KEPPEL ENERGY PTE LTD

# Environmental Impact Assessment (EIA) for the Advanced Gas Turbine Cogeneration Combined Cycle Plant on Jurong Island, Singapore

## Environmental Impact Assessment

Document no. Rev A: 412010-00158-EIA-RP-001

25 September 2023

438B Alexandra Road #04-09
Alexandra Technopark
Singapore 119968

T: +65 6735 8444
Worley Pte Limited



worley.com

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# 1 Introduction

Worley has been appointed by Keppel Energy Pte. Ltd. (Keppel) to undertake the Environmental Impact Assessment (EIA) for the development of Keppel's Advanced Gas Turbine Cogeneration Combined Cycle Power Plant (hereafter referred to as the 'Project'). The proposed Project is located on Lot 880L,03586L,02999L,02349P,03587C, MK 34 at Sakra Avenue, Jurong Island (Figure 1-1).

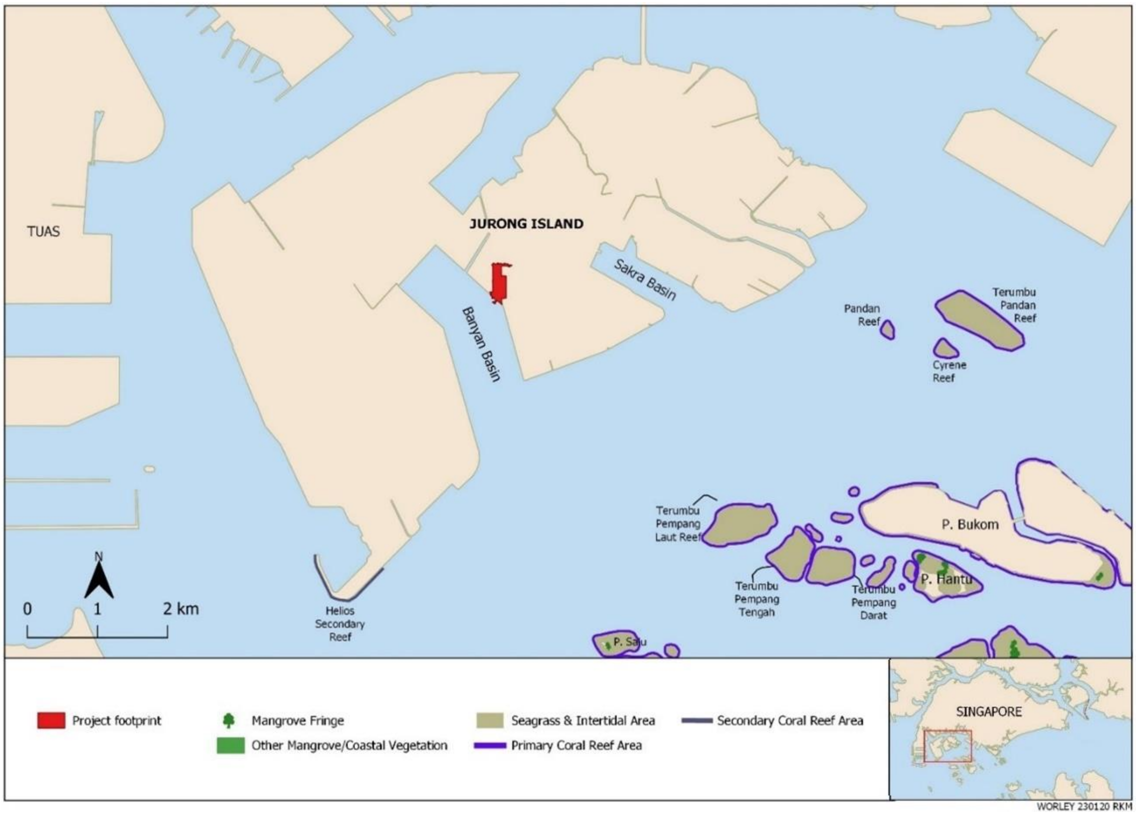



*Figure 1-1: Indicative locations of project*

The proposed development uses both a gas turbine (GT) and a steam turbine (ST) to generate electricity by burning natural gas, a fuel with a lower environmental impact. The exhaust heat from the GT is used to generate steam, generating electricity twice and minimizing waste production. The plant will also contribute towards greater efficiency and lower carbon emissions in which it will support Singapore's transition to a more sustainable energy future while ensuring the security and reliability of electricity supply to consumers. The single-shaft Combined Cycle Gas Turbine (CCGT) will deliver maximum gross power output of 600MW to 230kV Grid at Sakra Area, Jurong Island, Singapore.

The complete Cogen Plant facility will be developed in two (2) phases. For Phase 1, one (1) unit of Advanced Gas Turbine Cogeneration Combined Cycle Plant will be designed with a maximum net output of 600 MW, with potential for one (1) more unit of similar arrangement for Phase 2 in the future. A cooling water (CW) system is constructed under Phase 1. The intake and outfall are about 60 m and 24 m in length from shore respectively. This EIA report focuses on the development for Phase 1 only. This project shall utilise approximately 8 hectares of the 9.9 hectares of the allocated site with implementation of Phase 1 of the Power Plant.

The proposed Project shall comprise a single-shaft CCGT configuration, with dual fuel capability and is to include a best-in-class advanced GT with a ST and steam extraction capabilities. Additionally, seawater is continuously drawn through the intake structure located south of the site. The power plant requires 105,000 $m^3$/hr of seawater to be drawn from the sea and the subsequent hot water to be discharged to the sea via the condenser outlet. The construction of intake involves dredging of the seabed material to lay the pipeline within the trench. No dredging is expected for the construction of outfall as the outfall structure is a reinforced concrete (RC) boxed culvert located at the shoreline of Banyan Bay.

## 1.1 Study Objectives

The aim of the EIA process is to assess the potential environmental impacts that may arise from the proposed Project and identify measures that will be put in place to prevent or minimise these impacts. The EIA process is integral to the Project, assessing potential impacts and setting design and operational challenges to ensure that the residual impacts of the Project are minimal.

The objectives of this study are as follows:

- To establish the baseline conditions prior to construction of the Project;
- To assess the impact of the development on the current regime (hydrodynamics), during project construction and after the completion of the trenching works in relation to potential effects on navigation, mooring and environmental receptors;
- To assess the impact of the development on the water quality regime in relation to possible undesirable water quality impacts within and immediately adjacent to the Project area due to thermal and chlorine release from the proposed outfall;
- To assess the impact of the construction of intake's pipeline in relation to sediment spill and sedimentation from the trenching activities on marine habitats, navigation areas, ecological receptors, or other sensitive facilities (e.g., water intakes);
- To assess the impact of the project in relation to possible impacts to key components of the ecosystem (coral, seagrass, and plankton) in the study area;
- To assess the potential for any international boundary impacts from the Project; and
- To develop mitigation measures (if necessary) to avoid or minimise predicted environmental impacts.

## 1.2 Project Proponent

The Project Proponent for this Project is Keppel Energy Pte Limited. Enquiries and correspondence pertaining to this Report can be addressed to:

| | |
|---|---|
| Address: | Keppel Energy Pte Limited |
| | 1 Harbourfront Avenue, #05-05, Keppel Bay Tower, Singapore 098632 |
| Telephone: | +65 6278 1800 |
| Website: | www.kepinfra.com |

## 1.3 Environmental Consultant

Worley has been appointed to undertake this EIA. The Environmental and Social (E&S) team for the Southeast Asia (SEA) region is headquartered in Singapore. All enquiries and correspondence pertaining to this Report can be made to:


| | |
|---|---|
| Address: | Worley Pte Limited |
| | 38B Alexandra Rd, #04-09 Alexandra Technopark, Singapore 119968 |
| Telephone: | +65 6735 8444 |
| Website: | www.worley.com |
| Attention | Ms Wanli CHIN |


## 1.4 Scope of Works

The summary of the scope of works are presented in Table 1-1.

*Table 1-1: Summary of scope of works*

| Scope of Works | Report Reference |
|---|---|
| Current Impact | Section 9 |
| Wave Impact | Section 9 |
| Water Quality Impact (Thermal, Chlorine) | Section 9 |
| Sediment Plume Impact | Section 9 |
| Morphology | Section 9 |
| Safety Navigational | Section 9 |
| Marine Biodiversity | Section 10 |
| Cross Border, Recreational, Aquaculture facilities | Section 13 |

# 2 Assumption and Limitation

The following assumptions and limitations are considered in the preparation of this EIA.

- Worley have conducted this EIA Study to meet primarily local regulations and standards for use by Keppel in accordance with the agreement which potential impacts to the marine environment arising from the construction and operation activities. After consulting regulatory agencies, it was assessed that the main environmental impacts from this development would be on the marine environment. As such, the focus of the study would be to study the potential impacts on the marine environment, specifically, impacts of thermal pollution and sediment plume. The tree inventory and terrestrial biodiversity information provided in this report serves as the baseline record of trees and biodiversity observed during the study and serves to inform and guide the mitigating measures for subsequent land preparation phases.
- The study's information, assessment or professional advice in this report are solely for the agreed purposed of assessing the Project's impact on the environment, as part of URA's planning approval process and Worley does not accept any liability if used for any other purposes.
- All conclusions and recommendation made in this report are the professional opinion of the Worley personnel involved with the Project.
- Unless otherwise stated in this report, the assessments assume that the site and associated infrastructure will continue to be used for their stated purpose without significant change. The conclusions and recommendations contained in this report are based upon information provided by Keppel and third parties on the assumption that all relevant information has been provided. Information obtained from third parties has not been independently verified by Worley, unless otherwise stated in the report.
- Where field investigations have been carried out, these have been carried out to the level of detail required to achieve the objectives of this assessment. The results of any measurements taken may vary spatially or with time and further investigations should be made after any significant delay in using this Report. Given this, Worley offers the results merely as an indication of the possible impacts.
- The baseline and impact of the proposed project operational phase on air quality, noise quality, soil and groundwater, surface water, hazardous chemical management will not be assessed in this EIA.

# 3 Project Description

This section provides an overview of the proposed power plant including the overall Project size and capacity, the main Project activities from construction to operation as well as support ancillary facilities. Where applicable, reference has been made to the design of the Project.

## 3.1 Project Overview

The 600 MW Keppel Cogen Plant will be Singapore's first hydrogen-ready and most advanced, high-efficiency CCGT power plant, and capable to contribute towards greater efficiency and lower carbon emissions in which it will support Singapore's transition to a more sustainable energy future while ensuring the security and reliability of electricity supply to consumers.

The proposed CCGT will deliver a maximum gross power output of 600 MW and the major components for the CCGT are J Class GT, condensing and extraction ST connected with a common generator, and Heat Recovery Steam Generator (HRSG), as well as other required auxiliary systems. The GT shall be designed with dual fuel firing options considering natural gas as a primary fuel and distillate oil as a backup fuel.

The GT, ST, generator, and HRSG make up the power generating infrastructure. The GT is supplied with fuel which is combusted in conjunction with air to create energy that is utilized to generate power. To increase efficiency, the HRSG is given heat energy in the form of exhaust gases, which it uses to turn feedwater or condensate into steam. The steam is subsequently supplied to the ST, which also generator power. The ST produced steam will be condensed in a condenser, before being supplied back to the HRSG.

Natural gas fired is used for the CCGT with steam extraction capability to support the cogeneration functionality. The electrical energy generated at CCGT will be delivered to the existing 230 kV Grid at Sakra Area in Jurong Island, Singapore.

*Table 3-1: Proposed CCGT rating and fuel source*

| Characteristics | Description |
|---|---|
| Nominal Net Plant Rating | 600 MW gross on primary fuel. The plant also has capability of steam export of High Pressure (HP) – 7 tph, Intermediate Pressure (IP) – 63 tph, Medium Pressure (MP) – 40 tph, and Low Pressure (LP)-75 tph. Return Condensate is 185 tph |
| Fuel | Primary: Natural Gas<br>Backup: Diesel oil |

## 3.2 Project Components

The CCGT is comprised of the following key components and other auxiliary systems, in which the components are further discussed in the sections below.

- Gas Turbine (GT) and auxiliaries;
- Heat recovery steam generator (HRSG);
- Steam turbine (ST)and auxiliaries;

- Generator and auxiliaries;
- Feedwater / condensate system
- Boiler chemical feed system;
- Emergency diesel generator (EDG) / black start diesel generator (BSDG);
- Fuel gas system;
- Fuel oil system;
- CW system;
- Instrumentation and Control;
- Demineralised water system;
- Wastewater system;
- Stormwater system; and
- Fire Water system.

## 3.3 Project Activities

### 3.3.1 Construction

#### 3.3.1.1 Mobilisation of Construction Materials and Machinery

Prior to commencement of any construction activities, it is necessary to mobilise the required equipment and machineries to the Project site. Construction equipment and raw construction materials will be transported to the dedicated temporary laydown area.

#### 3.3.1.2 Earthworks

Earthworks for the Project includes the excavations activities to achieve the civil works (e.g., for foundations and general grading), as well as the backfilling after completion of the civil works. The excess material from excavation is to be reused or disposed at an approved dumping ground nearest from the construction site within 5 km radius or within Jurong Island.

The existing site is a reclaimed land with a relatively flat surface profile. The existing ground level at the Project site is in the range of +3.00 to +5.00m above Singapore Height Datum (SHD) (Figure 3-1). The plant site area is levelled and graded to +4.00m above SHD.

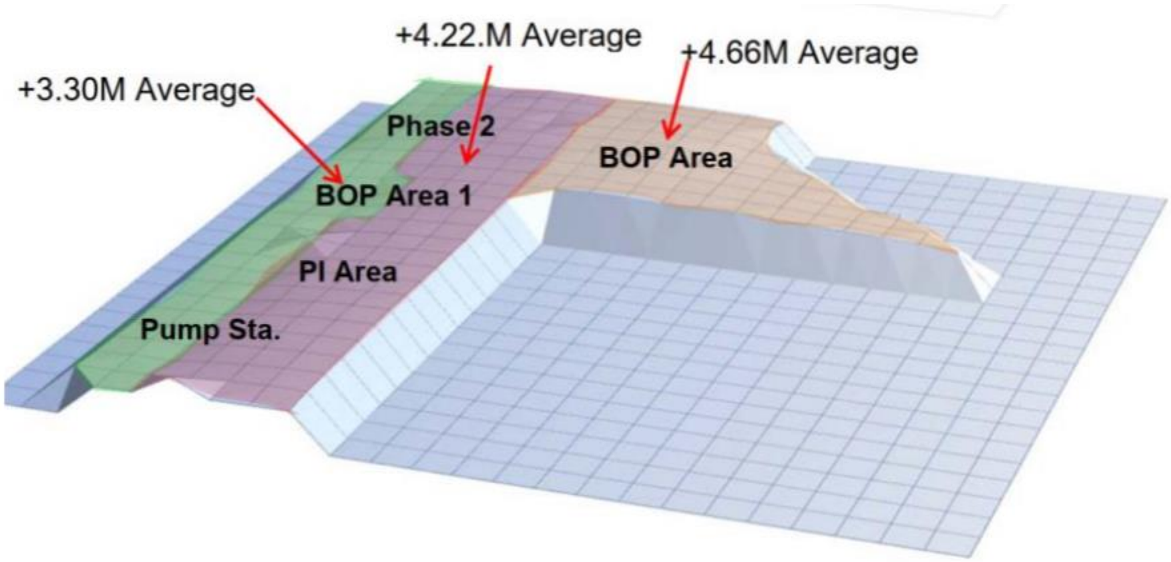



*Figure 3-1: Existing platform level*

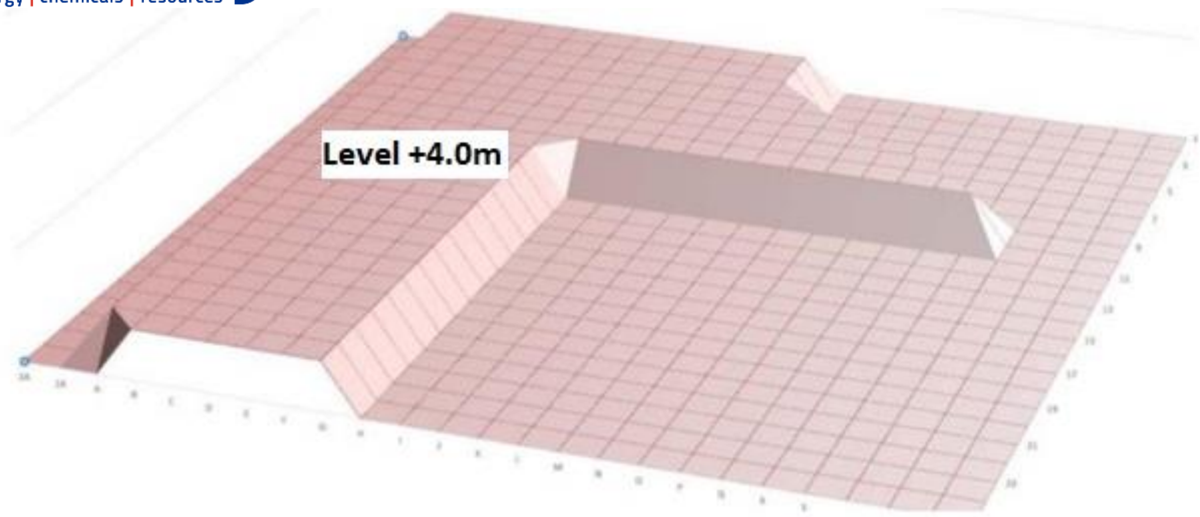



*Figure 3-2: Proposed platform level*

#### 3.3.1.3 Onshore Construction

The main activities in this stage of development are:

- Piling and foundation works – foundation works will require piling by using heavy machineries such as piling rigs. Shallow foundation is adopted for this Project site. The following assumptions are made and constitute a basis for foundation design:
  - The GT/ST/generator foundation and HRSG and stack foundation will be set on piled foundation.
  - The ST building, 230kV GIS building, and administration and control building shall be supported on piled foundation. Transformers, and pipe rack structure shall also be set on piles.
  - The requirement of piled or shallow foundation for other buildings, structures and equipment shall be assessed during detailed engineering stage and the appropriate foundation type will be provided accordingly based upon the geotechnical investigation.
  - Precast concrete piles will be used in this project. Pile sizes are 300 mm sq and 400 mm sq with 50 Ton capacity and 90 Ton capacity, respectively. The pile load tests shall be carried out as per Building and Construction Authority (BCA) requirements and subjected to approval by a Qualified Person/Professional Engineer.
- Civil and structural (C&S) works – all design and construction will be carried out in accordance with local Standards, International Codes of Practices, and good engineering practices. The C&S works include:
  - Reinforced Concrete (RC)
    - This involves structural concrete and reinforcing steel for the structural systems, including but not limited to, footings, mat/block foundations, pile caps, piers, grade beams, walls, slab on grades, above ground suspended slab, column, and beam structures. Where appropriate site precast or off-site precast concrete may be used as an alternative to cast in place concrete structures.

- Infrastructure works

    - **Road** – Construction of internal access road. The roads shall be of asphalt construction, with 6.0m width and without road shoulders. Adequate paved walkways shall be provided for the operating personnel to access the plant equipment.

    - **Landscaping** – Landscaping shall consist of either gravel fill or grass seeding to unpaved areas of the plant, depending on proximity to the plant equipment. Gravel filled area shall be provided with crushed stone of 100mm thickness. Phase-2 of Power Block area shall be levelled, and gravel filled finish. No piling/lean concrete is considered.

    - **Fencing** – Site boundary fencing will be provided for the security of the plant. The boundary fence shall consist of anti-climb welded mesh type.

    - **Drainage system** – Storm water shall be collected in a combination of open channel drains and buried drainage pipes. The storm water shall be routed and discharged to the CW discharge channel near to plant boundary.

    - **Shelters** – Shelter shall be provided for Fuel Gas Compressor, Fuel Oil Forwarding Station, Air Compressor and Dryer, Water Treatment Plant (WTP) and carpark.

    - **Platforms** – The plant shall be provided with steel access platforms, with ladders and/or stairs and galvanized grating/checkered plate. Access shall be provided for normal operation and maintenance of the plant.

- Erecting building structures

    - This involves formwork, work platforms, structure framework, placement of reinforcement bars, scaffolding, doors and windows installation, painting, gates, electrical and cable wiring, roofing, and other carpentry works. The main buildings to be constructed on site are as follow:

        - **Administration and control building** – The 3-storey administration and control building shall be a RC framed structure with concrete roof, 24.0m width x 42.0m length. Walls adjacent to transformers shall be constructed of block wall in accordance with the fire rating requirement.

        - **Turbine building** – The turbine building shall be a single-storey steel framed structure, 28.0m width x 57.5m length, housing the GT, ST and generator units.

        - **230kV GIS building** – The 230kV GIS building shall be a 2-storey RC framed structure with concrete roof, 20.0m width x 40.0m length. The first storey shall be cable camber while second storey houses the GIS Room, battery room, and panel rooms.

        - **Cooling Water Electro-Chlorination Building** – The single-storey CW Electro-Chlorination Building shall be a RC framed structure with steel roof, 20.7m width x 27.0m length for skid and transformer area, and concrete roof for electrical and battery room area, 11.0m width x 13.0m length.

        - **WTP Control Building** – The single-storey WTP Control Building shall be a RC framed structure with steel roof, 6.0m width x 19.0m. This building shall house the control room, MCC Room and chemical laboratory area, and rooms for the water treatment plant.

- **Guard House –** The single-storey guard house shall be a RC framed structure with concrete roof, 4.0m width x 6.0m. This building shall include guard office, toilet and locker.

- Installation of equipment - Once the buildings and infrastructures are established, installation of plant components such as ST, GT, heat recovery steam generator, and other ancillary equipment shall be carried out. Testing and commissioning of the equipment would be carried out prior to commencing full operation.
- Installation of below ground utility and drainage.

#### 3.3.1.4 Offshore Construction

Seawater will be extracted from the Banyan Basin by the intake structure and pumped to the CCGT to be used by the condenser, and the cooling seawater will be discharged back to the basin through the outfall structure.

#### 3.3.1.5 Cooling Water (CW) System Intake

The seawater intake system provides CW that is required for the generation of electricity by the proposed Combined Cycle Power Plant. The intake system is made up of the following components:

- A below ground, open-top RC pumphouse structure at the foreshore adjoining Banyan Basin;
- Subterranean GRP pipes connecting the intake tower in Banyan Basin to the forebay of the intake pumphouse; and
- An intake tower structure installed on the seabed in Banyan Basin.

For onshore section, the construction of the pumphouse will be carried starting with site preparation, followed by pilling works, temporary installation of shoring system for the RC pumphouse structure, setting up of dewatering system, structural concrete works, excavation works for pumphouse beyond shoreline, and installation of temporary decking/ platform for the construction beyond shoreline. Silt protector will be installed during earthworks to avoid siltation to the water bodies.

Trenching works are required for the installation of the piping system (GRP pipes) and intake tower structure for the proposed intake. The GRP pipes and intake tower structure are to be buried underground, hence, dredging using a grab dredger is proposed. The dredging of the trench is proposed to be carried out by using one (1) unit of grab dredger with daily average volume 1,000 $m^3$/day or up to 5000 $m^3$/day. The trenching works is scheduled to be carried out for 24 hours per day and 7 days per week, with the assumption of no interruptions to the operation. The trench for the intake pipeline extends to 60 m offshore and trenching up to -20 mCD. It is estimated about 25,000 $m^3$ of material from seabed will be dredged for the intake pipe trench. The dredged seabed material will be loaded to hopper barge and dumped at Maritime and Port Authority of Singapore (MPA) approved site. A grab dredger is a stationary dredger, where dredged materials are stored on a hopper barge or the ship. Soft clay, sand and gravel are suitable materials for the grab dredger.

