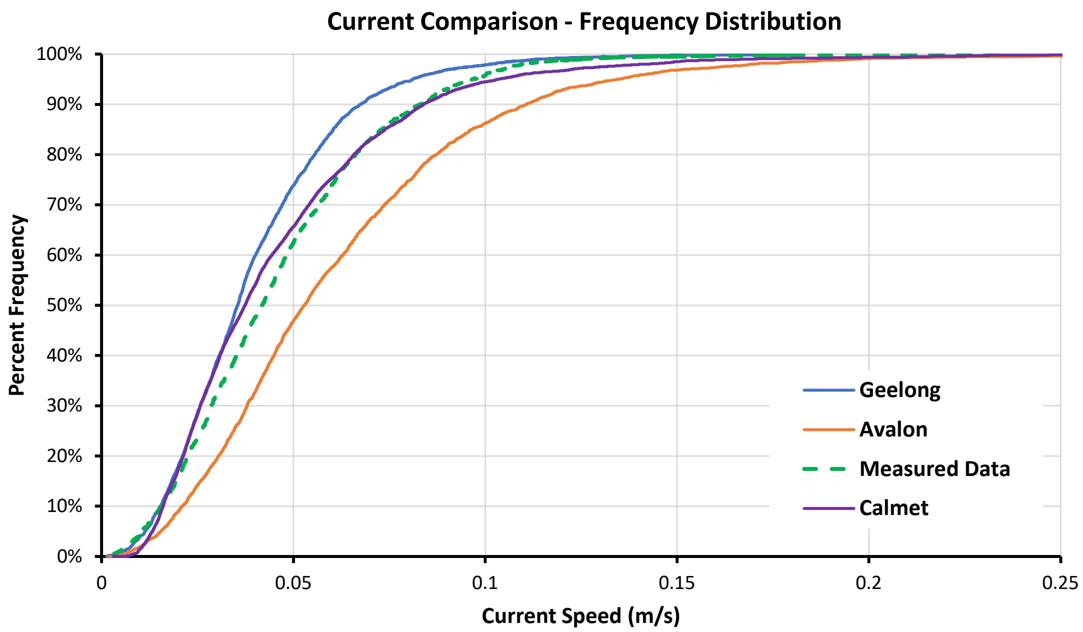


Figure 4-2. Comparison of Predicted and Measured Current Speeds

Figure 4-3 shows the temperature plumes predicted using the Geelong and Avalon winds; Figure 4-4 shows the chlorine plumes predicted using the Geelong and Avalon winds and Figure 4-5 shows the temperature and chlorine plumes predicted using the Calmet winds. The plumes for the Geelong and Calmet winds are similar while the plumes using the Avalon winds are significantly weaker. The plumes predicted using Calmet winds best match the measured plumes, as shown in Section 4.8.

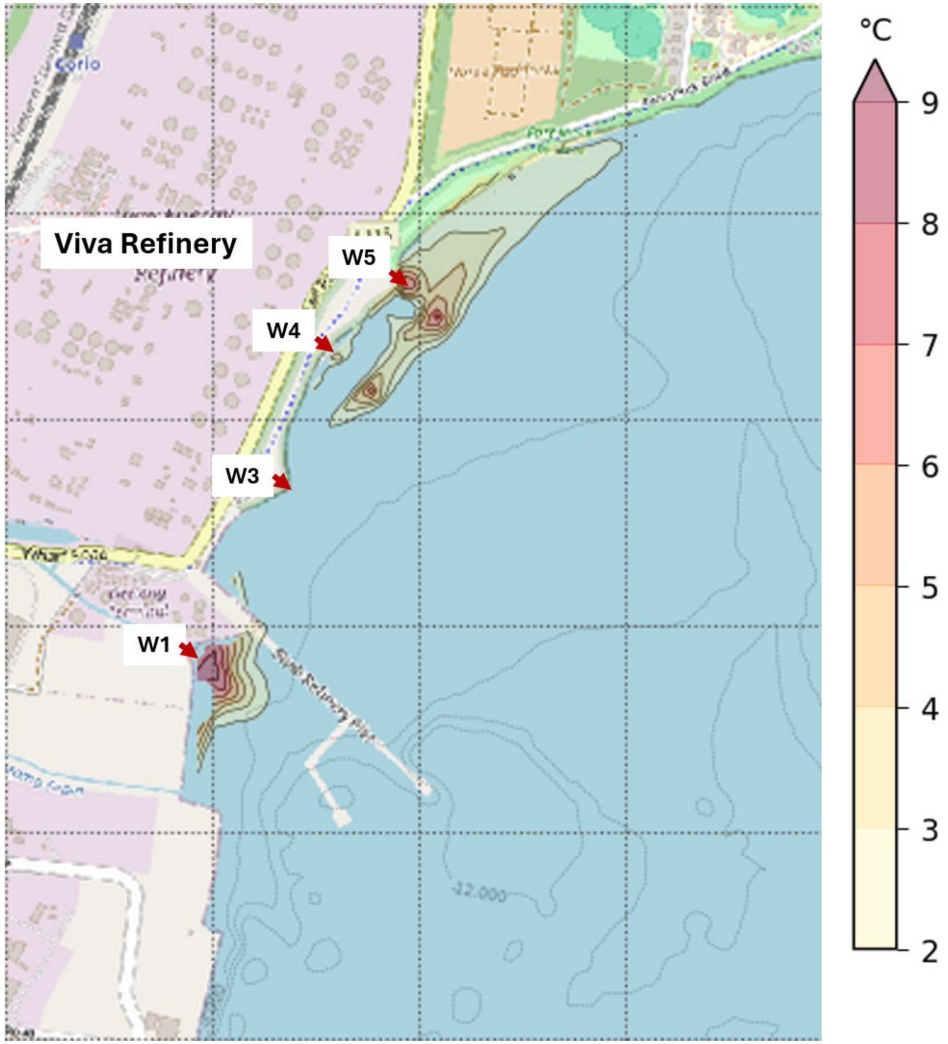
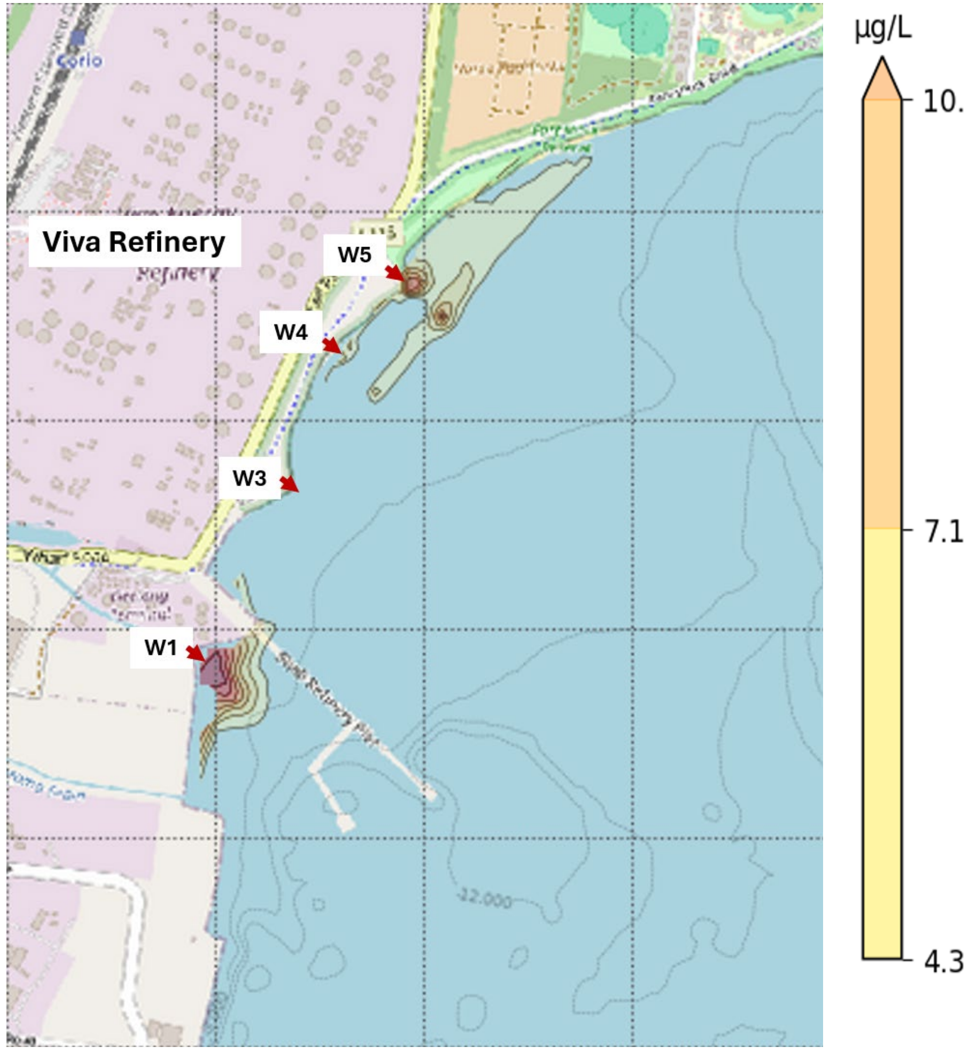
Temperature plume with Geelong Wind File	*Temperature plume with Avalon Wind File*
	

Figure 4-3. Predicted Median Temperature Plumes with Different Wind Files

Chlorine plume with Geelong Wind File	*Chlorine plume with Avalon Wind File*

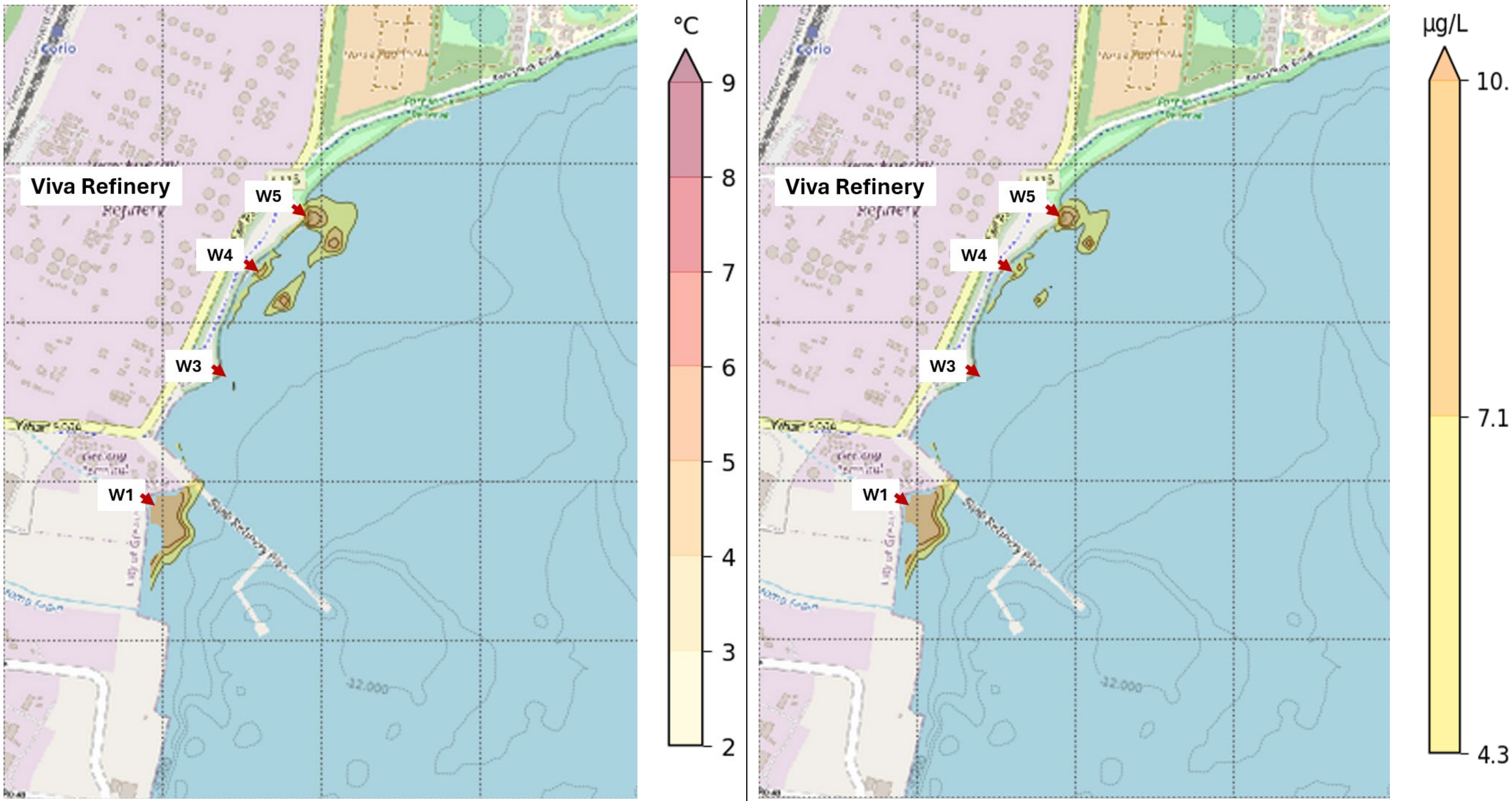


Figure 4-4. Predicted Median Chlorine Plumes with Different Wind Files

Temperature Plume with Calmet Wind File	*Chlorine Plume with Calmet Wind File*

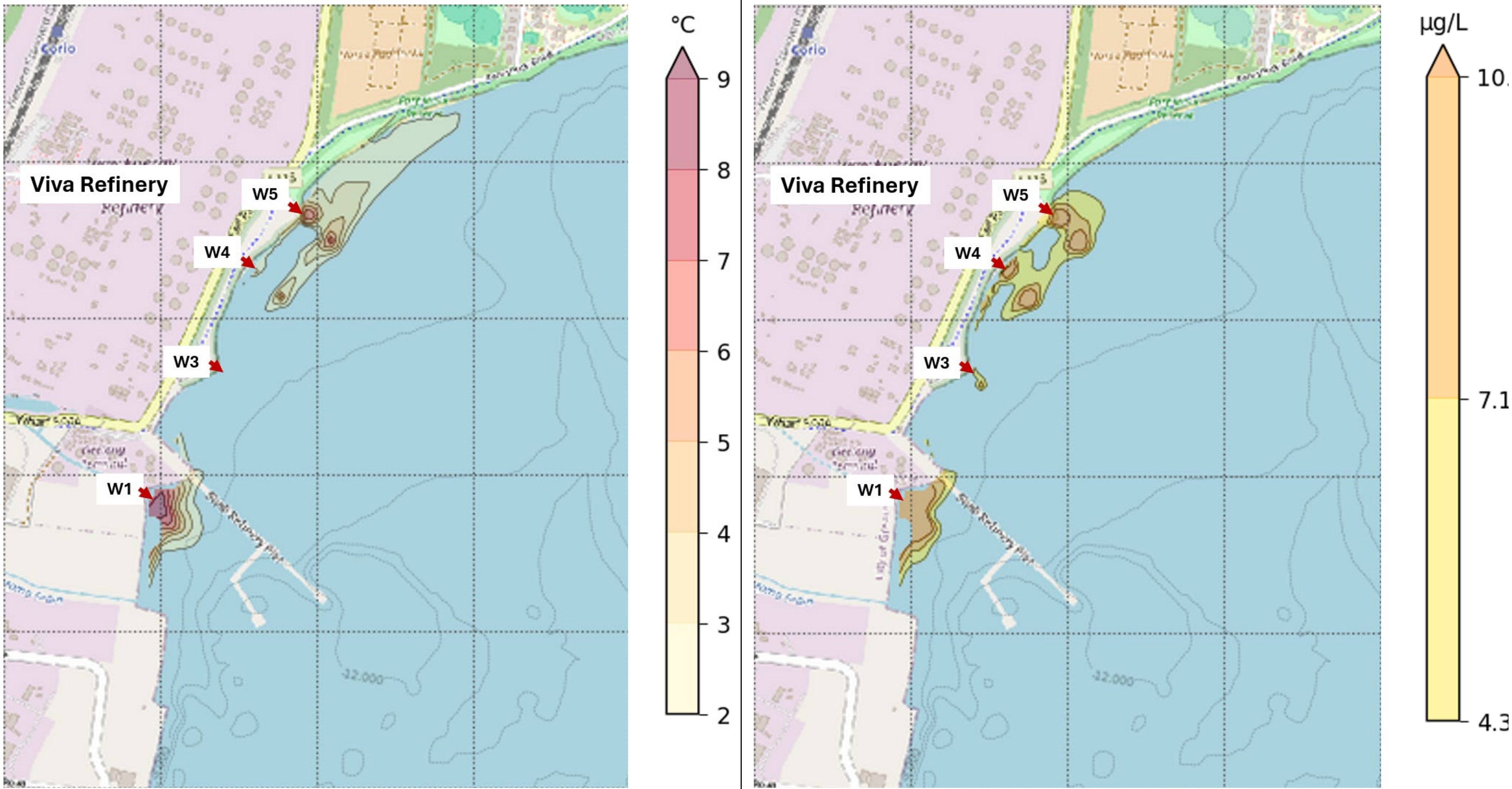


Figure 4-5. Modelled Median Temperature and Chlorine Plumes with Calmet

It was concluded from the current speed comparison in Figure 4-2 that the Calmet wind file gave the most representative results when compared to the measured current speeds.

The extent of the predicted plumes from the existing discharges, and the temperature and chlorine levels in the predicted plumes, best matched the typical measured plume extent and temperature and chlorine levels, on different days, using the Calmet wind file. The Avalon wind field resulted in smaller plumes and sharp temperature peaks near the discharges that the other two wind files. Otherwise, there was only a little difference in the extent of the predicted plumes with Geelong and Calmet wind fields.

The Calmet wind field, which uses all the available wind monitoring data in the region, provides the best match between predicted and measured current speeds and provides the best match between predicted and measured plume size, was adopted as the most appropriate wind file for the supplementary studies.

4.5 Task 2b – Improve Model Resolution in the Channels

Recommendation 2b of the Minister's Directions required more detailed horizontal resolution to better represent the Hopetoun Channel and North Channel.

4.5.1 Previous Sensitivity Tests

For the EES, the horizontal grid resolution in the model involved a 20 m x 20 m grid in the project area and a 400 m x 400 m grid in the western arm of Port Phillip Bay.

In response to an IAC request for additional information during the 2022 EES inquiry hearings, sensitivity tests were undertaken to examine finer horizontal resolution using a 20 m by 20 m grid in all of Corio Bay and the Hopetoun Channel and North Channel.

The results of the 2022 sensitivity tests showed that:

- The low tide level was resolved to a higher accuracy with the finer grid.
- Depth averaged current speeds and directions changed only marginally at the sites (from zero to a maximum 6 % shift in current speed) with the finer grid.
- The extent and shape of the thermal plumes changed to a small extent; with the range being 0.04°C beside the jetty to 0.24°C in the Ramsar site (due to better resolution of diurnal temperature variations near the discharge points);
- The extent and shape of the chlorine plume changed to a small extent; but the differences in the simulated depth-averaged chlorine at sites in north Corio Bay were less than 0.1 ug/L (Hydronumerics, 2022b).

4.5.2 Adoption of Extended Fine Grid

For this supplementary study, a finer horizontal grid of 20 m by 20 m over a larger extent was adopted, extending throughout Corio Bay, the Hopetoun Channel and North Channel, and further east into the western arm of Port Phillip Bay. This extension of the finer horizontal grid removed the section of coarser grid (of up to 400 m x 400 m) previously used in outer Corio Bay (CEE 2022 and Hydrodynamics 2022a).

The more detailed representation of the bathymetry of the channels accounted for some of the improvements while the updated tidal boundary condition was the more important factor.

The refined regional hydrodynamic model for this supplementary study included a more detailed horizontal grid of 20 x 20 m resolution throughout Corio Bay, Hopetoun Channel and North Channel, extending east into the western arm of Port Phillip Bay, as shown by the highlighted bathymetry area in Figure 4-6.

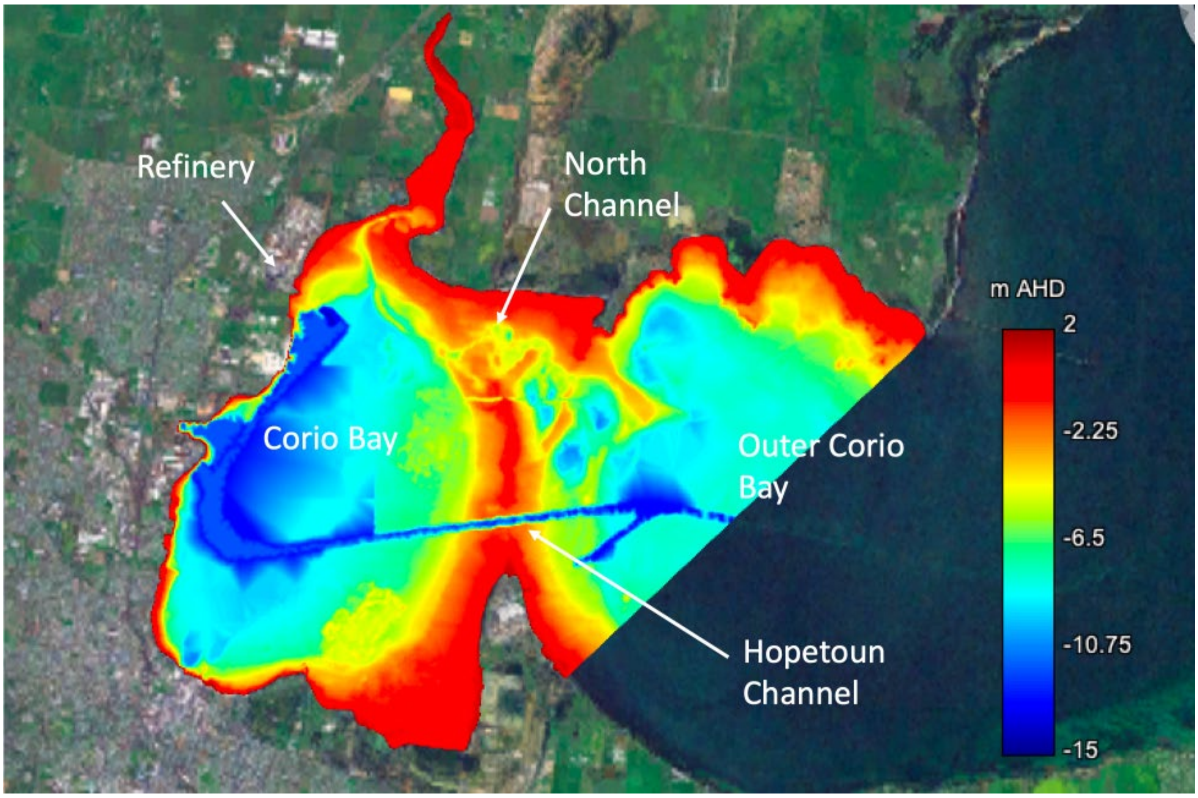


Figure 4-6 Updated Model Grid with 20 x 20 m Resolution

The increase in resolution of the model provided a detailed representation of the Hopetoun Channel and the North Channel, which convey most of the tidal exchange between Corio Bay and Outer Corio Bay and meets the Minister's recommendation 2b.

4.5.3 Updates to Tidal Boundary Condition in Port Phillip Bay

As the eastern boundary of the refined grid had been moved into Port Phillip Bay, it was necessary to update tidal conditions for the eastern boundary of the model. A new sea-level boundary condition at the eastern extent of the refined grid was generated from a far-field model that included Port Phillip Bay, Western Port Bay and the central Victorian coast, driven by tide measurements at Lorne and a wind field from the BoM ACCESS 5 km wind grid. The sea-level predictions from the far-field model were then used as boundary conditions for the refined Corio Bay model. This method ensured that both tidal harmonics and low-frequency sea-level oscillations recorded at Lorne tidal gauge are passed into the refined model grid from the far-field model.

4.5.4 Comparison of Predicted and Measured Sea Level Variation

Figure 4-7 compares the sea-level records at Geelong (in blue) and the refined model prediction of sea-level at Geelong (in red) for a sub-set of the January 2020 simulation. The results show good agreement between the observations and model predictions, with an improvement in the ability to reproduce low tide levels, compared to the predictions in the EES report. The correlation coefficient (R^2) between the tide height observations and predictions is 0.96 which is satisfactory. The R^2 agreement for the January 2020 observations is 0.96 as illustrated by the linear regression comparison in lower section of Figure 4-7.

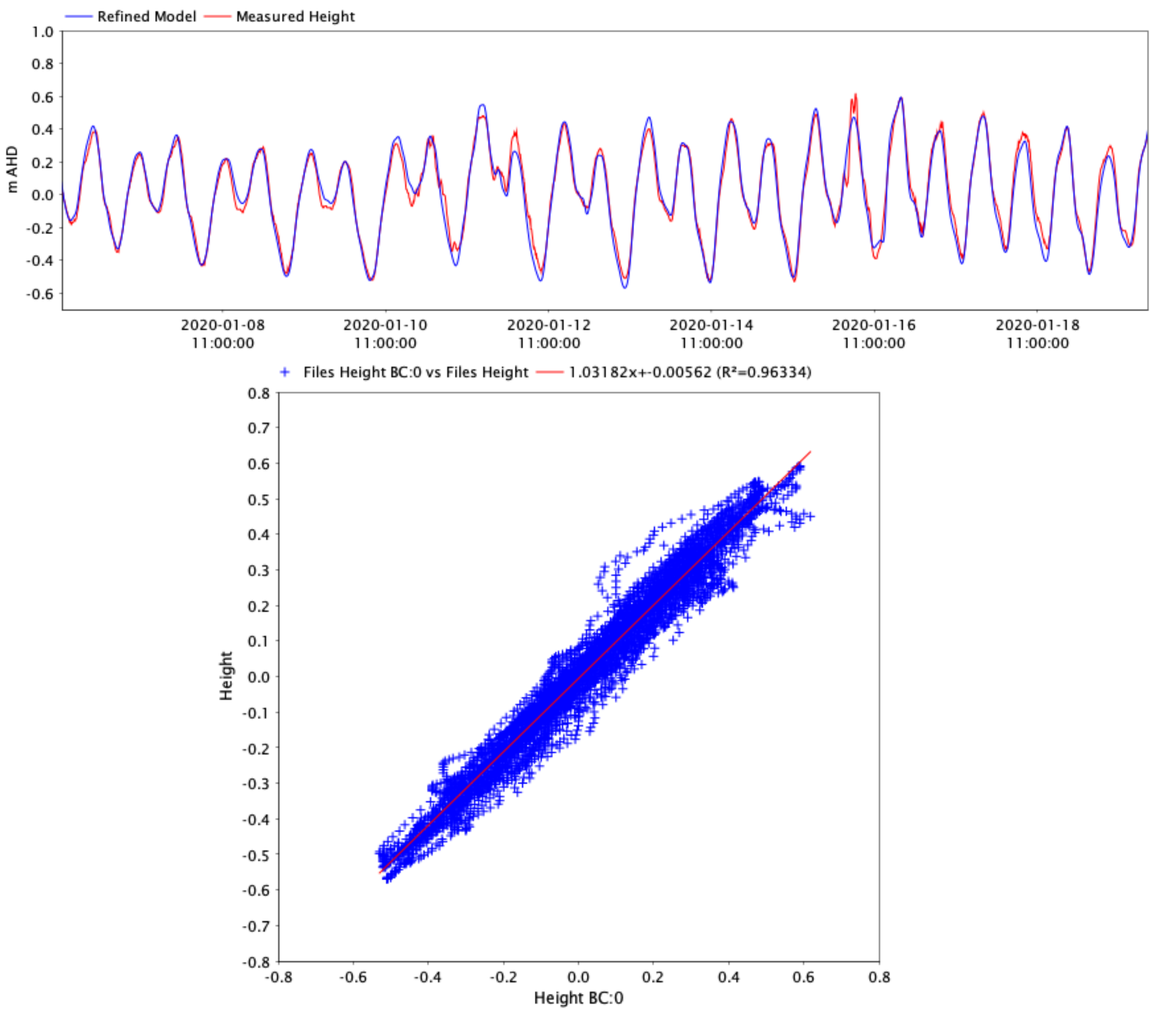


Figure 4-7. Comparison of Observed and Predicted Tide Level at Geelong

Note: Observed water level on x-axis and modelled water level on y-axis

4.6 Task 2c – Increase Vertical Resolution of the Model

Recommendation 2c of the Minister's Directions required the use of more detailed vertical resolution to represent shallow warm surface plumes in Corio Bay.

For the EES, the vertical grid resolution in the model used layers that were 1 m deep from the surface to the seabed. The top layer fills and empties with the tide and so has an average depth of about 0.5 m.

For the supplementary study, the model cells between 1 and -4 m AHD were refined to a depth of 0.5 m. This increased resolution in the vertical can better represent shallow warm surface layers at or near the refinery discharges, including the strong thermal gradients observed near the W1 discharge.

The increase in vertical resolution of the model provides a detailed vertical representation of the surface layers and meets the Minister's recommendation 2c.

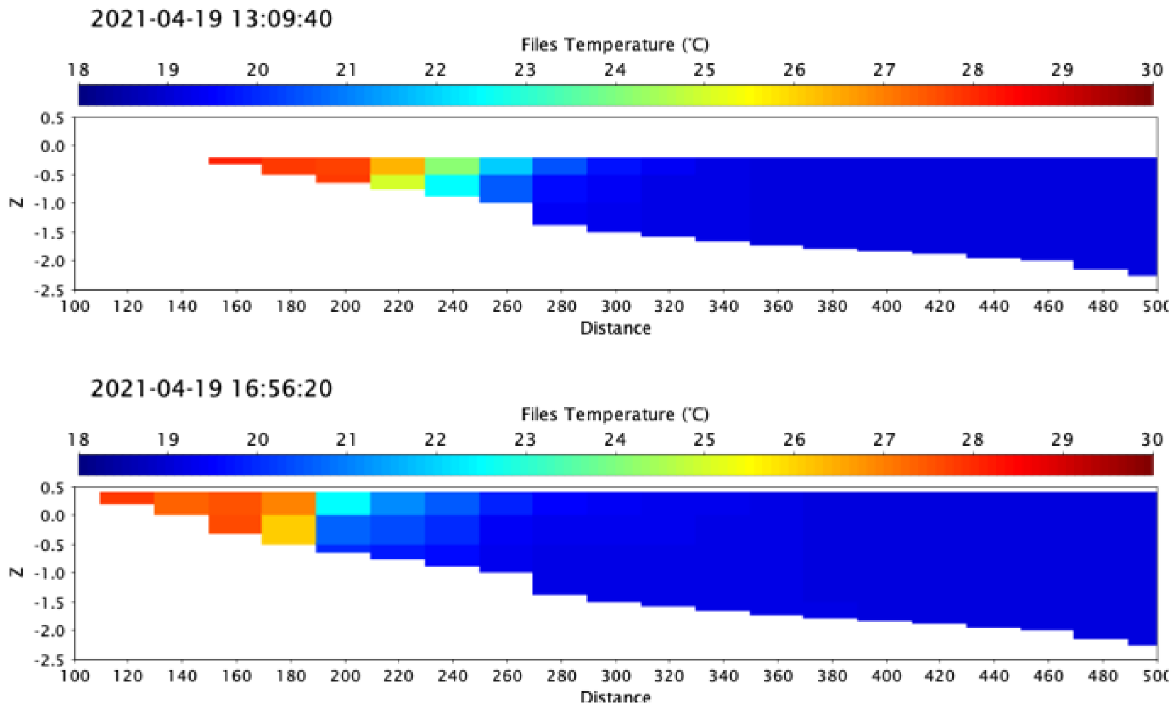
4.6.1 Structure of Vertical Grid

The regional hydrodynamic model uses a z-layer vertical grid structure, where the model layers remain horizontal over the domain. Layer thicknesses can vary in height as configured by the user. In this way the shallow regions have fewer layers compared to the deeper areas. At the bed, the deepest cells are only partially filled to match the bathymetry, allowing for gradual steps along bed slopes. At the surface, the cells will partially fill and drain during the incoming and outgoing tide, with wetting and drying of the intertidal area.

To improve the resolution of the vertical grid to better represent warm surface layers at or near to the refinery discharges, the depth of the model cells between 1 and -4 m AHD was reduced to 0.5 m for this supplementary study. This additional resolution provides a better representation of strong thermal gradients that have been observed near the refinery discharge points.

4.6.2 Modelling Thermal Plumes Near the Shore

The warm water discharges from the refinery enter the model cells (20 x 20 m) at the location of each discharge outlet; the entry depth and location on the shoreline tracks up and down the intertidal zone with the excursion of the tide to limit the maximum initial plunge depth to less than 0.5 m. Figure 4-8 illustrates the vertical grid structure and plume input offshore from the W5 discharge during low and high tide.



Top Panel = Low tide; Lower panel = high tide

Figure 4-8. Thermal Plume Mixing into Nearshore Cells of Model

The illustrations show that the large temperature difference between ambient seawater and the refinery discharge can be maintained in a shallow layer for 60 m from the discharge point, beyond which the thermal plume is mixed with the receiving waters. This occurs because the vertical mixing of the plume is inhibited by the thermal gradient associated with the plume (and hence density gradient). As a result, the plume travels at and near the surface, mixing with the ambient waters until the thermal gradients are weak (< 1˚C) when full mixing with the ambient waters occurs. The figure also illustrates the small steps in the bathymetry that is provided by the partial cell filling feature in the model at bed and surface, and the wetting and drying of the cells in the intertidal zone.

4.6.3 Comparison of Predicted and Measured Vertical Temperature Profiles

Vertical temperature profiles were measured in the discharge plumes during the field studies. A comparison of the measured vertical profiles with the predicted vertical profiles in the plume from the W1 discharge is shown in Figure 4-9. At Site 8, near the mouth of the W1 discharge, the plume occupies the water depth of 1.6 m with a relatively uniform temperature distribution at 5.3°C above ambient. The model predicts a very similar temperature and vertical profile.

At Site 11, in deeper water further from the discharge, the buoyant plume has lifted off the seabed and is spreading as a thin (0.5 m deep) layer at 3°C above ambient. At Site 16, in 3 m deep water even further from the discharge, the buoyant plume has lifted off the seabed and is spreading as a thin (0.5 m deep) layer at 2°C above ambient. The model predicts very similar temperature levels and vertical profiles.

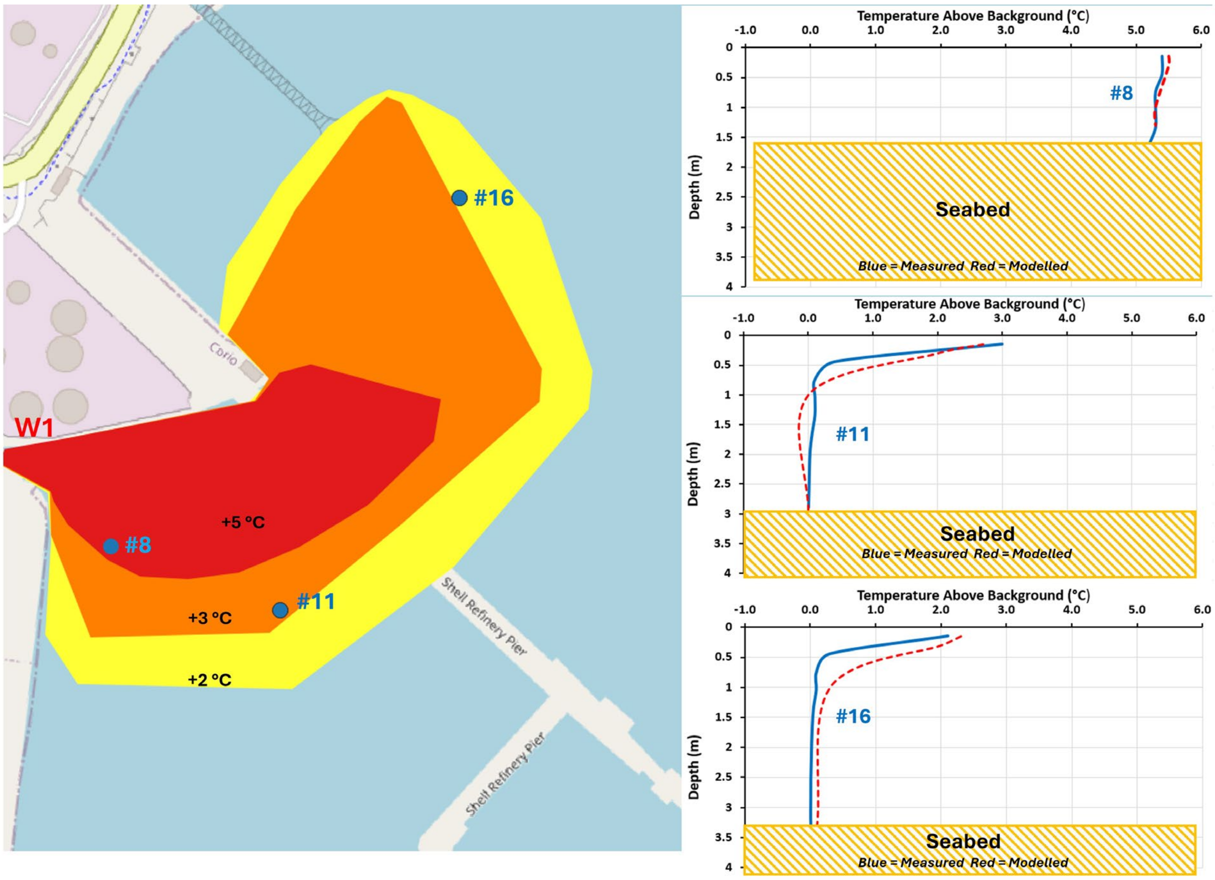


Figure 4-9. Measured Temperature Profiles Offshore from W1

A comparison of the measured vertical profiles with the predicted vertical profiles in the plume from the W4 and W5 discharges is shown in Figure 4-10. This plume remains in shallow water near the shoreline, and the plume occupies the layer at a relatively uniform temperature. The model predicts the temperature at 0.25 m and 0.75 m depth, which allows the vertical temperature distribution of the plume to be seen.

At Site 24, near the W5 discharge, the plume occupies the water depth of 1 m with a relatively uniform temperature distribution at 5°C above ambient. The model predicts a very similar temperature and vertical profile.

Similar vertical profiles are apparent further north at Site 25, where the temperature rise is about 3°C and there is a slight vertical variation. Further south at Site 22, the plume is in 0.7 m water depth, at around 4.7°C above ambient, with a small temperature decrease with depth. at Site 19, the plume is in 1.2 m water depth, at around 2.8°C above ambient, with a small temperature decrease with depth. The model predicts very similar temperature levels and vertical profiles.

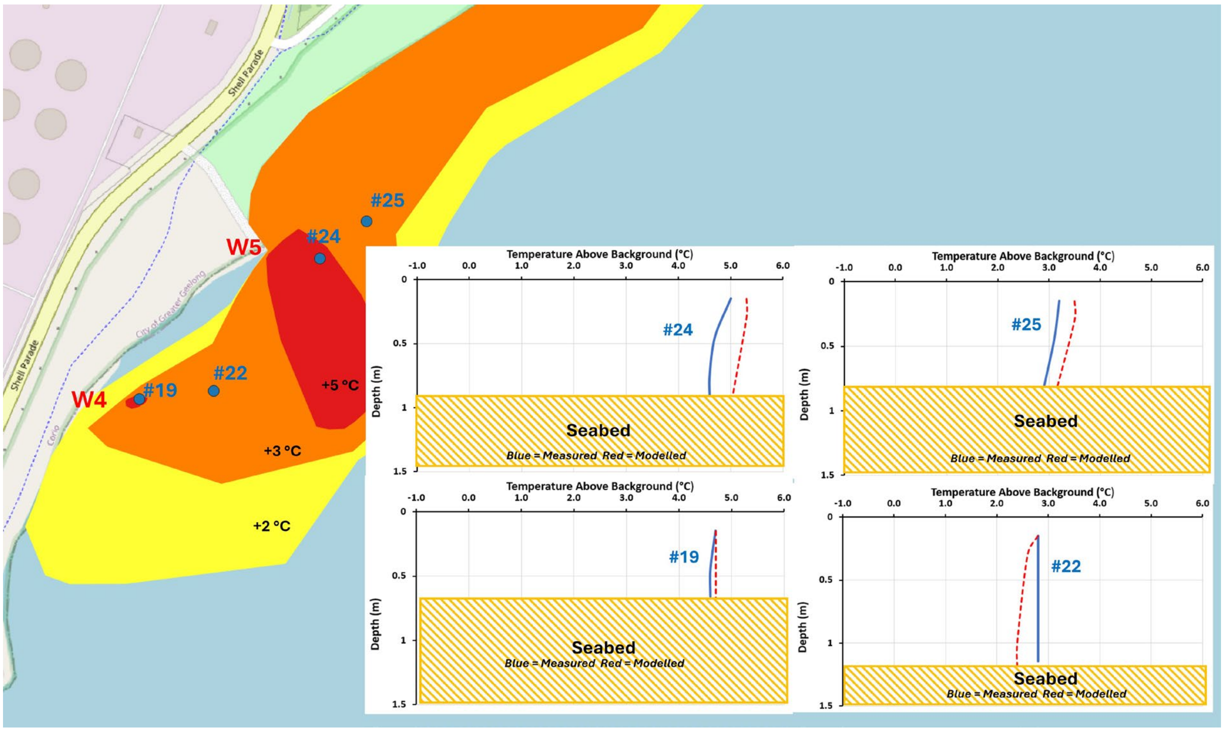


Figure 4-10. Simulated Vertical Temperature Gradients Offshore from W1

4.7 Comparison of Model Predictions with Measurements

The model predictions satisfactorily match field measurements of:

1. Frequency distribution of current speeds (see comparison in Figure 4-2);
2. Tide height over time (see comparison in Figure 4-7);
3. Vertical temperature distribution over the depth (see Figure 4-9 and Figure 4-10); and
4. Current speed over time see below); and
5. Length, width and extent of temperature plumes from the existing discharges (see comparison on predicted plumes in Figure 4-3, Figure 4-4 and Figure 4-5 with measured plumes).

4.7.1 Comparison of Predicted and Measured Currents Over Time

The predicted currents from the refined model with finer horizontal and vertical scales were compared to the ADCP current data collected during the EES. Note that the measured currents are mostly weak, in the range of 0.02 m/s to 0.07 m/s and there is a range of error associated with measurements of weak current speeds and directions as the accuracy is the ADCP is +/- 0.01 m/s.

Figure 4-12 shows a comparison of the 1-hour predicted and measured currents for the May 2020 ADCP deployment. The comparison showed that the refined model reproduced the measured current speeds and directions satisfactorily (Hydronumerics, 2024).

For the winter 2021 ADCP deployment, the refined model reproduced the measured current speeds and direction well except for brief periods of higher current speeds (with direction consistent with observed). The outcome is a model that is fit for purpose.

The increase in vertical resolution of the model provides a detailed vertical representation of the surface layers and meets the Minister's recommendation 2c.

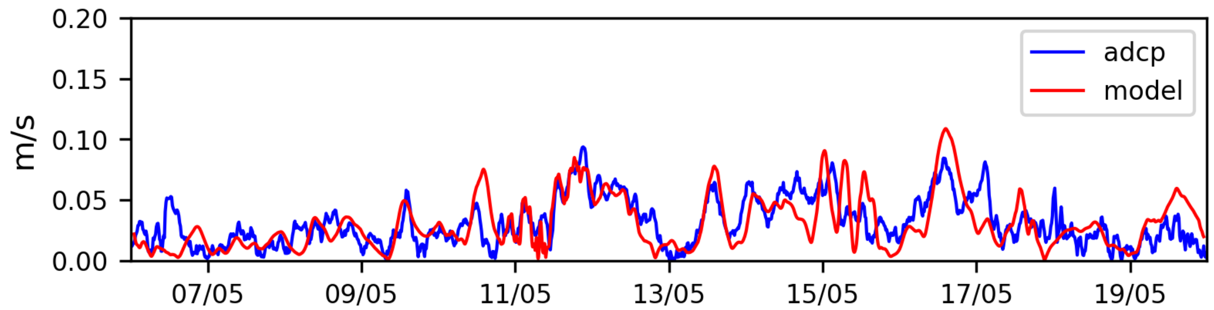


Figure 4-11. Comparison of Measured and Modelled Currents

4.7.2 Comparison of Measured and Predicted Plumes

Figure 4-12 shows the 2023 temperature measurements in the existing plumes and Figure 4-13 shows the thermal plumes simulated by the model under comparable conditions. Both were generated on the same tide and wind conditions in the model as during the day of field measurements. The comparison of the sets of images illustrate that the model reproduces plumes similar to the observed shape, temperature difference and extent of the plumes along the refinery shoreline. Plumes were measured as described in Section 3.4.

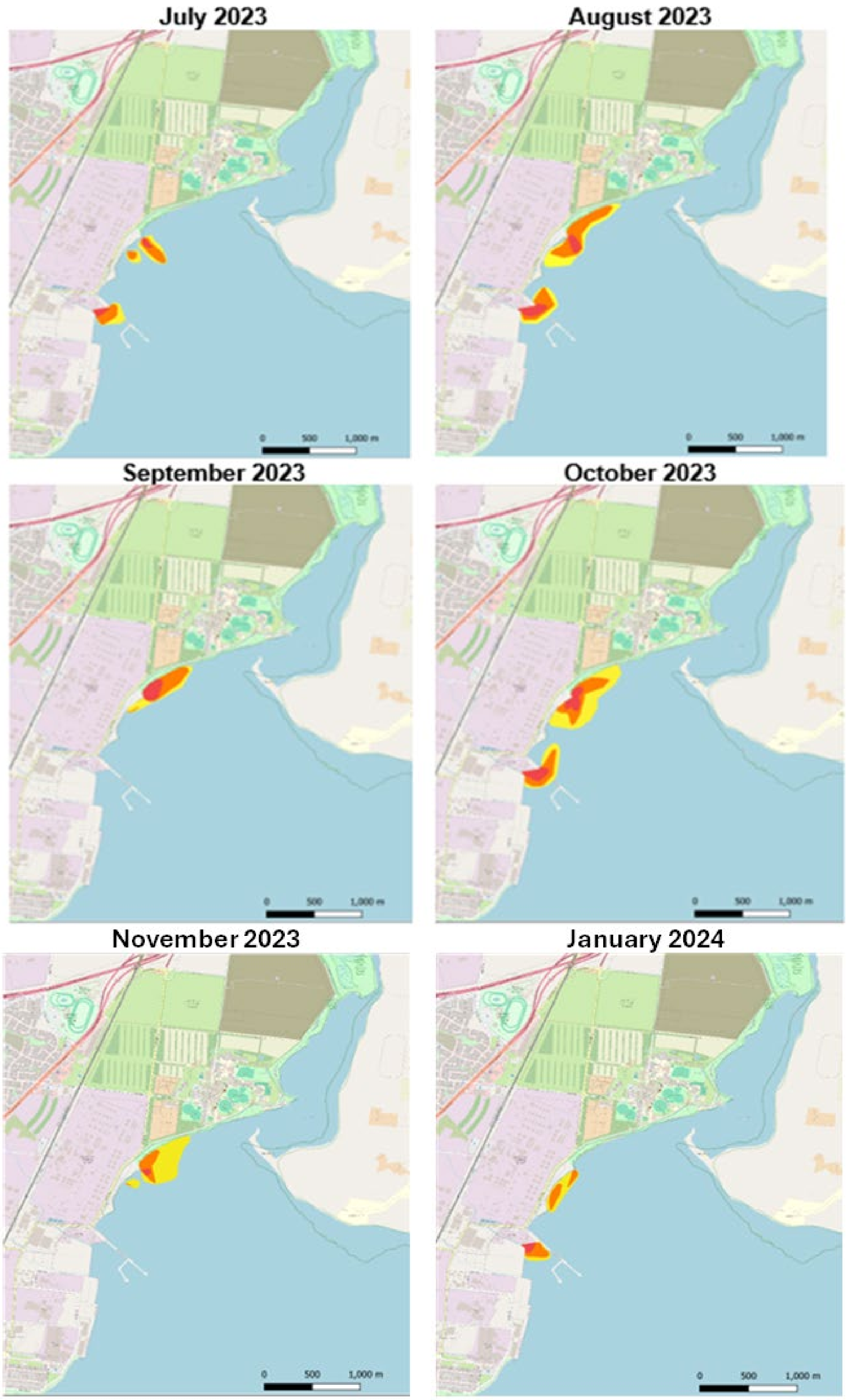


Figure 4-12. Measured Temperature Contours – July 2023 to January 2024

(Red = +5°C, Orange = +3°C, Yellow = +2°C) – Source: CEE 2024

Note: Contours show increment above ambient

Figure 4-13. Predicted Temperature Plumes Using Refined Model

Table 4-2 shows the average area of each of the temperature contours for the measured plumes and modelled plumes. The table shows that both the measured and modelled temperature plumes are similar in size, with the measured 2 and 3 degree plumes being slightly bigger in the measurements and the 5 degree contour being slightly bigger in the model.

Table 4-2. Average Measured and Modelled Plume Area

Plume Type	+2°C	+3°C	+5°C
Measured	20 ha	12 ha	3 ha
Modelled	18 ha	10 ha	5 ha

Overall, the refined model is fit for the purpose of predicting the present and future plumes from the refinery discharges, and the transport and dispersion of suspended solids from dredging.

Figure 4-14 shows the largest predicted chlorine plumes for the existing discharges in Corio Bay at high tide with a light southerly wind, calculated using the refined regional hydrodynamic model updated based on the Minister's directions. It can be seen that the predicted chlorine contours match the envelope chlorine contours inferred from temperature measurements (refer to Figure 3-5), with a similar small area of 10 µg/L chlorine.

The modelled 4.3 µg/L chlorine contours are larger than the contours inferred from temperature contours, although still very small. For W1, the measured 10 µg/L chlorine plume extends for 100 m while the predicted plume extends for 230 m. For W4, the measured 10 µg/L chlorine plume extends for 110 m while the predicted plume extends for 150 m.

For W5, the measured 10 µg/L chlorine plume extends for 120 m while the predicted plume extends for 160 m. The reason for the difference is that there is more initial dilution due to the outflow velocity than assumed in the input to the regional hydrodynamic model. The initial dilution is within the 20 m grid scale.

The small extent of the measured and predicted 4.3 µg/L chlorine plumes demonstrates that there is negligible risk of chlorine from the existing discharges reaching the Ramsar site.

