ART GALLERY OF NSW TRUST

# Art gallery of NSW Expansion - Sydney Modern Project, Seawater Heat Exchange System

MARINE IMPACT ASSESSMENT

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## MARINE IMPACT ASSESSMENT

**Art Gallery of NSW Trust**

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# ABBREVIATIONS

| | |
|---|---|
| AHD | Australian Height Datum |
| ANZECC | Australian and New Zealand Environment Conservation Council |
| ASS | Acid sulphate soils |
| dB | Decibel |
| EAC | Eastern Australian current |
| EIS | Environmental Impact Statement |
| EP&A Act | NSW *Environmental Planning and Assessment Act 1979* |
| EPBC Act | Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* |
| EPI | Environmental Planning Instrument |
| EPL | Environmental protection licence |
| ESD | Ecologically sustainable development |
| FM Act | NSW *Fisheries Management Act 1994* |
| KTP | Key threatening process |
| LAT | Lowest astronomical tide |
| mm | Millimetre (distance) |
| MNES | Matter of national environmental significance |
| $ms^{-1}$ | Metre per second (speed) |
| NSW EPA | NSE Environment Protection Authority |
| NSW OEH | NSW Office of Environment and Heritage |
| $^{o}C$ | Degrees Celsius |
| ppt | Parts per thousand |
| PSU | Practical salinity units |
| re: µPa | Sound exposure level (measured in micro pascal (pressure)) |
| SEARs | Secretary’s Environmental Assessment Requirements |
| TSC Act | NSW *Threatened Species Conservation Act 1995* |
| WQO | Water quality objectives |

# EXECUTIVE SUMMARY

## The proposal

The Art Gallery of NSW proposes to undertake a major expansion of the existing art gallery adjacent to the Phillip Precinct of the Domain. The expansion, proposed as a separate, stand-alone building, is located north of the existing gallery, partly extending over the Eastern Distributor land bridge and includes a disused Navy fuel bunker located to the north east of this land bridge.

The new building comprises a new entry plaza, new exhibition spaces, shop, food and beverage facilities, visitor amenities, art research and education spaces, new roof terraces and landscaping and associated site works and infrastructure, including loading and service areas, services infrastructure and an ancillary seawater heat exchange system.

The proposal also includes a district (building-wide) cooling system. The system would involve seawater being pumped from Sydney Harbour and transferred to a heat exchange where it would be used to cool condensed warm ambient air from within the gallery therefore providing district cooling. Once the exchange has occurred, the seawater would be discharged back into the harbour.

The system works by there being a regular flow of water through the heat exchange. Through this process, the seawater temperature used in the cooling process can increase by up to seven degrees Celsius. It is therefore important to ensure that the returned seawater would have no physical, chemical or ecological impact on the marine environment of Sydney Harbour. This report assesses this risk in the context of the proposal.

Under the concept design, the proposal would be to intake seawater from, and discharge it to, Woolloomooloo Bay via a series of pipes that would be between 30 and 50 metres apart and located about three metres above the seabed.

The inlet pipes would be installed opposite the end of the Lincoln Crescent wharf and the outlet pipes would be located off the nearby boardwalk. The inlet pipes would be located about 60 metres off the shoreline while the outlet pipes would be located about 35 metres off the shoreline.

To prevent biofouling (the clogging of the pipes), the system would be regularly cleaned (flushed) with fresh (collected rain) water that would be discharged to Woolloomooloo Bay via the same pipes as the seawater. The system would also be occasionally flushed using an amine-based biocide. It is anticipated that chemical flushing would take place once per year.

The cooling demand of the gallery would vary over the course of a day, week and across the seasons. Typically, there would be greatest demand on the system during the summer months across the middle of the day. Also, there would be more demand on the system when the gallery is busy as people generate mass thermal heat. As such, the system has a maximum operational demand, which, along with a range of other seasonal conditions, has been adopted in the modelling to ensure the assessment is conservative. This maximum operational demand is likely to only occur for short periods during the day in February, which is typically the hottest month when the gallery receives high visitor numbers. For the other months, it is estimated that the system would typically operate at about:

- 80 per cent of its maximum operational demand during the summer months.
- 60 per cent of its maximum operational demand during the autumn and spring months.
- Between 20 and 40 per cent of its maximum operational demand during the winter months.

## Legislation and guidelines

The following legislation, guidelines and environmental planning instruments have been considered in this impact assessment:

- NSW *Maritime Services Act 1935* (as amended)
- NSW *Environmental Planning and Assessment Act 1979*
- NSW *Fisheries Management Act 1994*
- NSW *Threated Species Conservation Act 1995**
- NSW *Contaminated Land Management Act 1997*
- NSW *Protection of the Environment Operations Act 1997 (as amended)*
- NSW *Marine Safety Act 1998*
- Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
- NSW *Pesticides Act 1999*
- Guidelines for Marine and Fresh Water Ecology 2000 (commonly referred to as the ANZECC guidelines), including the supporting fresh and marine water quality objectives
- Sydney Regional Environmental Plan (Sydney Harbour Catchment) 2005
- NSW *Marine Pollution Act 2012*
- NSW Ports and Maritime Administration Regulation 2012
- NSW Marine Safety Regulation 2016.

Note: the NSW *Threatened Species Conservation Act 1995* is currently being repealed and replaced by the NSW *Biodiversity Conservation Act 2016*. Despite this, the provisions of the repealed Act remain for any proposed development that is currently in the planning system, as is the case for this proposal.

## Existing environment

Sydney Harbour receives high volumes of runoff from the surrounding heavily-developed urban environment. Despite this, it supports several ecological communities and endangered and migratory species (Sydney Harbour Catchment Water Quality Improvement Plan, WaterNSW, 2010).

### WATER QUALITY

The State Government has developed water quality objectives (WQOs) for each catchment in NSW. These objectives were adopted following public consultation in 1998 (NSW DEC, 2006). The Sydney Harbour WQOs are to protect:

- Aquatic ecosystems
- Visual amenity
- Primary and secondary contact recreation
- Aquatic food production (aquaculture).

## BATHYMETRY

The seabed around Woolloomooloo Bay is between 11 and 12 metres below the surface at low-tide. This gives way to shallow sandstone platforms that outcrop up to five metres from the shoreline. In these locations, the seabed is between one and four metres below the surface at low-tide.

## CURRENTS AND CIRCULATION

While no tide, current or gauge data were obtained in Woolloomooloo Bay, it is understood that there is a net current flow towards Sydney Heads due to stormwater runoff from the land in combination with seaward movement of groundwater. This would mean that over any tidal cycle there would be a very small (likely about 0.01 $ms^{-1}$) net current towards the heads. A conservative assumption has been made in the modelling assessment that assumes that there is no ambient current. However in reality, the movement of the current, tides and wind action would help mixing.

## TEMPERATURE CONDITIONS

The average summer water temperature range is between 22.4 and 24.1 degrees Celsius, while the average high and low temperatures across the remaining months varies between 15.8 and 24.3 degrees Celsius.

## MARINE ECOLOGY

The intertidal habitat close to the proposed inlet and outlet pipes comprises vegetated boulders and a sand and sandstone bedrock outcrop at the base of a steep vegetated cliff. The intertidal area is backed by a sandstone block seawall, which features a 35-metre-long wooden boardwalk that extends over the intertidal rock and sand habitat.

The nearest protected area to the proposal footprint is a section of intertidal shoreline about 180 metres long extending from near the seaward-most pontoon of the jetties on the western shoreline of Woolloomooloo Bay. At its closest, it is about 70 metres to the north of the limit of the proposal footprint.

The protected area is designated under Sydney Regional Environmental Plan (Sydney Harbour Catchment) 2005 as a wetland. However, as observed in May 2016 and reconfirmed in October 2017, the area contains no significant wetland habitat features such as mangroves or saltmarsh plants or associated habitat or communities. No seagrass is mapped in Woolloomooloo Bay (NSW Department of Primary Industries (Fisheries), 2005) and none was observed within the protected area or elsewhere within Woolloomooloo Bay in 2016 and 2017.

The inlet and outlet pipes would run in parallel through the seawall and cross the intertidal area before dropping-off the ridge line.

## THREATENED SPECIES

Table ES-1 lists the threatened marine species and seabirds that occur locally. Following an assessment and supporting site walkover, it was concluded that there was a low-to-negligible potential for Woolloomooloo Bay to provide supporting key habitat for any of these species. The main reason for this is that the habitat needed for these species, such as well-developed seagrass beds (habitat for seahorses and their allies and feeding grounds for turtles) and open sandy beaches (nesting habitats for some threatened shorebirds and turtles) are absent, minimal or have been largely replaced by artificial structures.

**Table ES-1 State and Commonwealth-protected threatened species**

| COMMON NAME | SUMMARY |
|---|---|

| | |
|---|---|
| **Fish** | Four species, one endangered population of fish, and up to 23 species of seahorses (syngnathiforme) |
| **Marine mammals** | Six species |
| **Marine turtles** | Five species |
| **Birds** | 26 species and one population of birds |
| **Ecological communities/population** | The seagrass *Posidonia australis* meadows of the Manning-Hawkesbury ecoregion and populations in Port Hacking, Botany Bay, Sydney Harbour, Pittwater, Brisbane Waters and Lake Macquarie. |

## Environmental impacts, mitigation and monitoring

Then impact assessment has considered the impacts on the marine environment from building and operating the seawater heat exchange.

The main potential impacts associated with:

- Building the proposal are physical, and relate to the disturbance to the ecology of the foreshore and the seabed.
- Operating the seawater heat exchange are physiochemical, and relate to changes in the ambient water temperate and the release of biocides.

The conclusion of the impact assessment is that all potential impacts can be adequately managed and mitigated to acceptable levels so that they would have no material residual effect on the marine environment.

Table ES-2 summarises the potential environmental impacts and proposed mitigation and monitoring measures.

**Table ES.2 Potential environmental impacts and proposed mitigation and monitoring measures**

| POTENTIAL IMPACT | PROPOSED MITIGATION AND MONITORING MEASURES |
|---|---|
| **Construction** | |
| Possible risk of accidental spills when carrying out the installation work. | Prepare a spill management plan (SMP) as part of the construction environmental management plan (CEMP), which should describe:<br>→ The limitations, controls and methods to manage and control spills.<br>→ The protocols for reporting spills, the immediate actions to stop work, and the controls to prevent dispersion.<br>→ The need for regular inspections while the work is taking place.<br>→ The need for regular equipment maintenance during construction.<br>→ The need to keep, and ensure the safe disposal of, spill containment provisions/kits.<br>→ The need for staff to be training in spill management. |

| POTENTIAL IMPACT | PROPOSED MITIGATION AND MONITORING MEASURES |
|---|---|
| | To further minimise the risk of spills, ensure that:<br>→ Only biodegradable oils and lubricants are used on any equipment.<br>→ All ships hold current certificates for their class and function.<br>→ Any hydraulic equipment and other fuel storage is regularly serviced and maintained.<br>→ All ships operated within State, national and international safety, pollution control and environmental protection standards and regulations. |
| Localised seabed sediment disturbance from installing the pipes and the subsequent smothering of habitat in the local area. | → Minimise the size of the anchoring points used to support the installation of the pipelines.<br>→ Install a silt boom or curtain around the back hoe during trenching and backfilling. Allow for sediment settlement before removing the boom or curtain. |
| Construction barges and other boats striking marine mammals that enter the area. | Ensure ship pilots:<br>→ Are trained and aware of fauna movements in the area.<br>→ Undertake observations for marine megafauna before manoeuvring in to our out of the local area.<br>→ Maintain their speed to less than four knots. |
| The generation of underwater noise from installing the pipes and its impacts on fish and marine mammals leading to short-term disorientation. | As a precautionary measure:<br>→ Have a slow start-up when installing the anchoring points to provide opportunity for marine mammals and fish species to adjust to the noise levels and/or leave the area.<br>→ Undertake observations before installing the anchoring points to check that there are no noise-sensitive fauna and shoaling fish within 150 metres of the proposal footprint. Do not start work until they have moved out of this area.<br>→ Keep observation while the work is taking place. Notify staff if any fauna or shoaling fish are spotted within 400 metres of the proposal footprint and temporarily stop work if they are spotted within 150 metre for the proposal footprint. |
| The accidental spread of pest and pathogen species on ship-hulls and equipment. | To minimise the risk of marine pest and pathogen species being introduced into the area:<br>→ Undertake regular inspections of the ships, equipment and areas for the presence of pest species, notably including *caulerpa taxifolia*.<br>→ Ensure that each ship used on the proposal can demonstrate that its hull has been cleaned and inspected before work starts. This is to extend to any ships or equipment that is taken offsite while the work is taking place. |
| The generation of small volumes of construction waste from building the proposal. | Extend the proposal's waste management plan (WMP) to cover the marine work while ensuring there is a process for storing, treating, handling, managing and disposing of waste generated while installing the pipelines and other marine infrastructure. |
| Damage to intertidal and or subtidal habitat from installing the pipes if they are not installed using directional drilling. | To promote habitat regeneration, maintain and replace boulders in the same orientation prior to starting construction. |
| **Operation** | |

| POTENTIAL IMPACT | PROPOSED MITIGATION AND MONITORING MEASURES |
|---|---|
| A small increase in the seawater temperature around the outlet pipes and its effects on the marine ecology. | → Validate the modelling predictions within three months of operation by:<br>▪ Monitoring the surface temperature and eight metres below Australian height datum near the discharge point and at four metres and 10 metres from the discharge point in all directions.<br>▪ Use these data to compare the actual extent of the elevated temperature plume compared to the model-predications. This should include sampling at a reference site away from the influence of the inlet or outlet pipes to provide a reference point.<br>→ Ensure the outlet pipe includes jet diffusers to support mixing.<br>→ Use horizontally directed diffusers in preference to vertically directed diffusers to maximise the plume's discharge into the deeper more-open areas of the harbour and to minimise potential the impingement of mobile marine fauna.<br>→ Maintain at least a 30-metre separation between the inlet and outlet pipes or otherwise rerun the modelling to confirm there would be no positive feedback. |
| The rate of discharge of water from the pipes potentially causing increased turbulence and possible seabed scour. | → Increase the diameter inlet pipes to reduce the intake velocity.<br>→ Use risers to ensure the discharge occurs at about one-to-two metres above the seabed.<br>→ Raise pipelines off the seabed to prevent scour.<br>→ Discharge via three 150 millimetre risers to support mixing and reduce the discharge velocity. |
| The discharge of residual biocide in to the marine environment and its effects on the marine ecology. | Use freshwater flushing as the main means to manage the fouling of the pipes and to minimise any marine ecology impacts. Also, carry out physical cleaning and use an electrolytic anode to prevent marine growth. Only use of an amine-based biocide approved by Australian Pesticides and Veterinary Medicines Authority as a back-up method. |
| Equipment such as anchors or fishing lines becoming snagged on the pipes. | Include snag protection controls around the pipeline, riser, jets, and screens to prevent any snagging risk to other harbour users. |

# 1 INTRODUCTION

This Chapter introduces the purpose to install a seawater heat exchange in Sydney Harbour to support the renovation and expansion of the Art Gallery of NSW. It also describes the purpose of this report in supporting the environmental impact statement (EIS).

## 1.1 Background

The Art Gallery of NSW proposes to undertake a major expansion of the existing art gallery adjacent to the Phillip Precinct of the Domain. The expansion, proposed as a separate, stand-alone building, is located north of the existing gallery, partly extending over the Eastern Distributor land bridge and includes a disused Navy fuel bunker located to the north east of this land bridge.

The new building comprises a new entry plaza, new exhibition spaces, shop, food and beverage facilities, visitor amenities, art research and education spaces, new roof terraces and landscaping and associated site works and infrastructure, including loading and service areas, services infrastructure and an ancillary seawater heat exchange system.

The proposal also includes a district (building-wide) cooling system. The system would involve seawater being pumped from Sydney Harbour and transferred to a heat exchange where it would be used to cool condensed warm ambient air from within the gallery therefore providing district cooling. Once the exchange has occurred, the seawater would be discharged back into the harbour.

The system works by there being a regular flow of water through the heat exchange. Through this process, the seawater temperature used in the cooling process can increase by up to seven degrees Celsius. It is therefore important to ensure that the returned seawater would have no physical, chemical or ecological impact on the marine environment of Sydney Harbour. This report assesses this risk in the context of the proposal.

Under the concept design, the proposal would be to intake seawater from, and discharge it to, Woolloomooloo Bay via a series of pipes that would be between 30 and 50 metres apart and located about three metres above the seabed.

The inlet pipes would be installed opposite the end of the Lincoln Crescent wharf and the outlet pipes would be located off the nearby boardwalk. The inlet pipes would be located about 60 metres off the shoreline while the outlet pipes would be located about 35 metres off the shoreline.

### 1.1.1 Secretary’s environmental assessment requirements

In May 2016, the Art Gallery of NSW Trust (the Trust) lodged a request to modify the Secretary’s Environmental Assessment Requirements (SEARs) issued for the State Significant Development application for the planned gallery upgrade and extension (ref: SSD 6471). The modification request was made under the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) in recognition that the proposed seawater heat exchange never formed part of the original proposal.

Secretary’s Environmental Assessment Requirements describe the information and assessment that must be included in the EIS prepared to support the development application. Table 1.1 describes the SEARs that are relevant to this assessment, showing where they have been addressed in this report.

**Table 1.1 Secretary's environmental assessment requirements**

| SECRETARY'S ENVIRONMENTAL ASSESSMENT REQUIREMENT | SECTION REFERENCE |
|---|---|
| **Water quality and water cycle management** | |
| Outline the proposed intake and discharge of seawater including flow rates, temperatures, plumes, turbidity and deposits | Table 2.1 and Table 2.2<br>Section 6.1 and Section 6.2 |
| Assess the impact on water quality and circulation of Sydney Harbour and Woolloomooloo Bay | Section 6.1 and Section 6.2 |
| Outline how the proposal would be designed and operate, and proposed management, monitoring and mitigation measures | Chapter 2 and Chapter 7 |
| **Ecological impacts** | |
| An ecological impact assessment is to be provided, addressing both terrestrial and aquatic ecosystem. The assessment must consider direct impacts on ecological values, as well as indirect impacts that may be associated with water quality conditions and flow characteristics in the vicinity of the intake and discharge infrastructure. | Section 6.1 and Section 6.2 |
| Provide a detailed assessment of [any vegetation clearing on the site including the removal of significant trees,] any impact on threatened species populations, endangered ecological communities or their habitat and potential for offset requirements. | Section 6.2 |
| **Drainage and stormwater** | |
| Detail management techniques, including the use of antifouling chemicals for the maintenance of the heat exchange system. | Section 6.2 |
| Identify the potential impacts associated with the use of antifouling chemicals on water quality and marine ecosystems and outline the potential mitigation measures to manage any potential overdosing. | Section 6.2 |
| **Waste management** | |
| → Provide details of the scheduled, liquid and non-liquid wastes, and quantities, storage, treatment, disposal or reuse of generated waste. | Chapter 2 |
| **Noise** | |
| → Assess the noise impacts associated with the construction and operation of the proposal. | Section 6.1 and Section 6.2 |

## 1.2 Report structure

This report is structured as follows:

- Chapter 1 introduces the purpose of the assessment and how it responds to the relevant issued SEARs.
- Chapter 2 describes how the proposal would be built and how it would operate.
- Chapter 3 describes the environmental planning instruments (EPIs) and water quality guidelines adopted in the assessment.
- Chapter 4 describes the assessment method and approach to modelling.
- Chapter 5 describes the existing environment of the study area.

- Chapter 6 describes the predicted impacts that would occur from building and operating the proposal.
- Chapter 7 describes the proposed mitigation measures that would be used to avoid and reduce the predicted impacts.

## 1.3 Terms commonly used in this report

The following terms have been used throughout this report:

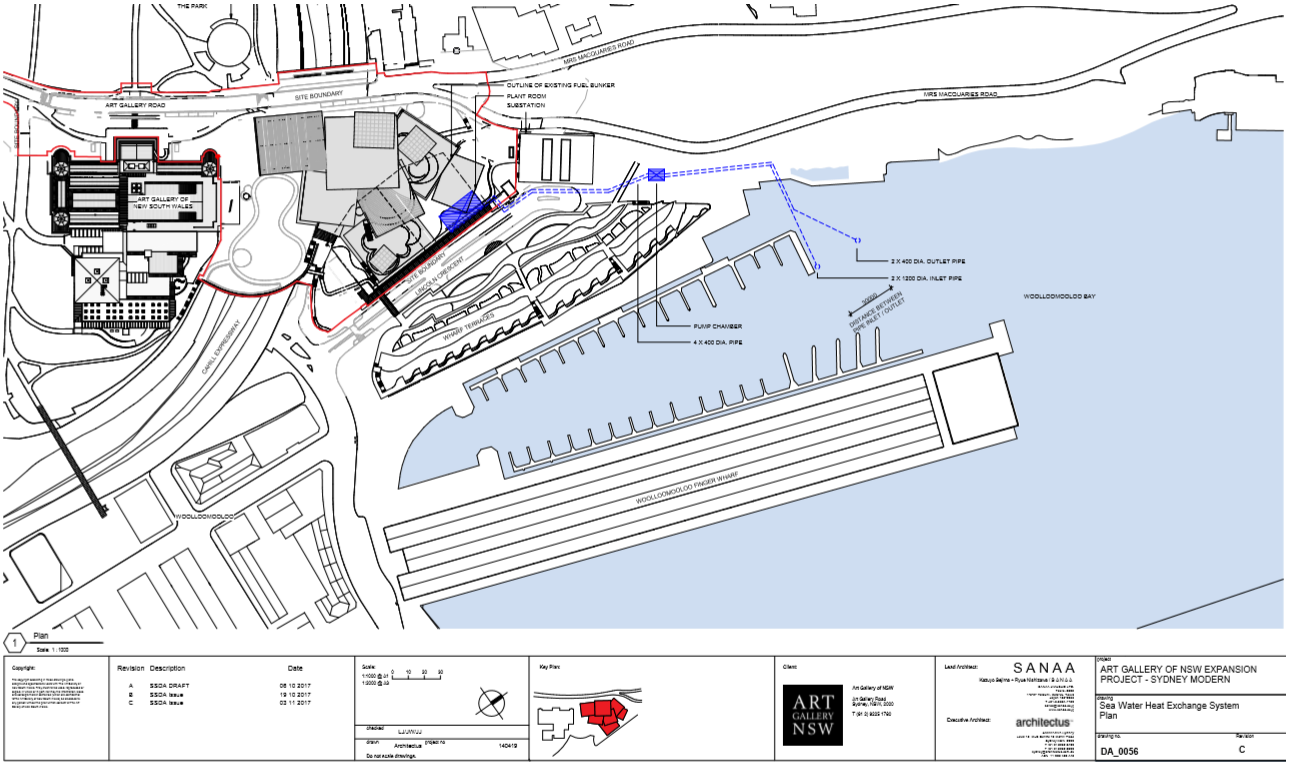
- The ‘proposal’ refers to the installation of heat water exchange equipment in Woolloomooloo Bay. The proposal forms part of the wider plan to renovate and extend the Art Gallery for NSW. It also represents ‘development’ for the purposes of Part 4 of the EP&A Act.
- The ‘proposal footprint’ refers to area directly impacted by the proposal and is shown on Figure 2.1.
- The ‘study area’ covers the extent of the existing environment described in Chapter 6. It represents the area that may be both directly and indirectly impacted by the proposal.
- The ‘locality’ represents a wider area where information has been gathered to describe the environment of the study area and proposal footprint. The locality would not be impacted by the proposal.

# 2 PROPOSAL DESCRIPTION

This Chapter describes the proposed seawater heat exchange system ('the proposal') and the aspects of its concept design that have been taken into consideration in this assessment.

## 2.1 District thermal cooling plant: overview

Figure 2.1 shows the location of the planned inlet and outlet pipes that would be used to service the seawater heat exchange. Section 2.2 and section 2.3 describe the relevant specifications of each pipeline in more detail. The main EIS document describes the alternatives that were considered in selecting the pipeline route alignment and discharge points/configurations, which focussed on avoiding any direct impact on non-Aboriginal heritage values in the foreshore area relating to a former swimming pool and the residents living in the Wharf Terraces of Lincoln Crescent.