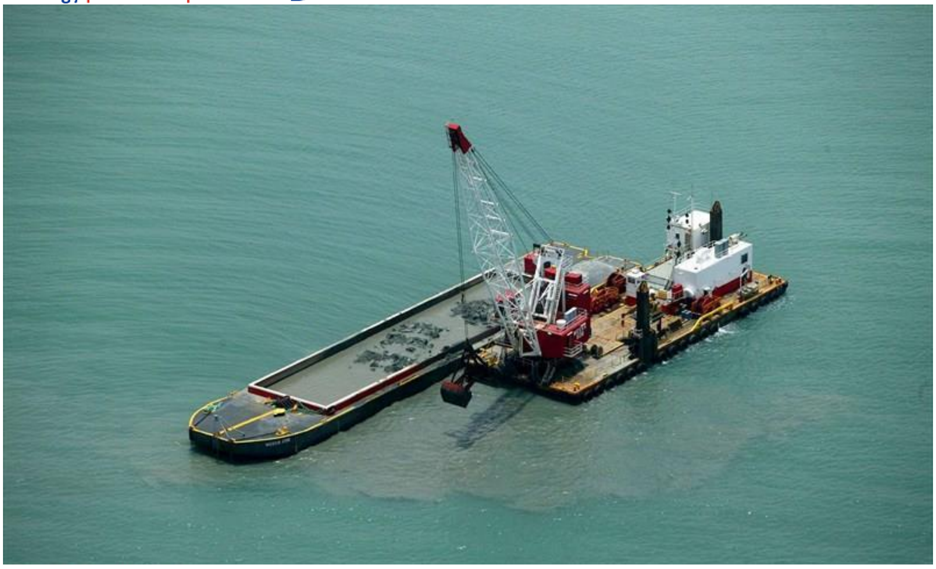
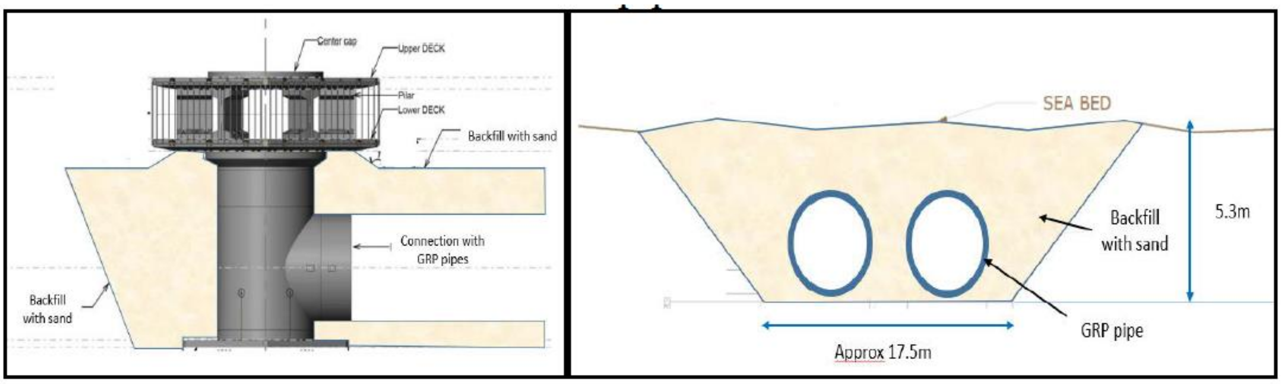


*Figure 3-3: Example of grab dredger*

Upon completion of the dredging works, crushed stones will be laid as base slab for intake tower and sand for the GRP pipes. Materials will be delivered using material barge and dumped into the cut profile using excavator. Crane barge will be deployed to lift the intake tower and GRP pipes to designated location. Once intake tower and GRP pipes are at designated position, sand will be used to backfill and cover the GRP pipes.




**Designs shown above are conceptual and subject to changes during detailed engineering*

*Figure 3-4: Backfill of sand plan after installation of intake tower and GRP pipes*

#### 3.3.1.6 Cooling Water (CW) System Outfall

For the CW system outfall, it will be constructed as a RC boxed culvert in a 32m(L) x 8m(W) x 5m(H). The construction of the discharge culvert involves site preparation works, followed by piling works, and construction of temporary shoring system. During site preparation works, underground water and storm water will not be discharged to the sea directly. Water will first be collected at settling basin before being discharged into the sea.

### 3.3.2 Operational

The main activities during this stage consist of power generation, water treatment and CW system. The power plant availability will be 360 days/year and the power plant will be operated 7 days a week, 24 hours a day, except for years where planned maintenance is scheduled.

#### 3.3.2.1 Environmental Pollution Controls

The environmental pollution control that will be put in place during operation phase includes:

- Stack emission control;
- Wastewater discharge; and
- Materials chemical usage and handling.

##### 3.3.2.1.1 Stacks Emission Control

Natural gas is used as the primary fuel and distillate oil is used as backup emergency fuel supply in case of loss of fuel gas. Natural gas is a relatively clean burning fossil fuel and it produced approximately 45% less $CO_2$ than coal. Nonetheless, CEMS will be installed at stack to continuously measure and monitor gaseous $SO_X$, $NO_X$, $CO_2$, CO, $O_2$, CO, and opacity.

##### 3.3.2.1.2 Wastewater Discharge

The key controls that will be in place for generation and disposal of process wastewater are as follows:

- Wastewater from the water treatment plant will go to the neutralisation sump where its pH will be monitored and controlled between pH of 6 - 9. If the pH is outside the acceptable limits the wastewater will be circulated until the pH has been corrected within the set limits at which point it will be pumped to the holding pond. The holding pond will have pH and temperature monitoring. When all parameters are within the prescribed limits range, the treated trade effluent will be discharged to the sea via the seawater outfall;
- Drain water will be directed to the Oily Water Separator at all areas of the plant where there is the possibility of oil spillage. Should there be a buildup of oily waste and sludge, the level switches fitted in the Oily Water Separator will be activated. This build up will be removed ensuring it is not carried over to the Holding Pond;
- All drains will always be closed from the GSU / Auxiliary Transformer and Fuel Oil Storage bund areas. After rainfall event, rainwater collected within bund wall will be visually checked ensuring no significant oil visible in the bund area. Collected rainwater in good condition (no excessive oil leak) will then be permitted to drain to the plant sump via the opening of the drain valve in the bund area. From then it will be pumped to the oily water separator;
- If the collected bund water was found to have an excessive oil leak, it will be removed by a licensed NEA contractor and disposed of in an appropriate manner; and
- The GT compressor wash effluent will be collected and disposed off-site through a licensed toxic industrial waste collector.

## 3.4 Project Schedule

Based on information provided by the client, the proposed construction schedule phases are broken down in Table 3-2. The overall Project construction is estimated to be 28 months.

*Table 3-2: Proposed construction schedule*

| Project Events | Phases | Duration (Days) |
|---|---|---|
| Ground Improvement work (vibro compaction | Design & Engineering | 35 |
| | Construction | 71 |
| General/ Common (design/engineering) | Piping Routing | 102 |
| | Electrical Cable Routing | 70 |
| | Plot Plan | 102 |
| Civil work | Design & Engineering | 177 |
| | Piling Work | 204 |
| | Foundation Work | 400 |
| | Building Work | 456 |
| Gas Turbine (GT)/ Steam Turbine (ST) & generator & auxiliaries | Design & Engineering | 121 |
| | Construction | 639 |
| HRSG system | Design & Engineering | 206 |
| | Construction | 302 |
| Fuel gas system | Design & Engineering | 201 |
| | Construction | 145 |
| Fuel oil system | Design & Engineering | 167 |
| | Construction | 290 |
| Material handling system | Design & Engineering | 277 |
| | Construction | 175 |
| Main cooling water system | Design & Engineering | 191 |
| | Construction | 166 |
| Auxiliary cooling system and closed water system | Design & Engineering | 210 |
| | Construction | 122 |
| Fire fighting and protection system | Design & Engineering | 146 |
| | Construction | 309 |
| Compressed air system | Design & Engineering | 155 |
| | Construction | 75 |
| Service water (Portable and NEWater) supply system | Design & Engineering | 155 |
| | Construction | 207 |

| Project Events | Phases | Duration (Days) |
|---|---|---|
| WTP (demin plant) and wastewater system | Design & Engineering | 180 |
| | Construction | 210 |
| Chlorination plant | Design & Engineering | 160 |
| | Construction | 112 |
| Auxiliary boiler (startup) | Design & Engineering | 137 |
| | Construction | 187 |
| Plant electrical system | Design & Engineering | 356 |
| | Construction | 216 |
| 230kv GIS substation | Design & Engineering | 170 |
| | Construction | 140 |
| DCS system | Design & Engineering | 300 |
| | Construction | 81 |
| Road/stormwater drain/ landscaping | Design & Engineering | 90 |
| | Construction | 176 |

# 4 Study Approach and Methodology

The EIA aims to identify the potential impacts that may arise due to the construction and operational phases of the CCGT Plant alongside its auxiliary facilities, namely, CW intake and outfall pipelines, followed by mitigating measures, and monitoring requirements to be put in place prior to, during, and after the construction phase, in order to prevent and/or minimize environmental impacts.

For this EIA, Worley had performed the following processes:

- Desktop assessment and documents review;
- Baseline assessment;
- Prediction of potential impacts through numerical modelling;
- Analysis and evaluation of potential impacts; and
- Reporting.

Each of these tasks is described in the following sections.

## 4.1 Desktop Assessment and Documents Review

The key documents used for the environmental and social examination include:

- General information: Project layout, process flow, plant maintenance plan and records
- Pre-Hydrographic Survey Report (DECP-00-UZV-RE-C111). Bathymetric survey for feasibility study of thermal intake and outfall;
- Computational Fluid Dimensional Study Report for Intake Pump (DECP-00-YYY—RE-M104). Thermal dispersion and hydraulic study;
- CW Intake Drawings (12644A; 12644B; 12644C; 12644D; 12644E);
- Existing Underground Utility Services Detection Report (DECP-00-UZV-RE-C112);
- Load Flow Study Report (DECP-00-YYY-RE-E106). Load flow analysis of Project based on SPPG grid requirement;
- Pre-conditional Dilapidation Photographic Survey Report (DECP-00-UZV-RE-C108). Notate and observed condition of properties;
- Quantitative Risk Assessment (QRA) Report (DECP-00-YYY-RE-G101). Evaluate the risk profile of the site facilities against the revised QRA guidelines;
- Short Circuit Study Report (DECP-00-YYY-RE-E107). Find the short-circuit contribution from project to 230kV system of SPPG to verify necessity of Neutral grounding Reactor;
- Soil Investigation (SI) Report (Onshore) (DECP-00-YYY-RE-C113). Land soil investigation works;
- Soil Investigation (SI) Report (Offshore) (DECP-00-YYY-RE-C114). Marine soil investigation works;
- Thermal Dispersion Study for Intake System of Keppel Cogen Plant (DECP-00-YYY-RE-M103_C);
- Topographic Survey Report (DECP-00-UZV-RE-C110);

- Navigation and Hydrodynamic Feasibility Study for the Advanced Gas Turbine Cogeneration Combined Cycle Plant on Jurong Island, Singapore (412010-00158-FS-RP-0001). Access potential hydrodynamic and safety of navigation impacts; and
- Test Report (*230434-2023-01-17_Hydrobiology_Sediment)*. Seabed sediment analysis.

## 4.2 Baseline Assessment

The purpose of the baseline assessment was to determine and establish the initial characteristics or environmental conditions of an area of interest prior to any development, in which this information will be used as a basis to assess the scale of impacts, monitor, and assess the effectiveness of the monitoring program. For this study, the baseline study involves:

- Gathering and evaluating information from existing sources (secondary data); and
- Baseline survey (primary data collection).

The baseline data reviewed and utilised by Worley are indicated in Table 4-1.

*Table 4-1 Baseline parameter*

| No | Parameter | Remarks |
|---|---|---|
| 1 | Land use | Desktop review based on satellite imagery or publicly available data |
| 2 | Meteorological data | Desktop review based on publicly available data on government websites |
| 3 | Marine biodiversity | Desktop review based relevant past report government websites, and desktop review on client-supplied secondary data |
| 4 | Marine sediment quality | Desktop review based on survey data collected on 17 Jan 2023 at five (5) survey stations, and marine SI report |
| 5 | Socio-economic | Desktop review based on satellite imagery or publicly available data |
| 6 | Soil characteristics | Desktop review based on land SI report |
| 7 | Water quality | Primary data collection at five (5) stations during spring flood and ebb tide for in-situ, ex-situ, phytoplankton, and zooplanktons, and desktop review on client-supplied secondary data. |
| 8 | Bathymetric data | Desktop review based on survey data collected 20 March 2022 |
| 9 | Current data | Primary data collection at three (3) current transects and desktop review on client-supplied secondary data. |
| 10 | Topography | Desktop review on Topographic Survey Report |
| 11 | Tree inventory | Desktop review based on tree inventory provided by Keppel. |

## 4.3 Numerical Modelling

Several model simulations were carried out for the environmental impact analyses of the construction and operation phase using a range of specific models covering the study area. Modelling for the Project is comprised of coastal dynamics studies. The modelling task is conducted to quantitatively assess the anticipated environmental impacts to the receptor of concerns, whose simulation results were incorporated into this EIA report.

The underlying model for all coastal impact assessments involving dredging was a calibrated hydrodynamic model of the Singapore domain. This base model describes the effect of the works on currents and water levels and, with a mud transport template, was also applied to analyse construction stage sediment dispersion from dredging and backfilling works. On the other hand, the water quality assessment involves the operation phase for the discharge of thermal and chlorine plume from the outfall into the Banyan Basin.

Table 4-2 summarized the model simulations undertaken by this Project. All relevant information or results obtained from third parties; it will be included in this EIA report unless stated otherwise.

*Table 4-2 Overview of numerical simulations undertaken for this Project*

| Model | | Model/Software adopted |
|---|---|---|
| Coastal dynamics | Hydrodynamic | 3D MIKE3 HD-FM |
| | Wave | MIKE21 SW |
| | Sediment plume and sedimentation | 3D MIKE3 MT |
| | Thermal release | 3D MIKE3 HD-FM and Advection |
| | Chlorine release | 3D MIKE3 HD-FM and Advection |

## 4.4 Analysis and Evaluation of Impacts

The assessment is to evaluate the impacts in the form of Impact Significance based on collated information from field surveys, laboratory results of samples, modelling results, and reviews of documents.

For this EIA, Rapid Impact Assessment Matrix (RIAM) framework was adopted. The details of the RIAM method (matrix) will be discussed further below.

### 4.4.1 Rapid Impact Assessment Matrix (RIAM) Framework and Approach

For this EIA, the impacts generated from this Project were assessed via RIAM. The framework has the ability to:

- Allow for a holistic, rapid, and easily comparable presentation and summary of the overall development impacts, which ultimately aids in pinpointing the most significant impacts predicted, in accordance with the broad definitions presented in Table 4-5;
- Reduce assessment subjectivity as compared to other methodologies; and
- Account for the presence of impacts that may be cumulative in nature.

With RIAM tool, the impacts arise from the project activities are evaluated against the environmental components, and for each component a score is determined. The significance of an impact is determined by translating the Environmental Score (ES) to impact significance. The formula for determining the ES is as follow:

$$ES = I \times M \times (P + R + C)$$

The five evaluation criteria (variables) used in the formula are defined as:

- **Importance (I)** – Assigns a level of importance in terms of variables such as spatial extent and socio-political interests related to the impact;
- **Magnitude (M)** – Expresses the level of change in a physio-chemical parameter or the scale of loss/change to ecological and socio-economic receptors;
- **Permanence (P)** – Assign a score based on the duration of an impact;
- **Reversibility (R)** – The score expresses whether an impact is permanent or reversible; and
- **Cumulative Impact (C)** – A score is defined based on the cumulative potential of an impact.

The approach of RIAM is therefore to couple the potential impact **Magnitude** experienced at the sensitive receptor(s) of interest, with a concurrent assessment of receptor **Importance**, impact **Permanence**, **Reversibility**, and **Cumulative** potential.

The multiplication of **Magnitude** and **Importance** in the formula ensures that the weight of each evaluation criteria is expressed and is individually able to significantly influence the resultant environmental score. The summation of **Permanence**, **Importance**, and **Cumulative** ensures that these criteria are represented collectively, but do not have a large influence on the resultant ES individually.

The standard (generic) definitions of each evaluation criteria, and the associated ordinal scores used to calculate the environmental score, are shown in Table 4-3. The detailed evaluation framework, with justifications, is elaborated in each assessment in the following sections.

*Table 4-3 Evaluation criteria and the associated standard definitions and ordinal scores used in the calculation of Environmental Scores*

| Evaluation Criteria | Standard Definitions | Ordinal Score |
|---|---|---|
| Importance | Important to national/international interests | 5 |
| | Important to regional/national interests | 4 |
| | Important to areas immediately outside the local condition | 3 |
| | Important to the local conditions (within a large direct impact area) | 2 |
| | Important only to the local condition (within a small direct impact area) | 1 |
| | No Importance | 0 |
| Magnitude | Major positive benefit or change | +4 |
| | Moderate positive benefit or change | +3 |
| | Minor positive benefit or change | +2 |
| | Slight positive benefit or change | +1 |
| | No change/status quo | 0 |
| | Slight negative disadvantage or change | -1 |
| | Minor negative disadvantage or change | -2 |
| | Moderate negative disadvantage or change | -3 |
| | Major negative disadvantage or change | -4 |

| Evaluation Criteria | Standard Definitions | Ordinal Score |
|---|---|---|
| Permanence | No change or not applicable | 1 |
| | Temporary or short-term change | 2 |
| | Permanent change or long-term; value and/or function unlikely to return | 3 |
| Reversibility | No change or not applicable | 1 |
| | Recoverable or controllable through EMMP | 2 |
| | Irrecoverable | 3 |
| Cumulatively | No change or not applicable | 1 |
| | Impact can be defined as non-cumulative/single (not interaction with other impacts) | 2 |
| | Presence of obvious cumulative/cascading effect that will affect other Developments or activities or trigger secondary impacts | 3 |

For each identified environmental impact affecting a sensitive receptor, an ES will be calculated. The environmental scores are then banded together and ranked in range bands as presented in Table 4-4, which are then translated to Impact Significance – the reported output of the impact assessment process.

*Table 4-4: Range bands used in RIAM*

| RIAM Environmental Score (ES) | Range Value (alphabetical) | Range Value (numeric) | Description of Range Value |
|---|---|---|---|
| 116 to 180 | D | 4 | Major positive change/ major positive impact |
| 81 to 115 | C | 3 | Moderate positive change/ moderate positive impact |
| 37 to 80 | B | 2 | Positive change/ positive impact |
| 7 to 36 | A | 1 | Slight positive change/ slight positive impact |
| -6 to 6 | N | 0 | No change/ no impact |
| -7 to -36 | -A | -1 | Slight negative change/ slight negative impact |
| -37 to -80 | -B | -2 | Negative change/ negative impact |
| -81 to -115 | -C | -3 | Moderate negative change/ moderate negative impact |
| -116 to -180 | -D | -4 | Major negative change/ major negative impact |

The impact classification is further defined and assigned against the corresponding ES and range values. The impact classification proposed for this study is summarised in Table 4-5. The following impact classifications have been well documented in published paper by S. M. Doorn-Groen and T.M. Foster, 2007, and have been adopted for several projects in Singapore, along with verification from Worley's experience in dredging and reclamation impact assessment in Singapore.

*Table 4-5: Impact classification*

| Impact Significance | Broad Definition |
|---|---|
| No Impact | Changes are below the level of model reliability or are significantly below recognized tolerance levels, so that no change to the quality or functionality of a receptor will occur. |
| Slight Impact | Changes can be identified by the numerical models but are unlikely to be detectable in the field as, for example, a change in living status. Typically, slight impacts are associated with changes that cause stress, but not mortality to marine ecosystems. Slight impacts may be recoverable once the stress factor is removed. |
| Minor Impact | Changes are identified by the predictive tools at a level where change (for example, mortality) can be expected to be identifiable in the field. Changes are limited in spatial extent and are unlikely to have any secondary consequences. |
| Moderate Impact | Changes are at a level that can be classified as locally significant and may result in secondary impacts. From a physical perspective, a moderate impact would typically require a change in operating procedure for the continued safe use of an existing facility. |
| Major Impact | Changes are often related to a complete loss of local habitat with consequent secondary impacts on linked ecosystem processes. From a physical perspective, a major impact would typically be associated with an impact that prevented the use of an existing facility. |

# 5 EIA Context and Legal Framework

## 5.1 Singapore Environmental Impact Assessment (EIA) Requirement

The aim of EIA is to protect the environment by ensuring that decisions made by the local planning authority are done so in the full knowledge of the likely significant environmental effects of a project.

As a requirement by the Singapore Authorities, new development is required to undertake a scoping exercise to determine its potential risk and environmental impact before the development is allowed to proceed. Keppel and Worley have engaged the relevant Technical Agencies (TAs) for the CCGT development.

## 5.2 Applicable Legislation, Laws, and Standards

Worley conducted a review of environmental legislations, plans, standards, and criteria that are relevant to the Project. The details of the applicable Singapore and International legislations are described in the sections below. The latest Singapore legislations and relevant subsidiary regulations are available at the Singapore Statues Online website (https://sso.agc.gov.sg). It should be noted that the list mentioned in the Section below is not exhaustive. It shall be noted that specific standards and guidelines may be referenced throughout the relevant sections of the EIA Report

### 5.2.1 Relevant Singapore Legislation, Standards, Guidelines, and Code of Practice

The applicable Singapore legislation, standards, and guidelines to the EIA and EMMP for the Project are listed in Table 5-1.