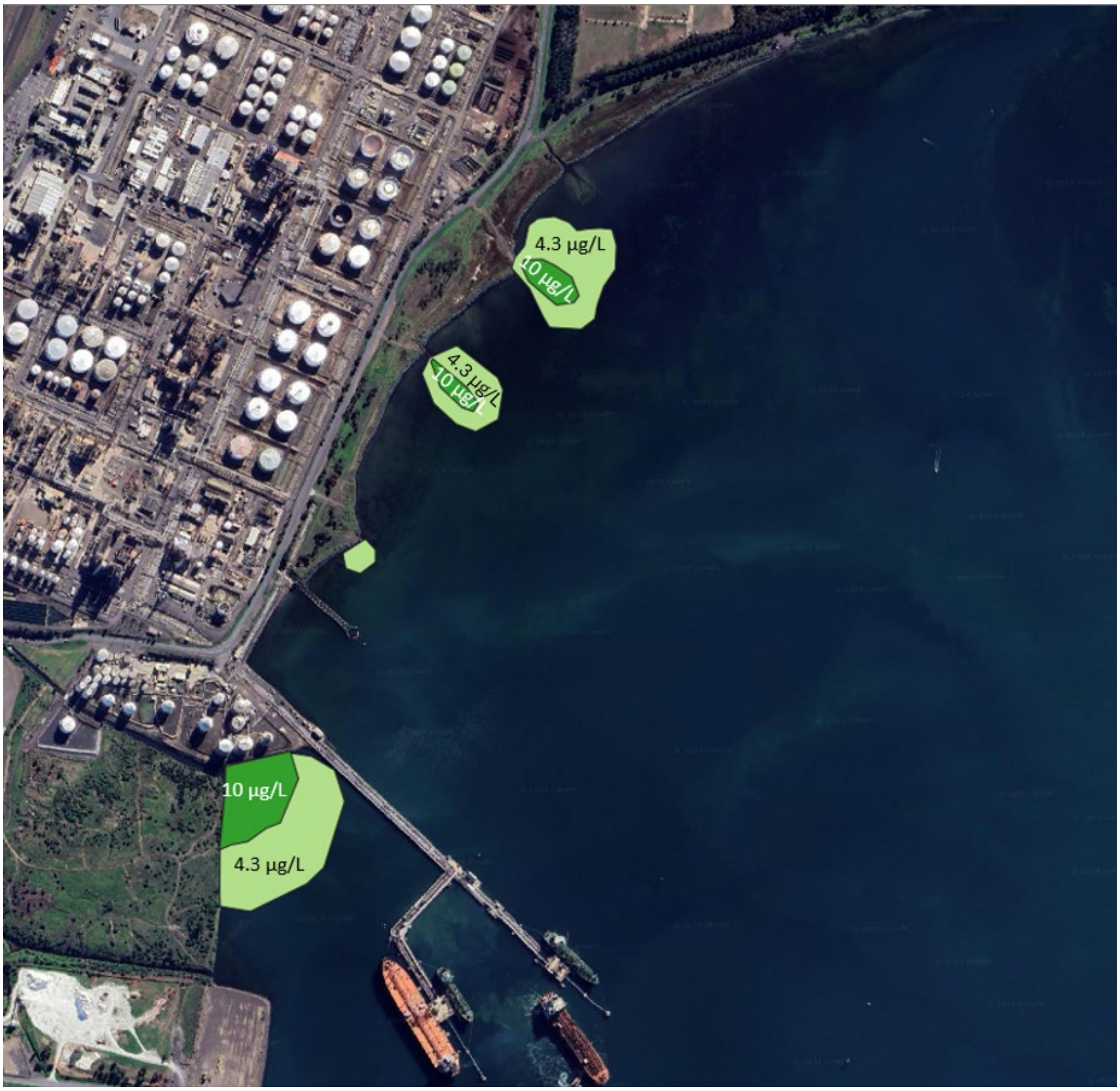


Figure 4-14. Modelled Chlorine Contours in Existing Plumes in Corio Bay

4.8 Task 2d: Include the FSRU in the Model

Recommendation 2d of the Minister's Directions is related to the effects of the presence of the FSRU on currents.

The following information is provided in this section:

- a description of the flow in the plume under the FSRU
- a description of Task 2d which involved the inclusion of the FSRU as a solid barrier in the model to determine the effects of the presence of the FSRU on currents and address Recommendation 2d

In the EES, near-field modelling was used to predict the mixing of the multiple jets from the diffuser. The jets would be rapidly mixed due to shear between by the high-velocity discharge jets and the adjacent water creating a shallow layer of slightly denser water on the seabed about 1 m deep. This layer flows under the FSRU and in the EES it was assumed there was minimal interaction between this deep layer and the FSRU.

During the IAC hearings, it was suggested that under some conditions (very low tide with a fully loaded FSRU), the gap beneath the FSRU could reduce to 1.45 m so there could be some interaction between the FSRU and the flow on the seabed.

The simulate the effects of the FSRU on the plumes generated by the proposed diffuser under the FSRU, the regional hydrodynamic model was refined to include the FSRU in the model as a solid barrier in the grid (depth 10 m, length 300 m and width of 40 m) that matched the size of a moored FSRU at the proposed refinery pier extension.

Figure 4-15 shows a series of images depicting the northward flow patterns with existing conditions, with the FSRU and with the FSRU and diffuser at the surface (left) and seabed (right). At the surface the FSRU and the density flow from the diffuser increases the currents that flow south-west into the shipping channel, with additional fanning out of the currents around the hull of the FSRU. At the seabed the currents are much weaker. The FSRU and FSRU and diffuser cause in increase in current velocity underneath the hull of the vessel which assists the flow from the diffuser along the seabed.

Figure 4-16 shows a series of images depicting the southward flow patterns with existing conditions, with the FSRU and with the FSRU and diffuser at the surface (left) and seabed (right). At the surface the current deflects around the hull of the FSRU with a small wake of lower current speed behind it. To the north the currents in the shipping channel are very weak for both the existing case and the case with a FSRU and diffuser. The FSRU increases the current speed near the bed, which assists the flow from the diffuser along the seabed.

The result of the FSRU slightly increasing current speeds and mixing increases the rate of dilution of the temperature and chlorine plumes to a minor extent. As the DGV for temperature in Corio Bay is 2^{o}C, the diluted plume is well under the DGV for temperature well before the plume reaches the FSRU. The same conclusion applies for chlorine where the DGV for chlorine in Corio Bay is 10 µg/L and the chlorine concentration in the plume under the FSRU is 0.5 µg/L.

The predicted chlorine and temperature levels have no adverse ecological implications.

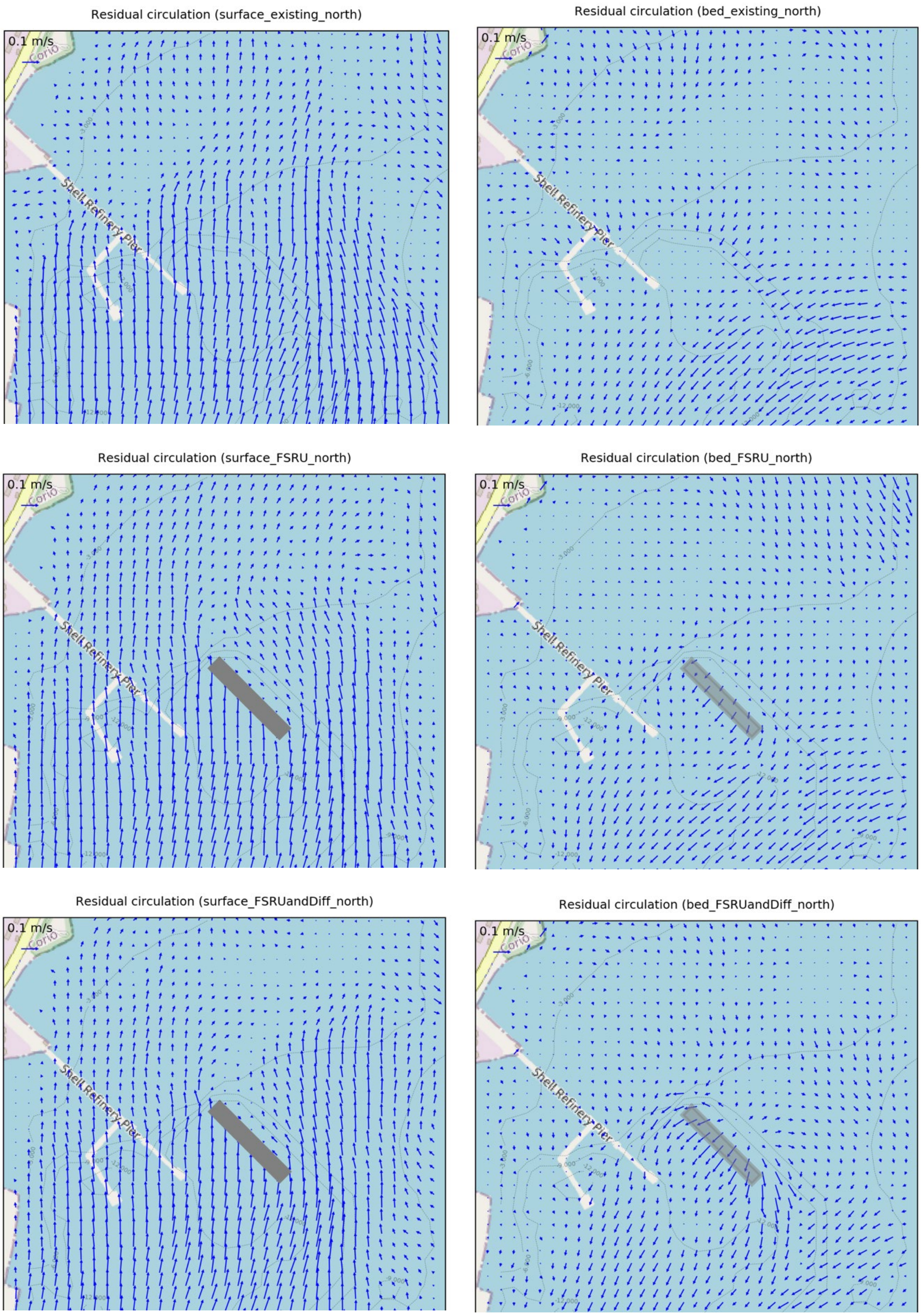


Figure 4-15 Velocity Maps (4-hour average) in Simulated Northward Current

<u>Left Hand Side (Surface)– Top = Existing, Mid = FSRU, Bottom = FSRU & Diffuser</u>

<u>Right Hand Side (Seabed) – Top = Existing, Mid = FSRU, Bottom = FSRU & Diffuser</u>

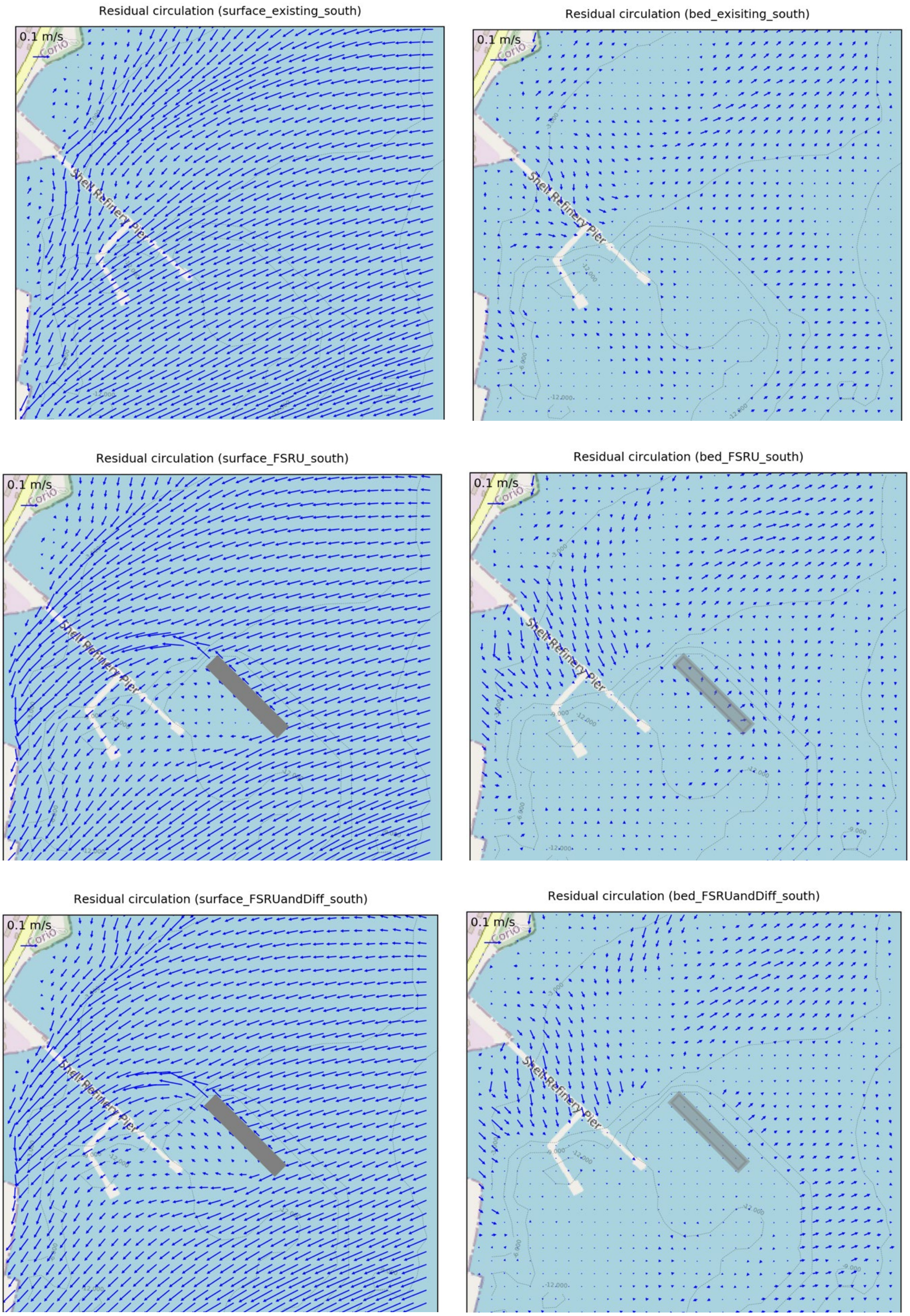


Figure 4-16 Velocity Maps (4-hour average) in Simulated Southward Current

Left Hand Side (Surface)– Top = Existing, Mid = FSRU, Bottom = FSRU & Diffuser

Right Hand Side (Seabed) – Top = Existing, Mid = FSRU, Bottom = FSRU & Diffuser

4.9 Task 2e: Independent Peer Review

The peer review of the model was undertaken by Stantec. Comments and suggestions were provided to CEE and HydroNumerics. The report on refining the regional hydrodynamic model was updated in response to the comments. Thus, the peer review of the model has been completed. Stantec's Peer Review Report B is provided as an attachment to the Supplementary Statement, please refer to Attachment I: *Peer Review Report B*. CEE's response to the findings and recommendations of the peer review are provided in Appendix A of this report.

4.10 Conclusions

Recommendation 2 of the Minister's Directions required refinement and calibration of the regional hydrodynamic model so that it more accurately reproduces observed water levels, currents, tidal range, and tidal exchange in Corio Bay.

While there are no significant changes in the model processes, the refined regional hydrodynamic model has a smaller horizontal and vertical grid, improved boundary conditions and uses a more representative wind file, as detailed above and all modelling that relied on the model (entrainment, suspended solids extent) was re-run.

The following updates were made to refine the regional hydrodynamic model as part of this supplementary statement:

- a Calmet wind file, which combines and interpolates between measured wind fields at Geelong Racecourse, Avalon Airport, Point Wilson and the Geelong Refinery, was selected and used in the model.
- a more detailed horizontal grid of 20 x 20 m resolution throughout Corio Bay, Hopetoun and North Channels was used to better represent the Hopetoun and North Channels more accurately.
- a more detail vertical resolution of 0.5 m in the upper 4 m of water in Corio Bay was used to better represent warm surface layers at or near the refinery discharges more accurately.
- Representation of the FSRU in the model, implemented as a solid barrier in the grid (height 10 m, length 300 m and width 40 m) to ensure that the effects of FSRU on currents were considered and represented in the model.

To calibrate the modified model, the predicted plumes were compared to data collected and observations made during field investigations. It was found that the modified model could reproduce sea level, tidal exchange, currents, and the thermal plumes satisfactorily for the purpose of this project.

In summary, a refined regional hydrodynamic model was produced following the completion of these tasks. This refined model was used for the tasks undertaken to address Recommendations 3, 5 and 6 of the Minister's Directions.

5. Recommendation 3 – Re-run Wastewater Discharge Modelling

5.1 Summary of original EES findings

In the EES, the near-field model was used to predict the path, initial dilution and extent of the discharge plumes close to the point of discharges. The predictions from the near-field modelling were then incorporated into the regional hydrodynamic model which was used to simulate the existing conditions of Corio Bay and predict potential impacts related to construction and operation of the project.

A Computational Fluid Dynamics (CFD) near-field model was used to simulate the existing refinery seawater intake and to simulate discharge plumes close to the four existing refinery discharge outlets, with and without the project.

As there is potential for the FSRU to discharge directly into Corio Bay on occasions when discharging into the refinery cooling water system is not feasible, most notably if the refinery was partially offline for maintenance activities or in the event that the refinery was permanently decommissioned in the future and the option for reuse of the FSRU discharge water was no longer available, modelling of this discharge was also undertaken to assess the potential impacts of a direct discharge into Corio Bay. This is discussed in Section 8.7 and Section 9.10 of EES Technical report A: *Marine ecology and water quality impact assessment* (CEE 2022). In this situation, cool seawater (approximately 7°C below ambient seawater temperature) would be discharged directly from the FSRU through a diffuser located under the new Refinery Pier extension when the refinery is offline.

The CEE INITDIL near-field model was used to simulate the discharge plume within 50 metres of the proposed diffuser which would be approximately 300 metres long with 180 small high-velocity ports and located 0.5 metres below Lowest Astronomical Tide (LAT) under the new pier. The INITDIL model was used for the diffuser as this model has the capability to simulate discharge plumes created from multiple high velocity discharge points. The predictions were checked using two other initial dilution models.

The high-velocity ports would discharge the seawater at around 5 metres per second (m/s) and at an angle of 30° away from the underside of the pier. The cool seawater would be spread out across a number of outlets rather than being concentrated directly from a single point of discharge on the FSRU. This configuration would result in greater mixing and dilution.

Considering this, INITDIL predicted that there would be a dilution of 20:1, which means that there would be 20 parts of seawater for every1 part of discharge. The other models gave similar results.

5.2 Overview

Recommendation 3 of the Minister's Directions is related to this conclusion and was as follows:

Re-run the wastewater discharge modelling with revised inputs based on the refined regional hydrodynamic model. Consider:

a) Revising the nearfield modelling of discharges from the diffuser to address the matters raised by Dr McCowan in his written evidence (D75).

b) The IAC's recommended default guideline values (DGV) for chlorine discharges.

The IAC concluded that the 95 % default guideline value (DGV) for chlorine was appropriate for Corio Bay and the waters in the vicinity of the discharge points and a 99 % DGV should be applied to any part of a chlorine plume that extends into the Ramsar site, on the basis that a 99 % species survival rate is the default protection level in the ANZ Water Quality Guidelines for ecosystems with high conservation significance.

It is noted that the Australia New Zealand DGV for chlorine produced oxidants in marine waters have been revised following review. The EPA advised that the 95 % DGV for chlorine in Corio Bay is 10 ug/L (formerly 7.2 ug/L), and the 99 % DGV at the Ramsar site is 4.3 ug/L (formerly 2.2 ug/L). The revised DGVs provided by the EPA were adopted.

5.3 Summary of Tasks

A number of tasks were undertaken as per the study program developed for the Supplementary Statement to address Recommendation 3 of the Minister's Directions. An overview of these tasks and their objectives is provided in this section of the report and are described in further detail in subsequent sections of this report.

<u>Task 3a: Re-run the wastewater discharge modelling with revised inputs based on the refined regional hydrodynamic model, as per Recommendation 2, including:</u>

- Examining the near field modelling of discharges from the proposed diffuser located on Refinery Pier to assess whether the super-elevation raised during the IAC hearing (Dr McCowan written evidence D75) is significant in influencing currents.

<u>Task 3b: Re-run the wastewater discharge modelling</u>

The wastewater discharge modelling was re-run using the refined regional hydrodynamic model to predict future FSRU discharges via the diffuser and via the existing refinery.

5.4 Task 3a: Near-field Modelling of Diffuser Discharge

Recommendation 3 of the Minister's Directions refers to re-running the wastewater discharge modelling with revised inputs and examining near field modelling of discharges from the proposed diffuser.

The following information is provided in this section:

- a summary of the evidence to the IAC by Dr McCowan (Section 5.4.1).
- the methodology for Task 3 (Section 5.4.2).
- the results of Task 3 (Section 5.4.3).

5.4.1 Background to EES

Evidence by Dr McCowan

During the IAC hearing, Dr A McCowan, presenting as a witness for Geelong Grammar, made a number of statements regarding the near-field modelling presented in the EES. Dr McCowan did not provide any alternative modelling or further substantiation of his evidence, so the response requested in Recommendation 3 of the Minister's Directions is based on Dr McCowan's written evidence.

The written evidence of Dr McCowan was as follows (including the flow schematic shown in Figure 5-1):

CEE (2022) use their INITDIL model to predict an initial dilution of 20:1 at the base of the slope at the FSRU berth. At this point, the INITDIL results presented in their Figure 6-9 show that the plumes from the 100 individual diffuser ports will have a width of about 6m and will have merged into a single linear plume that continues to flow under the FSRU.

CEE note that the 20:1 dilution is a "worst case" scenario for slack water and that higher ambient currents of 0.045 m/s and 0.08 m/s would be expected to result in higher initial dilutions of 24:1 and 28:1, respectively.

They then note that "there would be no increase in dilution as the plume passes under the FSRU but then the dilution would increase on the far side of the FSRU".

I consider this scenario to be seriously flawed. My reasons for this are as follows:

The INITDIL model can be used to predict the behaviour of plumes in the open sea. It does not, however, allow for the effects of the presence of the FSRU, or for the additional effects of a possible LNG tanker moored beside the FSRU

- *The under-keel clearance scales to about 2.5 m. This would provide a barrier to the full depth of flow of the plume, which by Figure 6-9 or 6-10 of CEE (2022) would be expected to have a width of around 6 m at this point.*
- *With a maximum draft of 11.9 m (EES Chapter 12) a basin depth of -13.1 m to Chart Datum and a mean lower low water (MLLW) of +0.25 m to chart datum, the under-keel clearance could reduce to about 1.45 m. This would provide a more significant barrier to the plume. The presence of an LNG carrier beside the FSRU would further increase the barrier to the flow of the plume.*
- *Additionally, the flow in the colder denser discharge plume will be "super-critical" relative to the warmer receiving water at the point the plume reaches the seabed.*

In this respect, I note that:

- *The barrier caused by the presence of the FSRU will trigger an internal hydraulic jump which will form at the at the surface of the plume upstream of the FSRU.*

The hydraulic jump will cause cold water from the plume to accumulate upstream of the FSRU. This in turn will reduce the dilution achieved as the plume will be mixing with water that already contains a proportion of cold water. The scenario described above is shown schematically in Figure 6-A (below). It is considered to be more realistic than the CEE scenario. The level of the diluted plume water would build-up against the side of the FSRU until the hydraulic grade was sufficient to drive diluted plume water through the smaller flow area under the FSRU. The height of the plume at the FSRU is also likely to be sufficient to drive some of the diluted plume water to the north of the pier, as shown in Figure 5-1*.*

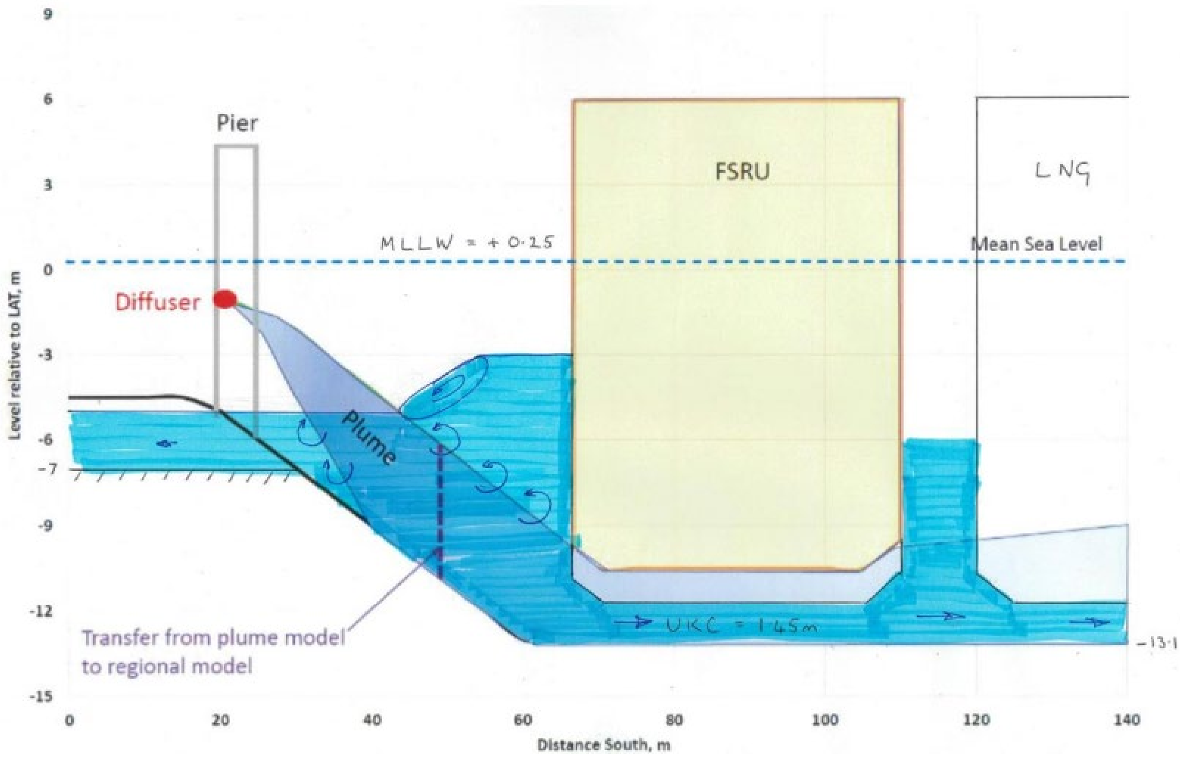


Figure 5-1 Flow Schematic in Evidence from Dr McCowan

In response to the evidence of Dr McCowan, the following points are noted:

- There is a 6:1 scale distortion in Figure 5-1 as the horizontal distance is 140 m and the vertical distance is 24 m. This makes to distance between the jetty and the FSRU (which is 50 m) look smaller than it is).
- All the near-field mixing in the jets takes place in the 20 m distance from the manifold. This, the FSRU at 50 m from the diffuser is well beyond the zone of near-field mixing.
- The width of the jets refers to the horizontal spread and should not be confused with the vertical height of the diluted jets which is much smaller;
- The diluted plumes flow under the FSRU – in the gap between the FSRU and the seabed;
- The FSRU and LNG carried cannot both be full, as LNG is transferred from the LNG carrier to the FSRU.

The other assertions regarding the hydraulic jump and the superelevation (almost 2 m high) as shown in Figure 5-1 are considered either too conservative or incorrect as outlined in the following sections.

In order to further assess the voracity of Dr Cowan's evidence, an independent analysis of the near-field modelling was undertaken by Prof Lee of Hong Kong University using *Visjet*. This is a different near-field model to the three used in the 2022 EES. *Visjet* predicted the same dilution of 20:1 as the CEE near-field model INITDIL in the EES. This is discussed in more detail in Section 5.4.3 below.

Diffuser geometry

The diffuser geometry used in near-field modelling is:

- Port spacing = 3 m;
- Port diameter = 0.094 m (by duckbill valve);

- Discharge velocity = 5 m/s
- Orientation = discharge 30 degrees below horizontal
- Depth at discharge = 1.2 m below sea level
- Discharge per port = 34.7 L/s (350 ML/d)
- Distance from manifold to FSRU = 50 m
- Direction of discharge = all ports facing to the south

5.4.2 Methodology

The supplementary marine environment investigations conducted to address Recommendation 3 of the Minister's Directions were as follows.

- Engage an independent modelling specialist to repeat the near-field modelling of discharges from the proposed diffuser located on Refinery Pier to check the dilution prediction.
- Assess whether the hydraulic jump and super-elevation raised during the IAC hearing (Dr McCowan's written evidence D75) is significant in influencing currents.
- Assess the effects of the hydraulic jump and likely height of super-elevation in front of the FSRU.
- Check the far-field dilution under the FSRU using the refined regional hydrodynamic model.
- Adopt the DGV set out by the EPA in assessing the impact of existing discharges.

5.4.3 Results - Independent Check of Near Field Model Predictions

Prof Lee of Hong Kong University made an independent check of dilution calculation for the parameters listed above using his model *Visjet.* He predicted that the plumes from the diffuser ports reach the downward sloping seabed at approximately 10 m from the discharge ports before merging. His predicted near-field dilution is 20:1 on reaching the seabed. This matches the near-field dilution of 20:1 predicted by CEE using three different jet dispersion models.

Prof Lee carried out a check to test the sensitivity to higher and lower ambient seawater temperature and concluded that the predicted dilution would be the same in summer and winter temperatures.

The predicted dilution of 20:1 would reduce the expected chlorine level in the FSRU discharge of 50 µg/L to 2.5 µg/L, which is well under the DGV for chlorine in Corio Bay of 10 µg/L. Thus, small variations in dilution due to currents would not have a significant effect.

Figure 5-2 shows the predicted plume path at a normal horizontal to vertical scale. The near-field dilution occurs close to the diffuser (within about 10 m according to Visjet or up to 20 m according to INITDIL), with jet mixing completed well before the FSRU.

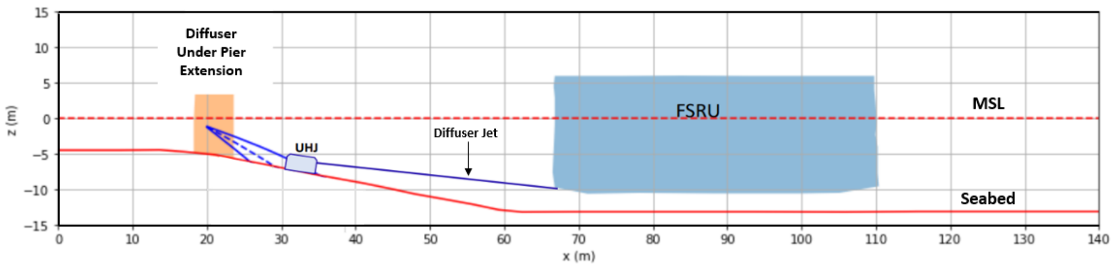


Figure 5-2 Predicted Plume Path from Near-field Dilution Model

(Source: Prof Lee, 2023)

In summary, initial dilution modelling has been carried out using four standard and well-tested near-field models. The results may be summarised as follows, in terms of initial dilution and chlorine concentration after dilution:

1. INITDIL: dilution of 20:1 resulting in chlorine concentration of 2.5 µg/L;
2. Cederwall: dilution of 25:1 resulting in chlorine concentration of 2.0 µg/L;
3. VPLUMES: dilution of 22:1 resulting in chlorine concentration of 2.3 µg/L;
4. VISJET: dilution of 20:1 resulting in chlorine concentration of 2.5 µg/L.

There is no basis to assert that the dilution will be less than 20:1 or that a low chlorine concentration, well below the FDGV of 10 µg/L would not be achieved because of the undular hydraulic jump or the minimum slot width under the FSRU of 1.45 m. The initial dilution is completed at least 30 m before reaching the FSRU.

The conservative or 'worst case' dilution of 20:1 is carried forward to the regional refined modelling.

Hydraulic Jump and Likely Super Elevation Next to FSRU

- *It was asserted that the barrier caused by the presence of the FSRU will trigger an internal hydraulic jump which will form at the at the surface of the plume upstream of the FSRU.*

The discharge jets from the diffuser ports slow and merge into a wide plume when they reach the seabed. Friction on the seabed slows the plume and there is a transition from supercritical flow (in the jets) to subcritical flow (in the plume on the seabed) through a local undular hydraulic jump (UHJ) which produces waves on the top surface of the jet flow and some further dilution. The location of the UHJ is shown in Figure 5-2 where the individual jets reach the seabed and merge together. The UHJ is small for Froude Numbers in the range of 1.5 to 2.9 (Chanson and Montes, 1995), which corresponds to this situation.

Note that the flow pattern associated with the UHJ occurs within the depth and does not produce significant waves on the surface of Corio Bay at 6 m above the plume. It is considered that the sketch in Figure 5-1 developed by Dr McCowan is misleading.

The worst case for flow under the FSRU is when the FSRU is fully loaded and at maximum draft of 11.9 m below sea level. When the FSRU is fully loaded, the adjacent LNG carrier would be empty (as all the LNG would have been transferred from the carrier to the FSRU). The sketch in Figure 5-1 developed by Dr McCowan is misleading as it shows both the FSRU and the LNG carrier full of LNG – this is not a feasible situation.

The gap between the base of the FSRU and the seabed is 1.45 m at lowest tide when fully loaded. The velocity of the flow through this gap in that event would be 0.16 m/s. The super-elevation due to a velocity of 0.16 m/s would be less than 2 mm. This is a very minor fraction of the 2 m super-elevation depicted by Dr McCowan in his Figure 5-1.

Vessels moored in port across tidal currents result in a small super-elevation of the water - of about a millimeter - on the side facing the current. Generally, the super-elevation is negligible in comparison with the effect of waves reaching the vessel.

In conclusion, the issues raised in the EES written evidence D75 have been examined and were found to be exaggerations.

5.5 Task 3b: Re-running Wastewater Discharge Modelling

The wastewater discharge modelling based on the refined regional hydrodynamic model for discharge of seawater from the FSRU into Corio Bay through the existing refinery discharge points, or alternatively, from the diffuser to be located under the new pier, are discussed in this section.

5.5.1 Modelled future plumes – Discharge Through the Diffuser

The refined model from the response to Recommendation 2 was used to model the flow under the FSRU. The FSRU is represented in the refined regional hydrodynamic model as a solid barrier in the grid (height 10 m, length 300 m and width of 40 m) that matches the size of a moored FSRU. The LNG carrier is not represented as it would be several metres higher in the water (because it is empty, having unloaded the LNG to the FSRU).

The EES modelled the diffuser outflow of 350 ML/d as a conservative maximum. As discussed in Section 1.4.2.2, cooling water flow during maintenance periods is 200 to 250 ML/day. When maintenance is scheduled a discharge of 250 ML/d was explored using the refined model.

The connection from the near-field model to the refined regional hydrodynamic model was made at 19 m along the path of the plume, where the plume is on the seabed at a dilution of 20:1.

Figure 5-3 shows the predicted temperature contours in the plume on the seabed (flowing under the FSRU) in the port area, with the proposed discharge from the diffuser. The predicted temperature contour of 0.2°C is well below the DGV of 2°C for temperature variations in Corio Bay.

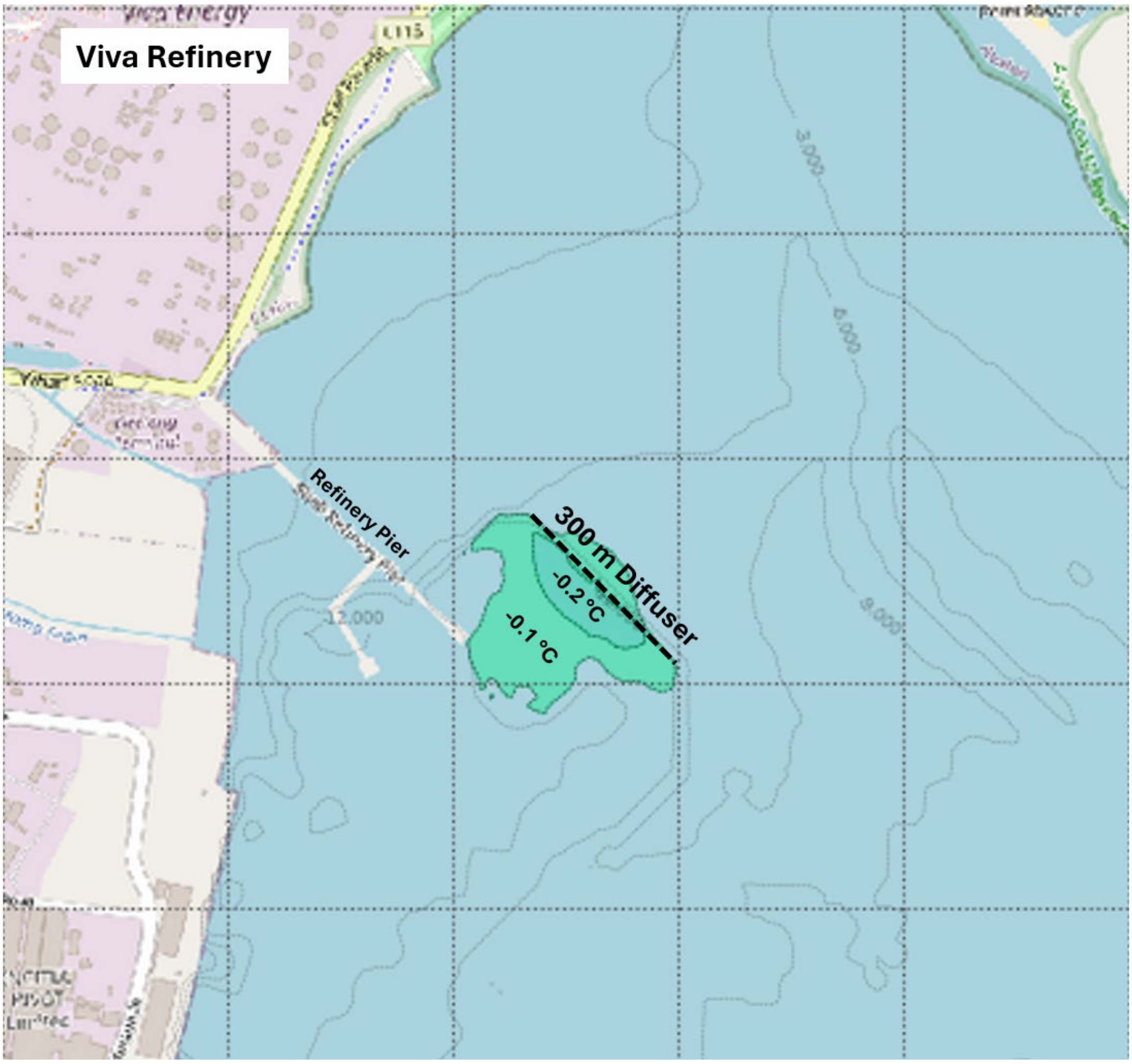


Figure 5-3. Regional Hydrodynamic Model Prediction of Temperature

Figure 5-4 shows the predicted chlorine concentration in the plume on the seabed in the port area. The predicted chlorine contour of 3 µg/L is well below the DGV of 10 µg/L for chlorine in Corio Bay.

The refined model shows that the area of residual chlorine in the model is 0.4 ha and is all under 3 µg/L. The EES results (Section 9 of Technical Report A: *Marine environment impact assessment* (CEE 2022)) also showed a total area of residual chlorine from the diffuser of around 0.4 ha. Thus, the outcome of the modelling has not changed based on the results of the refined model.

Figure 5-4. Regional Hydrodynamic Model Prediction of Chlorine

The results of the refined model predictions match the results presented in the EES. Overall, the diffuser mixes the plumes effectively creating small plumes that disperse quickly and are well away from seagrass.

Dilution with discharge from the diffuser is dominated by initial dilution with very little extra dilution in the flow under the FSRU. The length of the diffuser is proportional to the flow rate and therefore the resulting total dilution at a discharge of 250 ML/d (reported above) is essentially the same as a discharge of 350 ML/d (reported in the EES). With 350 ML/d discharge, the temperature and chlorine plumes would have the same concentration contours as shown in Figure 5-3 and Figure 5-4, but extend longer along the jetty.

5.5.2 Modelled Future Plumes - Discharge from FSRU Via the Refinery

Figure 5-5 to Figure 5-8 shows a series of images which depict the existing and an estimation of future plumes for temperature and chlorine. Figure 5-5 shows the existing temperature plume based on the CEE measurements.

Gas use in summer is projected to be about 40 % of peak capacity (see Table 1-1). Figure 5-6 shows the reduced envelope of the future temperature plumes in summer, when cooling of seawater in the FSRU would be less than the heating of seawater in the refinery.

Gas use in winter is projected to be average about 90 % of peak capacity. Figure 5-7 shows the much-reduced envelope of the future temperature plumes in winter, when cooling of seawater in the FSRU would be almost equal to the heating of seawater in the refinery.

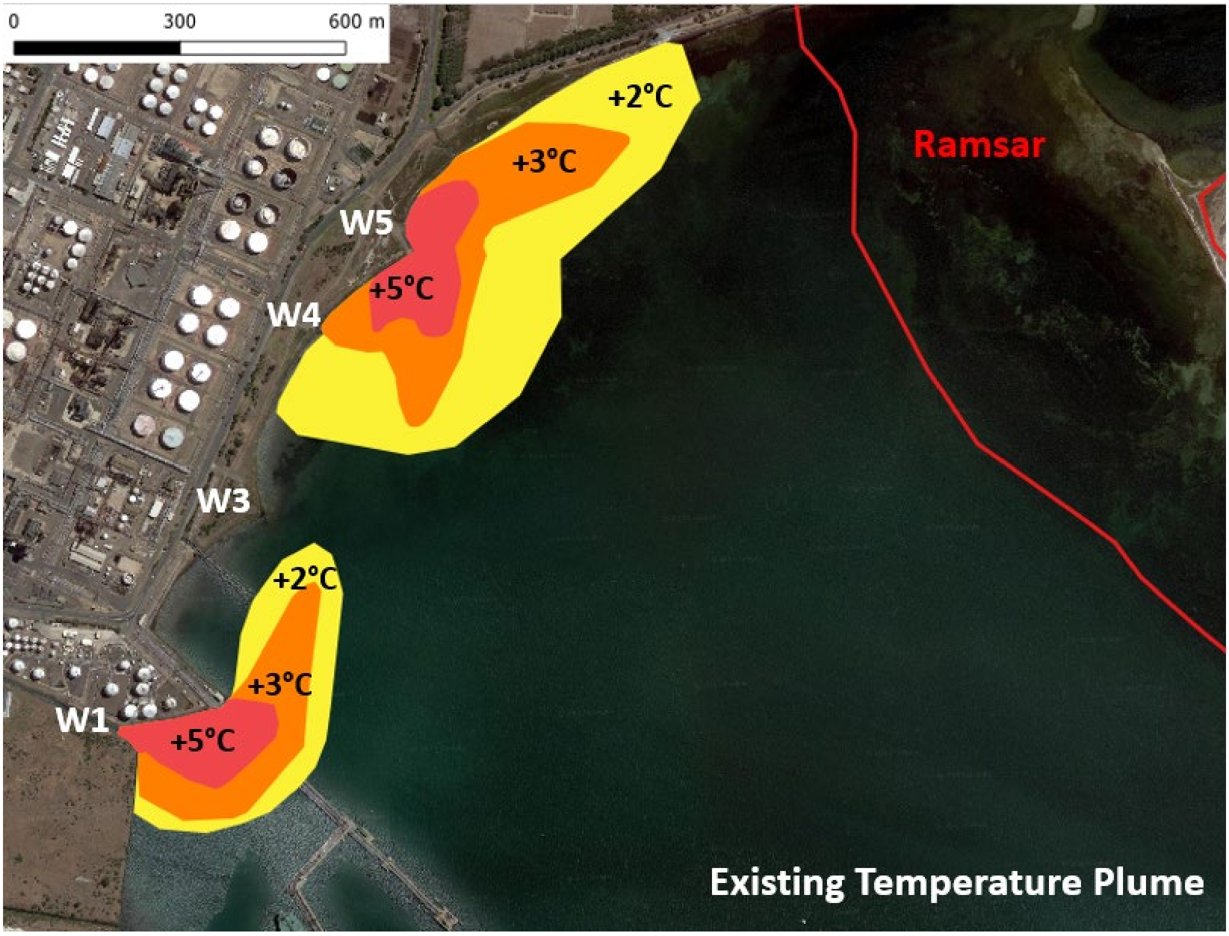


Figure 5-5. Existing Temperature Plume

Figure 5-8 shows the existing chlorine plumes. As use of chlorine to control biofouling is not expected to change, the future chlorine plumes would be the same as the existing chlorine plumes.

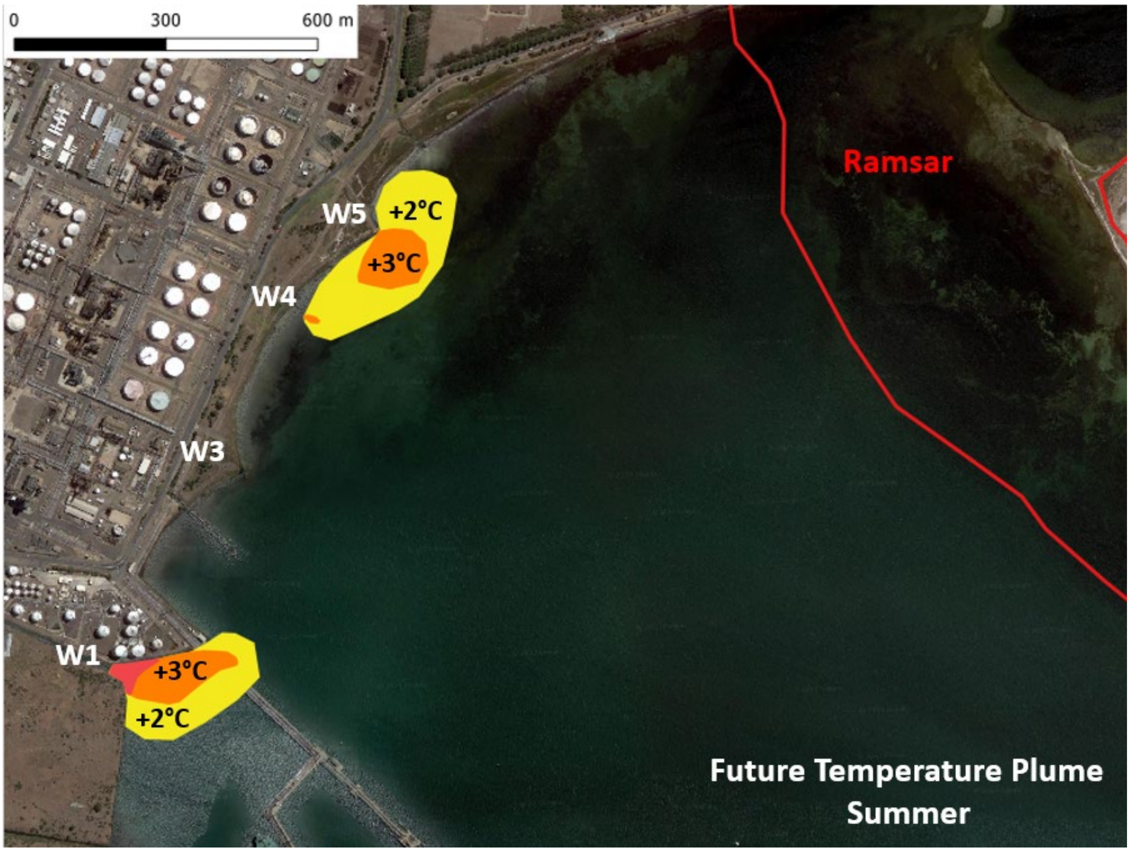


Figure 5-6. Future Temperature Plume - Summer

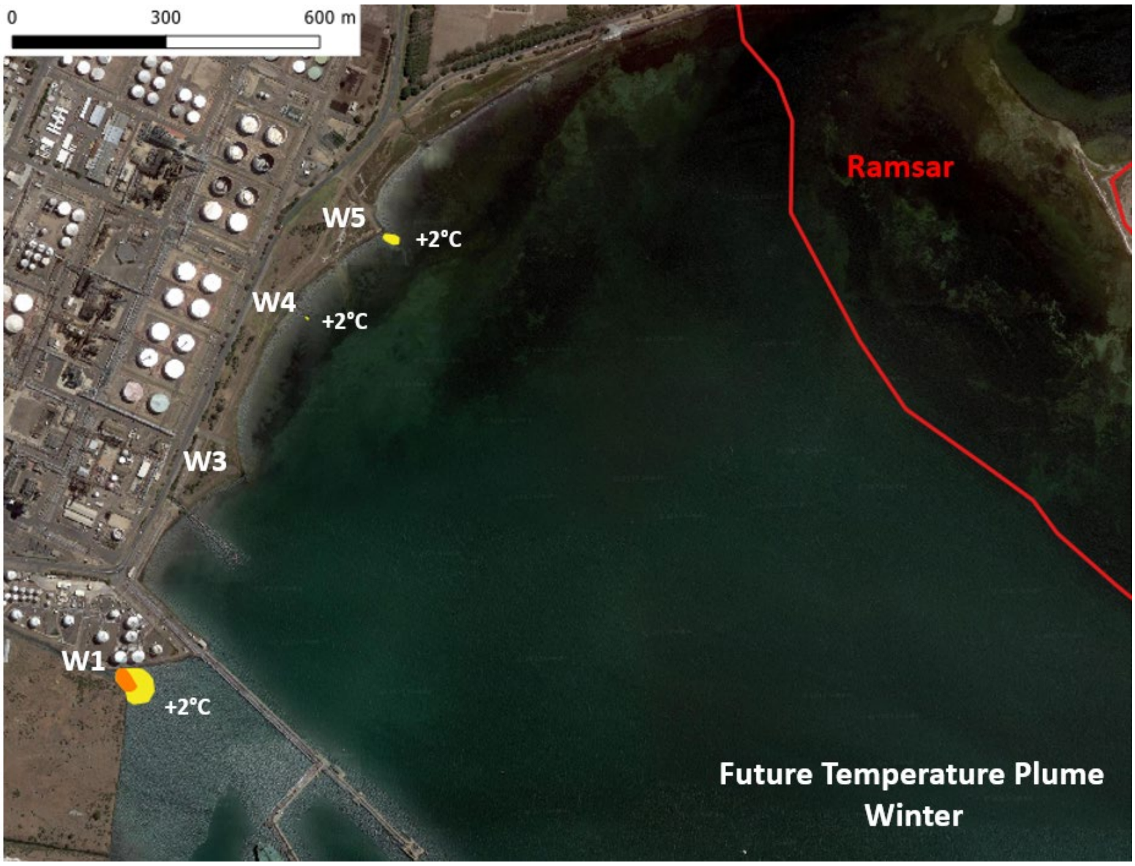


Figure 5-7. Future Temperature Plume - Winter

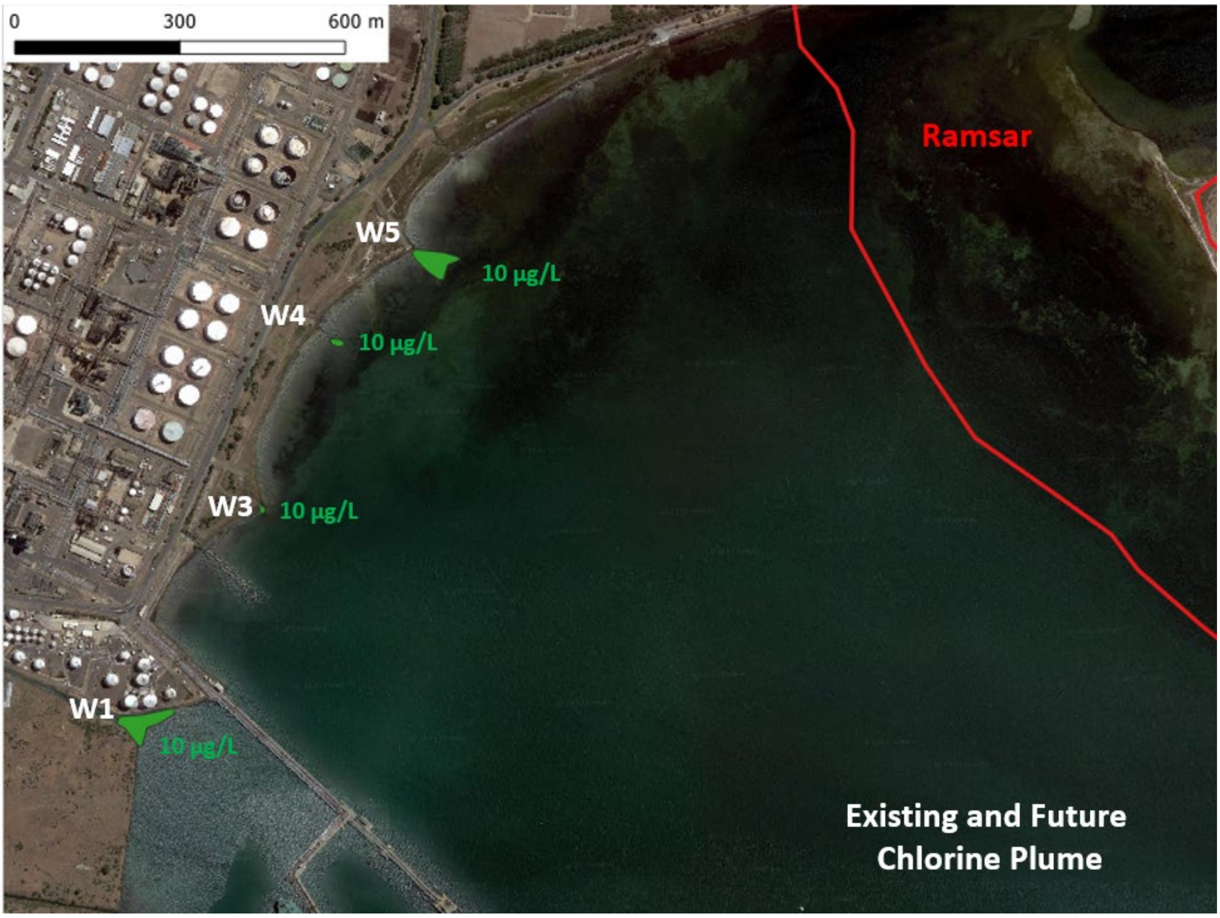


Figure 5-8. Existing and Future Chlorine Plumes (No Change)

5.6 Conclusions

Recommendation 3 of the Minister's Directions required a re-run of the refined regional hydrodynamic model with the FSRU represented in the model. This involved re-examining the near field modelling of discharges from the proposed diffuser located on Refinery Pier to assess whether the super-elevation raised by Dr McCowan during the IAC hearing is significant in influencing currents.