*Source: Steensen Varming, 2017*

**Figure 2.1 Proposed location of the inlet and outlet pipes in Sydney Harbour**

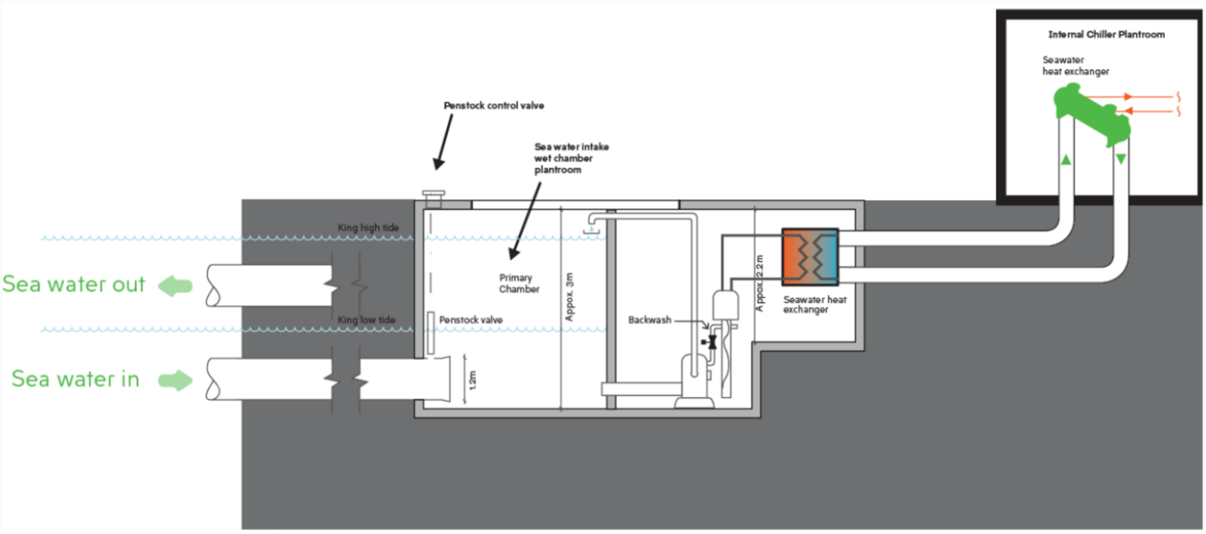
## 2.2 Overview

The seawater heat exchange would comprise:

- A harbour water intake below the minimum tide level
- Two inlet and outfall pipes located in Woolloomooloo Bay
- A plant room in the Art Gallery that would contain:
  - Pump equipment
  - Heat exchangers
  - A flooded chamber/dry pit
  - Filters and strainers to assist in preventing biofouling (the accumulation of microorganisms, plants, algae and animals).

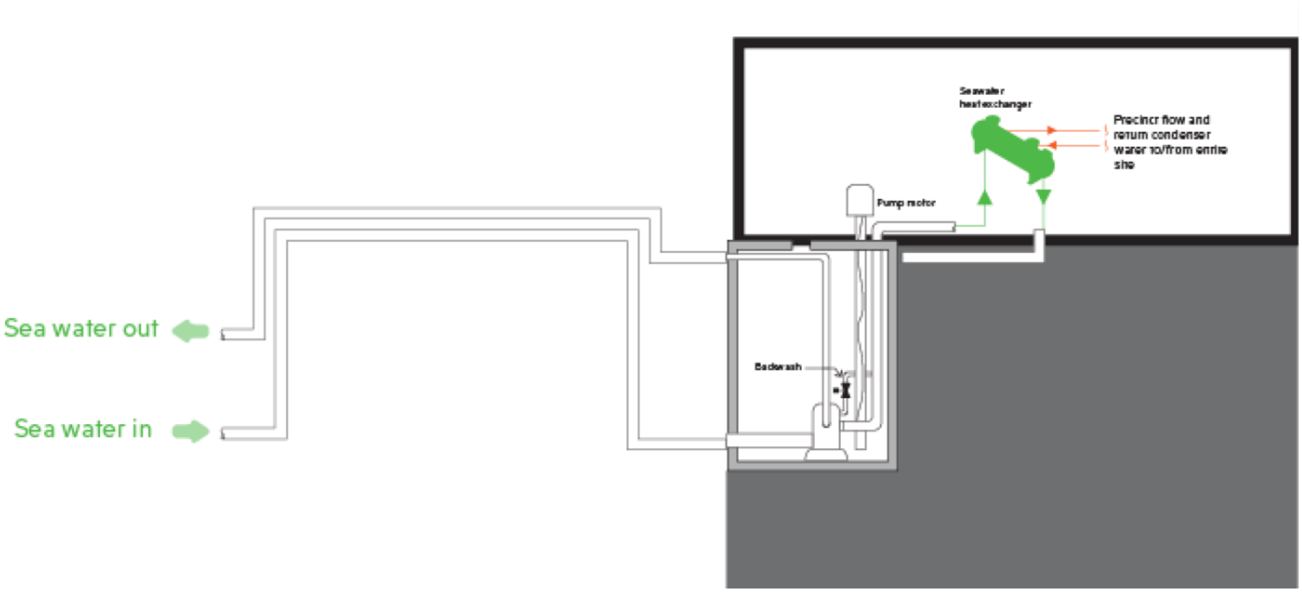
The development application provides the detail of the proposed district cooling system including the seawater exchange (Steensen Varming, 2017).

Figure 2.2a and Figure 2.2b show a schematic of the proposed (flooded and dry) system.




*Source: Steensen Varming, 2017*

**Figure 2.2a Schematic of a flooded chamber plant**




*Source: Steensen Varming, 2017*

**Figure 2.2b Schematic of a dry chamber plant**

The inlet and outlet pipes would be located between 30 and 50 metres apart. The inlet pipes would be located beyond the limit of the Lincoln Crescent wharf and the outlet pipes located off the boardwalk (refer to Figure 2.1). The inlet pipes would be located about 60 metres off the shoreline while the outlet pipes would be located about 35 metres off the shoreline.

To prevent biofouling (the clogging of the pipes), the system would be regularly cleaned (flushed) with fresh (collected rain) water that would be discharged to Woolloomooloo Bay via the same pipes as the seawater. The system would also be occasionally flushed using an amine-based biocide (refer to section 6.2.1). It is anticipated that chemical flushing would take place once per year, the specification of which would be confirmed during the detailed design.

The cooling demand of the gallery would vary over the course of a day, week and across the seasons. Typically, there would be greatest demand on the system during the summer months across the middle of the day. Also, there would be more demand on the system when the gallery is busy as people generate mass thermal heat. As such, the system has a maximum operational demand, which, along with a range of other seasonal conditions, has been adopted in the modelling to ensure the assessment is conservative and above the final design specifications described in Table 2.1. This maximum operational demand is likely to only occur for short periods during the day in February, which is typically the hottest month when the gallery receives high visitor numbers. For the other months, it is estimated that the system would typically operate at about:

- 80 per cent of its maximum operational demand during the summer months.
- 60 per cent of its maximum operational demand during the autumn and spring months.
- Between 20 and 40 per cent of its maximum operational demand during the winter months.

## 2.3 Intake system

Table 2.1 shows the intake parameters. The data outside of the brackets was used in the predictive modelling described in Chapter 3 while the data in brackets shows the adopted design parameters. The difference in the numbers accounts for a theoretical design maximum versus the current concept design parameters. As described above, by adopting these parameters the modelling predictions are conservative in adopting a worst-case impact.

Table 2.1 Intake system parameters

| PARAMETER | SPECIFICATION |
|---|---|
| **Net heat rejection capacity** | 1,600 kW |
| **Inlet pipe diameter (mm)** | 1,200 (350) |
| **Water intake velocity ($ms^{-1}$)** | 0.2 to 0.4 (0.78) |
| **Intake rate ($Ls^{-1}$)** | 117 (69) |
| **Orientation of inlet pipe relative to the seabed** | Horizontal |
| **Inlet pipe location** | Refer to Figure 2.1 |
| **Water depth at inlet pipe location (m)** | ~ 10 |
| **Inlet pipe height from the seabed (m)** | Up to 2 |

Before entering the inlet pipe, the water would pass through a coarse screen (comprising vertical bars separated by 100 mm) and then a fine screen (comprising vertical bars separated by about 25 to 50 mm). This would act as a gross pollutant trap and it would also prevent any large marine fauna impingement or entrainment. The seawater would also pass through two penstock (sluice) valves that could be opened and closed to regulate/prevent the flow of seawater into the exchange.

The system would be built to include two inlet pipes. Only one pipe would be operational at a time. This would allow the other pipe to operate as a backup. It would also allow the continual operation of the system while the non-operational pipe was offline for servicing and maintenance.

## 2.4 Exchange system

The exchange plant would be located in the gallery. The seawater would be pumped to the gallery and either held in a flooded chamber or dry pit. Both processes allow the seawater to exchange with condensed air taken from the building. The exchange would take place in a unit comprising a network of pipes with a high surface area to increase the efficiency of the exchange. The only difference between the systems is that the dry pit would pump the water directly to the exchange whereas the flooded chamber would allow a residual volume of seawater to be stored in a chamber in the gallery. This would then be pumped to the exchange and returned to the chamber before being discharged.

The efficiency of the system would also depend on the difference in temperature between the inlet and the outlet. The system would be at its most efficient where there would be a temperature variation of up to seven degrees Celsius across the system (i.e. between the intake and discharge seawater temperature).

## 2.5 Discharge system

Once the seawater leaves the cooling system it would be pumped to the outlet pipe where it would be discharged up to seven degrees Celsius above ambient conditions at the inlet pipe.

The returned seawater would flow through a 300-mm pipe laid just above the seabed and the discharge would occur via three 150 mm diameter risers directing the discharge towards the mouth of Woolloomooloo Bay. Discharging the warmer seawater via smaller diameter risers would cause it to mix with the ambient seawater more effectively. It would form a plume that would initially discharge upwards, due to its increased temperature, after which it would disperse via natural mixing.

As with the inlet, two pipes would be built to service the outlet. This would allow one to be online while the second pipe would act as a backup or it would be offline for servicing and maintenance. The rate of discharge (termed peak velocity) would vary depending on the daily, weekly and seasonal variances in cooling demand as described in the previous section.

Table 2.2 shows the parameters that have been used to undertake the thermal and physicochemical modelling described in Chapter 3. Again, the values in the brackets are the design parameters while the values outside of the brackets were used in the modelling to make a worst-case assessment.

Table 2.2 Discharge system parameters

| PARAMETER | SPECIFICATION |
|---|---|
| **Outlet pipe diameter (mm)** | 400 (300) |
| **Discharge rate ($Ls^{1}$)** | 117 (69) |
| **Salinity (ppt)** | 33 |
| **Differential temperature (°C)** | 5 to 7 |
| **Water depth at outlet pipe location (m)** | ~10 |
| **Number of risers** | 3 |
| **Diameter of outlet risers (mm)** | 150 |
| **Riser height above seabed (m)** | ~2 |
| **Riser spacing (m)** | ~3 |
| **Maximum discharge velocity ($ms^{-1}$)** | 0.95 |
| **Outlet pipe location** | Refer to Figure 2.1 |

## 2.6 Marine infrastructure

The marine-related infrastructure would comprise:

- Four pipes (two inlet pipes and two outlet pipes).
- A coarse and fine screen at the inlet pipes comprising a metal screen.
- A separate metal cage around each set of inlet and outlet pipes to prevent the risk of either damaging the pipes or potentially causing a snagging risk for anchors or other submerged structures.

## 2.7 Pipework installation

The likely method, staging, work hours, plant and equipment requirements needed to build the proposal are described in this section. An indicative work plan and method are also provided. The contractor(s) appointed to build the proposal would prepare a detailed construction plan and method once the proposal's detailed design is finalised. The work plan and method may allow for several activities to be carried out at the same time. It would also account for the need to minimise any impacts on commercial and recreational user enjoyment of Woolloomooloo Bay.

The actual work method may vary from the description provided in this section due to the identification of additional constraints before work starts, ongoing detailed design refinements, feedback from community and stakeholder consultation, and contractor requirements/limitations.

### 2.7.1 Construction activities

The marine infrastructure needed under the proposal would connect in to the pipework installed between the gallery and the shoreline. The marine infrastructure would be likely installed using a jack-up barge or floating pontoon and backhoe or small crane. It is expected that the pipelines would be installed in prefabricated sections that would be welded/joined together, lowered and secured into place above the harbour floor. Close to the shoreline the waters are shallow (refer to Figure 5.1) therefore the initial section of pipeline (close to the shore) would be entrenched. Further offshore, the pipe would be anchored and secured close to the seabed. Once installed, the pipes would be connected to the landside pipes using divers, a remote operating vehicle, or if needed, hyperbaric welding. The final tasks would be to install the screens and security cages; tasks that would also be likely undertaken using divers or a remote operating vehicle. As such, there are likely to be six main activities needed to build the proposal.

- Activity 1: site demarcation and exclusion zone establishment.
- Activity 2: nearshore trenching, pipe assembling and welding/joining.
- Activity 3: landside connection.
- Activity 4: securing the pipes and installing the screens and security cages and trench backfilling.
- Activity 5: pressure testing and flushing.
- Activity 6: site demobilisation.

Table 2.3 shows typical work activities associated with the work.

**Table 2.3 Typical work activities**

| ACTIVITY | WORK DESCRIPTION |
|---|---|
| **Activity 1** | → Setup environmental and marine safety controls.<br>→ Set out a demarked exclusion zone (likely using buoys) to create a safe working area.<br>→ Potentially deploy divers or a remote operating vehicle to drill anchoring points.<br>→ Install the jack-up barge or anchor the floating pontoon. |
| **Activity 2** | → Use a barge-mounted backhoe to create a single trench about four metres wide, up to two metres deep and about 20 metres long to entrench the four pipelines nearshore.<br>→ Receive pipe lengths by barge, which would moor alongside the jack-up barge/floating pontoon.<br>→ Transfer, weld and inspect the pipes.<br>→ Float the pipes off the back of the jack-up barge/pontoon.<br>→ Allow the pipes to partially fill with seawater to allow them to be manoeuvred into their final positions. |
| **Activity 3** | → Deploy divers or a remote operating vehicle to connect pipe sections and the shoreline tie-in.<br>*Depending on the connection method, this may involve bolting or welding the pipes together. It may possibly require the use of hyperbaric welding. This would involve placing an air-tight casing around the two sections of pipe and draining the water to create a water tight seal to undertake the welding.* |
| **Activity 4** | → Fill the 'offshore' section of pipes with seawater to allow them to be submerged to their final depth close to the seabed.<br>→ Deploy divers or a remote operating vehicle to secure the pipes to the anchoring points.<br>→ Use the barge-mounted backhoe to backfill the trench.<br>→ Deploy divers or a remote operating vehicle to secure the screens and security cages to either the anchoring points or pipes. |

| ACTIVITY | WORK DESCRIPTION |
|---|---|
| **Activity 5** | → Flush the pipes.<br>→ Undertake pressure and integrity testing.<br>→ Undertake pre-commission testing. |
| **Activity 6** | → Reinstate the area.<br>→ Remove the barge anchors or jack-ups.<br>→ Remove the exclusion buoys and the safety and environmental controls. |

### 2.7.2 Construction program and hours

Work could only take place with the permission of Roads and Maritime (as the 'owners of the seabed) and the Harbour Master. While external agencies would ultimately determine the work schedule and working hours, it is anticipated that work would take place in accordance with the recommended standard hours for construction work set by the NSW Interim Construction Noise Guidelines 2009, namely:

- Monday to Friday 7am to 6pm
- Saturday 8am to 1pm
- No work on Sunday or public holidays.

### 2.7.3 Plant and equipment

The plant and equipment needed to build the proposal would vary depending on the work activity being carried out. Various equipment would be common to all work activities while certain specialist equipment would be brought in for specific activities. Not all the equipment would be used at the same time. Its use would depend on the activity being carried out, which would be confirmed during the detailed design in consultation with the work contractor(s). Indicatively, it is expected that the following main equipment would be used:

- Jack-up barge or floating barge
- Work barge/work ship
- (Barge-mounted) crane
- (Barge-mounted) back hoe
- Compressor
- Diesel generator
- Welding and cutting equipment
- Hand-held grinders/oxy-acetylene cutting equipment.

### 2.7.4 Sediment and habitat disturbance

The need to nearshore trenching would cover an area of about 80 $m^2$. By trenching up to a depth of two metres this would see about 160 $m^3$ sediment and rock being disturbed. It would also impact on the nearshore inter-tidal habitat as described in section 5.2.2.

To prevent the generation of unnecessary sediment plumes a silt boom or curtain would be installed around the trenching area. If needed, the curtain/boom would be removed while the pipe is being installed and reinstated while the trench is being backfilled. Also, the nearshore boulders (as shown on Figure 5.5) would be carefully moved to the side to allow trenching (Activity 2) and reinstated (in the same location and aspect) once the area is backfilled (Activity 4).

### 2.7.5 Waste management

It is estimated that nominal amounts of construction waste would be produced from installing the marine infrastructure. Given the installation of the pipes above the seabed (refer to Table 2.1 and Table 2.2) there is no expected need to dredge or remove any harbour sediment.

Any other waste would be produced at surface. The types and volumes of waste would be consistent with that generated during any construction work. It would likely include:

- Waste metal (pipe offcuts).
- Waste welding materials.
- Cardboard, paper and wood (packaging waste).
- Minor quantities of spent chemicals (including lubricants used to join the pipes, diesels and fuel containers).

Covered skips would be present on the jack-up barge/working barge/floating pontoon. They would be used to separate and collect all waste for transfer ashore for recycling or disposal at a licenced facility by a licenced contractor.

## 2.8 Pipe operation

The pipework and exchange equipment would be maintained and repaired by a nominated contractor appointed by The Trust. This would require the occasional inspection of the pipe, which would involve a boat and dive team. The final depth and location of the pipe would also need including on admiralty charts. It would also be marked with a safety buoy. This would be confirmed with Roads and Maritime and Harbour Master. Due to the depth and location of the pipework it is not anticipated that there would be a need for boats to anchor near the pipelines. As such, the proposal is unlikely to interfere with routine boat movements within Woolloomooloo Bay.

The other key operational activity would be foul management. As described above, freshwater would be used to flush the pipes. This would be used to prevent and manage any fouling in the pipes. The water would also be used to minimise any marine ecology impacts. Occasionally, an approved amine based biocide would be used to flush the system.

# 3 LEGISLATION AND GUIDELINES

The Chapter describes the EPIs and water quality guidelines adopted in the assessment.

## 3.1 Development and land ownership

### 3.1.1 NSW Environmental Planning and Assessment Act 1979

The proposal forms part of a State significant development proposal to renovate and extend the Art Gallery of NSW. Before the seawater heat exchange is installed and the proposal is developed, it needs the consent of the NSW Minister for Planning in accordance with the provisions of Part 4 of the NSW *Environmental Planning and Assessment Act 1979*. This report forms part of the EIS that is being submitted in accordance with Section 78(A) of the above Act. In accordance with Section 79(C)(1) of the above Act this report therefore:

- Includes information on the provisions of relevant EPIs.
- Includes information on whether the proposal is deemed to satisfy the requirements of the NSW Environmental Planning and Assessment Regulation 2000.
- Assesses the suitability of installing heat water exchange infrastructure in Woolloomooloo Bay.
- Reports whether the proposal’s impacts and the residual environmental effects are acceptable.
- Has considered any comments or feedback on the proposal including wider public interest.

### 3.1.2 NSW Maritime Services Act 1935 (as amended)

The above Act provisions for Roads and Maritime to administer and manage the State’s coastal waters as the ‘landowner’. Typically, The Trust would need the consent of Roads and Maritime before installing the marine infrastructure in the Harbour. This would need securing before lodging the development application. However, this need has been removed through The Trust seeking a landowner’s consent exemption as described in the EIS.

## 3.2 Ecology

### 3.2.1 NSW Biodiversity Conservation Act 2016

On the 25 August 2017, the provisions of the above Act were enacted in NSW. The purpose of Act is wide ranging consolidating and replacing various legislation. Specifically, the act replaces the NSW *Threatened Species Conservation Act 1995*, which is being repealed. Despite this, any development that is currently within the planning approvals process can still progress under the NSW *Threatened Species Conservation Act 1995*. As such, the provisions of the NSW *Threatened Species Conservation Act 1995* remain relevant to this proposal.

### 3.2.2 NSW Threated Species Conservation Act 1995

The NSW *Threatened Species Conservation Act 1995* (TSC Act) provides for the protection of vulnerable and endangered flora, fauna, communities and populations and their associated habitat. The Act is administered by the Office of Environment and Heritage (OEH) and includes provisions to declare threatened species, populations, ecological communities and key threatening processes (KTP). Species, populations and communities identified as:

- Endangered are listed in Schedule 1.

- Critically endangered are listed in Schedule 1b.
- Vulnerable are listed in Schedule 2.

Marine birds, mammals and reptiles are included in the Schedules of the above Act whereas all fish and marine vegetation are listed under the NSW *Fisheries Management Act 1994* (see below). The above Act also provides for the identification and listing of habitat that is critical to the survival of an endangered species, population or ecological community.

Section 109 to Section 113 of the above Act require The Trust to prepare a species impact statement in instances where the proposal would have significant effect either on: terrestrial critical flora and fauna habitat or terrestrial threatened species, populations and ecological communities and their habitat. The proposal is not expected to have any material impact on communities and species protected in under the above Act (refer to Chapter 6) within the meaning and definitions of the supporting impact assessment guideline. This removes the need to prepare species impact statements.

### 3.2.3 NSW Fisheries Management Act 1994

The NSW *Fisheries Management Act 1994* (FM Act) aims to protect the fish stocks, key fish habitats and threatened species, populations and ecological communities of fish and marine vegetation for current and future generations. Species, populations and communities identified:

- Endangered are listed in Schedule 4.
- Critically endangered are listed in Schedule 4A.
- Vulnerable are listed in Schedule 5.

The FM Act also lists KTP that may threaten the survival of listed species, populations and ecological communities. Section 19 of the FM Act allows for the declaration of specified species as protected to prevent it becoming threatened in the future. Nominated aquatic habitats and aquatic reserve are protected under provisions of Part 7 of the Act. A permit is needed for activities that may damage protected habitats, flora and fauna are administered. Habitats that are critical to the survival of an endangered species, population or ecological community are identified under Division 3 of the above Act.

Section 221J and section 221K of the above Act require The Trust to prepare a species impact statement in instances where the proposal would have significant effect either on: critical aquatic flora and fauna habitat, or aquatic threatened species, populations and ecological communities and their habitat. In the case of the proposal, it would have no material impact that would trigger the provisions of the above Act such that it would require The Trust to prepare a species impact statement (refer to Chapter 6). The Act also sets out several permitting provisions for certain work activities where it is likely to impact on key fish habitat.

The proposal is not expected to have any material impact on communities and species protected in under the above Act (refer to Chapter 6) within the meaning and definitions of the supporting impact assessment guideline. This removes the need to prepare species impact statements or the need to obtain a permit to carry out the work.

### 3.2.4 Commonwealth Environment Protection and Biodiversity Conservation Act 1999

The *Commonwealth Environment Protection Biodiversity Conservation Act 1999* aims to:

- Provide for the protection of the environment, especially Matters of National Environmental Significance (MNES).
- Promote ecologically sustainable development (ESD) through conservation and ecologically sustainable use of natural resources.

- Promote conservation of biodiversity.

In the aquatic environment, the above Act lists the following MNES relevant to this study:

- Nationally threatened and listed marine species, ecological communities and critical habitats.
- Migratory species.
- Wetlands of national significance (termed Ramsar sites after the 1971 Convention on Wetlands).

Under the above Act a referral is required to the Australian Government for proposed “actions that have the potential to significantly impact on matters of national environmental significance or the environment of Commonwealth land”. As concluded in Chapter 6, the proposal is considered unlikely to have any impact on MNES. As such, it has not been referred to the Australian Government.

## 3.3 Water quality and pollution

### 3.3.1 NSW Protection of the Environment Operations Act 1997 (as amended)

Environmental protection is provisioned under the above Act. The underlying objective of the Act is to reduce pollution and manage the storage, treatment and disposal of waste. A key feature of the Act is the issuing of environmental protection licences (EPLs) for certain (scheduled) activities. Until 2001, seawater exchange was considered a scheduled activity within the meaning and definition of the above Act. As such, a proponent needed an EPL to operate a seawater exchange. The EPL allowed the Environment Protection Authority (EPA), as the authority responsible for administering the provisions of the Act, to set conditions to control potentially polluting activities. While the de-scheduling of seawater exchanges from under the above Act occurred in 2001, the Trust would still introduce controls to ensure the systems operates in accordance with the pollution prevention controls and requirements of the above Act.

Under Section 120 of the above Act, is it an offence to pollute any waters (including tidal waters and the sea) within the State. Water pollution under the Act is defined as causing a ‘physical, chemical or biological’ change to the condition of the water. It also includes making the water ‘unclean, noxious, poisonous, impure, or detrimental to health, safety, welfare or property’. This includes making the water unsuitable for fauna, livestock, fish, irrigation, or human consumption. Schedule 5j of the supporting NSW Protection of the Environment Operations (General) Regulation 2009 describes ‘thermal waste’ as being a potential source of water pollution. Thermal waste is defined as being “any liquid which, after being used in, or in connection with any activity, is more than two degrees Celsius hotter or colder than the water into which it is discharged”.