*Table 5-1: List of applicable Singapore legislation, standards, and guidelines*

| Parameter | Singapore legislation, standards, and guidelines | Description |
|---|---|---|
| General | Environmental Protection and Management Act 1999, 2020 revised edition | An Act administered by NEA to consolidate the laws relating to environmental pollution control (i.e., air, water, noise pollution, and hazardous substances management), to provide for the protection and management of the environment and resource conservation, and for purposes connected therewith. |
| | Environmental Public Health Act 1987, 2020 revised edition | An Act administered by NEA to consolidate the law relating to environmental public health and to provide for matters connected therewith. |
| | SS 593:2013 Singapore Standard on Code of Practice for Pollution Control | This standard specifies the recommended pollution control requirements and good practices to safeguard clean air, clean land, clean water, and a quality living environment. |
| Ambient Air Quality | Environmental Protection and Management Act 1999, 2020 revised edition, Part IV on Air Pollution Control | An Act administered by NEA to consolidate the laws relating to environmental pollution control (i.e., air, water, noise pollution, and hazardous substances management), to provide for the protection and management of the environment and resource conservation, and for purposes connected therewith. |

| Parameter | Singapore legislation, standards, and guidelines | Description |
|---|---|---|
| | | Part IV on Air Pollution Control of this Act includes measures to limit airborne pollution. |
| | Environmental Protection and Management (Vehicular Emissions) Regulations, 2008 revised edition | A regulation administered by NEA which sets the minimum exhaust emission standards for all vehicles specified in the regulation. |
| | Environmental Protection and Management (Off-Road Diesel Engine Emissions) Regulations, 2012 | A regulation administered by NEA which specifies the standards for exhaust emission for off-road diesel engines (ORDEs), import of ORDEs, and use and examination of ORDES. Some examples of ORDEs are cranes, excavators, forklifts, power generators, etc. |
| | Environmental Protection and Management (Prohibition on Use of Open Fires) Order, 2008 revised edition | An order administered by NEA which states the prohibition of open fires in industrial or trade premises, except where such open fires are used for the purpose of firefighting practices or disposal of tail gases from industrial plants. |
| | Environmental Protection and Management (Air Impurities) Regulations, 2008 revised edition | A regulation administered by NEA which specifies method of smoke indication, standards of concentration of air impurities, testing procedures and requirements, and penalty for failure to comply with the regulation. |
| | SS 593:2013 Singapore Standard on Code of Practice for Pollution Control | This standard was prepared by the Technical Committee on Architectural Works under the purview of the Building and Construction Standards Committee. It specifies the recommended pollution control requirements and good practices to safeguard clean air, clean land, clean water, and a quality living environment. |
| Biodiversity | Wildlife Act 1965, 2020 revised edition | An Act administered by Singapore National Parks Board (NParks) for the protection, preservation, and management of wildlife for the purposes of maintaining a healthy ecosystem and safeguarding public safety and health, and for related matters. |
| | Parks & Trees Act 2005, 2020 revised edition | An Act to provide for the planting, maintenance and conservation of trees and plants within national parks, nature reserves, tree conservation areas, heritage road green buffers and other specified areas, and for matters connected therewith. |
| | Singapore Red Data Book, third edition, 2023 | The Singapore Red Data Book by NParks lists the national conservation status of the plant and animal species that has been recorded in Singapore. It includes information such as the scientific and common names, International Union for Conservation of Nature (IUCN) global status, national conservation status and description. |

| Parameter | Singapore legislation, standards, and guidelines | Description |
|---|---|---|
| | Biodiversity Impact Assessment (BIA) Guidelines, NParks, 2020 | The BIA guidelines by NParks are non-prescriptive and provides reference for developers and industry professionals to understand the common requirements for the biodiversity component of an EIA and how biodiversity related impact assessments are carried out. |
| Chemical Substances | Environmental Protection and Management (Hazardous Substances) Regulations, 2008 revised edition | A regulation administered by NEA which regulates the transport, import, storage, and supply of hazardous substances. |
| | SS 603:2014 Singapore Standard on Code of Practice for Hazardous Waste Management | This standard was prepared by the Working Group appointed by the Technical Committee for Chemistry under the direction of the Chemical Standards Committee. It specifies waste minimisation, site management and handling of hazardous wastes, and storage, treatment, transport, and disposal options for hazardous waste. |
| | Fire Safety Act 1993, 2020 revised edition | An Act administered by SCDF to make provisions for fire safety and for matters connected therewith. |
| | SS 532:2007 Singapore Standard on Code of Practice for the Storage of Flammable Liquids | This standard was prepared by the Technical Committee on Petroleum and its Products under the direction of the Chemical Standards Committee. It specifies the requirements and recommendations for the safe storage and handling of flammable liquids, as classified in the United Nations "Globally Harmonized System (GHS) of Classifications and Labelling of Chemicals", and covers liquids of flash point up to 150°C. |
| | Fire Safety (Petroleum and Flammable Materials) Regulations, 2008 revised edition | A regulation administered by SCDF which detailed the application for licences and permit, import, storage, dispensing and transport of petroleum and flammable materials. |
| Noise | Environmental Protection and Management Act 1999, 2020 revised edition, Part VIII Noise Control | An Act administered by NEA to consolidate the laws relating to environmental pollution control (i.e., air, water, noise pollution, and hazardous substances management), to provide for the protection and management of the environment and resource conservation, and for purposes connected therewith.<br><br>Part VIII Noise Control of this Act includes measures to limit noise pollution. |
| | Environmental Protection and Management (Control of Noise at Construction Sites) Regulations, 2008 revised edition | A regulation administered by NEA which states the permissible noise level, required equipment to measure and record noise level, restrictions of constructions at certain sites during certain periods, and penalty for failure to comply with the regulation. |

| Parameter | Singapore legislation, standards, and guidelines | Description |
|---|---|---|
| | Environmental Protection and Management (Boundary Noise Limits for Factory Premises) Regulations, 2008 revised edition | A regulation administered by NEA which states the boundary noise limits, measurement point and equipment, required equipment to measure and record noise level, and penalty for failure to comply with the regulation. |
| | SS 593:2013 Singapore Standard on Code of Practice for Pollution Control | This standard was prepared by the Technical Committee on Architectural Works under the purview of the Building and Construction Standards Committee. It specifies the recommended pollution control requirements and good practices to safeguard clean air, clean land, clean water, and a quality living environment. |
| | SS 602:2014 Singapore Standard on Code of Practice for Noise Control on Construction and Demolition Sites | This standard was prepared by a Working Group appointed by the Technical Committee on Construction Management which is under the purview of the Building and Construction Standards Committee. It lists the measures which can be adopted by those concerned in the development and execution of construction and demolition works to ensure that good practice in noise control is employed. |
| Surface Water Quality | Sewerage and Drainage Act 1999, 2020 revised edition | An Act administered by PUB to provide for and regulate the construction, maintenance, improvement, operation and use of sewerage and land drainage systems, to regulate the discharge of sewage and trade effluent and for matters connected therewith. |
| | Sewerage and Drainage (Surface Water Drainage) Regulations, 2007 revised edition | A regulation administered by PUB which states the requirements for plans, drawings and designs submitted under section 33 (3) of Sewerage and Drainage Act 1999, prohibition of discharge of silt, etc., into storm water drainage system, works approved under section 33 (5) of Sewerage and Drainage Act 1999, and penalty for failure to comply with the regulation. |
| | Sewerage and Drainage (Trade Effluent) Regulations, 2007 revised edition | A regulation administered by PUB which governs the requirements for discharge into public sewer, etc., permission required to discharge certain trade effluent, method of analysis and collection of samples, fees, and offences. |
| | Environmental Protection and Management Act 1999, 2020 revised edition, Part V on water pollution control | An Act administered by NEA to consolidate the laws relating to environmental pollution control (i.e., air, water, noise pollution, and hazardous substances management), to provide for the protection and management of the environment and resource conservation, and for purposes connected therewith.<br>Part V on water pollution control of this Act includes measures to protect waterbodies from pollution. |

| Parameter | Singapore legislation, standards, and guidelines | Description |
|---|---|---|
| | Environmental Protection and Management Act (Trade Effluent) Regulations, 2008 revised edition | A regulation administered by NEA which governs requirements for trade effluent to be treated, control mechanism and permission for discharge of trade effluent, and particulars, nature, and type of trade effluent to be discharged. |
| | PUB's Code of Practice on Surface Water Drainage (2018) with Amendment under Addendum No. 1 – April 2021 | This code by PUB specifies the minimum engineering requirements for surface water drainage for new developments which includes planning requirements, design requirements, and ensuring the integrity of storm water drainage systems. |
| | PUB's Handbook on Managing Urban Runoff (2013) | This handbook was jointly produced by PUB, the national water agency, and The Institution of Engineers Singapore. It includes the resources for designing stormwater drainage systems, source solutions to manage stormwater on-site, receptor solutions to protect developments from floods, and safety, operations, and maintenance considerations. |
| | SS 593:2013 Singapore Standard on Code of Practice for Pollution Control | This standard was prepared by the Technical Committee on Architectural Works under the purview of the Building and Construction Standards Committee. It specifies the recommended pollution control requirements and good practices to safeguard clean air, clean land, clean water, and a quality living environment. |
| | PUB's Guidebook on Erosion and Sediment Control at Construction Sites (2018) | This guidebook was prepared by PUB and includes the essential steps to effective earth control measures (ECM), ECM best practices, and ECM provisions at a Construction Site. |
| Sediment Quality | General guidelines on the requirements for application on dredging and dumping works | These general guidelines are applicable for dumping of dredged and land-based excavated materials at offshore dumping grounds managed by MPA, land reclamation sites and Offshore Disposal Sites (ODS). |
| Waste Management | Environmental Protection and Management Act 1999, 2020 revised edition, Part VII on Hazardous Substances | An Act administered by NEA to consolidate the laws relating to environmental pollution control (i.e., air, water, noise pollution, and hazardous substances management), to provide for the protection and management of the environment and resource conservation, and for purposes connected therewith.<br>Part VII on Hazardous Substances of this Act specifies measures to manage and handle hazardous substances. |
| | Environmental Protection and Management (Hazardous Substances) Regulations, 2008 revised edition | A regulation administered by NEA which regulates the transport, import, storage, and supply of hazardous substances. |

| Parameter | Singapore legislation, standards, and guidelines | Description |
|---|---|---|
| | Environmental Public Health (General Waste Collection) Regulations, 2000 revised edition | A regulation administered by NEA which regulates the licences, transportation, and disposal of wastes. |
| | Environmental Public Health (Toxic Industrial Waste) Regulations, 2000 revised edition | A regulation administered by NEA which regulates the collection, import, transport, storage, and disposal of the toxic industrial wastes. |
| | SS 593:2013 Singapore Standard on Code of Practice for Pollution Control | This standard was prepared by the Technical Committee on Architectural Works under the purview of the Building and Construction Standards Committee. It specifies the recommended pollution control requirements and good practices to safeguard clean air, clean land, clean water, and a quality living environment. |
| | SS 603:2014 Singapore Standard on Code of Practice for Hazardous Waste Management | This standard was prepared by the Working Group appointed by the Technical Committee for Chemistry under the direction of the Chemical Standards Committee. It specifies waste minimisation, site management and handling of hazardous wastes, and storage, treatment, transport, and disposal options for hazardous waste. |

### 5.2.2 Relevant International Guidelines, Conventions, and Protocols

The applicable international standards and guidelines to the EIA and EMMP for the Project are listed in Table 5-2.

*Table 5-2: List of applicable international standards, agreements, and guidelines*

| Parameter | International Standards, Agreements and Guidelines | Description |
|---|---|---|
| General | World Bank Group (WBC)'s Environmental, Health and Safety Guidelines | These guidelines by WBC include general and industry-specific examples of good international industry practice and are applied as required by one or more members of the World Bank Group which are involved in the project. |
| | International Financial Corporation (IFC)'s Performance Standards | The Performance Standards by IFC define IFC clients' responsibilities for managing environmental and social risks, as well as principles of sustainable project management, and ways to avoid, mitigate, and manage risks and impacts. |
| | International Financial Corporation (IFC)'s Environmental, Health, and Safety (EHS) Guidelines for Thermal Power Plants | The EHS Guidelines for Thermal Power Plants by IFC provides a summary of the most significant EHS issues associated with thermal power plants, which occur during the operational phase and provide recommendation for their management. |

| Parameter | International Standards, Agreements and Guidelines | Description |
|---|---|---|
| Ambient Air Quality | United Nations Framework Convention on Climate Change (UNFCCC) | UNFCCC an international environmental agreement ratified by 198 countries aiming to address the challenges associated with climate change. Singapore ratified the UNFCCC in 1997 and acceded to the Kyoto Protocol to the UNFCCC in 2006. Parties to the UNFCCC adopted the Paris Agreement which entered into force on 04 Nov 2016. The Paris Agreement requires all Parties to commit to reduce their emissions and work together to adapt to the impacts of climate change. Singapore signed the Paris Agreement on 22 Apr 2016 and ratified it on 21 Sep 2016. |
| Biodiversity | International Union for Conservation of Nature (IUCN) Red List of Threatened Species, version 2022-2 | IUCN Red List is an information source on the global conservation status of animal, fungi, and plant species. It provides information about range, population size, habitat, and ecology, use and/ or trade, and threats. |
| | CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora, 1983 | CITES is an international agreement between governments that aims to ensure that international trade in specimens of wild animals and plants does not threaten their survival. |
| | Convention on Biological Diversity (CBD) | CBD is an international agreement established by the United Nations and ratified by 196 nations. It aims to promote sustainable use, management, and conservation of biodiversity. Singapore signed the CBD on 12 Jun 1992 and ratified it on 21 Dec 1995. |
| | United States Environmental Protection Agency (USEPA) R.E.D. FACTS Chlorine gas | Provide level of concerns for outfall discharge of chlorine (free). |
| Soil and groundwater | Dutch National Institute for Public Health and the Environment (RIVM) guidelines, 2013 | No specific criteria exist in Singapore to address the level of soil and groundwater contamination. The JTC Corporation (JTC) has adopted the 2013 Dutch RIVM guidelines which were derived using a comprehensive risk-based toxicological model. |
| Water Quality | Association of Southeast Asian Nations Marine Water Quality Criteria (ASEAN MWQC) (ASEAN 2008) | There are no marine water quality standards in Singapore. The adoption of ASEAN MWQC provides marine water quality criteria. |
| | Australian and New Zealand guidelines for fresh and marine water quality (ANZECC, 2000) | There are no marine water quality standards in Singapore. The adoption of ANZECC provides marine water quality criteria not covered in ASEAN MWQC. |
| Sediment Quality | Dutch Target and Intervention Values (Ministry of infrastructure and the Environment, 2000) | Provide target and intervention value of sediment quality. |

### 5.3 Applicable Project Specific Compliance Criteria

To supplement the legislations mentioned above, relevant Environmental Quality Objectives (EQOs) and Environmental Tolerance Limits (ETLs) are applied for the EIA analysis, specifically for the marine environment. The tolerance limits and compliance criteria developed for this study is based on quantitative numerical modelling, relevant standards, limits, guidance, and Worley's experience in marine and coastal projects in Singapore, as well as industry best practices. Further details are provided under the evaluation framework under each impact assessment section.

- Corals;
- Currents;
- Seagrass;
- Marine infrastructure;
- Aquaculture facilities; and
- Aesthetic visual impacts/ International boundary.

# 6 Environmental Receptors

Environmental receptors are defined as areas or components of the natural environment (e.g., water, air, flora and fauna, ecology) and built environment (e.g., facilities, buildings, navigational, recreational areas, etc.), including various resource users or groups that may experience, can be exposed to, or affected by an impact from construction works and operations of a proposed development.

The development of the Advanced Gas Turbine Cogeneration Combined Cycle Plant on Jurong Island is located along Banyan Basin, the southern boundary of Jurong Island. The site is located within an area specifically zoned for industrial activity. There are no residential receptors identified in the vicinity of Jurong Island. The nearest residential area to the Project location is approximately 8.7 km northwest along West Coast Road on the Singapore mainland. The nearest water body is the Banyan Basin located approximately 25 m south of the Project area. The Project development is situated on a reclaimed and formerly brownfield area on Jurong Island. Jurong Island is an artificial island located to the southwest of the main island of Singapore. It was formed from the amalgamation of offshore islands through Singapore's land reclamation efforts. The land reclamation on Jurong Island was successfully completed in 2009, effectively transforming the region into a designated industrial zone. Access to this area is now restricted, limited to authorized personnel only. Furthermore, a portion of the Project site had been previously occupied by a chemical plant, and the land underwent a reinstatement process around the end of 2017.

The overview of receptors around the Project area is illustrated in Figure 6-1, with details of the ecological and marine socio-comic receptors presented in Figure 6-2 and Figure 6-3.


*Figure 6-1: Known receptors around the vicinity of the proposed construction site* [1]

[1] The Air Sensitive Receptors (ASRs) mentioned in this EIA report is based on the Pollution Control Study Report

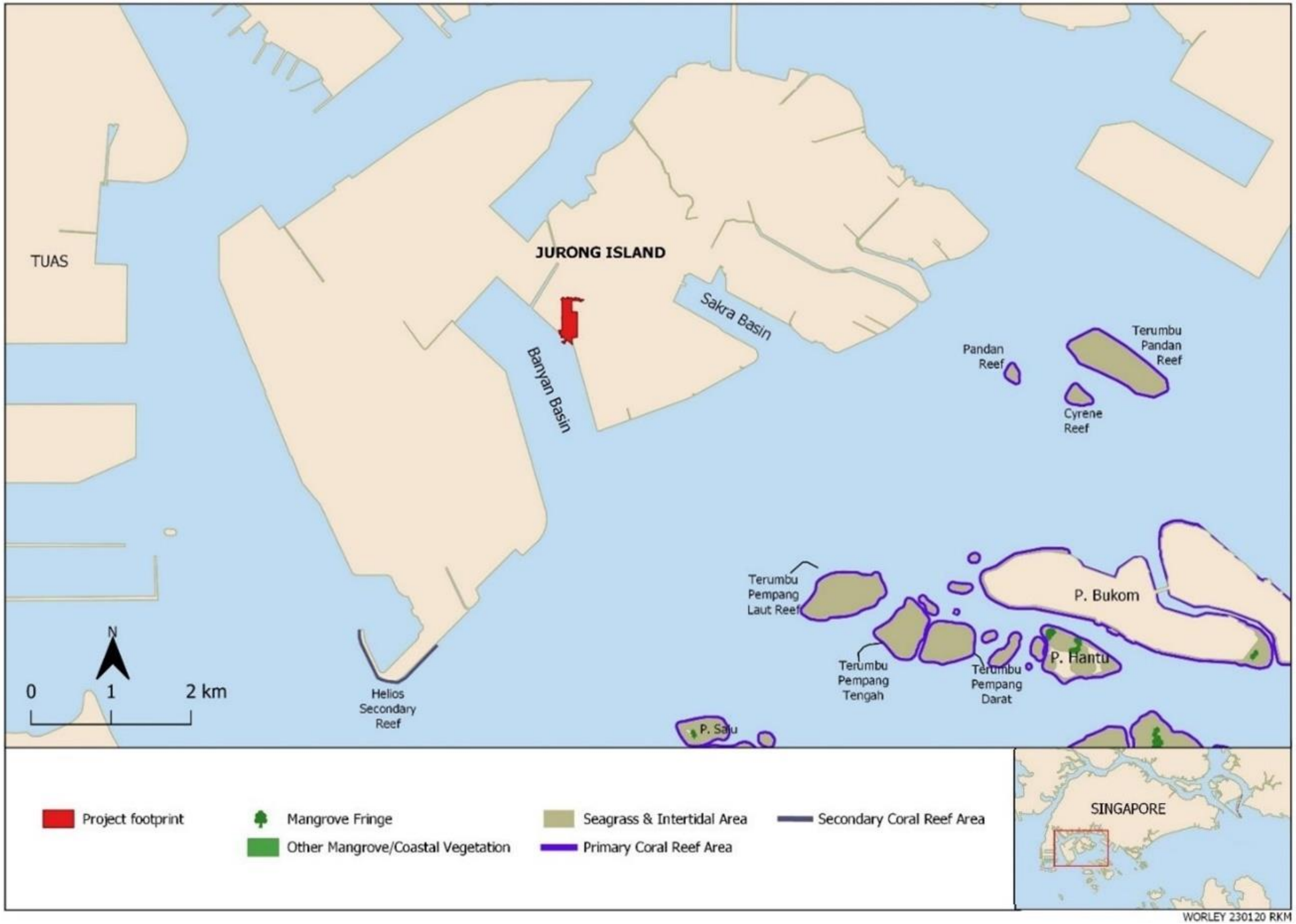



*Figure 6-2: Known ecological receptors around the vicinity of the proposed construction site*

Worley
energy | chemicals | resources

Advisian
Worley Group

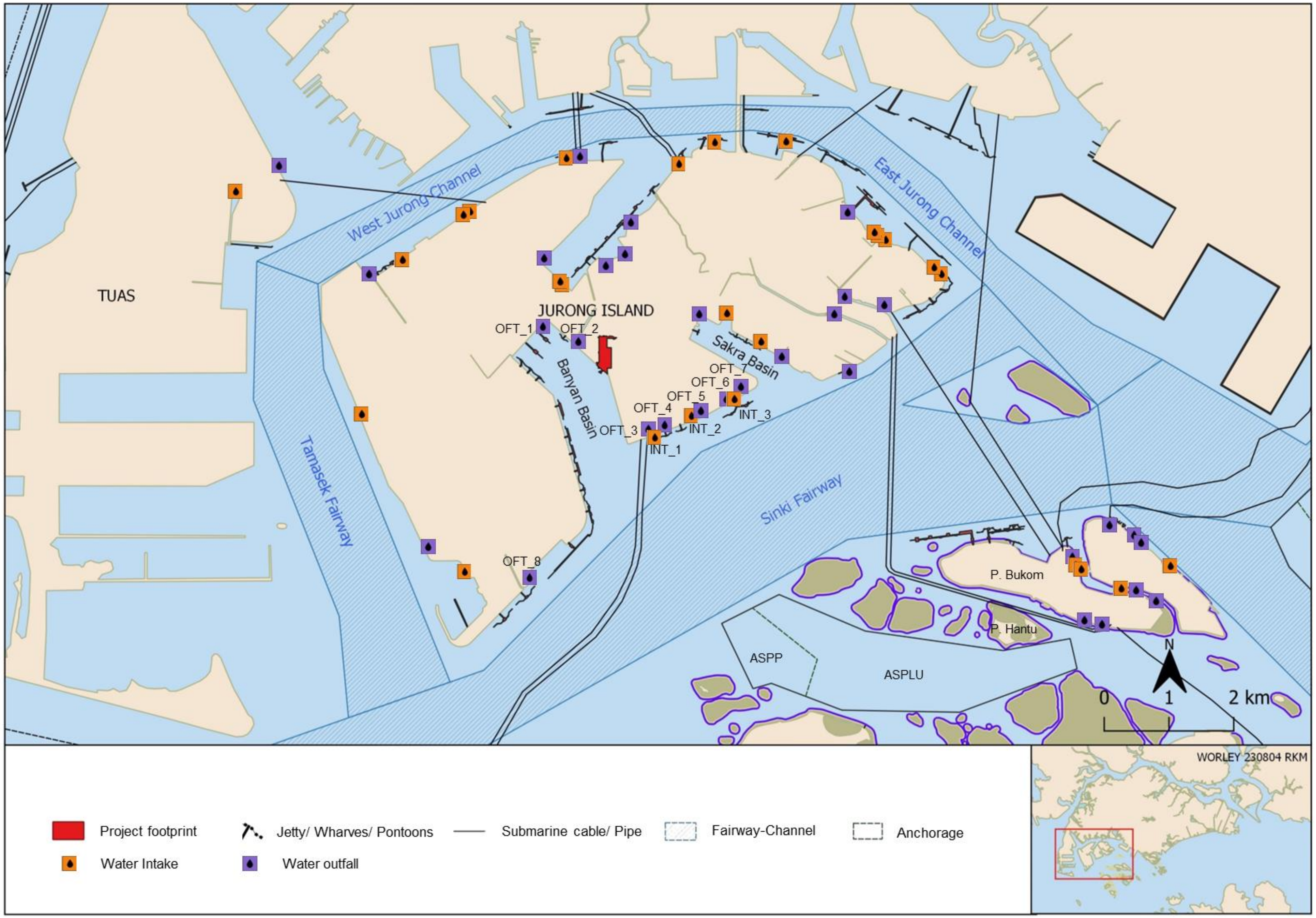



*Figure 6-3: Known marine socio-economic receptors around the vicinity of the proposed construction site*

The environmental receptors occurring in the general vicinity of the proposed works are listed below:

- Physico-chemical
  - Marine water quality; and
- Ecological
  - Corals; and
  - Seagrass.
- Socioeconomics
  - Navigational (Fairway and anchorage);
  - Marine facilities (Intakes, subsea infrastructure, and jetties);
  - Aquaculture facilities;
  - International boundaries; and
  - Human.

The coastal hydraulic, socio-economic, and human impacts have been considered in this EIA.

# 7 Environmental Baseline Settings

This section describes the main characteristics of the environment within 5 km radius zone (Figure 7-1) of study from the Project boundary with particular attention being given to areas that may be sensitive to or may be affected by the proposed Project's operations. Additionally, the EIA study area also covers the receptors identified beyond the 5 km radius, where the TAs required the developer to study and to take into account of any potential impacts that may arise resulting from the Project development. The purpose of this is to establish the baseline of the existing conditions prior to the commencement of the construction phase.