An independent analysis of the near-field modelling undertaken by Prof Lee of Hong Kong University (an independent specialist modeller) using *Visjet*, a different near-field model, predicted the same dilution of 20:1 as the CEE near-field model INITDIL in the EES. The predicted dilution of 20:1 would reduce the expected chlorine level in the FSRU discharge of 50 µg/L to 2.5 µg/L, which is well under the DGV for chlorine in Corio Bay of 10 µg/L. It is concluded that there is no basis to assert that the dilution will be less than 20:1 or that a chlorine concentration below the DGV of 10 µg/L cannot be achieved by the proposed diffuser, as the initial dilution is completed at least 30 m before reaching the FSRU.

Further investigation found that the assertions made by Dr McCowan about the hydraulic jump and super elevation were misleading and incorrect. The worst-case flow under the FSRU occurs when the FSRU is fully loaded and the LNG carrier is empty; the gap between the base of the FSRU and the seabed is 1.45 m at lowest tide when fully loaded, and the velocity of the flow through this gap would be 0.16 m/s. The super-elevation due to this velocity would be less than 2 mm which is a very minor fraction of the 2 m super elevation presented in Dr McCowan's evidence and is negligible in comparison with the effects of waves reaching the vessel.

The regional plume modelling was repeated using the refined and calibrated regional hydrodynamic model. The repeated modelling predicted the same results as in Section 6.2.5 of Technical Report A: *Marine environment impact assessment* (CEE 2022). The assertions made in written evidence D75 are not supported by the results.

With the project in operation, there would be smaller temperature plumes along the shoreline compared to the existing refinery discharges, and most of the plume would only be 1 to 3°C above ambient seawater temperature as a result of the cooled water input from the FSRU. The plumes would not reach the Ramsar site.

Consistent with the EES, future chlorine discharge plumes will be the same as existing chlorine discharge plumes.

The predicted temperature contour of 0.2°C from the diffuser is well below the DGV of 2°C for temperature variations in Corio Bay. The predicted chlorine contour of 3 µg/L from the diffuser is well below the DGV of 10 µg/L for chlorine in Corio Bay.

In summary, the near-field and regional hydrodynamic modelling has been repeated as required by the Minister's Recommendation 3 and the outcomes are essentially the same as in the EES. Sections 8 and 9 of Technical Report A: *Marine environment impact assessment* (CEE 2022) show that the area of plumes for temperature and residual chlorine have the same area as the results from the supplementary statement.

6. Recommendation 4 – Effects of Chlorine Discharges

6.1 Summary of Original EES Findings

For over 60 years, Viva Energy's Geelong Refinery has been using seawater from Corio Bay for cooling purposes and discharging it to Corio Bay, with residual levels of chlorine associated with biofouling control, through four EPA licensed discharge outlets. The reuse of seawater from the project in the refinery during operation means that residual chlorine concentrations in the discharge would remain the same.

To investigate whether the existing chlorine discharge from the refinery was producing significant levels of residual chemicals in marine life, during the EES, mussels were collected from six sites in northern Corio Bay and analysed for a wide range of chlorine residuals including trihalomethanes (THMs), haloacetic acids and bromophenols. The results are presented in Section 9.14 of EES Technical report A: *Marine ecology and water quality impact assessment* (CEE 2022)

Mussel sampling sites included Refinery Pier, directly within the dispersing plume, samples from navigational markers around the dredged channel and two reference sites further out in the Bay. The results showed no detectible levels of THMs, haloacetic acids and bromophenols in the mussels.

EES investigations did not identify evidence of negative impacts on marine ecology under the existing refinery discharge plumes. Seagrass in the vicinity of the plume was observed to be abundant and healthy; sea urchins, which are considered to be sensitive to chlorine, were abundant in the current discharge plume; and tests on mussels from the vicinity showed no detectable residual chlorine byproducts.

6.2 Overview

Recommendation 4 of the Minister's Directions states the following:

Consider undertaking further targeted investigations into the effects of existing chlorine discharges from the refinery to confirm likely project impacts resulting from chlorination by-products, including measurement of chlorination by-product concentrations in:

a) Seawater

b) Biota that have high susceptibility to contamination.

As noted in Technical Report A: *Marine environment impact assessment* (CEE 2022) and discussed extensively during the IAC Panel Hearing for the project EES, measurement of chlorination by-product concentrations in seawater is not considered feasible.

It was determined during the development of the EES that there is no laboratory in Australia that is able to analyse seawater to measure chlorine and chlorine by-product concentrations because chlorine rapidly reaches non-detect levels in this medium. The IAC noted this advice in its findings.

For this reason, the investigations in Section 9 of Technical Report A: *Marine environment impact assessment* (CEE 2022) into the effects of existing chlorine discharges from the refinery focused on measurement of residual chlorine and chlorine by-products in biota which are known to accumulate contaminants. Testing of sea urchins, which are reported to have a high susceptibility to chlorine contamination were considered; however, they were found during surveys undertaken for the EES to be proliferating in the existing refinery plumes which indicated that they were unlikely to be impacted by the existing refinery discharge plumes. So sea urchins were not a suitable species for testing. Thus, it was decided that mussels (which exist in the area and are known to bioaccumulate contaminants) would be used for chlorine testing as described below.

6.3 Summary of Tasks

A number of tasks were undertaken as per the study program developed for the Supplementary Statement to address Recommendation 4 of the Minister's Directions. An overview of these tasks and their objectives is provided in this section of the report and are described in further detail in subsequent sections of this report.

Task 4: Additional testing of mussels (*Mytilus edulis*) to confirm potential project impacts from chlorination by-products

- Mussels were obtained from Portarlington mussel farm and sets of eight mussels were deployed at seven sites in Corio Bay along the path of the existing refinery discharge plumes (see Figure 6-1 for deployment sites). Mussels were deployed at from 0.5 to 1 m below the surface, depending on the tide, in mesh allowing seawater to flow through and past the mussels. The placement of mussels was varied from the 2021 study in order to focus on chlorine in the dispersing plumes, as per the Minister's Direction.
- After four weeks, six sets of mussels were retrieved and taken on ice to Leeder Analytical Laboratory for analysis of a range of chlorine by-products (CBP). One set of mussels has been collected previously by an unknown person.
- Consideration was given to the food web and the potential for bioaccumulation of CBP in the marine food chain.

6.4 Task 4: Additional Testing of Mussels

6.4.1 Literature Review of Chlorine in the Marine Environment

This section considers the potential for impacts of CBP in the Ramsar site located approximately 1 km north of the project site at its closest point.

Chlorination of seawater is one of the most effective technologies for industrial biofouling control, but leads to the formation of halogenated chlorination byproducts (CBP) that, at elevated concentrations, could pose potential risks to environmental health. In seawater, the chlorine is rapidly replaced by bromine and the byproducts are generally forms of bromine, which is much less toxic in seawater than chlorine byproducts. It is convention to refer to chlorine and bromine byproducts as chlorinated byproducts.

Products of seawater chlorination other than oxidants are known as chlorination-produced by-products (CBP). They represent less than 6% of the chlorine concentration initially produced (Jenner and Wither 2011). Most of the CBP are present as trihalomethanes (THM), and most THM are tribromomethane or 'bromoform' (Abdel and Wahab 2011, Boudjellaba et al. 2016, Jenner and Wither 2011, Satpathy et al. 2010).

A range of brominated compounds, including bromoform, are produced naturally in the marine environment. The most common CBP in seawater is bromoform which is produced naturally by seaweeds and other marine organisms. These seaweeds grow in Corio Bay, Port Phillip Bay, Western Port Bay and many other bays and estuaries (Wallis and Chidgey, 2022).

Most CBP (whether natural or manufactured) are volatile and their ultimate fate is to be volatilized into the atmosphere where they degrade under UV light into other simpler products. The degradation process is illustrated in Figure 6-2.

In the intervening period, CBP could be taken up by fish, seagrass and algae, as well as smaller marine flora and fauna. Swans that feed in seagrass in shallow water are exposed to low levels of natural CBP. Marine biota are accustomed to brominated compounds and many can metabolically regulate low levels of bromine.

While it is theoretically feasible to catch and analyse swans, sea birds, fish and other higher components of the marine food chain, and analyse them for the same range of CBP as the mussels, the difficulty (other than the ethical considerations and permits) is that there are no published limits for CBP in their tissues and the concentrations of CBP will be much lower than in mussels and therefore more difficult to detect.

The discharges from the refinery form large shallow plumes that extend for several hundred metres along the shore of Corio Bay (see Section 3.4.3 and 5.5.2), but do not extend into the Ramsar site. As the discharge plumes occur on the surface, there is unlikely to be interaction with deep sediments or MBP. The field studies of the extent of the plumes have shown that detectible concentrations of chlorine extend only about 200 m from the discharge points. The chlorine plumes are well away from the Ramsar site.

The migratory birds in the Ramsar site feed well away from the discharge plumes where the residual CBP from the discharges are at extremely low concentrations. Natural levels of bromoform are likely to be higher than the residual bromoform from the discharges.

The previous analysis of mussels from Corio Bay shows that the levels of CBP, including bromoform, trihalomethanes, brophenols and haloacetic acids were all at very low levels in Corio Bay at significant distances from the Ramsar site, below the level of detection in sensitive laboratory analyses, even for mussels deployed in the discharge plumes.

Bromoform occurs naturally in seawater at around 1 to 3 µg/L as a result of natural production by marine macro-algae and micro-algae found in all coastal marine environments (USEPA 2012, Carpenter, 2006, Gribble 2012). The toxicity of chlorine-derived chemicals in seawater includes CPO and THM but is measured relative to the concentration of CPO or chlorine concentration.

6.4.1.1 Higher Concentrations in the Gulf of Fos, France

There are two published papers (Boudjellba et al, 2016 and Manasfi et al, 2019) that show detectible concentrations of CBP in seawater, sediments and conger eels (but no other fish) in the Golf of Fos in southern France.

The Gulf of Fos is a semi-enclosed bay with the largest port in France, receives the flow from the second largest Mediterranean river, namely the Rhône River, and hosts a major industrial zone that includes steel, petrochemical, waste incineration, and cement industries as well as gas and electricity power plants.

The Gulf receives discharges from power plants, steel mill, metal industries, oil refineries and two LNG plants, all using chlorine to control biofouling, with an estimated daily discharge of 2,400 ML. The Rhone River, which flows for 810 km through the centre of France, traverses many cities and industrial sites and also discharges from 15,000 to 70,000 ML/d into the Gulf of Fos. The following results were published in the two papers.

- Bromoform was the most abundant CBP and was detected at 0.5 to 3 µg/L at most harbour sites close to discharges. Similar ranges of bromoform were detected in both studies. The bromoform near discharges is very likely to be from the discharge of chlorine, which rapidly converts to bromoform and trace amounts of other CBP.
- Bromoform at 0.5 µg/L was measured at the reference site in the Mediterranean Sea, which is in the range commonly observed in shallow coastal waters with macro-algae beds.
- Other CBP detected in the Fos inner harbour close to discharge points were dibromoacetonitrile (DBAN) at 0.9 to 1.6 µg/L, chloroform, DBAA at 0.4 to 1.4 µg/L and the halophenols 24TDP at 0.4 µg/L and 2B4BC at 3.7 µg/L (in river channel).
- 24TBP was detected at very low concentration in a few sediment samples at 2 ng/g.

The tests of mussels in Corio Bay, which would be expected to concentrate CBP from seawater, showed no detectable DBAN (< 0.01 μg/L) and no detectible 24TBP (tribromophenol < 0.02 μg/L). Thus, the CBP concentrations in Corio Bay are substantially lower than the concentrations in the Gulf of Fos.

The preliminary risk assessment by Boudjellba et al, (2015) found there could be a toxicity risk from seven CBP <u>if</u> concentrations are 100 to 1000 times the highest measured concentration in their study. The concentrations that correspond to a risk were not found in ambient waters of the Gulf of Fos, nor do they occur in mussels (or by inference, seawater) in Corio Bay.

The organism selected for testing the accumulation of CBP in marine organisms was the congar eel, a long-lived fish that migrate from ocean waters to spawn in rivers when old. The young eels migrate back to ocean waters, and they are found throughout the Mediterranean Sea.

The only CBP detected in the 15 eel samples was 24TDP at 2 to 10 μg/kg wet weight (in 10 of the 15 eels sampled). The average concentration was 7 μg/kg compared to the average concentration in seawater of 1.5 μg/L in 7 of the 14 samples, with no detection in 7 samples). Thus, the biological magnification factor for eels, assuming they reside in the Gulf for a significant period, is around 5.

At a biomagnification factor of 5 or 10, there is no identifiable environmental risk from CBP in Corio Bay.

6.4.1.2 BEEMS Expert Panel Report

The UK BEEMS Expert Panel Report on *“Chlorination by-products in power station cooling water”*, 2011 analyses the chemistry and toxicity implications of chlorination by-products in the context of power station cooling water discharges. The report was prepared by an expert panel with a membership drawn from academia, Government and industry.

The report commences by noting that chlorine dosing and discharges to marine environments are common and have a long history, explaining that chlorine was first used as a drinking water disinfectant in Hamburg (Germany) in 1893. It is still extensively used as an agent for disinfection of tap water and taste and odour control. Of all disinfectants it is the most extensively studied with regard to chemistry, toxicity and ecotoxicity.

The findings of the BEEMS Report support the view that the concentrations of chlorine used at the refinery and proposed FSRU are unlikely to present a significant marine risk, noting that *“in seawater, CBPs [chlorination by-products] will be mainly brominated compounds due to the abundance of bromide. Chlorinated by-products, at initial dosing concentrations of about 2 mg/L as chlorine, are not expected to be formed in appreciable amounts in seawater.”* (Note that the refinery uses an appreciably smaller dose of 0.5 mg/L).

“The non-oxidizing secondary products, CBPs, are relatively stable and have the potential to express chronic toxicity to marine biota. Fortunately, they have only a limited tendency to bio-accumulate and, outside the immediate vicinity of a cooling water discharge, are found at concentrations two to three orders of magnitude below their acute toxic levels. This indicates that although their potential for causing environmental impact exists, in practical terms it is very limited.”

As the conversion from chlorine to bromoform proceeds, the toxic limit becomes less stringent. For 95 % species protection:

- Chlorine limit is 10 μg/L;
- Bromine limit is 48 μg/L;
- Chloroform limit is 770 μg/L;
- Dichloromethane limit is 4,000 μg/L;
- Methyl Tribromide (bromoform) limit is about 3,500 μg/L (Gibson, 2008).

6.4.2 Background to EES Mussel Study

The possibility of contamination of mussels in Corio Bay with CBP was examined in August 2021 in Section 9.14 of Technical Report A: *Marine environment impact assessment* (CEE 2022) as part of the EES, when naturally occurring mussels were collected from navigation piles at six sites in Corio Bay near the refinery. The sites included Refinery Pier and navigational markers around Refinery Pier as well as two reference sites further out in the Bay.

The mussels were placed in bags with appropriate labels. Each bag was held in a chilled esky and delivered directly to the Leeder Analytical Laboratory with the Chain of Custody forms for analysis of four trihalomethanes (THMs), six haloacetic acids and two bromophenols.

All chlorine by-products in the mussels were at low levels, below the laboratory detection level. It was therefore concluded in Section 9.15 of Technical Report A: *Marine environment impact assessment* (CEE 2022) that it is unlikely that there were impacts due to the existing discharge of low concentrations of chlorine from the refinery to Corio Bay. This finding has been confirmed by the 2023 mussel deployment described in Section 6.4.4 below.

6.4.3 Methodology in Supplementary Study

In October 2023 sets of six mussels were collected from the Portarlington mussel farm and deployed at the seven sites in north Corio Bay shown in Figure 6-1 which shows the locations of the previous mussel survey conducted during the EES including two control sites far east in Corio Bay. The mussels were deployed in mesh nets to keep them off the seabed and allow water to pass through and to keep the mussels within the plumes as much as possible.

Figure 6-1. Location of Mussel (*Mytilus edulis*) in Corio Bay – 2021 and 2023

The mussels were retrieved after four weeks and placed in bags with appropriate labels. All mussels were checked and alive at the beginning and end of each deployment. Discharge of chlorine from the refinery is continuous and mussels grow throughout the year. Each bag was held in a chilled esky and delivered directly to the Leeder Analytical Laboratory with the Chain of Custody forms for analysis of four THMs, six haloacetic acids and two bromophenols.

Three mussels from each site were composited for the analysis. Mussels from the farm and from both site deployments were retained for further analysis and two duplicates were analysed. As all results are zero, the need for further analysis is questionable.

The 2023 analysis of mussels was conducted by Leeder Analytical Laboratory (report number L230468). The analysis was done by Dr John F Leeder. Mussel samples were collected from Corio Bay on 19 October 2023 and were delivered to the lab within 2 hours of retrieval. The analysis was conducted on 24 November 2023.

The peer reviewer raised a question about the potential effects of translocation of mussels. In response, all the mussels analysed in 2021 were collected from existing piles and navigation structures in Corio Bay, and therefore there was no translocation of these mussels. The 2023 mussels were redeployed in Corio Bay within 3 hours, which is less than the time that mussels can be out of the water at each low tide. The Portarlington mussel farm advised that mussels are routinely moved during the growing stages without adverse effect. Whether mussels are growing naturally on piles or are translocated to a site, the method of accumulation remains the same. Thus, It is concluded that translocation of mussels had no effect on the results of the CBP analyses compared to the results from in situ mussel results as all mussels had no detectable CBPs.

6.4.4 Results

As shown in Table 6-1, all chlorine by-products in the mussels deployed at all locations were below the detection level. This confirms that it is very unlikely that there are impacts due to the existing discharge of low concentrations of chlorine from the refinery to Corio Bay.

In addition to providing additional measurements of chlorine by-products in biota *that have high susceptibility to contamination,* the 2023 deployment extended the scale of the original EES study into the discharge plumes and provided greater confidence in the 2021 study's conclusion that chlorine by-products in the tissues of deployed mussels were at very low levels.

Filter-feeding marine organisms, such as oysters and mussels, are routinely used in many countries as a means of collecting trace quantities of substances in marine waters. In the US, the National Centre for Coastal Ocean Science has been conducting a mussel watch program at 300 sites for organics, metals and other contaminants of concern since 1986.

Mussels are naturally occurring in Corio Bay and so were used in the Corio Bay study. Mussels accumulate contaminants in the water with little metabolic transformation and the contaminant levels in their tissue are multiple times the concentrations in the water. It is more practical to detect CBP in mussels, where the concentrations are many times the water concentrations, than in fish or other organisms, where the concentrations are similar to the water concentrations.

Table 6-1. Results of Analysis of Mussels Deployed in 2023

	Leeder ID	L230468-1	L230468-Duplicate	L230468-2	L230468-3
	Client Id	#1 & #5	#1 & #5	#2 & #4	#6 & #7
ANALYTE	PQL				
LAF-87 Trihalomethanes (THMs)					
Dichlorobromoethane	0.01	nd	nd	nd	nd
Dibromochloromethane	0.01	nd	nd	nd	nd
Tribromomethane	0.01	nd	nd	nd	nd
Trichloromethane	0.01	nd	nd	nd	nd
LAF-48 Haloacetic Acids					
Bromoacetic acid	0.05	nd	nd	nd	nd
Bromochloroacetic acid	0.05	nd	nd	nd	nd
Chloroacetic acid	0.05	nd	nd	nd	nd
Dibromoacetic acid	0.05	nd	nd	nd	nd
Dichloroacetic acid	0.05	nd	nd	nd	nd
Trichloroacetic acid	0.1	nd	nd	nd	nd
8270 Bromophenols					
2,4,6-tribromophenol	0.02	nd	nd	nd	nd

Note that a duplicate analysis was conducted and both analyses gave the same results.

6.4.4.1 Discussion of Results of CBP in Mussels

Many marine seaweeds and microalgae produce bromoform (it smells like chlorine bleach). Bromoform (or tribromomethane, $CHBr_3$) is one of the most common bromine compounds in the marine environment. It has been found to suppress methane production in cattle. Consequently, the seaweed Asparagopsis is being grown to supplement the diet of cows to reduce methane production on a large scale. Asparagopsis and other macroalgae are common on seagrasses in Corio Bay, Port Phillip Bay and Western Port Bay.

Tribromophenol ($C_6H_3Br_3O$ or TBP) is another CBP produced by brown and red algae that are common in the Victorian Bays. The edible flesh of many species of Australian ocean fish contain natural concentrations of TBP, which is responsible for the natural ‘ocean flavour’ of seafoods and has been considered for addition to prawn farm ponds to provide a more natural tasting product (Whitfield et al., 1998).

The ANZECC water quality guidelines set default or trigger limits on toxological effects based in a species distribution curve developed from peer-reviewed and repeated tests on a range of different species. ANZECC trigger limits for chlorinated methanes in marine waters are 370 µg/L for chloroform and 4,000 µg/L for dichloromethane. Gibson (2008) suggested the trigger value for bromoform is about 3,500 µg/L. These limits are many orders of magnitude above what might be found in Corio Bay waters or mussels.

As a comparison, the measured bromoform concentration in mussels from Corio Bay was < 0.01 ug/L and the measured 246TBP (tribromophenol) concentration in mussels from Corio Bay was < 0.02 ug/L. There is a very large margin of safety between measured concentrations in Corio Bay and the levels of concern. CBPs are produced naturally by a range of marine biota, notably marine algae (see Figure 6-2). While these compounds may be toxic to freshwater biota, they are part of life in the marine environment.

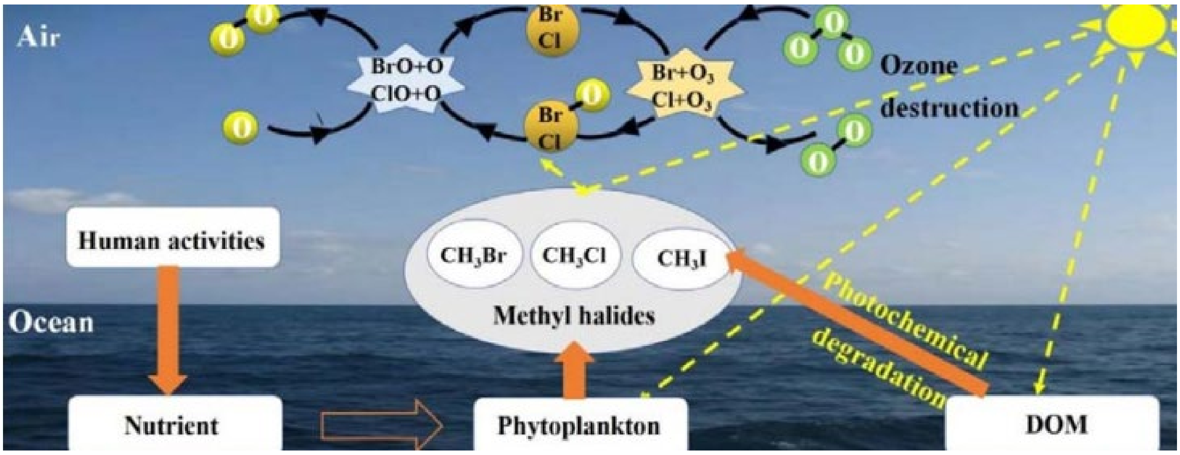


Figure 6-2. Transfer of Halogens Between the Ocean and the Atmosphere

Marine biota can regulate (accumulate or depurate) the concentration of these chemicals. The concentrations of bromophenols are naturally high in many marine invertebrates, including burrowing marine worms in Australia with TBP concentrations commonly ranging from 2 µg/kg to more than 8,000 µg/kg (Whitfield et al, 1999). After exposure to high concentrations, they can lower the concentrations in their bodies within hours or days. Consequently, marine biota are far less sensitive to chlorine and bromine than their freshwater ecological equivalents (Lebaron et al, 2019).

Mussels have the same methods of accumulation regardless of whether they are naturally occurring or translocated. Given the results of analysis of all mussels collected in the two mussel studies were all below detection, there is no issue in comparing results of in situ and translocated mussels. Mussels are widely recognised as biomarkers for accumulation of contaminants. The absence of detectable levels of CBPs in both wild and translocated mussels is a good indication that levels in the wider ecosystem are very low.

6.5 Conclusions

Recommendation 4 of the Minister's Directions required further targeted investigations into the effects of existing chlorine discharges from the refinery to assess likely impacts resulting from chlorine byproducts (CBP).

The supplementary studies of chlorine by-products in Corio Bay focused on measurement of chlorine by-products in mussels which are filter-feeding marine organisms known to accumulate contaminants.

Mussels were collected from the Portarlington mussel farm and deployed at seven sites in north Corio Bay where the discharge plumes from the refinery occur. The mussels were retrieved after four weeks and analysed for four trihalomethanes, six haloacetic acids and two bromophenols (all potential chlorine by-products). All compounds were below the limit of laboratory detection and therefore at very low levels. This study confirmed the findings from mussel sampling conducted in 2022 and reported in Section 9.14 of Technical Report A: *Marine environment impact assessment* (CEE 2022) of the original EES.

The evidence from the mussel accumulation tests show that there are not high levels in Corio Bay and there is no evidence that CBP is a significant ecological risk in Corio Bay. Marine organisms live in an environment with 19,000 mg/L of chloride, where algae naturally convert chloride to chlorine and bromoform. It follows that marine organisms are habituated to low levels of chlorine and chlorine by-products that occur naturally in bays and coastal waters with algae.

Bromoform and other CBP escape to the atmosphere, so the potential of accumulation in biota is limited, particularly with the shallow surface effluent fields formed by the refinery discharges in Corio Bay which have a large surface area per unit volume. The field measurements of the chlorine plumes show that the chlorine discharges decay to background well before the plumes could reach the Ramsar site.

Mussels are widely recognised as biomarkers for accumulation of contaminants. The absence of detectable levels of CBP in both wild and translocated mussels is a good indication that levels in the wider ecosystem are very low.

Mussels have the same methods of accumulation regardless of whether they are naturally occurring or translocated. Given the results of analysis of all mussels collected in the two mussel studies were all below detection, there is no issue to be examined by comparing results of in situ and translocated mussels.

In conclusion, there is no evidence that there is a significant risk to fish, birds, or other biota from the existing chlorine discharges from the refinery to Corio Bay.

7. Recommendation 5 – Refine Entrainment Predictions

7.1 Summary of Original EES findings

Entrainment is the collection of fish or small marine organisms in a water intake. Entrainment of fish larvae or plankton that spawn in Corio Bay, including the Ramsar site and Limeburners Bay, could affect populations and productivity, the food chain and in turn the ecological character of the Ramsar site and food availability for migratory shorebirds.

The EES examined phytoplankton, zooplankton and ichthyoplankton abundance, distribution and seasonality in Corio Bay, as well as marine species inhabiting and visiting Corio Bay, as these are an important consideration in assessing the potential impacts of the project, in relation to entrainment.

Detailed plankton and larvae surveys conducted over 12 months indicated that plankton abundance per megalitre of water is relatively uniform throughout Corio Bay, with no significant difference detected between plankton in North Corio, South Corio and the Geelong Arm. The data collected as part of the plankton monitoring program was incorporated into the regional hydrodynamic model.

Entrainment modelling was undertaken to simulate the potential transport and dispersion of plankton and larvae from different regions of the Bay and predict the entrainment of plankton in the seawater intakes during operation of the FSRU.

The assessment considered entrainment of plankton and larvae from the Ramsar site, northern Corio Bay, southern Corio Bay, and changes to entrainment rate. It concluded that there would be a slight increase to the number of plankton entrained from the Ramsar site and northern and southern Corio Bay, because of the project compared to the refinery intake. However, the entrainment rates are considered low to negligible in comparison to natural predation and other losses.

The assessment concluded that entrainment as a result of the current refinery seawater intake has a negligible effect on plankton populations in Corio Bay and the proposed FSRU intake also would have negligible impact. Therefore, there would be negligible impact on food availability for shorebirds that eat zooplankton, or animals that consume zooplankton.

7.2 Overview

Recommendation 5 of the Minister’s Directions states the following:

Re-run the entrainment modelling with revised inputs based on the refined hydrodynamic model.

To provide context, the IAC acknowledged that the refinery has been taking in seawater for many years and that, whether or not the project proceeds, the volume of seawater used for cooling will not change. The IAC also noted that the impacts of entrainment as a result of the project “are likely to be relatively contained, as indicated by the entrainment modelling” but recommended re-running the entrainment modelling based on the refined regional hydrodynamic model to confirm this.

The refined regional hydrodynamic model was used to re-run the entrainment modelling and address Recommendation 5.

7.3 Summary of tasks

A number of tasks were undertaken as per the study program developed for the Supplementary Statement to address Recommendation 5 of the Minister's Directions. An overview of these tasks and their objectives is provided in this section of the report and are described in further detail in subsequent sections of this report.

Task 5: Re-run the entrainment modelling with revised inputs and using the refined regional hydrodynamic model developed as per Recommendation 2 to address Recommendation 5

- Conduct further desk research investigations to identify the species of fish likely to breed in Corio Bay and the likely breeding areas to define the areas from which particles are released (Section 7.4.4).

7.4 Task 5a: Confirm Sources of Ichthyoplankton in Corio Bay

7.4.1 Background to Ichthyoplankton Sources

The EES study in Section 5.12 of Technical Report A: *Marine environment impact assessment* (CEE 2022) of the abundance of ichthyoplankton established that ichthyoplankton are spread widely and uniformly across Corio Bay.

Ichthyoplankton were sampled at ten sites in Corio Bay using a 4 m long, 500 µm mesh net with a mouth of 0.8 m towed behind the vessel. Tows extended from the seabed to the water surface which provided a depth-integrated sample over the water column. Each tow lasted for 12 minutes and extended for an average of 450 m. Sampling was monthly from October 2020 to August 2021. The plankton adhering to the inside sides of the net were rinsed out and collected in a sample bottle. All samples were preserved in 5% v/v buffered formalin.

7.4.1.1 Ichthyoplankton Identification

The samples collected during the EES were sent to an ichthyoplankton specialist (Dr. A. Miskiewiz) at the Australian Museum for identification of fish eggs, fish larvae, *syngnathids* and *cephalopods*. Larvae were identified to the lowest practical level, which was typically genus or species. Eggs of pilchards and anchovy were identified based on egg morphology.

The results were standardised using the number of cubic meters of seawater which had been filtered through the ichthyoplankton net. There were more ichthyoplankton and typically 10 to 12 species in the late spring-summer months (Oct – Dec). Numbers were much lower from January onwards and did not begin to increase again until the following spring.

7.4.1.2 Ichthyoplankton Abundance

Figure 7-1 shows the number of ichthyoplankton at the Corio Bay sampling sites for the peak months of Nov-Dec 2020 expressed as larval fish units per m^3 of seawater. There was a large variability from month to month, but typically there are from 3 to 25 larval fish units per m^3 of seawater, with an average of about 15 larval fish units per m^3 in north Corio Bay (mean ± standard deviation shown in the figure).

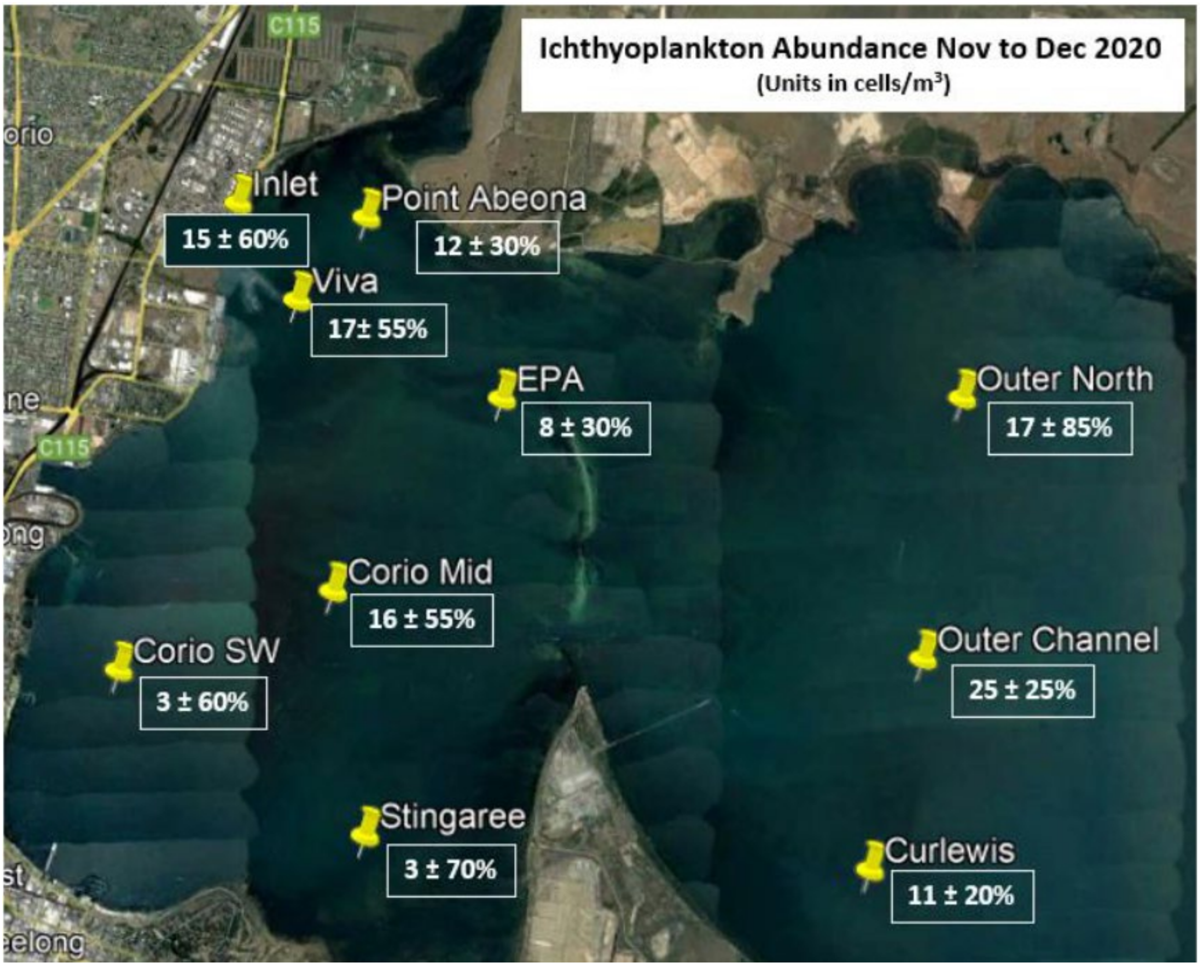


Figure 7-1. Abundance of Ichthyoplankton in Corio Bay in Summer 2020

During the EES the majority of ichthyoplankton captures (99%) were fish eggs which could not be further identified down to the species level. The main species that were identified were anchovies and gobies.

Australian Anchovies (*Engraulus australis*) were a dominant species in the summer months with very high numbers recorded at the refinery inlet in November 2020. However, after this short bloom in abundance, the number of Australian Anchovy larvae declined, mostly to zero, through the autumn and winter months. Gobies were present in most monthly samples.

7.4.2 Methodology of Supplementary Statement Study

An eDNA survey was undertaken to supplement the ichthyoplankton surveys and expand the list of fish species in Corio Bay, particularly smaller species. The eDNA technique was used in 2023 to explore the range of fish eggs in Corio Bay as this new method can allow additional species to be identified.

The DNA was extracted and counted using primers held by the Monash University DNA library. Fish, and other aquatic animals, shed DNA into their surrounding environment via skin cells, scales, mucous and more. This DNA can be concentrated from water samples and the DNA extracted and identified.

For the eDNA surveys, seawater samples of 1 litre were collected at five sites in northern Corio Bay (shown in Figure 7-2) at a depth of 0.2 m and analysed to determine the DNA of fish species. Two rounds of sampling were conducted, two weeks apart.

Figure 7-2. Sampling Sites for eDNA Analysis of Fish in Corio Bay

7.4.3 Results of eDNA survey of Fish in Corio Bay

Sixteen species of fish were identified based on their DNA with an average of 32,000 identifications per sample (range was from 6,000 to 54,000 per sample). An average of 5 fish species were identified in each sample (range was from 3 to 7 species per sample).

Figure 7-3 shows the sixteen fish species identified, sorted from the most frequently identified to the least frequently identified. DNA from three species (silver fish, weed whiting and black bream) were found in seven of the nine samples. A brief description of the common species found in more than 40 % of the seawater samples is given in Table 7-1.

The sampling was conducted in December 2023 and so the results show species which were present in the seagrass areas of northern Corio Bay at that time. Other species may also be detected at other times of the year which are not presented below. However, the entrainment results apply to all species that spawn in seagrass in Corio Bay at any time of the year.

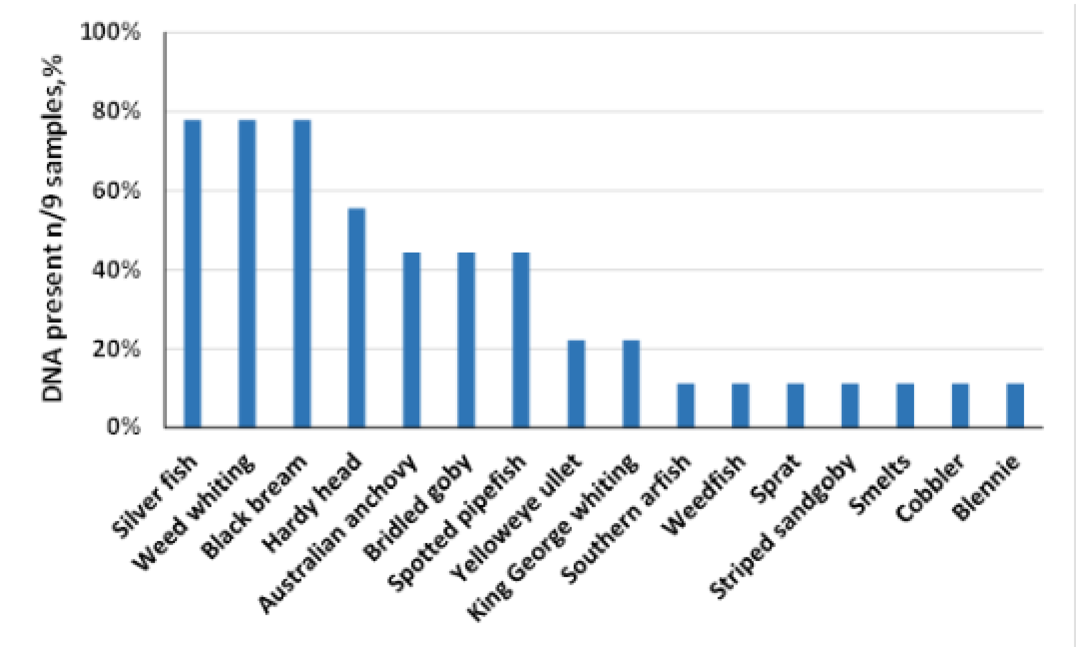


Figure 7-3. Common Fish DNA Identified in Corio Bay Seawater Samples

Table 7-1. Common Fish Species in Corio Bay eDNA Samples

Common fish species (DNA present in >40% of samples)

Silverfish

Silver fish (*Leptatherina presbyteroides*) are found in sheltered sandy areas and seagrass beds in shallow bays, estuaries and sheltered inlets along the SE Australian coast, in shallow waters up to 5 m deep.

Weed whiting

Weed whiting (*Neoodax balteatus*) are a common species in and around seagrass beds in Port Phillip Bay. They are also common in seagrass and on reefs in bays, estuaries and along the coast of Southern Australia.

Black bream

Black bream (*Acanthopagrus butcheri*) are an important recreational and commercial fish in Victoria. They are found in bays, inlets, estuaries, and in the lower reaches of rivers, throughout Southern Australia.

Anchovies

Anchovies (*Engraulis australis)* are small fish of commercial importance throughout their range. They form large, dense schools in offshore and inshore surface waters and are key prey for other fish species, sharks, seabirds and marine mammals. Anchovies live in Southern, Eastern and Western Australia, and New Zealand.

Gobies

Bridled and half-bridled gobies (*Arenigobius bifrenatus, A frenatus*) are small fish found in shallow seagrass beds and mangrove creeks in bays, estuaries and coastal lagoons in eastern Victoria.

Spotted pipefish

The spotted pipefish (*Stigmatopora argus*) is a common species in seagrass in Port Phillip and Western Port, Victoria, and throughout Australia. Individuals are well-camouflaged in *Zostera* seagrass.

7.4.4 Additional Sources of Fish Eggs in Corio Bay

Additional information on fish species in Corio Bay was obtained from Professor Jenkins (Professorial Fellow in Fish Ecology at Melbourne University) and it is summarised below. His research trawl and video surveys in Corio Bay identified 18 common fish species as listed in Table 7-2. Thirteen are known to release eggs although these eggs cannot be visually distinguished from each other or the eggs of other fish species. Understanding which fish breed in Corio Bay help to estimate what species of fish eggs are likely to be entrained.

Table 7-2. Fish Species Caught in Surveys in Corio Bay (Jenkins 2019)

Fish name	*Scientific name*	*Planktonic eggs*
Australian Anchovy	*Engraulis australis*	*Yes*
Bridled Leatherjacket*	*Acanthaluteres spilomelanurus*	*Yes*
Eastern Shovelnose Stingaree	*Trygonoptera* sp.	*No*
Globefish*	*Diodon nicthemerus*	*Yes*
Greenback Flounder*	*Rhombosolea taparina*	*Yes*
Hardyhead*	Atherinnidae	*Yes*
King George Whiting*	*Sillaginodes punctatus*	*Yes*
Little Weed Whiting*	*Neoodax balteatus*	*Yes*
Red Mullet*	*Upeneichthys vlamingii*	*Yes*
Sand Flathead*	*Platycephalus bassensis*	*Yes*
Smooth Toadfish	*Tetractenos glaber*	*Not known*
Snapper*	*Chrysophrys auratus*	*Yes*
Southern Calamari	*Sepioteuthis australis*	*No*
Southern Cardinal Fish	*Vincentia conspersa*	*No*
Sparsely-spotted Stingaree	*Urolophus paucimaculatus*	*No*
Toothbrush Leatherjacket*	*Acanthaluteres vittiger*	*Yes*
Yank Flathead*	*Platycephalus speculator*	*Yes*
Yellowtail Scad*	*Trachurus novaezelandiae*	*Yes*

Source: Jenkins 2019

**Species with platonic eggs*

Additional information on fish breeding in Corio Bay from Jenkins, 2019 is provided below.

Little weed whiting are distantly related to King George Whiting and probably breed in Corio Bay. Adult fish are small and may be used as bait by anglers but are not valued for eating.

King George Whiting are popular with anglers but do not breed in Corio Bay. They develop from larvae that drift across from breeding grounds in South Australia. The King George Whiting caught in Corio Bay are juvenile fish that have migrated from Port Phillip Bay when about three years old. The adult fish return to live and breed in South Australia.

Snapper breed in Port Phillip Bay offshore from Frankston, and this is the main known area for snapper breeding in Victoria. No snapper larvae were present in the Corio Bay ichthyoplankton samples and Professor Jenkins advised that it is most unlikely that snapper breed in Corio Bay. Juvenile snapper enter Corio Bay when they develop from larvae in Port Phillip Bay. Most snapper migrate out of Port Phillip Bay and Corio Bay in autumn.

It is likely that garfish and various species of leatherjackets breed in Corio Bay. Many species release eggs into the water column in seagrass beds. These include little weed whiting, some leatherjackets, boxfish, gobies and garfish. There is a range of small fish species in Corio Bay including anchovies and gobies. They are seldom seen by anglers or divers and are not commercial species.

Many other small species are present within the shelter of seagrass around the coast of Corio Bay. The bare patches within seagrass beds and the deeper edges provide a diversity of seabed habitat that increases the range of fish. It is expected that all areas with similar depths and habitats around Corio Bay have similar fish communities.

Much of the seabed of Corio Bay is muddy. There are few species breeding in deep-water mud beds where light levels are low and the exchange of biota with seagrass habitats is low, but gobies can use this region for laying eggs.

Almost all eggs and larvae will (1) starve competing for food or (2) be consumed before they become juveniles, and most juveniles will starve be or consumed before becoming adults. The greatest competition for food is between individuals of the same species.

Very few snapper eggs and larvae survive in most years and the renewal of the snapper population in Port Phillip, Corio and Western Port Bays depends on a combination of suitable conditions that occur only once or twice a decade.

7.5 Task 5b: Repeat Entrainment Modelling Using Refined Model

7.5.1 Background to Entrainment Modelling

The movement and dispersion of ichthyoplankton from the Ramsar site in Corio Bay was assessed by tracking neutrally-buoyant particles using the refined regional hydrodynamic model of Corio Bay. The modelling in the 2022 EES examined the dispersion of larvae from three sites in Corio Bay, including the Ramsar site in northern Corio Bay and two other areas in central and southern Corio Bay. Particles were released at four times (high tide, half ebb, low tide and half flood), and the average entrainment result reported.

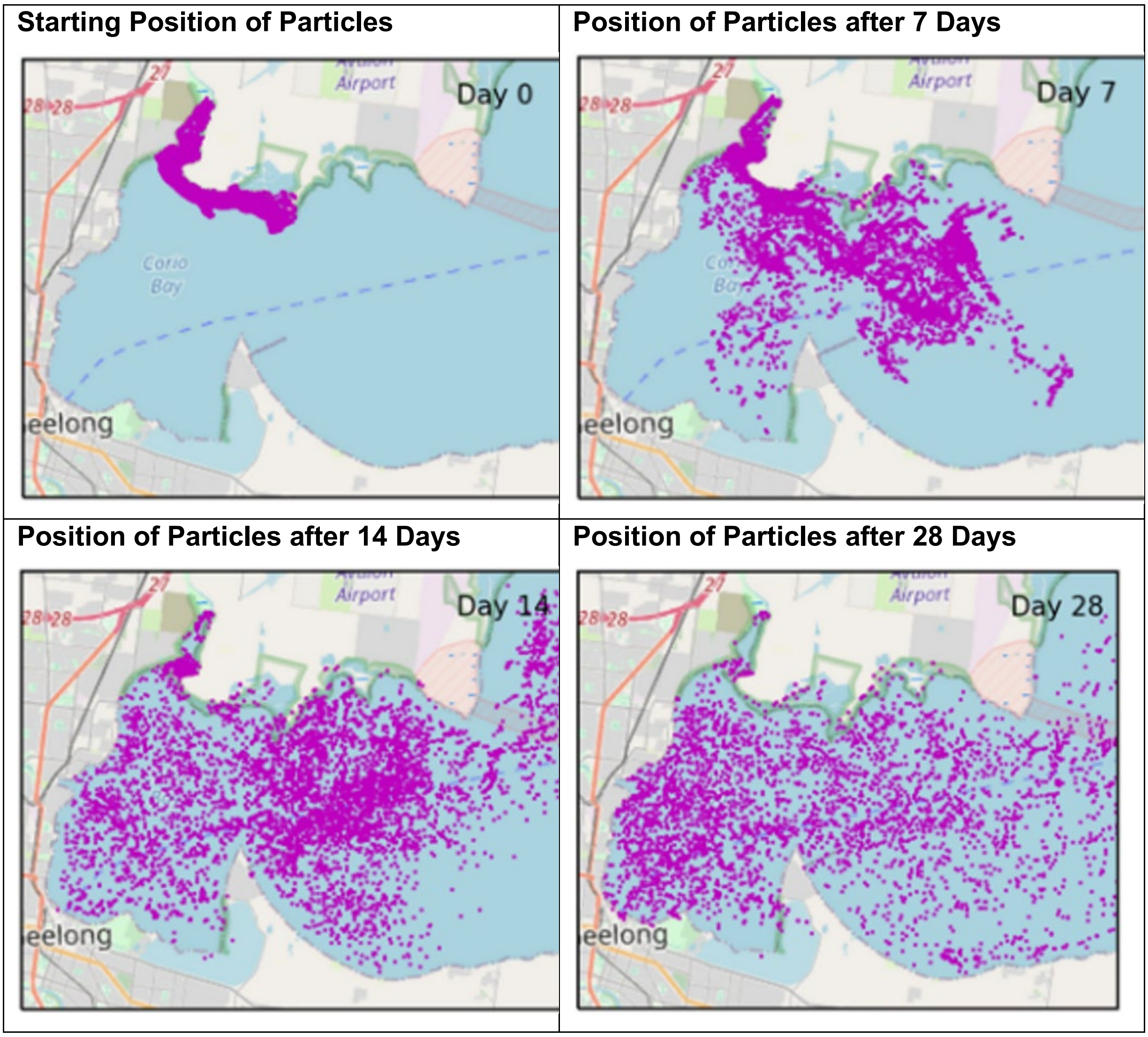
The number of particles entering the refinery intake was counted by the model from the flow entering the seawater intake channel. The results were checked by a second method of modelling a 50 m by 50 m by 2 m deep box located at the position of the intake and counting the particles. The average of these two estimates is shown in Table 7-3 as the percentage of the original particles in the Ramsar site captured in the refinery intake. The box dimensions were selected to correspond to a net inflow of 350 ML/d at the average current speed at 0.04 m/s.

Movement of particles in EES Study

The particles entering the FSRU intake were calculated using a similar box set at 5 m to 7 m depth (the location of the FSRU intake) and reduced in width to match the average current at the FSRU of 0.06 m/s. The location of the FSRU is shown in Figure 1-2.

The particle locations over time are analysed to determine how many of the released particles reach selected areas in Corio Bay or move out to Port Phillip Bay. The counts were made for 7, 14, and 28 days after release of the particles and, as a sensitivity check, repeated for releases at high tide and low tide. Figure 7-4 shows the spread of the particles after 7, 14 and 28 days after release in the Ramsar site. The results show that the particles disperse widely from their initial release within the Ramsar site.

After 7 days, the particles have moved mostly eastward into Port Phillip Bay, with a smaller proportion moving down into the south-east part of Corio Bay. Only 42 % of the particles remain in Corio Bay, of which 39 % are in northern Corio Bay and 3 % are in southern Corio Bay (an east-west line divides Corio Bay in half). This indicates that approximately half of all the particles in the Ramsar site move east out of Corio Bay.