While the Regulation defines thermal waste, the discharged seawater would need to trigger the limits under section 120 of the above Act for it to ‘pollute’ Woolloomooloo Bay. To determine if this risk is likely, threshold criteria have been developed under the Guidelines for Marine and Fresh Water Ecology 2000 (refer to section 3.3.2).

The Act also requires The Trust to notify the EPA in instances where any pollution incident has the potential to “cause or threaten material harm to the environment” (refer to section 148 of the Act).

**Waste discharge and pollution**

The National Environmental Protection Measure (NEPM) and the NSW *Waste Classification Guidelines 2009* describe types of waste in terms of their environmental risk. Under the NEPM, waste biocide is deemed a ‘controlled waste’ meaning that it must be tracked and disposed to a licenced facility. The NEPM, and waste above guidelines, also consider the discharge of stormwater (or freshwater) into the marine environment as a waste discharge. The above Act, as supported by the Protection of the Environment Operations (General) Regulation 2009, prescribes certain matters for preventing and controlling water pollution, one of which is the discharge of ‘waste’ that may materially harm the water quality values. As such, the proposal would be subject to the same discharge controls as general stormwater runoff to the Harbour as set in the context of the above Act.

With regards to the use of biocides, only residual concentrations would be discharged in accordance with their approved use by Australian Pesticides and Veterinary Medicines Authority (AVPMA). This would ensure that any biocide flushing would not trigger the waste and/or pollution triggers of the above environmental planning instruments.

### 3.3.2 Guidelines for Marine and Fresh Water Ecology 2000 (ANZECC guidelines)

Australian and New Zealand Environment Conservation Council (ANZECC) published its revised Australian and New Zealand guidelines for fresh and marine water quality in 2000, commonly referred to as the ANZECC guidelines. These guidelines provide a framework for conserving ambient water quality in Australian rivers, lakes, estuaries and marine waters. The ANZECC Guidelines provide the means to define and assess water quality based on whether the physical, chemical and biological characteristics of a waterway supports community environmental values including:

- Protection of aquatic ecosystems
- Drinking water
- Primary and secondary recreation
- Visual amenity
- Agricultural water for irrigation, livestock and growing aquatic foods.

The guidelines have specified three different levels of aquatic ecosystem protection (high ecological value, slightly-to-moderately disturbed, highly disturbed), for which indicative values for key parameters such as pH, turbidity, nutrients, turbidity and dissolved oxygen are outlined. The guidelines recommend the development of site-specific levels, which are consistent with the objectives for the water quality of the catchment, support the planning objectives for the waterway, and are derived from site-specific values for appropriate water quality indicators.

### 3.3.3 NSW water quality objectives

The NSW WQOs are the environmental values and long-term goals for consideration when assessing and managing the likely impact of activities on waterways. They are not intended to be applied directly as regulatory criteria, limits or conditions, but are one factor to be considered when making decisions affecting the future of a waterway.

The policy in NSW is that the level of protection applied to most waterways is the one suggested for 'slightly-to-moderately disturbed' ecosystems. Sydney Harbour (Port Jackson), however, may be considered as a highly disturbed waterway and reduced level of protection may be appropriate as a pragmatic short-term goal, with the aim of eventually restoring it to the status of 'slightly-to-moderately disturbed'. However, it is not acceptable to allow poor environmental management or water pollution, simply because a waterway is currently degraded.

## 3.4 Other relevant legislation

There are a number of other legal provisions and EPIs that are relevant to the proposal or the land on which the proposal would be developed.

### 3.4.1 NSW Marine Safety Act 1998 and the Marine Safety Regulation 2016

The above 1998 Act sets out the requirements for marine safety in State waters. While it primarily covers navigational safety, it is relevant with regards to the need for this proposal to ensure marine and navigational safety while undertaking the construction work and once the associated infrastructure is installed and operational. The 2016 Regulation sets out the requirements for marine safety and the roles of the Harbour Master and marine pilots. It includes provisions relating to marine and navigational safety including: collision prevention, spill limits, no-wash zones, shipping operation restrictions, and controls on reckless, dangerous or negligent navigation. As the proposal would involve being in the harbour (a navigable water under the terms of the Act), and would restrict its used by the public, it would be subject to licencing under the terms of section 97 of the Regulation. Also, a navigational exclusion zone would need installing while the work its taking place. This would include updating the Harbour Master and Ports Authority. Where required, nautical charts would be updated once the infrastructure is installed.

### 3.4.2 NSW Contaminated Land Management Act 1997

The general objective of the NSW *Contaminated Land Management Act 1997* is to establish a process for investigating, and where appropriate, remediating land that is considered to pose a significant risk to human health or the environment. This Act would require the Trust to immediately notify the EPA if it suspected that the work has resulted in ground contamination or encountered/remobilised existing ground contamination (as defined under the Act).

### 3.4.3 NSW Pesticides Act 1999

The above Act controls the use of pesticides in NSW. The Act aims to reduce the risks associated with the use of pesticides to human health, the environment, property, industry and trade. It also aims to promote collaborative and integrated policies for the use of pesticides. The proposal includes for the occasional use of biocides, a form of pesticide that falls under the Act.

The Act sets controls on the use, application, storage, and disposal of certain pesticides given their ability to cause ecological damage. In the case of the proposal there is the intention to use Mexel ® 432, which has been approved for use by the APVMA. This approval is consistent with the provisions of the above Act. Providing the biocide is used in accordance with the specifications, and controls are introduced to regulate its use, then the risk of causing direct environmental harm or pollution, within the meaning and definition of NSW *Protection of the Environment Operations Act 1997 (as amended),* would be reduced to acceptable levels by way of its approved use.

### 3.4.4 Sydney Regional Environmental Plan (Sydney Harbour Catchment) 2005

Certain regional plans were retained at the point SEPPs were established. These are referred to as ‘deemed SEPPs’. This is the case with the Sydney Regional Environmental Plan (Sydney Harbour Catchment) 2005 which became a deemed SEPP in 2009. The plan governs certain aspects of development control in Sydney Harbour that focus on ensuring the natural assets and water quality of the catchment are preserved. The SREP includes various provisions that are relevant to the proposal that relate to:

→ Adhering to the SREP’s aims (Clause 2).

→ Complying with the SREP’s maritime water objectives (Clause 17 and Clause 18).

→ The need for DPE to consider various matters before consenting to the proposal being developed (Clause 21 to Clause 27).

→ Adhering to various heritage provisions (Clause 53).

→ Complying with the SREP’s wetland protection area objectives (Clause 61) and including certain provisions and controls when working in wetland protection areas (Clause 63).

Given the purpose of this report, it has only considered the provisions, objectives and matters relating to wetland protection areas. The other provisions, aims and objectives are considered in the main EIS.

The proposal would be installed in a wetland protection area covered under the SREP (refer to Figure 5.4). As such, DPE needs to consider if the proposal would be installed so that it would:

- Preserve, protect and encourage the restoration and rehabilitation of wetlands.
- Maintain and restore the health and viability of wetlands.
- Prevent the fragmentation of wetlands.
- Preserve the scenic qualities of wetlands.
- Ensure that wetlands continue to perform their natural ecological functions (such as the provision of wetland habitat, the preservation of water quality, the control of flooding and erosion).

In the case of the proposal it would have a direct impact on a wetland area defined under the above plan (refer to section 5.2.2). Accordingly, section 5.2.2 concludes, through a site investigation, that the impacted and adjacent areas show little to no characteristics of a wetland and the area holds limited ecological value requiring the need for protection. That said, there is a realised wider responsibility on the Trust to work to the ESD principles that include adopting precaution. As such, the proposal needs to be built to ensure there is no impact on the ecological values of the area including the protection of wetlands in the locality. Mitigation measures have therefore been proposed based on the adoption of the precautionary principle mindful of upholding the above objectives.

The plan also refers to other legal provides that govern development control in the harbour citing Aboriginal protection under the NSW *National Parks and Wildlife Act 1974* and impacts on fisheries and their resources as defined under the NSW *Fisheries Management Act 1994.* A separate heritage assessment has been prepared to support the development application (GML, 2016) that considers the implications of the NSW *National Parks and Wildlife Act 1974* while section 3.3.2 provides commentary on the relevant provisions of the NSW *Fisheries Management Act 1994.*

### 3.4.5 Marine Pollution Act 2012

The above Act sets out the requirements to prevent pollution in the marine environment. While focussed on shipping, it is relevant to the proposal's construction as insofar as ensuring the work activities do not lead to the discharge of oil, 'noxious liquids', pollutants, sewage and/or garbage. Providing relevant standard controls are implemented and monitored, as set out in published guidelines, there is unlikely to be any oil, noxious liquid, pollutant, sewage or garbage discharge from the proposal as controlled under this Act.

### 3.4.6 NSW Ports and Maritime Administration Regulation 2012

This regulation requires Harbour Master permission to alter any structure or disturb the harbour floor within Sydney Port (which extends to cover Sydney Harbour). Accordingly, as the proposal would be located within Sydney Port, and it would involve disturbing the harbour floor, it could only take place with the written permission of the Harbour Master before work starts (refer to Section 67ZN of the Regulation).

# 4 ASSESSMENT METHOD

This Chapter describes the assessment method and approach to modelling.

## 4.1 Method

The assessment:

- Identified the existing hydrodynamic, bathymetric and temperature conditions in the Woolloomooloo Bay area by referring to:
  - Admiralty charts
    - Hydrographic and bathymetric data
  - The Sydney Harbour Hydrodynamic Model
    - Bottom, middle and surface water current data
  - University of Sydney supplied information
    - Temperature data collected in 2013
    - Water salinity data collected in 2013.
- Identified the existing marine ecology environment in the Woolloomooloo Bay area by referring to:
  - National Parks and Wildlife Services wildlife atlas database covering NSW TSC Act listings.
  - The Commonwealth Government EPBC Act protected matters search tool.
- Recorded existing conditions during a walkover at low-tide in May 2016 as verified in October 2017.
- Developed a three-dimensional nearfield model to predict plume dispersion characteristics.
- Confirmed the design parameters, operating conditions and limits of the proposed seawater heat exchange system.
- Determined the discharge and nearfield mixing that would take place in the receiving environment using the various worst-case modelling parameters.
- Predicted if the ambient temperature and velocity in the nearfield environment would remove any potential thermal pollution and water velocity-related risk in the context of the adopted site-specific triggers and within the meaning and definition of the NSW *Protection of Environment Operations Act 1997* (as amended).
- Assessed the predicted impacts on the marine environment.
- Identified adverse impacts that would need mitigating or managing.

## 4.2 Study area

The marine assessment study area focussed on the water quality, marine ecology and hydrodynamic conditions of Woolloomooloo Bay, and where required, the wider locality of Sydney Harbour.
The hydrodynamic assessment considered two study areas defined by the limits of the modelling. They included:

- The near-field environment is the area where the thermal plume reaches neutral buoyancy. It is also known as the mixing zone. The edge of the near-field is where any site-specific trigger values regarding temperature, water chemistry or discharge velocity would need to be met.

- The far-field environment is the area outside of the near-field where the wider values of the receiving environment need to be considered in relation to the proposal.

## 4.3 Site walkover

A walkover of the study area (Figure 2.1) was carried out during low tide (0.29 metres above Australia Height Datum (AHD)) on 5 May 2016. The purpose of the walkover was to observe and record sedentary and mobile biota occurring in the intertidal and shallow subtidal areas adjacent to the proposal. A second walkover was carried out in October 2017 to confirm the validity of the 2016 walkover. This confirmed that there the conditions onsite had not changed.

## 4.4 Hydrodynamic modelling

The purpose of hydrodynamic modelling was to consider coastal and marine water movement. It provided the base on which advection-diffusion, sediment transport, particle tracking and morphological changes were investigated. It was used in this case to predict how the discharged seawater would mix and disperse in Woolloomooloo Bay.

A three-dimension validated numerical hydrodynamic model (Visjet) was used in conjunction with the information in Table 2.2, and published bathymetric (water depth), current, water temperature and water salinity data, to predict the dispersion characteristics of the discharged seawater. The physical (depth, current data and temperature) and chemical (salinity) characteristics define how the discharged seawater would mix and disperse in the receiving environment.

A range of scenarios were modelled under a process of selective analysis that considered variations in the discharge conditions (height, direction, speed, and temperature) and the physical and chemical parameters. The modelling predictions also considered the maximum operation demand across seasonal variances by considering typical yet conservative summer, autumn, winter and spring conditions.

Appendix A details the modelling method, inputs and set up.

## 4.5 Marine ecology

The marine ecology assessment focussed on assessing the impact on:

- Intertidal and subtidal habitat, flora and fauna.
- Listed protected species, populations, communities and habitats.
- Adult and larval marine biota.
- The general marine ecology.

## 4.6 Environmental assessment impact ratings

Impact significance was assessed in accordance with the following guidelines:

- Threatened Species Assessment Guidelines: The Assessment of Significance (DECCW, 2007).
- Significant Impact Guidelines 1.1: Matters of National Environmental Significance (Commonwealth Department of Environment, 2013).

The above two guidelines define the processes for determining if a proposal's impacts are significant within the statutory meaning and definition of the corresponding Acts. They provide a statutory basis for defining impact significance and if this would trigger additional legal and statutory requirements and provisions.

# 5 EXISTING ENVIRONMENT

This Chapter describes the existing environment of the study area.

## 5.1 Hydrodynamic and physical conditions

### 5.1.1 Sydney Harbour

Sydney Harbour, along with Middle Harbour, North Harbour and the Lane Cove and Parramatta Rivers collectively form Port Jackson, which covers an area of 55 $km^2$, comprises 317 kilometres of shoreline, and at high-tide, contains about 650 million cubic metres of water.

The majority of Port Jackson's shoreline is fronted by urban development. The associated catchment, including Sydney Harbour, receives high-volumes of stormwater runoff from the surrounding urban environment. This runoff is mostly discharged by Council, Roads and Maritime and Sydney Water owned infrastructure. Typically, the only stormwater pollution prevention controls in place regionally are gross pollutant (litter) traps. As a result "Sydney Harbour's water quality is graded 'poor' as the result of ongoing gross pollutant, sediment, suspended solid, nutrient, organic material, heavy metal and hydrocarbon discharges" (Sydney Harbour Catchment Water Quality Improvement Plan, WaterNSW, 2010). Despite this, Sydney Harbour supports a number of endangered species, communities and migratory species (Sydney Harbour Catchment Water Quality Improvement Plan, WaterNSW, 2010).

As a result, the surrounding councils, Roads and Maritime, and Sydney Water have developed stormwater management plans that are being implemented to improve the Harbour's water quality.

### 5.1.2 Water quality

#### OBJECTIVES

The State Government has developed WQOs for each catchment in NSW. These objectives were adopted following public consultation in 1998 (NSW DEC, 2006). The Sydney Harbour WQO are to protect:

- Aquatic ecosystems
- Visual amenity
- Primary and secondary contact recreation
- Aquatic food production (aquaculture).

#### CHEMISTRY

The salinity of seawater affects its density and buoyancy compared to freshwater. In coastal and estuarine areas, the salinity of the seawater will affect how well it mixes and exchanges with the freshwater. In low-energy environments the saline seawater and fresh water do not mix. The fresh water sits on top of the saline water (a process known as stratification). This can lead to anoxic conditions.

Offshore of Sydney Harbour, the salinity is about 35 practical salinity units (PSU) which is typical of open ocean conditions (Sydney Institute of Marine Science, 2016). Salinity data collected in Woolloomooloo Bay by the University of Sydney in 2013 confirmed that the water's average salinity in the summer is about 35 parts per trillion (which is broadly comparable to PSU) and in the winter, it is about 34 ppt.
The corresponding annual minimum in 2013 was about 30 ppt while the maximum was just above 35 ppt.
The data confirm that the seawater in the proposal footprint is slightly less saline than the seawater, which

reflects the limited, but still present, mixing of fresh and saline water and the discharge of stormwater in to the harbour close to this location.

### 5.1.3 Tides

Sydney Harbour is tidally influenced, and the cycle is semi-diurnal meaning there is 12.5 hours between high-tides. At Fort Denison the tidal conditions are as follows:

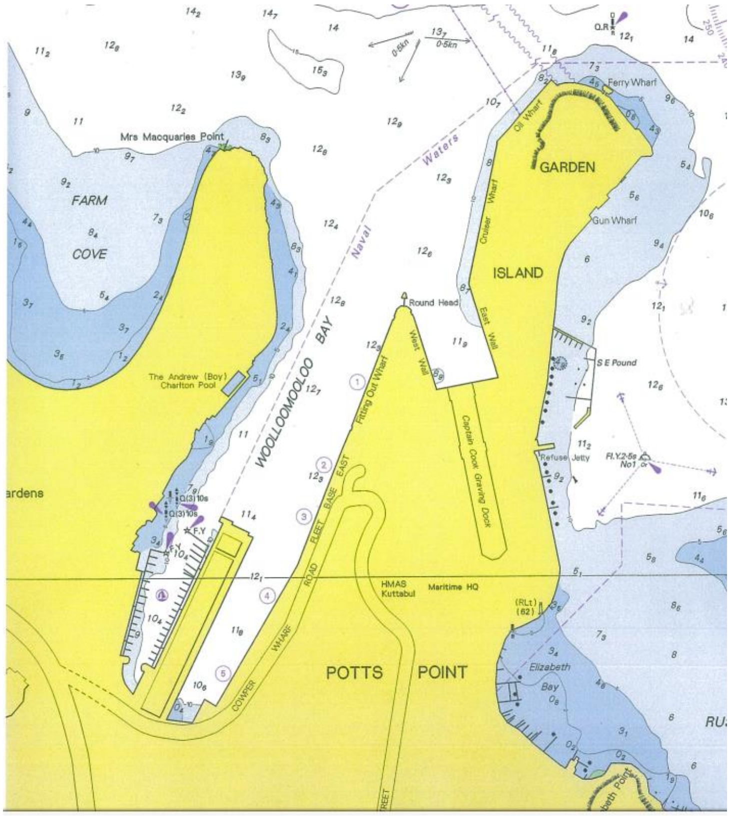
- Mean spring tide is 1.23 metres above AHD.
- Mean neap tide is 0.75 metres above AHD.
- Mean high water is about 0.5 metres above AHD.
- Mean low tide can be about one metre below AHD.
- The highest high tide that would occur once every 50 years is about 1.6 metres above AHD.

### 5.1.4 Physical characteristics

#### Bathymetry

There is a complex bathymetry across Sydney Harbour. The natural seabed has been heavily modified in locations through dredging shipping and navigation channels. There are also a number of ‘holes’ across the middle of the harbour that are up to 45 metres deep separated by shoals that are as shallow as three metres (Sydney Institute of Marine Science, 2016).

The seabed around Woolloomooloo Bay is between 11 and 12 metres below the surface (based on lowest astronomical tide, LAT). This gives way to shallow sandstone platforms that outcrop up to five metres from the shoreline. In these locations the seabed is between one and four metres below the surface (based on LAT) as shown on Figure 5.1.




*Source: Sydney Ports Corporation, Waterways Authority*

Figure 5.1 Bathymetric data around Woolloomooloo Bay

## Currents and circulation

Sydney Harbour is influenced by the East Australian Current (EAC). It generally provides a nutrient depleted sub-tropical water mass (Sydney Institute of Marine Science, 2016). Average offshore current speeds are about 1.5 $ms^{-1}$, meaning that the water flowing past the heads is being constantly renewed. This allows for mixing, flushing and seawater exchange.

While no tide, current or gauge data were obtained in Woolloomooloo Bay, it is appropriate to consider the current speeds to be at or close to zero. This reflects the sheltered and enclosed environment. In reality however, the stormwater runoff from the land, in combination with seaward groundwater movement, would mean that the water would trend towards the main deep channel and heads. Over any tidal cycle there would therefore be a very small (likely about 0.01 $ms^{-1}$) net current towards the heads.

## Wind and wave conditions

Three dominant wind patterns affect Sydney Harbour. The strongest winds, which occur for about 17 per cent of the time, come from the south. These affect the northern shoreline with the southern shoreline, which includes Woolloomooloo Bay, being comparatively sheltered. The most frequently observed winds come from the north east (about 22 per cent of the time), and the third most common pattern are winds coming from the west, which occur for about 17 per cent of the time mainly during the winter (Sydney Institute of Marine Science, 2016).

Sydney Harbour is largely an enclosed system. This means the waves generated in the Harbour are typically only wind-generated. The maximum wave heights are closer to the heads and across the main channels, however they are typically less than one metre peak to trough. However, the low-energy and sheltered nature of the many bays, including Woolloomooloo Bay, means that the wave conditions are further limited, resulting in very small waves and typically calm to still conditions other than in storm conditions.

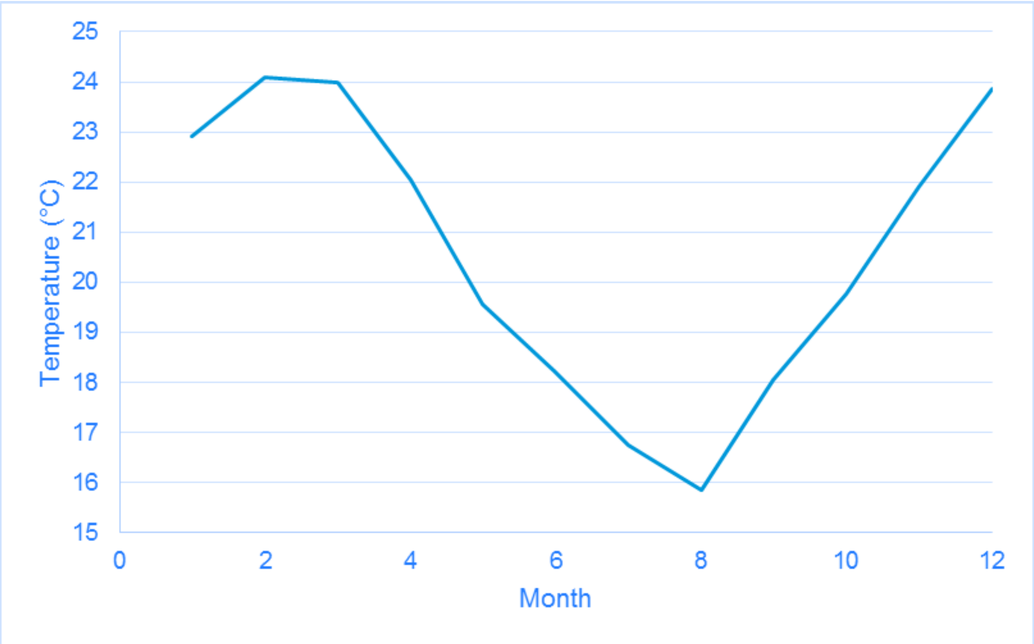
## Temperature conditions

Average offshore water temperatures at depths of 100 metres range between 12 and 25 degrees Celsius in summer and 16 and 20 degrees Celsius during the winter (Sydney Institute of Marine Science, 2016).

This compares to the proposal footprint where data collected by the University of Sydney in 2013 along the shoreline immediately next to the proposal footprint (Figure 2.1 in Appendix A) confirmed the average summer water temperature to range between 22.4 and 24.1 degrees Celsius, while the average high and low temperatures across the remaining months varied between 15.8 and 24.3 degrees Celsius at other times of the year.

It is clear that the temperatures in Woolloomooloo Bay are comparable to open ocean temperatures. This suggests that the seawater in the Bay is regularly replaced and replenished by seawater reinforcing the dynamic nature of the environment of the proposal footprint.

Figure 5.2 shows the season variation in seawater temperature based on the University of Sydney's 2013 data.




*Source: Horton (University of Sydney), 2013*

**Figure 5.2 Seasonal variation of average water temperature**

## Flushing and anoxia

Broadly, the harbour can be divided into a main channel of deeper water surrounded by a number of large shallow bays. As a result, the main tidal mixing occurs in the main deep channel. Current speeds are typically higher in the main channel, which allows for improved flushing. This compares to the bay areas, which are sheltered, typically have lower current speeds and poorer flushing.

However, the difference is comparative. In the lower reaches of the harbour around the heads and associated lower areas of the harbour, the currents and tides are sufficient to allow reasonable water exchange over a tidal cycle. This reduced the risk of stagnant anoxic water (Sydney Institute of Marine Science, 2016). This is certainly true of the proposal footprint.

### 5.1.5 Geology and sedimentology

Sydney Harbour is in the Sydney Basin, which comprises a base geology of Hawkesbury Sandstone typically overlain by Quaternary deposits. The sandstone comprises cross-bedded, medium-to-coarse quartz sand with minor shale and laminate beds. It resists weathering and erosion to outcrop as prominent headlands along the coastline. The Quaternary deposits are up to 160 metres deep and comprise sand, silty-sand, clayey-sand and clay with peat lenses.