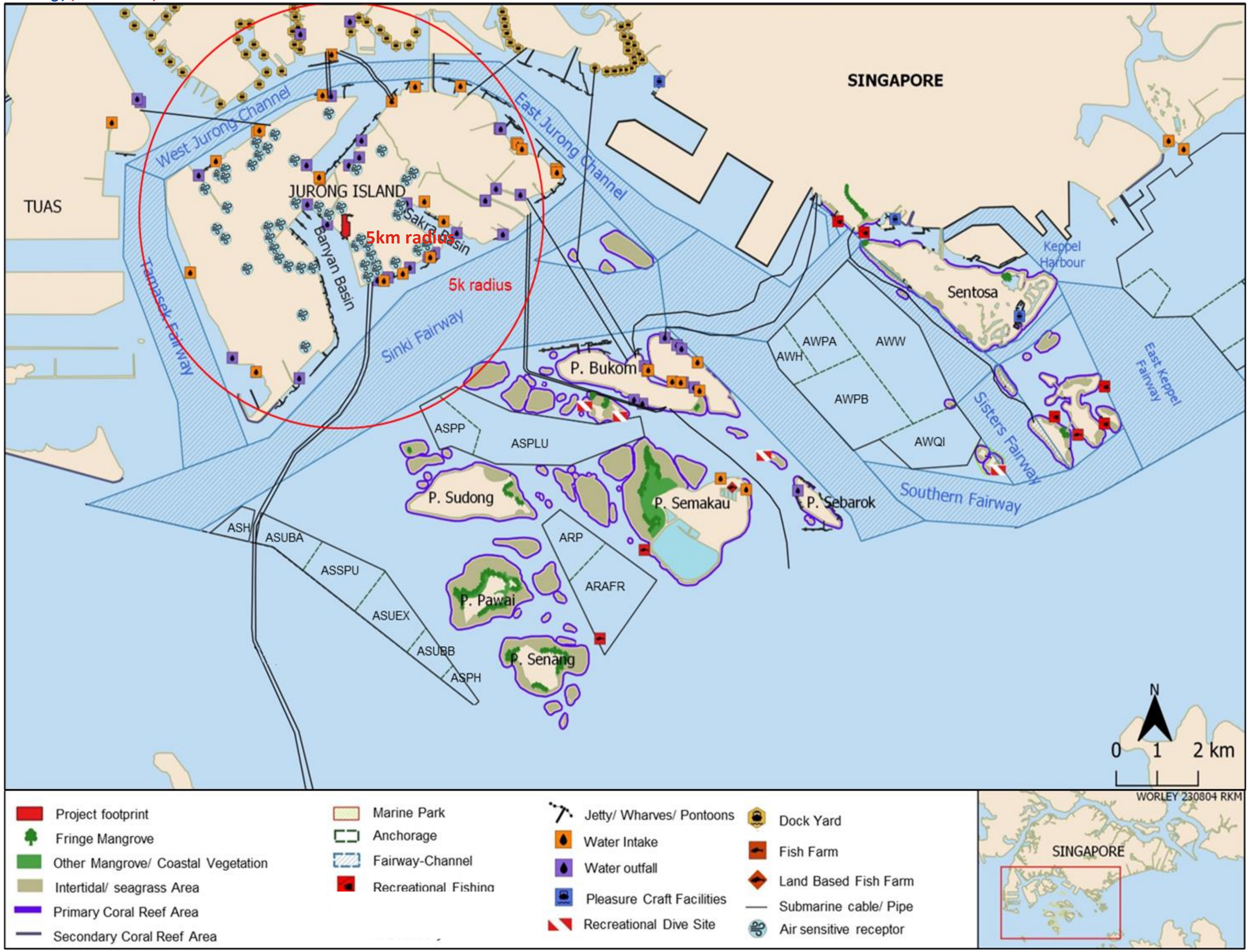



*Figure 7-1:Main environmental characteristic of 5 km radius zone of project boundary*

The following baseline environment will be discussed in detail in the following section.

- Physico-chemical environment;
- Ecological environment; and
- Socio-economic environment.

The baseline settings are based on primary data collection through a series of field campaigns and secondary sources, where available. Refer to following sections for further details.

## 7.1 Physico-chemical Environment

### 7.1.1 Site Feature

The proposed development Project is located along Sakra Avenue, Jurong Island, Singapore and it is bounded on the east by Mitsui Phenols (south of Sakra Ave) and Eastman Chemicals (north of Sakra Ave). The ExxonMobil Chemical Plant is located north of the Project site and the northern side of Jurong Island highway.

The Project development is situated on a reclaimed and formerly brownfield area on Jurong Island. Jurong Island is an artificial island located to the southwest of the main island of Singapore. It was formed from the amalgamation of offshore islands through Singapore's land reclamation efforts. The land reclamation on Jurong Island was successfully completed in 2009, effectively transforming the region into a designated industrial zone. Access to this area is now restricted, limited to authorized personnel only. Furthermore, a portion of the Project site had been previously occupied by a chemical plant, and the land underwent a reinstatement process around the end of 2017.

The southern boundary of the Project site borders the Banyan Basin which is a small basin in Jurong Island with a surface area of 2km$^2$. The Banyan Basin is a semi-enclosed bay, and it is extended to connect with the Sinki Fairway, which is approximately 1.5km from the Project footprint. The basin is sheltered, and experience limited or restricted water exchange with open coastal waters, except at the mouth of the bay.

The choice of an offshore location like Jurong Island to host special industries helped ensure adequate buffer distances between residential and industrial land use, therefore establishing a precedence of minimising nuisances.


*Figure 7-2: Site location and surrounding infrastructures*

### 7.1.2 Topography

The existing site is a sea-reclaimed land with a relatively flat surface profile. Based on the topographical survey carried out by the Contractor, it is confirmed that the existing ground level at the Site is in the range of +3.00 to +5.00m above SHD. Refer to Appendix I for details.

### 7.1.3 Bathymetry

A bathymetric survey was conducted to map the underwater features and provide more detailed topology of the bottom surface seafloor off Project site on 20 Mar 2022. The survey was carried out in accordance with MPA regulations and guidelines. Figure 7-3 represents the surveyed seabed area ranging from -0.52 mCD to -16.92 mCD.

The two (2) cross sections of the survey area show that the morphology of the seabed was similar along the coastline where a gradual slope was observed from rock bund to seawards, with the approximate distance of 35 m, followed by a flat surface of approximately 20 m. Subsequently, there was a slope that led to the deepest part of the survey area at -16.92 mCD.

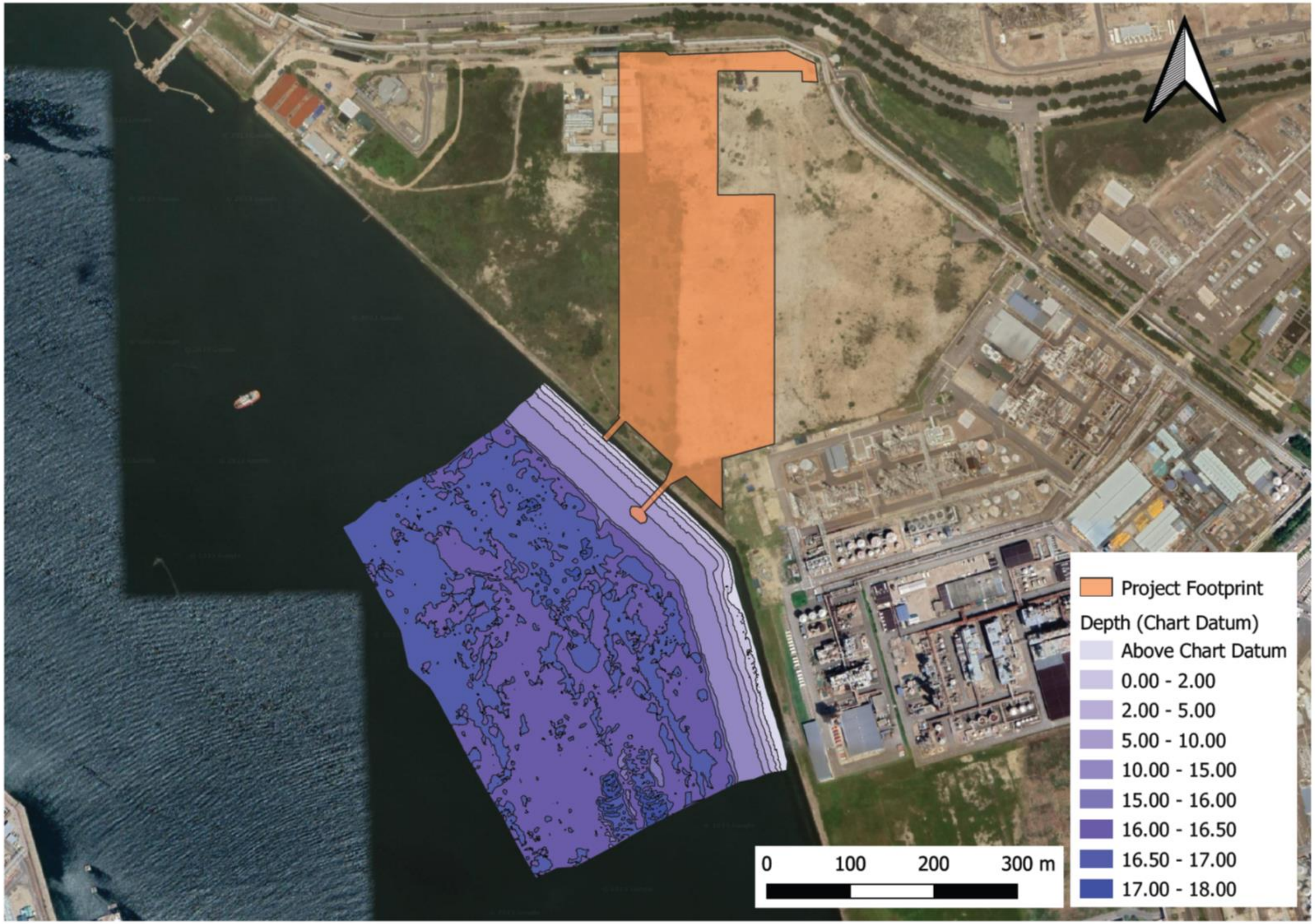



*Figure 7-3 Bathymetric survey plan*

### 7.1.4 Meteorology

#### 7.1.4.1 General Climate

Singapore is located at the confluence of two significant tidally driven water bodies, comprising the South China Sea and the Indian Ocean which converge in the Malacca and Singapore Straits.

Singapore's equatorial climate is characteristically warm and humid, and although rainfall is likely to occur throughout the year, precipitation is heavily influenced by the Asian monsoon. Two distinct monsoons occur which are punctuated by corresponding inter-monsoon seasons that typically coincide within the following temporal windows (NEA, 2016):

- March - May (inter-monsoon): Elevated ambient temperatures create hot conditions which are occasionally interspersed with severe afternoon thunderstorms.
- June-September (Southwest monsoon): A shift in wind direction from the south, southeast and occasional 'Sumatra Squalls', and associated high early morning –midday wind speeds of 40-80 km/h. Afternoon thunderstorms are common.
- October-November (inter-monsoon): Light and variable winds and afternoon thunderstorms result in typically more rainfall events during this period than the April-May inter-monsoon.
- December-April (Northeast monsoon); This period is characterised by monsoon surges resulting in moderate to heavy rainfall events and typically strong north easterly winds up to 25-35 km/h. The later end of this period is generally characterised by sustained winds with less rainfall.

Monsoonal forcing causes the Singapore Strait to receive inflows from the South China Sea during the Northeast monsoon (net westerly flow) and influx from the Java Sea and Malacca Strait during the Southwest monsoon.

#### 7.1.4.2 Current

The northeast (NE) and southwest (SW) monsoon conditions are relevant for understanding the hydraulic baseline of the Project area. The overview of current direction and average speed at peak flood and ebb tide during NE and SW monsoon are presented in Figure 7-4 and Figure 7-5 respectively.

Since the project site is located inside the Basin, a relatively weak current flow conditions are expected. The maximum average speed along the pipeline can be between 0.02 m/s and to speeds not exceeding 0.05 m/s, while the areas extending from the proposed work area to the Basin's mouth do not exceed 0.8 m/s for both monsoons. The low current speeds recorded in the Basin during NW monsoon period will not be expected to be significantly different from the SW monsoon period.

The current directions are flowing towards west during flood tide and towards east during ebb tide, for both NE and SW monsoon. The current flows in *Sinki* Fairway are generally strong during peak ebb tide conditions.

As the project side is located within Basin or semi enclosed environment, the nearshore current is influenced by local winds and regional flows. The water exchange in Banyan Basin is dependent on the tidal exchange from the Basin to the outer water bodies located at the southern boundary of the Basin. Given by the weak current, low circulation/ weak mixing between the inner Basin and the outer water bodies is expected and the outer basin will experience a better mixing/ circulation.

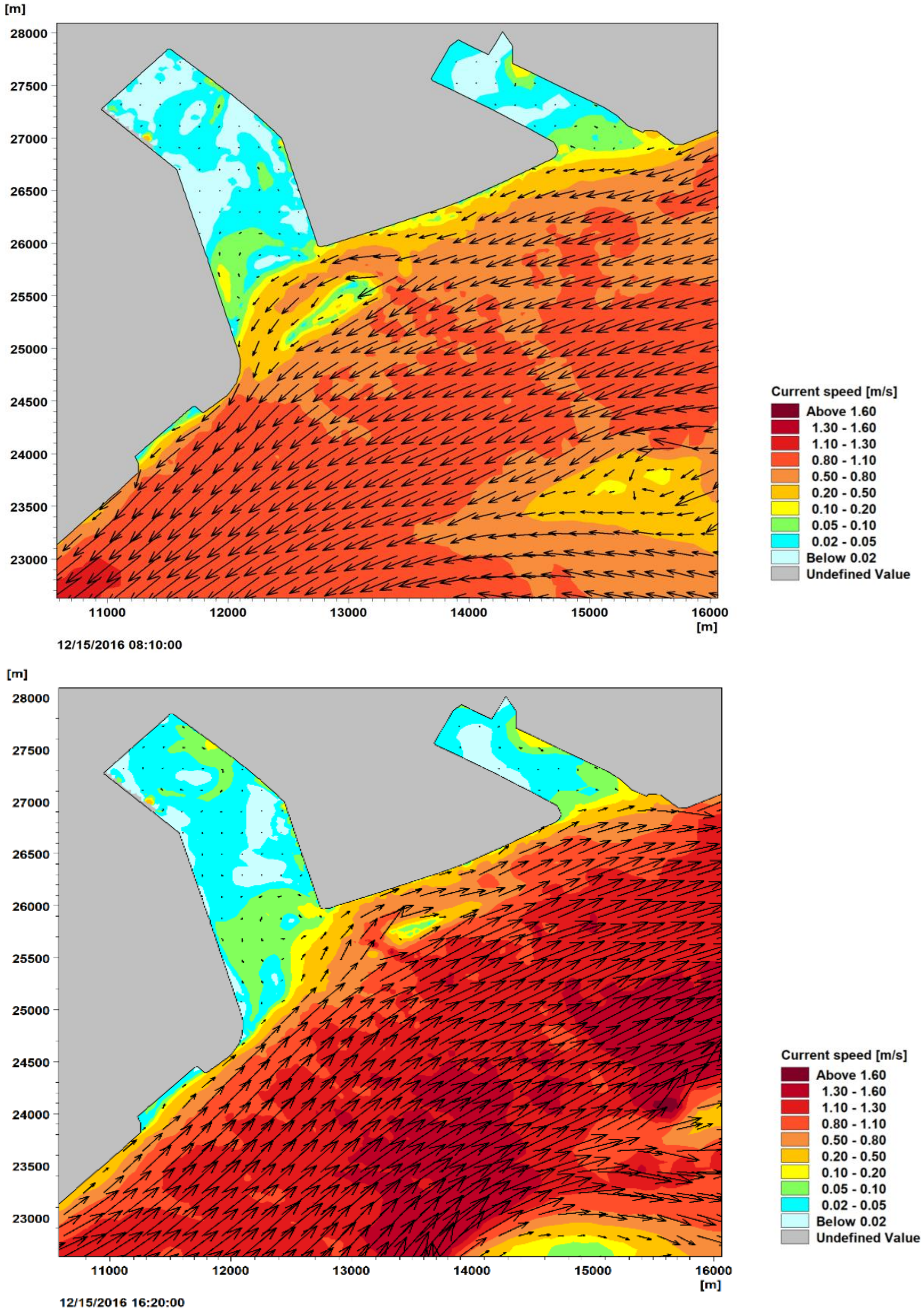



*Figure 7-4: Average current speed at peak flood (top) and peak ebb (bottom)) during NE monsoon*

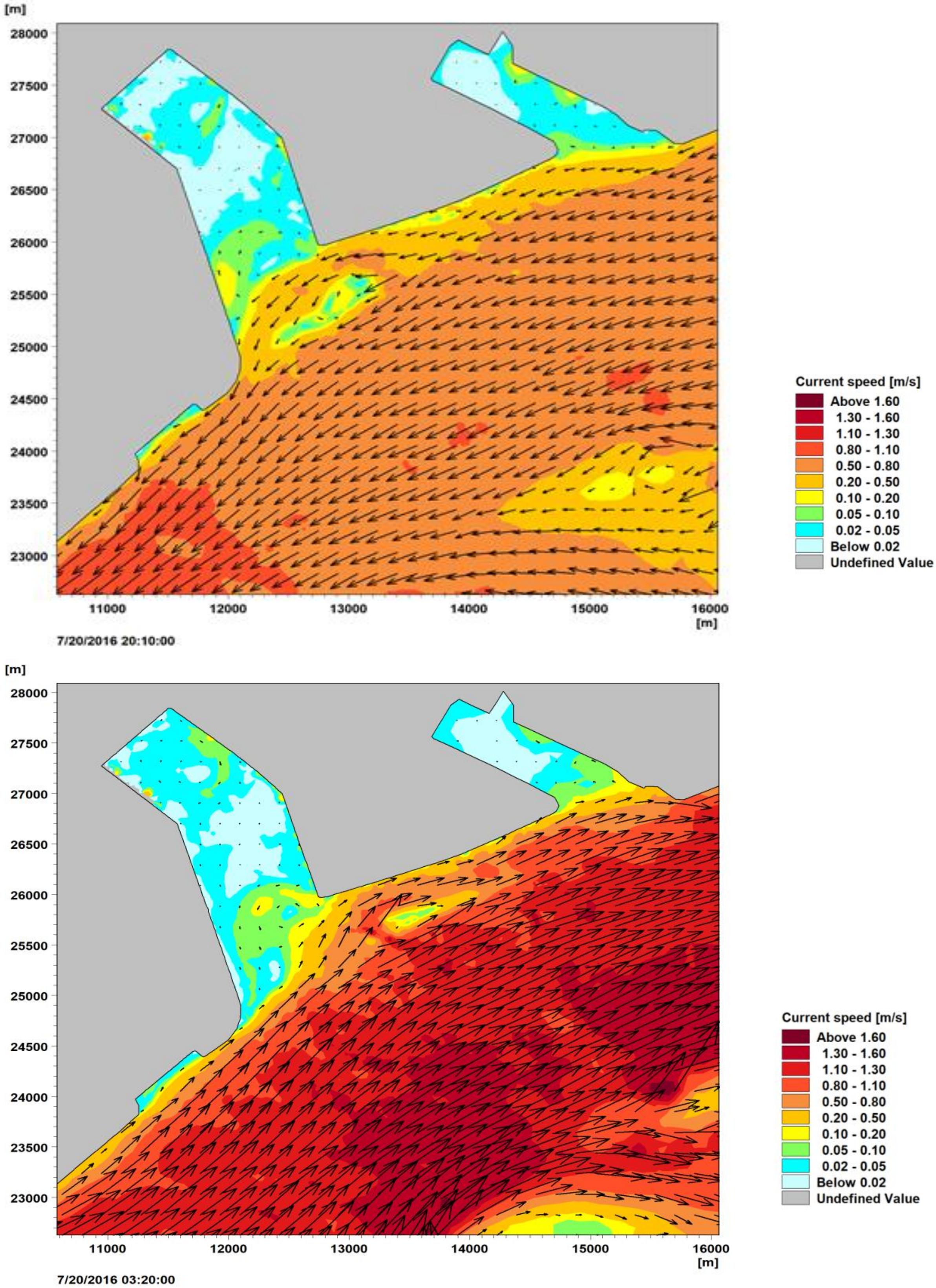



*Figure 7-5: Average current speed at peak flood (top) and peak ebb (bottom) during SW monsoon*

#### 7.1.4.3 Surface Wind

Mean wind speed data was extracted from Meteorological Service Singapore (Meteorological Service Singapore, 2023) from the period of 01 Jan 2022 to 31 Dec 2022 (Figure 7-6). The average, maximum and minimum mean wind speed observed was 8.62 km/h, 15.7 km/h, and 4.6 km/h respectively.

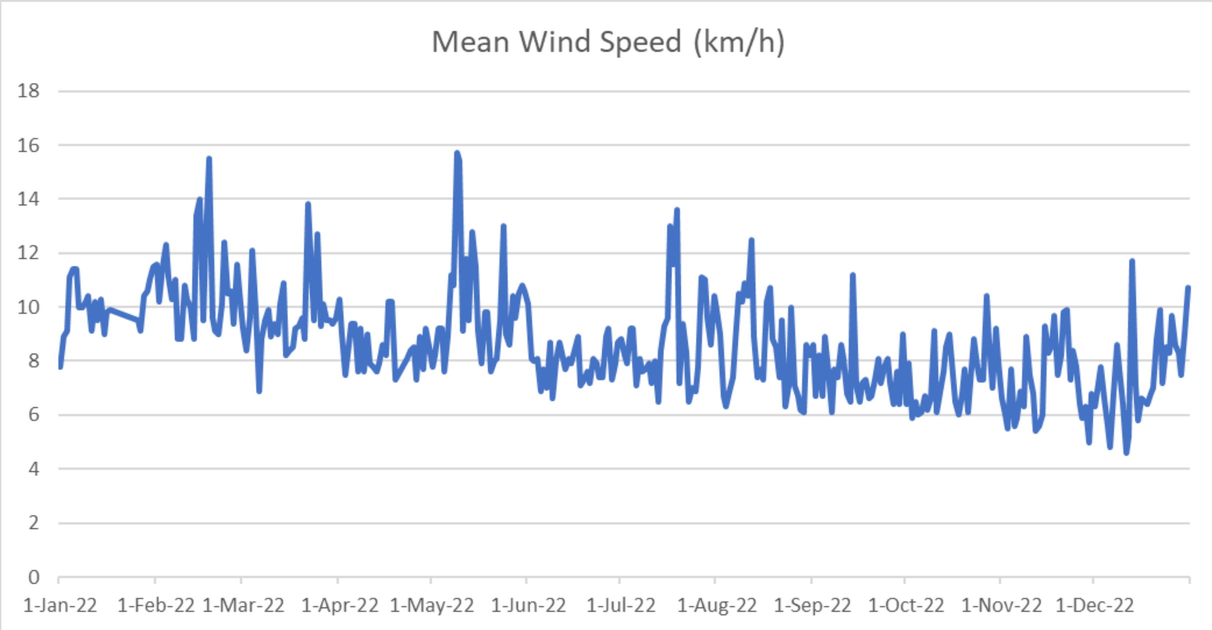



*Figure 7-6: Mean wind speed observed on Jurong Island weather station from 01 Jan 2022 to 31 Dec 2022*

Maximum wind speed data was extracted from Meteorological Service Singapore (Meteorological Service Singapore, 2023) from the period of 01 Jan 2022 to 31 Dec 2022 (Figure 7-7). The average, maximum and minimum maximum wind speed observed was 34.2 km/h, 63.3 km/h, and 17.6 km/h respectively.