Source: CEE EES, 2022

Figure 7-4. Movement of Particles Released from Ramsar Site

7.5.2 Methodology of Dispersion Simulations

For this repeat of the entrainment calculations, the refined regional hydrodynamic model has been used to predict the entrainment of fish eggs from the Ramsar Site and from all seagrass areas in Corio Bay, providing a better representation of total entrainment of ichthyoplankton by: (1) the existing refinery seawater intake; and (2) a seawater intake on the FSRU. The Ramsar site section includes all the site west of the line connecting Point Lillias to Point Henry while the 'seagrass area' is defined as the 0 m to 5 m depth zone (red area in Figure 7-5) where fish breed.

The simulation of particle dispersion started with 10,490 neutrally buoyant particles equally spaced over the defined area (e.g., the Ramsar site) at 10 cm above the seabed. The particles then moved laterally and vertically in the water depending on the currents in response to the tide, wind and other hydrodynamic processes. The source area for the particles is shown in the top left image in Figure 7-4. The position of each particle is calculated every 20 seconds (the model time step) based on the currents and the location of each particle is recorded every hour. Note that in 1 hour at the median current speed of 0.045 m/s, the particles move 160 m, so the trajectories of the particles between the output times was calculated by interpolation between sequential locations.

7.5.3 Results of Entrainment Modelling for Ramsar Site

At 14 days from release, there is an even wider distribution of particles. Only 25 % remain in Corio Bay, with 51 % moving into Port Phillip Bay. The particles that remain in Corio Bay after 14 days are more evenly spread between northern Corio Bay (14 %) and southern Corio Bay (11 %). Also, after 14 days, the particles are more evenly spread over Port Phillip Bay.

At 28 days from release, there are more particles in Port Phillip Bay than in Corio Bay, and a small percentage (2 %) of particles have reached southern Corio Bay after travelling back into Corio Bay from Port Phillip Bay. After 28 days, there are more particles from the Ramsar site release in southern Corio Bay (17 %) than in northern Corio Bay (9 %).

The particle movement enables a calculation of how many particles make their way to Port Phillip Bay or to the southern part of Corio Bay and allows the rate of entrainment of plankton in the intake of the refinery or the FSRU to be determined. Table 7-3 lists the percentage of the original particles in the Ramsar site captured in the FSRU intake.

Table 7-3. Results of Entrainment Modelling – Ramsar Site Release

Time after release	*Refinery Intake*	*FSRU*	Overall-summer
1 week	0.03 %	0.03 %	0.03 %
2 weeks	0.07 %	0.07 %	0.07 %
4 weeks	0.12 %	0.12 %	0.12 %

In Table 10-3 and 10-4 of Technical Report A: *Marine environment impact assessment* (CEE 2022) of the EES, the estimated entrainment into the refinery intake also was 0.12 %. Thus, there has been no change in the refinery entrainment with the refinement of the regional hydrodynamic model.

In Table 10-3 and 10-4 of Technical Report A: *Marine environment impact assessment* (CEE 2022) of the EES, the estimated entrainment into the FSRU intake was 0.26 %. This proportion has reduced to 0.12 % with the refinement of the regional hydrodynamic model and the adjustment for the higher current speeds at the FSRU.

7.5.4 Results of Entrainment Modelling for Seagrass Area

An additional simulation was made of entrainment for fish eggs released from all the seagrass areas in Corio Bay as the investigations of fish breeding established that seagrass areas are major habitats for fish breeding in Corio Bay. The location from which particles were released is the surface to 5 m depth zone (red area) around the perimeter of Corio Bay, as shown in Figure 7-5 and is the depth range where seagrass has enough available light to grow which is confirmed by seagrass measurements as shown in Section 3.5 and aerial imagery. The same procedure as outlined above was used to calculate entrainment. Table 7-4 lists the percentage of fish eggs entrained in the refinery or FSRU seawater intakes over periods of 1, 2 or 4 weeks. The entrainment percentages for summer assume half the inflow occurs via the FSRU and half via the existing intake channel.

Table 7-4. Results of Entrainment Modelling – Seagrass Zone Release

Time after release	*Refinery Intake*	*FSRU*	Overall-summer
1 week	0.07 %	0.04 %	0.05 %
2 weeks	0.14 %	0.16 %	0.15 %
4 weeks	0.25 %	0.34 %	0.29 %

For all seagrass zones, the refinery intake and the FSRU entrain similar proportions of ichthyoplankton, with slightly more at the FSRU because the FSRU intake is further offshore.

In summer there are approximately the same total amount drawn in through the FSRU as the existing intake for model runs for particle release from the Ramsar site and all seagrass areas.

Note: Sections divided into depth ranges below sea level

Figure 7-5. Depth Ranges in Corio Bay (Seagrass Area in Red)

7.5.5 Implications of Entrainment by Refinery or FSRU

To provide a perspective on the entrainment rates, a numerical example is as follows. A female goby will typically lay 20,000 eggs in a batch, with two batches per year. Approximately half die from starvation (competition for food) and half are eaten by other organisms (predation) leaving around 1% which hatch into larvae. Therefore, in the first month, 19,800 eggs are lost: 9,880 due to starvation, 9,880 due to predation and 40 (0.2 %) due to entrainment.

Thus, a month later there are approximately 200 eggs that hatch into larvae, when they can swim and are no longer subject to passive entrainment.

The 200 fish larvae that continue will face further competition for food and predation before becoming a breeding adult, and about 2 will achieve this (on average) with 99 % of the larvae also being lost due to starvation and predation. A year later, 2 of them are ready to breed and produce another 20,000 eggs.

To some extent, there will be slightly more food available for the survivors, and thus a small reduction in starvation may to some extent balance an increase in predation.

To summarise, of an initial 20,000 eggs laid in a batch, only 2 (0.01 %) survive into maturity and can breed, and the remining 99.99 % are lost naturally to starvation and predation. The entrainment of eggs in the existing or proposed intake has negligible effect on the natural losses experienced by eggs. The (very small) percentage entrainment by the FSRU or refinery intakes applies to all fish species, whatever the number of eggs produced.

7.6 Conclusions

Recommendation 5 of the Minister's Directions required the entrainment modelling to be repeated with the refined regional hydrodynamic model. This has been done. The results are very similar to those presented in the EES.

The risk being assessed with the entrainment modelling is whether the change in the seawater intake location from the existing inlet channel on the shore to an offshore location on the FSRU would lead to a significant change in the entrainment of fish eggs.

The number of fish species that breed in Corio Bay is most likely between 20 to 40 species. Many of these species are small fish that are seldom seen (such as gobies or anchovies), unless specifically sought using fine nets. Different species breed in different depth ranges – some in seagrass in shallow water; some in deeper seagrass or on bare patches in deeper seagrass. Only a very small proportion of planktonic eggs and larvae from Corio Bay will survive due to the competition for food, and predation pressure.

The refinery seawater intake has been capturing a very small proportion of ichthyoplankton in Corio Bay for the last 60 years. Transfer of the seawater intake to the FSRU is predicted to not change the proportion of fish eggs that are entrained. The very small number of ichthyoplankton captured has negligible effect on plankton and fish populations in Corio Bay, or on the availability of ichthyoplankton as food in the Ramsar site.

Modelling results show that the proportion of fish eggs entrained is very small in relation to the natural processes of starvation and predation. Considering the results of the field sampling and counting of fish eggs and the two simulations of the entrainment of fish eggs from different zones, it can be concluded that there would not be a significant change in the proportion of fish eggs entrained with the FSRU in operation compared to the current entrainment as a result of the existing refinery intake.

The results are very similar to the previous entrainment predictions presented in the EES. It is concluded that a change in seawater intake location would not have a significant effect on entrainment.

8. Recommendation 6 – Sediment Transport Modelling

8.1 Summary of Original EES Findings

The FSRU berth would be dredged to a depth of 13.1 m and the swing basin would be dredged to a depth of 12.7m over an 8-week campaign. A total of 490,000 m^3 of dredged material would be removed over an area of approximately 12 ha adjacent to the existing shipping channel to provide sufficient water depth at the new berth and within the swing basin for visiting LNG carriers.

Dredging and disposal of dredged material would result in spill and loss of material into the water column resulting in increased suspended solids concentrations and turbidity. The material to be dredged consists of clay, silt and sand. The EES assumed that only clay and silt would contribute to dispersed suspended solids in the water column and potential turbidity impacts as, sand would settle out rapidly on the seabed near the dredge.

The regional hydrodynamic model was used to simulate the dispersion and settling of fine sediments released by dredging and from disposal of dredge spoil from a barge at the dredged material ground. The model was configured to simulate four different sediment sizes, each with a density of 2,600 kg/m^3 including:

- Clay with a particle size of 2 micron which makes up 46% of the dredged material
- Silt with a particle size of 30 micron which makes up 17% of the dredged material
- Fine sand with a particle size of 125 micron which makes up 12% of the dredged material
- Sand with a diameter of 250 microns for the remaining 25% of the dredged material.

Sediment dispersion was simulated based on a rate of loss of 6.5 kg/s of material during dredging and 76 kg/s of material during disposal. Settling rates were calculated based on the type of material that was being modelled and it was found that clay particles settle at a slow rate and experience coagulation while settling. These modelling outputs were used to inform the potential impacts of sediment settlement and dispersion on the marine ecosystem.

Predictions of the modelling that was conducted as described in Section 7.10 of EES Technical report A: *Marine ecology and water quality impact assessment* (CEE 2022), show the median suspended solids (SS) concentration in north Corio Bay over the 8 week dredging period during the months of August and September.

There would be a small 7 ha patch of 5 mg SS/L above ambient and a large 210 ha patch of 2 mg SS/L above ambient at the surface. There would be larger patches and higher concentrations on the seabed.

Short periods of elevated turbidity and suspended solids levels occur naturally in Corio Bay during periods of strong winds when wave action mobilises shallow and shoreline sediments. During the 8-week dredging period, areas of elevated suspended solids and turbidity would be expected, however, these areas would be limited to the dredging zone and surrounding area. The Ramsar site and central Corio Bay would only have minor increases in turbidity for short periods of time. The main sediment plume associated with the dredging does not extend to the Ramsar site.

The accretion of solids on the seabed was also modelled in the EES and is presented in Section 7.13 of EES Technical report A: *Marine ecology and water quality impact assessment* (CEE 2022). Accretion of solids on the seabed could harm to seagrass communities, infauna or mobile marine communities as sediments could smother or bury plants and animals, reduce the amount of light that reaches these communities and reduce visibility.

In the EES, the increment in seabed elevation due to sedimentation if dredging was conducted during the months of August and September was modelled. It was predicted that the highest accretion of 20 mm occurs on the seabed in the area to be dredged and deepened. Lower accretion rates of 2 to 10 mm would occur over a larger area surrounding the dredging zone. The rate of accretion (0.04 mm/day to 0.2 mm/day) would have negligible impact on the muddy seabed and the infauna or mobile marine communities.

Seagrass naturally traps sediments and studies show healthy seagrass beds with sedimentation rates of up to 20 mm/year (Cabaco et al., 2008) and 31 mm/year (Potouroglou et al., 2017). The accretion rate on seagrass beds, none of which are in the dredged area, is predicted to be from zero to 3 mm, which is expected to have negligible to very minor impact as seagrass naturally traps and accumulates sediment.

8.2 Overview

Recommendation 6 of the Minister's Directions states the following:

Re-run the sediment transport modelling with revised inputs based on the refined regional hydrodynamic model. Consider including a 'worst-case' scenario for sediment fractions and settling rates which includes the largest expected proportions of fine and very fine materials that have the slowest expected settling velocities.

Impacts on seagrass, with consideration of the predictions of the sediment transport model discussed in this section, is presented in Section 9 and a summary of the impacts to the Ramsar site is presented in Section 10.

8.3 Summary of Tasks

A number of tasks were undertaken as per the study program developed for the Supplementary Statement to address Recommendation 6 of the Minister's Directions. An overview of these tasks and their objectives is provided in this section of the report and are described in further detail in subsequent sections of this report.

<u>Task 6: Re-run the sediment transport modelling with revised inputs and using the refined regional hydrodynamic model developed as per Recommendation 2 to address Recommendation 6.</u>

Recommendation 6, to re-run the entrainment model, involved the following tasks:

- Re-examine Corio Bay sediment characteristics using extra borehole data to assess the expected proportions of fine and very fine materials from various dredging areas;
- Re-assess the dredge spill rates for an 8-week dredging program using the latest available information;
- Define the size range and settling rates of suspended solids for the most credible settling rates as well as for a range of possible settling velocities, including the worst-case scenario.
- Use the modified, calibrated and peer reviewed regional hydrodynamic model to address Recommendation 6.
- Check the predictions against the outcomes using the sediment fractions adopted by Lawson and Treloar in their "verification" model. The verification model was prepared to define the model parameters that provided the best match to the measured water quality in the Channel Improvement Program in Corio Bay.
- Consider a "worst-case" scenario.

8.4 Task 6: Re-run Sediment Transport Model

8.4.1 Background of Dredging in Corio Bay

Corio Bay has been extensively modified by dredging of channels to allow access by sea-going vessels, development of the Port of Geelong and development of marinas for recreational boats. The first dredging program for the North Channel occurred in the 1850's. In the early 1860's, the South Channel was formed to allow better access to the Bay (Geelong Port, 2018). Figure 8-1 shows the location of the North Channel and South Channel as well as the site of the Refinery Pier (shaded in red).

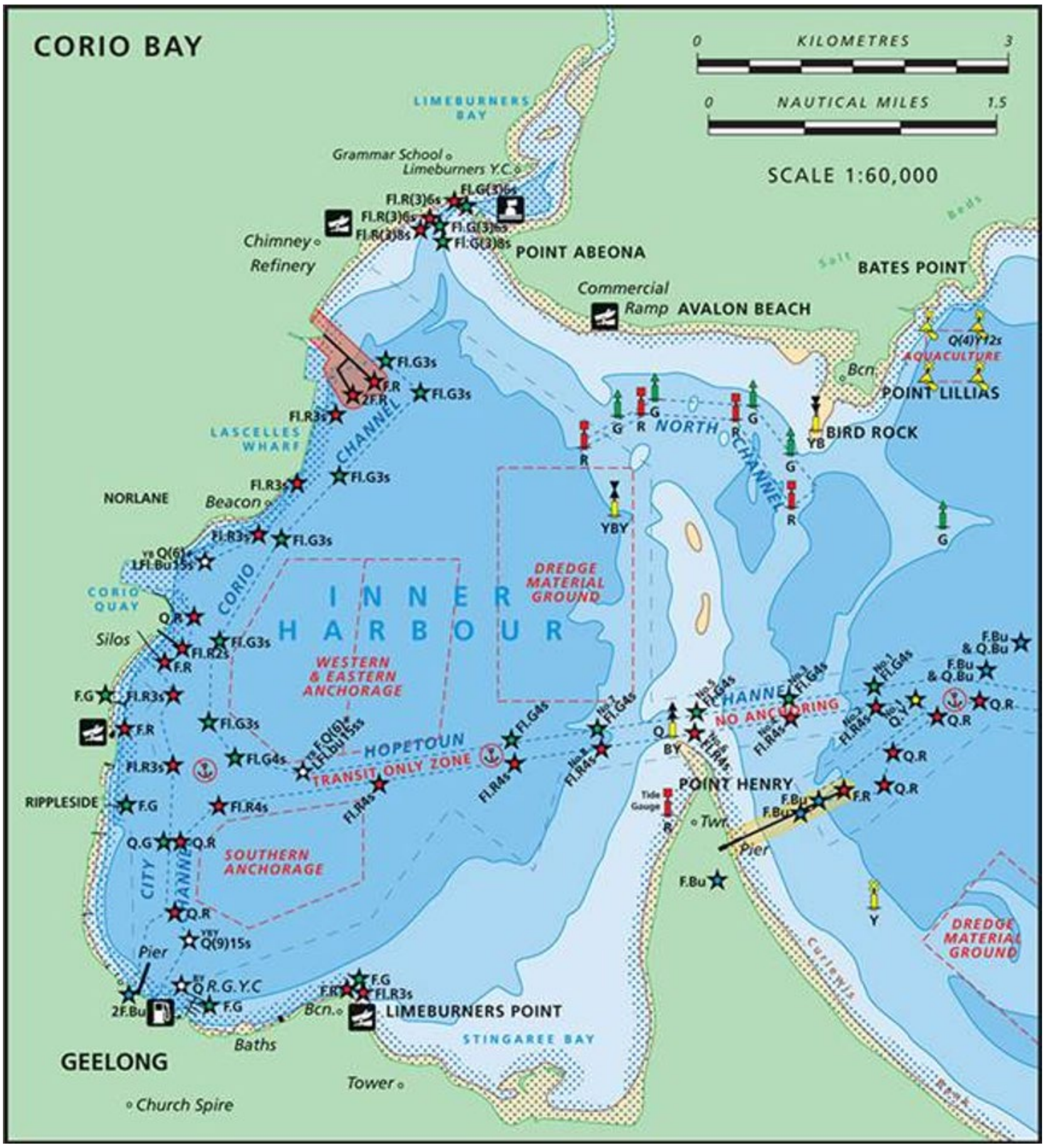


Figure 8-1. Dredged Channels in Corio Bay

The 1890's saw a third dredging program as the Hopetoun Channel was cut into Corio Bay with a minimum depth of 7.1 m and a navigable width of 39.6 m (GeelongPort, 2018). In the early 1900's, the Hopetoun Channel was widened and deepened as the port of Geelong continued to develop.

In 1958, channels were widened and the channel from Refinery Pier to Pt. Richards was expanded to 91.4 m wide and 10.9 m deep. In 2004, the Victorian Regional Channels Authority (now Ports Victoria) commenced deepened the channel to 12.3 m (Geelong Port, 2018).

In summary, shipping channels for the port of Geelong have been progressively enlarged and modified over a period of approximately 150 years to allow for safe ship access to the port (Worley Parsons 2011) with approximately 20 million m^3 of material dredged to create and maintain the shipping channels between 1854 and 1997.

The volume of dredging in historical dredging programs is shown in Figure 8-2. The Channel Improvement Program in 1996-1997, which is the reference project for the proposed dredging, involved the excavation of 4,500,000 m^3 of the same types of sediment and is shown as the orange column. The proposed dredging for the Viva project is 490,000 m^3 and shown as the final red column. It can be seen that the proposed dredging is small in comparison with several previous dredging programs in Corio Bay.

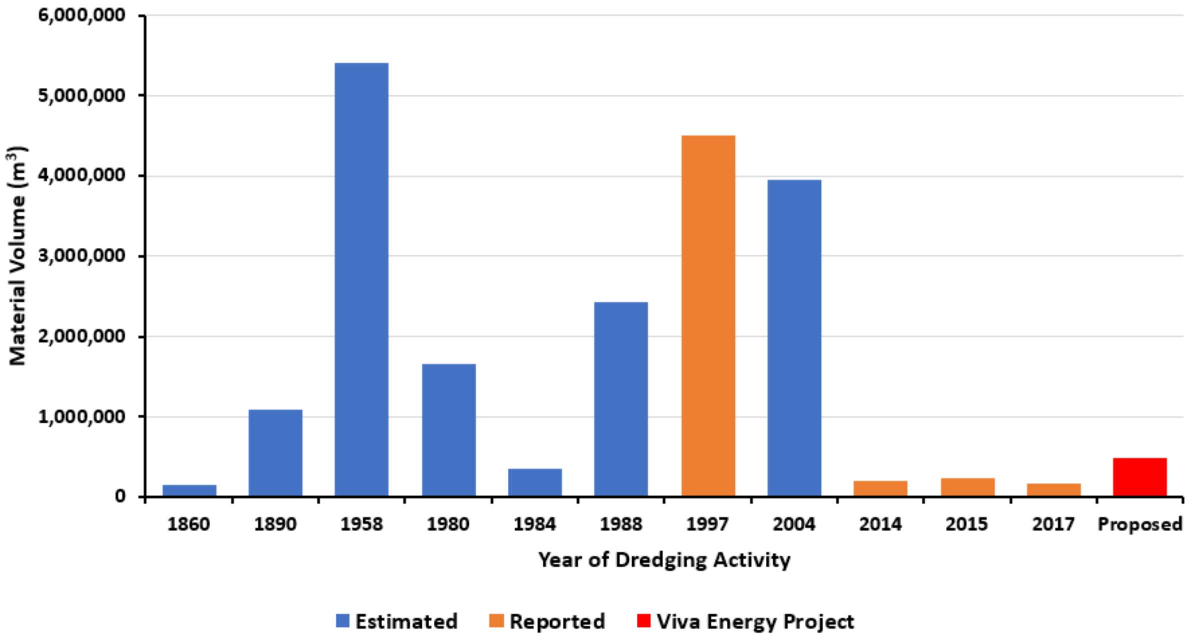


Figure 8-2. Comparison of Dredging Programs in Corio Bay

The Channel Improvement Program involved dredging sediments at the Grain Pier, Lascelles Wharf and Refinery Pier and Point Henry, mostly areas close to the proposed dredging at Refinery Pier, involving the same sediment characteristics and a similar rate of excavation. There was extensive monitoring of turbidity during the Channel Improvement Program and the results can be used to check the predictions of suspended solids and turbidity made for the project.

Lawson and Treloar (1997) developed a “verification” hydrodynamic model that they reported matched the measured turbidity in the Channel Improvement Program. The model inputs and predictions of the verification model provide a reference for comparison to the predictions of the regional hydrodynamic model used in this project.

8.4.2 Dredging Footprint and Volume

It is proposed to extend Refinery Pier with a third berth and extended ship turning basin which would involve deepening 12 ha of north Corio Bay. The extra 12 ha will increase the area dredged in the Port of Geelong, including the channels from 310 ha to 322 ha. In the context of Corio Bay, the 12 ha to be dredged constitutes less than 0.3 per cent of the 4,300 ha of Corio Bay.

Figure 8-3 shows the proposed dredging footprint. The proposed FSRU berth section is approximately 600 m long and an average of 130 m wide, and would be dredged to a depth of 13.1 m below chart datum (shown in purple).

The turning basin is approximately 500 m long and an average of 160 m wide, and would be dredged to a depth of 12.7 m (shown in brown).

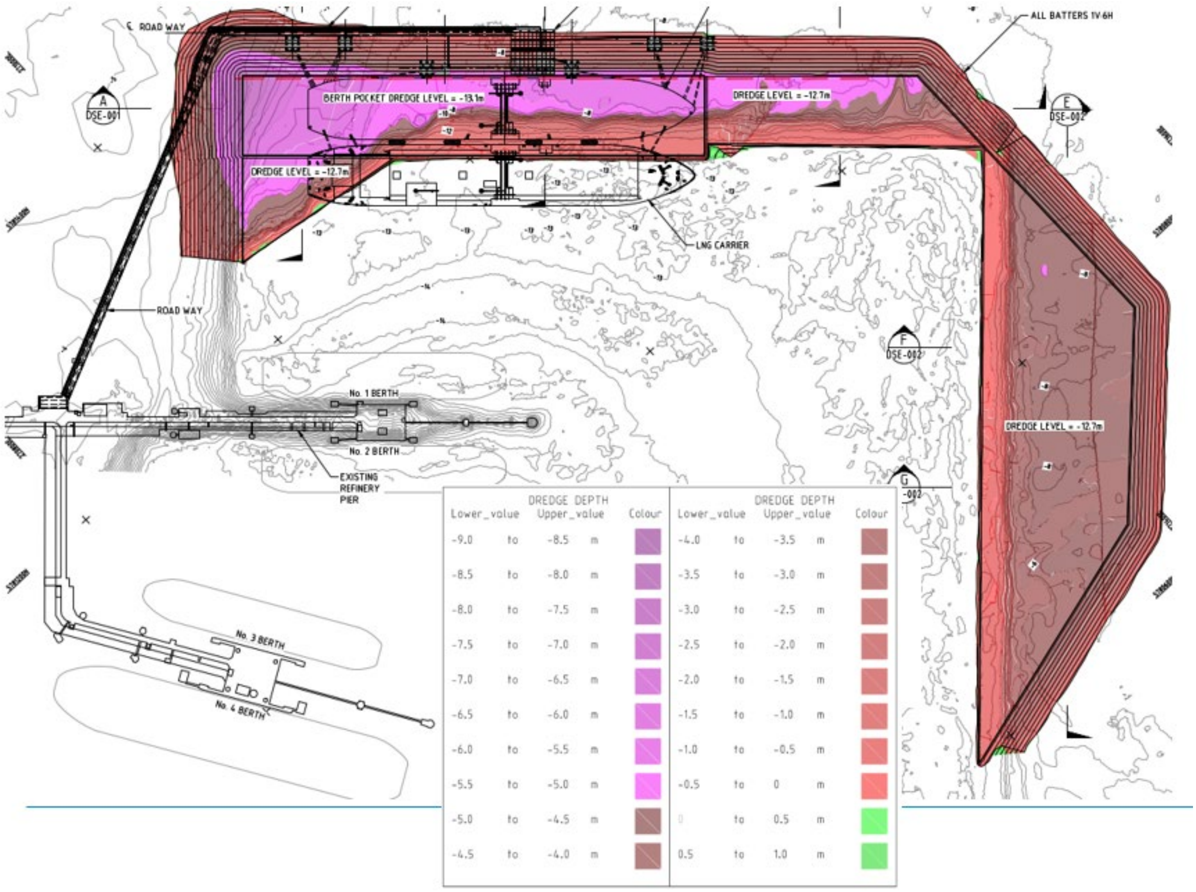


Figure 8-3. Extent of Proposed Dredging

All the material to be excavated is sediment – there is no rock or reef. The surface layers are soft clay and sandy clay; there are thin layers of sand at intermediate depths and the deeper layers are classified as clay or sandy clay. The proposed dredging will not alter the wave climate on the north shore or the Ramsar site.

The size of the proposed dredging program is similar to the annual maintenance dredging program carried out by the Port of Melbourne in Port Phillip Bay.

8.4.3 Characteristics of the Sediment

Table 8-1 lists the characteristics of the sediment. A cross section on the proposed excavation to form the new Berth 3 is shown in Figure 8-4. The material to be dredged comprises layers of sandy clay, clayey sand, shells, compacted sand and cohesive clay.

Units A-1 and A-2 represent recent (Holocene) deposits in Corio Bay. Unit A-1 is sandy silt grading to sandy clay with clay of high plasticity. The sand is mostly fine-grained quartz and shell fragments. Worley diver observations show a thin layer of ‘liquid mud’ and organic material on the surface of Unit A-1 that is easily moved into suspension.

Unit A-2 is comprised predominantly of sandy clay grading to clay with sand. The sand is fine-grained quartz and shell fragments, along with layers of coarser shell.

Unit B-1 is mostly clay and sandy clay. Only a small depth in Unit B-1 will be excavated.

Due to the relatively low strength of the majority of these sediments, excavation conditions are not expected to be difficult. The sediments comprise mostly sandy clay grading to cohesive clay. Cohesive materials have internal bonding due to molecular attraction, i.e. the sediments ‘stick together’. There is potential for the material to form lumps or ‘clay balls’ and clay flocs. The lumps will settle quickly near the dredge.

Table 8-1. Characteristics of the Sediment Layers to be Dredged

Unit	Description	Thickness
Recent Marine Sediments A-1 and A-2	SANDY SILT: high liquid limit, dark grey, dark brown, grey, fine grained sand, with shell fragments, very soft	0.2 to 1 m
	SANDY CLAY/CLAY: high plasticity, dark grey, black, with silt, fine to medium grained sand and shell fragments, very soft to firm material	2 to 5 m
Tertiary Age Brighton Group (Moorabool Viaduct Sands) B-0 and B-1	SILT: high liquid limit, pale brown, grey-brown, very stiff to hard silt	1 to 2 m
	SANDY CLAY/CLAY: medium to high plasticity, brown, pale brown, grey with silt and fine to coarse grained sand, stiff to very stiff material	3 to 5 m
	CLAYEY SAND/SAND: fine to coarse grained, pale brown, brown, grey, high plasticity clay, medium dense to dense material	3 to 5 m
	SANDSTONE: fine to medium grained, high strength	>1 m

Figure 8-4 shows a cross section of the sediments to be dredged along the proposed jetty based on an assessment of the borehole data. Units A-1 and A-2 are Holocene deposits near the seabed and shown in blue. Units B-0 and B-1 are deeper and represent older (Pleistocene) deposits in Corio Bay. Unit B-0 is loose to medium dense Clayey/Silty Sand distributed as discontinuous lenses and channel-infill deposits. Unit B-1 is expected to underlie Units A-1 and A-2 and is mostly stiff to very stiff, Clay of low to very high plasticity.

Examination of the cores reported by Worley shows that the sediments were in layers, with bands of silt, clayey silt and silty clay (showing increasing proportions of clay) interspersed with layers of grey and yellow cohesive clays. Because the material was most likely deposited underwater, there are variations in the thickness and composition of the various layers, with thin lenses of other materials (shells, sand or gravels) interspersed between the sandy silt and sandy clay.

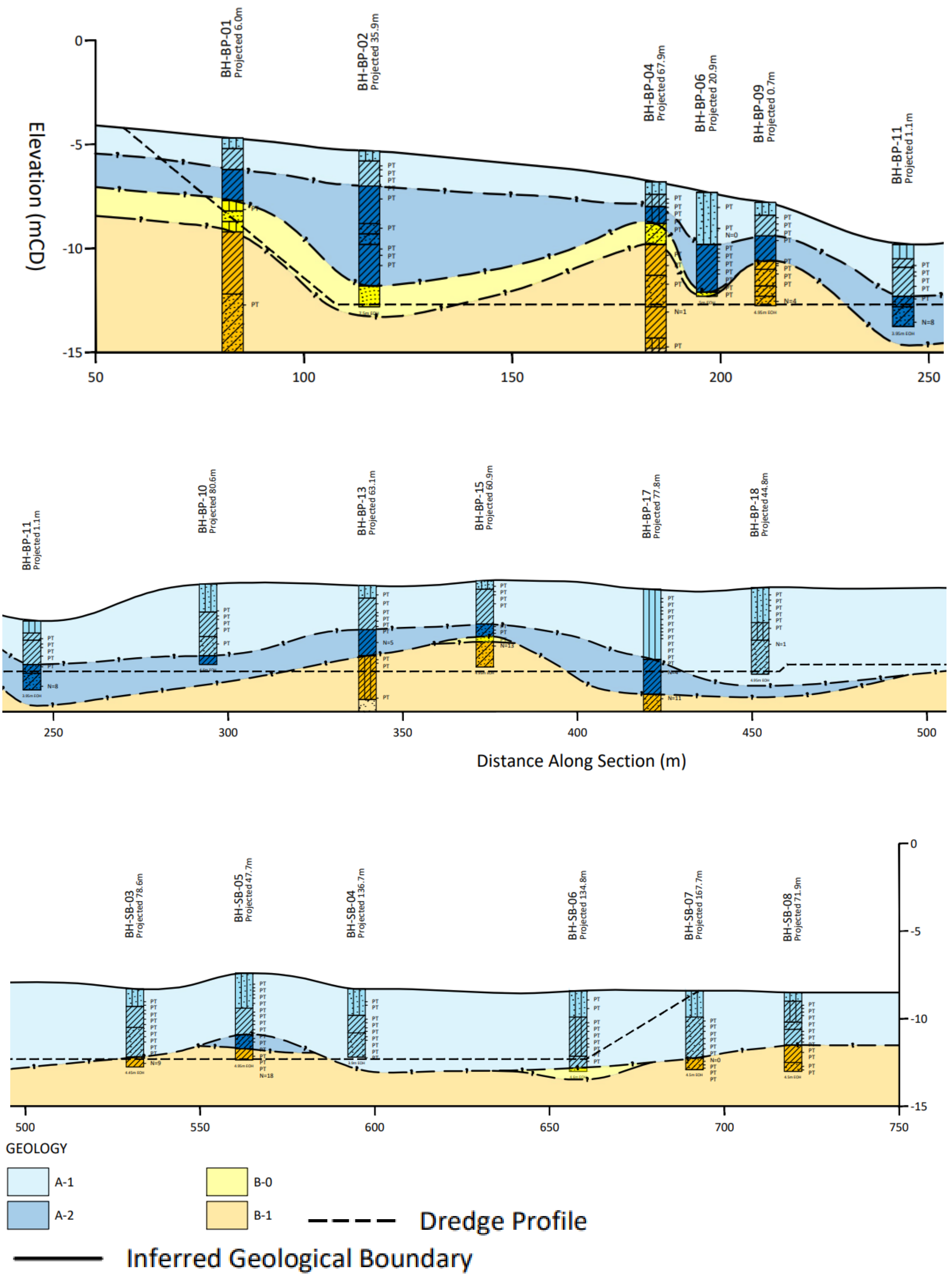


Figure 8-4. Profile of Proposed Dredging Along Jetty

8.4.4 Expected Spill Rates During Dredging

Spill and loss rates during the dredging were supplied by Boskalis (an experienced dredging operator) and are based on the sediment characteristics outlined above and the experience gained by Boskalis in previous dredging projects in Corio Bay and for the Port of Geelong on the same sediments.

The 8-week dredging program would involve an average removal of 8,800 m^3/d of sediment. Boskalis advised the spill rate from the dredge would be between 4 % and 5 %, depending on the weather, operator and depth of the excavation.

As a check, published spill rates using the same equipment in similar sediments were reviewed. Other spill rates were 2 % loss measured in Darwin Harbour with more compacted sediments; 2.5 % loss for grab dredge spill (Jiang et al 2019); 4 % loss in source terms for modelling backhoe dredging (J Becker 2015) and 5 % loss in Webb Dock dredging (Cardno, 2012). From this comparison, it was concluded that the 4 % to 5 % loss rate provided by Boskalis was realistic.

For these model predictions, a spill rate of 5 % from the dredge was adopted. This corresponds to 440 m^3/d.

The second source of spilled sediment is overflow from the barges transporting the dredged sediment. The overflow spill rate also was provided by Boskalis. The barges would have a capacity of 1,400 m^3 of sediment, and there would be 8 barge movements per day. Barges would be permitted to overflow for 15 minutes, spilling an estimated 17 m^3/barge of sediment or 160 m^3/ d.

Total spill of sediment from the dredge (440 m^3/d) and the barge overflow (160 m^3/d) is estimated to be 600 m^3/d. This corresponds to 480 t/d of dry sediment or an average spill rate of 6 kg/s.

Based on dredging industry experience with spills from buckets and barge overflows, the spill at the dredge site of 6 kg/s was distributed over the water column as follows:

- 40 % released in the top 2 m = 2.4 kg/s;
- 30 % released at mid-depth = 1.8 kg/s; and
- 30 % released in bottom 2 m = 1.8 kg/s.

The release positions are the same as used in the EES and reflect the release of solids in the water column during dredging – some near the seabed, some as the bucket moves from the seabed to the surface, and returns, and some at the surface due to spills and barge overflow.

8.4.5 Potential to Decrease Spill Rate if Necessary

Ceasing barge overflow is a management measure which can be used at times of strong southerly winds, reduces the spill rate by 27 % to 440 m^3/d (or 4.1 kg/s). This procedure is retained as an operations contingency for days where there could be elevated turbidity where the barge is filled less to reduce overflow at the cost of slower operation.

8.4.6 Particle Size Distribution Measurements

The composition and size distribution of particles released during dredging was assessed from the measured particle size distribution. Table 8-2 lists the particle size distribution of the material to be dredged based on borehole sampling and analysis in 2020 (Coffey, 2020), AECOM (2021) and Worley (2022). Coffey showed the variability of sediment characteristics between boreholes and provided the particle size distribution for each geological unit. There were similar particle size distributions for the four sediment layers, and thus the combined particle size distribution for the 45 boreholes is shown in Table 8-2.

Further testing of the particle size distribution and other properties of the sediment was carried out in 2021 (AECOM, 2021). The AECOM results used slightly different size ranges and fewer boreholes in their classification and therefore came up with different proportions of clay, silt and sand. However, the proportion of fine sediment (silt + clay) established by AECOM (70 %) was similar to Coffey (63 %).

Worley drilled an extra 27 boreholes along the length of the proposed jetty and seawater transfer pipeline. Their average particle size distribution was similar to that of Coffey, but with less sand and more clay.

Table 8-2. Particle Size Distribution for Sediments

Material	Size range	Coffey	AECOM	Worley	Adopted
Sand	63-125 micron	37 %	30 %	29 %	**32 %**
Silt	2 – 63 micron	17 %	32 %	19 %	**22 %**
Clay	< 2 micron	46 %	38 %	52 %	**46 %**
Total		100 %	100 %	100 %	**100 %**
Number of boreholes		45	32	27	

Taking into account all of the results, the proportion of sand (> 63 microns) is estimated to be 32 % of the sediments to be dredged. Fine sediments therefore comprise 68 % of the sediments and they are divided into silt (22 %) and clay (46 %).

The silt is further subdivided into medium size silt (11 %) and fine silt (11 %) based on the size distributions from Worley. The clay fraction is divided into 44 % as clay particles, (predominantly flocculated as described below) and 2 % as a thin layer of 'liquid mud' and organic material on the surface, that is easily moved into suspension.

Based on this analysis of the measured particle distributions, the dredge spill modelling was conducted with five particle sizes:

1. Fine sand: 32 % at 1 mm/s
2. Medium silt: 11 % at 0.8 mm/s
3. Fine silt: 11 % at 0.26 mm/s
4. Clay: 44 % at 0.063 mm/s
5. Organics and clay: 2 % at 0.01 mm/s.

As a comparison, an additional simulation was made using the same two fractions listed as the Lawson & Treloar verification model parameters (Lawson & Treloar, 1997):

1. Medium silt: 62.5 % at 0.26 mm/s
2. Clay: 12 % at 0.011 mm/s.

The missing Lawson and Treloar proportion of 25.5 % is assumed to fine sand with a settling velocity of 1 mm/s (same as CEE fraction 1). As described below, the CEE and L&T size distributions give similar results in terms of predicted suspended solids concentrations.

8.4.7 Settling Velocities

Particles settle through the water column under gravity at a velocity where the gravitational force is equal to the drag force. There are computer programs and charts readily available to show settling velocity for various conditions.

Sands have particle diameters in the range of 0.06 to 0.2 mm and settling velocities of 1 to 10 mm/s for gravity settling of fine sand in seawater. For this assessment, the lowest settling velocity for fine sand of 1 mm/s was adopted as the settling rate for all sand in the dredge spill.

This corresponds to 3.6 m of settling in an hour, and all sand particles would settle out in an hour or two close to the dredging site.

Based on published charts, the settling velocity of medium silt is 0.8 mm/s and the settling velocity of fine silt is 0.26 mm/s.

Clay constitutes 44 % of the sediments. There will be a high concentration of clay particles around the dredge and flocculation will occur. Sediment mixtures with more than 10 % of clay particles have cohesive properties because electrostatic attraction forces act between the particles. Consequently, the clay particles do not behave as individual particles but stick together forming aggregates known as flocs whose size and settling velocity are much larger than those of the individual particles (van Rijn, 2023)

Similarly, the clay particles in the barge overflow will comprise mostly flocculated clay particles with an adopted settling velocity of 0.063 mm/ s, based on the published settling rates of flocs.

Data for settling rates of clay flocs is summarised in Figure 8-5 and was drawn from van Rijn (2022) design curve for clay floc (settling velocity of 0.01 mm/s at 1 mg/L to 1 mm/s at 240 mg/L); size of clay flocs measured in-situ in San Francisco Bay by Smith and Fredrichs (2011, with settling velocity of 0.03 to 0.2 mm/s); previous tests for Corio Bay sediments published by McCowan and Kakl, 2005 (settling velocity of 0.01 mm/s to 0.1 mm/s) and CEE tests of clay settling using samples from the Worley cores (settling velocity of 0.02 mm/s to 0.08 mm/s).

Based on these data, the floc settling rate should be in the range of 0.03 to 0.1 mm/s. A central settling rate of 0.063 mm/s was adopted.

The Port of Gladstone in Queensland has a large maintenance dredging program and an extensive turbidity monitoring program. From these investigations, the Port has determined that clays flocculate into larger particles that can best be represented as particles with a settling velocity of 0.2 mm/s (Symonds et al, 2023). The settling velocity for clay of 0.063 mm/s used in this assessment is one-third of this settling rate and therefore more conservative.

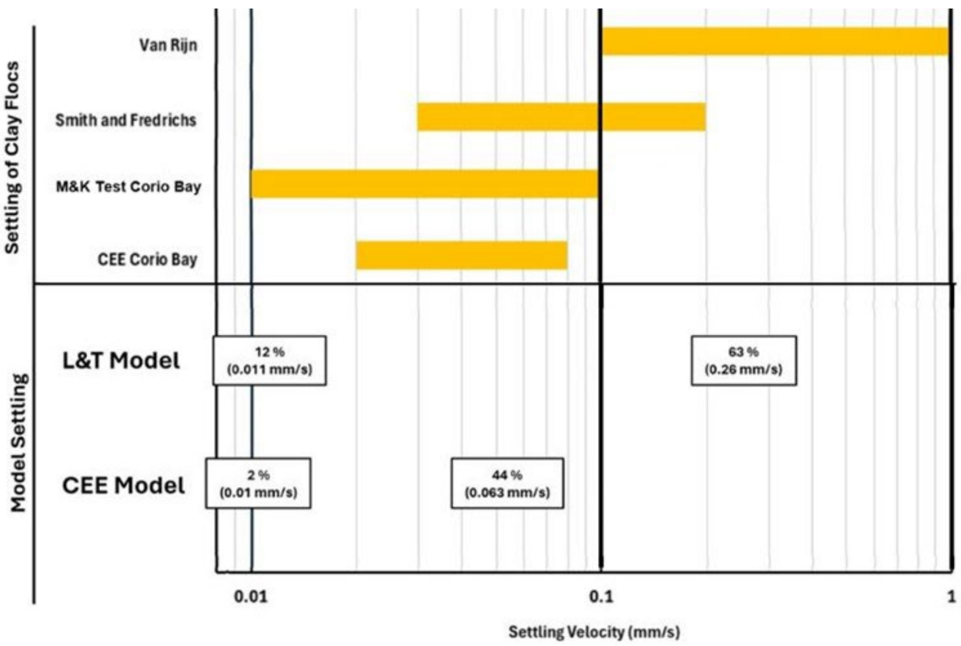


Figure 8-5. Summary of Clay Floc Settling Rates

CEE divers noted that there is a thin layer of soft sediment mixed with organics that forms the top 20 to 40 mm depth of the sediments in the project area. This layer is easily disturbed and is readily sheared into suspension by the action of ship propellers or the wakes of large vessels in the channels.

Local turbidity plumes formed by this material form in eddies behind jetties, piles and at the exit of strong tidal currents from the channels. Thus, the final sediment fraction used in this modelling is organic fines with a settling velocity of 0.01 mm/s.

In summary, the sediment fractions and settling velocities used in this model are:

Table 8-3. Settling Velocities for Model

Fraction	Proportion	Settling Vel, mm/s
Fine sand	30 %	1 cm/s
Medium silt	11 %	0.08 mm/s
Fine silt	11 %	0.026 mm/s
Clay flocs	44 %	0.063 mm/s
Organic fines	2 %	0.01 mm/s

Figure 8-5 shows that the adopted settling velocities are within the range of other published and measured settling rates.

The model predictions of suspended solids and turbidity are compared to the measurements of turbidity made during the 1996-1997 Channel Improvement Program as a verification. As a second verification, the model predictions are compared to the predictions of the Lawson and Treloar verification model of suspended solids distribution in Corio Bay.

The Lawson and Treloar verification model used significantly different sediment fractions and settling rates as shown below:

Table 8-4 Lawson and Treloar Settling Parameters

Fraction	Proportion	Settling Vel, mm/s
Fine sand	25.5 %	0.5 cm/s
Coarse silt	62.5%	0.26 mm/s
Fine silt	12 %	0.011 mm/s

Source: Lawson and Treloar, 1997

8.4.8 Predictions of Suspended Solids

The refined regional hydrodynamic model (from Recommendation 2) was used to simulate the transport, dispersion and mixing of the spilled material in Corio Bay. As described in more detail in the Response to Direction 2, the model has a 20 m by 20 m horizontal grid throughout Corio Bay, the channels and the Geelong Arm of Port Phillip Bay, and a time step for sediment of 1 minute. The spilled material at the dredge site was added to four grid squares (area of 40 m by 40 m) which were progressively moved around the area proposed to be dredged over 8 weeks.

Simulations were made using tides, seasonal winds and seawater temperature and salinity conditions for an 8-week periods of August - September 2020 (which avoids the October-March period of seagrass growth, fish breeding and migratory bird feeding).

Figure 8-6 shows the **predicted increase** in average suspended solids (SS) concentration in north Corio Bay due to dredging over the simulated 8 week dredging period of August-September 2019 from the regional hydrodynamic model. At the surface, the predictions show a small patch (5 ha) of 5 mg/L SS above ambient and a large patch (200 ha) of 2 mg/L SS.

At the seabed, the predictions show higher SS higher concentrations with a 20 ha patch at 20 mg/L SS and a larger area of 200 ha of 2 mg/L SS. Using the conversion listed in the *Victorian Dredging Guidelines*, 2 mg/L SS corresponds to 2.4 NTU.

Comparison with Turbidity Measurements in Channel Improvement Program

The Channel Improvement Program excavated the same sediment from the same and similar areas of Corio Bay (including other berths of Refinery Pier) over a 14 month dredging period. Monitoring by Lawson and Treloar (1998) for the Corio Bay Channel Improvement Program showed the following results for average turbidity in Corio Bay:

- Pre-dredging turbidity = 0.4 to 1.2 NTU (23 surveys)
- During dredging turbidity = 0.5 to 2.5 NTU (19 surveys); and
- Post-dredging turbidity = 0.4 to 1.0 NTU (7 surveys).

The upper turbidity during dredging of 2.5 NTU is equivalent to 2.1 mg/L SS and closely matches the extended area of 2 mg/L SS predicted by the model and shown in Figure 8-6.

Figure 8-6. Predicted Increase in Average Suspended Solids at Surface (Increment Above background)

8.4.9 Background SS Concentration in North Corio Bay

Water samples were collected at 0.2 m depth at five sites in the Ramsar site during the plume surveys and analysed for suspended solids concentration at Monash University. The range of SS values was 1.2 mg/L to 2.3 mg/L and the average SS concentration from all samples was 1.8 mg/L.

Higher SS levels occur in shipping channels and the port caused by the movement of ships and tugs stirring up the fine organic layer on the seabed. Large scale eddies at the entrance of the channels and the waters downstream of structures (jetties, piers, moored ships) also create eddies that stir up this layer. The sediment fractions used in the CEE model allow for 2 % proportion of organic fines, to represent this effect during dredging.

Related measurements show low turbidity in northern Corio Bay of 0.4 to 0.5 NTU (Provis, 2009), 0.3 median (Longmore 1990 to 1996 data), 0.3 NTU average and 0.35 NTU (CVA, 1997). The latter three values are quoted from the Victorian Dredging Guidelines.

The EPA measured SS monthly in the centre of Corio Bay from 2000 to 2023. The range of SS values in the EPA data was 0.1 mg/L to 31 mg/L and the median SS concentration from all samples was 2.3 mg/L while the median for 2009-2016 was 1.5 mg/L. These values bracket the adopted background SS concentration of 1.8 mg/L.

The waters in the seagrass habitat of Ramsar have weak currents and generally quiescent conditions (other than during storms). On the basis of the available data, the background SS concentrations for the Ramsar site is taken as 1.8 mg/L, the same as the average of the site measurements.

8.4.10 Time Series of SS Concentration

The time series of suspended solids concentration above background was modelled at four sites in Corio Bay as shown in Figure 8-7. Three of the sites are on the outer boundary of the Ramsar Site north-east of the dredged area while the fourth site is on the 2 m depth contour in dense seagrass towards the refinery.

Figure 8-7. Sites Used to Predict Increase in SS Concentration

Figure 8-8 shows the time series of the SS concentration increment at the four sites for the Aug-Sept 2019 modelling period.

- At Site 1, the average SS increment over the 8 weeks of dredging is 1.3 mg/L with a peak of 10 mg/L. The average including background SS). is 3.1 mg/L
- At Site 2, the average SS increment over the 8 weeks of dredging is 2.4 mg/L with a peak of 15 mg/L. The average including background SS). is 4.2 mg/L
- At Site 3, the average SS increment over the 8 weeks of dredging is 3.0 mg/L with a peak of 25 mg/L. The average including background SS). is 4.8 mg/L
- At Site 4, the average SS increment over the 8 weeks of dredging is 3.2 mg/L with a peak of 23 mg/L. The average including background SS). is 5.0 mg/L

The predictions show low average SS and turbidity concentrations and match the turbidity measurements made in the previous dredging program and summarised above. The increase in turbidity will be visible within about 250 m of the dredging area but have very little effect on water quality or light attenuation in the Ramsar site.

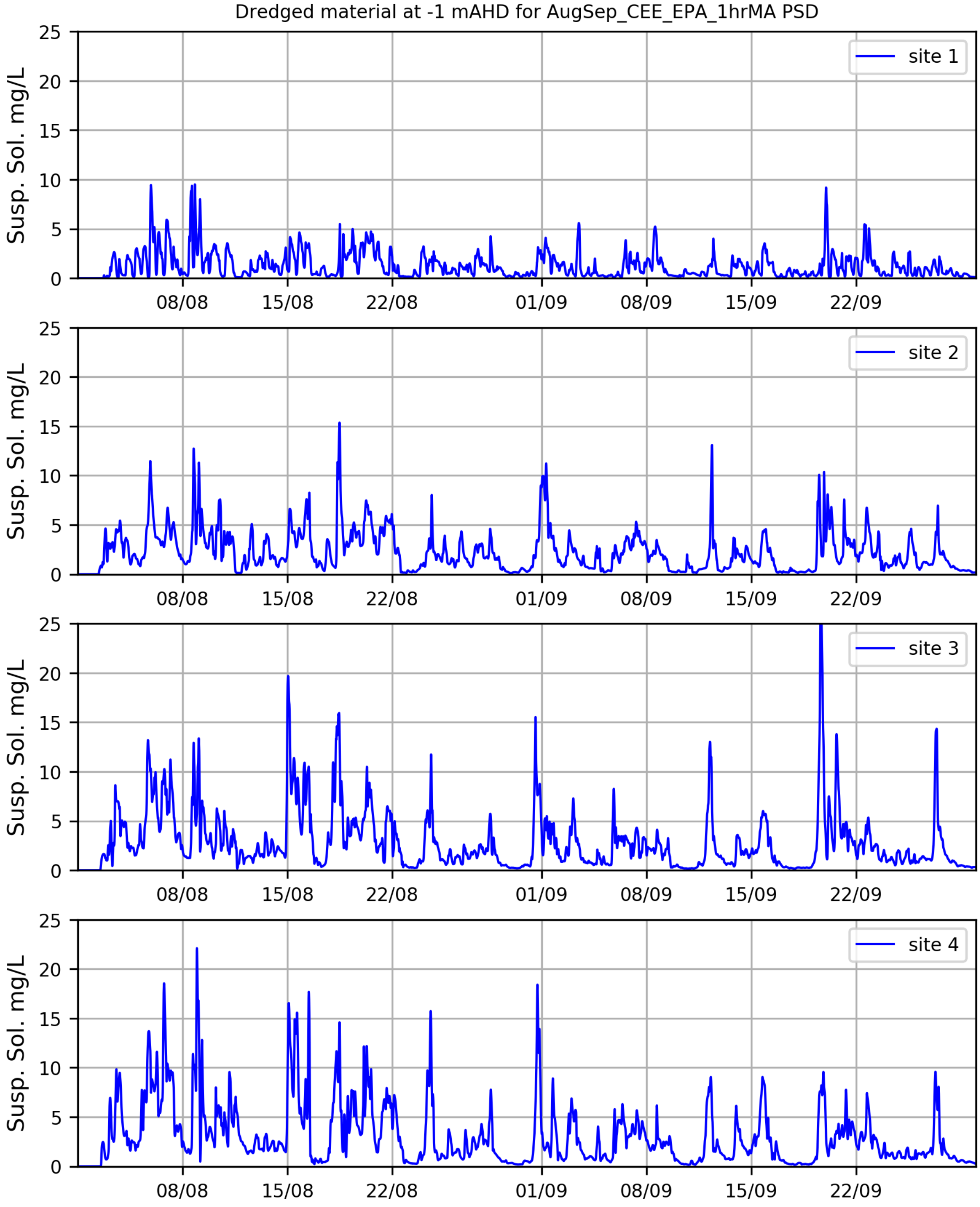


Figure 8-8. Predicted Time Series of CEE Suspended Solids Concentration

Note that between short periods of higher SS concentrations, there are longer periods of lower concentrations. Analysis of the hourly readings for Site 3 shows that the SS concentration is less than 5 mg/L for 85 % of the 8-weeks of dredging. This corresponds to 8.4 days of elevated SS levels, of which half are at night. Therefore, there would be a significant reduction in light reaching seagrass for only 4.2 days during the dredging period, which should have very little impact on seasonal seagrass growth.