Sandstone underlays Sydney Harbour and the proposal footprint. While occasionally exposed at surface, as is evident along the shoreline next to the proposal footprint, the sandstone is either directly overlain by up to seven metres of sub-benthic sediment or a sequence of Quaternary deposits, which in turn, are overlain by sub-benthic sediment.

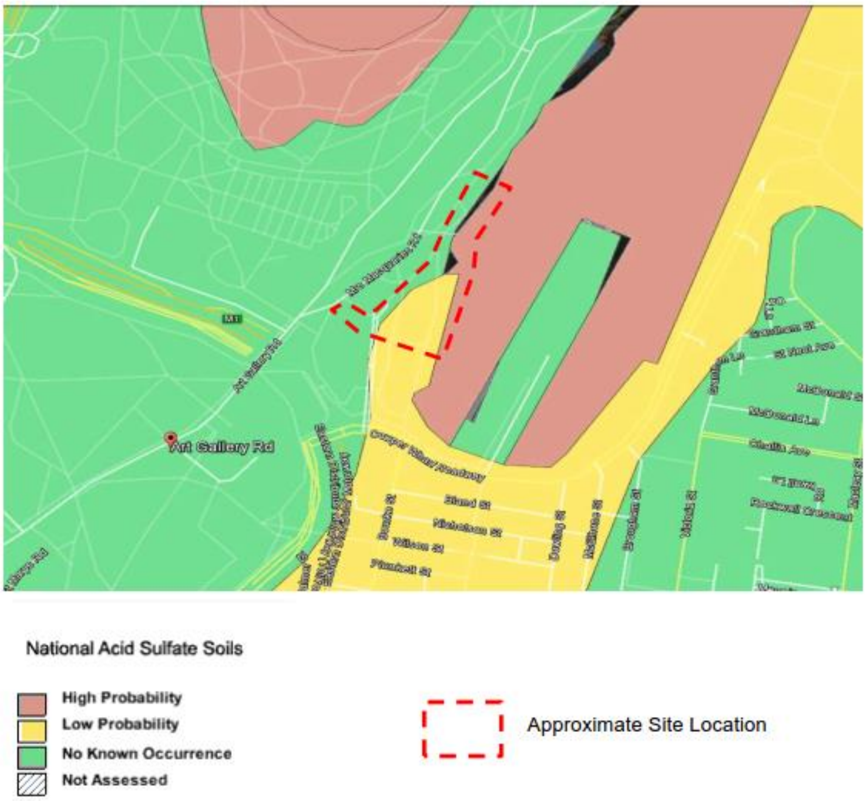
These sub-benthic sediments comprise occasional stiff-clay lenses, peat deposits and silty sands. There is also variability across Sydney Harbour, with the main channel and seabed close to the heads comprising sediments formed of a mixture of modern and relict sand and biogenic material (gastropod shells, bivalve shells and rock fragments) transported from offshore.

In the bay areas, including Woolloomooloo Bay, the low-energy means that finer marine sediment have settled comprising find sand, muddy deposits and even occasional peat lenses.

### 5.1.6 Acid Sulphate Soil

Acid sulphate soil (ASS) occurs in areas rich in iron sulphide, which generate sulphuric acid if exposed to the air (oxygen). The acid is an issue in its own right as well as causing the mobilisation of metals (e.g. aluminium, iron, manganese), which can also have a detrimental environmental impact. ASS can also decrease the amount of dissolved oxygen in surface waters, leading to eutrophic conditions and fish kill.

While there is extensive land-based mapping of ASS potential, the marine sediments of the harbour are largely unmapped. This is the case of Woolloomooloo Bay. However, while the areas next to the Bay either have no ASS risk potential or a low risk, the marine sediments in the Bay are considered to have a high potential (red areas in Figure 5.3 as concluded by Coffey in 2016).




*Source: CSIRO Land and Water Atlas of Australian Acid Sulphate Soils, 2010*

**Figure 5.3 Map of ASS covering the land surrounding the proposal footprint**

## 5.2 Marine ecology

The proposal footprint (refer to Figure 2.1) is located on the south western side of Woolloomooloo Bay, which like much of Sydney Harbour, has undergone extensive modification through reclamation and construction of extensive foreshore structures.

The eastern shoreline of Woolloomooloo Bay comprises a manmade built habitat of continuous seawall, large ship berths and wharf facilities for a variety of vessels. Adjacent land uses are dominated by maritime activities backed by a mixture of commerce and residential.

The shoreline next to the proposal footprint comprises small vessel pontoon berths (to the south), seawalls (to the north and south), a boardwalk (to the north), a jetty (to the north) and remnants marking the original location of the Andrew (Boy) Charlton Swimming Pool (to the north). The swimming pool is a locally listed heritage items, as described further in the main EIS. The remainder of the western shoreline extending to Mrs Macquarie's Chair includes seawalls and modified and natural intertidal habitat. The adjacent land use to the west is mainly passive recreation, dominated by The Domain, while to the east is the Royal Australian Navy facility at Garden Island.

### 5.2.1 Overview

The intertidal habitat of the proposal footprint consists of a field of vegetated boulders, sand and bedrock at the base of a steep, vegetated cliff. The intertidal area is backed by a sandstone block seawall and features a 35-metre-long wooden boardwalk over the intertidal rocks and sand habitat. The intertidal zone covers the shallow waters that are between one-to-eight metres deep depending on the state of the tide. This compares to the deeper waters of Woolloomooloo Bay that are about 12 metres below the surface at low tide (refer to section 5.1.4). There is a distinct shelf where the intertidal boulder field gives way to the deeper waters. Typically, this occurs about four-to-five metres from the seawall opposite the end of the finger wharf. Where the inlet and outlet pipes cross the intertidal area, the zone is about three metres wide. Consistent with the bathymetry, the vegetated subtidal area drops steeply to a water depth of between 10.5 metres and 11 metres below the surface (based on LAT).

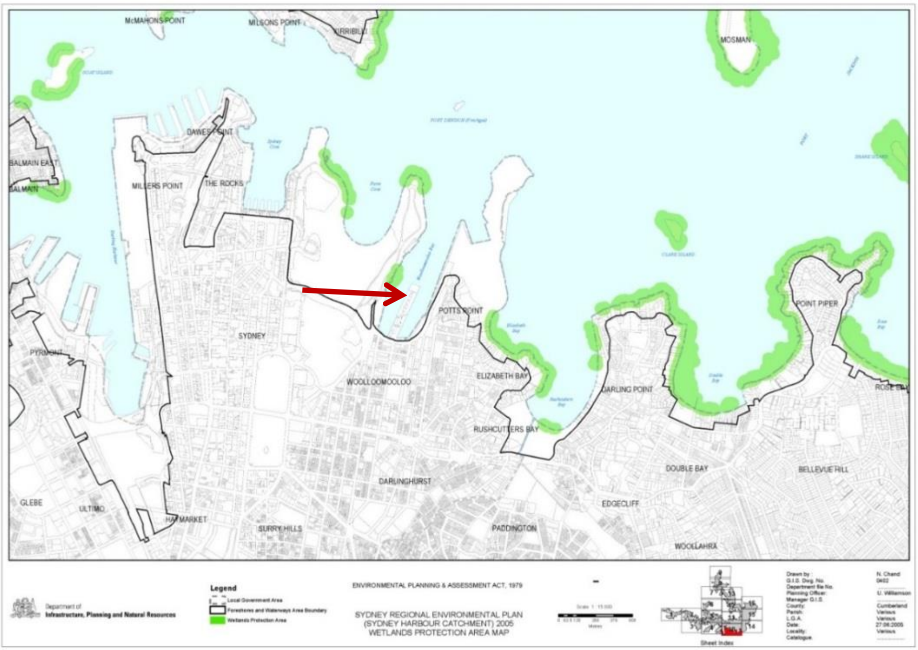
### 5.2.2 Protected areas

The nearest protected area to the proposal footprint is a section of intertidal shoreline about 180 metres long extending from near the seaward-most pontoon of the jetties on the western shoreline of Woolloomooloo Bay. At its closest it is about 70 metres to the north of the limit of the proposal footprint (refer to Figure 5.4).

The protected area is designated under Sydney Regional Environmental Plan (Sydney Harbour Catchment) 2005 as a wetland, However as observed in May 2016 and October 2017, it contains no significant wetland habitat features such as mangroves or saltmarsh plants or communities. No seagrass is mapped in Woolloomooloo Bay (NSW Department of Primary Industries (Fisheries), 2005) and none were observed within the protected area or elsewhere within Woolloomooloo Bay.

As observed during the site walkovers (refer to section 4.3), the protected wetland area was backed by a steep cliff vegetated with a variety of common coastal trees, shrubs and weeds common along the foreshore.

Although its borders are ill defined, the intertidal section of the protected area is characterised by a narrow band of vegetated boulders over sandstone bedrock with interspersed pockets of shelly debris and sand. The area is backed by a low seawall at its southern limit. Collectively, it shows little to no characteristics of a wetland. Nonetheless, the area does retain a statutory basis for protection under planning policy that is relevant to the assessment.




*Source: Sydney Regional Environmental Plan (Sydney Harbour Catchment) 2005 Wetlands Protection Area Map Sheet 10, DIPNR 2005*

Figure 5.4 Location of Wetland Protection area near the proposal footprint (red arrow)

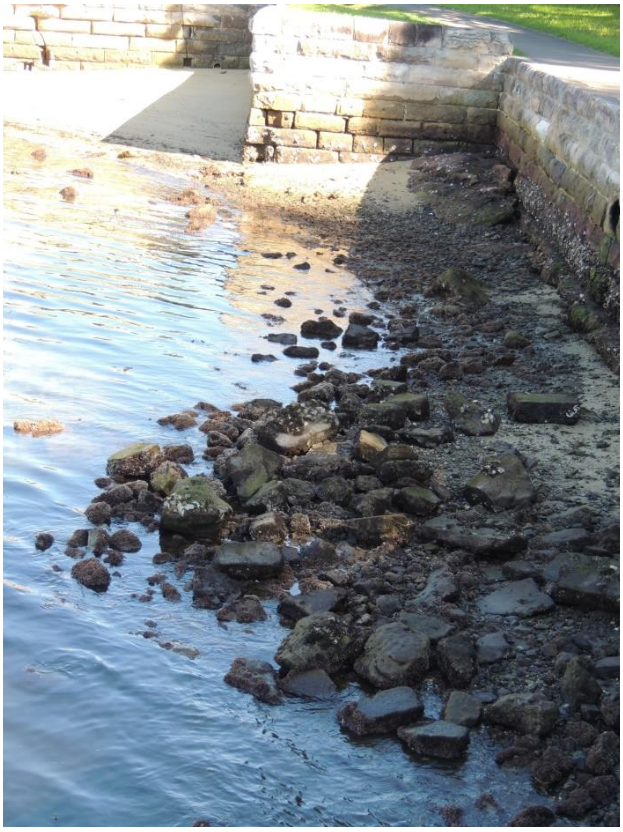


Figure 5.5 Seawall and intertidal boulder habitat near the proposed pipework

As per Figure 2.1, the inlet and outlet pipes would run in parallel through the seawall and cross a two-to-three-metre-wide area of sand and boulders (refer to Figure 5.5). The proposed two inlet pipes would extend to about 60 metres from the seawall, immediately west of the seaward-most pontoon berth along the western shoreline associated with residences off Lincoln Crescent. The two outlet pipes would terminate about 30 metres to the north of the inlet, opposite the seaward-most berth of the finger wharf. The vegetated boulder field is about three to four metres wide at this point and drops off sharply to a water depth of about 10.5 metres below the surface at low tide.

### 5.2.3 Marine habitat

The following observations were made during the site walkovers:

- The intertidal boulders host an assemblage of estuarine algae and invertebrate animals typical of Sydney Harbour's sheltered bays.
- Boulders of varying sizes were interspersed with small patches of sandy and shelly sediment, consistent with the geology and sediments of the wider harbour (refer to section 5.1.5).
- No seagrass, saltmarsh or mangrove habitats, sensitive ecological environments common to Sydney Harbour, were present in the study area, nor where there any indicative plant or animal components of those habitats.
- Vegetated boulders extended in to the subtidal habitat and persisted until the drop-off into deeper water of the channel.

- Artificial habitats dominate the proposal area (wharf and boardwalk piles, navigation structures and pontoons) and supporting intertidal and subtidal communities are characterised by dense oyster and/or algal communities.

### 5.2.4 Protected biodiversity

Searches of relevant databases of listed threatened species under the EBPC Act, TSC Act and FM Act (refer to section 4.1) returned a list of relevant threatened species, populations and communities that occur within 10 kilometres of the proposal footprint. Most of these species are land-based given the proposal footprint's location. Table 5.1 therefore only summarises the marine species, population and communities and seabirds that are recorded locally.

**Table 5.1 Protected species**

| COMMON NAME | SUMMARY |
|---|---|
| **State and Commonwealth protected species** | |
| Fish | Four species, one endangered population of fish, and up to 23 species of seahorses (syngnathiforme) |
| Marine mammals | Six species |
| Marine turtles | Five species |
| Birds | 26 species and one population of birds |
| Ecological communities/population | The seagrass *posidonia australis* meadows of the Manning-Hawkesbury ecoregion and populations in Port Hacking, Botany Bay, Sydney Harbour, Pittwater, Brisbane Waters and Lake Macquarie. |

The relevance of the activities associated with building and operating the proposal and the likelihood of the species to occur in the proposal footprint were considered to determine which species, communities and populations require further assessment. The key project-specific considerations included:

- The proposal footprint is in a small, relatively shallow bay within Sydney Harbour and consists of modified and urbanised intertidal and subtidal habitats that have relatively low habitat diversity and moderate existing biotic diversity.
- The work that would affect intertidal and subtidal habitats would occur immediately next to the shoreline. It would have a relatively short duration and it would have a small footprint due to the parallel installation of inlet and outlet pipes.
- The operation of inlet and outlet pipes are unlikely to impact on deeper soft-bottom habitats.
- From the perspective of impacts on marine species, the higher impact construction work is limited to installation of inlet and outlet pipes at a point where the intertidal and subtidal habitats are narrow, before dropping off to deeper water.
- The volume of seawater used for operation of the heat exchange system would be small relative to the volume of Sydney Harbour (refer to section 5.1.1) making the loss of planktonic life forms insignificant and unlikely to alter the ecology of intertidal or subtidal habitats.
- The low current speeds at the inlet pipes (refer to section 5.1.4) have been shown to minimise the likelihood of impingement for the vast majority of fish and macroinvertebrates on inlet screens.
- The impact of increased water temperature close to the outfall pipes is limited, on average to two degrees Celsius within a plume of one metre (in the horizontal plane) radius (refer to Table 6.1) and, given ambient average temperature, tidal exchange and local water circulation unlikely to cause thermal stress in intertidal or subtidal marine organisms.

No threatened or protected species required formal tests of significance (refer to section 4.6) due to one or more of the above considerations. Appendix B, Table 1 lists the specific reasons applicable to each of the relevant threatened or protected marine species, community or population. The main reason for the lack of threatened species in the proposal footprint and across the study area is that the habitat that threatened marine faunal species require, such as well-developed seagrass beds (habitat for seahorses and their allies and feeding grounds for turtles) and open sandy beaches (nesting habitats for some threatened shorebirds and turtles) are absent, minimal or have been largely replaced by artificial structures, reducing the likelihood of finding threatened or protected species in the inner reaches of Woolloomooloo Bay.

### 5.2.5 Flora and Fauna

Flora and fauna observed in the proposal footprint and across the study area included encrusting and foliose algae growing on seawalls, boardwalk piers, intertidal boulders and intertidal reef flats, attached invertebrates such as oysters, sponges and sea squirts, mobile invertebrates such as limpets, chiton, periwinkles, snails and whelks, fish and birds. Table 5.2 lists the macro algae and macroinvertebrates observed during site examination undertaken during low tide.

**Table 5.2 Intertidal and subtidal flora and fauna observed in the study area**

| COMMON NAME | SCIENTIFIC NAME |
|---|---|
| **Marine Algae (flora)** | |
| Green algae | *Ulva* spp., *Enteromorpha* spp. |
| Brown algae | *Zonaria* spp. |
| Funnel weed | *Padina elegans* |
| Bubble weed | *Sargassum linearifolium* |
| Kelp | *Ecklonia radiata* |
| Brown forkweed | *Dictyota dichotoma* |
| Red algae | *Gelidium* spp., *Dilophus* spp. |
| Encrusting red algae | *Hildenbrandia* spp. |
| Turf forming coralline algae | *Corallina* spp., *Jania* spp. |
| **Marine Invertebrates (fauna)** | |
| Sydney Rock oyster | *Saccostrea glomerata* |
| Barnacles | *Elminius modestus, Catomerus polymerus, Tetraclitella purpurascens, Chthamlus antennatus, Austrominius covertus* |
| Limpets | *Cellana tramoserica, Patelloida mimula, Spihonaria* spp. |
| Chiton | *Chiton pelliserpentis* |
| Periwinkles and snails | *Bembicium* spp.,*Littorina* spp., *Austrocochlea porcata, Nerita atramentosa* |
| Whelk | *Morula marginalba* |
| Cunjevoi, Sea squirts | *Pyura stolonifera* |
| **Finfish (fauna)** | |
| Smooth Toadfish | *Tetractenos glaber* |

| COMMON NAME | SCIENTIFIC NAME |
|---|---|
| Eastern hulafish | *Trachinops taeniatus* |
| Luderick | *Girella tricuspidata* |
| Threadfin butterfly fish | *Chaetodon auriga* |
| Bait fish, Schooling fish | Young of several species |
| **Birds (fauna)** | |
| White faced heron | *Ardea novaehollandiae* |
| Silver gull | *Larus novaehollandia* |

The flora and fauna above are typical of estuarine assemblages in Sydney Harbour. The observed biodiversity of the intertidal and shallow subtidal areas can be considered average with assemblages that are common in sheltered bays dominated by built structures (Chapman, 2003). Figure 5.6 shows intertidal and shallow subtidal habitat in the vicinity of the proposed inlet and outlet pipes. A grey (or white-faced) heron (*Ardea novaehollandiae* ) can be seen fishing near the boardwalk amongst boulders covered in green, red and coralline turfing algae and Sydney rock oysters with a school of juvenile fish are visible in the background.

**Figure 5.6 Inter- and subtidal habitats during low tide on 5 May 2016 near where the proposed pipework would traverse the seawall and intertidal zone**

## 5.2.6 Key threatening processes

Key threatening processes is actions that (have the capability to) threaten the survival or evolutionary development of any species, population or community protected under State legislation. A series of standard processes have been defined under State legislation (refer to section 4.1). Those processes that may adversely affect the identified threatened species within Woolloomooloo Bay, and hence require consideration in the approvals process, are:

- Clearing of native vegetation.
- Entanglement in or ingestion of anthropogenic debris in marine and estuarine environments.

No threatened or protected species required formal tests of significance (refer to section 4.6) due to one or more of the considerations listed in section 5.2.4 above. Appendix B, Table 2 lists the specific reasons applicable to each of the relevant threatened or protected marine species, community or population.

# 6 MARINE IMPACT ASSESSMENT

This Chapter describes the predicted impacts that would occur on the marine environment from building and operating the seawater heat exchange system.

## 6.1 Construction

While the work activities needed to install the marine infrastructure would be limited to a small area of Woolloomooloo Bay, and they would occur for up to two months, there remain a number of general risks associated with working in the marine environment as described below.

### 6.1.1 Hydrodynamic and water quality

#### HYDRODYNAMIC CHANGES

The proposal involves three activities that that would cause physical disturbance to the marine environment; the drilling of the anchoring points (Activity 1), the landside connection (Activity 3) and securing the pipes, screens and security cages (Activity 4). However, the scale of the disturbance would be minimal and insufficient to cause any dynamic changes in current speed, wave characteristics, tidal mixing or flushing.

#### LOCALISED SEDIMENT DISTURBANCE AND SMOTHERING

While the harbour comprises a substrate of sub-benthic marine sediment that can be several metres deep, the localised sediments are confirmed to comprise exposed hard substrate (sandstone) that has weathered to boulders close to the shoreline overlain by a thin layer of mobile silty sand. The anchoring points (Activity 1) and deployment of the jack-ups or anchors (Activity 1) and the nearshore trenching and backfilling (Activity 2 and Activity 4) would be the activities to disturb the harbour floor. While each anchoring point would be most likely about 50-60 mm wide and it would be drilled a few metres into bedrock, the amount of sediment disturbance would be minimal. The jack-ups/anchors would also only cause minimal disturbance to the harbour floor. In the case of the trenching, this would disturb an area of about 80 $m^2$ (refer to section 2.7.4) mobilising no more than about 160 $m^3$ of sediment. This level of disturbance would be far less than the natural dynamic disturbance and processes that take place in the harbour (Cardno, 2012).

The coarse fraction of any disturbed sediments would settle out of suspension almost immediately, while the fine fractions could mobilise over a greater area (Cardno, 2012). The settled sediments would then be subject to subsequent tidal mixing and natural transport processes. As the majority of the sediment is expected to settle out of suspension within a few minutes (Cardno, 2012) there is expected to be no risk of light preclusion. The small amount of sediment generated under the proposal would mean there is no predicted or expected smothering impacts, however as a precaution, either a silt boom or curtain would be used (refer to Chapter 7) to contain any sediment, meaning the impact would be limited to this area.

#### ACCIDENTAL SPILLS (SEDIMENT AND POLLUTANT DISCHARGE)

The materials needed to install the marine infrastructure would be generally inert and harmless except for the small quantities of welding material, pipe lubricant, solvents, fuels, oils and diesels. The use of these materials in the marine environment is controlled in accordance with the NSW *Protection of the Environment Operations Act 1997* (as amended, refer to section 3.3.1) and to some extent the NSW *Marine Pollution Act 2012* (refer to section 3.4) in relation to the ships that would be used to undertake the work. These materials would be stored in small quantities in an intrinsically safe area (i.e. double-skinned containment). They would only be used under controlled conditions in a designated area on the barge/pontoon, where any discharge would be collected. Standard practices would therefore limit the risk of any spilt materials impacting on the marine environment. However, there would be an inherent risk of:

- Accidental spills outside of the self-contained areas.
- Accidents, including loading and unloading risks.
- Leaks and drips from poorly maintained machinery and equipment.
- The mismanaged storage of waste materials.

These risks would be present throughout the construction program and when undertaking all activities in Table 2.3. The risks would also be greater when undertaking work over or in harbour namely:

- Drilling the anchoring points (Activity 1).
- Floating the pipes (Activity 2).
- Connecting into the land side pipes (Activity 3).
- Securing the pipes, screens and security cages (Activity 4).

The principal risks for an accidental spill would be worker exposure in its clean-up and any pollution impact on the marine environment. The impact would depend on the quantity and type of material spilt. However, with effective well-practiced site management controls in place there would be negligible risk of a major spill occurring. The risk of minor spillages are more likely, the impact of which could be minor given the scale of any discharge and the mixing and dilution that would occur in the water column.

### EROSION AND SCOUR

Any work taking place in the marine environment has the potential to cause erosion and scour impacts. This is caused from introducing new structures typically on, or close to the harbour floor, which would alter sediment transport patterns. Under the proposal, the jack-up barge/floating pontoon would be the only equipment that would anchor to the seafloor. However, the jacks or anchors would only be in place for a few weeks. This would be an insufficient amount of time to cause any material scour or erosional impacts, despite there being some localised effects (potentially extending up to one metre around each jack/anchor).

### ACID SULPHATE SOILS

Acid sulphate soils are likely present across Woolloomooloo Bay (refer to section 5.1.6). As such, there is a risk that they would be disturbed during the trenching and installation work (Activity 2 and Activity 4). As such, controls would be introduced under an acid sulphate soil management plan (described as a mitigation measure in the main EIS).

### LOCALISED POLLUTANT DISTURBANCE

Despite not undertaking any geochemical testing, it is reasonable to assume that the sediment and water quality of the proposal footprint has been affected due to runoff from the surrounding land and the range of activities that take place in the harbour, including the proximity of Royal Australian Navy facility at Garden Island. The main pollutants expected to be present in the area would be:

- Surfactants, oils, fuels, diesels and metals due to stormwater runoff.
- Hydrocarbons (and their derivatives) and heavy metals due to the operations at Garden Island and from the ships berthing in Woolloomooloo Bay.
- Residual tributyltin, from the legacy of ships mooring at Garden Island.

Tributyltin forms a group of tin-derivatives that were used extensively in antifouling paint in the shipping industry until an international ban in 2003 prevented their use on vessels less than 25 metres in length. However, tributyltin has an exceptionally long residence time in the marine environment, and if disturbed, can still have water quality and ecotoxicology effects over many years.