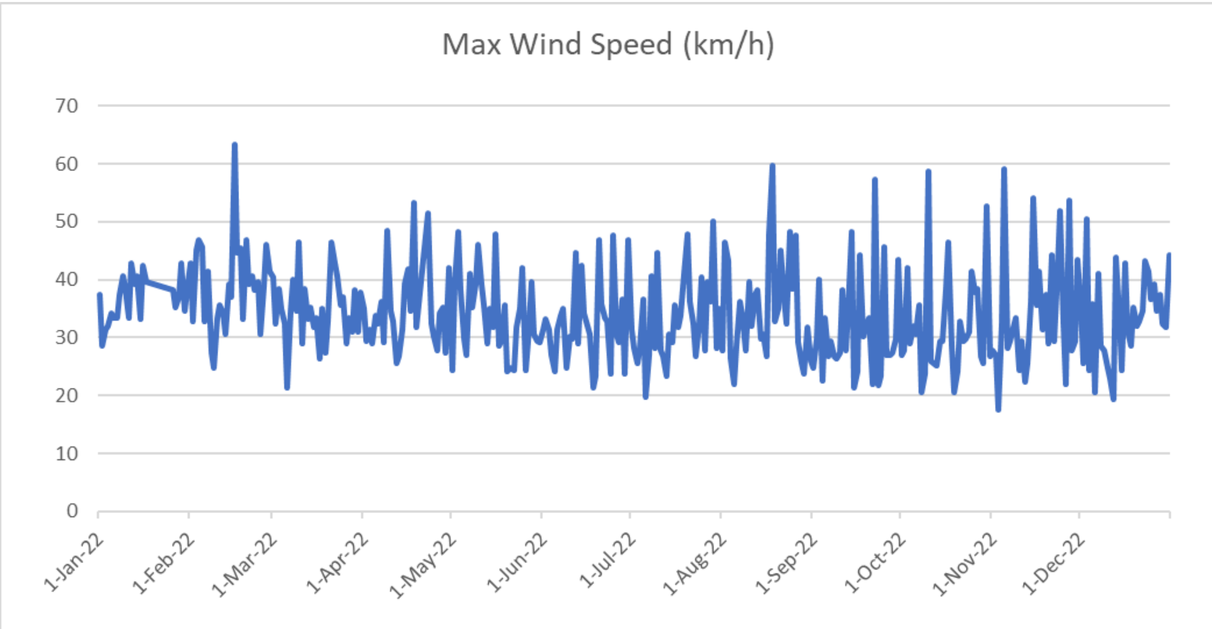



*Figure 7-7: Max wind speed observed on Jurong Island weather station from 01 Jan 2022 to 31 Dec 2022*

#### 7.1.4.4 Ambient Temperature

Mean temperature data was extracted from Meteorological Service Singapore (Meteorological Service Singapore, 2023) from the period of 01 Jan 2022 to 31 Dec 2022 (Figure 7-8). The average, maximum and minimum mean temperature observed was 28.1 °C, 30.9 °C, and 24.6 °C respectively.

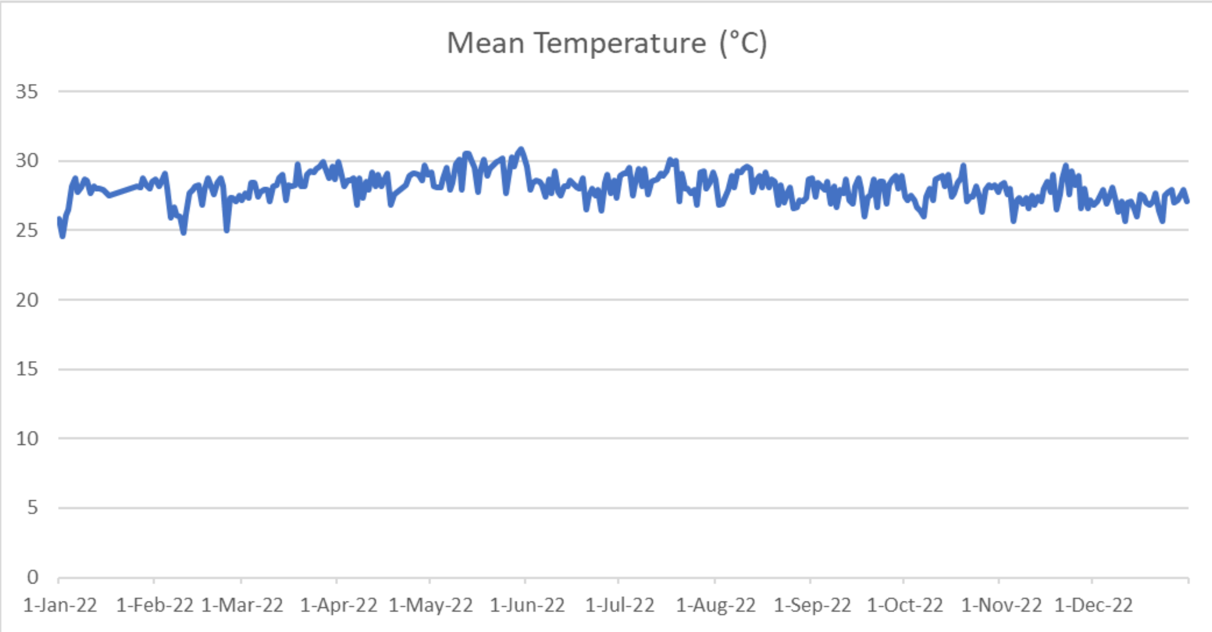



*Figure 7-8: Mean temperature observed on Jurong Island weather station from 01 Jan 2022 to 31 Dec 2022*

Maximum temperature data was extracted from Meteorological Service Singapore (Meteorological Service Singapore, 2023) from the period of 01 Jan 2022 to 31 Dec 2022 (Figure 7-9). The average, maximum and minimum maximum temperature observed was 31.3 °C, 34.9 °C, and 25.5 °C respectively.

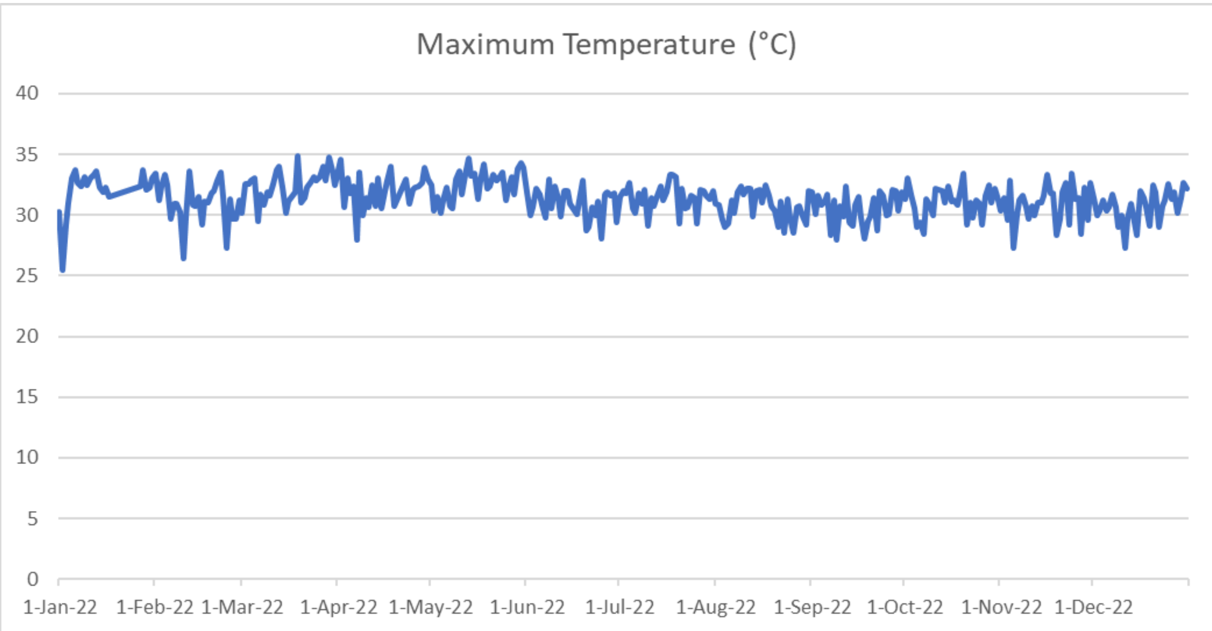



*Figure 7-9: Maximum temperature observed on Jurong Island weather station from 01 Jan 2022 to 31 Dec 2022*

Minimum temperature data was extracted from Meteorological Service Singapore (Meteorological Service Singapore, 2023) from the period of 01 Jan 2022 to 31 Dec 2022 (Figure 7-10). The average, maximum and minimum minimum temperature observed was 25.4 °C, 28.6 °C, and 22.2 °C respectively.

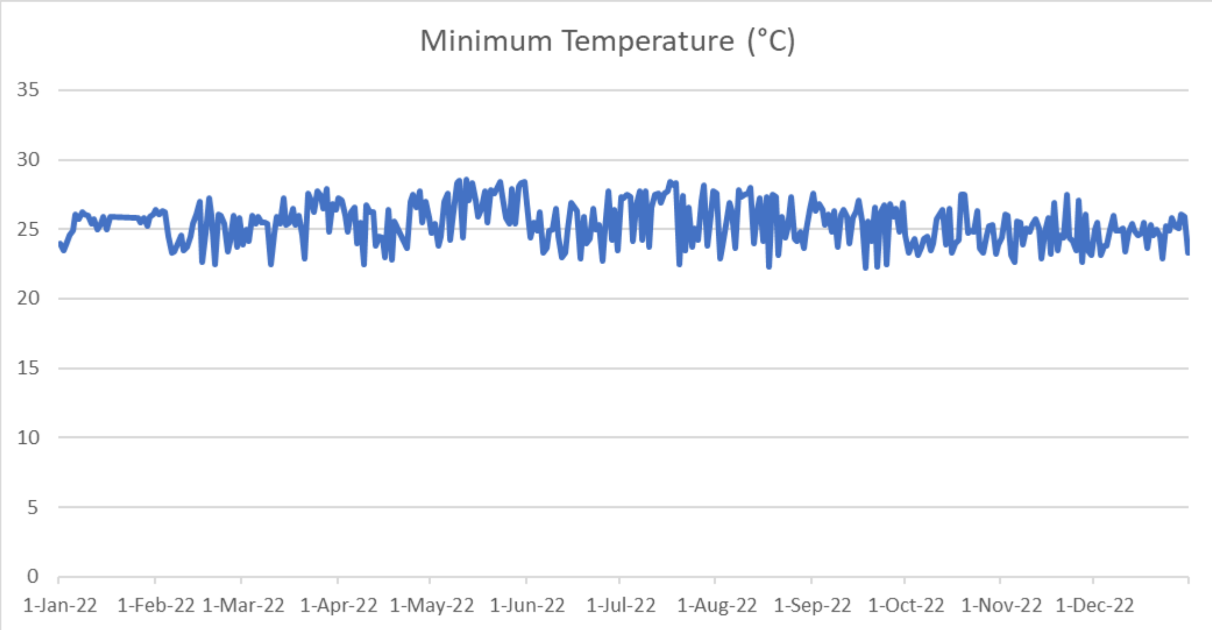



*Figure 7-10: Minimum temperature observed on Jurong Island weather station from 01 Jan 2022 to 31 Dec 2022*

#### 7.1.4.5 Rainfall

Daily rainfall total data was extracted from Meteorological Service Singapore (Meteorological Service Singapore, 2023) from the period of 01 Jan 2022 to 31 Dec 2022 (Figure 7-11). The average, maximum and minimum daily rainfall total observed was 7.18 mm, 124.6 mm, and 0 mm respectively.

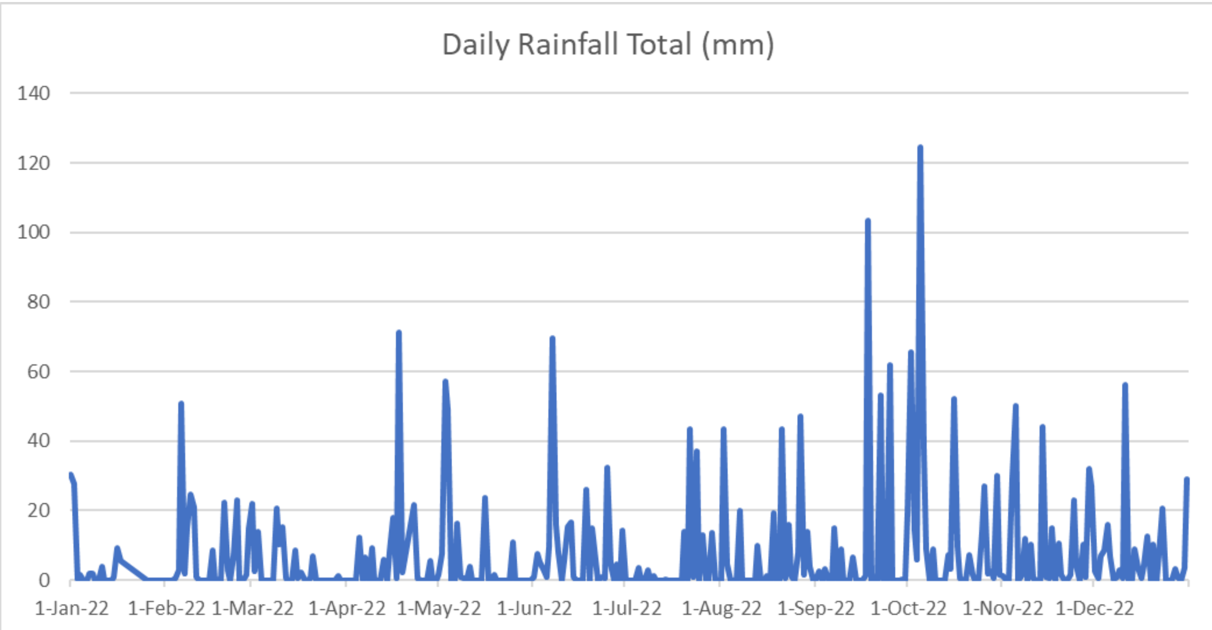



*Figure 7-11: Daily rainfall observed on Jurong Island weather station 01 Jan 2022 to 31 Dec 2022*

### 7.1.5 Soil Characteristic

The soil characteristic within the Project site was referenced to the Soil Investigation (SI) report.

- SI report
  - The onshore Soil Investigation (SI) was conducted in the Project area between 11 May 2022 and 16 Jun 2022.
  - All SI works were carried out in accordance with BS 5930:1999, BS 5930:2015 and BS EN ISO 14688-1, BS EN ISO 14688-2 & 14689-1 “Identification and Classification of Soil and Rock”, encompassing the following tasks:
    - ❖ Drilling a total of fourteen (14) boreholes at Project area, shown in Figure 7-12, to determine subsurface conditions and to obtain undisturbed samples for a laboratory testing; and
    - ❖ Field and laboratory tests to evaluate engineering characteristic of underlying subsoil layer.
  - The soil physical characteristics are elaborated in the following section. The SI focused on the geophysical characteristic of the soil and thus, no laboratory analysis for chemical parameters was carried out under SI work.

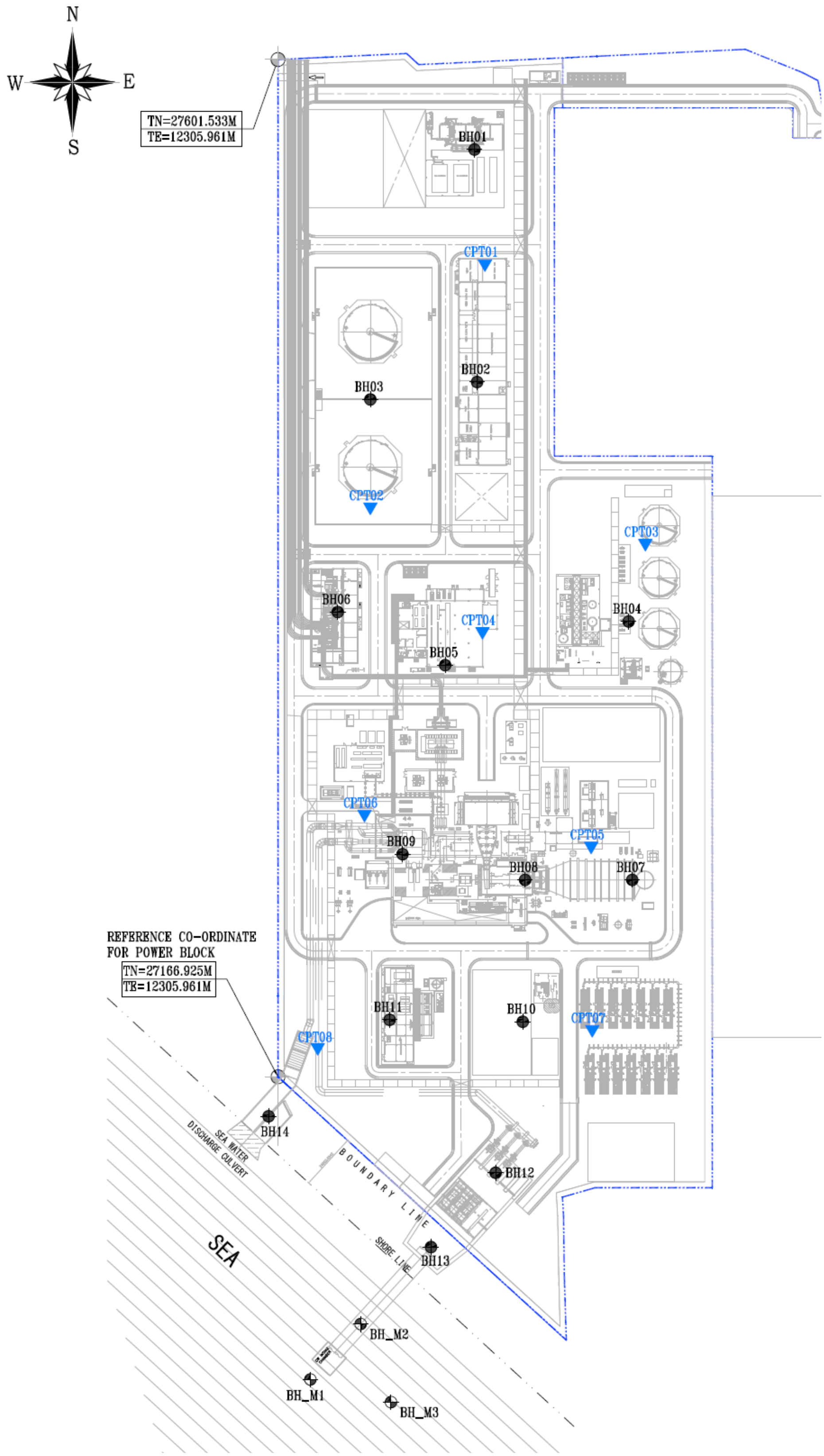



*Figure 7-12: Borehole locations of land SI*

#### 7.1.5.1 Physical Characteristic

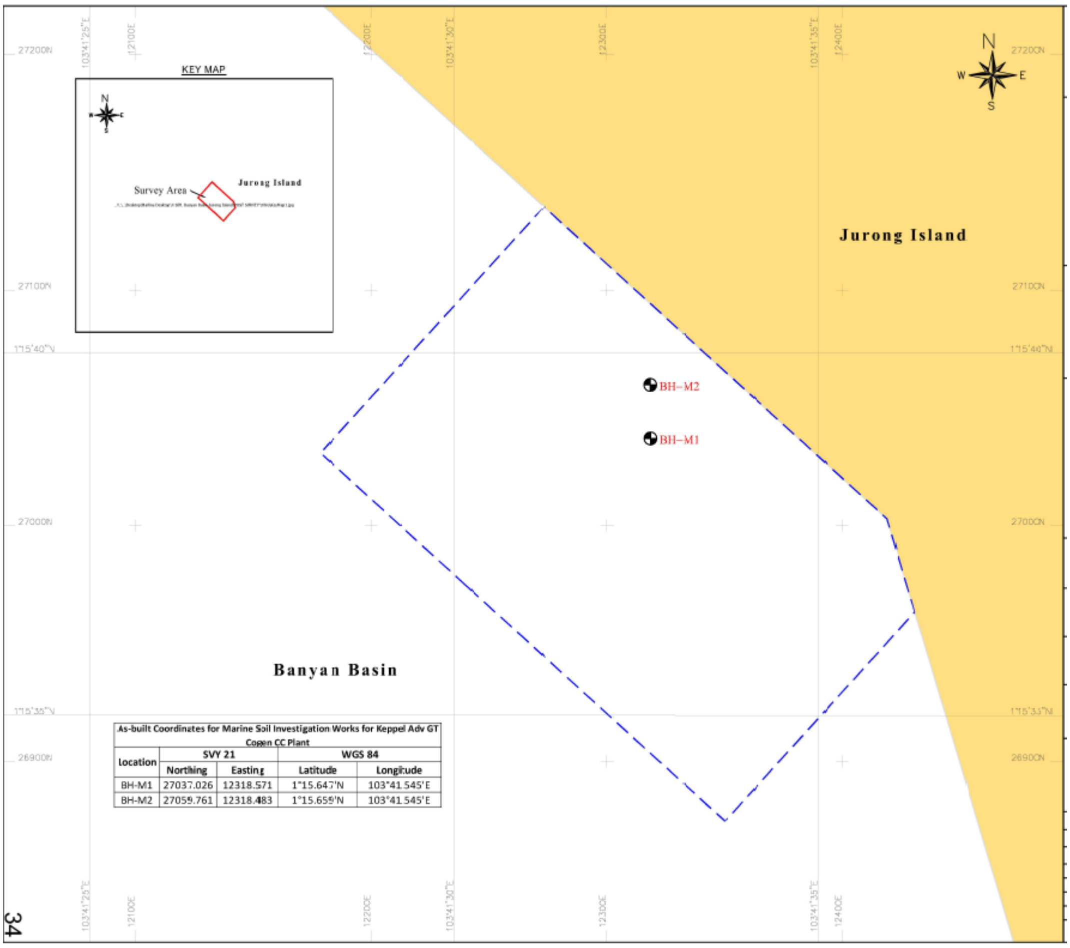
Based on the Geological Map of Singapore, Sheet 4, the Project area is located within reclaimed land of sand, which is underlain by Marine Member of Kallang Formation (Km), predominantly blue-grey clayey mud, with peat and sand horizons present. Km is usually unconsolidated with occurrences of lightly consolidated beds.

The soil at the Project area comprises fill material from ground surface up to depths around 18 to 24 m below ground surface, that covers site-wide according to the conclusions drawn. Generally, the fill material is mainly fine to coarse grained size sand with shell fragments, brown colour and loose characteristic. Underlying the fill material is a mixture of both soft grey to brown sandy clay of Km and gravelly sandy silt of Jurong Formation. SI findings reported that the bulk density, dry density and particle density of samples collected from site ranged from 1.09 Mg/m$^3$ to 2.14 Mg/m$^3$, 1.33 Mg/m$^3$ to 1.85 Mg/m$^3$ and 2.65 Mg/m$^3$ to 2.85 Mg/m$^3$, respectively.

### 7.1.6 Marine Sediment Characteristic

The characteristic of marine sediment of Banyan Basin was referenced to the marine soil investigation (SI) report and an independent sediment sampling data.