8.4.11 Lawson and Treloar Verification Model

Lawson and Treloar (1997) prepared four dispersion model predictions for the Victorian Channels Authority using different spill and settling rates. Their model 4 (*Actual Production with Modified ECAV+C Settling Rates)* was showed a good fit to observations, with the following statements:

"The general extent of the plume is similar to that of the observations. The modelled turbidity levels are also similar to those observed. Overall, the Van Oord turbidity generation rates coupled with the modified ECAC settling velocities gives the best results for prediction of sediment suspension and movement around Corio Bay".

Figure 8-9 shows the time series of the increment in SS concentration at sites 3 and 4 predicted by the CEE model using the Lawson and Treloar (L&T) parameters for the August-September 2020 modelling period. Overall, the predictions using L&T parameters show very similar average SS values to the CEE results but lower peaks in SS.

- At Site 3, the average SS increment over the 8 weeks of dredging using the L&T parameters is 3.0 mg/L (total of 4.8 mg/L including background) which is the same as the CEE prediction.
- At Site 4, the average SS increment over the 8 weeks of dredging using the L&T parameters is 3.1 mg/L (total of 4.9 mg/L including background). This is very similar to the average SS increment of 3.3 mg/L predicted using the regional hydrodynamic model for this assessment.

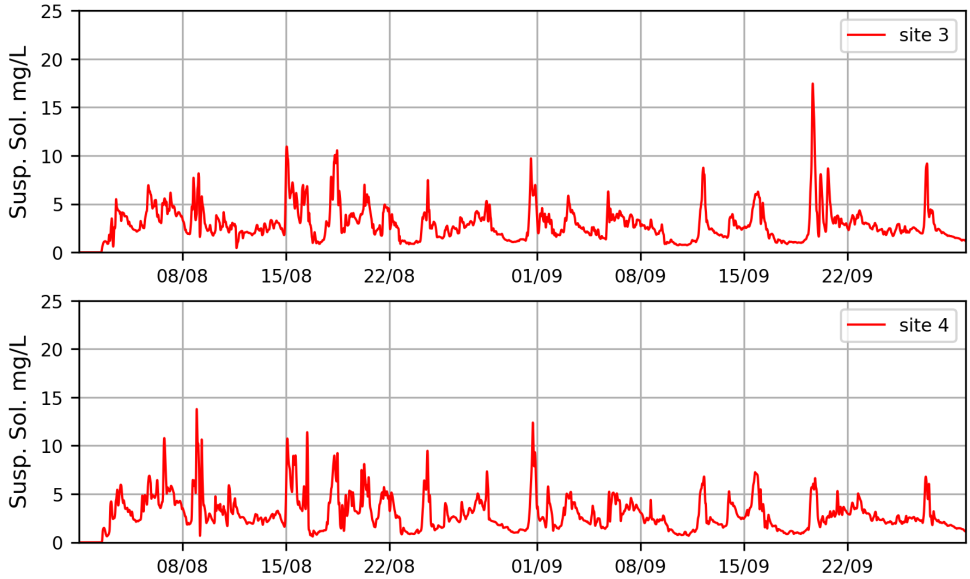


Figure 8-9. Predicted Time Series Using L&T Parameters in CEE Model

The comparison of the CEE model predictions and the L&T verification model predictions show little difference between the average SS concentrations. The CEE model predicts higher peak concentrations which is probably more realistic. The monitoring data show mostly low NTU levels but there is a peak measurement of 20 NTU at Avalon, which suggests the regional hydrodynamic model prediction is more realistic.

Figure 8-10 compares the average SS concentrations on the surface from the L&T model using L&T parameters (from their 1977 report to VRCA) with the CEE model predictions using CEE parameters. The extent of predicted SS above 2 mg/L by the CEE model is larger than from the L&T model, which suggests the regional hydrodynamic model predictions are possibly conservative (on the basis that the L&T predictions match the observed SS and turbidity in previous dredging).

The smaller 2 mg/L SS contour in the lower panel represented the prediction without the 2 % organic fines fraction. As shown in Figure 8-10, inclusion of the 2 % clay-organics fraction increases the extent of the 2 mg/L contour. However, the areas of the 5 mg/L plumes are very similar. Note that all concentrations are increases above ambient SS levels.

Figure 8-10. Comparison of SS Predictions (Above Background)

8.4.12 "Worst case" Assessment

The IAC requested a worst-case' scenario which includes the largest expected proportions of fine and very fine materials that have the slowest expected settling velocities. An example of such a 'worst-case' scenario could be from a prolonged storm event.

As shown in Table 8-2, the adopted clay fraction was 46 % of the total, based on the average of the three sets of boreholes. The largest fraction in any group of boreholes was 52 %, which is 13 % higher than the average. This is used as the "worst case" proportion of fines.

Higher Fines Proportion

A higher proportion of fines could occur on some days, with a possible 13 % increase in the spill rate considered for this "worst case" scenario analysis. In that scenario, all the predicted SS concentrations would increase by up to 13 %. Thus, the average SS at Site 3 would increase from 3.0 mg/L to 3.4 mg/L. This is still a low SS and turbidity level.

The peak concentration would increase from 25 mg/L to 28 mg/L. As peak events occur for only a few hours, and half of them occur at night, a 13 % increase in the fines proportion would not involve a significant adverse impact.

Slower Settling Rate

Variations in the settling rate arise because the characteristics of the sediment varies from site to site, as seen in the variability in composition of different boreholes. A "worst case" scenario involves a reduction in the clay floc settling velocity from 0.063 mm/s to 0.04 mm/s.

In that scenario, the average predicted SS concentration at Site 3 would increase from 3.0 mg/L to 4.9 mg/L. This would still represent a relatively low SS and turbidity level.

The L&T scenario uses a slower settling velocity for clay of 0.011 mm/s (0.04 m/hr) instead of the settling rate of 0.063 mm/s (0.22 m/hr) used in this assessment. As discussed above, the L&T scenario showed the same average SS concentrations but lower peak SS concentrations.

In the Port Phillip Bay dredging tests carried out for the VRCA, the plume settled out in 4 to 6 hours after dredging. This is equivalent to a settling rate of approximately 0.2 m/hr (or 0.056 mm/s) which matches the settling rate for clay flocs adopted for this assessment of 0.063 mm/s.

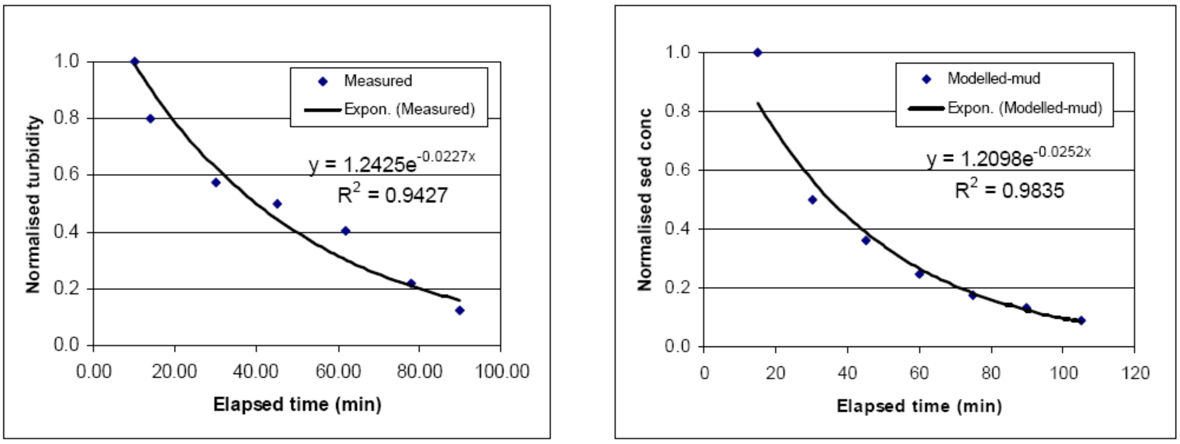


Figure 8-11. Decay of Turbidity in PPB Dredging Investigations

Source: Cardno, Lawson, Treloar (2006)

In conclusion, the "worst case" assessments involve an increase in the average predicted SS concentration at Site 3 from 3.0 mg/L to 3.4 mg/L (more fine sediment) or 4.9 mg/L (slower settling velocity). These would still represent a relatively low SS and turbidity level, and a low impact on seagrass.

8.4.13 Accretion of Solids on the Seabed

The suspended solids resulting from the proposed dredging would settle and accrete on the seabed. Settling of sediments is simulated by the regional hydrodynamic model using inert particles. Resuspension of settled particles is calculated from bottom shear stress (above a critical shear stress) and the particle density. Because of the weak currents in Corio Bay, and the cohesion and flocculation of the predominant clay material, the rate of resuspension in Corio Bay was very small.

Figure 8-12 shows the increment in seabed elevation due to sedimentation in the August – September period.

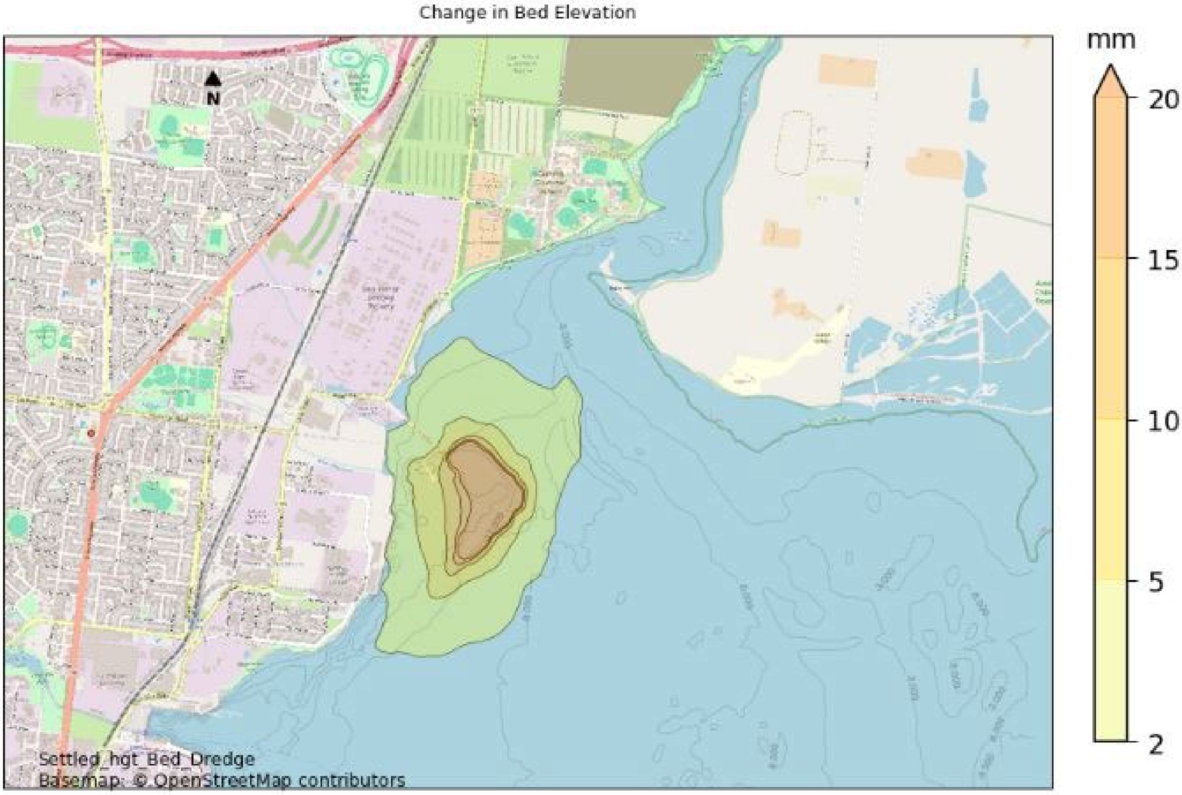


Figure 8-12. Accretion of Suspended Solids on the Seabed

Highest accretion (of 20 mm in 8 weeks) occurs on the seabed in the area dredged but this settling does not matter as the material would be re-dredged to lower the seabed down to the defined depth.

Lower accretion rates of 2 to 10 mm in 8 weeks would occur in north Corio Bay. This rate of accretion (0.04 mm/day to 0.2 mm/day) would have negligible impact on the muddy seabed and the infauna or mobile marine communities that inhabit muddy seabed. This seabed is generally bare of surface-dwelling biota except for microscopic algae (microphytobenthos or 'MPB'), patches of ephemeral unattached filamentous macroalgae and sparsely distributed fan worms Sabella Spallanzani (an introduced species).

The accretion rate on seagrass beds is from zero to 3 mm over the 8-week dredging period, which is expected to have negligible to very minor impact as seagrass naturally traps and accumulates sediment with sedimentation rates up to 20 mm/yr (Cabaco et al., 2008) and 31 mm/yr (Potouroglou et al., 2017).

The change in seabed level due to the accretion of sediment and dredging will not cause measurable changes in regional currents or wave conditions at the shoreline.

8.5 Conclusions

Recommendation 6 of the Minister's Directions required the dredge spill modelling to be repeated with the refined regional hydrodynamic model.

The updated sediment modelling using the refined regional hydrodynamic model shows only minor changes from the results reported in the EES.

The predicted 14-day average SS at monitoring points on the Ramsar site boundary averages 3 mg/L over 8-weeks. There are short peaks in SS concentrations of up to 25 mg/L (over several hours), but these would occur during storms and last for less than a day. As described in the Sections 9 and 10, this turbidity will cause only a small reduction in light reaching seagrass and all seagrass in the Ramsar site (zero to 2 m depth) will always receive sufficient light for growth.

The dredging is not expected to have any impact on intertidal seagrass, as that seagrass is exposed to high light intensity every low tide (during daylight hours).

The predictions show the seagrass in the Ramsar site would experience only a minor increase in turbidity over the 8-week dredging program. The change is too small to cause an adverse impact on seagrass productivity in the site.

The predictions show low suspended solids and turbidity in the Ramsar site. As such, it can be concluded that dredging will not affect Critical Processes and Services of the Ramsar site.

The 'worst case scenario' was described as a period where there is a higher proportion of fine sediment which cause as slower settling rate. The peak concentration would increase from 25 mg/L to 28 mg/L. As peak events occur for only a few hours, and half of them occur at night, a 13 % increase in the fines proportion would not involve a significant adverse impact.

The 'worst case scenario' was described as a period when there is a higher proportion of fine sediment which cause a slower settling rate. The peak concentration would increase from 25 mg/L to 28 mg/L. As peak events occur for only a few hours during the 8-week dredging period, and half of them occur at night, a 13 % increase in the fines proportion would not involve a significant adverse impact.

The accretion of sediment on seagrass beds in the Ramsar site is from zero to 2 mm which is expected to have negligible to very minor impact as seagrass naturally traps and accumulates sediment. Accretion in other seagrass beds may be up to 3 mm.

The predictions in the supplementary study used updated sediment parameters (size fractions and settling rates). The results matched measurements of turbidity in a previous dredging program and also matched the predicted extent of turbidity by the L&T verification model (Lawson and Trelaor, 1997).

In summary, the area of elevated suspended solids and turbidity is limited to the dredging zone and the surrounding area. The potential impacts will be short-term in Corio Bay and negligible in the Ramsar site.

9. Recommendation 7 – Assessment of Light Available for Seagrass Growth

9.1 Summary of Original EES Findings

EES Technical report A: *Marine ecology and water quality impact assessment* (CEE 2022) assessed the potential impact of light availability on seagrass (refer to Section 7.11).

It was determined that light attenuation would increase in the areas where elevated suspended solids concentrations and increased turbidity are predicted to occur during the 8-week dredging program (refer to recommendation 6). The increase in turbidity and light attenuation would occur over an area of about 160 ha and would result in a minor loss in productivity of seagrass in the shallow waters within this zone. If dredging occurs in spring, seagrass growth would slow considerably. There would be little effect in winter when seagrass is mostly dormant.

The light transmission would recover quickly to the original conditions after dredging ceases i.e., within one or two days. Any seagrass growth slowed by turbidity would recover shortly after completion of dredging.

The EES concluded that the area of predicted 5 mg/L suspended solids does not extend over any seagrass. The area of predicted 2 mg/L suspended solids extends over a 6 ha patch of seagrass. The increase in turbidity and light attenuation is expected to result in a temporary loss in productivity of seagrass in the shallow waters within and around the area to be dredged. If dredging occurs in summer or autumn, seagrass growth would slow considerably. There would be little effect in winter when seagrass is mostly dormant. Modelling results indicated that fine sediments remaining in the water column would settle out in 1 to 2 days after dredging stopes. Hence, light transmission is expected to recover quickly to original conditions after dredging ceases and seagrass recovery would begin shortly afterwards.

9.2 Overview

Recommendation 7 of the Minister's Directions states the following:

Undertake further assessment of dredging impacts on seagrass based on:

- *a. The revised sediment transport modelling*
- *b. Revised light thresholds of 10 percent to 20 percent surface irradiance (20 percent surface irradiance should be applied to any sediment plumes that extend to the Port Phillip Bay (western shoreline) and Bellarine Peninsular Ramsar Site)*
- *c. The updated seagrass mapping (Rec. 1b)*

To provide context, the IAC noted that the source-path-receptor approach used in the EES to determine the impacts of dredging on seagrass was acceptable but recommended further work to assess potential impacts on seagrass using the revised sediment transport modelling and updated seagrass mapping. The IAC also noted that it was appropriate for the EES to adopt a minimum light threshold approach for assessing impacts of dredging on seagrass and recommended adopting 10% of surface irradiance in Corio Bay and 20% of surface irradiance on seagrass in the Ramsar site for the further assessment.

9.3 Summary of Tasks

A number of tasks were undertaken as per the study program developed for the Supplementary Statement to address Recommendation 7 of the Minister's Directions. An overview of these tasks and their objectives is provided in this section of the report and are described in further detail in subsequent sections of this report.

Task 7: Determine the potential impacts on seagrass beds as a result of dredging activities to address Recommendation 7

Determine the potential impacts on seagrass beds as a result of dredging activities by:

- Analysing the results of the refined sediment transport model predictions (the outcome of tasks completed to address Recommendation 6) against the existing mapped seagrass boundaries (the outcome of tasks completed to address Recommendation 1) to determine the extent of seagrass that may have reduced light.
- Using the refined sediment transport model predictions (the outcome of tasks completed to address Recommendation 6) to calculate the frequency and duration of events with less than 10 and 20 percent surface irradiance within the Ramsar site and assessing the potential impacts.
- Comparing the predicted impacts of the proposed dredging program with actual impacts observed in previous (larger) dredging programs in Corio Bay.

9.4 Task 7: Assessing Dredging Impacts on Seagrass

9.4.1 Literature Review and Background to EES

9.4.1.1 Previous Dredging in Corio Bay

In assessing the effects of the proposed dredging program, it is useful to use, as a comparison, the measured effects of previous dredging in Corio Bay.

As previously discussed, shipping channels for the Port of Geelong have been progressively enlarged and modified over a period of approximately 150 years to allow for safe ship access to the port (Worley Parsons 2011) with approximately 20 million m^3 of material dredged to create and maintain the shipping channels between 1854 and 1997 including the channel improvement program on 1996 - 1997.

The volume of dredging in historical dredging programs is shown in Figure 8-2. In summary, there has been frequent dredging in Corio Bay, with a total of approximately 20 million m^3 of sediment dredged. For comparison, the proposed dredging (490,000 m^3) as part of this project is relatively small, as shown by the final red column in Figure 8-2.

The 1996-1997 Channel Improvement Program involved dredging 4.5 million m^3 of sediments at the Grain Pier, Lascelles Wharf and Refinery Pier and Point Henry, mostly areas close to the proposed dredging at Refinery Pier and involving the same sediment characteristics.

There was extensive monitoring of turbidity in Corio Bay generated by the Channel Improvement Program with turbidity during dredging being in the range of 0.5 to 2.5 NTU.

Marine Sciences & Ecology (2006) conducted a study on the effects on seagrass between Avalon and Pt Wilson of the 1997 dredging program. Monthly surveys of seagrass density and biomass were undertaken – 14 surveys prior to dredging; 14 surveys during dredging and 3 surveys after dredging. The MSE monitoring demonstrated that both the cover and biomass (standing crop) of *H. nigricaulis* was unaffected by turbidity generated during the dredging program.

The biomass of filamentous algae that covered a small proportion of the seagrass declined with the reduction in incident light due to turbidity, allowing some extra growth of the seagrass that had been shaded by the algae (MSE, 2006).

9.4.1.2 Amount of Material to be Dredged

As context, the project would involve dredging 490,000 m^3 of sediment to provide a new berth and turning basin.

The proposed duration of dredging the new berth and turning basin is 8 weeks. Thus, the average rate of sediment removal is 8,800 m^3/d.

9.4.1.3 Light Sources for Seagrass

Light is a critical input for the growth of seagrass, as it enables leaf photosynthesis and growth of the plant. Nutrients are another critical input, particularly nitrogen. Additional factors affecting the growth and density of seagrass are sediment movement and erosion, wave attack, shading by epiphytes and drifting algae, and grazing by swans and other birds, sea urchins, fish and crabs.

The light available to seagrass is the proportion of solar radiation that is in the 400 to 700 nm waveband, known as photosynthetically active radiation (PAR). Typically, PAR is approximately 50 % of the incoming solar radiation. There is also a small loss of light due to reflectance at the surface of the ocean which averages 4 % over a day (but varies from 3 % to 15 % depending on the angle of the sun).

Incoming solar radiation is measured by the Bureau of Meteorology at many sites, including Avalon Airport, and recorded as total daily radiation (in $MJ/m^2.d$). The daily radiation can be converted to PAR by multiplying by 0.48 and then converting to photons of light expressed as µmole/m^2.d.

Figure 9-1 shows the PAR at Avalon Airport converted to the photosynthetic photon flux density (PPFD). The orange curve shows the daily values and the blue line shows the 7-day average values.

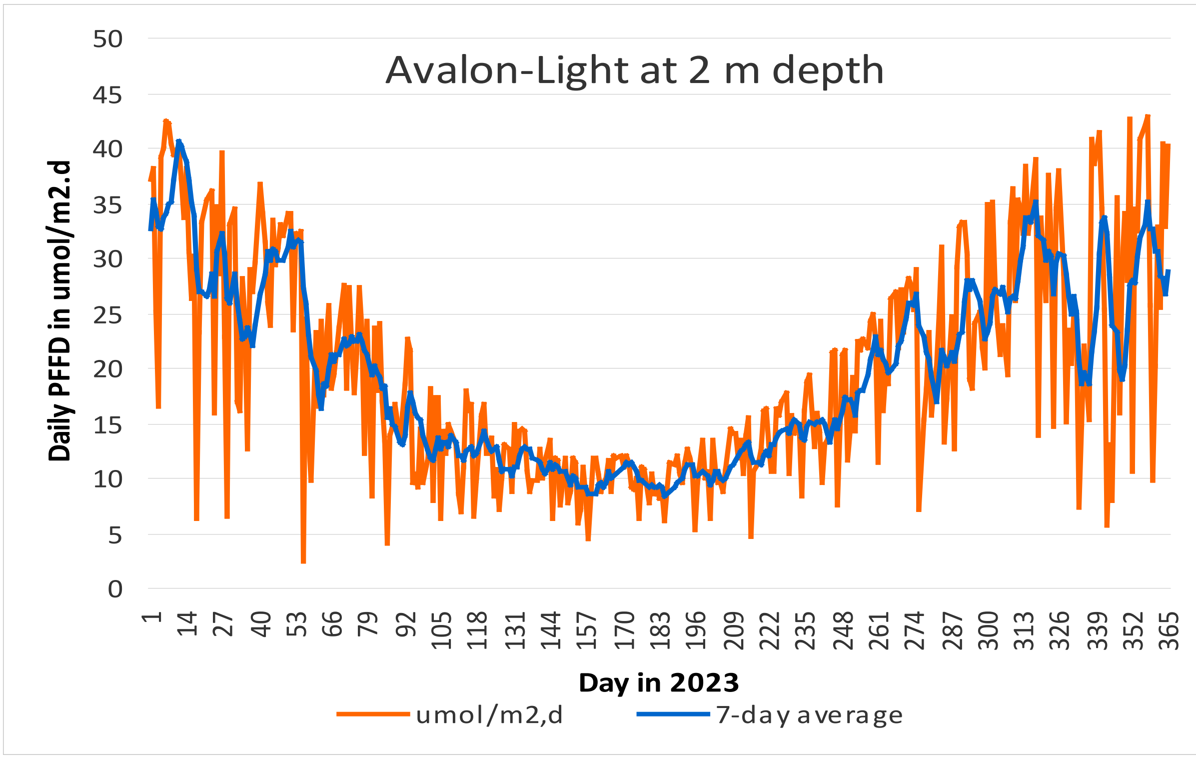


Figure 9-1. PAR at 2 m Depth at Avalon.

There is a regular seasonal variation in PPFD from a minimum of 5 µmole/m^2.d in winter to a maximum of 43 µmole/m^2.d in summer. There are large variations in the PPFD from day to day, particularly in summer. In November 2023, the 7-day average decreased from 35 µmole/m^2.d to 18 µmole/m^2.d over three weeks. Seagrass copes with this natural variation by adjusting the rate of photosynthesis to the light conditions.

There are two main methods for defining limits in the reduction of light due to increased turbidity during dredging. The method set out in the Victorian Dredging Guidelines (VIC EPA Publ 691, 2001) and adopted by the IAC is to require the light available to seagrass to be at least 20 % of incident light (in the Ramsar Area to the north-east of the project area) and 10 % of incident light (in the rest of Corio Bay). The available light is calculated from the predicted turbidity or suspended solids in the water column over a nominated period (typically 14 days or 30 days).

The second method is to define a minimum PPFD, for example at least 3 µmole/m^2.d in any 14-day period (WAMSI Dredging Science Node, 2017). Alternatively, if a reduction in PPFD is specified as a decrease below the natural level (e.g., not more than 5 µmole/m^2.d reduction in 14-days), then this method is equivalent to the Victorian approach but using different units.

Theoretically, it may be possible to develop a model for seagrass development on a day by day or even hour by hour basis. This would be feasible if light was the only or the dominant factor responsible for growth of seagrass. There are, however, other processes that counterbalance the increase in turbidity caused by dredging. Dredging releases nitrogen from the pore water, which encourages seagrass growth in a nitrogen-limited environment such as Corio Bay. Other plants, including algae that settle over the seagrass and epiphytes that grow on the leaves, appear to be more sensitive to the reduction in light than seagrass, allowing seagrass to grow at a faster rate with slightly higher turbidity. This increased growth of seagrass and reduction in drifting algae was observed in the 14-month dredging program in 1997 in Corio Bay (MSE, 2006). The reduction in algae cover over the short 8 week dredging period is not expected to have lasting impacts on food availability or other marine biota and recovery to normal is quick.

The extra sediment may reduce grazing of seagrass. Weather and other natural processes are variable and alter light, nutrient levels, turbulence and sedimentation. Due to this complexity of factors, a workable model to predict the biomass of seagrass in short-term dredging events has not yet been developed. Chartrand et al. 2016 highlight the complexities of seagrass responses and emphasise that seagrass responses are difficult to predict, even in laboratory tests, as:

"seagrasses can tolerate periods of time below their minimum light requirement without long-term impacts; and a range of other environmental parameters including water temperature and sediment chemistry can further influence in situ light requirements. The plant response to fluctuating light begins with explicit gene regulation driving changes in photosystems and pigment composition before growth rates and eventual plant morphology or meadow scale reductions become apparent".

"While laboratory experiments have helped to resolve the fundamental timeline of many of these responses, the actual timeline of in situ seagrass growth dynamics is likely to be quite different due to additional extrinsic factors that cannot easily be replicated in laboratory or mesocosm trials such as nutrient availability, water temperature, hydrodynamics, epiphyte loads, water column oxygen fluxes and sediment chemistry".

9.4.2 Methodology

The assessment of the potential impacts on seagrass beds from the proposed dredging at Refinery Pier involved:

- Defining the daily global solar radiation in Corio Bay and convert it to photosynthetic active radiation (PAR) and photosynthetic photon flux density (PPFD in µmol/m2.d)
- Summarising the results of the refined sediment transport model predictions of suspended solids concentration in terms of reduced light intensity;
- Converting the suspended solids predictions to changes in available light for seagrass;
- Using the mapped extent of intertidal and subtidal seagrass to calculate the frequency and duration of events with less than 10 % and 20 % surface irradiance within the Ramsar site and at other seagrass sites in north Corio Bay to assess the potential impacts;
- Considering the implications of other light thresholds and other factors on seagrass health;
- Comparing the predicted impacts of the proposed dredging program with actual impacts observed in previous (larger) dredging programs in Corio Bay.

9.4.3 Results of the Sediment Modelling

Figure 9-2 shows the predicted increase in median suspended solids (SS) concentration in the surface layer (zero to 2 m depth) above background due to dredging over 8 weeks from the refined regional model. Figure 9-3 shows the predicted increase in median suspended solids (SS) concentration at the seabed.

Figure 9-2. Predicted SS Concentration at the Surface (Above Background)

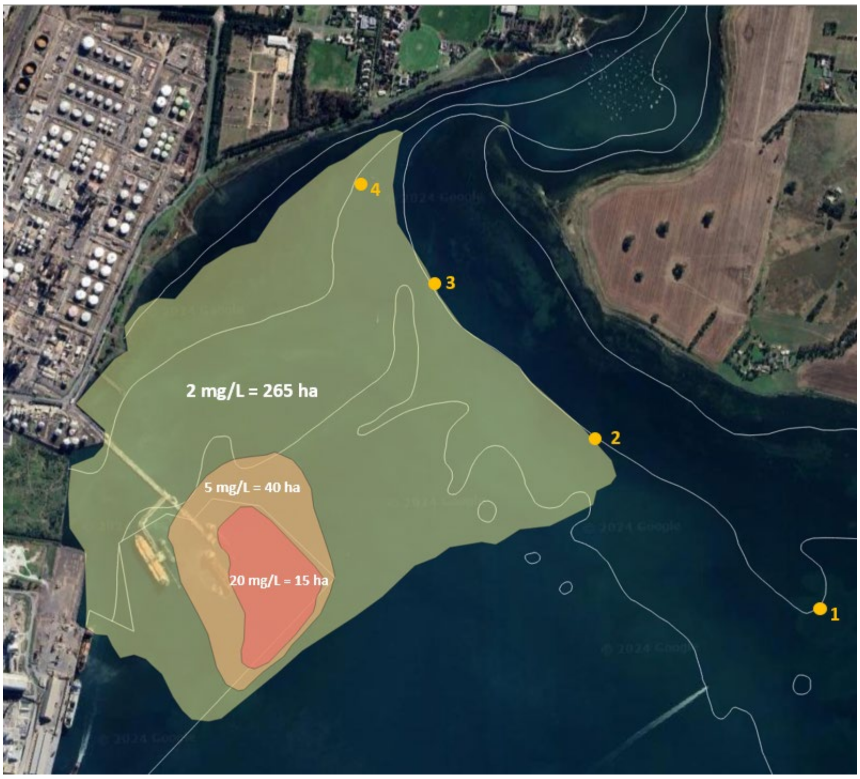


Figure 9-3. Predicted SS Concentration at the Seabed (Above Background)

At the surface there is a small patch (around 5 ha) adjacent to the dredge where SS would be 5 mg/L above ambient and a large patch (200 ha) where SS would be 2 mg/L above ambient. At the seabed the 5 mg/L SS covers a seabed area of 40 ha, predominantly in the port zone and offshore from the seagrass meadows, and the 2 mg/L SS covers a seabed area of 265 ha.

Figure 9-4 shows the predicted 3 mg/L, 4 mg/L and 5 mg/L increases in average SS concentrations in the water column above the seagrass during the dredging period. The zones of different seagrass species and the boundary of the Ramsar Site are also shown. It can be seen that elevated average SS levels do not extend to the Ramsar Site. An area of only 2 ha of seagrass is within the 3 mg/L contour.

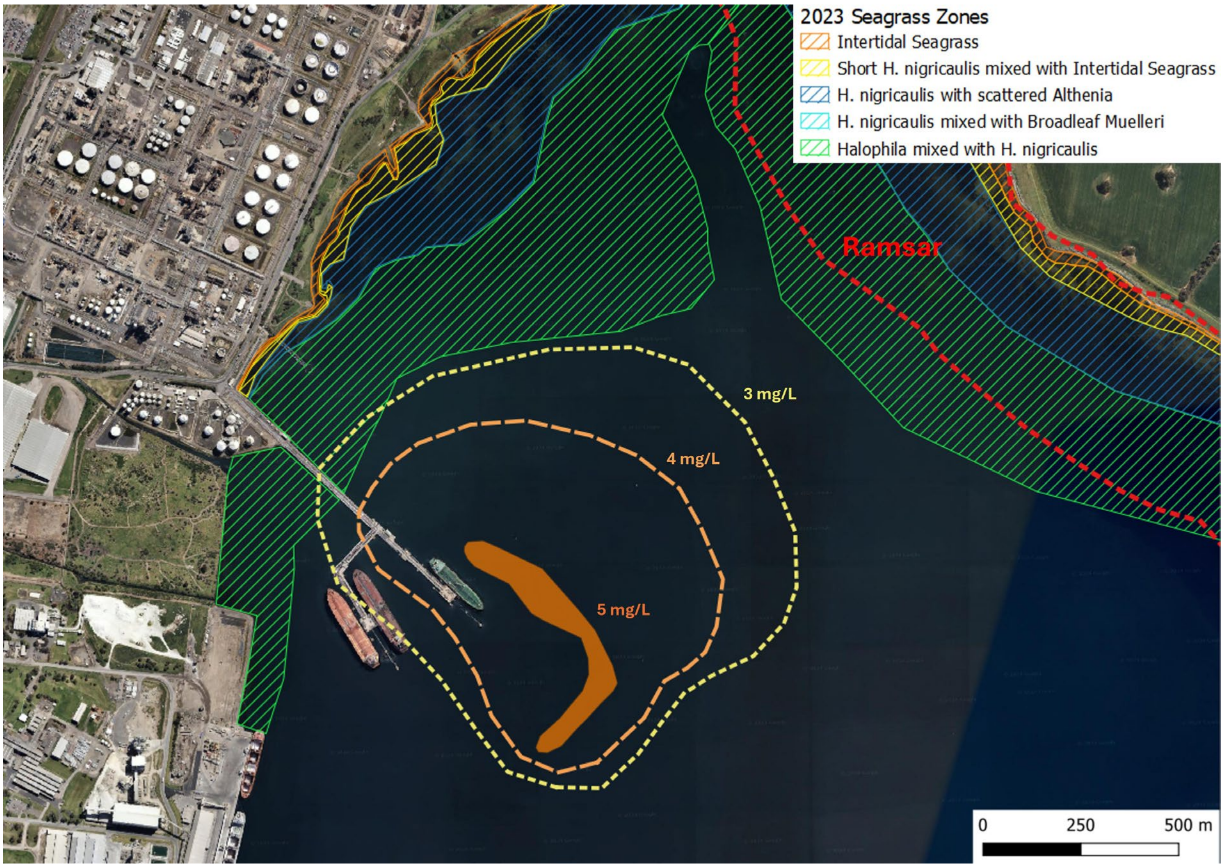


Figure 9-4. Contours of Average SS Concentration

McMahon et al (WAMSI Dredging Science Node, 2017) and Chartrand et al. 2012 suggest an appropriate time scale for monitoring and detecting impacts on seagrass is 2 weeks. Therefore, 14-day average suspended solids concentrations, including background, have been extracted for the four nominated sites and are listed in Table 9-1.

Table 9-1. Summary of 14-Day Average SS Concentrations (mg/L)

SS	Background	Week 1-2	Week 3-4	Week 5-6	Week 7-8	Peak
Site 1	1.8	3.6	3.2	2.8	2.9	3.6
Site 2	1.8	4.8	4.4	3.8	3.7	4.8
Site 3	1.8	5.9	4.9	4.1	4.3	5.9
Site 4	1.8	6.7	5.2	4.2	4.0	6.7

Site 3, which is in the Ramsar site has a highest 14-day average SS concentration of 5.9 mg/L including background.

Site 4, which is outside the Ramsar site has a highest 14-day average SS concentration of 6.7 mg/L, including background.

For comparison, Table 9-2 lists the 14-day average SS concentrations, including background, using the Lawson & Treloar (L&T) verification model parameters. The L&T average values are similar, but about 15 % lower than the refined regional hydrodynamic model predictions.

Table 9-2. Summary of 14-Day Average L&T SS Concentrations (mg/L)

SS	Background	Week 1-2	Week 3-4	Week 5-6	Week 7-8
Site 1	1.8	3.5	3.6	3.3	3.5
Site 2	1.8	4.5	4.5	4.1	4.2
Site 3	1.8	5.0	4.9	4.4	4.7
Site 4	1.8	5.5	4.9	4.5	4.5

9.4.3.1 Converting Suspended Solids to Light Level

The predicted suspended solids levels are converted to a reduction in light using the equations listed in Appendix 5 of the Victorian Dredging Guidelines (EPA, 2001). The equations were developed based on experiments in Corio Bay involving Corio Bay sediments. The sequence involves (1) converting SS to turbidity as NTU; (2) converting turbidity to a light extinction coefficient K_d and (3) calculating available light at the depth that seagrass is growing.

Background levels of turbidity in northern Corio Bay are available from several sources. The Victorian Dredging Guidelines quotes values of:

- 0.3 median NTU (Longmore 1990 to 1996 data);
- 0.3 NTU average (Black et al, 1994); and
- 0.35 NTU (VCA, 1997).

Lawson & Treloar made extensive measurements before and after the Channel Improvement Program and derived background turbidity values of:

- 0.4 to 0.5 NTU (Provis, 2009).

The EPA monitors turbidity in central Corio Bay and the data for 1998 to 2023 show a range of 0.4 to 2.0 NTU with a median of 0.9 NTU.

The relationship between suspended solids (SS) and turbidity (NTU) in the Victorian Dredging Guidelines (VGG) is:

$$SS = 1.2 \times NTU$$

A relationship between suspended solids (SS) and turbidity (NTU) can also be developed from the EPA Monitoring data from Corio Bay:

$$SS = 2 \times NTU + 1.8$$

The data leading to this equation is shown in Figure 9-5. The EPA turbidity values range from 0.1 to 2.2 NTU.

Both equations were used, and the results are presented below.

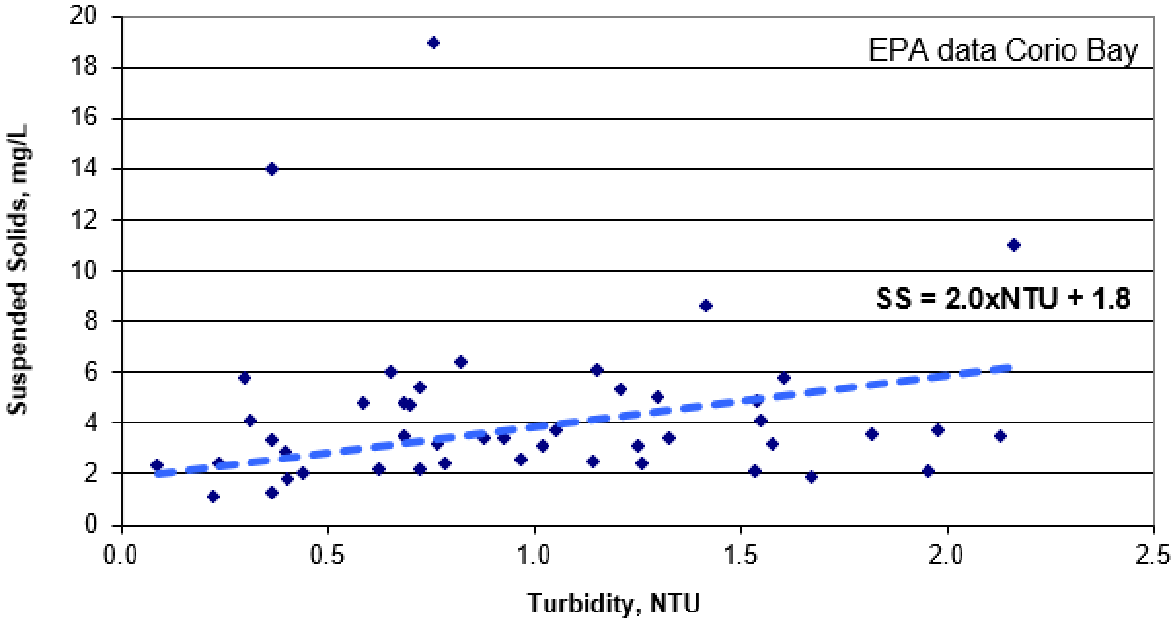


Figure 9-5. Summary of EPA TSS and Turbidity Data in Corio Bay

There are two relationships listed in the Victorian Dredging Guidelines between light attenuation coefficient (k) and turbidity (NTU):

k = 0.276 + 0.028 x NTU and

k = 0.263 + 0.055 x NTU.

Both relationships were derived from data collected in Corio Bay using Corio Bay sediments. The two equations give very similar k values for the range of turbidity values considered in this report. The second equation is adopted for this light analysis.

The relationship between surface light (Io) and light (Id) at depth d is:

$I_d = I_o \times \exp^{(-k\ d)}$

As the edge of the Ramsar Site is at 2 m depth, then d = 2 and the equation becomes:

$I_d = I_o \times \exp^{(-2\ k)}$

As shown in Table 9-1, the peak 14-day average SS including background is 5.9 mg/L.

- Using the first VGG equation, this corresponds to 22 % available light for seagrass growing in the Ramsar site.
- Using the second VGG equation, this corresponds to 26 % available light for seagrass growing in the Ramsar site.

This meets the IAC threshold of 20 % available light.

For Site 4 and seagrass at 3 m depth, the peak 14-day average SS is 6.7 mg/L.

- Using the first VGG equation, this corresponds to 14 % available light for seagrass growing in the Ramsar site.
- Using the second VGG equation, this corresponds to 18 % available light for seagrass growing in the Ramsar site.

This meets the IAC threshold of 10 % available light.

The 12-month baseline monitoring program will include 12 months of turbidity and light recording. The collected data can be used to refine turbidity trigger values which can be used during the dredging program to assist in the prevention of impact to seagrass.

9.4.3.2 Summary of Results for Available Light

In summary, the calculations of available light for seagrass are:

- The 20 % available light threshold for the Ramsar Site is met (either 22 % or 26 % available light);
- The 10 % available light threshold for the rest of Corio Bay is met (either 14 % or 18 % available light).

Sites 1 to 3 are on the edge of the Ramsar site at a depth of 2 m (Chart datum). The assessment of light levels has shown that the highest 14-day average SS level at the sites, and at shallower sites within the Ramsar site, there will be more than 20 % available light.

Seagrass at Site 4, which is outside the Ramsar site will receive more than 10 % available light.

9.4.3.3 Deeper Seagrass

Figure 9-6 shows the depth range of dense, medium and sparse patches of *H nigricaulis* in Corio Bay based on surveys in 2021-2023. Dense patches grow to 4 m depth (below MSL) while sparse patches were observed to 4.4 m depth and occasional sparse patches to about 5.1 m depth.

During dredging, the light at 4 m to 5 m depth should be higher than 10 % surface irradiance. However there are sparse plants near 5 m depth that are close to the threshold of light required for growth. There might be some reduction in growth rate for these plants during the 8 week dredging program. However, the duration of reduced light is too short to cause a major setback.

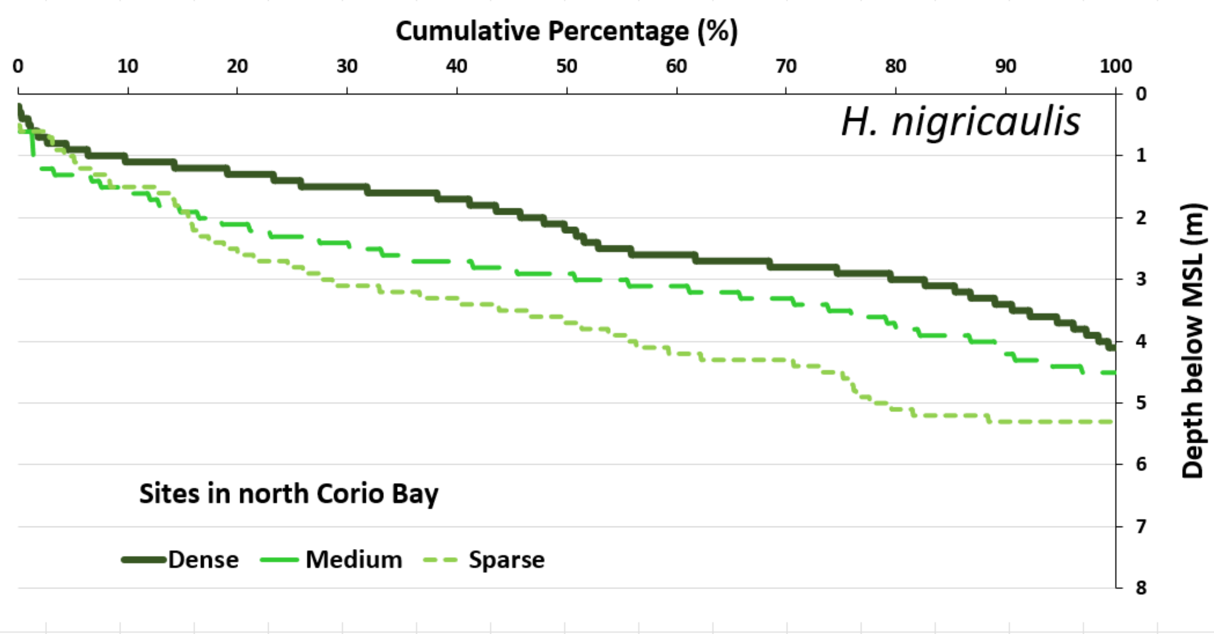


Figure 9-6. Depth Range of *H. nigricaulis* in Corio Bay

9.4.3.4 Further Assessment of Peaks in Suspended Solids

Examination of the time series plots in Figure 8-8 shows a series of elevated peaks in SS, lasting for 4 to 20 hours, during the 8-week dredging period with low SS in the intervening periods. Since half the peak SS events occur at night, the significant reduction in light occurs less than 15 % of the time, or the equivalent of one day a week.

Experiments on seagrass in Gladstone Harbour showed that seagrass decline occurred 4 to 8 weeks after <u>continuous</u> shading during the growing season with light maintained in the range of only 4–5 μmol photons/m^2.d· Seagrass was less sensitive to shading and managed for longer periods when shading was applied in alternate 2-week intervals (fortnightly) rather than continuously (Chartrand et al, 2016). Experiments on seagrass in Moreton Bay showed that the seagrass *Zostera capricorni* survived for several months under 5 % light (Ebal et al, 1996).

Observations of the lower limits of vertical distribution *H. tasmanica* in Western Port and Port Phillip Bay, Victoria together with the experimental irradiance reduction data, suggest that *H. tasmanica* requires a minimum of 5 % of surface irradiance for survival (Bulthuis, 1983).

Figure 9-7 shows the depth range of dense, medium and sparse patches of *Halophila* in Corio Bay based on surveys in 2021-2023. Dense patches grow to 4.7 m depth (below MSL) while medium patches were observed to 5.3 m depth and occasional sparse patches to about 6 m depth. Using 4 mg/L SS as a typical level of SS during the dredging period, the light at 5 m depth is 14 % of surface irradiance while the light at 6 m depth is 9 % of surface irradiance. Only sparse *Halophila* grows where light intensity is less than 10 % surface irradiance and some setback in growth rates might be expected for this deeper seagrass during the dredging period.

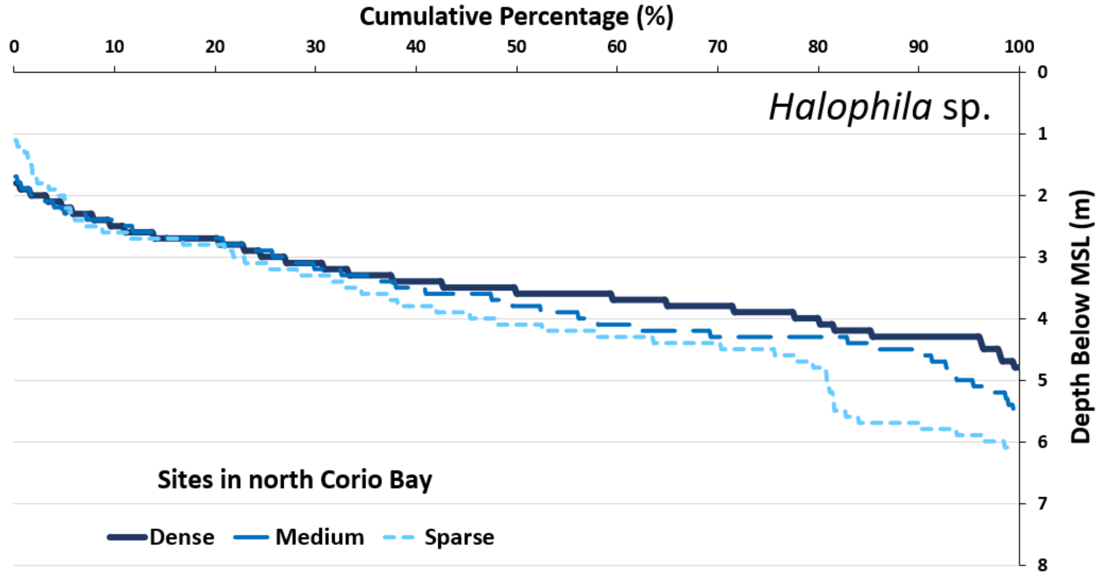


Figure 9-7. Depth Range of *Halophila* in Corio Bay

However, experiments at WAMSI on *Halophila ovalis* led to recommended light thresholds of 2.3 μmol/m^{2}d over 9 weeks and only 0.9 μmol/m^{2}d over 3 weeks. These thresholds suggest no effect of *Halophila* in an 8-week dredging program with intermittent turbidity peaks (Statton et al, 2017).

Measurable loss in seagrass was identified 4 and 8 weeks after shading in the growing season in Gladstone (Chartrand et al, 2016). Studies in coastal NSW established that for *Z. muelleri*, 6 to 35 weeks of daily light data was required to best correlate light and seagrass biomass. The authors conclude that these time periods provide an upper limit on the time that this species should be subjected to light deprivation (Adams et al. 2015).

Recovery of seagrass is well established. Where the rhizomes are not damaged, recovery occurs rapidly – in less than 2 months (Vanderklift, 2017).

In summary, this assessment of light levels for seagrass shows that:

- All seagrass in the Ramsar site will receive more than 20 % of available light during the dredging program.
- Almost all seagrass in Corio Bay will receive more than 10 % of available light during the dredging program.
- Deep sparse seagrass near the dredging site may experience a setback in growth rates during the dredging period.