Despite the poor water quality of Sydney Harbour (refer to section 5.1.1), supplemented by the additional potential pollutant/contaminant sources locally, the risk of any impact on the marine environment would be minimal. This is due to the limited disturbance of the harbour floor sediments to complete the work and the limited sediment depth in the proposal footprint. Also, the extent of disturbance would be consistent with the many small-scale activities that routinely take place in the harbour, even including the propeller wash from the many ships in the area. As such, despite there being reasonable potential for pollutants and contaminants to be present locally, the scale of disturbance would mean that any impacts would be negligible.

#### WASTE MANAGEMENT AND CLASSIFICATION

Despite the need to trench an area and potentially generate up to 160 $m^3$ of sediment (refer to section 2.7.4), there is no intention to collect and remove this material. Instead, the sediment would be contained through the use of a silt boom or curtain (refer to Chapter 7) and it would fall out of suspension locally.

The small volumes of generated waste (i.e. pipe offcuts, packaging, greases, refer to section 2.7.5) would be brought ashore for classification and either reuse or recycling, or as a last resort, disposal to a licenced facility by a licenced contractor.

### 6.1.2 Marine ecology

The work needed to install the marine infrastructure is unlikely to have any ecological impacts for the following reasons.

#### PROTECTED AREAS, SPECIES AND COMMUNITIES

The protected wetland area near the proposal footprint (refer to Figure 5.4) may be directly impacted by the trenching work (Activity 2 and Activity 4). Despite the definition and limit of this wetland being unclear, and its observed ecological value being limited (refer to Chapter 5), the trenching would have a direct disturbance impact. Importantly, no threatened species habitat was identified in the proposal footprint, this protected area or the wider study area. As such, there is assessed to be no direct impact on threatened or protected species, populations or communities from installing the marine infrastructure.

#### INJURY AND MORTALITY

Other marine biota likely to be killed or disturbed as a result of pipe installation are limited to the algal and invertebrate assemblages on mainly the undersides of rocks (worms, whelks, snails, limpets, chitons, periwinkles and oysters). Given the implementation of mitigation measures (refer to Chapter 7), mortality and injury would be minimised and likely undetectable from the surrounding habitat within about one year.

Injury, due to ship strike, is also considered unlikely as the majority of work would be staged from land. Note there is existing potential risk of ship strike due to movement of ships accessing the finger wharf and jetties.

#### HABITAT AND PLANT LOSS

The proposed pipeline construction method is assumed to be open-trench through the intertidal zone. In this case, intertidal and subtidal algal communities would be removed during construction; however, these are likely to regenerate naturally over a period of one-to-two years given implementation of the identified mitigation measures. No threatened plant species would be removed as a result of installation of the marine infrastructure. Overall, the impact of trenching through the narrow width of intertidal and subtidal habitats is considered acceptable and low given the implementation of identified mitigation measures.

### UNDERWATER NOISE

Construction work taking place in the marine environment can result in the creation of underwater noise impacts. The only two notable underwater noise-generating activity would from drilling the anchoring point (Activity 1) and the limited trenching (Activity 2 and Activity 4). Drilling can generate peak noise levels of up to 225 dB (1 µPa, Greene & Moore, 1995 and Southall *et al*, 2007) while the trenching can generate noise up to 180 dB (1 µPa, Greene & Moore, 1995 and Southall *et al*, 2007). In both instances, the maximum limit is theoretical, and based on the use of a range of associated equipment with different sizes and specifications, including equipment that is typically used for major marine work. Consequently, the above limits are conservative. Also, any underwater noise would only be generated temporarily and for a short-period (a number of hours each day for about one week).

Ambient conditions in the area are likely dominated by ship propeller noise, which depending on the size of the ship, may be as high as 190 dB (1 µPa) for any large ships docking at Garden Island and 125 dB (1 µPa) for the ships using the berths in Woolloomooloo Bay (Bowles & Graves, 2007).

Underwater noise has the potential to cause varying impacts on marine fauna, ranging from mild behavioural disturbance to death due to acoustic shock. If the noise generated from installing the anchoring points is comparable to piling, then research confirms that ambient noise would be reached about 400 metres away, while any fauna more than 30 metres of the noise source would avoid the area (Engell-Sorensen, 2000). Closer than this, certain fish species are shown to experience a temporarily loss of hearing, while there is the risk for mortality immediately adjacent to any piling work (Engell-Sorensen, 2000).

The noise from installing the anchoring points would depend on the methods use. It would most likely generate repetitive and impulsive noise that would cause an initial startled response (when the work began) followed by mammals avoiding the area during the work. While there is a risk for fish to be affected within 30 metres of where any anchoring points were installed, the local habitat does not form an important or sensitive fish habitat. As such, the potential for either harm or injury would be rare and exceptional.

### MARINE PEST SPECIES

Another potential issue is the introduction of marine pest and pathogen species. This is an issue where ships and equipment are moved from one location to another without the provision of adequate inspection and cleaning, potentially spreading pests. The main species of concern is *caulerpa taxifolia;* a fast-growing seaweed that can out complete seagrass and algal species and alter habitat. *C. taxifolia* tolerates desiccation, can grow quickly from small fragments and is difficult to eradicate. In the case of the proposal, the work activities are unlikely to introduce or spread marine pests or pathogens due to the limited amount of equipment involved and the low number of expected ship movements. Mitigation measures (refer to Table 7.1) designate that water-based equipment and ships would be inspected and cleaned before work starts. As such the risk of the spread of pathogens and pest species is exceptionally low. Nonetheless, any impact could be notable.

## 6.2 Operation

Once the proposal is operational it has the potential to have a range of direct and indirect impacts on the marine environment:

- Hydrodynamic and water quality
  - Temperature changes
  - Erosion and scour

  - Water quality changes: chemistry
  - Accidental and emergency discharges
  - Marine growth
- Marine ecology
  - Thermal and chemical pollution
  - Entrainment and impingement
  - Primary production changes
  - Operational noise
  - Impacts on threatened species, communities, populations and habitats.

### 6.2.1 Hydrodynamic and water changes

#### TEMPERATURE CHANGES

Appendix A reports the predicted increase above ambient temperature due to the discharge of warm seawater at the location and under the conditions described in Chapter 2. An outlet discharge rate of 117lL/s, was used in the discharge pipe plume modelling, which is about 70 per cent higher than the design discharge rate of 69 L/s as per Table 2.2. Because the gradient of temperature variation and the extent of the impacted area are directly related to the discharge flow rate, it is expected that using the design discharge flow rates would result in lower differential temperatures and a smaller impacted zone at the pipe outlets. As such, it is expected that the modelled results are associated with a reasonable degree of conservatism.

Table 6.1 summarises the average model-predicted temperature increase above ambient seawater temperature across the seasons based on the output of the sensitivity analysis and adopting the conservative values. The temperature gradients associated with a discharge at seven degrees above ambient temperature are shown for four modelled scenarios:

- Horizontally directed discharge during summer.
- Vertically directed discharge during summer.
- Horizontally directed discharge during the rest of the year.
- Vertically directed discharge during rest of the year.

The modelling focussed on the summer months when there would be the maximum operational demand on the system (refer to section 2.2). During this period, the discharged seawater would be at its warmest. However, it would be discharged into warmer ambient seawater. For the remainder of the year, the model predictions were based on using the maximum (summer) operational demand; however, the ambient seawater temperature was adjusted to reflect the cooler conditions. As such, the modelling was carried out under conservative conditions.

As the water would discharge as a plume, it can be represented horizontally and vertically to provide two maximum planes (lateral distances). This describes how the model predicts the discharged water to disperse up and down the water column (vertical lateral dispersion) and how it would disperse left and right in the water column (horizontal lateral dispersion). The modelling also considered the difference between discharging the water vertically or horizontally. Notably:

- A vertical discharge would reduce the spread of the plume horizontally; however it would result in a greater difference in temperature gradient within the plume. It may also be visible from the surface (depending on the depth of discharge). While the vertical configuration results in reduced lateral temperature effects compared to the horizontal configuration, it should be noted that the plume would reach the surface more rapidly if directed vertically and would move laterally across the surface.

- A horizontal discharge would reduce the spread of the plume vertically and it would reduce the difference in the temperature gradient in the plume. It would also likely avoid any issue of the plume being visible from the surface, and it has the benefit that the discharge can be directed away from sensitive areas into deeper waters that support better mixing. The horizontally directed discharge would disperse more prior to reaching the surface.

**Table 6.1 Model-predicted average temperature gradient in the horizontal plane for a discharge temperature of 7 degrees above ambient temperature**

| SEASON | AVERAGE TEMPERATURE ABOVE AMBIENT |
|---|---|
| **Summer** | → Horizontal discharge<br>▪ 2 degrees Celsius at one metre<br>▪ 1 degrees Celsius at three metres<br>▪ 0.5 degrees Celsius at six metres<br>→ Vertical discharge<br>▪ 0.5 degrees Celsius at 0.2 metres |
| **Autumn, Winter and Spring** | → Horizontal discharge<br>▪ 2 degrees Celsius at one metre<br>▪ 1 degrees Celsius at three metres<br>▪ 0.5 degrees Celsius at six metres<br>→ Vertical discharge<br>▪ 0.5 degrees Celsius at 0.2 metres |

*Note: the predictions between the summer months and other times of the year are recorded as being identical. While there was a difference it was in the order of a 0.1 metre increase in dispersion in the non-Summer months. Given the uncertainty in the modelling it is not valid to report this predicted variation. In effect, the results should be regarded as being broadly similar irrespective of the receiving ambient temperature of the seawater and dependent upon the temperature difference between the discharge and ambient water.*

As noted in section 3.3.1, if the discharge temperature of the water is greater than two degrees Celsius this is deemed 'thermal waste' within the meaning and definition of the NSW Protection of the Environment Operations (General) Regulation 2009.

The above regulation does not provide the specific conditions under which 'thermal waste' would result in 'water pollution' other than defining the resultant environmental impact. This is defined with the ANZECC Guidelines (refer to section 3.3.2), through the concept of assessing the potential exceedance of 'trigger values'. These are values above which, there is an increased risk of causing water pollution that must be investigated further.

Section 7.4.4.1 of the ANZECC Guidelines contains a summary of the approach recommended for comparing results from a test site with a guideline trigger value. It is emphasised that trigger values are an 'early warning' mechanism of a potential problem. They are not intended to be an instrument to assess 'compliance' and should not be used in this capacity. The recommended trigger-based approach for physiochemical stressors (changes in the natural environment that can cause an impact on marine values) such as temperature is stated as follows; "a trigger for further investigation will be deemed to have occurred when the median concentration of independent samples taken at a test site exceeds the $80^{th}$ percentile of the same indicator at a suitably chosen reference site".

Table 6.2 shows the 80th percentile and median baseline ambient temperatures based on Harrison, 2013 compared to the modelled increase at the edge of the near-field. The near-field zone is defined as the area within which the plume reaches the surface; this occurs over greater lateral extent with horizontally oriented discharge so the temperature gradient within the plume is smaller and the temperature at the edge of the plume is lower compared to the vertical orientation. Vertically oriented discharge result in a smaller, more focused plume with higher temperature gradients.

**Table 6.2 Comparison of baseline and elevated temperatures adjacent to the proposal footprint**

| STATISTIC | TEMPERATURE (°C) | | | |
|---|---|---|---|---|
| | SPRING | SUMMER | AUTUMN | WINTER |
| **80th percentile (trigger value)** | 21.9 | 24.0 | 24.2 | 18.0 |
| **Baseline median** | 19.9 | 23.3 | 22.0 | 16.6 |
| **Modelled increase in temperature at the edge of the near-field:** | | | | |
| **Horizontal discharge** | 0.1 | 0.1 | 0.1 | 0.1 |
| **Vertical discharge** | 0.3 | 0.3 | 0.3 | 0.3 |
| **Predicted Median temperature post discharge** | | | | |
| **Horizontal discharge** | 20.0 | 23.4 | 22.1 | 16.7 |
| **Vertical discharge** | 20.2 | 23.6 | 22.3 | 16.9 |

The above table confirms that the model-predicted median temperature post discharge is less than the 80th percentile ambient temperature and the discharge is therefore not considered to have an adverse impact on the receiving waters either in terms of the ANZECC Guidelines, or by extension, the definition of thermal water pollution under the NSW *Protection of the Environment Operations Act 1997* (as amended).

### Far-field modelling

The predicted modelling results confirm that there would be sufficient initial mixing and dilution in the nearfield that the water temperature would return close to ambient conditions within the near field zone (i.e. a few metres of the discharge point). It also confirms that the discharge would be below the ANZECC Guideline trigger value in the near field. As such, there would be no need to consider the impacts across the far field. It can also be concluded that the zone of impact would be localised to the near field.

## EROSION AND SCOUR

Appendix A also predicts the decrease in discharge velocity from the outlet. At its maximum operating demand under the conservative assumptions adopted in the modelling, the outlet would discharge 117 litres of seawater per second via three 150 mm risers (refer to Table 2.2). This is equivalent to a discharge speed of about 2.2 $ms^{-1}$. The modelling predicts that:

- The horizontal plume speed would drop to:
  - 1 $ms^{-1}$ within one metre of the outlet
  - 0.5 $ms^{-1}$ within two metres of the outlet
- The velocities within the vertical plume speed would reduce to negligible amounts within one metre.

The conditions under which erosion and scour occur in the marine environment vary depending on local sediment conditions. In this case, they would be influenced by the discharge height above the seabed. Due to the buoyancy of the plume causing it to immediately rise; there would be no impact under the design basis of it being discharged up to two metres above the seabed.

## ACCIDENTAL AND EMERGENCY DISCHARGES

There is always the potential for an accidental or emergency discharge outside of the above operating parameters. The system includes monitoring sensors that allow automatic regulation. In the event of a detected accident or emergency the system would shut down and a conventional back-up air conditioning until would operate. Any seawater within the system at this point would be pumped and collected for treatment and disposal at a licenced facility by a licenced contractor.

## MARINE GROWTH

The proposal is to clean and flush the system using fresh water to prevent algal growth. This would need supplementing with the occasional use of a biocide. The biocide dosage and usage frequency would be determined during the detailed design phase.

### Freshwater flushing

This would be adopted as the ongoing routine method to prevent marine growth. Its success varies depending on ambient characteristics. It relies on the sudden drop in salinity caused by introducing freshwater. This can lead to osmotic shock, which can be used to kill organic material growth. While it typically relies on large quantities of freshwater that can affect the salinity of the ambient environment, any effects can be reduced by working offline. This allows a closed section of the system to be flushed and treated in isolation. This approach requires notably less water and it would be effective for this proposal due to the plan to have an operational and offline pipe at any one time.

### Biocides

Biocides would provide an antifouling coat on the inside of the pipes. They are either applied to a wet or dry surface or introduced as a (single or continuous) dose into the operational system. They can therefore work online or offline. While achieving the same outcome of treating and preventing marine growth their chemistry is different. They either work via an oxidation (chlorine, hypochlorite, ozone, bromine) or non-oxidation (amines, copper salts, ammonium salts) process.

Oxidising biocides have been used for longer. They are effective however they corrode pipes and they need to be used in large quantities to be effective. Their effectiveness can be improved by using a combination of oxidation biocides and electro-chlorination (a chlorine cell), which is emerging as a common preferred alternative for treating marine growth. The alternative non-oxidising biocides form a surface film, meaning they have a longer residual time, which means a reduction in the quantity needed. They are also non-corrosive. They therefore have a low impact on the marine environment providing they are used in appropriate concentrations.

The proposed biocide would be the amine based, film forming biocide: Mexel ® 432. This product has been approved for use by the APVMA.

### Marine impacts

The use of any biocide treatment has the potential to result marine impacts from chemical discharge; including the pollution caused from freshwater discharge leading to desalination.

However, the occasional use of an APVMA-approved amine based biocide as a back up to freshwater flushing is considered to pose a negligible risk of impact. Providing the correct concentrations, treatments and controls are introduced and the plant is operated within manufacturer specifications, the risk of any impact can be managed to acceptable levels. The active constituents in Mexel 432 dispersant would largely be consumed within the cooling system and would be unlikely to persist in the marine environment following discharge because of their strong absorptive characteristics and biodegradability (APVMA, 2012). Due to this, cumulative impacts of other local systems using this product are unlikely to cause unacceptably high concentrations in receiving waters.

The Commonwealth Department of Environment and Energy has recommended that the APVMA be satisfied that the proposed use of Mexel 432 dispersant would not be likely to have an unintended effect that is harmful to animals, plants or things, or to the environment (APVMA, 2012).

The only other risk would be one of an accidental or emergency discharge or overdose. This risk would be managed through automated dosing or dosing only by suitably qualified personnel. All personnel involved in the dosing would need to be trained in the dosing equipment. Furthermore, the system would be monitored and shut down in such an event.

### 6.2.2 Marine ecology

#### THERMAL AND CHEMICAL POLLUTION

**Temperature impacts**

Modelling indicates that discharged warmer seawater would mix with ambient water quickly sufficient not to clause any thermal pollution (refer to section 6.2.1). Marine organisms within one metre of the outlet pipe (within the horizontal extent of the discharge plume) would be exposed to an average temperature increase up to two degrees Celsius above ambient conditions.

Generally estuarine organisms are well adapted to changes in temperature and salinity (McLusky and Elliott, 2004) and the small predicted increase above ambient temperature over a small area would be easily tolerated by both the mobile and sedentary marine biota observed in the proposal footprint and near-field environment.

The most sensitive species in the vicinity of the discharge is the Sydney rock oysters, which forms bands around the mid-tide level. Research on this common estuarine species indicates that the average two degree Celsius elevation is well within its temperature tolerance over the range of salinities likely to occur in the study area (O'Connor *et al*., 2008). Little is known about the temperature tolerances of most of the other common species found in the intertidal zone, but the slight temperature elevation is well within the maximum range recorded in intertidal habitats in which the organisms occur and would occur over a small area.

Mobile organisms are capable of avoiding areas of elevated temperature. However, anecdotal evidence suggests that many mobile fish species are attracted to the edges of significant and persistent temperature plumes, such as those associated with discharges from water-cooled power plants, possibly due to concentration of food items. As a result, such sites are often recreational fishing 'hotspots'. The attraction effect of this proposal would likely be minimal due to the small extent of the elevated temperature plume and the small magnitude of the temperature elevation compared to ambient conditions. Furthermore, there are no reports of fish concentrations in the vicinity of other warm water discharges in Sydney Harbour, which are generally larger capacity systems than the current proposal.

**Physicochemical impacts**

Freshwater would be used to purge pipelines as described above. Estuarine biota in the proposal footprint are adapted to periods of high freshwater inflow and little to no impact from this activity is predicted. This is reinforced by the high volumes of point source (outlet) and dispersed (overground) stormwater runoff into

Woolloomooloo Bay from the surrounding urban areas. The intertidal and subtidal estuarine biota in the study area are therefore tolerant of freshwater influx.

As noted above, the system will be flushed with biocides. While the specifics would be defined during the detailed design any adopted system would be designed to operate to include controls to prevent an accident or emergency. However, the low concentrations of discharged biocide released to the marine environment would be rapidly and thoroughly diluted. After the point of initial mixing, the biocide's residual concentration would be diluted such that it would be unlikely detectible beyond the near field (about two metres from the outlet location).

Levels of dissolved oxygen in pipelines would be lower than those in the ambient seawater due to the elevated temperature of the seawater as circulates around the cooling system. The use of three diffuser jets discharging at 2.25 $ms^{-1}$ in shallow water would create initial mixing that would result in the water's re-oxygenation within two metres of the outlet. As such, no physiological changes in marine biota are likely to be detectable due to lower dissolved oxygen in discharge water.

## ENTRAINMENT AND IMPINGEMENT

Small, floating marine biota in the water column would pass through inlet screens (refer to section 2.3) before being taken up into system in a process termed entrainment.

**Plankton**

This entrainment process removes microscopic floating plants, larval and adult marine animals (plankton) from the ecosystem. As such, it affects the most vulnerable life stages (eggs and larvae) of familiar marine biota such as fish, crabs and shellfish (oysters, clams, snails) (Dixon *et al.*, 2001). The planktonic phase of the reproductive cycle is the most precarious and marine biota have evolved reproductive strategies that can produce eggs and larvae far in excess of the numbers required for population replacement to counteract the significant mortality experienced in early life stages (Underwood and Chapman, 1995). Given that the volume of water taken up is small relative (about 3.7 million cubic metres per year or 0.6%; Table 2.2) compared to the volume of Port Jackson (650 million cubic metres, refer to section 5.1.1).

**Impingement of mobile marine species**

Mobile marine species such as fish, squid and prawns can become trapped against screens on the end of inlet pipes if the intake velocity exceeds the speed the animal is capable of swimming at. The impact is greater where intake velocities are high and the inlet pipe is oriented vertically.

A range of designs have been developed and demonstrated to minimise impingement impacts on mobile marine fauna (Water Reuse Association, 2011). These design features optimally include the use of multiple screens, distribution of the intake velocity in the horizontal plane and reduction of velocity as far as practical at the screen face (Water Reuse Association, 2011). For this proposal:

- The inlet pipe layout is horizontal (refer section 2.3).
- Multiple screen would be used ranging from 100 mm to 25 mm to 50 mm (refer to section 2.3).
- The water velocity at screen face would be 2.25 $ms^{-1}$ (refer to section 6.2.1).

The inlet pipe layout and low current speed at the screen face would minimise the likelihood of impingement for the most fish and macroinvertebrates. Consequently, impingement of mobile fauna is considered not to have a material impact on local marine populations.

## CHANGES IN PRIMARY PRODUCTION

The entrainment of microscopic plants describe above would occur, however on a scale that would have no impact on the primary productivity of either Woolloomooloo Bay or Sydney Harbour.

The slightly elevated temperature of the discharge water would circulate from the relatively nutrient-rich deeper water to the upper lit portion of the water column, to increase the rate of photosynthesis by phytoplankton in the small area within the discharge plume. While these two effects would likely cancel out, any net impact on primary productivity would be likely impossible to detect, and highly unlikely to affect the net primary productivity of Sydney Harbour.

## OPERATIONAL NOISE

The operational pipeline would be discharging water at about 2.25 $ms^{-1}$ (refer to section 6.2.1). At this velocity, the associated operational noise of the pipes would be within the limit of the variance in ambient conditions. As a constant low noise source, it would not display any of the peak tonal characteristics that lead to the range of impacts described above in section 6.1. As such, there is assessed to be no operational impact or risk. By comparison, studies into the underwater noise from a high-pressure operational gas pipeline (Zykov, *et al.,* 2013) confirm the low-risk to marine fauna and mammals. This is a pipeline where the operating pressures (and noise levels) would far exceed those experienced under this proposal.

## IMPACTS ON THREATENED SPECIES, COMMUNITIES, POPULATIONS AND HABITATS

No threatened or protected marine species, populations or ecological communities listed under the EPBC Act, TSC Act and FM Act were observed with the proposal footprint and those that have very low probability of occurrence are able to move away from temporary disturbance such as would be caused by the installation of the proposed marine infrastructure. Section 5.2.2 discusses the limited impact on marine protection area local to the works.

Of the marine species that occur locally, mobile forms such as fish are able to avoid temporary disturbance caused by pipe installation and have low probability of impingement on inlet screens whose design incorporates mitigation measures (refer to Chapter 7). Disturbance to intertidal and subtidal habitats would cause small-scale loss of common sedentary biota such as algae and invertebrates which are expected to recover given post-construction habitat rehabilitation measures (refer to Chapter 7).

# 7 CONSULTATION

As per the SEARs issued for the planned gallery upgrade and extension (ref: SSD 6471) the following Government authorities have been consulted regarding the seawater heat exchange system.

## 7.1 Environment Protection Authority

Through discussion with the EPA regarding the proposal, the advice was that such systems do not require an EPL and that the authority would not be involved in a regulatory capacity. It may however, provide technical advice if requested by DPE.

## 7.2 Department of Primary Industries – Water

The NSW Department of Primary Industries: Water has advised that they would not be involved in a seawater heat exchange project as it is concerned with freshwater in the environment and anything involving seawater would not require their input as a stakeholder.

## 7.3 Transport for NSW

Transport for NSW is considering two possible ferry routes within Woolloomooloo Bay, one at the south end of the Bay near Cowper Wharf Road and one along the western foreshore near the entry to the Bay. As such, it has indicated that they expect to have minimal impact on a future wharf and ferry service providing the following conditions apply:

- The ‘depth’ of the piping is sufficient to be well clear of any ferry draft.
- Any installed infrastructure does not restrict the location of a ferry wharf.
- Any structure or operation of the system does not impact on the passage of ferries to or from the area.
- Any structure is adequate in its design to not be impacted or disrupted by the wash or ferry operations in using the wharf.

The draft structural details of the system would be provided to Transport for NSW for review and comment to ensure no conflicts arise during the design detailing (Arup, 2016).