- Marine SI
  - The marine SI was conducted between 27 May 2022 and 06 Jun 2022.
  - All SI works were carried out in accordance with BS 5930:1999, BS 5930:2015 and BS EN ISO 14688-1, BS EN ISO 14688-2 & 14689-1 “Identification and Classification of Soil and Rock”, encompassing the following tasks:
    - ❖ Drilling a total of two (2) boreholes (BH-M1 and BH-M2) located south of Project area, shown in Figure 7-13, to determine subsurface conditions and to obtain undisturbed samples for a laboratory testing; and
    - ❖ Field and laboratory tests to evaluate engineering characteristic of underlying subsoil layer.
  - The physical characteristics of sediment are elaborated in the following section.
- Independent sediment sampling
  - The sampling was conducted at Sakra Avenue on 17 Jan 2023.
  - Collection of five (5) surface sediment samples via grab sampling from five (5) locations, shown in Figure 7-14 with coordinates tabled in Table 7-1.
  - Laboratory tests of the samples for heavy metals, Total Organic Carbon (TOC), Total Hydrocarbon, Total Petroleum Hydrocarbon (TPH), Polycyclic Aromatic Hydrocarbons (PAHs) and Particle Size Distribution.




| Location | SVY 21 | | WGS 84 | |
|---|---|---|---|---|
| | Northing | Easting | Latitude | Longitude |
| BH-M1 | 27037.026 | 12318.571 | 1°15.647'N | 103°41.545'E |
| BH-M2 | 27059.761 | 12318.483 | 1°15.659'N | 103°41.545'E |

*Figure 7-13 Location and Coordinate of Marine Boreholes (Soil Investigation PTE LTD., 2022)*

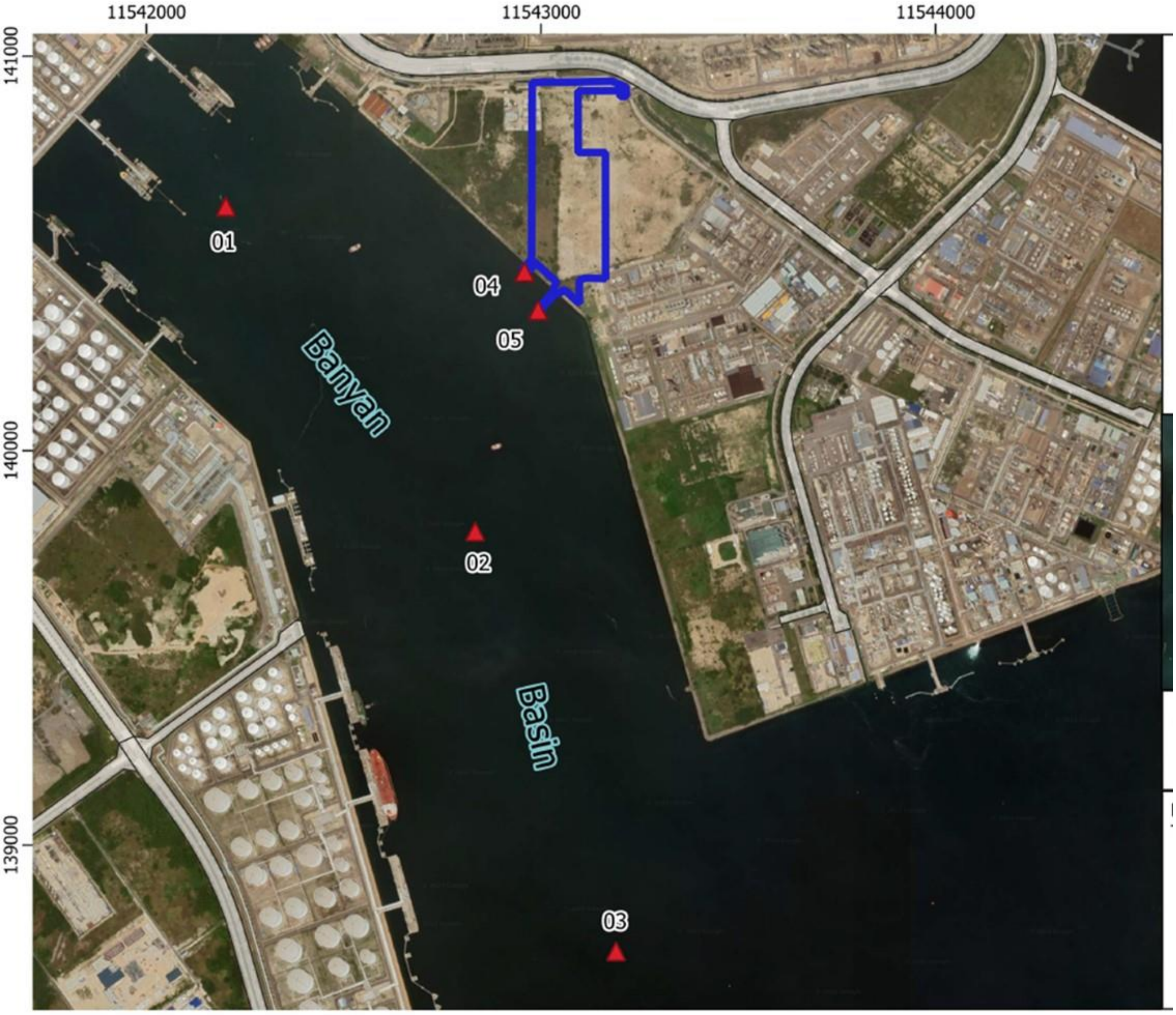



*Figure 7-14: Surface sediment sampling stations map (red triangle represents sampling stations, blue solid line represents project site)*

*Table 7-1 Coordinates of Sediment Sampling Stations*

| Sediment Sampling Station | Coordinates (SVY21) | |
|---|---|---|
| | Easting | Northing |
| 01 | 11533 | 27293 |
| 02 | 12165 | 26475 |
| 03 | 12521 | 25419 |
| 04 | 12289 | 27128 |
| 05 | 12324 | 27032 |

#### 7.1.6.1 Physical Characteristic

According to the report prepared by Soil Investigation Pte Ltd (2022), both BH-M1 and BH-M2 are overlain with Jurong Formation, comprising sedimentary rocks of late Triassic to early Jurassic age such as sandstones, siltstones, mudstones, conglomerate and limestone. Generally, sandy silt was observed at upper layers of seabed, followed by sandstone at both BH-M1 and BH-M2. The only difference between the two was that fill material, sand, was recorded from 1.00 m to 2.00 m below the seabed surface at BH-M2. The details of the on-site findings from SI are as below, with the detailed survey methods and laboratory results further described in Appendix A.

*Table 7-2 Summary of subsurface layers with geological units*

| Borehole (BH) | Depth of layer | | SPT Results | | Soil/Rock Description | Geological Units | |
|---|---|---|---|---|---|---|---|
| | Top (m) | Btm (m) | Min | Max | | Type Name | Description |
| BH-M1 | 0.00 | 1.60 | - | - | Slightly gravelly slightly sandy silt | | Seabed |
| | 1.60 | 3.00 | 15 | 15 | Slightly gravelly slightly sandy silt | S(VI) | Jurong Formation |
| | 3.00 | 3.90 | - | - | Slightly sandy silt | S(V) | |
| | 3.90 | 4.50 | 51 | 51 | Slightly fine to coarse sandy silt | | |
| | 4.50 | 6.00 | 30 | 30 | Slightly fine to coarse sandy silt | | |
| | 6.00 | 7.00 | - | - | Slightly sandy silt | | |
| | 7.00 | 10.00 | 39 | 39 | Slightly sandy silt | | |
| | 10.00 | 13.00 | 35 | 35 | Fine to coarse sandy silt | | |
| | 13.00 | 19.00 | 23 | 28 | Slightly fine to coarse sandy silt | | |
| | 19.00 | 19.30 | 100 | 100 | Slightly gravelly silty fine to coarse sand | | |
| | 19.30 | 20.60 | - | - | Fine to coarse grained sandstone | S(IV)/S(III) | |
| | 20.60 | 21.95 | - | - | Fine to coarse grained sandstone | S(III) | |
| | 21.95 | 24.30 | - | - | Sandstone with thinly bedded siltstone | | |
| BH-M2 | 0.00 | 1.00 | - | - | Wash boring | | Seabed |
| | 1.00 | 2.00 | 32 | 32 | Slightly gravelly silty fine to coarse sand | FILL | Made Ground |
| | 2.00 | 3.00 | 33 | 33 | Slightly gravelly fine to coarse sandy silt | S(V) | Jurong Formation |
| | 3.00 | 4.00 | - | - | Slightly sandy silt | | |
| | 4.00 | 4.50 | 21 | 21 | Slightly fine to medium sandy silt | | |
| | 4.50 | 5.00 | 24 | 24 | Slightly gravelly fine to coarse sandy silt | | |
| | 5.00 | 6.00 | - | - | Slightly gravelly slightly sandy silt | | |

| Borehole (BH) | Depth of layer | | SPT Results | | Soil/Rock Description | Geological Units | |
|---|---|---|---|---|---|---|---|
| | Top (m) | Btm (m) | Min | Max | | Type Name | Description |
| | 6.00 | 9.00 | 15 | 15 | Slightly gravelly sandy silt | | |
| | 9.00 | 12.00 | 88 | 88 | Slightly gravelly fine to coarse sandy silt | | |
| | 12.00 | 13.60 | 64 | 100 | Silty fine to medium sand | | |
| | 13.60 | 14.60 | - | - | Sandstone | S(III) | |
| | 14.60 | 18.60 | - | - | Sandstone | S(IV)/ S(III) | |

Source: Soil Investigation Pte Ltd (2022)

**Notes:**

(1) S(III) – Sedimentaries that are considerably weakened and discoloured, but larger pieces cannot be broken by hand.
(2) S(IV) – Sedimentaries whose core can be broken by hand or consist of gravel size pieces. Generally, highly to very fractured, but majority of sample consists of lithorelics. Material does not slake in water.
(3) S(V) – Sedimentaries that are weathered down to soil-like material but bedding intact. Material slakes in water.
(4) S(VI) – Sedimentaries (rocks and associated soils) that are degraded to a soil in which none to the original bedding remains.
(5) – SPT not carried out due to success of extraction of undisturbed soil samples.

The results of Particle Size Distribution from the separated sediment sampling campaign also aligned with the findings from marine SI where the surface of all sampling locations was predominantly covered with silt/clay material as shown below:

*Table 7-3 Particle Size Distribution Results*

| Samples | Soil Type (%) | | | |
|---|---|---|---|---|
| | Clay | Silt | Sand | Gravel |
| **Marine SI** | | | | |
| BH-M1<br>TW1T (1.00-1.60m) | 0 | 73 | 26 | 1 |
| BH-M1<br>TW1B (1.60-1.90m) | 0 | 68 | 29 | 3 |
| BH-M1<br>TW2 (3.00-3.90m) | 17 | 81 | 0 | 2 |
| BH-M1<br>MZ1 (6.00-7.00m) | 11 | 84 | 0 | 5 |
| BH-M2<br>MZ1 (3.00-4.00m) | 0 | 77 | 23 | 0 |
| BH-M2<br>MZ2 (5.00-6.00m) | 12 | 54 | 32 | 2 |
| BH-M2<br>MZ3 (8.00-9.00m) | 10 | 48 | 42 | |
| **Independent Sediment Sampling** | | | | |
| 01 | 32 | 54 | 14 | 0 |
| 02 | 45 | 38 | 17 | 0 |
| 03 | 40 | 41 | 19 | 0 |
| 04 | 42 | 37 | 21 | 0 |
| 05 | 43 | 36 | 21 | 0 |

Source: Soil Investigation Pte Ltd (2022) and MLS (2023)

#### 7.1.6.2 Chemical Characteristic

The sediment results were referenced with borehole geophysical data provided by Keppel, from the site investigation conducted on 21 Oct 2022. Sediment samples were taken from two (2) locations within the proposed development site as shown (Figure 7-13), with three (3) samples from each borehole were collected at various depth for chemical analysis for heavy metal content. The parameters tested are listed in Table 7-4 and are compared with the MPA's General Guidelines on the Requirement for Application on Dredging and Dumping Works and Dutch Target and Intervention Values.

The marine sediment samples collected were below the MPA Guideline Limits, except for two (2) samples from BH-M2 of marine SI exercise. Exceedances of lead were noted in both SPT3 (collected from 4.00 m to 4.45 m) and SPT5 (collected from 6.00 m to 6.45 m).

*Table 7-4 Laboratory analysis result for marine soil samples*

| Parameter | Dutch Ministry of Infrastructure and the Environment, 2000 | | MPA Guidelines Limit (MPA, 2014) | Marine SI (2022) | | | | | | Independent Sediment Sampling (2023) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | BH-M1 | | | BH-M2 | | | | | | | |
| | Target value | Intervention value | | SPT1 (1.90 – 2.35m) | TW2 (3.00 – 3.90m) | MZ1 (6.00 – 7.00m) | SPT1 (1.00 – 1.45m) | SPT3 (4.00 – 4.45m) | SPT5 (6.00 – 6.45 m) | 01 | 02 | 03 | 04 | 05 |
| | mg/kg (unless specified) | | | | | | | | | | | | | |
| Arsenic | 29.0 | 55.0 | 30 | 5 | 1.30 | 16.20 | 7.40 | 12.70 | 10.50 | 8.89 | 7.60 | 7.52 | 8.43 | 6.11 |
| Cadmium | 0.8 | 12.0 | 1 | ND | ND | ND | ND | ND | ND | 0.78 | 0.36 | 0.28 | 0.44 | 0.28 |
| Chromium | 100.0 | 380.0 | 50 | 13.6 | 1.40 | 5.80 | 2.30 | 1.60 | 2 | 1.42 | 19.30 | 11.30 | 20.60 | 14.10 |
| Copper | 36.0 | 190.0 | 55 | 7.20 | 10.80 | 16.30 | 5.60 | 6.30 | 8.30 | 46.80 | 24.80 | 12.40 | 30.20 | 20 |
| Lead | 85.0 | 530.0 | 65 | 9.60 | 5.70 | 16.40 | 25 | 223 | 74.70 | 18 | 23.50 | 13.60 | 26.90 | 18.80 |
| Mercury | 0.30 | 10.0 | 0.8 | ND | ND | ND | ND | ND | ND | ND | 0.064 | 0.034 | 0.061 | 0.041 |
| Nickel | 35.0 | 210.0 | 35 | 3 | ND | 4.80 | ND | 3.20 | 5.60 | 23.20 | 11.60 | 6.60 | 12.40 | 8.73 |
| Zinc | 140.0 | 720.0 | 150 | 35.90 | 9.60 | 127 | 25.60 | 14.80 | 119 | 75.30 | 91.10 | 56.30 | 136 | 84.80 |
| Aluminium | - | - | - | NA | NA | NA | NA | NA | NA | 2768 | 15599 | 10886 | 17278 | 11666 |
| Barium | 160 | 625 | - | NA | NA | NA | NA | NA | NA | 4.37 | 19.10 | 16.60 | 21.30 | 16.20 |
| Iron | - | - | - | NA | NA | NA | NA | NA | NA | 19044 | 24462 | 16540 | 24522 | 18514 |
| Vanadium | - | - | - | NA | NA | NA | NA | NA | NA | 3.85 | 19.90 | 13.60 | 20.10 | 14.70 |
| TOC (%) | - | - | - | NA | NA | NA | NA | NA | NA | ND | 0.96 | 0.60 | 1.12 | 0.69 |

Worley energy | chemicals | resources

Advisian Worley Group

| Parameter | Dutch Ministry of Infrastructure and the Environment, 2000 | | MPA Guidelines Limit (MPA, 2014) | Marine SI (2022) | | | | | | Independent Sediment Sampling (2023) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | BH-M1 | | | BH-M2 | | | | | | | |
| | Target value | Intervention value | | SPT1 (1.90 – 2.35m) | TW2 (3.00 – 3.90m) | MZ1 (6.00 – 7.00m) | SPT1 (1.00 – 1.45m) | SPT3 (4.00 – 4.45m) | SPT5 (6.00 – 6.45 m) | 01 | 02 | 03 | 04 | 05 |
| | mg/kg (unless specified) | | | | | | | | | | | | | |
| Total Hydrocarbons | - | - | - | NA | NA | NA | NA | NA | NA | ND | ND | ND | ND | ND |
| Total Petroleum Hydrocarbons | - | - | - | NA | NA | NA | NA | NA | NA | ND | 120 | 41.70 | 183 | 114 |
| 16 PAHs | 1* | 40* | - | NA | NA | NA | NA | NA | NA | ND | ND | ND | ND | ND |

**Note:**

(1) [pink box] – Exceedance of MPA Guidelines Limit
(2) NA – Not Applicable
(3) ND – Not Detected
(4) - – No standard presented
(5) * – Standard presented as a sum

## 7.1.7 Current Transect

Current transect (CT) surveys was conducted in and near vicinity of Banyan basin for the Keppel's Advanced Gas Turbine Cogeneration Combined Cycle Plant. Current transect are measured using an Acoustic Doppler Current Profiler (ADCP) mounted on a survey boat. This purpose of the current transect is to enable a spatial comparison of the model performance against the transect measurements. Specifically, the model and measured current transects vectors are compared at the same location in space and time, so the time taken to sail the transect is not an issue in the comparison. This section discussed the current transect methodology and the detailed result of the model performance is described in Appendix B.

A current transect survey campaign has been carried out on 24 Nov 2022 and 30 Nov 2022 during spring and neap tide respectively. Three (3) current transects measurement, namely T1, T2, and T3 have undertaken as shown in Figure 7-15. The transect length is approximately 1.1 km for T1 and 0.5 km for T2 and T3 for both spring flood and spring ebb tide and neap flood and neap ebb tide event. The start and end coordinates of each transect is illustrated in Table 7-5.


*Figure 7-15: Current transect (red lines) in and near vicinity of Banyan basin*

*Table 7-5: Transect coordinates*

| Parameters | Station Name | Coordinates (SVY21) | |
|---|---|---|---|
| | | Latitude | Latitude |
| Current Transect | T1-Start | 12244 | 12244 |
| | T1-End | 12738 | 12738 |
| | T2-Start | 12065 | 12065 |
| | T2-End | 12369 | 12369 |
| | T3-Start | 13832 | 13832 |
| | T3-End | 14084 | 14084 |

#### 7.1.7.1.1 Methodology

*7.1.7.1.1.1 Survey Timing*

The survey was conducted on 24 Nov 2022 and 30 Nov 2022 for spring and neap tide respectively. The daily tidal variation, as predicted at the West Coast tidal station (20026 Easting, 30452 Northing was 3.0 m for 24 Nov 2022 and 2.2m for 30 Nov 2022. Timing of individual transects for spring flood and ebb tide and neap flood and ebb tide are provided in Figure 7-16 and Figure 7-17 respectively. Tides conditions captured are presented in Table 7-6. West Coast has been chosen due to proximity to the project site and availability of tidal forecast and was considered as appropriate to illustrate tidal stage. The survey was conducted during the fully developed flood and ebb tides.

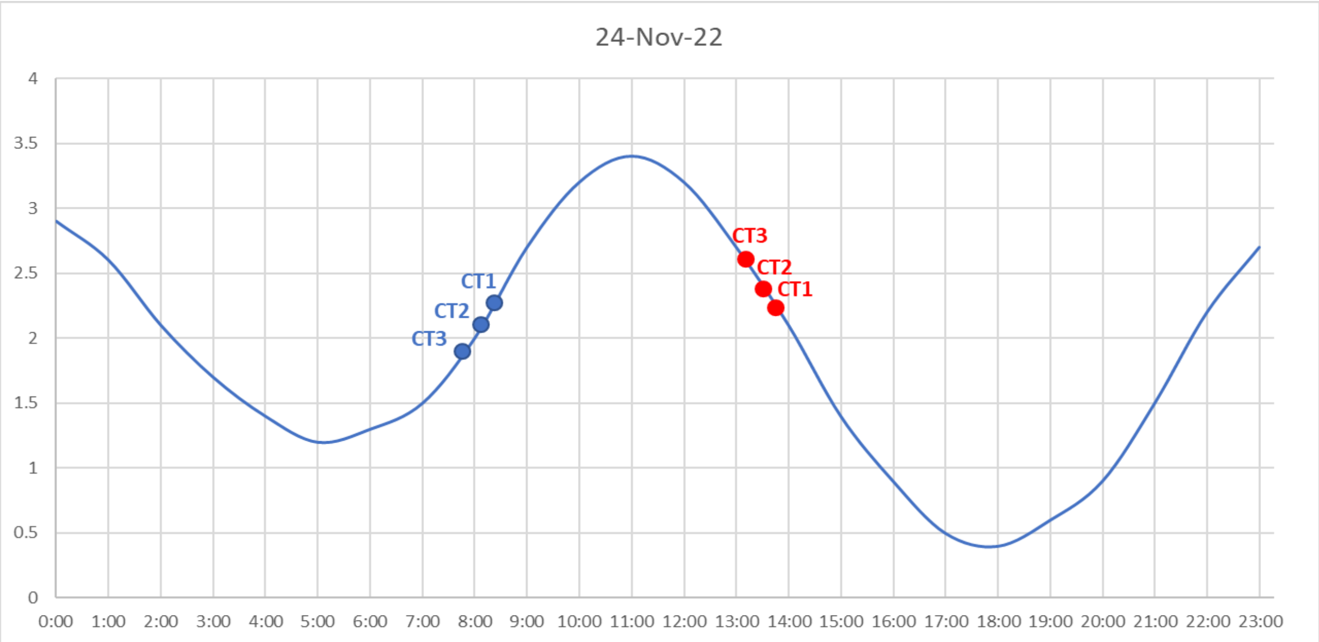



*Figure 7-16: Transect timing relative to predicted water levels at West Coast on 24 Nov 2022 spring tide (flood tide transects presented in blue; ebb tide transects are presented in red)*

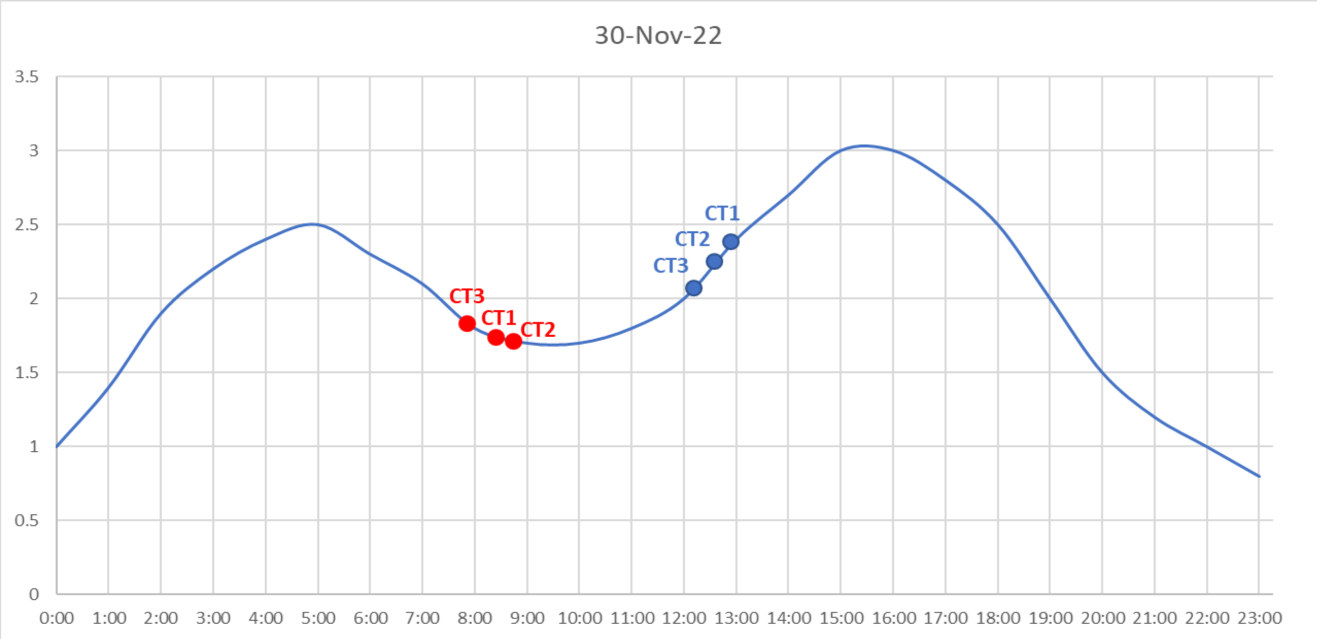



*Figure 7-17: Transect timing relative to predicted water levels at West Coast on 30 Nov 2022 neap tide (flood tide transects presented in blue; ebb tide transects are presented in red)*

*Table 7-6: Survey dates and tide condition*

| Transect | Tide Condition | Survey Date and Start Time | Survey Date and End Time |
|---|---|---|---|
| CT1 | Spring Flood | 24 Nov 2022, 08:23 | 24 Nov 2022, 08:32 |
| CT2 | Spring Flood | 24 Nov 2022, 08:05 | 24 Nov 2022, 08:08 |
| CT3 | Spring Flood | 24 Nov 2022, 07:47 | 24 Nov 2022, 07:51 |
| CT1 | Spring Ebb | 24 Nov 2022, 13:40 | 24 Nov 2022, 13:49 |
| CT2 | Spring Ebb | 24 Nov 2022, 13:26 | 24 Nov 2022, 13:31 |
| CT3 | Spring Ebb | 24 Nov 2022, 13:09 | 24 Nov 2022, 13:17 |
| CT1 | Neap Flood | 30 Nov 2022, 08:25 | 30 Nov 2022, 08:34 |
| CT2 | Neap Flood | 30 Nov 2022, 08:43 | 30 Nov 2022, 08:48 |
| CT3 | Neap Flood | 30 Nov 2022, 07:53 | 30 Nov 2022, 07:57 |
| CT1 | Neap Ebb | 30 Nov 2022, 12:52 | 30 Nov 2022, 13:02 |
| CT2 | Neap Ebb | 30 Nov 2022, 12:35 | 30 Nov 2022, 12:41 |
| CT3 | Neap Ebb | 30 Nov 2022, 12:10 | 30 Nov 2022, 12:17 |

##### *7.1.7.1.1.2 Data Collection*

Transects were conducted using a 600kHz RDI Workhorse Sentinel Acoustic Doppler Current Profiler (ADCP). Spatial information was obtained using a C-Nav3050 Differential Global Positioning System (DGPS).