- All seagrass will recover within 2 months to normal growth after completion of the 8-week dredging program as rhizomes will not be damaged.

9.4.3.5 Potential Impacts on Intertidal Seagrass

The dredging is not expected to have any impact on intertidal seagrass, as that seagrass is exposed to high light intensity every low tide (during daylight hours) regardless of sedimentation as it is regularly exposed to the air.

9.4.3.6 Sedimentation and Seagrass

The suspended solids resulting from the proposed dredging would settle and accrete on the seabed. Settling of sediments is simulated by the regional hydrodynamic model using inert particles with a defined size range, density and settling velocity.

Resuspension of settled particles is calculated from bottom shear stress (above a critical shear stress) and the particle density. Once the critical shear stress for resuspension has been reached and the material lifts from the bed, the erosion rate is calculated using the Bengtsson et al. (1990) erosion equation in g m^{-2} day^{-1}. Because of the weak currents in Corio Bay, and the cohesion and flocculation of the predominant clay material, it was found that the rate of resuspension in Corio Bay was very small as shown in Figure 9-8 and explained below.

Figure 9-8 shows the increment in seabed elevation due to sedimentation in the August – September period. Highest accretion (of 20 mm in 8 weeks) occurs on the seabed in the area dredged but this is of no significance, as the bed would be dredged down to the defined depth.

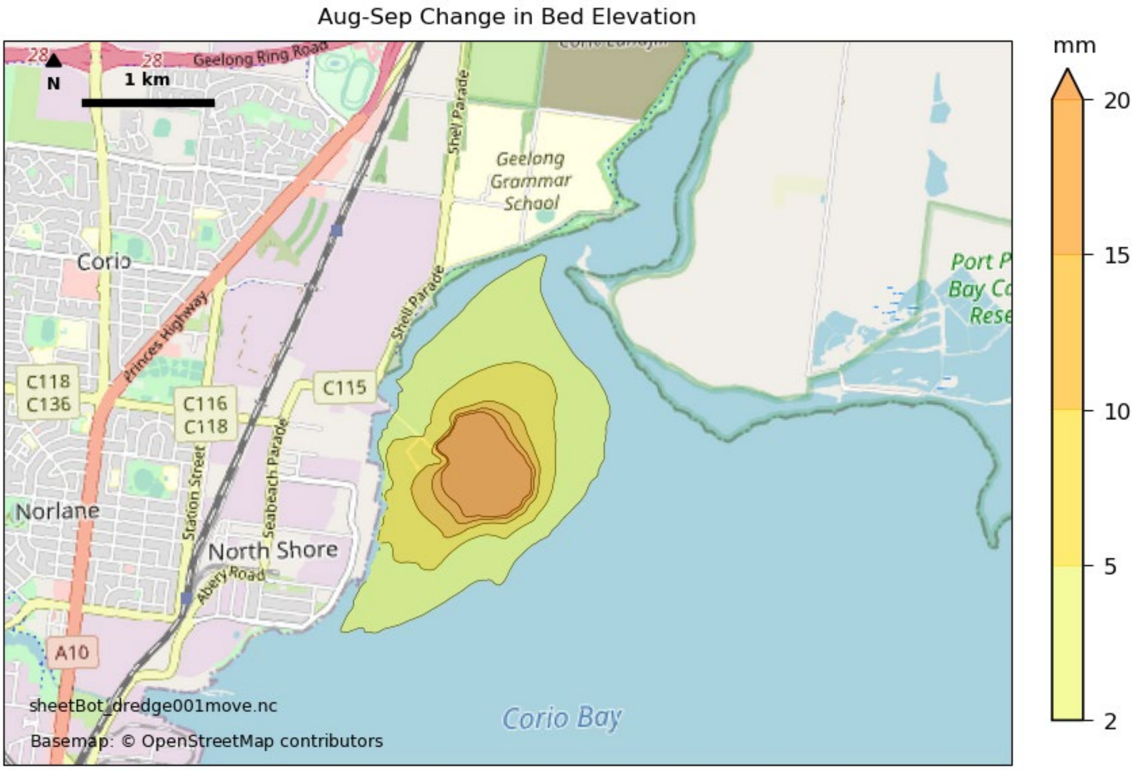


Figure 9-8. Increment in Seabed Elevation in 8 Weeks of Dredging in Aug-Sep

Lower accretion rates of 2 to 10 mm in 8 weeks would occur in north Corio Bay over a large area surrounding the dredging zone. This rate of accretion (0.04 mm/day to 0.2 mm/day) would have negligible impact on the muddy seabed and the infauna or mobile marine communities that inhabit muddy seabed. This seabed is generally bare of surface-dwelling biota except for microscopic algae (microphytobenthos or 'MPB'), patches of ephemeral unattached filamentous macroalgae and sparsely distributed fan worms *Sabella Spallanzani* (an introduced species).

Infauna monitoring conducted as part of the EES for the project demonstrated that the sediments of Corio Bay contain large numbers of bioturbating polychaetes, crustaceans, echinoderms and bivalves. Approximately 90 % of the infauna in samples from the dredging area are deposit feeders, that sift through the surface layer of sediment to find organic materials that suits their tastes. Deposit feeding infauna are capable of burrowing through 0.1 to 10 cm^3 of sediment per hour (Gingras et al,) to a depth of 10 to 50 mm per day.

The additional deposition of suspended material from dredging (0.04 mm/day to 0.2 mm/day) represents a very small proportion of the daily volume of sediments disturbed (bioturbed) by the deposit feeders through the sediments over a day.

Surveys by MSE found that recolonisation by infauna at spoil ground in Corio Bay was rapid, taking approximately 6 months for populations at each spoil ground to reach pre disposal levels of abundance and diversity. The same recolonisation is expected at dredged sites (MSE, 2003).

Figure 8-12 shows the increment in seabed elevation due to sedimentation in the November-December modelled simulation period. The rate and extent of accretion is similar to that in the August-September simulation. Highest accretion (of 10 to 20 mm in 8 weeks) occurs in the area dredged. Lower accretion rates of 0.04 mm/day to 0.2 mm/day would occur in north Corio Bay over a large area surrounding the dredging zone. This rate of accretion would have negligible impact on the muddy seabed and the infauna or mobile marine communities that inhabit muddy seabed, as outlined above as well as negligible impacts on other marine biota.

The accretion on seagrass beds is from zero to 3 mm, which is expected to have negligible to very minor impact as seagrass naturally traps and accumulates sediment with sedimentation rates up to 20 mm/yr (Cabaco et al., 2008) and 31 mm/yr (Potouroglou et al., 2017). With the low range of sedimentation expected from the proposed dredging (generally under 10 mm/yr outside the dredging activity zone), the accumulation of sediment containing nitrogen and accompanied by dissolved oxygen, is positive for the growth of seagrass (NIWA, 2004). Thus, the sedimentation rates shown in Figure 8-12 are expected to have negligible impact on seagrass beds as they are located beyond the 5 mm accretion zone.

McMahon et al (WAMSI Final Report, 2017) indicates tolerable sedimentation is 2 cm for *Halophila* and 4 cm for *H. nigricaulis.* As the maximum sedimentation in seagrass zones in north Corio Bay is predicted to be less than 0.5 cm, there is a significant margin of safety below these thresholds and sedimentation is not considered to be a significant potential impact.

9.4.3.7 Comparison with Previous Dredging Projects

As a check on the predictions made in this supplementary assessment of the predicted effects on seagrass of the proposed dredging of 490,000 m^3 of sediment in Corio Bay, the measured effects on water quality and seagrass of the previous dredging in Corio Bay in the 1996-1997 Channel Improvement Program provide context.

There was extensive water quality monitoring conducted before (November 1995 to January 1997), during (January 1997 to February 1998) and after (February 1998 to October 1998) for the Channel Improvement Program dredging (Lawson and Treloar, 1998). The program included:

- Turbidity measurements each month at 33 stations;
- Continuous turbidity monitoring at six sites (including Avalon);
- PAR readings and light attenuation values calculated at 21 sites;
- Secchi disc readings and suspended solids analyses at 21 sites.

The results of the turbidity measurements are summarised in Table 9-3 (from Provis, 2009). It is noted that the original publication provides averages, but not standard errors. Turbidity readings increased during windy periods and were also elevated around the piers due to ship and tug movements. The average turbidity values are the best indication of trends. As shown in Table 9-3, turbidity increased during the 14-month dredging program but quickly returned to pre-dredging levels after dredging ceased.

Table 9-3. Corio Bay Average Turbidity and Light Attenuation Measurements

Location	Turbidity, NTU			PAR Attenuation, m^{-1}		
	Before	During	After	Before	During	After
Inner Harbour	0.8	2.8	0.8	0.34	0.42	0.33
North Shore	0.4	0.7	0.5	0.35	0.34	0.30
Outer Harbour	0.7	1.3	0.6	0.33	0.30	0.27
Stingaree Bay	0.4	1.0	0.5	0.37	0.38	0.43

Source: Provis, 2009

(Averages from original publication)

Light attenuation coefficients were calculated for each of the 21 stations where PAR was measured. The light attenuation increased in north Corio Bay but remained much the same at the other three monitoring sites. After dredging, the attenuation coefficient in Corio Bay returned quickly to the same rate as before dredging. The results of previous monitoring during dredging indicate that the predictions of SS increments in the EES and supplementary studies are conservative.

9.4.3.8 Seagrass Monitoring

There was extensive seagrass monitoring of the dredging program conducted before (January 1996 to January 1997), during (March 1997 to February 1998) and after (February 1998 to July 1998) for the Channel Improvement Program conducted by Marine Science and Ecology (MSE, 1998).

The program included 31 surveys involving:

- Quantitative photographic and video monitoring supported by qualitative insitu analysis;
- Estimation of biomass by harvesting seagrass and algae.

The MSE analysis of measurements noted large background variations in both cover and biomass of seagrasses during the monitoring period, masking any seasonal trends. The two sites close to dredging operations at Moolap and Pt Henry were subject to moderate turbidity and some sedimentation. No effects other than minor leaf necrosis, seen towards the end of the 14-month dredging program, could be attributed to sediment deposition.

There was an increase in seagrass cover or biomass at the other five sites which coincided with a marked reduction in algal epiphytes. *"In summary, the intensive biological monitoring program demonstrated that both ground cover and biomass (standing crop) of Heterozostera nigricaulis was virtually unaffected by turbidity generated during the CIP dredging program"* (MSE, 2006). A similar outcome is expected for future dredging.

9.4.3.9 Channel Deepening Program

The Channel Deepening Program involved dredging 5.4 million m^3 of clay and silt from Hobsons Bay and the Yarra River, 2.4 million m^3 of clay and silt from the shipping channels in the north of Port Phillip Bay, 14.6 million m^3 of mainly sand from shipping channels in the south of the Bay and 0.55 million m^3 of sandstone and limestone from the entrance at Port Phillip Heads. Dredging continued for 20 months between Feb 2008 and Nov 2009. The dredged material was taken to various disposal sites in Port Phillip Bay.

The turbidity limit established was 15 NTU over a 14-day averaging period. There was a very extensive environmental monitoring program with 82 reports on turbidity measurements, 7 reports on plume intensity and extent, 55 water quality monitoring reports, 18 seagrass monitoring reports, 45 penguin monitoring reports, 29 fish monitoring reports, and 29 recreational fishing surveys.

The Office of the Environmental Monitor (OEM) was established to provide an independent and transparent audit and review of the outcomes of the environmental monitoring program for the Channel Deepening Program.

The only observed effect from the project on water quality was the presence of a turbidity plume as a result of dredging during the construction stage. Environmental monitoring data showed that turbidity levels rose rapidly with the start of dredging in 2008 and returned to background when dredging ceased in November 2009. Water quality parameters were within expected levels during the reporting period, with minor exceptions.

Seagrass monitoring found that changes to seagrass were within the normal variability. As expected, measures of seagrass health were variable from site to site and through time. Seagrass cover increased at some sites and remained the same or decreased at other sites. Light levels monitored during the construction stage remained above the threshold for survival of seagrass.

During the dredging and the two years after its completion, some water quality and fish population indicators were outside the expected ranges. OEM's assessment, using an accepted decision-making framework, determined these results were not caused by the dredging program.

The auditor general review of the OEM work concluded that: *"environmental impacts of the project were well within the acceptable ranges which were set at project approval. The environment of Port Phillip Bay has not been adversely affected by the project. The bay remains in good health"* (Victoria Auditor General, 2012). A similar outcome is expected for future dredging.

9.5 Conclusions

Recommendation 7 of the Minister's Directions required further assessment of dredging impacts on seagrass using the refined regional hydrodynamic model and light thresholds of 20 per cent surface irradiance for the Ramsar Site and 10 per cent surface irradiance for the rest of Corio Bay. The sediment transport modelling has been completed as per Recommendation 2 of the Minister's Directions.

The results of the updated modelling are much the same as the previous dredge spill predictions presented in the EES, even though there are higher wind speeds in the Calmet wind file that was selected as part of Task 2a (see Section 4.5) and slightly different spill rates and settling velocities have been used based on the extra borehole data and an 8-week dredging period.

The predicted SS results from the refined model correspond to the turbidity measurements in a previous dredging program in Corio Bay and also match the results obtained using the optimized L&T sediment parameters.

The three sites on the boundary of the Ramsar sites show incremental SS concentrations of 1.3 to 3.0 mg/L, which are low. These correspond to small turbidity.

The maximum sedimentation in seagrass zones in north Corio Bay is predicted to be less than 0.5 cm, which is well below established thresholds and sedimentation is not considered to be a significant potential impact.

For the highest 14-day SS level, seagrass in the Ramsar site would receive more than 20 % of available light during the dredging program, which meets the threshold suggested by the IAC.

Seagrass at Site 4 which is outside the Ramsar site will receive at least more than 10 % of available light during dredging which meets the threshold suggested by the IAC.

10. Recommendation 8 – Confirm EES Conclusions for Impacts of Dredging on the Ramsar site

10.1 Summary of Original EES Findings

EES Technical Report A: *Marine ecology and water quality impact assessment* (CEE 2022) concluded that, given no seagrass would be removed as a result of the proposed dredging, the pathway for an impact of dredging on the Ramsar site is an increase in turbidity and light attenuation over the seagrass beds within the Ramsar site boundary. The assessment of impacts on the Ramsar site is presented in Section 12.9 of EES Technical report A: *Marine ecology and water quality impact assessment* (CEE 2022).

The EES demonstrated that during dredging, the median 5 mg/L suspended solids contour would not extend into the Ramsar site.

Increased turbidity and reduced light transmission would occur in the area close to the dredging over the 8-week period and a temporary loss of productivity of seagrass is expected within an 80-hectare area. The increased turbidity may have a minor effect in slowing seagrass growth and productivity in deeper waters of Corio Bay for a day or two; however, the impact would be too small to measure and would not be of ecological consequence to seagrass beds or the Ramsar site.

Sediment accretion modelling (settling on the seabed) suggests the highest accretion of 20 millimetres (mm) in 8 weeks is confined to the area being dredged and is therefore of no significance to the Ramsar site.

The EES concluded that, although dredging could result in minor turbidity increases at the Ramsar site, the sediment plume is unlikely to significantly affect seagrass meadows or the abundance and diversity of seagrass or algae. As such, dredging is unlikely to impact species reliant on seagrass habitat or change the ecological character of the Ramsar site.

10.2 Overview

Recommendation 8 of the Minister's Directions states the following:

Confirm the EES conclusion that dredging will not impact the Ramsar site after considering:

a. *The revised marine modelling*

b. *The revised assessment of impacts on seagrass*

10.3 Summary of Tasks

<u>Task 8: Update or confirm EES conclusions to address Recommendation 8 and this involves:</u>

After considering potential direct and indirect impacts from dredging on the Ramsar site in light of the updated sediment transport modelling (Recommendation 6) and the assessment of the impacts of dredging on light availability for seagrass (Recommendation 7) either:

- update the conclusions reached in the EES if the findings of the modelling and further assessment show that potential impacts change; or
- confirm that there is no change to the EES conclusions (if appropriate).

10.4 Results of Supplementary Studies

The supplementary studies involved a refinement of the regional hydrodynamic model, new predictions of suspended sediment levels for an 8-week dredging program and an assessment of the changes in available light for seagrass in the Ramsar site.

Key refinements made in in the supplementary marine studies are:

- The regional hydrodynamic model has been improved by using a smaller grid (20 m by 20 m grid squares) and finer vertical scale (0.5 m layers to 4 m depth), together with a new Calmet wind file for Corio Bay, with further calibrations to show the model correctly reproduces tides and currents.
- The particle size distribution of sediment to be dredged, in terms of sediment composition and settling rates, has been refined taking into account data from extra boreholes completed since 2021.
- The suspended solids (SS) concentration has been predicted using the refined regional model for an 8-week dredging period at three points on the boundary of the Ramsar site;
- The 14-day average SS at monitoring points on the Ramsar site boundary averages 3 mg/L over 8-weeks with the highest 14-day average being 4.1 mg/L. There are short peaks in SS concentrations of up to 25 mg/L (over several hours), but these occur during storms and last for less than a day.
- Calculations of available light in the Ramsar site show that, for the highest 14-day suspended solids level, seagrass in the Ramsar site will receive more than 20% of the incident light during the dredging program. This meets the light threshold suggested by the IAC and indicates very low risk to seagrass growth.
- All seagrass in the Ramsar site (zero to 2 m depth) will always receive sufficient light for growth.
- The model predictions have been checked against measurements of turbidity and light attenuation in a previous dredging program in Corio Bay. The predictions match the previous measurements by Cardno.
- The maximum sedimentation in the Ramsar site is predicted to be less than 2 mm over the dredging period, so sedimentation in the Ramsar site is not considered to be a significant potential impact.
- Note that the Ramsar Site has proposed boundary changes described in Section 1.3.1. The changes do not impact the conclusions of the EES or Supplementary Statement.

10.4.1 Comparison with Results of Previous Dredging

There have been several previous dredging programs in Corio Bay including the Channel Improvement Program which involved dredging 4.5 million m^3 of sediment from Point Henry, Bulk Grain Pier, Lascelles Wharf and Refinery Pier in 1996-1997.

The average turbidity values are the best indication of trends, and as shown in Table 10-1, turbidity increased only a small amount during the 14-month dredging program and quickly returned to pre-dredging levels after dredging ceased. The predicted increase in turbidity for the proposed dredging program matches the measured increase in turbidity in the previous dredging program.

Table 10-1. Previous Corio Bay Average Turbidity and Light Attenuation

Location	Turbidity, NTU			PAR Attenuation, m^{-1}		
	Before	During	After	Before	During	After
Inner Harbour	0.8	2.8	0.8	0.34	0.42	0.33
North Shore	0.4	0.7	0.5	0.35	0.34	0.30
Outer Harbour	0.7	1.3	0.6	0.33	0.30	0.27
Stingaree Bay	0.4	1.0	0.5	0.37	0.38	0.43

Source: Provis, 2009

(Averages from original publication)

The previous monitoring found the light attenuation coefficient increased in the inner Harbour but remained much the same at the other three monitoring sites. After dredging was completed, the light attenuation coefficient in Corio Bay returned quickly to the same rate as before dredging.

The measured changes in turbidity and light attenuation during previous dredging programs are similar but slightly lower than the predicted changes in turbidity and light attenuation from the modelling in this assessment. This correlation provides a further line of evidence that there will be only small and temporary (8-week duration) effects on regional water quality during the proposed dredging program.

10.4.2 Seagrass Monitoring

There was extensive seagrass monitoring for the Channel Improvement Program with 31 surveys conducted over several years before, during and after dredging. The MSE analysis of measurements noted large variations in seagrass cover and biomass during the monitoring period, masking any seasonal trends. Two sites close to dredging operations at Moolap and Pt Henry were subject to moderate turbidity and some sedimentation. No effects other than minor leaf necrosis, seen towards the end of the 14-month dredging program, could be attributed to sediment deposition.

There was an increase in seagrass cover or biomass at the other five sites which coincided with a marked reduction in algal epiphytes. *"In summary, the intensive biological monitoring program demonstrated that both ground cover and biomass (standing crop) of Heterozostera nigricaulis was virtually unaffected by turbidity generated during the CIP dredging program*" (MSE, 2006). A similar outcome is expected for future dredging.

The monitoring showed that seagrass was not adversely affected by changes in turbidity and light attenuation during the previous dredging program. Based on consideration of sufficient available light to seagrass and low sedimentation, it is predicted that there will be minimal impacts on seagrass due to the proposed dredging program. This correlation between previous measurements of seagrass condition and the current prediction for the proposed program provides a further line of evidence that there will be minimal impacts on seagrass during the proposed dredging program.

10.4.3 Seagrass Beds

Figure 10-1 below shows the average suspended solids concentrations during the 8-week dredging period in relation to the extent of seagrass beds and the Ramsar site boundary. There are short-term peaks in suspended solid concentrations (see Figure 8-8) but the 14-day average concentrations are most relevant in predicting impacts on seagrass. Section 9.4.3.4 shows that an average SS level of 4 mg/L is the threshold for possible reduction in growth rate (corresponding to 10 % available light). The 4 mg/L contour is shown in Figure 10-1 as well as the 3 mg/L and 5 mg/L contours. The predicted impact of SS on seagrass is minimal in north Corio Bay and negligible in the Ramsar Site.

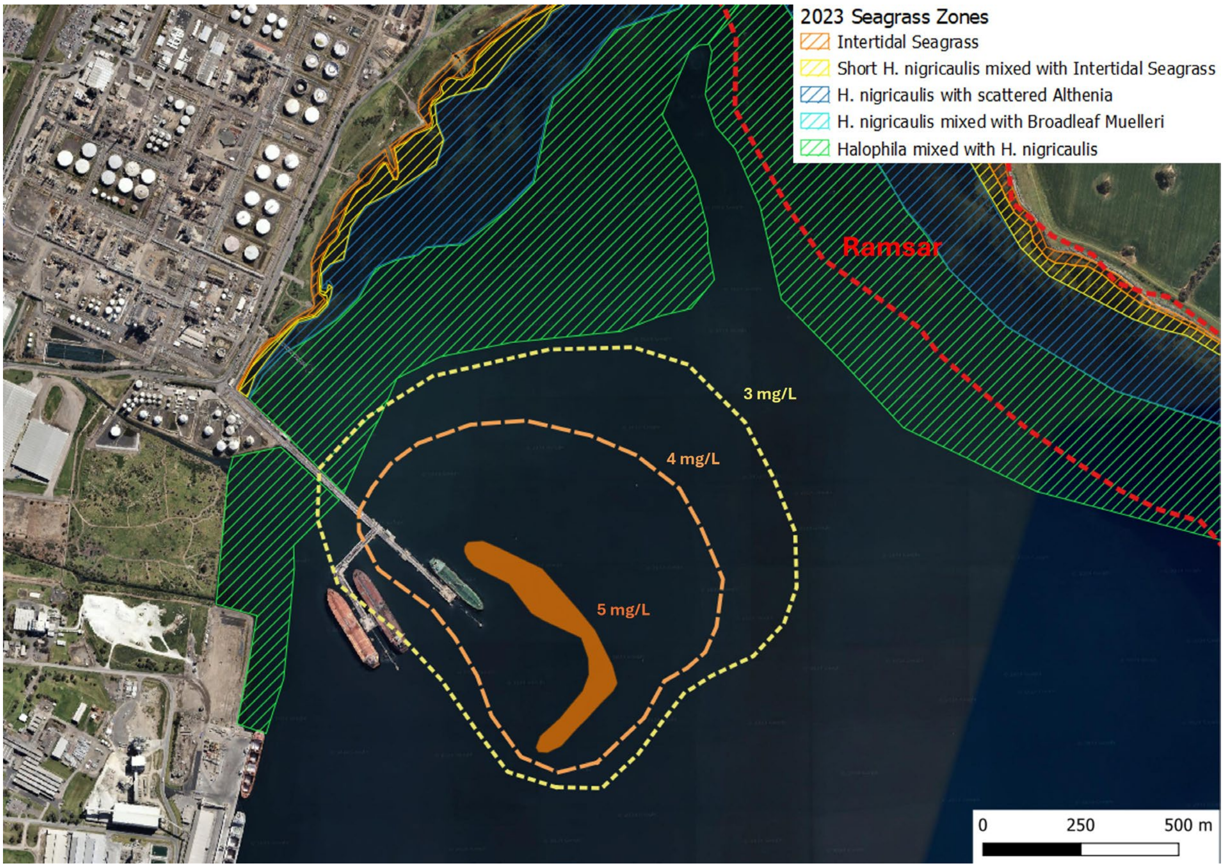


Figure 10-1 Suspended Solids Plume and Seagrass Beds

10.4.4 Indirect Impacts on Ramsar Site

A separate report (Technical Report B) addresses Recommendation 9 and assesses the impacts of the dredging program on migratory birds and bird energetics, drawing on the results of the predictions of the dredge plume modelling described in this report.

Microphytobenthos (MPB) are small algae that grow on the seabed and can grow at depths where there is only 4 per cent of surface light and are unlikely to be affected by the minor increase in turbidity in the Ramsar site. In any event, MPB recover quickly after storms and other events with elevated turbidity.

The surface layer of sediment in north Corio Bay is highly mobile and is regularly put into suspension by storms, strong currents, ship and tug movements and large-scale eddies caused by tidal water movement. The fraction of sediment that settles away from the dredging will be similar fine material, possibly with slightly higher nitrogen content. It will be rapidly assimilated in the natural bioturbation processes on the seabed without any measurable change in conditions.

There is a large flock of swans in Corio Bay that feed on seagrass. The swans are generally on the shallow waters of the north shore or in Limeburners Bay depending on the wind pattern. As no impacts are expected for seagrass in the shallow water used by the swans, no indirect impact on swans is expected.

The outcomes of the supplementary studies show no change to the EES conclusions and that dredging will not impact the Ramsar Site.

10.5 Conclusions

The additional assessments conducted for the supplementary marine studies confirm the conclusions in the EES with respect to the impact of dredging on the Ramsar site.

There would be only a minor increase in turbidity and the change is insufficient to cause any adverse impacts on seagrass in the Ramsar site or in central and south Corio Bay.

The 8-week average SS increment at the Ramsar site boundary is 3 mg/L. The Ramsar site along the north coast would have only a minor increase in turbidity and the change is insufficient to cause any adverse impacts on seagrass in the Ramsar site. No significant amount of suspended solids or turbidity will enter Limeburners Bay. Thus, dredging will not affect Critical Processes and Services of the Ramsar site.

Calculations of available light in the Ramsar site show that, for the highest 14-day suspended solids level, seagrass in the Ramsar site will receive more than 20% of the incident light during the dredging program. This meets the light threshold suggested by the IAC and indicates very low risk to seagrass growth.

Seagrass at a site outside the Ramsar site and closer to the dredging will receive at least 14 % of available light which is more light than the limit of 10% of surface irradiance suggested by the IAC.

The dredging is not expected to have any impact on intertidal seagrass, as that seagrass is exposed to high light intensity every low tide (during daylight hours).

The outcomes of the supplementary studies show no change to the EES conclusions and that dredging will not impact the Ramsar Site.

11. Seagrass Removal for Seawater Transfer Pipe

Extensive seagrass surveys were undertaken as part of this supplementary marine study. These seagrass surveys built upon surveys undertaken during the original EES. The seagrass surveys undertaken during the supplementary statement identified the potential for a small area of seagrass to be removed during installation of the seawater transfer pipe. The only area where seagrass would be removed for the project is the inshore section of the seawater transfer pipe alignment. The trench for the seawater transfer pipe would extend about 550 m from the proposed extension to Refinery Pier to the existing refinery seawater intake channel, as shown by a grey line in Figure 11-1 and Figure 11-2. The seabed along the alignment comprises silty mud and sand with no reef or other hard seabed. There is sparse to medium density seagrass on the shallower, inshore 230 m of the proposed alignment. The seagrass cover varies from site to site and from year to year, as documented in the EES and this supplementary study. The seagrass species present along the transfer pipe alignment are *Halophila and H. nigricaulis* as indicated by the green hatching in Figure 11-1 and Figure 11-2.

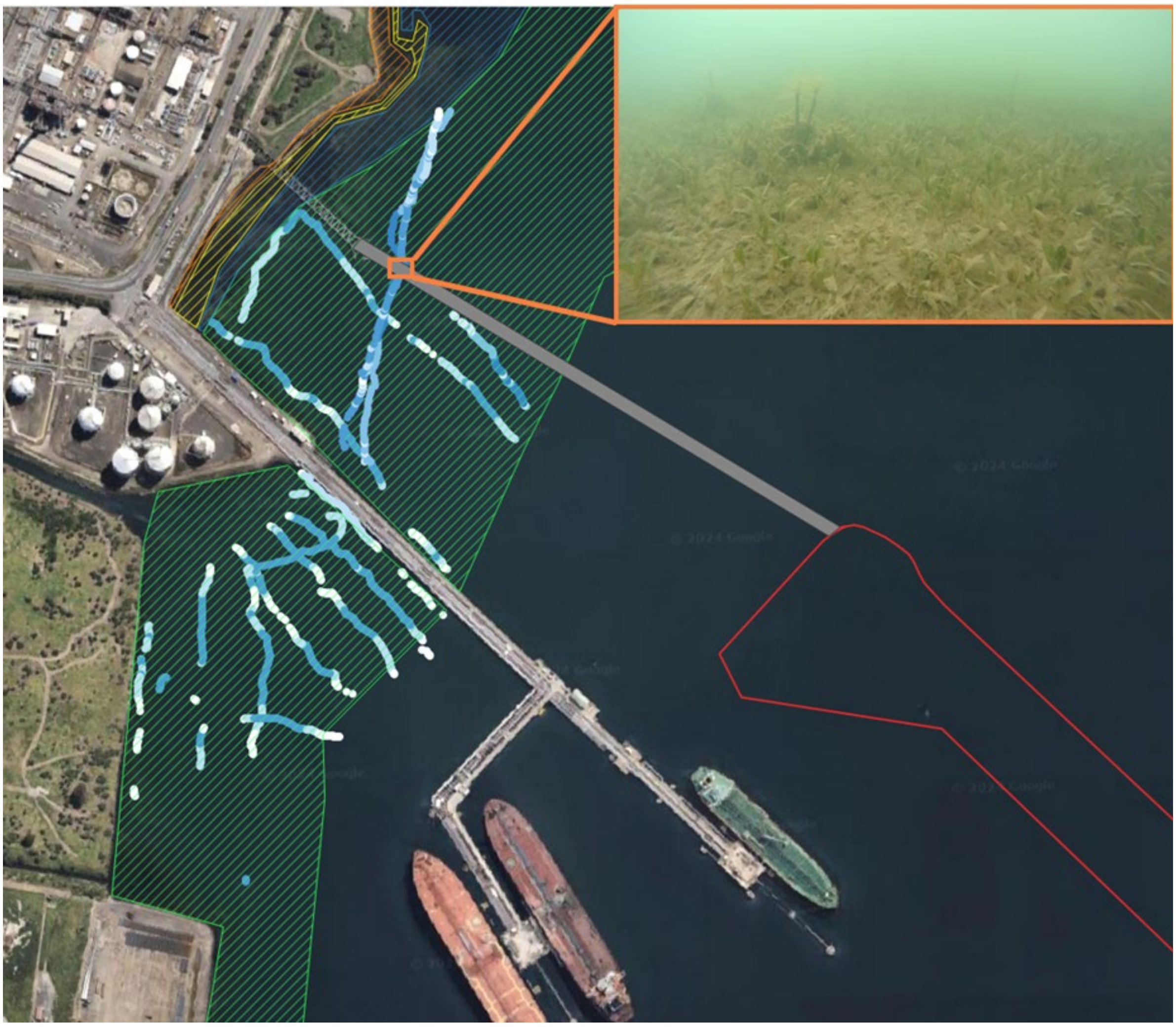
The 2023 survey transects in Figure 11-1 show very little *H. nigricaulis* around the mouth of the existing refinery seawater intake channel with a small area with moderate to dense cover of *H. nigricaulis* further offshore. *H. nigricaulis* is listed as endangered under the Flora and Fauna Guarantee Act 1988 (FFG Act).

The surveys conducted in 2023 showed moderate to dense cover of *Halophila* at the existing seawater intake and for 230 m offshore along the alignment of the seawater transfer pipe (refer to Figure 11-2). *Halophila* is not a listed species under the FFG Act.

Legend: Density of *H. nigricaulis:* light green = sparse; dark green = dense

- Intertidal *N. muelleri*
- Short *H. nigricaulis* mixed with *N. muelleri*
- *H. nigricaulis* with scattered *Althenia*
- *H. nigricaulis* mixed with *Broadleaf muelleri*
- *Halophila* mixed with *H. nigricaulis*

Figure 11-1. *H. nigricaulis* Surveyed at the Seawater Transfer Pipe



Legend: Density of *Halophila:* light blue = sparse; dark blue = dense

- Intertidal *N. muelleri*
- Short *H. nigricaulis* mixed with *N. muelleri*
- *H. nigricaulis* with scattered *Althenia*
- *H. nigricaulis* mixed with *Broadleaf muelleri*
- *Halophila* mixed with *H. nigricaulis*

Figure 11-2 *Halophila* Surveyed at the Seawater Transfer Pipe

11.1.1 Direct Impacts to Seagrass

Considering the results of the seagrass surveys and the extent of the proposed seawater transfer pipe, approximately 0.3 ha of seagrass would be removed during excavation of the pipe trench. A further 0.2 ha of seagrass would be smothered as the excavated sediment is temporarily placed on the seabed adjacent to the trench (prior to being replaced after the pipe is installed). Of the total potentially impacted area of seagrass only 10% is likely to be *H. nigricaulis* (i.e., an area of 0.05 ha) and 90% is likely to be Halophila (i.e., an area of 0.45 ha). Noting that the actual area of *H. nigricaulis* loss won't be known until detailed design and a pre-excavation seagrass survey have been completed.

Halophila is the most prevalent seagrass species along the transfer pipe alignment however surveys have shown that although this species is persistent the distribution and cover changes from year to year and a site can have dense cover one year and moderate (or sparse) cover the following year. There is no intertidal seagrass present along the seawater transfer pipe alignment.

Corio Bay has an estimated 1,050 ha of seagrass (excluding the seagrass in Outer Harbour, which is counted under Port Phillip Bay). The zone of temporary impact to seagrass from the seawater transfer pipe installation is expected to be 0.5 ha. The loss of seagrass would be temporary, and there would be no regional effect of removing 0.5 ha of seagrass on the ecological services or seagrass meadows in Corio Bay.

Seagrass would remain present on either side of the trench and rhizomes would be present in the excavated sediment. Seagrass would regrow from rhizomes near the surface and from plants adjacent to the cleared strip of seabed on the seawater transfer pipe alignment. Jenkins et al (2015) found that recovery to control levels of seagrass from high intensity disturbance took between 2 months at Altona and Blairgowrie and 13 months at Point Richards and Swan Bay South. On this basis, and considering the results of seagrass renovation projects in WA and SA, it is considered that three years after pipe installation, seagrass cover on the pipeline route would to be much the same as elsewhere in Corio Bay.

11.1.2 Approval Requirements

Secondary approval requirements for the removal of seagrass relate to Victoria's Native Vegetation Removal Regulations and protected flora controls under the FFG Act.

Seagrass is considered as native vegetation under the Victorian Native Vegetation Removal Regulations where local council areas extend over lakes, estuaries or the sea (DELWP 2018). The Greater Geelong Planning Scheme (GGPS) covers the area of the seawater transfer pipe therefore removal of seagrass in that area will be considered as a removal of a patch of native vegetation in accordance with the Guidelines for the removal, destruction or lopping of native vegetation (DELWP 2017) under Clause 52.17 of the planning scheme.

The area of seagrass to be removed is comprised of a mixture of species that includes Australian Grass-wrack *H. nigricaulis* which is listed as endangered under the FFG Act. As all land from the high tide line is public land, a protected flora permit will be required for *H. nigricaulis* under the FFG Act. This permit will be in addition to a threatened community permit to remove FFG Act listed Western (Basalt) Plains Grassland Community, required where the community is removed from public land for construction of the gas pipeline (subject to the finalisation of the design).

Section 11.1.4 contains further integration with the findings of the original EES terrestrial ecology study regarding native vegetation removal for construction of the gas pipeline.

11.1.3 Mitigation Measures

To minimise the potential impact of removal of seagrass during installation of the seawater transfer pipe, a new mitigation measure has been added to the Environmental Management Framework (please refer to Supplementary Statement Chapter 9: Environmental Management Framework,) Mitigation measure MM-ME20 requires a pre-excavation seagrass survey to be conducted, seagrass disturbance during excavation to be minimised as far as practicable, and seagrass transplantation to facilitate rehabilitation in accordance with the published Western Australian seagrass transplantation manual (Transplanting Posidonia Seagrass in Temperate Western Australian Waters: A Practical 'How To' Guide, BMT Oceanica, July 2013).

11.1.4 Offsets

This section on offsets was prepared by AECOM for inclusion in the report. Offsets are works or actions that compensate for biodiversity losses arising from the impacts to protected ecological matters. Removal of native vegetation will be offset in accordance with Victoria's *guidelines for the removal, destruction or lopping of native vegetation* which is an Incorporated Document within the Victorian Planning Provisions under Clause 52.17 (Native Vegetation). The project triggers general offsets owing to the proposed removal of approximately 0.5 ha of seagrass during installation of the seawater transfer pipe and approximately 0.1 ha of Plains Grassland during construction of the gas pipeline (refer to EES Technical Report D: *Terrestrial Ecology Impact Assessment*).

Offsets for the removal of both marine and terrestrial native vegetation would be secured once the full extent of vegetation clearance is confirmed. Noting that as stated in the original EES, under the Pipelines Act, a permit (under Clause 52.17 of the GGPS) is not required for the removal of native vegetation for the gas pipeline. The Pipelines Act does not apply to the seawater transfer pipe however the gas pipeline does require a licence under the Pipelines Act. The licence under the Pipelines Act for the gas pipeline will provide the mechanism for regulation of terrestrial native vegetation removal and offset obligations through the imposition of conditions on the licence.

Native vegetation offsets

A native vegetation offset consists of a site that protects existing patches of native vegetation, large trees and/or involves planting of new native vegetation. Offset owners secure and manage offset sites to improve native vegetation condition. There are two types of offsets:

- General offsets: required when the removal of native vegetation does not have a significant impact on habitat for rare or threatened species.
- Species offsets: required when the removal of native vegetation has a significant impact on habitat for a rate or threatened species. This offset must compensate for the removal of that species' habitat.

The gains that these offsets deliver are measured in habitat units and the relative size of an offset is graded according to its conservation significance.

Offset requirements

The EnSym Native Vegetation Regulations Tool has been used to test offset requirements for the total extent of native vegetation (both marine and terrestrial) loss identified for the project, as per Appendix 2E of the Assessor's Handbook (DELWP, 2018).

A total of 0.401 General Habitat Units (GHU), with a minimum strategic biodiversity score of 0.222, will need to be offset in the Corangamite CMA or Greater Geelong City Council areas. No Species Habitat Units (SHU) are required to be offset. A copy of the EnSym report is provided in Appendix B.

The DEECA Native Vegetation Credit Register (NVCR) online tool was consulted on 29 August 2024 to confirm the existence of sites which meet the projects' offset requirements at the time of the search. The sites, offset units, and location identified by the NVCR are listed in Appendix C.

The NVCR will be consulted again when an official NVR report for the project is requested from DEECA. The DEECA Barwon South West region will be consulted in relation to preferred offset location.

12. Integrated Assessment

This section integrates the outcomes of the supplementary marine environment study with the outcomes and findings of the original marine EES study.

Table 12-1 summarises the key findings from the original EES and Supplementary Statement, as related to the Minister's Directions. The findings of the Supplementary Statement are essentially the same as the findings of the original EES and are that that there would be no significant impacts to the marine environment identified. Table 12-1 provides an integrated view of the findings to enable an assessment of how the supplementary studies have added to the original body of work and where initial findings have changed, if at all.

Table 12-1. Summary of EES and Supplementary Statement Results

Original Marine EES Study	Supplementary Statement Marine Study
Recommendation 1	
Method	**Method**
• In the original EES, the regional hydrodynamic model was used to predict the future temperature and chlorine plumes during operation of the project. • Different scenarios were modelled to understand the existing refinery temperature and chlorine plumes, and to predict the extent of the temperature and chlorine plumes once the FSRU was in operation. • Scenarios included existing discharge conditions, FSRU discharge to Corio Bay via the refinery and the direct discharge of the FSRU to Corio Bay via a diffuser under refinery pier. • Surveys of seagrass in Corio Bay were undertaken to assess the potential impacts of historical temperature and chlorine discharges from the refinery. • The cover and extent of Corio Bay was assessed in the original EES to identify variability in seagrass extent over time. • To obtain a more detailed understanding of the seabed characteristics in north Corio Bay near the project area, benthic habitat was surveyed along 49 transects in north Corio Bay using a towed underwater camera. • The surveys focused on habitats including seagrasses with macroalgae on shallow soft seabed, and microalgae (microphytobenthos) and burrowing invertebrates (bioturbation) on deeper soft seabed. • Data from the seagrass surveys was then used to map seagrass in the vicinity of Corio Bay.	• In the supplementary statement, the existing plumes were defined from extensive temperature measurements in the four existing four refinery discharge points and within the discharge plumes. Measurements were taken monthly between July 2023 and January 2024, at hundreds of locations within the discharge points, on a range of tide conditions using a highly sensitive temperature probe. • This allowed for the accurate measurement of temperature contours in the existing refinery discharges on a more extensive basis than conducted for the original EES. • As the chlorine levels in the existing refinery discharge plumes are below the level of detection, chlorine levels in the plumes were calculated using the measured temperature rise relative to ambient seawater, the known ratio of chlorine to temperature in the discharges and the known decay rates of chlorine and temperature with time. • Guideline values (DGV) to protect environmental values were established for temperature and chlorine for the Ramsar site and Corio Bay. • To further understand the spatial distribution of seagrass in Corio Bay, towed underwater camera transects were run throughout northern Corio Bay with a total of around 11,300 images analysed which built further on the data collected for the original EES. • To establish the potential impact on seagrass from the existing refinery discharges, a comparison was conducted of seagrass distribution and cover along the shoreline within the existing discharges and at the Ramsar site.

<table>
<tr><th>Original Marine EES Study</th><th>Supplementary Statement Marine Study</th></tr>
<tr><td>Results
The existing +3°C temperature contour extends approximately 200 m offshore from the existing refinery discharge points W4 and W5, and 700 m to the north along the shore.
The plume of warmer water from the existing refinery discharges is below the DGV at the Ramsar site.
The extent of the chlorine plumes, measured at contours of 7.2 µg/L, 5.4 µg/L and 3.6 µg/L are confined to an area within 200 m of the shoreline.
The existing chlorine plume does not extend to the Ramsar site or to Limeburners Bay.
The northern shore of Corio Bay has extensive seagrass in intertidal and shallow subtidal waters
In front of the refinery, there is a mixture of sparse to dense seagrass.
Halophila seagrass is typically found in deeper water compared to H. nigricaulis and is normally patchy with sparse sediments between plants.</td><td>These surveys were undertaken in winter, spring and summer.
Results
The extensive additional temperature measurements conducted for the supplementary statement built on historical Viva Energy data and measurements taken for the original EES. The measurements provided comprehensive data on the extent of existing discharge plumes and where the plumes met the DGV.
The detailed measurements showed that the existing +5°C temperature contour from the refinery extends only 150 m from discharge point W5.
The +3°C contour extends approximately 560 m to the north along the shore from W5.
The +2°C contour, representing the guideline value for protection of the Ramsar site values, extends a further 90 m north along the shore but does not reach the Ramsar site.
For all existing discharges, the inferred 10 µg/L chlorine contour for protection of environmental values within Corio Bay is reached within the mixing zone defined in the refinery’s current EPA operating licence.
The inferred 4.3 µg/L chlorine contour which reflects the guideline value for protection of the Ramsar site values extends approximately 200 m from the W1 discharge point and approximately 60 m from W5 and reaches the guideline level well before the Ramsar site.
The more extensive seagrass surveys conducted to build on those done for the original EES confirmed that the three main species of seagrass in northern Corio Bay – Muelleri in the intertidal zone and H. nigricaulis and Halophila in the subtidal zone.
Seagrass species are mixed in Corio Bay and the proportion of different species varies over time. An updated map showing the extent of the different seagrass species in Corio Bay was prepared.
The supplementary studies included a comparison of seagrass cover in the vicinity of the existing refinery discharges and at the Ramsar site and concluded that the existing discharges have no measurable effect on seagrass cover as there was very little difference in cover in areas within and</td></tr>
</table>

<table>
<tr><th>Original Marine EES Study</th><th>Supplementary Statement Marine Study</th></tr>
<tr><td></td><td>outside the discharge plumes. It was concluded that the three key services provided by seagrass – for primary productivity, as habitat and as food supply were at the same levels in the Ramsar site not influenced by the refinery discharges, and within the exiting plumes.
• The more detailed seagrass surveys conducted for the supplementary statement provided a more comprehensive overview of seagrass in Corio Bay and confirmed the findings of the original EES. Both the original EES and the supplementary studies concluded that seagrass coverage varies considerably over time due to a variety of factors but there is no evidence that seagrass is adversely affected by temperature and chlorine within the existing refinery plumes or will be affected by the project.</td></tr>
<tr><td colspan="2">Recommendation 2</td></tr>
<tr><td>Method
• In the original EES, the regional hydrodynamic model was developed to underpin the assessment of temperature and chlorine impacts on the marine environment in Corio Bay.
• Key model inputs included wind data from Geelong Racecourse, a 1 metre vertical grid, a 20 metre by 20 mere horizontal grid within the project area, a 400 metre by 400 metre horizontal grid in the outer regions of the model domain and a 400 metre by 20-50 metre horizontal grid In the Hopetoun Channel.
• The regional hydrodynamic model did not include the potential influence of the FSRU on currents and discharges.
Results
• The regional hydrodynamic model was used to:
▪ Simulate the existing currents, temperatures, and salinities in Corio Bay.
▪ Predict the fate and transport of fine sediments (clay and silt) that are likely to be mobilised during dredging and dredge spoil disposal.
▪ Predict the path and dispersion of the discharge plumes under two scenarios, namely the FSRU discharging into the refinery for use as cooling water and direct discharge of chilled water from the FSRU through a diffuser into Corio Bay.</td><td>Method
• In the supplementary statement, the regional hydrodynamic model was refined with a horizontal grid of 20 m by 20 m cells; a vertical grid of 0.5 m layers to 4 m depth, improving the resolution of tides and other sea level variations at the model boundary in Port Phillip Bay and by representing a fully loaded FSRU as a blockage to current flow.
• A new CALMET wind file, which combines and interpolates between measured wind fields at Geelong Racecourse, Avalon Airport, Point Wilson and the Geelong Refinery, was created and adopted.
Results
• The refined regional hydrodynamic model more accurately reproduce observed water levels, currents, tidal range, and tidal exchange in Corio Bay
• The refined regional hydrodynamic model was used to re-run the wastewater discharge model, entrainment model and sediment transport model.
• Temperature plumes predicted by the refined regional hydrodynamic model were compared with the measured plume temperatures made as part of the supplementary studies.
• The comparison showed that the refined regional hydrodynamic model predicted plumes with the same shape, temperature and extent as the measured plumes.</td></tr>
</table>

<table>
<tr><th>Original Marine EES Study</th><th>Supplementary Statement Marine Study</th></tr>
<tr><td>Simulate the potential transport and dispersion of plankton and larvae (key elements of the marine ecosystem) from different regions of Corio Bay and predict the amount of entrainment of plankton during operation of the FSRU.</td><td>An expert and independent peer review conducted on the refined regional hydrodynamic model concluded that it was appropriate and fit for purpose to model the existing environment in Corio Bay and predict relevant project impacts.</td></tr>
<tr><td colspan="2">Recommendation 3</td></tr>
<tr><td>Method
In the original EES, the near-field model, and the regional hydrodynamic model, were used to predict the path, initial dilution and extent of the discharge plumes close to the point of the existing refinery discharges.
A Computational Fluid Dynamics (CFD) field model was used to model temperature and chlorine discharge plumes close to the four existing refinery discharge outlets.
The CEE INITDIL near-field model was used to simulate the cold-water discharge plume within 50 metres of the proposed diffuser on Refinery Pier
Results
With the project in operation and the FSRU discharging cooled water into the refinery prior to discharge through the existing refinery outlets, the area of the modelling showed that the temperature plume along the shoreline would be smaller, and most of the plume would only be 1 to 2°C above ambient seawater temperature, as a result of the cooled water input from the FSRU.
The temperature plume would return to ambient temperature well before the Ramsar site.
Future chlorine discharges would be the same as existing discharges as the same volume and same concentration of residual chlorine would be discharged with the project in operation.
The diffuser would achieve a 20:1 dilution and to ensure that the discharge had a temperature change of less than 0.4°C from ambient to minimise the impact of the plume.
The diluted plume is slightly more dense than ambient seawater and would form a plume approximately 1 m thick on the seabed in the dredged shipping channel.
The predicted chlorine concentration with the diffuser would be 5.4 µg/L, which is well below the (then) 7.2 µg/L guideline value for chlorine in marine waters.</td><td>Method
As part of the supplementary statement, the near-field model was re-run using the refined regional hydrodynamic model.
An independent analysis of the near-field modelling was undertaken by Prof Lee, Director of the Croucher Laboratory of Environmental Hydraulics at the University of Hong Kong (an independent specialist modeller) using Visjet, a different near-field model.
The assertions made during the hearing on superelevation and other matters were assessed.
Results
The independent specialist modeller predicted the same dilution of 20:1 from the diffuser, matching the dilution predictions in the original EES and confirming the original findings.
Consistent with the original EES modelled findings, the temperature and chlorine levels in the plume from the diffuser would meet the DGV with a large factor of safety.
The predicted chlorine dilution of 20:1 would reduce the expected chlorine discharge concentrations from 50 µg/L to 2.5 µg/L, which is well below the guideline value of 10 µg/L. It is noted that in the original EES, a conservative chlorine concentration of 100 µg/L was assumed to discharge from the FSRU. This has been revised to 50 µg/L in the supplementary statement, as the refinery does not exceed chlorine discharges of 50 µg/L.</td></tr>
</table>

Original Marine EES Study	Supplementary Statement Marine Study
Recommendation 4	
Method • In the original EES, mussels were collected from six sites in northern Corio Bay and analysed for a wide range of chlorine residuals including trihalomethanes (THMs), haloacetic acids and bromophenols. • Mussels accumulate contaminants in the water with little metabolic transformation and the contaminant levels in their tissue are multiple times the concentrations in the water. As such, they are an appropriate species to assess for bioaccumulation of contaminants. • The six survey sites included Refinery Pier and locations directly within the dispersing refinery plumes from the discharge points, as well as samples from navigational markers around the dredged channel and two reference sites further out in Corio Bay. **Results** • The laboratory analysis from mussels from each location, including the reference sites, found no detectible levels of THMs, haloacetic acids and bromophenols in the mussels. • It was concluded that the chlorine discharged from the refinery either decays or is volatilised in a short period, and there is no accumulation of toxic by-products in mussels or, by inference, other marine life in Corio Bay as a result of existing refinery discharges. Of interest, marine surveys conducted during the original EES studies found an abundance of sea urchins present directly in the refinery plumes. Sea urchins are considered to be highly sensitive to chlorine and anecdotally suggested that chlorine in the discharges was at levels not adversely affecting this sensitive species.	**Method** • To provide a further data in relation to bioaccumulation of chlorine in biota, the IAC recommended that the mussel bioaccumulation study conducted for the original EES was repeated for the supplementary studies. • Fresh mussels were collected from the Portarlington mussel farm and deployed at seven sites within the existing refinery discharge zone. • The mussels were collected after four weeks and analysed for a wide range of chlorinated compounds, including four trihalomethanes, six haloacetic acids and two bromophenols (all potential chlorine by-products). **Results** • In the repeat mussel investigation, all compounds analysed in the mussels were below the level of laboratory detection, and therefore well below Australian water quality guideline limits. • This additional testing of mussels as part of the supplementary studies confirmed and supported the findings of the original EES that chlorinated compounds were not bioaccumulating in this species and were decaying or volatilising in a short period over short distances.
Recommendation 5	
Method • The original EES assessed the potential for entrainment of plankton and fish larvae into the intake of the FSRU • A detailed survey of plankton (phytoplankton, zooplankton and ichthyoplankton (fish eggs and fish larvae)) in Corio Bay was conducted from November 2020 to November 2021. The survey assessed the type and spatial distribution of plankton and larvae In Corio Bay.	**Method** • During the supplementary statement, an eDNA survey was undertaken expand the list of fish species in Corio Bay, particularly smaller species. • The IAC determined that re-running the plankton and larvae modelling using the refined model would be prudent to assess whether the refined model resulted in any material impacts to entrainment of plankton and larvae.