# 8 MITIGATION MEASURES

This Chapter describes the proposed mitigation measures that would be adopted when building and operating the proposal.

## 8.1 Mitigation and monitoring

Table 8.1 lists the marine environment mitigation and monitoring measures that would be implemented to account for the identified impacts identified in Chapter 6.

**Table 8.1 Impacts and mitigation measures**

| POTENTIAL IMPACT | PROPOSED MITIGATION AND MONITORING MEASURES |
|---|---|
| **Construction** | |
| Possible risk of accidental spills when carrying out the installation work. | Prepare a spill management plan (SMP) as part of the construction environmental management plan (CEMP), which should describe:<br>→ The limitations, controls and methods to manage and control spills.<br>→ The protocols for reporting spills, the immediate actions to stop work, and the controls to prevent dispersion.<br>→ The need for regular inspections while the work is taking place.<br>→ The need for regular equipment maintenance during construction.<br>→ The need to keep, and ensure the safe disposal of, spill containment provisions/kits.<br>→ The need for staff to be training in spill management. |
| | To further minimise the risk of spills, ensure that:<br>→ Only biodegradable oils and lubricants are used on any equipment.<br>→ All ships hold current certificates for their class and function.<br>→ Any hydraulic equipment and other fuel storage is regularly serviced and maintained.<br>→ All ships operated within State, national and international safety, pollution control and environmental protection standards and regulations. |
| Localised seabed sediment disturbance from installing the pipes and the subsequent smothering of habitat in the local area. | → Minimise the size of the anchoring points used to support the installation of the pipelines.<br>→ Install a silt boom or curtain around the back hoe during trenching and backfilling. Allow for sediment settlement before removing the boom or curtain. |
| Construction barges and other boats striking marine mammals that enter the area. | Ensure ship pilots:<br>→ Are trained and aware of fauna movements in the area.<br>→ Undertake observations for marine megafauna before manoeuvring in to our out of the local area.<br>→ Maintain their speed to less than four knots. |

| POTENTIAL IMPACT | PROPOSED MITIGATION AND MONITORING MEASURES |
|---|---|
| The generation of underwater noise from installing the pipes and its impacts on fish and marine mammals leading to short-term disorientation. | As a precautionary measure:<br>→ Have a slow start-up when installing the anchoring points to provide opportunity for marine mammals and fish species to adjust to the noise levels and/or leave the area.<br>→ Undertake observations before installing the anchoring points to check that there are no noise-sensitive fauna and shoaling fish within 150 metres of the proposal footprint. Do not start work until they have moved out of this area.<br>→ Keep observation while the work is taking place. Notify staff if any fauna or shoaling fish are spotted within 400 metres of the proposal footprint and temporarily stop work if they are spotted within 150 metre for the proposal footprint. |
| The accidental spread of pest and pathogen species on ship-hulls and equipment. | To minimise the risk of marine pest and pathogen species being introduced into the area:<br>→ Undertake regular inspections of the ships, equipment and areas for the presence of pest species, notably including *caulerpa taxifolia*.<br>→ Ensure that each ship used on the proposal can demonstrate that its hull has been cleaned and inspected before work starts. This is to extend to any ships or equipment that is taken offsite while the work is taking place. |
| The generation of small volumes of construction waste from building the proposal. | Extend the proposal's waste management plan (WMP) to cover the marine work while ensuring there is a process for storing, treating, handling, managing and disposing of waste generated while installing the pipelines and other marine infrastructure. |
| Damage to intertidal and or subtidal habitat from installing the pipes if they are not installed using directional drilling. | To promote habitat regeneration, maintain and replace boulders in the same orientation prior to starting construction. |
| **Operation** | |
| A small increase in the seawater temperature around the outlet pipes and its effects on the marine ecology. | → Validate the modelling predictions within three months of operation by:<br>▪ Monitoring the surface temperature and eight metres below Australian height datum near the discharge point and at four metres and 10 metres from the discharge point in all directions.<br>▪ Use these data to compare the actual extent of the elevated temperature plume compared to the model-predications. This should include sampling at a reference site away from the influence of the inlet or outlet pipes to provide a reference point.<br>→ Ensure the outlet pipe includes jet diffusers to support mixing.<br>→ Use horizontally directed diffusers in preference to vertically directed diffusers to maximise the plume's discharge into the deeper more-open areas of the harbour and to minimise potential the impingement of mobile marine fauna.<br>→ Maintain at least a 25-metre separation between the inlet and outlet pipes or otherwise rerun the modelling to confirm there would be no positive feedback. |
| The rate of discharge of water from the pipes potentially causing increased turbulence and possible seabed scour. | → Increase the diameter inlet pipes to reduce the intake velocity.<br>→ Use risers to ensure the discharge occurs at about one-to-two metres above the seabed.<br>→ Raise pipelines off the seabed to prevent scour.<br>→ Discharge via three 150 millimetre risers to support mixing and reduce the discharge velocity. |

| POTENTIAL IMPACT | PROPOSED MITIGATION AND MONITORING MEASURES |
|---|---|
| The discharge of residual biocide in to the marine environment and its effects on the marine ecology. | Use freshwater flushing as the main means to manage the fouling of the pipes and to minimise any marine ecology impacts. Also, carry out physical cleaning and use an electrolytic anode to prevent marine growth. Only use of an amine-based biocide approved by Australian Pesticides and Veterinary Medicines Authority as a back-up method. |
| Equipment such as anchors or fishing lines becoming snagged on the pipes. | Include snag protection controls around the pipeline, riser, jets, and screens to prevent any snagging risk to other harbour users. |

# 9 CONCLUSIONS

This report has considered the impacts of building and operating a seawater heat exchange system as part of the renovation and extension of the Art Gallery of NSW. The system would operate to provide district cooling across the gallery using sea water as a coolant. The process would involve the installation of twin inlet and outlet pipes located in Woolloomooloo Bay. This assessment has considered the physical and ecological environment of Sydney Harbour to understand how the marine environment would be impacted under this component of the proposal. Through this process the following can be concluded.

## 9.1 Construction impacts

The following can be concluded about the likely construction impacts:

- The nature and scale of the construction work is insufficient to cause material physical disturbance to the marine environment, including dynamic changes in current speed, wave characteristics, tidal mixing or flushing.
- There would be some localised sediment disturbance from trenching nearshore to install the pipelines, which could be managed and contained through the use of a boom or curtain, with the sediment quickly settling out of suspension.
- The risk of accidental spillage and discharge when carrying out the work could be managed through standard controls.
- The temporary installation of anchoring points or jacks on the harbour floor would be insufficient to cause material scour or erosion impacts.
- There is a likely presence of ASS across Woolloomooloo Bay, however providing the sediments remain underwater (to prevent oxidation), the risks could be managed.
- Despite the potential for encountering elevated concentrations of certain contaminants and pollutants the extent of disturbance would be consistent with natural processes in the bay such that the impact would not be material.
- Despite the presence of a wetland protected area locally (the limit of which is poorly demarked) site investigations carried out in 2016 concluded the ecological value of the impacted area is limited. Nonetheless, precaution would be introduced when installing the pipelines to minimise impacts.
- There is an inherent risk of marine mammal strike associated with any boat movements in the harbour, however controls to manage ship movements and speeds would reduce the risk of any material impact.
- While the trenching nearshore would impact on the intertidal zone, removing subtidal algal communities, these would naturally regenerate over time. Importantly, the work would not impact on any threatened flora or fauna, communities, populations or associated habitat.
- The work would generate repetitive and impulsive underwater noise for short periods when drilling and trenching. This would be at levels that could cause a startle response in marine life but would be unlikely to have any long-term physiological impacts. It would also be unlikely to cause either harm or injury to marine life. Nonetheless, noise management controls would be introduced to reduce the risks to prevent any material impact.
- Common to any marine based development would be the risk of spreading marine pest species. Standard inspection and cleaning measures would be adopted to reduce the risk.

In summary, the scale and nature of the work is unlikely to have any material impact on the physical or ecological environment of Woolloomooloo Bay. Nonetheless, mitigation controls have been proposed to manage and further reduce risks to levels where any potential impacts could be controlled and managed to avoid any unacceptable residual outcome or effect. Other impacts would be managed by adopting standard controls that are common to all ship movements and development activities and works that take place in the harbour.

## 9.2 Operational impacts

The following can be concluded about the likely operational impacts:

- A plume dispersion modelling was performed using a conservative discharge rate of about 70 per cent higher than the design discharge rate to assess the potential impacts on the ambient temperatures due to increased temperature. The predicted temperature increase at the edge of the near-field zone through the use of horizontally oriented diffusers is 0.1ºC. Comparison of the modelled results to the 80th percentile ambient temperature data shows that these indicative trigger values are not exceeded.
- The small predicted increase above ambient temperature over a small area would be easily tolerated by both the mobile and sedentary marine biota observed in the proposal footprint and near-field environment.
- The most sensitive species close to the outfall points is the Sydney rock oyster, which forms bands around the mid-tide level. Research on this common estuarine species indicates that the average two degree Celsius elevation is well within its temperature tolerance over the range of salinities likely to occur in the study area. Mobile organisms are capable of avoiding areas of elevated temperature.
- The marine ecology of the bay and harbour would be able to accommodate and adapt to the operational pipeline and limited localised increases in temperature. This would include both tolerance and physicochemical impacts.
- Based on the conservative modelling approach mentioned above, the discharge velocities for the horizontally oriented diffusers reduce to 1 $ms^{-1}$ within one metre of the outlet and further to 0.5 $ms^{-1}$ within two metres from the outlet. Furthermore, the discharge would take place up to two metres above the seabed. Due to the negligible velocity increases and the buoyancy of the plume causing it to immediately rise; there would be no material velocity related impacts, such as erosion, scour or disturbance to marine life.
- Freshwater would be used to purge pipelines. Estuarine biota in the proposal footprint are adapted to periods of high freshwater inflow, from point source (outlet) and dispersed (overground) stormwater runoff, so little to no impact from this activity is predicted.
- The system would be occasionally flushed with biocides. Low concentrations of discharged biocide released to the marine environment would be rapidly and thoroughly diluted. After the point of initial mixing, the biocide's residual concentration would be diluted such that it would be unlikely detectible beyond the near field (about two metres from the outlet location).
- The system includes monitoring sensors that allow automatic regulation. In the event of a detected accident or emergency the system would shut down and a conventional back-up air conditioning until would operate. Any seawater within the system at this point would be pumped and collected for treatment and disposal at a licenced facility by a licenced contractor.
- The inclusion of screens and grates on the pipelines would reduce the risk of entrapment and entrainment of larger marine species (i.e. mammals and fish), while the volume and rate of water uptake would have a limited non-material impact on smaller species such as plankton and juveniles.
- There is not expected to be any impact in primary production as the warmer discharged water (which can reduce production) would increase natural circulation of nutrient-rich deeper water (which would increase production). As such, the impacts would be antagonistic.
- The noise generated from the operational pipelines would be of low risk to noise-sensitive marine fauna and mammals.

In summary, the operational exchange is unlikely to have any material impact on the physical or ecological environment of Woolloomooloo Bay.  This has been demonstrated through modelling predictions and a review of relevant data. Effectively, the scale of the facility would be insufficient to materially impact on the tolerances of the marine environment in this location. While there would be some perceived change the marine environment would be able to adapt to this without any material impact, such that providing the mitigation measures are introduced there would be no significant residual effects.

# 10 REFERENCES

APVMA, 2012. Commonwealth of Australia gazette No. APVMA 5, Tuesday, 13 March 2012. Australian pesticides and veterinary medicines. 26466 Cat. No. 0189623.

Arup 2016. Art Gallery of NSW Expansion – Sydney Modern Traffic impact assessment. Document reference: 245767, dated: 24 June 2016.

Bowles, AE & Graves SK, (2007), Aquatic Noise Pollution from Oil Tankers and Escort Vessels in Prince William Sound, its Effects and Impacts on the Marine Environment of the Sound, Literature Search from 1980 to present, Report on Project 854.07.01.

Cardno (2012) Sediment Transport Modelling Appendix D1 and Appendix D2 to Kurnell Port and Berthing Upgrade, Major Project 5353.

Chapman G.A. and Murphy C.L., (1989), Soil Landscapes of the Sydney 1:100,000 Sheet report, Department of Conservation and Land Management, Sydney.

Chapman G.A., Murphy, C.L., Tille P.J., Atkinson G. and Morse R.J., 2009 Ed. 4, Soil Landscapes of the Sydney 1:100,000 Sheet map, Department of Environment, Climate Change and Water, Sydney.

DIPNR (2005). Sydney Regional Environmental Plan (Sydney Harbour Catchment) 2005 Wetlands Protection Area Map Sheet 10.

Dixon, D., Veil, J.A and Wisniewski, J. (2001). Defining and Assessing Adverse Environmental Impact from Power Plant Impingement and Entrainment of Aquatic Organisms: Symposium in Conjunction with the Annual Meeting of the American Fisheries Society, 2001, in Phoenix, Arizona, USA.

Engell-Sorensen, K (2000), Evaluation of the Effects from Offshore Pile Driving on Marine Fish, Bio-Consult Tech rep. 1980-1-03-1-rev 2. To SEAS, Slagterivej 25, DK-4690, Haslev.

Greene. CRJ & Moore., SE (1995) Manmade Noise in Marine Mammals and Noise (pp.101-158) in Richardson, WJ, Greene, CRJ, Malme, CI and Thomson, DH (ed). Academic Press, San Diego.

Harrison, D. P. (2013) “Sydney Harbour Water Quality Improvement Plan field survey program” Report to Greater Sydney Local Land Services. Sydney Institute of Marine Sciences.

Holmes, N (1970), Mussel Fouling in Chlorinated Cooling Systems, Chemistry and Industry 1244 – 1147.

Horton, P.R., Lee, J.H.W. and Wilson J.R. (1997). “Near-field JETLAG modelling of the Northwest Territories Sewage Outlet, Urmston Road, Hong Kong”, Proc. 13th Australasian Coastal and Ocean Engr. Conf., Christchurch, New Zealand, Sept. 97, Vol.2, pp. 561-566.

McLusky, D.S. and Elliott, M (2004). The Estuarine Ecosystem: Ecology, Threats and Management. Oxford University Press, 214 pp.

Naylor, S.D., Chapman, G.A., Atkinson, G., Murphy, C.L., Tulau, M.J., Flewin, T.C., Milford, H.B. and Morand, D.T. (1998). Guidelines for the use of acid Sulfate Soil Risk Maps, 2nd ed., Department of Land and Water Conservation, Sydney.

NSW Department of Primary Industries (Fisheries) (2005). Estuarine Macrophytes of New South Wales, Australia.

O’Conner, W.A., Dove, M. and Finn, B. (2008). Sydney Rock Oysters: Overcoming constraints to commercial scale hatchery and nursery production. FRDC Project 2003/209. NSW Department of Primary Industries Port Stephens Research Centre Nelson Bay NSW 2135.

Southall BL, Bowles AE, Ellison WT, Finneran JJ, Gentry RL, Green RS, Kastak D, Ketten DR, Miller JH, Nachtingall PE, Richardson WJ, Thomas AJ & Tyack PL (2007) Marine Mammal Noise Exposure Criteria: Initiial Scientific Recommendations. Aquatic Mammals, 33(4): 411-509.

Sydney Local Environment Plan (2012). Acid Sulfate Soils Map ASS_021.

Tanner, E. Jones, I. S. F., Harrison D. P., Birch G. (2016, pers comm) Sydney Harbour Real Time Model, Sydney Harbour Observatory, University of Sydney, https://sho.sydney.edu.au/

Underwood AJ and Kennelly SJ (1990), Ecology of Marine Algae on Rocky Shores and Sub-Tidal Reefs in Temperate Australia, Hydrobiologia 192:3-40.

Water Reuse Association (2011). Desalination Plant Intakes Impingement and Entrainment Impacts and Solutions White Paper March 2011; revised June 2011. https://www3.epa.gov/region1/npdes/schillerstation/pdfs/AR-026.pdf

Sydney Institute of Marine Science, 2016: http://harbourprogram.sims.org.au/about-sydney-harbour?bcsi-ac-1e3ac187d937ecd3=24CC73F200000203Shu+C5FtyV3ZhUsv5A4IGMCZGAHJGgAAAwIAANqtmQEQDgAAEwAAAJyZBQA=

WSP | Parsons Brinckerhoff, 2016. Art Gallery of NSW Expansion - Sydney Modern Project Seawater Heat Exchange System Marine Impact Assessment. Prepared for Art gallery New South Wales Trust.

Zykov M, Bailey L, Deveau T, Racca R (2013) South Stream Pipeline, Turkish Sector, Underwater Sound Analysis, PO1226-003, Jasco Applied Science, Canada.

# Appendix A

MODELLING REPORT

ART GALLERY OF NSW TRUST

# Art gallery of NSW Expansion - Sydney Modern Project, Seawater Heat Exchange System

## APPENDIX A - MODELLING REPORT

PUBLIC

OCTOBER 2017

# Art Gallery of NSW Expansion - Sydney Modern Project, Seawater Heat Exchange System

## MARINE IMPACT ASSESSMENT - MODELLING REPORT

**Art Gallery of NSW Trust**

**Public**

Project no: 2270096A-ENV-REP-002 RevC.docx
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# 1 INTRODUCTION

The following technical report is written as an appendix to the Sydney Modern Project seawater heat exchange system marine impact assessment (WSP | Parsons Brinckerhoff, 2016). This report is specifically concerned with modelling the thermal plume created by the discharge water to provide thermal and velocity gradients for use in the assessment of ecological impacts.

This modelling assessment is an initial assessment using publicly available data and is not based on the collection of focussed temperature, velocity and bathymetric datasets. The datasets used are from within Woolloomooloo Bay and where required, conservative assumptions have been made such that the use of more focussed data will most likely lead to a reduction in the predicted temperature and velocity effects and hence reduced impacts.

## 1.1 Discharge overview

As part of the plan to renovate and extend the Art Gallery of NSW, there is the proposal to install a seawater heat exchange as part of a district cooling system. The system would require seawater to be pumped from Sydney Harbour and transferred to a heat exchange, where it would be used to cool condensed warm ambient air from within the gallery therefore providing district cooling. Once the exchange has occurred, the seawater would be discharged back into the harbour. The system works on the regular flow of seawater through the heat exchange. Through this process, the seawater temperature used the cooling process can increase by up to seven degrees Celsius. An antifouling management plan had not been considered at the time of writing so the concentration of antifouling agents within the discharge water has not been modelled.

The increase in the temperature will increase the buoyancy of the discharge water relative to the cooler ambient water. As the water exits through the outlet, the plume will rise towards the surface. In this region mixing and dilution is rapid and mainly caused by the turbulence generated by the discharge flow rate and velocity. This initial mixing region is called the near-field zone where the impact of the heated discharged water on the ambient environment is at its highest.

Depending on the density stratification of the receiving water the rising plume may reach a level of neutral buoyancy where it stops rising and begins to spread laterally. This spreading field drifts with the any currents present and is diffused by turbulence in a wider region called the far field. The rate of dilution in the near-field is much faster than the far field.

# 2 NUMERICAL MODEL

For the near-field modelling, the PC-based interactive flow visualisation tool VISJET was used which incorporates the Lagrangian jet model JETLAG (Lee et al, 1997). This model was developed by Professor Joseph Lee and his colleagues at the University of Hong Kong and provides 3D flow visualization of the predicted path and mixing of arbitrarily inclined buoyant plumes in moving receiving waters which may be density-stratified.

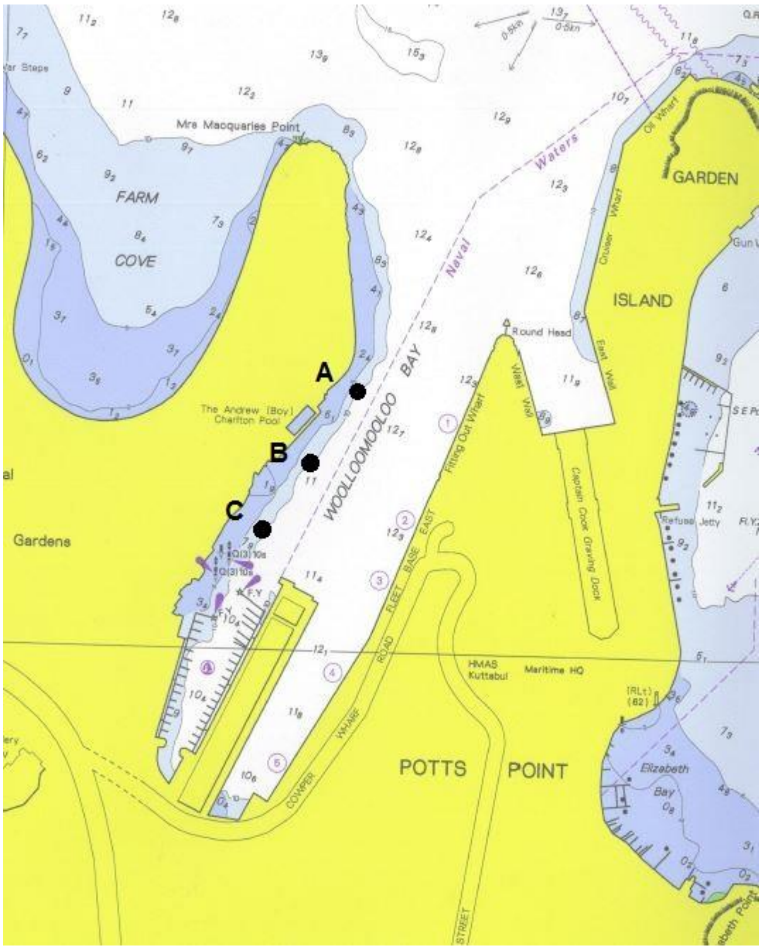
JETLAG has been validated against extensive analytical, laboratory experiments and field data and is widely used in design and assessment of ocean outfalls including sites in NSW and specifically in Sydney Harbour. Examples of sites where JETLAG has been used are Barangaroo South District Cooling Plant, Sydney Sewage Treatment Plant Effluent Outfalls and The Star Casino Cooling Plant System.

## 2.1 Model set up and input data

### 2.1.1 Flow fields

The flow fields and components of water velocity adjacent to the outlet location were derived from the Sydney Harbour Hydrodynamic Model[1] (property of the University of Sydney) at three depths (bottom, middle and surface). The hourly velocity data for three locations (A, B and C in Figure 2.1) were derived from the Sydney Harbour Hydrodynamic Model and used in the near-field modelling. The flow field velocities used are for summer months as the operation of the cooling system is considered to be in peak usage in summer.

[1] The temperature/Salinity data extracted from: Harrison, D. P. (2013) “Sydney Harbour Water Quality Improvement Plan field survey program” Report to Greater Sydney Local Land Services. Sydney Institute of Marine Sciences.
The Model Data sourced from: Tanner, E. Jones, I. S. F., Harrison D. P., Birch G. (2016, pers comm) Sydney Harbour Real Time Model, Sydney Harbour Observatory, University of Sydney, https://sho.sydney.edu.au/

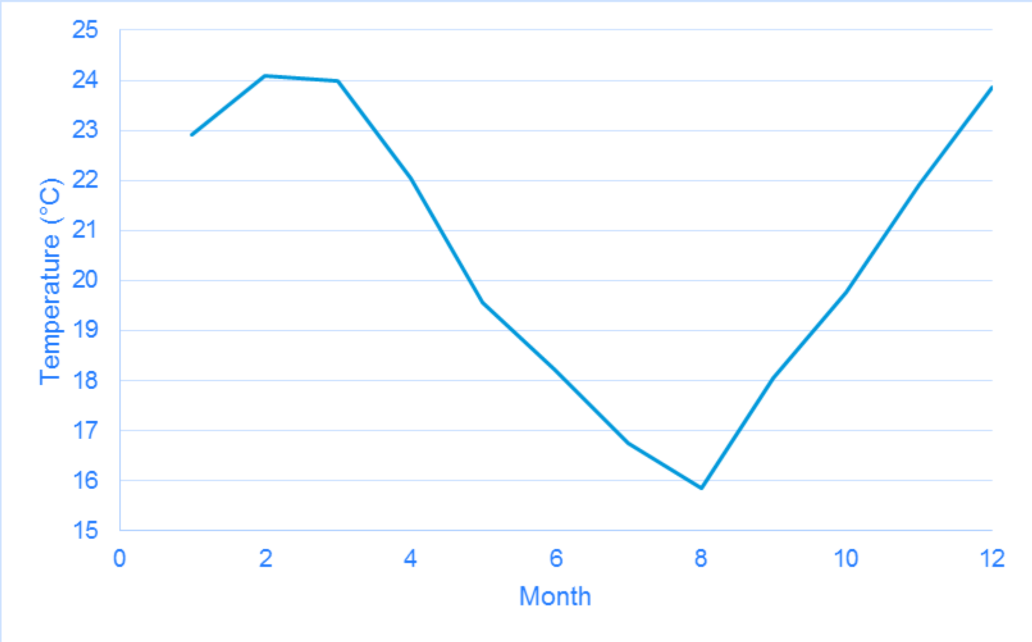



*Source: Sydney Harbour admiralty chart 1:7500. Sydney Ports Corporation, Waterways Authority*

**Figure 2.1 Flow field assessment locations**

### 2.1.2 Temperature conditions

Sydney Harbour water temperature data in vicinity of the Points A, B and C (Figure 2.1) was collected by University of Sydney during 2013. These data are based on monthly surveys and is shown in Figure 2.2.