The ADCP was mounted to the starboard side of the vessel (Figure 7-18) on a custom made 316-grade stainless steel clump with the transducers 0.4 m below the water surface (Fulford, 1992). The instrument was setup with bottom-tracking to correct the ADCP data relative to the vessel motion. The ADCP was configured with a vertical bin size of 0.5 m, maximum depth of 25 m, blanking distance of 0.4 m (where the midpoint of the first measurement was recorded at approximately 1.1 m below the water surface) and sample rate of 2Hz. A summary of the technical specifications of this instrument is shown in Table 7-7.

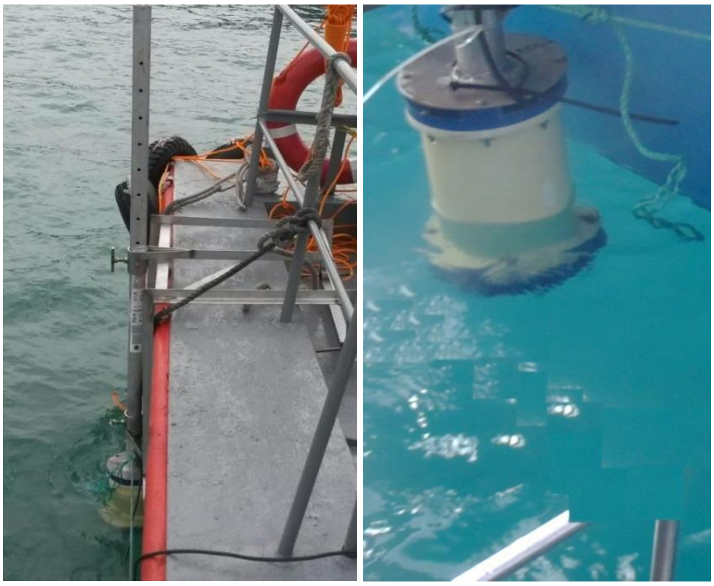


*Figure 7-18: ADCP vessel mount configuration*

The survey vessel was a 20-ft SR3627G survey vessel chartered by Worley, that operated at a speed between 1 and 5 knots. This vessel typically managed well given the strength of spring tidal currents encountered in Singapore waters.

*Table 7-7: Technical specifications of the workhorse sentinel 600kHz ADCP*

| Parameter | Vertical Resolution (m) | Range (m) | Std. Dev (cm/s) |
|---|---|---|---|
| Water Profiling (typical range 50 m) | 0.5 | 38 | 14.0 |
| | 1 | 42 | 7.0 |
| | 2 | 46 | 3.6 |
| | 4 | 51 | 1.8 |
| Long range mode | 4 | 66 | 3.6 |
| **Standard Sensors** | **Range** | **Precision** | **Resolution** |
| Temperature | -5°C to 45°C | ±0.4°C | 0.01°C |
| Tilt | ± 15° | Accuracy ±0.5°<br>Precision ±0.5° | 0.01° |
| Compass | ±2° | ±0.5° | 0.01° (Maximum tilt ±15°) |
| **Environmental Properties** | | | |
| Standard depth rating | | 200m; optional to 500m, 1000m, 6000m | |
| Operating temperature | | -5°C to 45°C | |
| Storage temperature (without batteries) | | -30°C to 60°C | |
| Weight in air | | 13.0 kg | |
| Weight in water | | 4.5 kg | |

#### 7.1.7.1.2 Quality Assurance/ Quality Control

Data was acquired and monitored in real-time through the acquisition software WinRiver II. After acquisition, data from each transect was stored into separate files with unique names. Global positioning was recorded in National Marine Electronics Association (USA) (NMEA) format and after completing the survey each transect line was exported, quality controlled (ISO 1983) and processed to produce plots in SVY21 datum.

To reduce the magnetic variation introduced by ferrous material in the ADCP internal compass, a 316-grade stainless steel pole mount bracket was fitted to the survey vessel and its vertical and horizontal alignment checked by a qualified engineer/ scientist with spirit levels. Attachment of the ADCP was done so in a controlled environment with subsequent pre-deployment tests completed to the manufacturer's specifications. On completion of all dry tests, the instrument was deployed, and an active test logged.

The ADCP pre-deployment tests were conducted as per the manufacturer's recommendations. The ADCP, ADCP clock, pressure sensor and compass calibration are all tested prior to each survey. For setting the ADCP clock, the unit was synchronized with the field laptop set on local (Singapore) time (GMT +8 hours). The orientation of the unit, in terms of installation height and heading, remained consistent throughout the survey to preclude the need to re-calibrate the unit daily.

Assessment of the compass accuracy was confirmed by conducting two short transects (transducers facing up and down) along the same course. These testing transects were then observed in the WinRiver II program to ensure that the compass had been calibrated accurately. The resulting stick ship track plots (corrected and uncorrected) can be observed in Figure 7-19 as an example. Both test-transect 'Stick Ship Tracks' produced the same direction[1] and a comparable velocity magnitude which indicates the internal compass has been calibrated correctly.

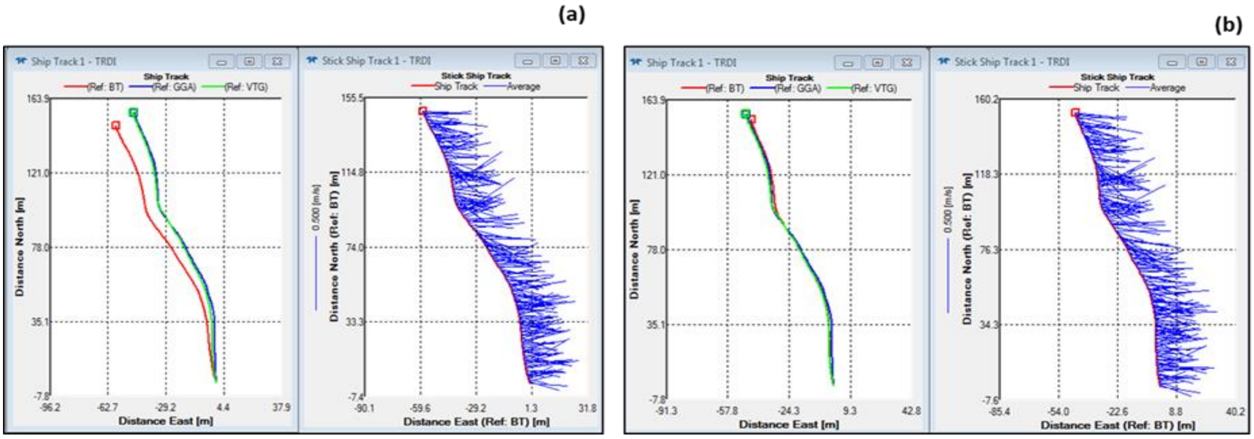



*Figure 7-19: ADCP compass check: (a) Uncorrected Heading, and (b) Corrected Heading; where Red line = bottom track; Blue line = DGPS track (vessel track), and Green line = the ADCP track.*

The standard processing offsets and assumptions applied to each transect are summarised in Table 7-8.

*Table 7-8: RDI Workhorse ADCP configuration [(1)]*

| Properties | Field Configuration | Variable |
|---|---|---|
| Processing | Speed of Sound | Use of ADCP Value |
| | Backscatter | Calculate for each ping |
| | River Depth Source | Composite |
| | Data Screening | Mark Below Bottom “Bad” |
| | | Mark Below Sidelobe “Bad” |
| | | Use 3 Beam Solution for BT |
| | | Use Weighted Beam Depth |
| | Cross sectional Area | Parallel to Average Course |
| | Thresholds | Bottom Track (BT)<br>Error Vel. (m/s) = 0.100 |
| | | Transmission Pulse Length (WT)<br>Error Vel. (m/s) = 1.067 |
| | | BT Up Vel (m/s) = 0.305 |
| | | WT Up Vel. (m/s) = 0.500 |
| | | Fish Intensity [(2)] (count) = 50 |
| Discharge | Shore | Left bank Edge Type – Triangular (0.3535) |
| | | Right bank Edge Type – Triangular (0.3535) |
| Offsets | ADCP Transducers location relative to water surface | Depth (m) = 0.4 |
| | Compass | Magnetic Variation (°) = 0 |

**Note:**

(1) A description of each configuration field may be found in WinRiver II user manual (RD Instruments, 2001).

(2) Fish Intensity (WinRiverII terminology) refers to threshold applied to the echo intensity to filter out ‘false targets’ such as fish or other foreign objects (e.g., debris, etc.).

The comparison of the current transect measurement against the predicted current is shown in Figure 7-20 and Figure 7-21. The transects which were measured on the 24 Nov 2022 and 30 Nov 2022 shows a satisfactory performance when compared to the modelled data.

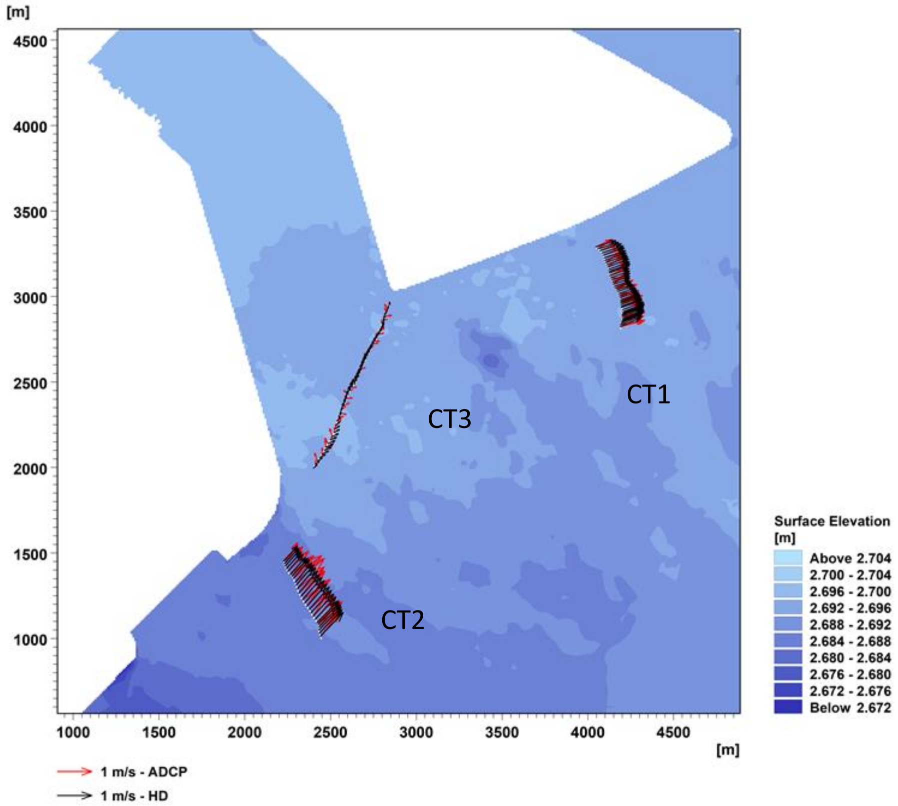



*Figure 7-20: Model validation with ADCP transect on peak ebb tide*

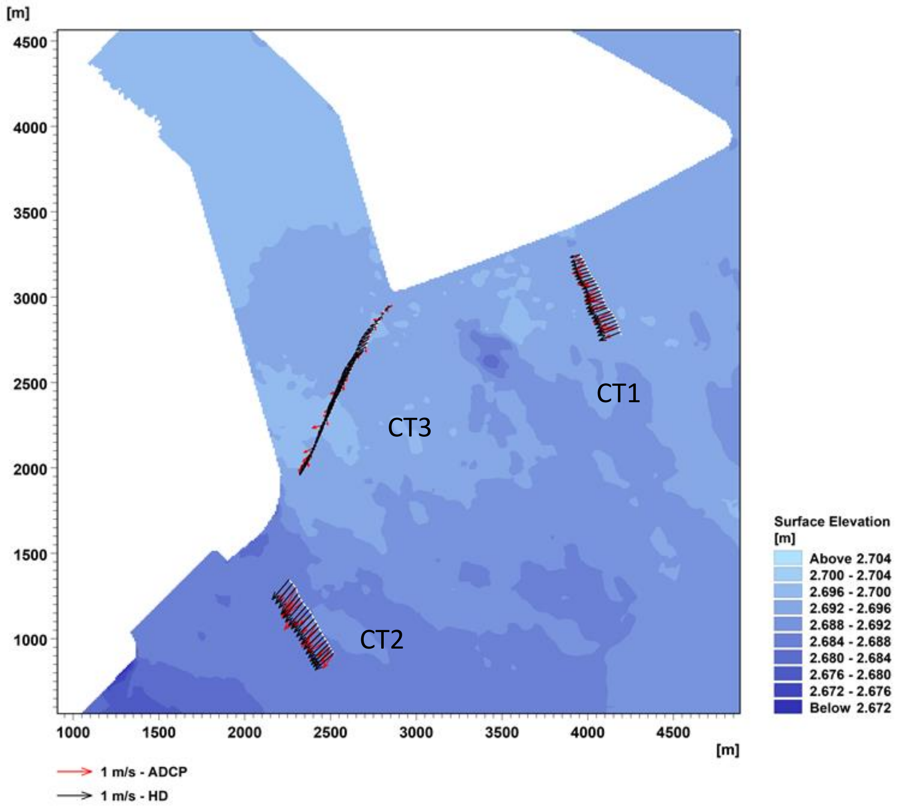



*Figure 7-21: Model validation with ADCP transect on peak flood tide*

### 7.1.8 Marine Water Quality

Marine water quality surveys were conducted at five (5) survey stations at surface and mid-depth in the vicinity of the Project footprint. The location of the marine water quality surveys is indicated in Figure 7-22. and the survey is carried out on 24 Nov 2022 during spring flood and ebb tides. The surveys include sample collections water samples for laboratory analysis (ex-situ) at surface and mid-depth and in-situ measurements.


*Figure 7-22: Water quality survey location*

Compliance assessment of the water quality monitoring program, for both in-situ and ex-situ are reported based on the guideline or criteria listed in Table 7-9 and Table 7-10. Guidelines referenced include:

- Association of Southeast Asian Nations Region Marine Water Quality Criteria (ASEAN MWQC, 2008);
- National Environment Agency, National Parks Water Quality Guidelines 2008 (NEA, 2008);
- Australian and New Zealand guidelines for fresh and marine water quality (ANZECC, 2000); and
- Other relevant Marine Water Quality Guidelines (MWQG) where applicable.

*Table 7-9: In-situ water quality criteria*

| Parameters | Water Quality Criteria | | | |
|---|---|---|---|---|
| | ASEAN MWQC | ANZECC [(1)] | NEA (2008) | National Parks (NParks) |
| Secchi disc depth | N.A. | N.A. | ≥ 1.2m (recreational waters) | ≥ 0.5m (non-recreational waters) |
| Temperature | ≤ 2°C above the maximum ambient temperature | N.A. | N.A. | N.A. |
| Salinity | N.A. | N.A. | N.A. | N.A. |
| pH | N.A. | 8.5 | N.A. | N.A. |
| Dissolved oxygen | > 4 mg/L | N.A. | N.A. | N.A. |
| Turbidity | N.A. | < 20 NTU | N.A. | N.A. |

**Note:**

*(1) No project guideline specified. ANZECC guidelines are utilized for comparison purpose only.*

*Table 7-10: Ex-situ water quality criteria*

| Parameters | Water Quality Criteria | | Detection Limit | Sampling Depth |
|---|---|---|---|---|
| | ASEAN MWQC | ANZECC [(1)] | | |
| Total suspended solids, TSS | <10% increase over seasonal average | N.A. | 1 mg/L | Surface & Mid depth |
| Total Nitrogen, TN | N.A. | N.A. | 0.01 mg/L | Surface & Mid depth |
| Nitrate as $NO_3$-N | 0.06 mg/l | N.A. | 0.01 mg/L | Surface & Mid depth |
| Phosphate as $PO_4$-P | 0.015 mg/L | N.A. | 0.01 mg/L | Surface & Mid depth |
| Total Phosphorus, TP | N.A. | 0.015 mg/L | 0.01 mg/L | Surface & Mid depth |
| Ammonia as NH3-N | 0.07 mg/l | N.A. | 0.01 mg/L | Surface & Mid depth |
| Aluminium as Al | N.A. | N.A. | 0.1 ug/L | Surface & Mid depth |
| Arsenic as As | N.A. | N.A. | 0.1 ug/L | Surface & Mid depth |

| Parameters | Water Quality Criteria | | Detection Limit | Sampling Depth |
|---|---|---|---|---|
| | ASEAN MWQC | ANZECC [1] | | |
| Cadmium as Cd | 10 µg/L | N.A. | 0.1 ug/L | Surface & Mid depth |
| Chromium as Cr | 50 µg/L | N.A. | 0.1 ug/L | Surface & Mid depth |
| Copper as Cu | 8 µg/L | N.A. | 0.5 ug/L | Surface & Mid depth |
| Lead as Pb | 8.5 µg/L | N.A. | 0.1 ug/L | Surface & Mid depth |
| Mercury as Hg | 0.16 µg/L | N.A. | 0.05 ug/L | Surface & Mid depth |
| Nickel as Ni | N.A. | 70 µg/L | 0.5 ug/L | Surface & Mid depth |
| Zinc as Zn | N.A. | 15 µg/L | 0.5 ug/L | Surface & Mid depth |
| Biochemcial Oxygen Demand, $BOD_5$ | N.A. | N.A. | 1.0 mg/L | Surface & Mid depth |
| Chlorophyll-a | N.A. | 0.7-1.4 µg/L | 0.1 ug/L | Surface & Mid depth |
| Oil & Grease | 0.14 mg/L | N.A. | 1.0 mg/L | Surface & Mid depth |
| Faecal Coliform | 100 MPN/100 mL | 150 MPN/100 mL | 1.8 MPN/100mL | Surface & Mid depth |
| Total *Escherichia coliform* | N.A. | N.A. | 1 CFU/100mL | Surface & Mid depth |
| Phytoplankton (Total) | N.A. | N.A. | 1 cell/mL | Surface |
| Zooplankton (Total) | N.A. | N.A. | 1 org/m3 | Water profile |

**Note:**
*(1) No project guideline specified. ANZECC guidelines are utilized for comparison purpose only.*

#### 7.1.8.1 In-Situ

For in-situ water quality surveys, temperature, salinity, turbidity, pH, and dissolved oxygen (DO) were measured at 1-m interval across the water column, using a calibrated (Appendix D) EXO 2 Multiparameter Sonde to provide a depth profile reading. Measurements were collected at both flood and ebb tides at five (5) survey stations and Table 7-11 summarised the in-situ water quality result from the water quality campaign carried out by Worley on 24 Nov 2022. The detailed in-situ data are presented in Appendix E.

**Secchi disc depth**

Secchi disc is used to measure water clarity. Secchi depth reading is influenced by the presence of high suspended or dissolved material in water. The recommended target depth by Singapore National Parks (NParks) and Singapore National Environmental Agency (NEA) is > 0.5 m (non-recreational waters) and >1.2m (recreational waters) respectively. The secchi depth readings recorded ranged between 2.1 m and 3.0 m during ebb tide, and 2.3 m to 2.5 m during ebb tide. The measurements were all above the recommended NEA target depth for non-recreational waters of 0.5 m and recreational waters of 1.2 m.

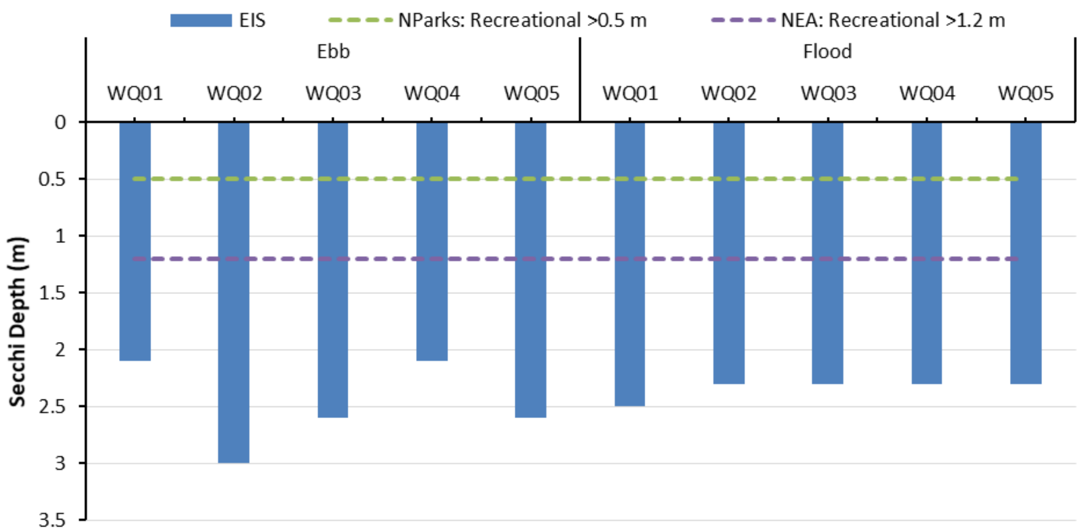



*Figure 7-23: Secchi depth recorded during the water quality survey*

**Temperature**

Temperature is one of the key drivers of water quality. It has direct influence on dissolved oxygen (DO) concentrations, salinity, and pH, which is also coupled to diurnal cycles and associated photosynthesis activity. Temperature readings during the in-situ baseline survey were relatively stable across the depth profile at both flood and ebb tides. The mean temperature readings ranged from 29.50°C to 30.12°C across stations and tides. Worley notes that the ASEAN MWQC for temperature is only applicable for an extended monitoring period in comparison to the baseline.