<table>
<tr><th>Original Marine EES Study</th><th>Supplementary Statement Marine Study</th></tr>
<tr><td>

- The sampling included collection and identification of phytoplankton, zooplankton and ichthyoplankton at ten sites in Corio Bay, including the existing refinery seawater inlet, other sites around Corio Bay and the Geelong Arm of Port Phillip Bay.
- An analysis of the results showed that the plankton have similar composition and abundance throughout the Bay with no significant difference detected between plankton in North Corio, South Corio and the Geelong Arm.
- Entrainment modelling was undertaken to simulate the potential transport and dispersion of plankton and larvae from different regions of the Bay.
- Particles that entered the intake zone were counted and assumed to be entrained. The counts were made for 7-, 14- and 28-day periods after release and repeated for release at high tide and low tide.

Results

- The original EES concluded that the majority of fish larvae originating from the Ramsar site are dispersed into Port Phillip Bay as a result of currents and other physical processes.
- The proportion of plankton and larvae originating from the Ramsar site that would be entrained in the existing refinery seawater intake and the proposed FSRU intake would be no more than 0.13% and 0.27% respectively.
- This was considered inconsequential when compared with natural attrition rates and the EES concluded that operation of the FSRU would have negligible impact on plankton and larvae populations.

</td><td>

- Additional information on fish species in Corio Bay was obtained from Professor Jenkins (Professorial Fellow in Fish Ecology at Melbourne University).
- The entrainment modelling from the original EES was re-run using the refined regional hydrodynamic model and further understanding of fish species present in Corio Bay.

Results

- The results from running the refined regional model indicated that for the proportion of plankton and larvae originating from the Ramsar site, approximately the same percentage (0.12%) of particles (used as a proxy for plankton and larvae in the model) would be entrained in the existing refinery inlet and at a future FSRU intake. This correlates closely with the 0.13% entrainment predicted for the refinery intake in the original EES modelling and is slightly lower than the 0.27% predicted for the FSRU intake in the original modelling.
- Overall, it is concluded that there would not be a significant change in the proportion of fish eggs entrained with the FSRU in operation compared to the current entrainment in the existing refinery intake and that the proportion of fish eggs entrained is very small in relation to the natural processes of starvation and predation.
- The supplementary modelling concluded that the project would have negligible impact on plankton and larvae populations and productivity, the food chain and in turn the ecological character of the Ramsar site and food availability for migratory shorebirds.

</td></tr>
<tr><th colspan="2">Recommendation 6</th></tr>
<tr><td>

Method

- The original EES marine studies modelled the likely movement and settlement of sediments released during the proposed 8-week dredging in and around Refinery Pier.
- The regional hydrodynamic model was used to simulate the dispersion and settling of fine sediments released by the project dredging and from disposal of dredge spoil from a barge at the dredged material ground in Port Phillip Bay.

</td><td>

Method

- The IAC recommended that the modelling of sediment transport and settlement associated with the proposed project dredging be rerun with the refined regional hydrodynamic model and adopting a 'worst case' scenario which assumed fine and very fine sediments with the slowest settlement times.
- The spill rates and settling velocity were refined using additional borehole data collected after the EES.

</td></tr>
</table>

Original Marine EES Study	Supplementary Statement Marine Study
• The model was configured to simulate four different sediment sizes including: ▪ Clay with a particle size of 2 micron which makes up 46% of the dredged material. ▪ Silt with a particle size of 30 micron which makes up 17% of the dredged material. ▪ Fine sand with a particle size of 125 micron which makes up 12% of the dredged material. ▪ Sand with a diameter of 250 microns for the remaining 25% of the dredged material. **Results** • Suspended solids modelling predicted that there would be a small 7 ha patch of 5 mg/L suspended solids above ambient and a large 210 ha patch of 2 mg/L suspended solids above ambient at the surface during dredging. • There would be larger patches and higher concentrations on the seabed • Modelling indicated the highest sediment accretion of 20 mm occurs on the seabed in the area to be dredged and deepened. Lower accretion rates of 2 to 10mm would occur over a larger area surrounding the dredging zone. • The rate of accretion (0.04mm/day to 0.2mm/day) would have negligible impact on the muddy seabed and the infauna or mobile marine communities. • The implications of these sedimentation results from the modelling on marina biota is discussed under Recommendation 7.	• The sediment transport model was updated to include: ▪ Organic fines, with a settling velocity of 0.01 mm/s, making up 2% of the dredged material. ▪ Clay, with a settling velocity of 0.063 mm/s, making up 44% of the dredged material. ▪ Fine silt, with a settling velocity of 0.26 mm/s, making up 11% of the dredged material. ▪ Medium silt, with a settling velocity of 0.8 mm/s, making up 11% of the dredged material. ▪ Sand, with a settling velocity of 1 mm/s, making up 32% of the dredged material. • To verify the model, parameters from an independent sediment transport model completed following the Corio Bay Channel Improvement Program were used as a comparison. **Results** • The refined modelling indicates that there is a small area of 5 ha adjacent to the dredging area where the suspended solids concentration would be 5 mg/L above ambient and a large area of approximately 200 ha where the suspended solids concentration would be 2 mg/L above ambient. • The comparison of the project model with an independent model previously used for modelling dredging in Corio Bay showed little difference between the predicted average concentrations. • The rate of accretion results were much the same as in the EES. • Both modelling programs predicted similar results. • The predicted suspended solids levels are expected to cause minimal impacts..
Recommendation 7	
Method • The method for predicting the increase in suspended solids in the original EES is described in more detail in Recommendation 6 in this report (and summarised above). The method involved using the original hydrodynamic model to predict the transport and settlement of sediments based on the various sediment particle sizes adopted.	**Method** • The IAC recommended that a minimum surface irradiance light threshold was applied to seagrass in the Ramsar site (20%) and Corio Bay (10%) to assess potential impacts of reduced light during dredging. • The predicted suspended solids concentrations from Recommendation 6

<table>
<tr><th>Original Marine EES Study</th><th>Supplementary Statement Marine Study</th></tr>
<tr><td>Results
• The results of the modelling for the original EES indicated that suspended solids and turbidity would be limited to the proposed dredging area and immediate surrounds with the Ramsar site and central Corio Bay experiencing only a minor increase in turbidity.
• The area of predicted 5 mg/L suspended solids modelled in the original EES does not extend over any seagrass.
• The increase in turbidity and light attenuation could result in a temporary loss in productivity of a small area of deeper seagrass around the area to be dredged but within the tolerance range of seagrass as outlined in the Victorian Dredging Guidelines.
• The increase in turbidity and light attenuation could result in a minor loss in productivity of seagrass in deeper waters.
• The original EES concluded that while there could be minor losses of seagrass productivity over the 8 week dredging period, the levels of light attenuation and settlement of sediments predicted are well within the ranges experienced by seagrass and impacts would be minimal.</td><td>were converted to a reduction in light using the equations listed in Appendix 5 of the Victorian Dredging Guidelines (EPA, 2001).
• WAMSI Dredging Science Node suggest an appropriate time scale for detecting impacts on seagrass is 2 weeks.
Results
• The highest average 14-day suspended solids concentration in the Ramsar site was 5.9mg/L, including background.
• This corresponds to 22% light availability for seagrass in the Ramsar site meaning that all seagrass in the Ramsar site would receive more than the specified minimum 20 % of available light during the dredging program and meets the IAC recommended threshold.
• In summary, all seagrass in the Ramsar site (zero to 2 m depth) will always receive sufficient light for growth during the proposed dredging program.
• The highest average 14-day suspended solids concentration in Corio Bay seagrass at 4 m depth is 6.7mg/L.
• This corresponds to 14% light availability for seagrass in Corio Bay meaning that seagrass in Corio Bay would receive more than the specified minimum 10 % of available light during the dredging program as recommended by the IAC.
• Deep sparse seagrass near the dredging area may experience a minor setback in growth rates during the 8-week period of dredging.
• Any seagrass growth slowed by turbidity would recover soon after completion of the dredging program.
• The modelling for a ‘worst case’ sediment scenario indicated that there would be no unacceptable impacts on seagrass from light attenuation both in the Ramsar site and Corio Bay and supports the original EES findings.</td></tr>
<tr><td colspan="2">Recommendation 8</td></tr>
<tr><td>Method
• The original EES determined that the pathways for an impact of dredging on the Ramsar site would be direct removal of seagrass, impacts associated with temperature and chlorine discharges for the project or an increase in turbidity and light attenuation over the seagrass beds within the Ramsar site boundary.</td><td>Method
• The methods used to conduct the additional assessments in the supplementary statement involve use of a refined regional hydrodynamic model and conservative parameters for sediment sizing and light attenuation thresholds.</td></tr>
</table>

<table>
<tr><th>Original Marine EES Study</th><th>Supplementary Statement Marine Study</th></tr>
<tr><td>

The methods used to assess seagrass impacts in the Ramsar site in the original EES are described below and involved an assessment of temperature and chlorine plumes from discharges, sediment transport and accretion and light attenuation associated with dredging.
The proposed dredging would not involve any removal of seagrass.
The assessment of whether temperature and chlorine impact would potentially impact on seagrass in the Ramsar site is described in the response to Recommendation 1 in this supplementary report and summarised in this table above.
The assessment of whether sedimentation from dredging would impact the Ramsar site is described as part of Recommendation 1 (seagrass surveys and mapping), Recommendation 6 (Sediment transport modelling) and Recommendation 7 (Further assessment of dredging on seagrass).

Results

The original EES modelling indicated that the median 5 mg/L suspended solids contour would not extend into the Ramsar site.
The original EES findings showed that the level of sedimentation expected in the Ramsar site are well within the tolerance ranges of by seagrass and there would be no material impacts on the Ramsar seagrass beds or to the Ramsar values.
There would be no reduction in the area of seagrass or seagrass health in the Ramsar site. The predicted increases in turbidity would occur for short periods within the limited 8-week dredging period and impacts would recover quickly post dredging.

</td><td>
Results

The area predicted to have 5 mg/L median suspended solids is approximately 5 ha.
The 5 mg/L suspended solids contour would not extend into the Ramsar site and would not have any impact on seagrass in the site.
The highest average suspended solids concentration predicted at the outer edge of the Ramsar site is approximately 3 mg/L which is well within the tolerance ranges experienced by seagrass and there would be no material impacts on the Ramsar seagrass beds or to the Ramsar values.
There would be no reduction in the area of seagrass or seagrass health in the Ramsar site.
The predicted increases in turbidity would occur for short periods within the limited 8-week dredging period.
This could have a minor effect in slowing the growth of seagrass in deeper waters near the dredging, but the impact would be too small to be measured and of no ecological consequence.
There is no change to the conclusion in the original EES that dredging would not impact the Ramsar site.

</td></tr>
</table>

12.1 Summary of Supplementary Study

The supplementary studies consisted of 8 recommendations from the Minister each of which has been thoroughly addressed in this report. The following table below provides a summary of the results of these studies.

Recommendation 1. *Establish existing environment and impacts of existing refinery discharges.* The dominant habitat in the area of the existing refinery discharges of warm seawater is seagrass, with algae epiphytes growing on the seagrass being the next largest habitat. Seagrass is dominant in both the intertidal and subtidal zones, to a depth of 5 m. Seagrass cover was adopted as the most appropriate indicator of the existing seagrass habitat and was used to establish the effects of the existing discharges. Seagrass cover in the intertidal zone averaged 31 % +/- 6 % in the discharge zone (average plus or minus standard deviation of seagrass cover measurements) and 30 % +/- 9 % in the Ramsar site. Seagrass cover in the subtidal zone averaged 72 % +/- 4 % in the discharge zone and 68 % +/- 6 % in the Ramsar site. It is concluded that there are no detectible impacts of the existing discharges on seagrass cover or seagrass habitat. *Update seagrass mapping to include the intertidal zone and information on the different seagrass species.* Extensive surveys were carried out to define the extent of the three main species of seagrass in northern Corio Bay – *Nanozostera Muelleri* in the intertidal zone and *Heterozostera nigricaulis* and *Halophila australis* in the subtidal zone. Seagrass species are mixed together in Corio Bay and the proportion of different species varies over time. An updated map showing the extent of the different seagrass species in Corio Bay was prepared.
Recommendation 2. *Refine calibration of the regional hydrodynamic model so that it more accurately reproduces observed water levels, currents, tidal range, and tidal exchange in Corio Bay. Peer review of the model calibration.* The regional hydrodynamic model was upgraded by refining the horizontal grid to 20 m by 20 m cells; refining the vertical grid to 0.5 m layers, improving the resolution of tides and other sea level variations at the model boundary in Port Phillip Bay and representing a fully-loaded FSRU as a blockage to current flow. The refinements led to a small improvement in the prediction of tide heights and currents. The predicted plume dilution and extent remained much the same as shown in the EES.
Recommendation 3. *Re-run the wastewater discharge modelling with revised inputs based on the refined hydrodynamic model.* Future temperature and chlorine discharges from the existing discharges and the FSRU were predicted using the refined regional hydrodynamic model. *Revise the near-field modelling of discharges from the diffuser, noting the revised chlorine default guideline values (DGV) for chlorine.* The near field modelling of dilution from the discharge of the proposed diffuser beneath the refinery pier was repeated by an independent specialist. The same dilution of 20:1 was predicted, matching the dilution predictions in the EES. The effect of the FSRU on dilution of the flow on the seabed under the FSRU was explored and found to be not significant.

Recommendation 4. *Further targeted investigations to confirm potential project impacts resulting from chlorination by-products.* A further six sets of fresh mussels were deployed in the discharge zone. The mussels were collected and analysed for a wide range of chlorinated and brominated compounds. All compounds analysed were at very low concentrations – below the level of laboratory detection and therefore well below Australian water quality guideline limits. The results of the two sets of mussel tests indicate negligible contamination of CBP in Corio Bay.
Recommendation 5. *Re-run the entrainment model with revised inputs based on the refined hydrodynamic model*. The entrainment modelling was repeated using the refined regional hydrodynamic model. For particles released in the seagrass of the Ramsar site, the same percentage of particles (0.12 %) were entrained in the existing refinery inlet and at a future FSRU intake. This is the same result as established in the 2022 EES and indicates no significant change in entrainment rate with operation of the FSRU.
Recommendation 6. *Re-run the sediment transport model with revised inputs based on the refined hydrodynamic model. Consider including a 'worst-case' scenario for sediment fractions and settling rates.* The sediment size fractions and settling velocities were refined on the basis of data from additional boreholes, settling tests and published data on clay floc settling rates. Suspended solids concentrations were predicted for sites on the outer edge of the Ramsar site. The predicted concentrations varied over the proposed 8-week dredging program, with the concentration at the highest site averaging 3 mg/L. The revised concentrations matched the concentrations measured in an earlier dredging project in Corio Bay, and also matched the concentrations predicted using the sediment size fractions and settling velocities adopted by previous consultants to verify the measured concentrations. There is no significant change from the suspended solids predictions in the 2022 EES. The results indicate low risk to seagrass health.
Recommendation 7. *Undertake further assessment of dredging impacts on seagrass based on the updated sediment transport modelling and light thresholds of 20 percent surface irradiance for the Ramsar site and 10 percent irradiance for the rest of Corio Bay.* Calculations of available light in the Ramsar site show that, for the highest 14-day suspended solids level, seagrass in the Ramsar site will receive more than 20% of the incident light during the dredging program and the rest of the seagrass areas will receive over 10% light. This meets the light threshold suggested by the IAC and indicates very low risk to seagrass growth. The installation of the seawater transfer pipe would potentially require the removal of a small (approximately 0.5 ha) area of seagrass. Seagrass surveys in the area show that the main seagrass species present is *Halophila* with some *H. nigricaulis*.
Recommendation 8. *Confirm the EES conclusion that dredging will not impact the Ramsar site.* After considering (1) the revised marine modelling of the sediment plumes; and (2) the revised assessment of dredging impacts on seagrass, it is considered that the dredging will not have any impact on seagrass. There is no change from the EES conclusions.

12.2 Modelled Future Plumes – Discharge from FSRU Via the Refinery

The figures from Chapter 5 showing the predicted future chlorine and temperature plumes are repeated here to illustrate the reduction in the extent of the temperature plumes with the project.

Figure 12-1 shows the existing chlorine plumes at the 10 µg/L contour. The future chlorine plumes are the same as the existing chlorine plumes because the seawater discharge rate and chlorine concentration in the discharges will not change with the project, as the use of chlorine to control biofouling in the refinery will not change.

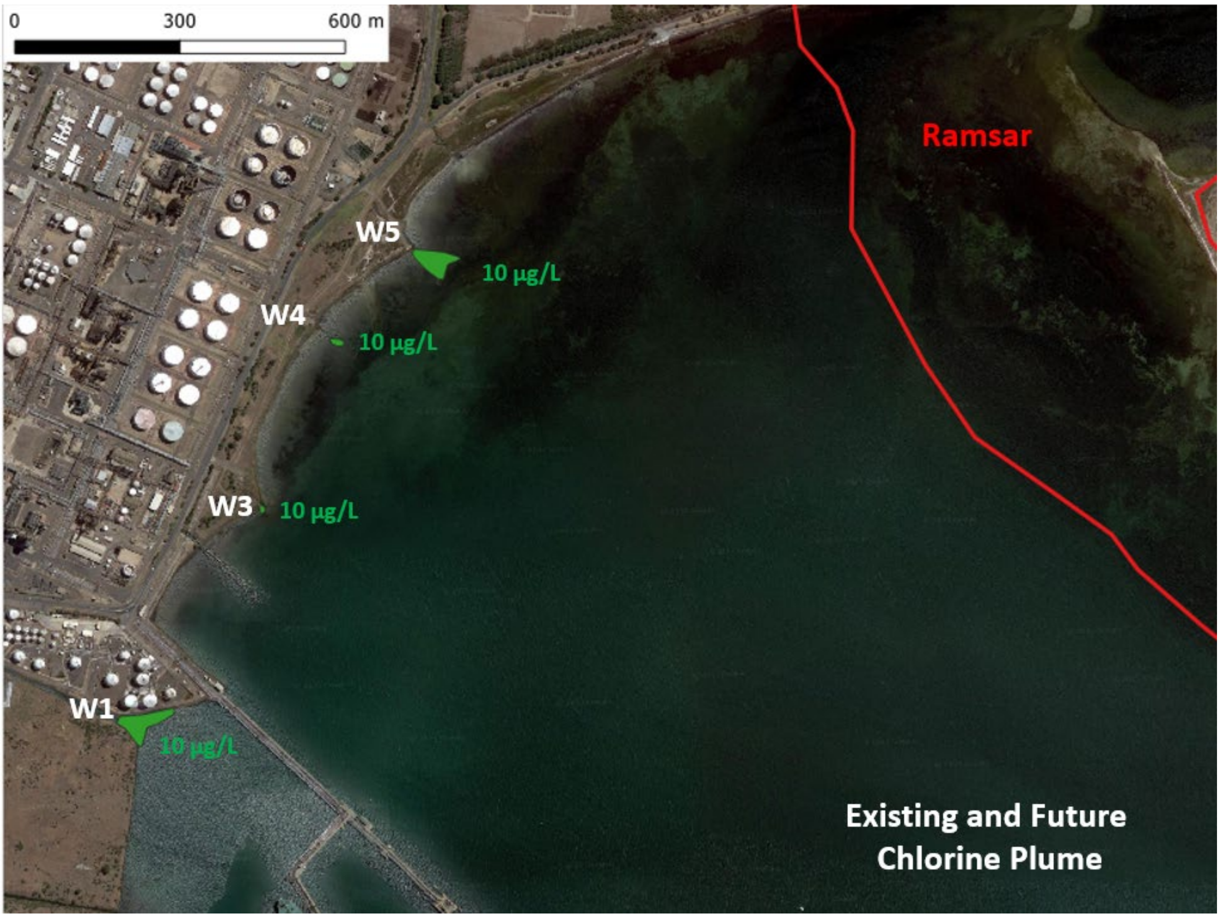


Figure 12-1. Existing and Future Chlorine Plumes (No Change)

(Note: Future chlorine plumes will be the same as existing chlorine plumes)

Gas use in summer is projected to be about 40 % of peak capacity. Figure 12-2 shows the reduced envelope of the future temperature plumes in summer, when cooling of seawater in the FSRU would be less than the heating of seawater in the refinery.

Gas use in winter is projected to be average about 90 % of peak capacity. Figure 12-3 shows the much-reduced envelope of the future temperature plumes in winter, when cooling of seawater in the FSRU would be almost equal to the heating of seawater in the refinery.

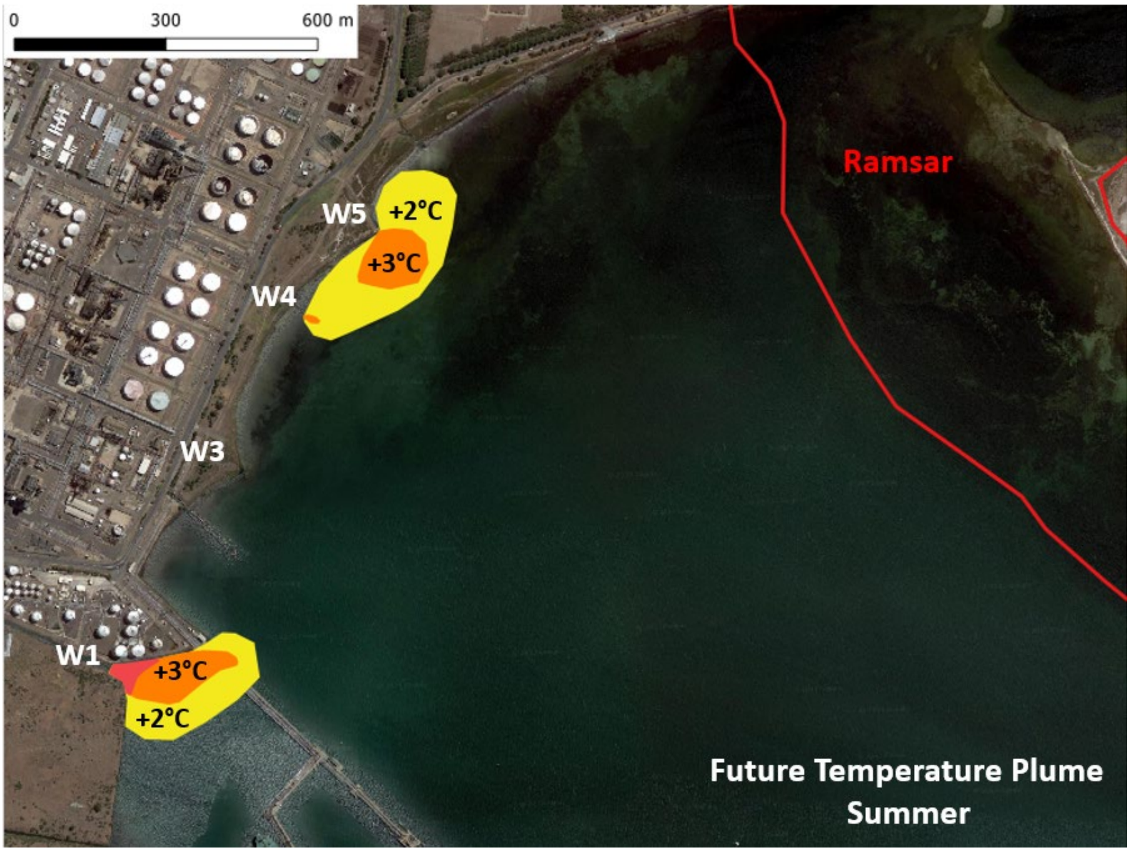


Figure 12-2. Future Temperature Plume - Summer

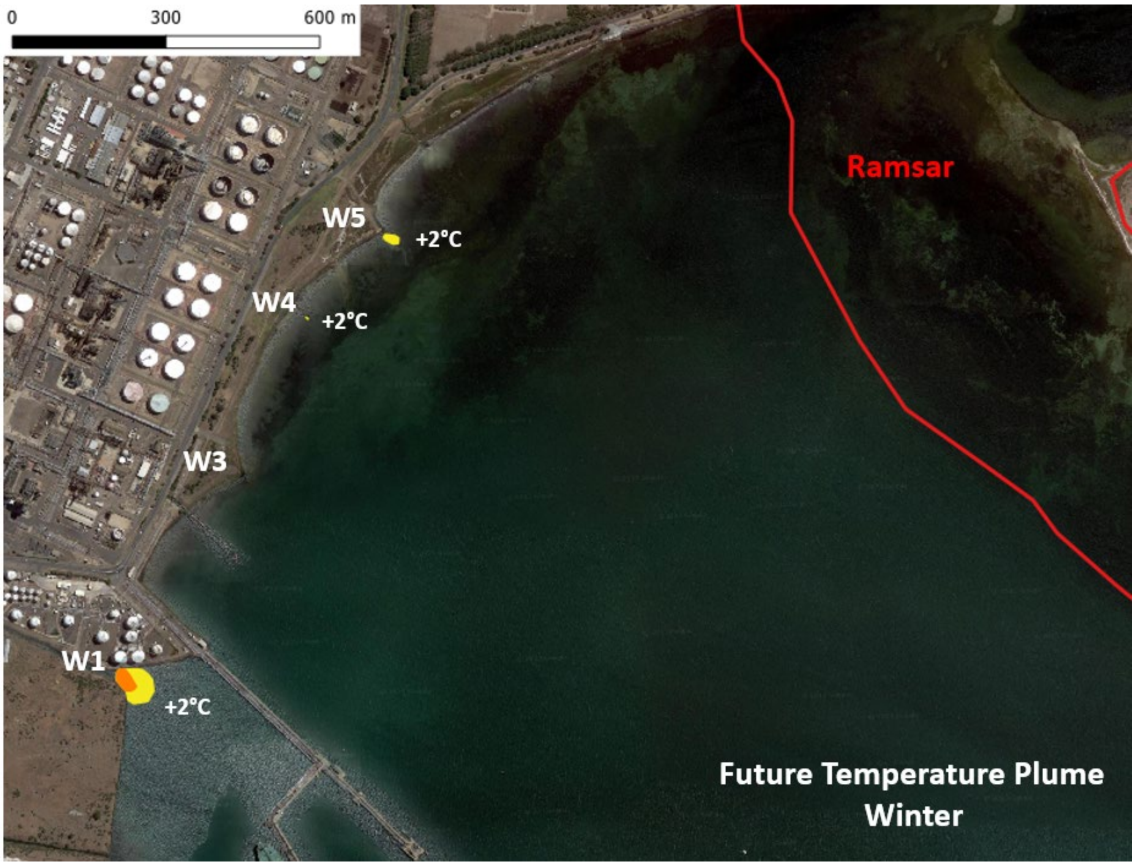


Figure 12-3. Future Temperature Plume - Winter

13. References

M Adams, A Ferguson, CJ Collier and M Baird (2015). Assessment of light history indicators for predicting seagrass biomass, Conf: 21st Internat Congress on Modelling and Simulation, Gold Coast

LaboranK Laboran, S Richard, A Austruy and J Boudenne J, (2019). Assessment of individual and mixed toxicity of bromoform, tribromoacetic acid and 2,4,6 triborphenol on the embro-larval development of Paracentrous lividus sea urchin, Environmental Science and Pollution Research, July.

A Abdel-Wahad, A Khodary and N Bensalah, (2010). Formation of Trihalomethanes during seawater chlorination. Journal of Environmental Protection, Vol 1, 456-465.

EG Abal, (1996). Light, nutrient and water quality interactions with the seagrass, Zostera capricorni Aschers. PhD Thesis, School of Biological Sciences, The University of Queensland.

EG Abal, N Loneragan, P Bowen, CJ Perry, JW Udy and WC Dennison (1994). Physiological and morphological responses of the seagrass Zostera capricorni to light intensity, J Expt Marine Biology and Ecology, Vol 178 113-129.

AD McCowan and A Kahl (2005). Dredging Simulations for the Port Adelaide Channel Deepening, Proc Coasts and Ports, IE Aust

AECOM. (2021). Dredging and Offshore Contamination Assessment. Report to Viva Energy

Amsterdam, The Netherlands. pp. 1–165.

ANZECC (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Vol 1. paper 4.

ANZG. (2018). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Canberra, ACT, Australia.

ANZG. (2020). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Canberra, ACT, Australia.

Ball, D, Sokolov-Berlson and P Young (2014). “Historical seagrass mapping in Port Phillip Bay, Australia”. J Coast Conserv (2014) 18:257-272

D Ball, M Soto-Berelov and P Young (2014). Historical Mapping of Seagrass in Port Phillip Bay, Australia, J Coastal Conservation, Vol 18, pp 257-272

J Becker, E van Eekelen, J van Wiechen, W de lange, T Damsma, T Smolders and M van Koningsveld (2015). Estimating Source Terms for Far Field Dredge Plume Modelling, J Envir Magmt, 149, 282-293

BEEMS Expert Panel Report, Chlorination by-products in power station cooling water (2011). British Energy Estuary and Marine Studies, Scientific Advisory Report No 9.

Bengtsson, L., Hellstrom, T., & Rakoczi, L. (1990). Redistribution of sediments in three Swedish lakes. Hydrobiologia, 192: 167-181.

Bengtsson, U., McMahon, J., Quarrell, O., rubenstein, C., David, K., greenburg, F., & Wasmuth, J. (1990). Phenotypically normal carriers of unbalanced terminal deletions of 5p transmit the deletions to offspring who display growth and developmental delay. AM J Hum Genet.

S Blake S and D Ball (2001) Seagrass mapping Port Phillip Bay. Marine and Freshwater Resources Institute Report No. 39, Queenscliff, Australia

Boudjellaba D, Dron J, Revenko G Demalas C and J-L Boudenne (2016). Chlorination by-product concentration levels in seawater and fish of an industrialised bay (Gulf of Fos, France) exposed to multiple chlorinated effluents. Science of the total environment 541: 391-399

D. Boudjellaba, J. Dron, G. Revenko, C. Démelas and J.-L. Boudenne (2016). Chlorination by-product concentration levels in seawater and fish of an industrialised bay (Gulf of Fos, France) exposed to multiple chlorinated effluents, Science of the Total Environment, Vol 541, pp 391-399.

Bulthuis, D. A. (1983). Effects of in situ light reduction on density and growth of the seagrass Heterozostera tasmanica, J Exp Marine Biology and Ecology, 67-91.

DA Bulthuis (1983). Effects of in situ light reduction on density and growth of the seagrass Heterozostera tasmanica in Western Port, Victoria, Australia, J Expt Marine Biology and Ecology, Vol 67, pp 91-103

DA Bulthuis, (1987). Effects of temperature on photosynthesis and growth of seagrasses, Aquatic Botany Vol 27, pp 27-40.

Cabaco, S., Santos, R., & Duarte, C. (2008). The Impact of Sediment Burial and Erosion on Seagrass:. Estuarine, Coastal and Shelf Science, 354-366.

Cardno (2011). Corio Bay Channel Adjustment Safety Program – Turbidity from Dredging, Report to Vic Channels Authority

Cardno, Lawson, Treloar (2006). Data for Turbidity Model Calibration and Validation, Port of Melbourne Corporation.

Carnell PE, Keough MJ (2020). More severe disturbance regimes drive the shift of a kelp forest to a sea urchin barren in south-eastern Australia. Sci Rep Jul 9;10(1):11272. doi: 10.1038/s41598-020-67962-y. PMID: 32647344; PMCID: PMC7347924.

LJ Carpenter, CEJones, RM Dunk, KE Hornsbyand J Woeltjen,J.:(2006) Air-sea fluxes

CEE (2022). Marine ecology and water quality, Tech Report A1 for EES, Viva Energy Australia Gas Import Facility

CEE (2022). Technical Report A: Marine environment impact assessment.

CEE (2023a). Technical Memorandum 1: Seagrass in Corio Bay

CEE (2023b). Technical Memorandum 4: Impact of Existing Discharges on Seagrass – Winter 2023

CEE (2023c). Technical Memorandum 5: Impact of Existing Discharges on Seagrass – Spring 2023

CEE (2023d). Technical Memorandum 6: Impact of Existing Discharges on Seagrass – Summer 2023.

CEE (2024a). Technical Memorandum 3: Temperature and Chlorine Plumes from Existing Discharges

CEE (2024b). Technical Memorandum 2: Mapping seagrass distribution in Corio Bay

H Chanson, and JS Montes (1995). "Characteristics of Undular Hydraulic Jumps. Experimental Apparatus and Flow Patterns." J of Hyd. Engin., Vol. 121, 129-144.

KM Chartrand, CV Bryant, AB Carter, PJ Ralph and MA Rasheed (2016). Light Thresholds to Prevent Dredging Impacts on the Great Barrier Reef Seagrass, Zostera muelleri, Frontiers Marine Science, Vol 8

Coffey (2020). Geotechnical Factual Report, Report to Viva Energy Australia, No 754

Cornelissen, S. (2004). Numerical Modelling of Stratified Flows Comparison of the σ and z coordinate systems. Masters Thesis, Tech Univ Delft.

Coyer, J.A., Hoarau, G., Kuo, J., Tronholm, A., Veldsink, J., Olsen, J.L., (2013). Phylogeny and temporal divergence of the seagrass family Zosteraceae using one nuclear and three chloroplast loci. Syst. Biodivers. 11, 271–284.

CSIRO, (1996). Port Phillip Bay - Environmental Study Report to Melbourne Water.

M Eigenraam, F McCormack and Z Contreras (2016). Marine and Coastal Ecosystem Accounting – Port Phillip Bay, Report to the Commissioner for Environmental Sustainability.

EPA (2001). Best Practice Guidelines for Dredging, EPA Publ 691. Melbourne.

EPA Victoria, (2001). Guidelines for Dredging, Publication 691

EPA Victoria. (2021). Environment Reference Standard. Melbourne.

EPA Victoria. (2023). Design Guidelines Values for Chlorine in Marine Waters, Included in TRG comments response. Melbourne.

EPA Western Australia (2021). Environmental Impact Assessment of Marine Dredging Proposals, Technical Guidance

GeelongPort (2018). Port of Geelong Development Strategy, Ports VIC

Gibson. C, Tone. F, Wilkinso. P, Blaylock. J (2008). Toxicity and effects of bromoform on five marine species, ozone: science and engineering, pgs: 47 – 54.

Gribble G.W (2012). Chapter 1—Occurrence of halogenated alkaloids. In: Knölker H.-

Hirst, D Ball and S Blake (2012). Baywide Seagrass Monitoring Program – Milestone Report no 15", Fisheries Victoria Tech Rpt No 164, Feb 2012.,

Hydrodynamics (2024). Refinement of Regional Hydrodynamic Model of Corio Bay for Supplementary Marine Studies, Report to CEE

Hydronumerics (2022a). Viva Re-gasification Project - Hydrodynamic Modelling Report

Hydronumerics (2022b). Viva Energy Gas Terminal Inquiry and Advisory Committee Tabled Document 497, Technical Note 015: Regional Hydrodynamic Modelling Model Grid Sensitivity Tests.

Hydronumerics (2022c). Viva Energy Gas Terminal Inquiry and Advisory Committee Tabled Document 499, Technical Note 017: Wind comparison and hydrodynamic modelling.

INPEX (2013). Dredging and spoil disposal management plan – East Arm Darwin Harbour. Doc No.: C075-AH-PLN-0028, 275 pp.

G Jenkins, M Keough, D Ball, P Cook, A Ferguson, J Gay, A Hurst, R Lee, A Longmore, P Macreadie, S Nayer, C Sherman, T Smith, J Ross and P York (2015). Seagrass Resilience in Port Phillip Bay", Final Report, DELWPJenkins (2019). Overview of the Ichthyoplankton Samping Program in the Lower Arm, Western Port, Report to CEE

Jenner H and A Wither (2011). Chlorination by-product in power station cooling water. Science Advisroy report. BEEMS Expert Panel. EDF Energy UK. https://infrastructure.planninginspectorate.gov.uk/wp

JWH Lee (2023). lot of Visijet Output and Interpretation", email, Sept 2023.

Kuo, J. (2005). A revision of the genus Heterozostera (Zosteraceae). Aquatic Botany 81, 97–140.

Larkum, Anthony & Orth, Robert & Duarte, Carlos (2006). Seagrasses: Biology, Ecology and Conservation. 10.1007/978-1-4020-2983-7_5.

Lawson & Treloar (1997). Corio Bay - Sediment Transport Model Verification. Final Report to Vic Channels Authority

Lawson & Treloar (1998). Corio Bay Channel Improvement Program – Turbidity Monitoring Post Dredging – Final Report, Report #RM1033/J5125 to Vic Channels Auth

Leeder Analytical, report number L230468 (2023). The 2023 analysis of mussels was conducted by Leeder Analytical. The analysis was done by Dr John F Leeder. Mussel samples were collected from Corio Bay on 19 October 2023 and were delivered to the lab within 2 hours of retrieval. The analysis was conducted on 24 November 2023

Les, D.H., Moody, M.L., Jacobs, S.W.L., Bayer, R.J. (2002). Systematics of seagrasses (Zosteraceae) in Australia and New Zealand. Syst. Bot. 468–484

SD Ling, Kriegisch, N., Woolley, B., & Reeves, S. E. (2019). Density-dependant feedbacks, hyseresis, and demogrphy of overgrazing sea urchins. Hobart: institute for marine and Antarctic Studies - University of Tasmania.

T Manasfi, K Lebaron, M Verlande, J Dron and C Demelas, (2019). Occurrence and speciation of chlorination byproducts in marine waters and sediments of a semi-enclosed bay exposed to industrial chlorinated effluents. Internat J Hygiene and Environmental Health, 222 (1), pp.1-8.

Marine Science & Ecology (2006). Review of Impacts of Dredging Turbidity Plumes on Seagrasses in Corio Bay in the Geelong Arm Channel Improvement Program, Report to Victorian Channels Authority

Mazor, T., Edmunds, M., Flynn, A., Ferns, L. (2021). Port Phillip Bay Habitat Map. Habitat Complex Modelling (CBiCS Level 3). The State of Victoria Department of Environment, Land, Water and Planning 2021.

K McMahon, P Lavery, J Statton, R McCallum and U Hernawan (2017). Current state of knowledge regarding the effects of dredging related pressures on seagrass, WAMSI Dredging Science Node Report 5.1.1.

National Centre for Coastal Ocean Science (Website Accessed 2024). https://coastalscience.noaa.gov/news/noaas-mussel-watch-program-expands-coastal-contamination-monitoring/#:~:text=Since%201986%2C%20at%20nearly%20300,kind%20in%20the%20United%20States.

Nature Conservancy (2022). Sea Urchins to the Rescue. Hawai'i Marine.Nature.org/urchins"

M Potouroglou, JC Bull, KW Krauss, HA Kennedy, M Fusi, D Daffonchoi, MW Mangora, MN Githaigi, K Diele and M Huxman (2017). Measuring the Role of Seagrasses in regulating sediment surface elevation, Scientific Reports Online

D Provis and C Taylor (1999), “Corio Bay Channel Improvement Program – Turbidity Monitoring” Proc 14th Coasts and Ports Conference. IE Aust

DG Provis, and S Aijaz, S. (2009). Prediction of plume generation and movement from dredging operations in Port Phillip Bay, Melbourne. In Coasts and Ports 2009: In a Dynamic Environment. Engineers Australia.

B Quack and Wallace (2002). Air–sea flux of bromoform: controls, rates and implications, Global Biogeochem. Vol 17, 1023

EL Robertson (1984). Seagrasses”. In: Womersley HBS 1984 The benthic flora of Southern Australia part one. DJ Woolman Government Printer South Australia

K Satpathy, A Mohanty, G Sahu, S Biswas and M Selvanayagam (2010). Biofouling and its Control in Seawater Cooled Power Plant Cooling Water System - A Review. Open Access DOI 10.5772/9912

SJ Smith and C Friedrichs (2011). Size and settling velocities of cohesive flocs and suspended sediment aggregates in a trailing suction hopper dredge plume, Continental Shelf Research, Vol 31(2011) 50–63.

J Statton, K McMahon, P Armstrong, S Strydom, R McCallum, G Kendrick and P Lavery (2017). Determining light stress bio-indicators and thresholds for a tropical multi-species seagrass assemblage, WAMSI Dredging Science Node Report, Project 5.5.1

Symonds, P Erftemeijer, R White and G Dwane (2023). The Importance of Flocculation in Dredge Plume Modelling, Terra et Aqua

The 2023 analysis of mussels was conducted by Leeder Analytical (report number L230468). The analysis was done by Dr John F Leeder. Mussel samples were collected from Corio Bay on 19 October 2023 and were delivered to the lab within 2 hours of retrieval. The analysis was conducted on 24 November 2023.

Van Rijn (2020), Settling Velocity and Equivalent Size of Mud, www.aquapublications.nl

M Vanderklift, D Bearham, M Haywood, R McCallum, J McLaughlin, K McMahon, N Mortimer and Paul Lavery (2017). Recovery mechanisms: understanding mechanisms of seagrass recovery following disturbance, WAMSI Dredging Science Node Report Project 5.4

Victorian Auditor General (2012). Report on the audit of Port of Melbourne Channel Deepening Project, Report to Victorian Parliament, November 2012

Wallis, I & Chidgey, S (2022). Chlorine Tolerance in Marine Biota,

I Wallis and S Chidgey (2023). New Guidance Values for Chlorine in Marine Waters, Water e-Journal, Vol 7, No 2.

MJ Warne, GE Batley, RA van Dam, JC Chapman, DR Fox, CW Hickey and JL Stauber (2018). Revised method for deriving Australian and New Zealand water quality guideline values for toxicants, Report to ANZECC

Worley (2011). Corio Bay Channel Safety Adjustment Program, Report to Vic Channels Authority

Worley (2022). Geotechnical Report, Report to Viva Energy

F.Ziska, B.Quack, K.Abrahamsson, SD.Archer,E.Atlas, T.Bel, JH.Butler, LJ.Carpenter, CE.Jones, NRP Harris, H Hepach, KG Heumann, C Hughes, J.Kuss, KKruger, P.Liss, RM Moore, A Orlikowska, S Raimund, CE Reeves, W Reifenhauser, AD Robinson, CSchall, T.Tanhua, S.Tegtmeier, S.Turner, L.Wang, D.Wallace, J.Williams, H.Yamamoto, S.Yvon-Lewis and Y.Yokouchi (2013). Global sea-to-air flux climatology for bromoform, dibromomethane and methyliodide, Atmos.Chem.Phys.,Vol 13, 8915–8934.

Appendix A – Response to Peer Review Report B

Viva Energy Gas Terminal Project

Supplementary Environment Effects Statement

Response to Stantec Peer Review

Consulting Environmental Engineers

August 2024

1. Summary of Response

The peer review report submitted by Stantec in August 2024 contained six conclusions and recommendations on the marine studies report. Several positive comments were made:

- The assessment of existing conditions is accurate and comprehensive in relation to the values relevant to the assessment.
- The regional hydrodynamic modelling calibration is sound, and the model reflects observed current and tide data.
- The revised nearfield modelling enables a better understanding of the effect of the FSRU on dispersion of marine discharges from the FSRU.
- The re-runs of the wastewater discharge modelling, entrainment modelling and sediment transport modelling provide for a better understanding of the potential environmental effects of the project.
- The impacts assessment methodology presented in Technical Report A appears sound.
- Conclusions drawn in the impact assessment in Technical Report A are sound.

Two items for improvement were identified. It was recommended that the statistical analysis of the monitoring results presented in Technical Report A be more clearly explained, and it was recommended that additional comparisons between the regional model predictions and measured data be made in the final report to further quantify the model's calibration metrics. In response, Technical Report A has been revised to address these two items. The updated report is now considered to satisfy all requirements.

2. Statistical Analysis of Monitoring Data

The statistical analysis for the comparison of seagrass cover in the discharge zone compared to the reference zone (in the Ramsar Site) has been revised to address the reviewer's comments. The analysis has been clarified by deleting any reference to seasonal change or consistent change. There are simply six measurements of seagrass cover in the discharge zone to compare with six measurements of seagrass cover in the reference zone.

The two-sided t-test was used to determine whether the seagrass cover in the discharge cover was the same or different from the seagrass cover in the reference site. The updated text for the comparison of intertidal seagrass cover and subtidal seagrass cover in the two zones is provided on the following pages. Note that the figure and table numbers match those used in the updated supplementary marine studies report.

Chapter 6 of the supplementary report presents results from an analysis of mussels in Corio Bay for chlorine byproducts. Mussels were deployed at seven sites in north Corio Bay where the discharge plumes from the refinery occur. The mussels were retrieved after four weeks and analysed for four trihalomethanes, six haloacetic acids and two bromophenols (all potential chlorine by-products). All compounds were below the limit of laboratory detection and therefore at very low levels. As all results had effectively zero detectible concentration, no statistical analysis was required.

A further question in the Stantec review is Comment 76 where confidence limits for published PAR and NTU measurements were requested to be included. The published data were the average turbidity (NTU) and light attenuation (PAR) measurements published by Provis in 2009 from multiple measurements made before dredging (Nov 1995 to Jan 1997), during dredging (Jan 1997 to Feb 1998) and after dredging (Feb 1998 to Oct 1998) in Corio Bay (1998). The program included monthly measurements at 33 stations.

Table 10-1. Previous Average Turbidity and Light Attenuation Measurements

Location	Turbidity, NTU			PAR Attenuation, m^{-1}		
	Before	During	After	Before	During	After
Inner Harbour	0.8	2.8	0.8	0.34	0.42	0.33
North Shore	0.4	0.7	0.5	0.35	0.34	0.30
Outer Harbour	0.7	1.3	0.6	0.33	0.30	0.27
Stingaree Bay	0.4	1.0	0.5	0.37	0.38	0.43

Source: Provis, 2009

The publication in 2009 by Provis does not provide confidence limits and standard errors, and therefore they cannot be provided in the 2024 CEE report.

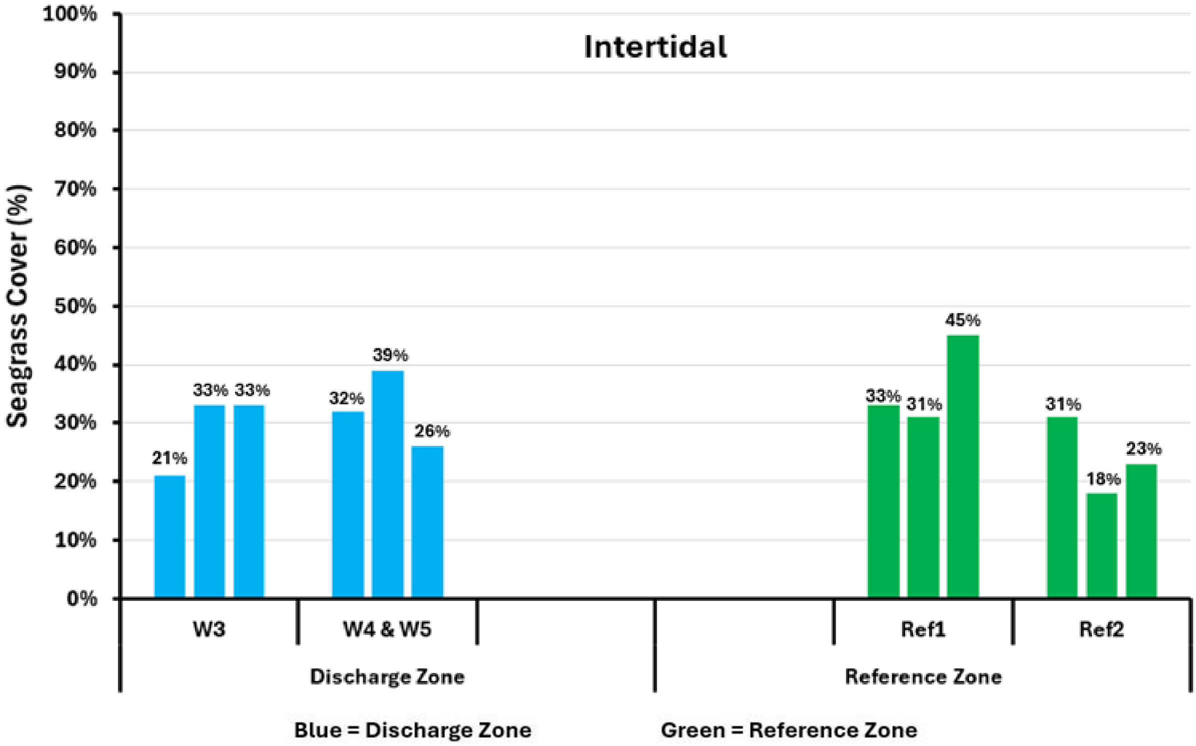
Note that the historical measurements show higher turbidity during dredging with a return to baseline levels after dredging concluded. The average PAR data show higher light attenuation during dredging at the closest site to the dredge (Inner Harbour) but very little change at the more distant monitoring sites.

2.1 Comparison of Seagrass Cover in Discharge Zone and Reference Zone

2.1.1 Intertidal Sites (2023)

Figure 3-17 shows the data for the intertidal seagrass cover measured in the discharge zone (blue columns) and the intertidal seagrass cover measured in the reference zone (green columns). Although there was variability from month to month, the average seagrass cover in the discharge zone of 31 % over the measurement period was about the same as the average seagrass cover in the reference zone of 30 %.

Figure 3-17. Comparison of Cover in Intertidal Discharge and Reference Zones



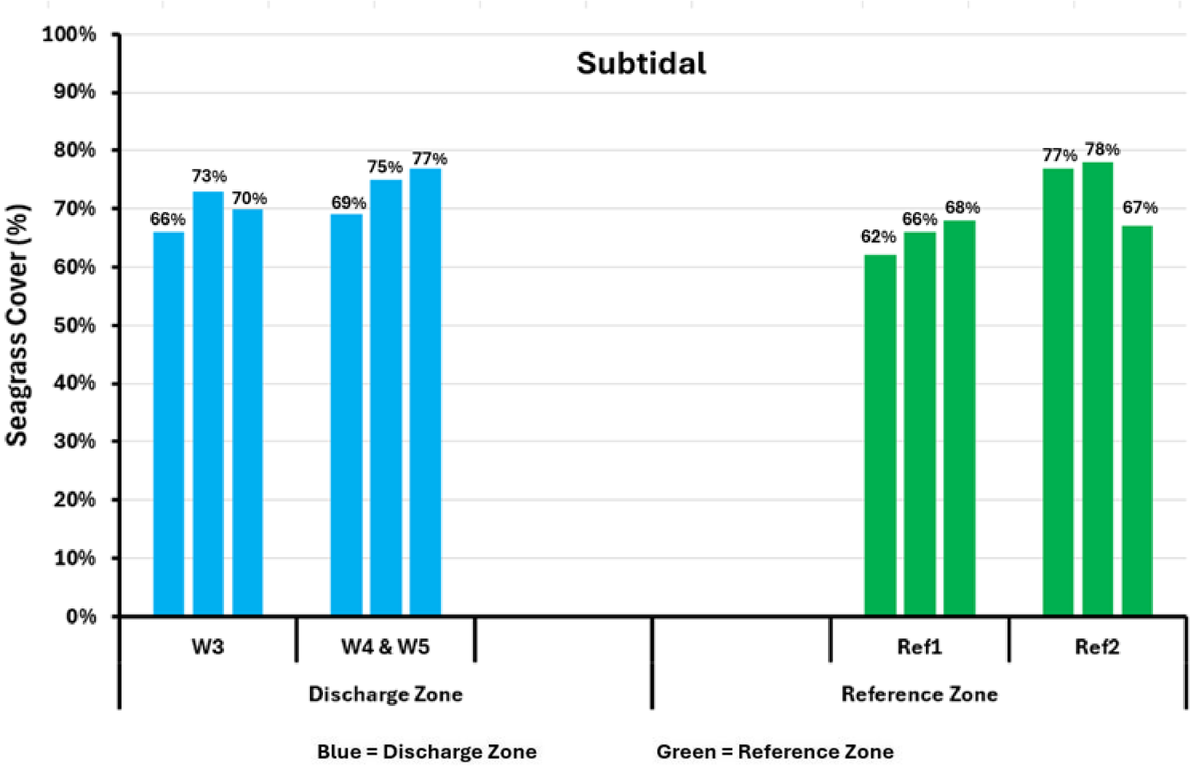
The two-sided t-test is used to determine whether there is a significant difference between the seagrass cover in the two zones. The 6 cover measurements in the discharge zone (Mean = 31, SD = 6.3) were compared to the 6 cover measurements in the reference zone (Mean = 30, SD = 9.3). The two-sided t value is 0.11. The p-value is 0.92. Degrees of freedom = 10. The difference in seagrass cover is not significant at $p < .05$.