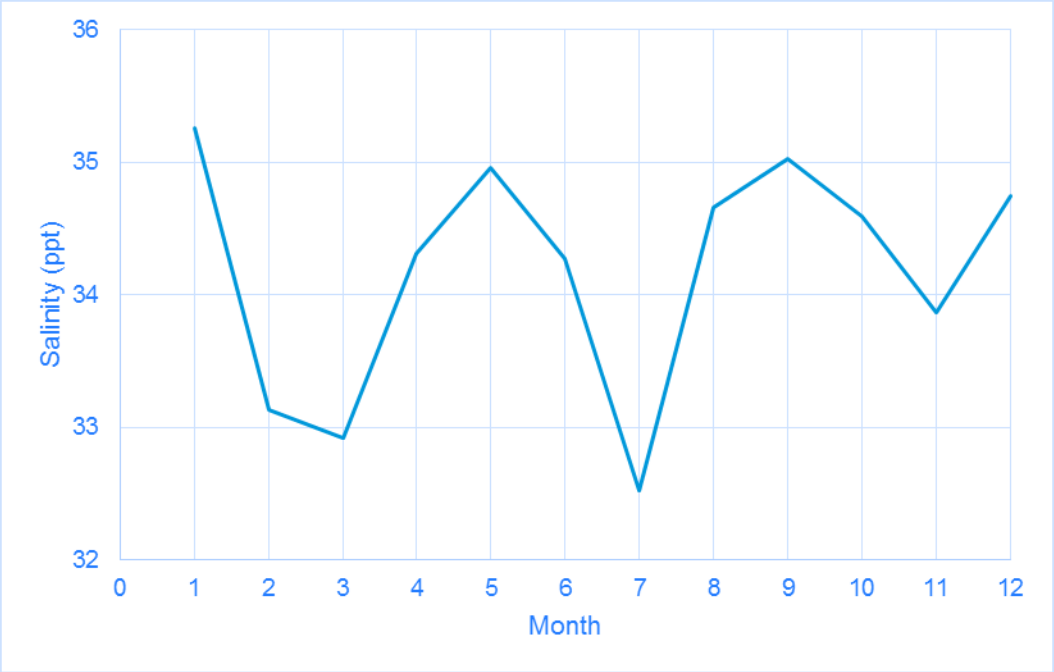

*Source:* *Horton, 2013*

**Figure 2.2 Seasonal variation of average water temperature**

Figure 2.2 shows that in summer the water temperature varies from 22.4°C to 24.1°C with a mean of 23.4°C. In spring, autumn and winter; water temperature varies from 15.8°C to 24.3°C with a mean value of 20.8°C.

### 2.1.3 Water salinity

Water salinity data recorded in the proximity of the outlet was derived from a survey by Ocean Technology Group, University of Sydney in 2013. The average salinity for the summer months is 34.75 ppt and 34.01 ppt for the rest of the year. The minimum and maximum salinity for the duration of record are 30.2 ppt and 35.3 ppt, respectively. The annual variation in salinity is shown in Figure 2.3.




*Source:* *Horton, 2013*

**Figure 2.3 Annual variation in seawater salinity in the vicinity of the outlet**

### 2.1.4 Outlet design

The returned seawater would flow through a 400 mm pipe laid just above the seabed and the discharge would occur via three 150 mm diameter risers. Discharging the warmer seawater via smaller diameter risers would cause it to mix with the ambient seawater more effectively.

The density of the receiving waters increases with depth, i.e. the receiving waters are density-stratified. The resulting buoyancy force deflects the jets upward forming plumes which are transported by ambient currents. The plumes entrain ambient seawater as they rise, causing them to be diluted and decreasing the density difference with the ambient waters. If the receiving water is stratified, the rising plumes can reach a level of neutral buoyancy below the surface. If the receiving waters are not stratified the plumes will rise to the surface.

In the scenarios modelled in this investigation the depth of the outlet is less than 10m in an environment that is sufficiently energetic to maintain negligible stratification. On this basis the plume will reach the surface and will not reach neutral buoyancy below the surface.

### 2.1.5 Adopted parameters

The adopted model parameters for the discharge, outlet and receiving waters are shown in Tables 2.1 and 2.2. The data outside of brackets in Table 2.2 was used in the predictive modelling, while the data in brackets shows the adopted design parameters. The difference in the numbers accounts for a theoretical design maximum versus the current concept design parameters. As described above, by adopting these parameters the modelling predictions are conservative in adopting a worst-case impact.

**Table 2.1 Adopted receiving waters parameters used as model inputs from Horton (2013)**

| AMBIENT WATER PARAMETER | VALUE |
|---|---|
| Mean bottom current velocity | 0.008m/s (Point A), 0.012m/s (Point B), 0.0125m/s (Point C) |
| Salinity | 34.75 ppt (summer), 34.01 ppt (spring, autumn and winter) |

| AMBIENT WATER PARAMETER | VALUE |
|---|---|
| Temperature | Spring: 17.9°C (min), 20.2°C (mean), 22.0°C (max)<br>Summer: 22.4°C (min), 23.4°C (mean), 24.1°C (max)<br>Autumn: 19.4°C (min), 22.1°C (mean), 24.3°C (max)<br>Winter: 15.8°C (min), 16.8°C (mean), 18.5°C (max) |

**Table 2.2 Adopted outlet parameters used as model inputs (Steensen Varming, Tanner *et al.* (2017)**

| OUTLET PARAMETER | VALUE |
|---|---|
| Outlet pipe diameter (mm) | 400 (300) |
| Discharge rate ($Ls^{-1}$) | 117 (69) |
| Salinity (ppt) | 33 |
| Differential temperature (ºC) | 5 to 7 |
| Number of risers (jets) | 3 |
| Diameter of outlets (mm) | 150 |
| Riser height above seabed (m) | ~2 |
| Riser spacing (m) | ~3 |
| Maximum discharge velocity ($ms^{-1}$) | 0.95 |

## 2.2 Modelled scenarios

A number of scenarios were investigated to analyse the sensitivity of dilution rate to discharge temperature, discharge flow rate and configuration of the outlet in order to optimise the outlet design.

The actual average current velocities from the Sydney Harbour Hydrodynamic Model (Tanner *et al.* 2016) were used in the model to represent the degree of mixing that would occur within Woolloomooloo Bay. Modelled scenarios were considered for different ambient temperatures and discharge temperatures as per Tables 2.1 and 2.2.

The summer discharge scenarios were performed using minimum, mean and maximum ambient temperatures while discharge temperature was varied from 5 to 7°C above ambient temperatures.

For the spring, autumn and winter scenarios the modelling was also carried out for minimum, mean and maximum ambient temperatures with the same differential temperatures of 5°C to 7°C.

Both vertical and horizontal discharge orientations were included in the modelled scenarios as shown in Figures 2.4 and 2.5. The horizontal discharge can be more appropriate where the outlet and discharge locations can be extended far enough into the bay to minimise the risk of returning flows back to the shore.

The vertical discharge alternative can be more suitable for a nearshore outlet design in cases where it is important to confine the temperature and velocity effects to within a more focussed plume. With a vertically oriented discharge configuration the plume will reach the surface more rapidly than if horizontally oriented and can then move laterally across the surface.

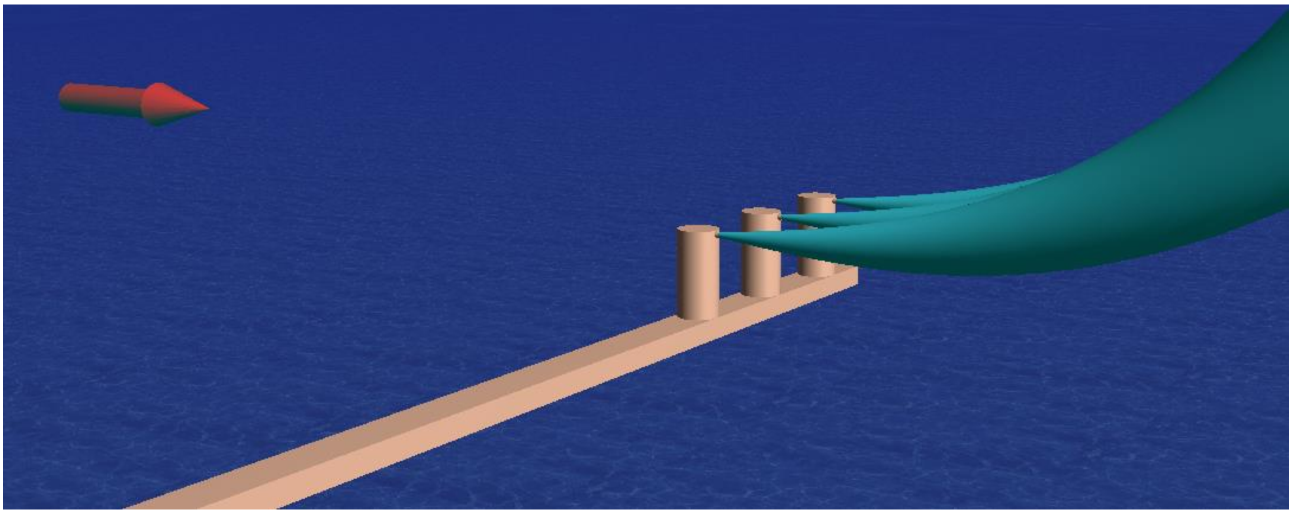


Figure 2.4 Typical outlet configurations for horizontal discharge

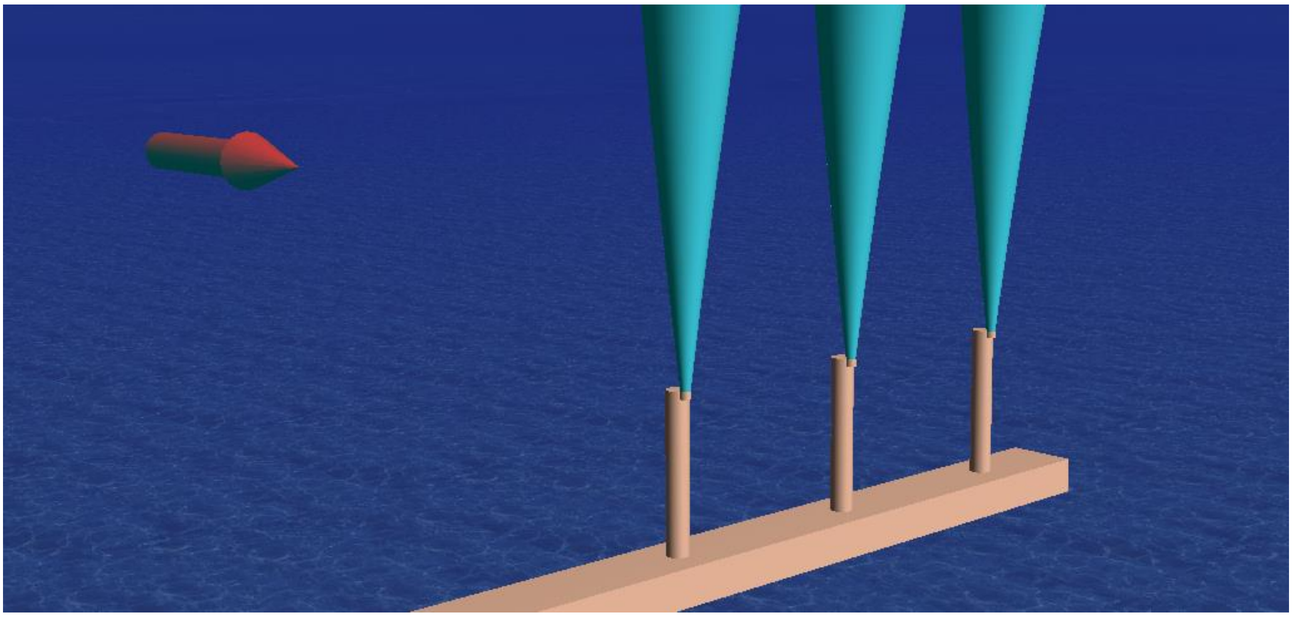


Figure 2.5 Typical outlet configurations for vertical discharge

# 3 MODEL RESULTS

The following Section details the modelled predictions using the input parameters discussed in Section 2.1. Modelled scenarios assess the sensitivity of the seasonal variation in ambient water temperatures and the outlet configuration.

Modelled predictions are presented as plume temperature decay laterally from the outlet.

## 3.1 Summer conditions

### 3.1.1 Horizontal discharge

For the horizontally oriented discharge configuration in summer the plume temperature reduction to 2°C above ambient temperature was evident within 1 m of the outlets, and a temperature reduction to 1°C above ambient temperature was achieved within 3 m. A temperature reduction to 0.5°C above ambient was achieved within 6 m of the outlets.

The temperature reduction trend for the horizontal discharge option in summer is presented in Figure 3.1 in which ambient temperature is at its minimum 22.4°C.

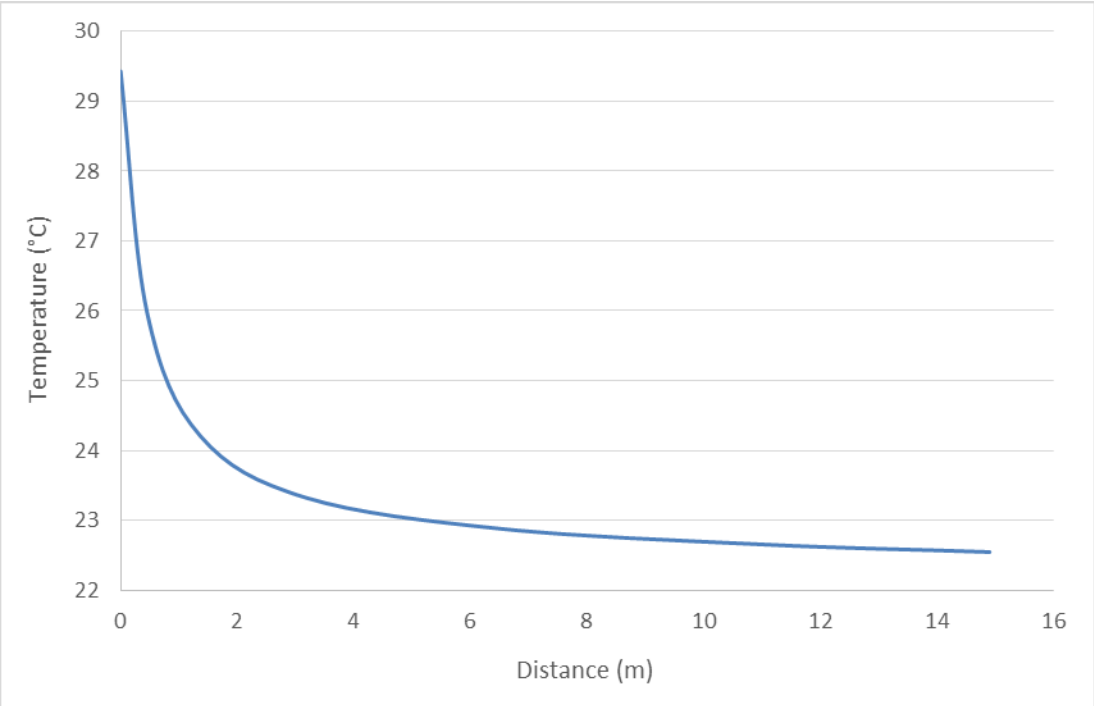



**Figure 3.1 Reduction in temperature in near-field for the horizontal discharge in summer**

### 3.1.2 Vertical discharge

For the vertically oriented discharge configuration in summer the temperature gradient will be more confined and less far reaching than with the horizontal configuration. In the vertical discharge scenario a temperature reduction to 0.5°C above ambient was achieved within 0.2 m of the outlets.

The temperature reduction trend for the vertical discharge option in summer is presented in Figure 3.2 for ambient temperature 23.2°C.

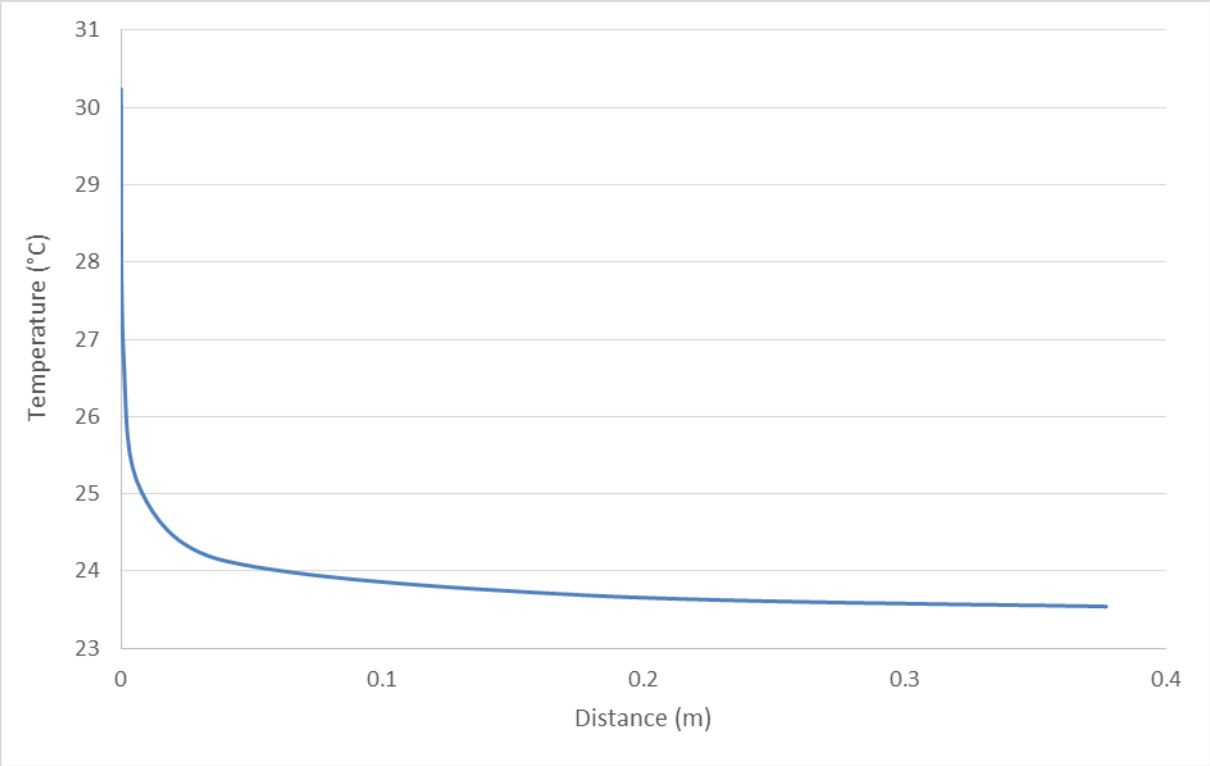



**Figure.3.2 Reduction in temperature in near-field for the vertical discharge in summer**

Whilst the vertical configuration results in reduced lateral temperature effects compared to the horizontal configuration, it should be noted that the plume will reach the surface more rapidly if directed vertically and will move laterally across the surface.

## 3.2 Spring, autumn and winter conditions

For the horizontally oriented discharge configuration during the rest of the year, the temperature reduction to 2°C above ambient temperature was achieved within 1 m of the outlets, and a temperature reduction to 1°C was achieved within 3 m. A temperature reduction to 0.5°C above ambient temperature was achieved within 6 m of the outlets.

The temperature reduction trend for the horizontal discharge option in spring, autumn and winter for an ambient temperature 15.8°C is presented in Figure 3.3.

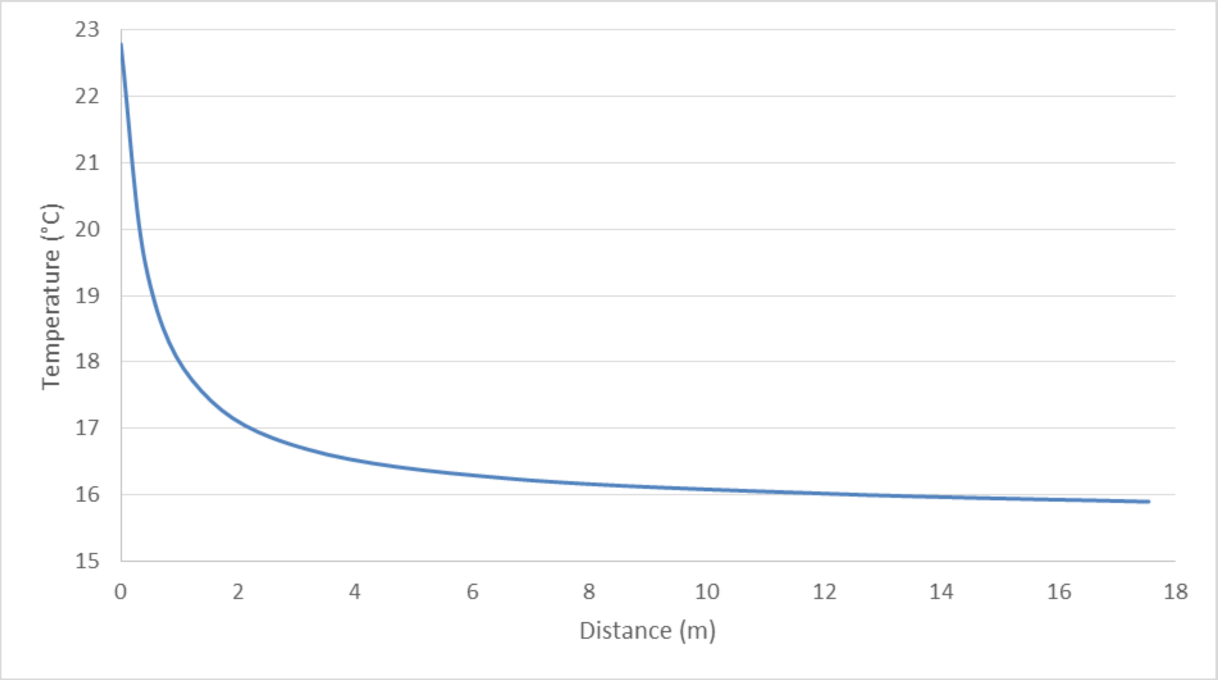



**Figure 3.3 Reduction in temperature in near-field for the horizontal discharge in spring, autumn and winter**

For the vertically oriented discharge configuration in spring, autumn and winter the temperature gradient will be more confined and less far reaching than with the horizontal configuration. In the vertical discharge scenario a temperature reduction to 0.5°C above ambient was achieved within 0.2 m of the outlets.

The temperature reduction trend for the vertical discharge option for a minimum temperature of 15.8°C is presented in Figure 3.4.