The intertidal seagrass in the discharge zone is immersed in the discharge plumes during high tides, but the t-test analysis shows there is no significant effect on seagrass cover – with neither more seagrass or less seagrass. It is concluded that the discharge plumes do not have a significant impact on intertidal seagrass cover.

2.1.2 Subtidal Sites (2023)

Figure 3-18 shows the data for the subtidal seagrass cover measured in the discharge zone (blue columns) and the subtidal seagrass cover measured in the reference zone (green columns). The average seagrass cover in the discharge zone of 72 % is slightly higher than the average seagrass cover in the reference zone of 68 %.

Figure 3-18. Comparison of Cover in Subtidal Discharge and Reference Zones



The two-sided t-test is used to determine whether there is a significant difference between the seagrass cover in the two zones. The 6 cover measurements in the discharge zone (Mean = 72, SD = 4.1) are compared to the 6 cover measurements in the reference zone (Mean = 68, SD = 5.7). The two-sided t value is 1.22. The p-value is 0.25. Degrees of freedom = 10. The difference in seagrass cover is not significant at $p < .05$.

Even though the subtidal seagrass in the discharge zone is in the discharge plumes most of the time, there is no significant change in seagrass cover – with neither more seagrass or less seagrass. It is concluded that the discharge plumes do not have a significant impact on subtidal seagrass cover.

As discussed in Section 3.5.2.1, Hirst et al. (2012) state that seagrass cover may be the most useful proxy for seagrass health under a range of circumstances because it is strongly correlated with seagrass length, stem/shoot density and canopy structure.

3. Comparisons on Hydrodynamic Predictions and Measurements

The Stantec review reported that the marine supplementary report does not sufficiently demonstrate that :

- the most appropriate wind data has been used in the model.

There is insufficient information presented in the report to confirm the adequacy of the model that has been applied. Specific examples include:

- no time series comparisons between measured and modelled currents have been provided.
- the measured temperature profiles appear noisy and unrealistic, indicating that that the measurements collected to support the modelling may be erroneous or require further processing

In response, the text in the supplementary marine report describing the regional model has been updated to highlight the information that was suggested to be missing. The updated text for comparing the hydrodynamic model predictions with tide height, currents and plume length is presented in the following pages.

Figure 4-4 compares frequency distribution of predicted and measured current speeds for the three wind files. There is little difference between the currents predicted by the refined model and measured currents using either the Geelong wind file (as used in the 2022 EES) or the compromise Calmet wind file (as used in the 2024 supplementary marine studies).

A time series comparison of predicted and measured current speeds for was already in the supplementary marine studies report (Figure 4-8). The reviewers must have missed seeing it. The model reproduced the measured current speeds and direction well (and is reproduced on the following page).

The diagram showing measured temperature profiles in the supplementary report showed multiple vertical profiles on the same figure, which gave the appearance of noisy data. This diagram has been changed to show each measured and predicted temperature profile separately, which makes the comparison of predicted and measured vertical profiles easier.

The model provides a detailed representation of the surface layers in 0.5 m layers which meets the Minister's recommendation 2c. It is shown in Chapter 4 of the supplementary report that the model predictions satisfactorily match field measurements of:

1. Tide height over time;
2. Current speed over time;
3. Frequency distribution of current speeds; and
4. Length, width and extent of temperature plumes from the existing discharges;
5. Vertical temperature distribution over the depth.

Section 8 of the supplementary report demonstrates that the distribution of suspended solids predicted by the model from dredging in Corio Bay provides a reasonable match to the reported extent of suspended solids in a previous dredging program in Corio Bay. It is concluded that the model is fit for purpose.

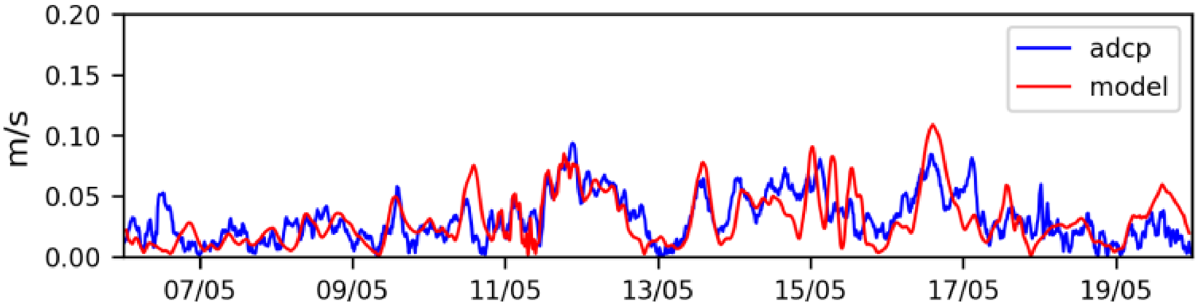
3.1 Comparison of Predicted and Measured Currents

The predicted currents from the refined model with finer horizontal and vertical scales were compared to the ADCP current data collected during the EES. Note that the measured currents are mostly weak, in the range of 0.02 m/s to 0.07 m/s and the accuracy is the ADCP in weak currents is +/- 0.01 m/s.

A comparison between the 1-hour predicted and measured current roses and time series during the summer 2019-2020 ADCP deployment showed that the refined model reproduced the measured current speeds and directions satisfactorily (Hydronumerics, 2024).

As an example, a time series comparison of measured and modelled currents is provided in Figure 4-8. The refined model reproduces the measured current speeds and direction from the winter 2021 ADCP deployment to a satisfactory degree.

Figure 4-8. Comparison of Measured and Modelled Currents



3.2 Selection of the Appropriate Wind File

The wind file preferred for use in the Supplementary was selected from a consideration of: (1) predicted versus measured current speeds; and (2) predicted versus measured temperature contours and extent of temperature plumes.

Figure 4-2 compares the predicted current speed distributions using the three wind files with the measured current speeds (dashed green line) for the northern current meter location. The currents predicted using Calmet winds (purple line) show the best fit to the measured current speeds. The currents predicted using the Geelong winds (blue line) are similar to those for the Calmet winds in the lower half of the range, but slower than the measurements from 3 to 11 cm/s. The currents predicted using the Avalon winds (orange line) result in current speeds substantially higher than the measured currents.

Note that the difference between the predicted currents and measured currents using the Calmet wind file are within 0.01 m/s of the measured currents – which is within the accuracy of the measurement of the current meter of +/-0.01 m/s.

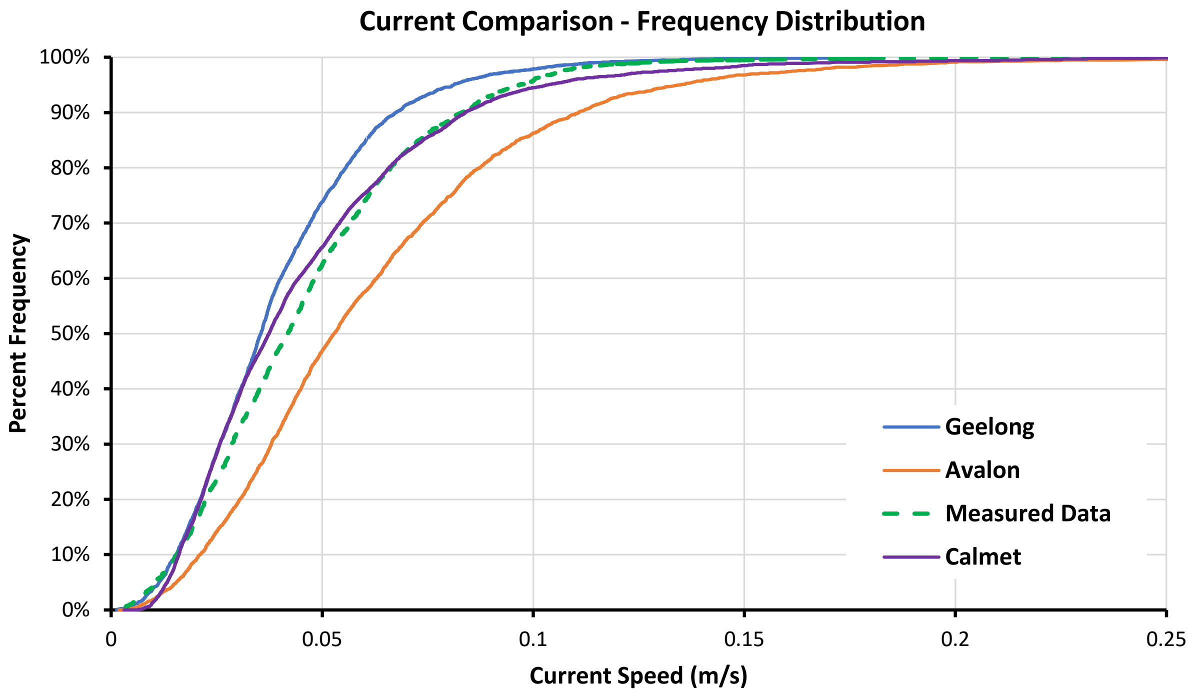


Figure 4-2. Comparison of Predicted and Measured Current Speeds

Figure 4-3 in the supplementary report shows the temperature plumes predicted using the Geelong and Avalon winds; Figure 4-4 shows the chlorine plumes predicted using the Geelong and Avalon winds and Figure 4-5 shows the temperature and chlorine plumes predicted using the Calmet winds. The plumes predicted using the Geelong and Calmet winds are similar while the plumes predicted using the Avalon winds are significantly shorter and weaker.

The plumes predicted using Calmet winds best match the measured plumes, as shown in Section 4-8.

3.3 Time Series Comparison of Measured and Modelled Currents

As noted above, a time series comparison of predicted and measured current speeds for was included in the supplementary marine studies report (as Figure 4-8). The reviewers must have missed seeing it. The model reproduced the measured current speeds and direction well (and is reproduced in Section 3-1 of this response).

3.4 Comparison of Predicted and Measured Temperature Profiles

The noise in the plotted vertical temperature profiles was caused by (1) multiple profiles on the same plot and (2) movement of the vessel when taking measurements caused a spread of temperature values. Extra processing has removed the spread, and the vertical profiles are now presented individually.

Vertical temperature profiles were measured in the discharge plumes during the field studies. A comparison of the measured vertical profiles with the predicted vertical profiles in the plume from the W1 discharge is shown in Figure 4-9. At Site 8, near the mouth of the W1 discharge, the plume occupies the water depth of 1.6 m with a relatively uniform temperature distribution at 5.3°C above ambient. The model predicts a very similar temperature and vertical profile.

At Site 11, in deeper water further from the discharge, the buoyant plume has lifted off the seabed and is spreading as a thin (0.5 m deep) layer at 3°C above ambient. At Site 16, in 3 m deep water even further from the discharge, the buoyant plume has lifted off the seabed and is spreading as a thin (0.5 m deep) layer at 2°C above ambient. The model predicts very similar temperature levels and vertical profiles.

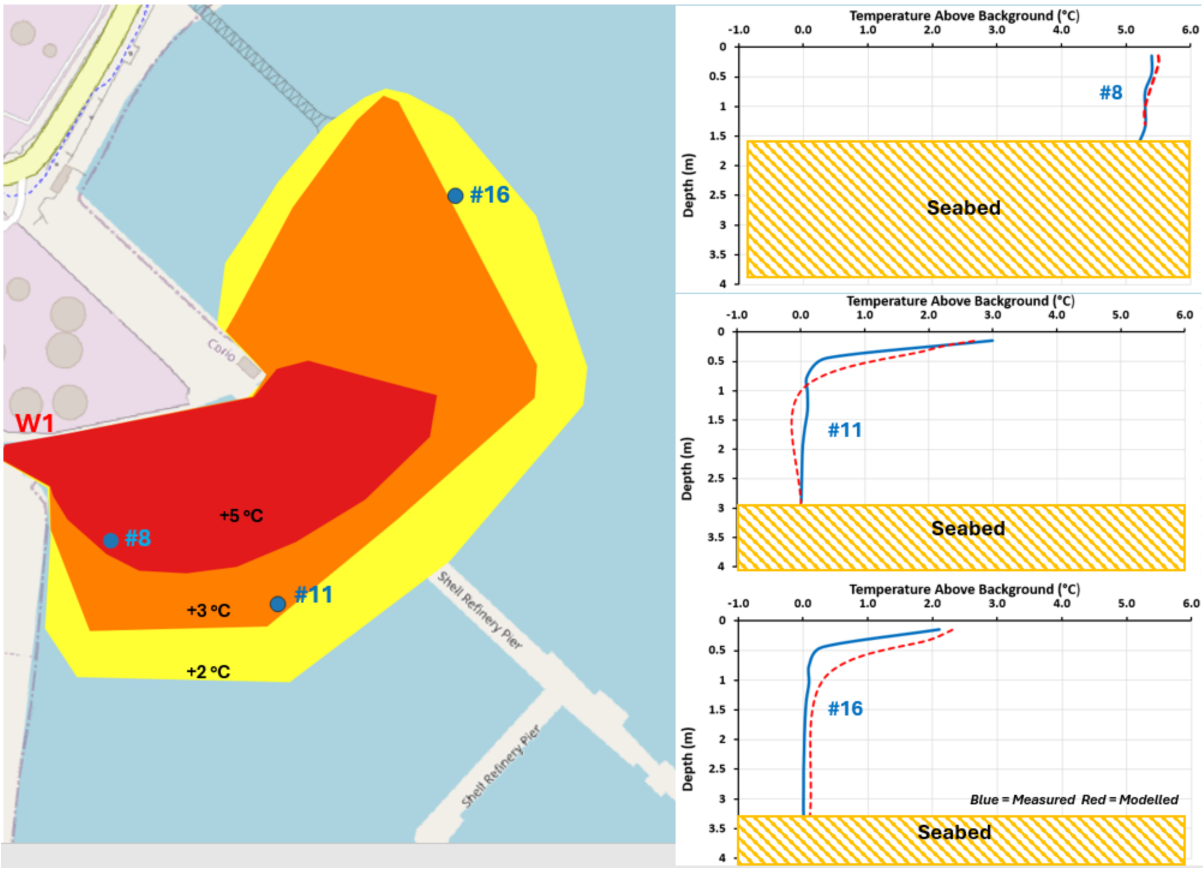


Figure 1-9 Measured Temperature Profiles Offshore from W1

A comparison of the measured vertical profiles with the predicted vertical profiles in the plume from the W4 and W5 discharges is shown in Figure 4-10. This plume remains in shallow water near the shoreline, and the plume occupies the layer at a relatively uniform temperature. The model predicts the temperature at 0.25 m and 0.75 m depth, which allows the vertical temperature distribution of the plume to be seen.

At Site 24, near the W5 discharge, the plume occupies the water depth of 1 m with a relatively uniform temperature distribution at 5^{o}C above ambient. The model predicts a similar temperature and vertical profile.

Similar vertical profiles are apparent further north at Site 25, where the temperature rise is about 3^{o}C and there is a slight vertical variation. Further south at Site 22, the plume is in 0.7 m water depth, at around 4.7^{o}C above ambient, with a small temperature decrease with depth. At Site 19, the plume is in 1.2 m water depth, at around 2.8^{o}C above ambient, with a small temperature decrease with depth. The model predicts very similar temperature levels and vertical profiles.

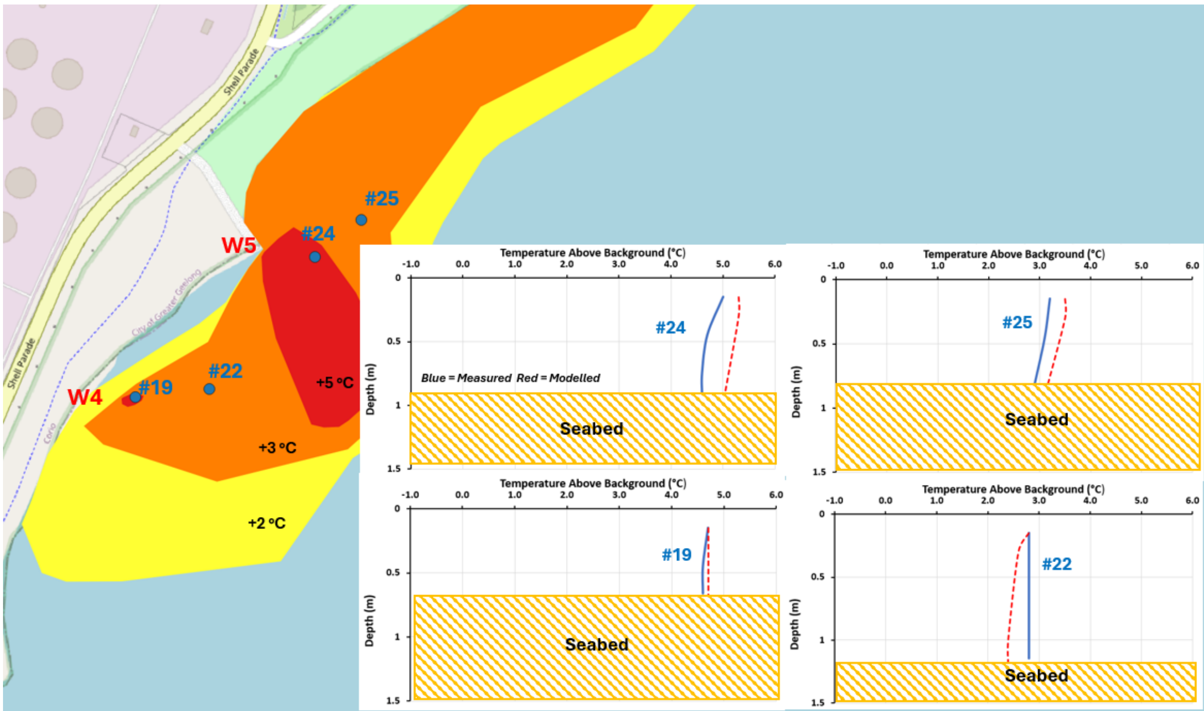


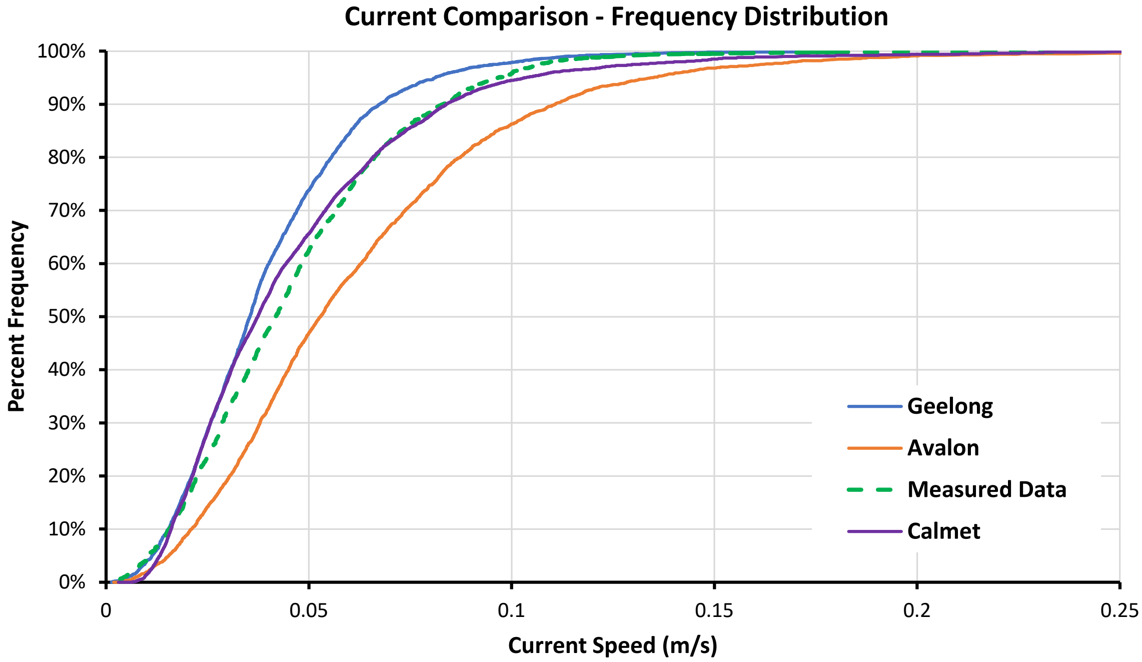
Figure 1-10 Simulated Vertical Temperature Gradients Offshore from W1

The measured plumes indicate that the thermal plumes (to 2^{o}C above ambient) extend from the discharge points up to approximately 300 m offshore and 500 to 600 m along the shoreline. Typically, the plumes travel alongshore to the north with the prevailing currents, and are trapped in shallow waters so that the mixing of the plume is inhibited, leading to an elongation to the north.

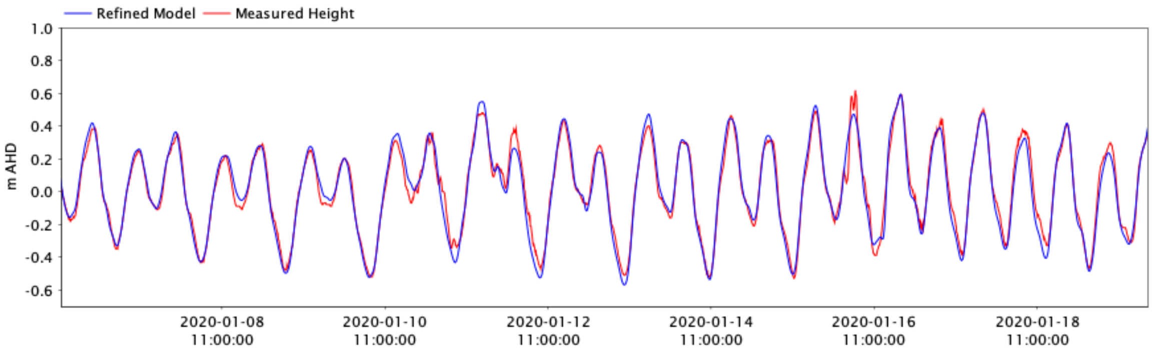
4. Summary of Comparison of Predictions with Measurements

The model predictions satisfactorily match field measurements of:

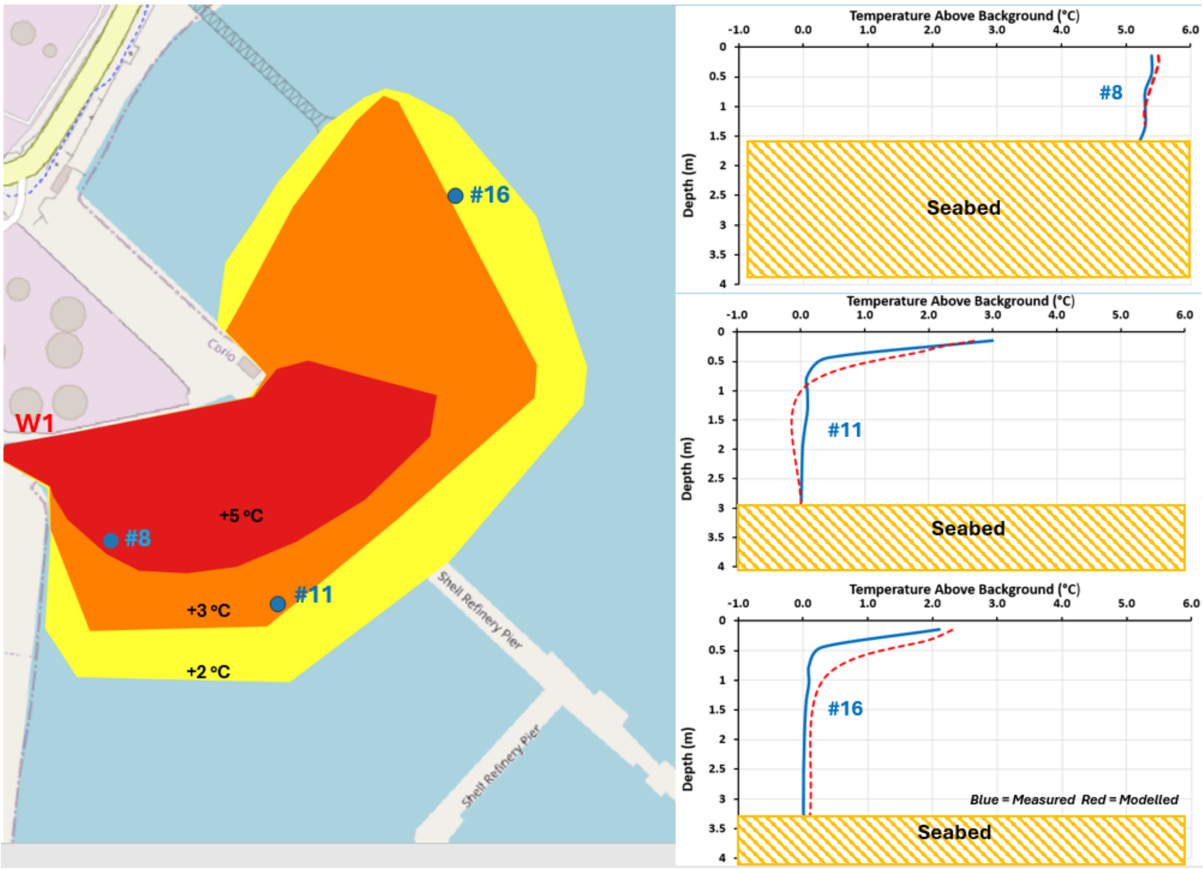
1. Frequency distribution of current speeds;



2. Tide height over time

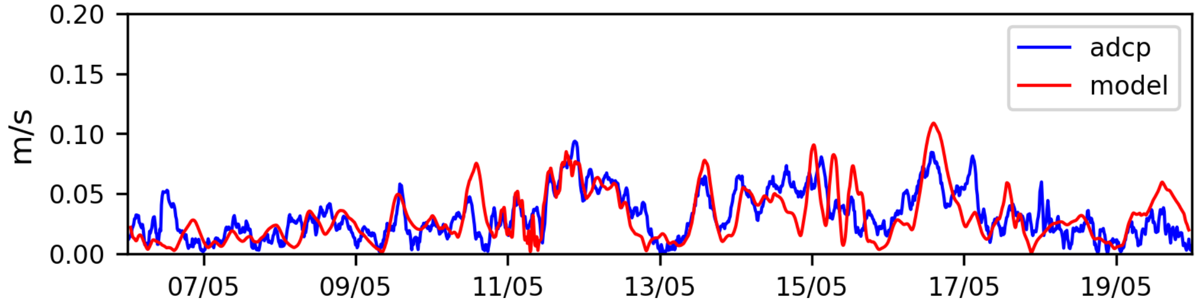


3. Vertical temperature distribution over the depth



Measured temperature profiles are in blue; Predicted profiles are in red

4. Current speed over time



5. Length, width and extent of temperature plumes

Figure 4-11 shows the 2023 temperature measurements in the existing plumes and Figure 4-12 shows the thermal plumes simulated by the model under comparable conditions. Both were generated with the same tide and wind conditions in the model as during the day of field measurements. Plumes were measured as described in Section 3.4.

The comparison of the sets of images illustrate that the model reproduces plumes similar to the observed shape, temperature difference and extent of the plumes along the refinery shoreline.

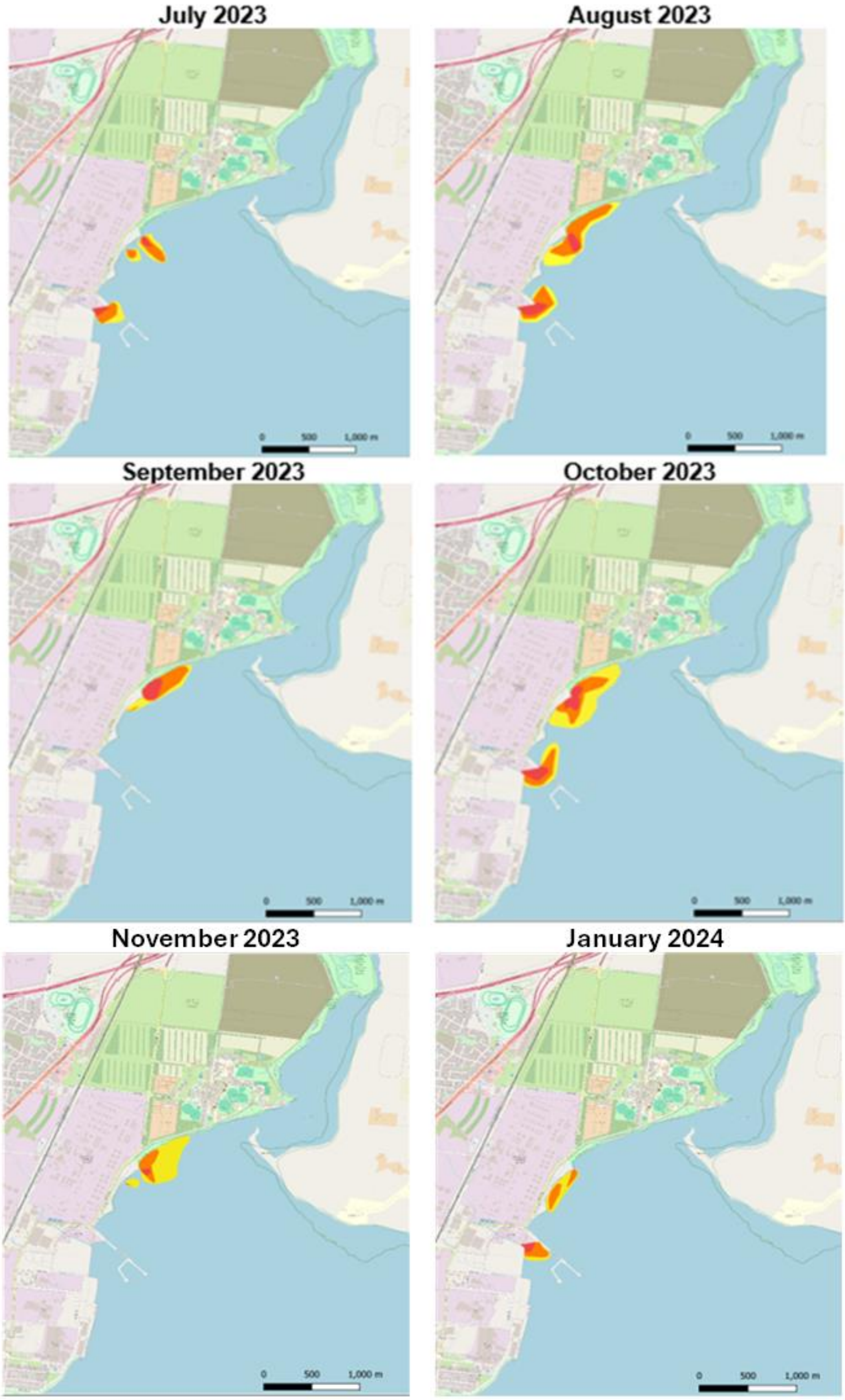


Figure 4-11. Measured Plume Temperature Contours – July 2023 to Jan 2024

(Red = +5°C, Orange = +3°C, Yellow = +2°C) – Source: CEE 2024

Note: Contours show increment above ambient

Figure 1-1. Predicted Temperature Plumes Using Refined Model

Table 4-3 shows the average area of each of the temperature contours for the measured plumes and modelled plumes. The table shows that both the measured and modelled temperature plumes are similar in size with the measured 2 and 3 degree plumes being slightly bigger in the measurements and the 5 degree contour being slightly bigger in the model.

Table 4-3. Average Measured and Modelled Plume Area

Plume Type	+2°C	+3°C	+5°C
Measured	20 ha	12 ha	3 ha
Modelled	18 ha	10 ha	5 ha

Overall, the refined model is fit for the purpose of predicting the extent of plumes from the refinery discharges.

Appendix B – Native vegetation removal report

Native vegetation removal report

This report provides information to support an application to remove, destroy or lop native vegetation in accordance with the *Guidelines for the removal, destruction or lopping of native vegetation*. The report **is not an assessment by DELWP** of the proposed native vegetation removal. Native vegetation information and offset requirements have been determined using spatial data provided by the applicant or their consultant.

Date of issue: **29/08/2024**
Time of issue: **12:47 pm**

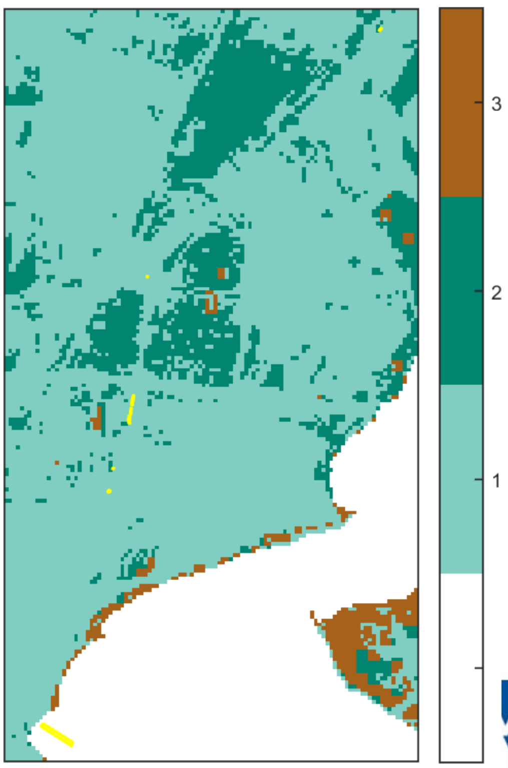
Report ID: ACM_2024_019

Project ID	Aecom60642423_VegLoss_VG94_20240827

Assessment pathway

Assessment pathway	**Detailed Assessment Pathway**
Extent including past and proposed	0.603 ha
Extent of past removal	0.000 ha
Extent of proposed removal	0.603 ha
No. Large trees proposed to be removed	0
Location category of proposed removal	Location 2 The native vegetation is in an area mapped as an endangered Ecological Vegetation Class (as per the statewide EVC map); and a wetland designated under the Convention on Wetlands of International Importance (the Ramsar Convention); and a wetland listed in the Directory of Important Wetlands of Australia; and an internationally important site for Migratory Shorebirds of the East Asian-Australasian Flyway. Removal of less than 0.5 hectares of native vegetation in this location will not have a significant impact on any habitat for a rare or threatened species.

1. Location map



Offset requirements if a permit is granted

Any approval granted will include a condition to obtain an offset that meets the following requirements:

General offset amount[1]	0.401 general habitat units
Vicinity	Corangamite Catchment Management Authority (CMA) or Greater Geelong City, Unknown Council
Minimum strategic biodiversity value score[2]	0.222
Large trees	0 large trees

NB: values within tables in this document may not add to the totals shown above due to rounding

Appendix 1 includes information about the native vegetation to be removed

Appendix 2 includes information about the rare or threatened species mapped at the site.

Appendix 3 includes maps showing native vegetation to be removed and extracts of relevant species habitat importance maps

1 The general offset amount required is the sum of all general habitat units in Appendix 1.

2 Minimum strategic biodiversity score is 80 per cent of the weighted average score across habitat zones where a general offset is required

Next steps

Any proposal to remove native vegetation must meet the application requirements of the Detailed Assessment Pathway and it will be assessed under the Detailed Assessment Pathway.

If you wish to remove the mapped native vegetation you are required to apply for a permit from your local council. Council will refer your application to DELWP for assessment, as required. **This report is not a referral assessment by DELWP.**

This *Native vegetation removal report* must be submitted with your application for a permit to remove, destroy or lop native vegetation.

Refer to the *Guidelines for the removal, destruction or lopping of native* vegetation (the Guidelines) for a full list of application requirements This report provides information that meets the following application requirements:

- The assessment pathway and reason for the assessment pathway
- A description of the native vegetation to be removed (partly met)
- Maps showing the native vegetation and property (partly met)
- Information about the impacts on rare or threatened species.
- The offset requirements determined in accordance with section 5 of the Guidelines that apply if approval is granted to remove native vegetation.

Additional application requirements must be met including:

- Topographical and land information
- Recent dated photographs
- Details of past native vegetation removal
- An avoid and minimise statement
- A copy of any Property Vegetation Plan that applies
- A defendable space statement as applicable
- A statement about the Native Vegetation Precinct Plan as applicable
- A site assessment report including a habitat hectare assessment of any patches of native vegetation and details of trees
- An offset statement that explains that an offset has been identified and how it will be secured.

Appendix 1: Description of native vegetation to be removed

The species-general offset test was applied to your proposal. This test determines if the proposed removal of native vegetation has a proportional impact on any rare or threatened species habitats above the species offset threshold. The threshold is set at 0.005 per cent of the mapped habitat value for a species. When the proportional impact is above the species offset threshold a species offset is required. This test is done for all species mapped at the site. Multiple species offsets will be required if the species offset threshold is exceeded for multiple species.

Where a zone requires species offset(s), the species habitat units for each species in that zone is calculated by the following equation in accordance with the Guidelines:

Species habitat units = extent x condition x species landscape factor x 2, where the species landscape factor = 0.5 + (habitat importance score/2)

The species offset amount(s) required is the sum of all species habitat units per zone

Where a zone does not require a species offset, the general habitat units in that zone is calculated by the following equation in accordance with the Guidelines:

General habitat units = extent x condition x general landscape factor x 1.5, where the general landscape factor = 0.5 + (strategic biodiversity value score/2)

The general offset amount required is the sum of all general habitat units per zone.

Native vegetation to be removed

Information provided by or on behalf of the applicant in a GIS file							Information calculated by EnSym					
Zone	**Type**	**BioEVC**	**BioEVC conservation status**	**Large tree(s)**	**Partial removal**	**Condition score**	**Polygon Extent**	**Extent without overlap**	**SBV score**	**HI score**	**Habitat units**	**Offset type**
1-CS	Patch	vvp_0302	Endangered	0	no	0.800	0.504	0.504	0.260		0.381	General
2-HZ1	Patch	vvp_0132	Endangered	0	no	0.160	0.007	0.007	0.470		0.001	General
3-HZ8	Patch	vvp_0132	Endangered	0	no	0.160	0.001	0.001	0.250		0.000	General
4-HZ17	Patch	vvp_0132	Endangered	0	no	0.200	0.035	0.035	0.470		0.008	General
5-HZ16	Patch	vvp_0132	Endangered	0	no	0.200	0.009	0.009	0.470		0.002	General
6-HZ15	Patch	vvp_0132	Endangered	0	no	0.200	0.031	0.031	0.270		0.006	General
7-HZ20	Patch	vvp_0132	Endangered	0	no	0.200	0.002	0.002	0.270		0.000	General
8-HZ25	Patch	vvp_0132	Endangered	0	no	0.200	0.013	0.013	0.250		0.002	General

Appendix 2: Information about impacts to rare or threatened species' habitats on site

This table lists all rare or threatened species' habitats mapped at the site.

Species common name	Species scientific name	Species number	Conservation status	Group	Habitat impacted	% habitat value affected
Prickly Arrowgrass	*Triglochin mucronata*	503447	Rare	Dispersed	Habitat importance map	0.0000
Small Golden Moths	*Diuris basaltica*	501473	Endangered	Dispersed	Habitat importance map	0.0000
Heath Spear-grass	*Austrostipa exilis*	503984	Rare	Dispersed	Habitat importance map	0.0000
Melbourne Yellow-gum	*Eucalyptus leucoxylon subsp. connata*	504484	Vulnerable	Dispersed	Habitat importance map	0.0000
Basalt Podolepis	*Podolepis linearifolia*	504658	Endangered	Dispersed	Habitat importance map	0.0000
Button Wrinklewort	*Rutidosis leptorhynchoides*	502982	Endangered	Dispersed	Habitat importance map	0.0000
Large-headed Fireweed	*Senecio macrocarpus*	503116	Endangered	Dispersed	Habitat importance map	0.0000
Spiny Rice-flower	*Pimelea spinescens subsp. spinescens*	504823	Endangered	Dispersed	Habitat importance map	0.0000
Plump Swamp Wallaby-grass	*Amphibromus pithogastrus*	503624	Endangered	Dispersed	Habitat importance map	0.0000
Brackish Plains Buttercup	*Ranunculus diminutus*	504314	Rare	Dispersed	Habitat importance map	0.0000
Small Scurf-pea	*Cullen parvum*	502773	Endangered	Dispersed	Habitat importance map	0.0000
Snowy Mint-bush	*Prostanthera nivea var. nivea*	502746	Rare	Dispersed	Habitat importance map	0.0000
Tough Scurf-pea	*Cullen tenax*	502776	Endangered	Dispersed	Habitat importance map	0.0000
Matted Flax-lily	*Dianella amoena*	505084	Endangered	Dispersed	Habitat importance map	0.0000
Pale-flower Crane's-bill	*Geranium sp. 3*	505344	Rare	Dispersed	Habitat importance map	0.0000
Rye Beetle-grass	*Tripogon loliiformis*	503455	Rare	Dispersed	Habitat importance map	0.0000
Arching Flax-lily	*Dianella sp. aff. longifolia (Benambra)*	505560	Vulnerable	Dispersed	Habitat importance map	0.0000
Pale Swamp Everlasting	*Coronidium gunnianum*	504655	Vulnerable	Dispersed	Habitat importance map	0.0000

Rosemary Grevillea	*Grevillea rosmarinifolia subsp. rosmarinifolia*	504066	Rare	Dispersed	Habitat importance map	0.0000
Branching Groundsel	*Senecio cunninghamii var. cunninghamii*	503104	Rare	Dispersed	Habitat importance map	0.0000
Velvet Daisy-bush	*Olearia pannosa subsp. cardiophylla*	502317	Vulnerable	Dispersed	Habitat importance map	0.0000
Small Milkwort	*Comesperma polygaloides*	500798	Vulnerable	Dispersed	Habitat importance map	0.0000
Cane Spear-grass	*Austrostipa breviglumis*	503268	Rare	Dispersed	Habitat importance map	0.0000
Dwarf Brooklime	*Gratiola pumilo*	503753	Rare	Dispersed	Habitat importance map	0.0000
Waterbush	*Myoporum montanum*	502240	Rare	Dispersed	Habitat importance map	0.0000
Hairy Tails	*Ptilotus erubescens*	502825	Vulnerable	Dispersed	Habitat importance map	0.0000
Buloke Mistletoe	*Amyema linophylla subsp. orientalis*	500217	Vulnerable	Dispersed	Habitat importance map	0.0000
Buloke	*Allocasuarina luehmannii*	500678	Endangered	Dispersed	Habitat importance map	0.0000
Large-flower Crane's-bill	*Geranium sp. 1*	505342	Endangered	Dispersed	Habitat importance map	0.0000
Dark Wire-grass	*Aristida calycina var. calycina*	503630	Rare	Dispersed	Habitat importance map	0.0000
Clover Glycine	*Glycine latrobeana*	501456	Vulnerable	Dispersed	Habitat importance map	0.0000

Habitat group

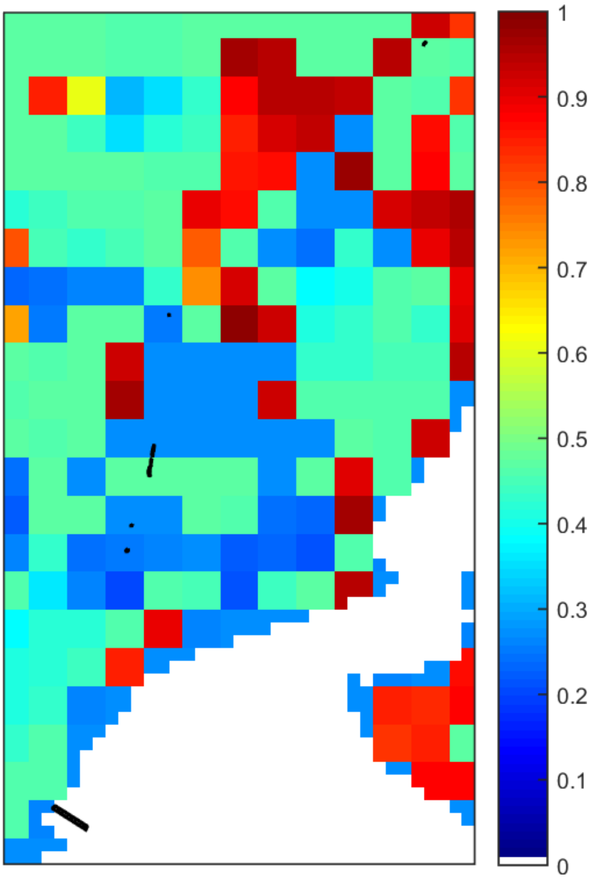
- Highly localised habitat means there is 2000 hectares or less mapped habitat for the species
- Dispersed habitat means there is more than 2000 hectares of mapped habitat for the species

Habitat impacted

- Habitat importance maps are the maps defined in the Guidelines that include all the mapped habitat for a rare or threatened species
- Top ranking maps are the maps defined in the Guidelines that depict the important areas of a dispersed species habitat, developed from the highest habitat importance scores in dispersed species habitat maps and selected VBA records
- Selected VBA record is an area in Victoria that represents a large population, roosting or breeding site etc.

Appendix 3 – Images of mapped native vegetation

2. Strategic biodiversity values map



3. Aerial photograph showing mapped native vegetation

4. Map of the property in context

Yellow boundaries denote areas of proposed native vegetation removal.

Appendix C – Native vegetation credit register report

Report of available native vegetation credits

This report lists native vegetation credits available to purchase through the Native Vegetation Credit Register.

This report is **not evidence** that an offset has been secured. An offset is only secured when the units have been purchased and allocated to a permit or other approval and an allocated credit extract is provided by the Native Vegetation Credit Register.

Date and time: 29/08/2024 01:16 **Report ID: 26158**

What was searched for?

General offset

General habitat units	Strategic biodiversity value	Large trees	Vicinity (Catchment Management Authority or Municipal district)	
0.401	0.222	0	CMA	Corangamite
			or LGA	Greater Geelong City

Details of available native vegetation credits on 29 August 2024 01:16

These sites meet your requirements for general offsets.

Credit Site ID	GHU	LT	CMA	LGA	Land owner	Trader	Fixed price	Broker(s)
BBA-0114	0.536	180	Corangamite	Colac Otway Shire	Yes	Yes	No	VegLink
BBA-0126	0.760	6	Corangamite	Moorabool Shire	Yes	Yes	No	Contact NVOR
BBA-2252	164.160	0	Corangamite	Colac Otway Shire	No	Yes	No	Contact NVOR
VC_CFL-3080_01	4.661	94	Corangamite	Golden Plains Shire	Yes	Yes	No	Bio Offsets
VC_CFL-3697_01	18.297	0	Corangamite	Golden Plains Shire	Yes	Yes	No	Bio Offsets
VC_CFL-3699_01	1.741	40	Corangamite	Colac Otway Shire	Yes	Yes	No	Contact NVOR
VC_CFL-3699_01	2.457	0	Corangamite	Colac Otway Shire	No	Yes	No	Bio Offsets
VC_CFL-3718_01	7.631	900	Corangamite	Corangamite Shire	Yes	Yes	No	Bio Offsets
VC_CFL-3739_01	5.605	276	Corangamite	Colac Otway Shire	Yes	Yes	No	Bio Offsets
VC_CFL-3786_01	0.402	528	Corangamite	Corangamite Shire	Yes	Yes	No	VegLink
VC_CFL-3787_01	9.579	895	Corangamite	Colac Otway Shire	Yes	Yes	No	VegLink

VC_CFL-3798_01	1.944	225	Corangamite	Colac Otway Shire	Yes	Yes	No	VegLink
VC_CFL-3812_01	21.115	4760	Corangamite	Colac Otway Shire	Yes	Yes	No	VegLink

These sites meet your requirements using alternative arrangements for general offsets.

Credit Site ID	GHU	LT	CMA	LGA	Land owner	Trader	Fixed price	Broker(s)

There are no sites listed in the Native Vegetation Credit Register that meet your offset requirements when applying the alternative arrangements as listed in section 11.2 of the Guidelines for the removal, destruction or lopping of native vegetation.

These potential sites are not yet available, land owners may finalise them once a buyer is confirmed.

Credit Site ID	GHU	LT	CMA	LGA	Land owner	Trader	Fixed price	Broker(s)

There are no potential sites listed in the Native Vegetation Credit Register that meet your offset requirements.

LT - Large Trees *CMA - Catchment Management Authority* *LGA - Municipal District or Local Government Authority*

Next steps

If applying for approval to remove native vegetation
Attach this report to an application to remove native vegetation as evidence that your offset requirement is currently available.

If you have approval to remove native vegetation
Below are the contact details for all brokers. Contact the broker(s) listed for the credit site(s) that meet your offset requirements. These are shown in the above tables. If more than one broker or site is listed, you should get more than one quote before deciding which offset to secure.

Broker contact details

Broker Abbreviation	Broker Name	Phone	Email	Website
Abezco	Abzeco Pty. Ltd.	(03) 9431 5444	offsets@abzeco.com.au	www.abzeco.com.au
Baw Baw SC	Baw Baw Shire Council	(03) 5624 2411	bawbaw@bawbawshire.vic.gov.au	www.bawbawshire.vic.gov.au
Bio Offsets	Biodiversity Offsets Victoria	0452 161 013	info@offsetsvictoria.com.au	www.offsetsvictoria.com.au
Contact NVOR	Native Vegetation Offset Register	136 186	nativevegetation.offsetregister@delwp.vic.gov.au	www.environment.vic.gov.au/native-vegetation
Ecocentric	Ecocentric Environmental Consulting	0410 564 139	ecocentric@me.com	Not avaliable
Ethos	Ethos NRM Pty Ltd	(03) 5153 0037	offsets@ethosnrm.com.au	www.ethosnrm.com.au
Nillumbik SC	Nillumbik Shire Council	(03) 9433 3316	offsets@nillumbik.vic.gov.au	www.nillumbik.vic.gov.au
TFN	Trust for Nature	8631 5888	offsets@tfn.org.au	www.trustfornature.org.au
VegLink	Vegetation Link Pty Ltd	(03) 8578 4250 or 1300 834 546	offsets@vegetationlink.com.au	www.vegetationlink.com.au
Yarra Ranges SC	Yarra Ranges Shire Council	1300 368 333	biodiversityoffsets@yarraranges.vic.gov.au	www.yarraranges.vic.gov.au

For more information contact the DEECA Customer Service Centre 136 186 or the Native Vegetation Credit Register at nativevegetation.offsetregister@delwp.vic.gov.au

VIVA Energy Australia