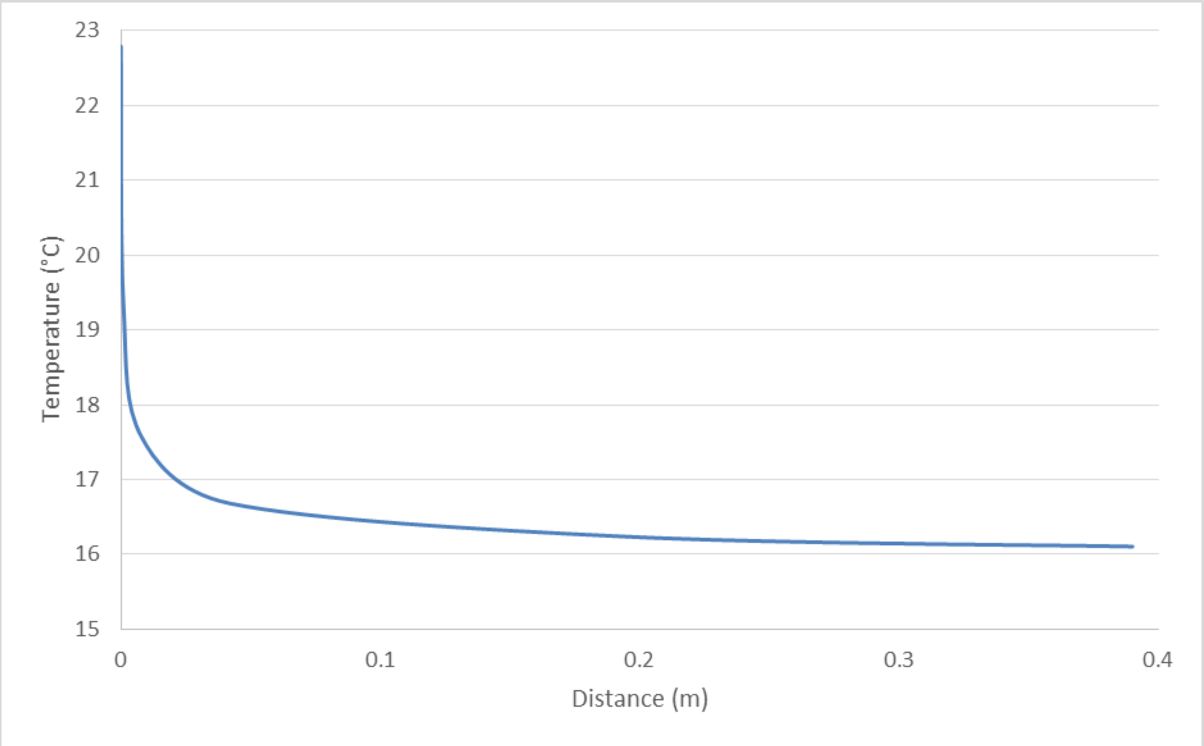


Figure 3.4 Reduction in temperature in near-field for the vertical discharge option in spring, autumn and winter

Whilst the vertical configuration results in reduced lateral temperature effects compared to the horizontal configuration, it should be noted that the plume will reach the surface more rapidly if directed vertically and will move laterally across the surface.

## 3.3 Assessment of temperature change against site-specific trigger values

It is the responsibility of the operator of heat rejection systems to demonstrate compliance with the Protection of the Environment Operations (POEO) Act 1997.

The method to quantify an adverse effect and demonstrate compliance with the POEO Act is provided in the ANZECC water quality guidelines through the calculation of trigger values using ambient data.

Section 7.4.4.1 of ANZECC (2000) contains a summary of the approach recommended for comparing results from a test site with a guideline trigger value (details of the method are contained in Appendix 7 of Volume 2, and Section 6.4.3 of the Monitoring Guidelines). It is emphasised that trigger values are an 'early warning' mechanism to provide an alert of a potential problem, and are not intended to be an instrument to assess 'compliance' and should not be used in this capacity.

The recommended trigger-based approach for physio-chemical stressors such as temperature is stated as follows: "A trigger for further investigation will be deemed to have occurred when the median concentration of independent samples taken at a test site exceeds the eightieth percentile of the same indicator at a suitably chosen reference site".

Based on this approach, 80th percentile and median baseline ambient temperatures have been calculated for summer and spring/autumn/winter seasons using the data from Harrison (2013) and presented in Table 3.1.

Table 3.1 Comparison of baseline and elevated temperatures adjacent to the proposed site

| STATISTIC | SPRING (°C) | SUMMER (°C) | AUTUMN (°C) | WINTER (°C) |
|---|---|---|---|---|
| $80^{th}$ percentile (trigger value) | 21.9 | 24.0 | 24.2 | 18.0 |
| Baseline median | 19.9 | 23.3 | 22.0 | 16.6 |
| Modelled increase in temperature at the edge of the near-field: | | | | |
| Horizontal Discharge | 0.1 | 0.1 | 0.1 | 0.1 |
| Vertical Discharge | 0.3 | 0.3 | 0.3 | 0.3 |
| Predicted Median temperature post discharge | | | | |
| Horizontal Discharge | 20.0 | 23.4 | 22.1 | 16.7 |
| Vertical Discharge | 20.2 | 23.6 | 22.3 | 16.9 |

Table 3.1 shows that the modelled median ambient temperature post discharge is less than the $80^{th}$ percentile ambient temperature and the discharge is therefore not considered to have an adverse impact on the receiving waters.

## 3.4 Sensitivity analysis

Sensitivity analysis was undertaken by varying the outlet diameter and spacing, discharge rate and the differential temperature between the discharge and the ambient temperature. However, the riser height in all scenarios was set to 2 m above seabed to minimise the potential adverse impacts, such as erosion and scouring, of turbulence and downward velocities around the outlet. The results included in this report represent the most conservative combination of ambient and discharge conditions with the highest impact radius.

## 3.5 Discharge velocities

Discharge velocities for the horizontal discharge configuration are presented in Figure 3.5. The velocity reduces to 1 m/s within 1 m from the outlet and further to 0.5 m/s within 2 m from the outlet. Such velocities will pose negligible risk to the receiving water due to the outlet discharge.

For the vertical discharge option the velocity reduction occurs at a greater rate as seen in Figure 3.6 where the velocities reduce to negligible amounts within a very localised area.

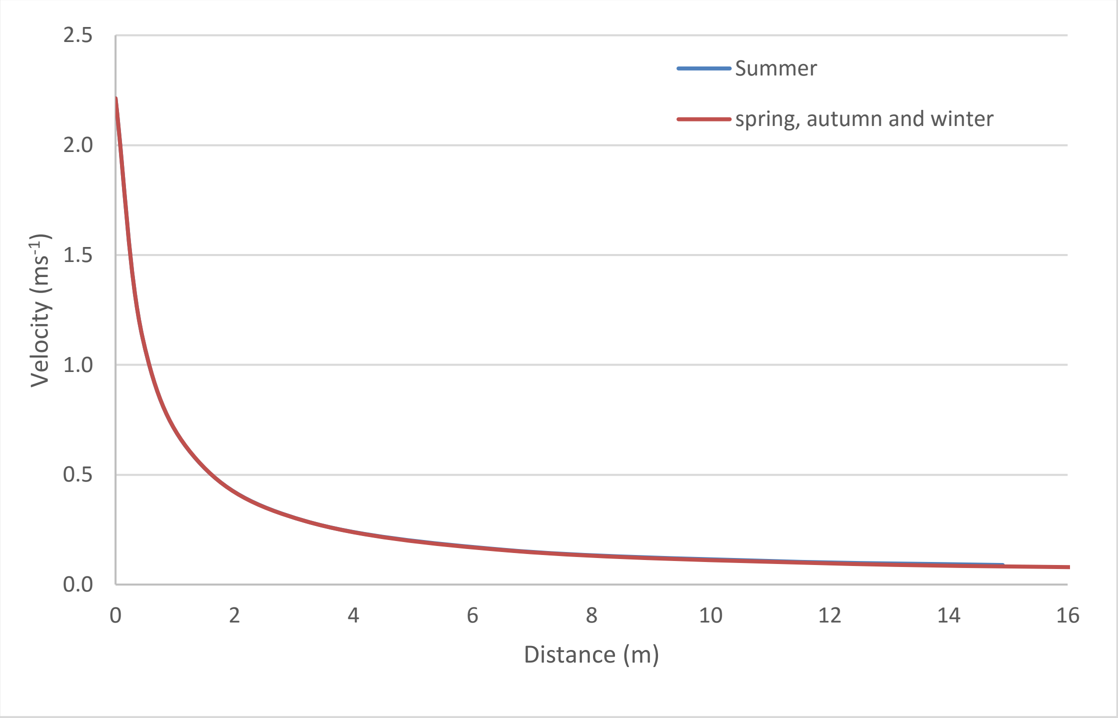



**Figure 3.5 Reduction in plume velocity for horizontal discharge**

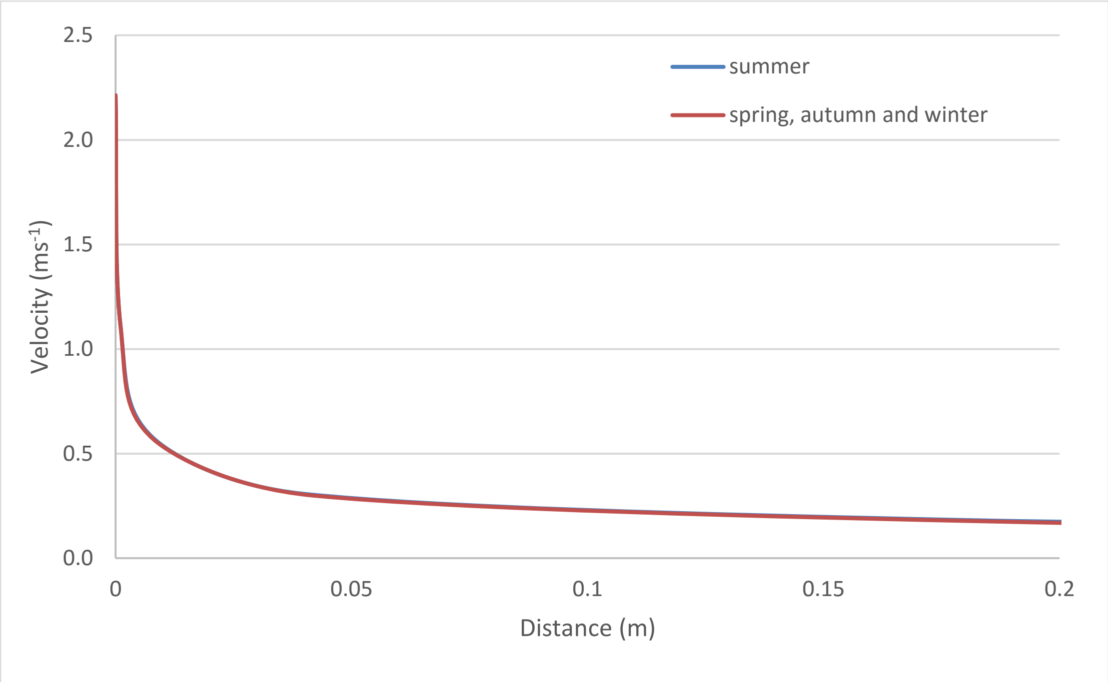



Figure 3.6 Reduction in plume velocity for vertical discharge

## 3.6 Far-field modelling

Based on the results of the near-field modelling it is concluded that no far-field modelling is required for the discharge as the impact of the discharge on the greater Sydney harbour is deemed to be negligible.

# 4 CONCLUSIONS AND RECOMMENDAITONS

The following conclusions are drawn from the modelling detailed in this report. This modelling assessment is an initial assessment using publicly available data and is not based on the collection of focussed temperature, velocity and bathymetric datasets. The datasets used are within Woolloomooloo Bay and where required conservative assumptions have been made such that the use of more focussed data will most likely lead to a reduction in the modelled temperature and velocity effects.

## 4.1 Outlet design

It is recommended that discharge occurs through three 150 mm risers as this will increase the velocity of the discharge and facilitate mixing with ambient water. The discharge pipe should lay horizontally along the seabed with 1 to 2 m risers as shown in Figures 2.4 and 2.5.

Directing the discharge upwards minimises the lateral extent of the plumes but results in greater temperature gradients within the plume. In shallow waters this may also lead to visual disturbance at the water surface and the plume may migrate laterally across the surface.

Directing the plume horizontally increases the lateral extent of the plume underwater but the temperature gradients within the plume will be lower than the vertical arrangement. The horizontal configuration can be useful in avoiding ecologically sensitive areas or facilitating mixing by directing the plume seaward.

The use of three 150 mm risers is recommended.

## 4.2 Outlet placement

The modelled results are based on the discharge occurring at a depth of 6 m with risers situated 2 m above the seabed. Therefore the total depth of the receiving water in the modelled scenario is 8 m.

The modelling shows that there will not be excessive temperature build up around the discharge and is unlikely to result in heated water feeding back to the inlet, providing there is sufficient separation between the inlet and discharge locations. A separation of 25m is recommended.

The effect of the movement of boats on the plume dispersion has not been considered in this assessment; however any additional water movement will facilitate mixing and reduce the temperature effects.

## 4.3 Temperature effects

The modelling predicts that the temperature increase at the edge of the near-field zone through the use of vertically oriented diffusers will be 0.3ºC.

The predicted temperature increase at the edge of the near-field zone through the use of horizontally oriented diffusers is 0.1ºC.

The near-field zone is defined as the area within which the plume reaches the surface, this occurs over greater lateral extent with horizontally oriented discharge so the temperature gradient within the plume is smaller and the temperature at the edge of the plume is lower compared to the vertical orientation. Vertically oriented discharge result in a smaller, more focused plume with higher temperature gradients.

Comparison of the modelled results to the 80$^{th}$ percentile ambient temperature data shows that these indicative trigger values are not exceeded.

## 4.4 Velocity effects

Discharge velocities for the horizontal discharge option reduce to 1 m/s within 1 m of the outlet and further to 0.5 m/s within 2 m from the outlet.

For the vertical discharge option the velocity reduction occurs at a greater rate with velocities reducing to negligible amounts within 1 m. However, in shallow water this may result in visual disturbance at the surface.

The mean ambient velocities are negligible and have negligible effect on the plume dispersion. The use of mean velocity is a conservative assumption and in reality the effects of wind, waves and tides will facilitate plume dispersion and most likely reduce the predicted effects.

# 5 REFERENCES

WSP | Parsons Brinckerhoff (2016). Sydney Modern Project harbour heat rejection system thermal marine ecology impacts assessment. Prepared for Art Gallery New South Wales Trust.

Horton, P.R., Lee, J.H.W. and Wilson J.R. (1997). "Near-field JETLAG modelling of the Northwest Territories Sewage Outfall, Urmston Road, Hong Kong", Proc. 13th Australasian Coastal and Ocean Engr. Conf., Christchurch, New Zealand, Sept. 97, Vol.2, pp. 561-566.

Harrison, D. P. (2013) "Sydney Harbour Water Quality Improvement Plan field survey program" Report to Greater Sydney Local Land Services. Sydney Institute of Marine Sciences.

Tanner, E. Jones, I. S. F., Harrison D. P., Birch G. (2016, pers comm) Sydney Harbour Real Time Model, Sydney Harbour Observatory, University of Sydney, https://sho.sydney.edu.au/

# Appendix B

## CONSIDERATION OF IMPACTS ON THREATENED AND PROTECTED MARINE SPECIES

# CONSIDERATION OF IMPACTS ON THREATENED AND PROTECTED MARINE SPECIES

To determine the potential impact on threatened species and ecological communities searches were made of marine species listed under the EPBC Act, the NSW Threatened Species Conservation Act 1995 (TSC Act) and the Fisheries Management Act that may occur in a 5 km radius of the proposed Stage 1 works. **Appendix B Table 1** below compiles the listing from those conservation instruments and presents justification for the need to complete a formal significance assessment for each species. Key project-specific considerations in determining whether a species, community or population listed below require further assessment include:

- The proposal footprint is small, relatively shallow bay within Sydney Harbour and consists of modified and urbanised intertidal and subtidal habitats that have relatively low habitat diversity and moderate existing biotic diversity.
- The work that would affect intertidal and subtidal habitats would occur immediately next to the shoreline. It would have a relatively short duration and it would have a small footprint due to the parallel installation of inlet and outlet pipes.
- The operation of inlet and outlet pipes are unlikely to impact on deeper soft bottom habitats.
- From the perspective of impacts on marine species, the higher impact construction work is limited to installation of inlet and outlet pipes at a point where the intertidal and subtidal habitats are narrow, before dropping off to deeper water.
- The volume of seawater used for operation of the heat exchange system would be small relative to the volume of Sydney Harbour (refer to section 5.1.1) making the loss of planktonic life forms insignificant and unlikely to alter the ecology of intertidal or subtidal habitats.
- The low current speeds at the inlet pipes (refer to section 5.1.4) have been shown to minimise the likelihood of impingement for the vast majority of fish and macroinvertebrates on inlet screens.
- The impact of increased water temperature in the vicinity of the discharge pipe is limited, on average to two degrees Celsius within a plume of one metre (in the horizontal plane) radius (Table 6.1) and, given ambient average temperature, tidal exchange and local water circulation unlikely to cause thermal stress in intertidal or subtidal marine organisms.

**Appendix B: Table 1 Listing of relevant threatened and protected species and justification for further assessment of significance**

P = Protected; V = Vulnerable; CE = Critically Endangered, E = Endangered; M = Migratory, L = Listed Marine

[1] = the entire east coast population of grey nurse sharks, [2] = the population of little penguins at Manly

| Common Name | Scientific Name | Conservation listing status | | | Project-specific considerations relevant to requirement for significance assessment | Formal assessment required? |
|---|---|---|---|---|---|---|
| | | EPBC | TSC | FM | | |
| **Finfish** | | | | | | |
| Grey nurse shark | *Carcharias taurus* | E[1] | | CE | Water at project site too shallow for species to occur, no resting habitat available (i.e. lack of caves) and very little availability of foraging area. Potential for occurrence in Project area very low. | No |
| Black cod | *Epinephelus daemelii* | V | | V | Relevant habitats available (caves, complex rocky reef) are absent or sub-optimal. Potential for occurrence very low. | No |
| Estuary cod | *Epinephelus coioides* | | | P | Relevant habitats available (caves, complex rocky reef) are absent or sub-optimal. Potential for occurrence very low. | No |
| Elegant wrasse | *Anampses elegans* | | | P | Adults are not likely to occur in the study area as they usually occupy deeper and more complex habitats (e.g. rocky reefs). Juveniles school in seaweed and rocky reefs habitats which are not present in significant extent in project area. Potential for occurrence is low. | No |
| Eastern blue devil | *Paraplesiops bleekeri-* | | | P | Usually occupies deeper and more complex habitats such as rocky reefs with crevices and caves. Juveniles are found in rocky reefs habitats which are not present in significant extent in the study area. Potential for occurrence in Project area is low. | No |
| Up to 23 species of seahorses, seadragons, pipefish, pipehorses, ghostpipefish and seamoths | Syngnathiformes | L | | P | Very little seagrass and limited macrophyte or other suitable habitat available. Potential for occurrence is low and disturbance of algal habitat is minimal. | No |

| Common Name | Scientific Name | Conservation listing status EPBC | TSC | FM | Project-specific considerations relevant to requirement for significance assessment | Formal assessment required? |
|---|---|---|---|---|---|---|
| **Marine Mammals** | | | | | | |
| Common dolphin | *Delphinus delphis* | L | P | | | No |
| Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin | *Tursiops aduncus* | M, L | P | | Very little foraging area available. Uncommon in shallow and intertidal habitats and able to move away from temporary disturbance. | No |
| Dusky dolphin | *Lagenorhynchus obscurus* | M,L | P | | | No |
| **Marine Reptiles** | | | | | | |
| Loggerhead turtle | *Caretta (M)* | E,M,L | E,P | | The Project area represents an unlikely foraging area due to the lack of seagrass beds or extensive algae mats. Potential for occurrence is very low. | No |
| Green turtle | *Chelonia mydas (M)* | V,M,L | V,P | | | |
| Leatherback turtle | *Dermochelys coriacea (M)* | E,M,L | E,P | | Highly pelagic species occurring near shore manly during the nesting season. It requires sandy beaches to nest which are absent in the Project area. Potential for occurrence is very low. | No |
| Hawksbill turtle | *Eretmochelys imbricata (M)* | V,M,L | V,P | | Highly pelagic species occurring near shore mainly during the nesting season and, occasionally for foraging in seagrass habitats. It requires sandy beaches to nest which are absent in the Project area. Potential for occurrence is very low. | No |
| Flatback turtle | *Natator depressus (M)* | V,M,L | P | | Adults inhabit soft bottom habitat over the continental shelf of northern Australia and occur nearshore mainly during the nesting season. It requires sandy beaches to nest which are absent in the Project area. Potential of occurrence is very low. | No |
| **Marine Birds** | | | | | | |

| Common Name | Scientific Name | Conservation listing status | | | Project-specific considerations relevant to requirement for significance assessment | Formal assessment required? |
|---|---|---|---|---|---|---|
| | | EPBC | TSC | FM | | |
| Little penguin | *Eudyptula minor* | L | E[2],P | | Little penguins spend most of their time foraging in open coastal waters. The only known breeding colony in NSW is in the Manly area of Sydney Harbour. Potential of occurrence in the Project area is very low. | No |
| Little pied cormorant | *Microcarbo melanoleucos* | L | P | | Could occur in the Project area, but Project area is not key roosting site for any of this group of birds. These species readily move away from disturbed habitats, or readily acclimate to them (e.g. pelicans). No Project construction activities would directly impact on birds temporarily using the foreshore to roost, and there is high availability of other roosting habitats. | No |
| Great cormorant | *Phalacrocorax carbo* | L | P | | | |
| Little black cormorant | *Phalacrocorax sulcirostris* | L | P | | | |
| Pied cormorant | *Phalacrocorax varius* | L | P | | | |
| Australian pelican | *Pelecanus conspicillatus* | L | P | | | |
| White-bellied sea eagle | *Haliaeetus leucogaster* | M,L | P | | Occurs mainly in large areas of open water (larger rivers, swamps, lakes, sea). Forages over in-shore waters and large expanses. The project area is not suitable for nesting. Potential occurrence is very low. | No |
| Black noddy | *Anous minutus* | L | P | | Could occur incidentally in the Project area but Project area does not represent key roosting, nesting or foraging habitat. All terns and gulls are able to move away from temporary disturbances. | No |
| Common noddy | *Anous stolidus* | L | P | | | |
| Whiskered tern | *Chlidonias hybrida* | L | P | | | |

| Common Name | Scientific Name | Conservation listing status | | | Project-specific considerations relevant to requirement for significance assessment | Formal assessment required? |
|---|---|---|---|---|---|---|
| | | EPBC | TSC | FM | | |
| White-winged black tern | *Chlidonias leucopterus* | L | P | | | |
| Silver gull | *Chroicocephalus novaehollandiae* | L | P | | | |
| Gull-billed tern | *Gelochelidon nilotica* | L | P | | | |
| White tern | *Gygis alba* | L | P | | | |
| Caspian tern | *Hydroprogne caspia* | L | P | | | |
| Kelp gull | *Larus dominicanus* | L | P | | | |
| Pacific gull | *Larus pacificus* | L | P | | | |
| Franklin's gull | *Leucophaeus pipixcan* | L | P | | | |
| Sooty tern | *Onychoprion fuscata* | L | P | | | |
| Grey ternlet | *Procelsterna cerulea* | L | P | | | |
| Common tern | *Sterna hirundo* | L | P | | | |
| Arctic tern | *Sterna paradisaea* | L | P | | | |
| White-fronted tern | *Sterna striata* | L | P | | Could occur incidentally in the Project area but Project area does not represent key roosting, nesting | No |

| Common Name | Scientific Name | Conservation listing status EPBC | TSC | FM | Project-specific considerations relevant to requirement for significance assessment | Formal assessment required? |
|---|---|---|---|---|---|---|
| Little tern | *Sternula albifrons* | L | | P | or foraging habitat. All terns, ternlets and gulls are able to move away from temporary disturbances. | |
| Fairy tern | *Sternula nereis* | L | | P | | |
| Crested tern | *Thalasseus bergii* | L | | P | | |
| **Ecological Communities** | | | | | | |
| | *Posidonia australis* seagrass meadows, population | T (Manning-Hawkesbury ecoregion) | | EP (Port Hacking, Botany Bay, Sydney Harbour, Pittwater, Brisbane Waters and Lake Macquarie) | No seagrasses present in the project area | |

**Appendix B: Table 2 Consideration of potential of the project to represent a relevant Key Threatening Processes (TSC and FM Act)**

| PROCESS | PROJECT-SPECIFIC CONSIDERATIONS RELEVANT TO REQUIREMENT FOR SIGNIFICANCE ASSESSMENT | FORMAL ASSESSMENT REQUIRED? |
|---|---|---|
| Clearing of native vegetation | No threatened species of aquatic vegetation were identified I the Project area.<br>For Option A, installation of pipeline using methods that disturb the surface would result in the removal of common intertidal and subtidal algae. The area of disturbance is considered small, is in the context of an altered, urbanised environment and algae | No |

| PROCESS | PROJECT-SPECIFIC CONSIDERATIONS RELEVANT TO REQUIREMENT FOR SIGNIFICANCE ASSESSMENT | FORMAL ASSESSMENT REQUIRED? |
|---|---|---|
| | would readily recolonise the area and new surfaces post construction.<br>No significant amounts of algae would be disturbed for the installation of the pipeline for Option B, and the intertidal portions of the pipelines would be colonised by the same range of organisms as currently present on wharf piles. | |
| Entanglement in or ingestion of anthropogenic debris in marine and estuarine environments | The probability of the occurrence of threatened species in the Project is considered very low.<br>The inlet pipes could attract floating marine debris such as plastic bags and fishing line, in which fish and mobile marine fauna could become trapped. Given the small size of the inlet pipe and the presence of other debris-attracting structures nearby, the increased risk of entanglement or ingestion of debris due to the operation of the seawater heat exchange system is considered insignificant. | No |