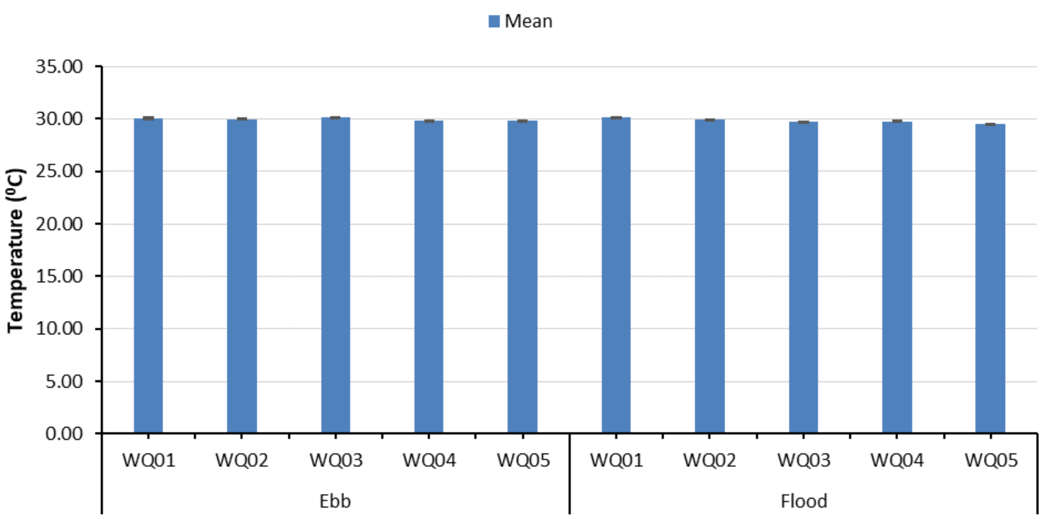



*Figure 7-24: Temperature recorded during the water quality survey*

**Salinity**

Salinity varies according to season and is particularly influenced by freshwater run-off during distinct monsoon events in Singapore's territorial waters. Salinity of water provide an indication of the extent of mixing and the presence of salinity stratification which may occur when there is significant freshwater run-off. Overall, salinity within Singapore's near shore coastal waters range between 29 ppt and 32 ppt (Din et. al., 1996) and (Behera et. al., 2013) observing salinities of up to 34.5 ppt. Salinity readings during the survey were relatively uniform across the depth profile at both flood and ebb tides. The mean salinity readings ranged from 30.83 ppt to 30.95 ppt across the tides and stations. The results are consistent with published literature sources.

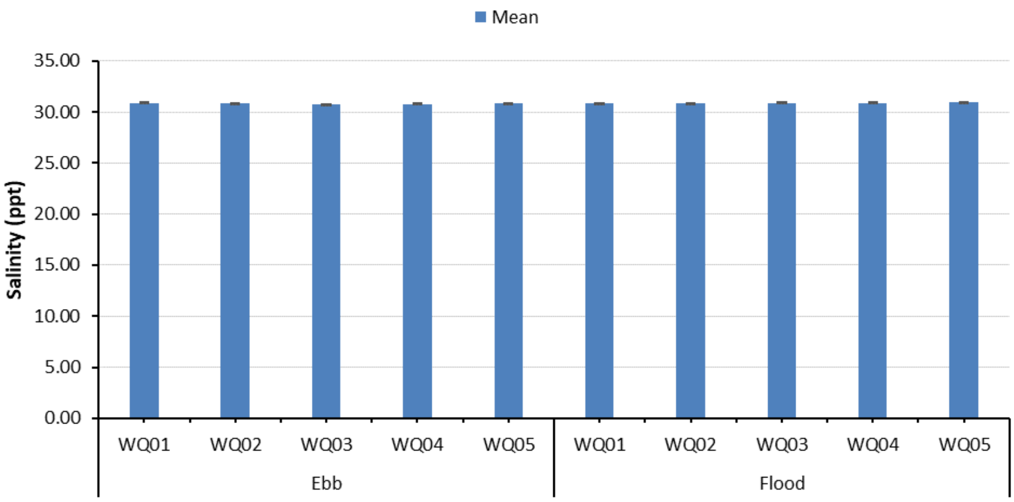



*Figure 7-25: Salinity recorded during the water quality survey*

**pH**

pH is a key physiological driver for many species of aquatic biota. The pH of marine waters should fall within the range of 7.5 to 8.5 (Canadian Council of Ministers of the Environment, CCME, 1999) and adverse physiological stress for marine biota is likely to occur when beyond this range.  H is defined as the negative logarithm of proton concentration and is a measurement of the acidity or alkalinity of aqueous solutions. Marine water pH is typically in the slightly alkaline range (CCME, 1999). pH readings recorded during the survey were relatively uniform across the depth profile at both flood and ebb tides. The mean pH readings ranged from 8.04 to 8.11 across stations and tides.

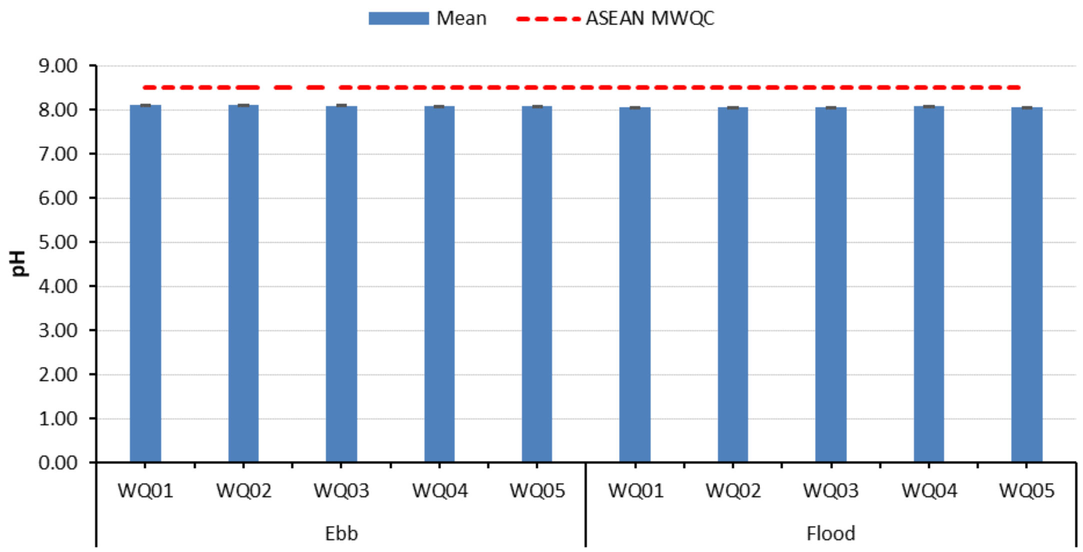



*Figure 7-26: pH recorded during the water quality survey*

**Dissolved oxygen**

DO concentrations are used as an indicator to determine the ecological condition of waters. It is primarily maintained through bio-physical processes such as wind driven agitation of surface waters, tidal exchange and biological processes such as photosynthesis from aquatic flora (algae, seagrass and phytoplankton). The mean DO recorded at both flood and ebb tides were above the ASEAN MWQC (≥ 4.00 mg/L) and it ranged from 5.98 mg/L to 6.07 mg/L. The water within the Project is generally well oxygenated.

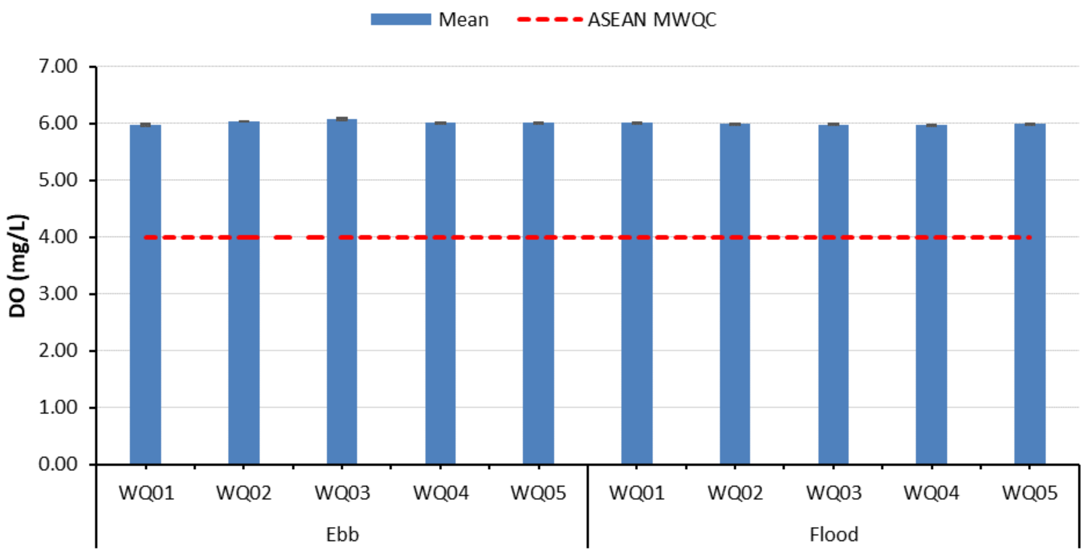



*Figure 7-27: Dissolved oxygen recorded during the water quality survey*

## Turbidity

Turbidity is an indicator for water clarity. It is also a measure of the degree to which the water loses its transparency due to the presence of suspended particulates and dissolved organic matter in water. The mean turbidity recorded across stations ranged from 1.54 NTU to 4.11 NTU, regardless of tides. There is no ASEAN MWQC for turbidity. When compared against the ANZECC criteria of 20.00 NTU, the mean turbidity readings at all survey stations were all within the ANZECC criteria.

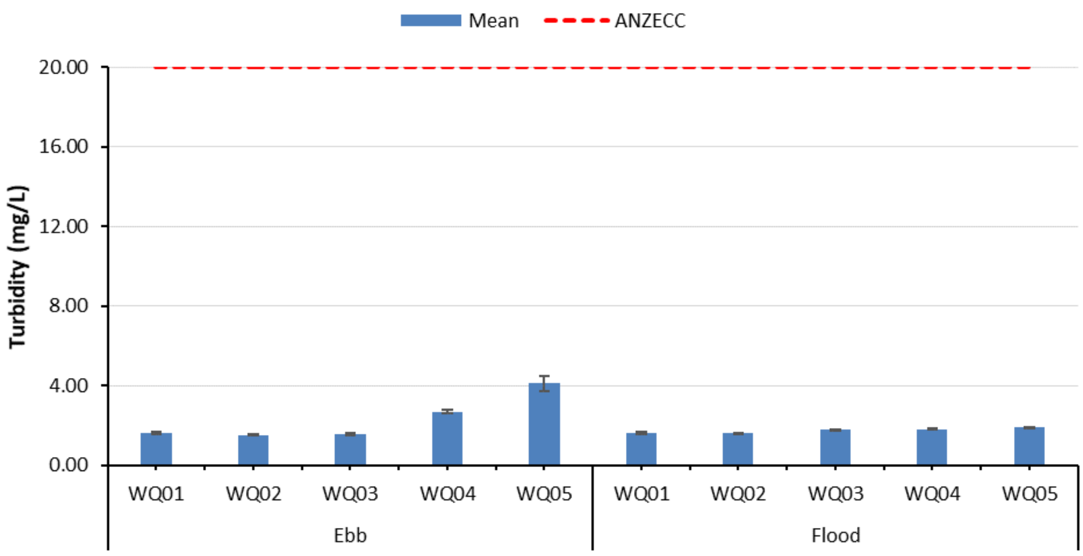



*Figure 7-28: Turbidity recorded during the water quality survey*

*Table 7-11: Mean in-situ marine water quality results*

| Sampling Date: 24 Nov 2022 | Descriptive Statistic | Stations | | | | | Stations | | | | | ASEAN MWQC | ANZECC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ebb | | | | | Flood | | | | | | |
| | | WQ01 | WQ02 | WQ03 | WQ04 | WQ05 | WQ01 | WQ02 | WQ03 | WQ04 | WQ05 | | |
| Secchi (m) | - | 2.1 | 3 | 2.6 | 2.1 | 2.6 | 2.5 | 2.3 | 2.3 | 2.3 | 2.3 | N.A | N.A |
| Temperature (°C) | Mean | 30.02 | 29.97 | 30.12 | 29.78 | 29.86 | 30.11 | 29.89 | 29.73 | 29.76 | 29.50 | ≤ 2°C above the maximum ambient temperature | N.A |
| | S.E. | 0.09 | 0.08 | 0.06 | 0.05 | 0.02 | 0.05 | 0.05 | 0.04 | 0.09 | 0.01 | | |
| | Max. | 31.37 | 30.88 | 30.74 | 30.31 | 30.1 | 31.07 | 31.01 | 30.37 | 31.53 | 29.83 | | |
| | Min. | 29.60 | 29.51 | 29.64 | 29.61 | 29.77 | 29.90 | 29.70 | 29.48 | 29.48 | 29.44 | | |
| Salinity(ppt) | Mean | 30.89 | 30.83 | 30.78 | 30.79 | 30.84 | 30.83 | 30.85 | 30.89 | 30.89 | 30.95 | N.A | N.A |
| | S.E. | 0.03 | 0.02 | 0 | 0.02 | 0.01 | 0.03 | 0.02 | 0.01 | 0.02 | 0 | | |
| | Max. | 31.17 | 31.01 | 30.84 | 30.90 | 30.88 | 31.16 | 31.19 | 30.98 | 30.97 | 31.01 | | |
| | Min. | 30.44 | 30.66 | 30.74 | 30.64 | 30.75 | 30.55 | 30.56 | 30.67 | 30.59 | 30.88 | | |
| pH | Mean | 8.11 | 8.10 | 8.09 | 8.09 | 8.07 | 8.04 | 8.07 | 8.07 | 8.07 | 8.06 | N.A | 8.5 |
| | S.E. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| | Max. | 8.12 | 8.11 | 8.10 | 8.10 | 8.08 | 8.07 | 8.08 | 8.08 | 8.08 | 8.06 | | |
| | Min. | 8.09 | 8.08 | 8.08 | 8.08 | 8.05 | 8.04 | 8.05 | 8.06 | 8.02 | 8.05 | | |
| Turbidity (NTU) | Mean | 1.64 | 1.54 | 1.59 | 2.71 | 4.11 | 1.63 | 1.61 | 1.79 | 1.82 | 1.91 | N.A | < 20 NTU |
| | S.E. | 0.05 | 0.05 | 0.05 | 0.08 | 0.36 | 0.04 | 0.02 | 0.04 | 0.03 | 0.02 | | |
| | Max. | 2.08 | 2.12 | 2.09 | 3.07 | 10.35 | 2.04 | 1.93 | 2.15 | 1.98 | 2.17 | | |
| | Min. | 1.24 | 1.2 | 1.13 | 1.71 | 1.69 | 1.21 | 1.12 | 1.31 | 1.48 | 1.59 | | |
| Dissolved Oxygen (mg/L) | Mean | 5.98 | 6.03 | 6.07 | 6.01 | 6.01 | 6.01 | 5.99 | 5.98 | 5.96 | 5.99 | > 4 mg/L | N.A |
| | S.E. | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0 | 0.01 | | |
| | Max. | 6.21 | 6.17 | 6.19 | 6.12 | 6.09 | 6.15 | 6.07 | 6.08 | 5.99 | 6.06 | | |
| | Min. | 5.82 | 5.88 | 5.96 | 5.93 | 5.77 | 5.95 | 5.90 | 5.92 | 5.89 | 5.92 | | |

#### 7.1.8.2 Ex-Situ

Water was collected for both flood and ebb tides at either surface, mid-depth or across the entire water column. Table 7-12 and Table 7-13 summarised the ex-situ water quality result from the water quality campaign carried out by Worley on 24 Nov 2022. The detailed lab results and analysis presented in Appendix F.

**Total Suspended Solid**

Natural sources of TSS include run-off, erosion, and transportation of sediments through riverine and estuarine processes, and decomposition of organic material. Variations in TSS values through anthropogenic related activities include point sources of pollutants from effluents, sewage, run-off from site clearances and large-scale marine construction projects. TSS results during the 24 Nov 2022 survey across the survey stations ranged between 1.2 mg/L and 23.7 mg/L. The highest TSS reading was recorded at WQ01, during ebb tide at the surface depth. According to the ASEAN MWQC for TSS, the permissible TSS was set at not more than 10 % increased over seasonal average concentration. Worley notes that the ASEAN MWQC for TSS is only applicable for an extended.

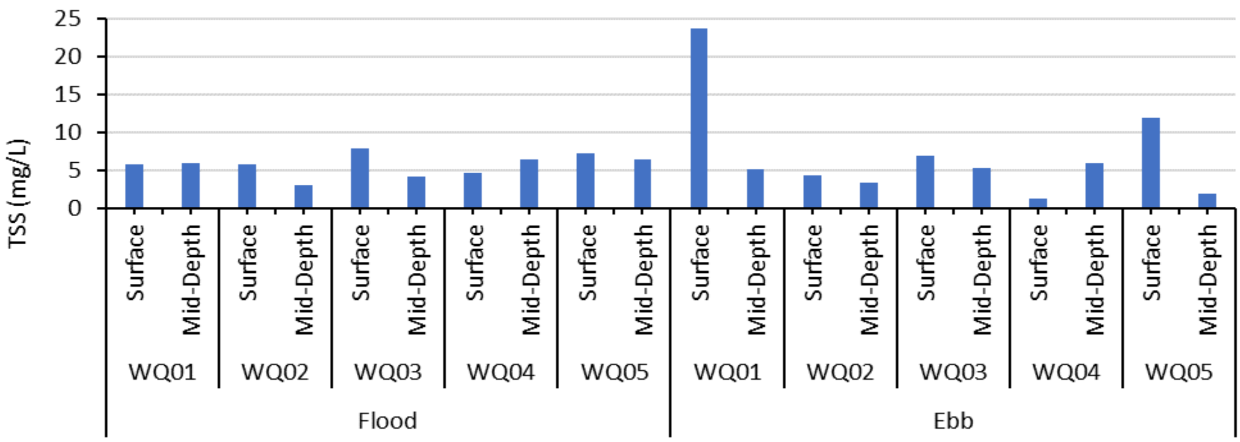



*Figure 7-29: Total suspended solid recorded during water quality survey*

**Nutrients**

For nutrients, there was no ASEAN MWQC for Total Nitrogen (TN) and Total Phosphorus (TP). The TN and TP concentrations recorded during the survey ranged from 0.212 mg/L and 0.623 mg/L, and 0.018 mg/L to 0.027 mg/L respectively. When comparing with the ANZECC for TP, the TP concentrations have exceeded the ASEAN MWQC for both flood and ebb tides at all survey stations. For phosphate and ammonia, the concentration recorded at all survey stations at both flood and ebb tides were below the ASEAN WMQC limit of 0.015 mg/L and 0.07 mg/L respectively, in which the phosphate and ammonia concentrations ranged from 0.017 mg/L to 0.024 mg/L, and 0.019 mg/L and 0.039 mg/L respectively across tides, depth, and stations. Nitrate concentrations have exceeded the ASEAN MWQC of 0.06 mg/L at several stations. The nitrate concentration recorded during the survey ranged between 0.053 mg/L and 0.097 mg/L. Typically, high concentrations of nutrients, particularly phosphorus and nitrogen can result in excessive growth of aquatic plants such as phytoplankton and other algal species in a range of ecosystems. Excess TN may lead to water quality problems such as odour, aesthetic problems and even lowered DO levels resulting from algal blooms that can be devastating to the marine environment. Exceedances were of no concern given that algal blooms were not sighted at the time of survey and DO within the Project is generally well oxygenated.

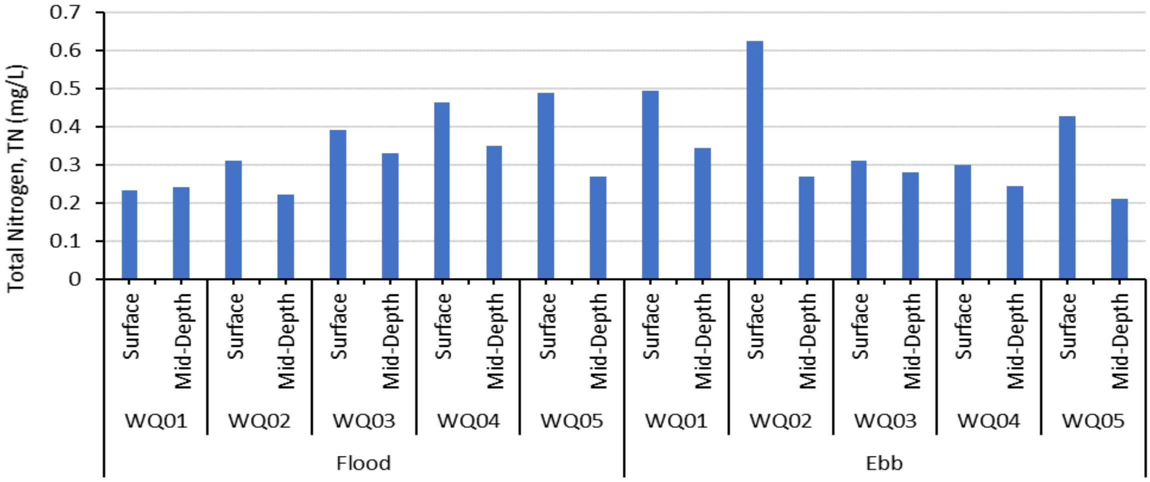



*Figure 7-30: Total nitrogen recorded during water quality survey*

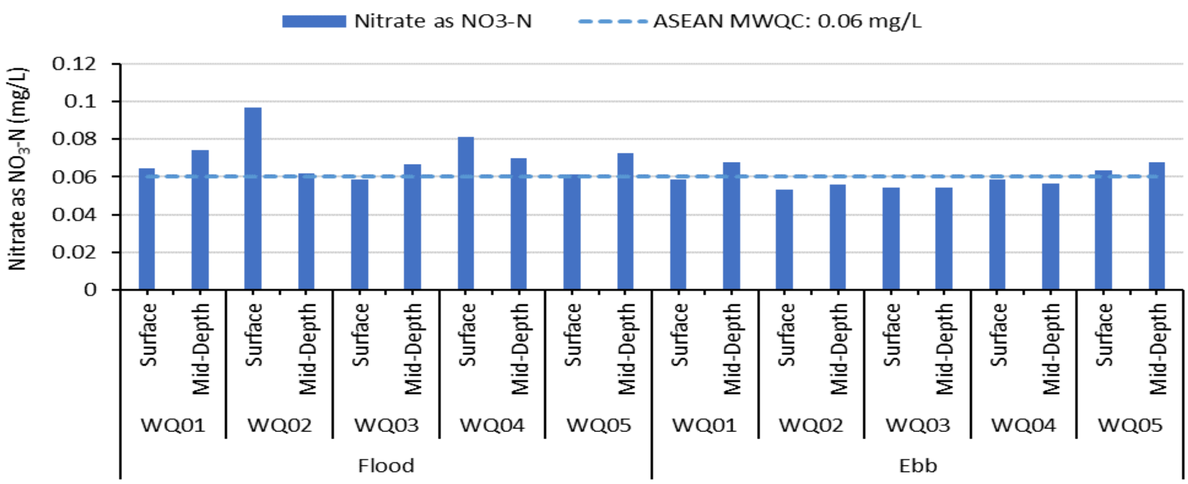



*Figure 7-31: Nitrate recorded during water quality survey*

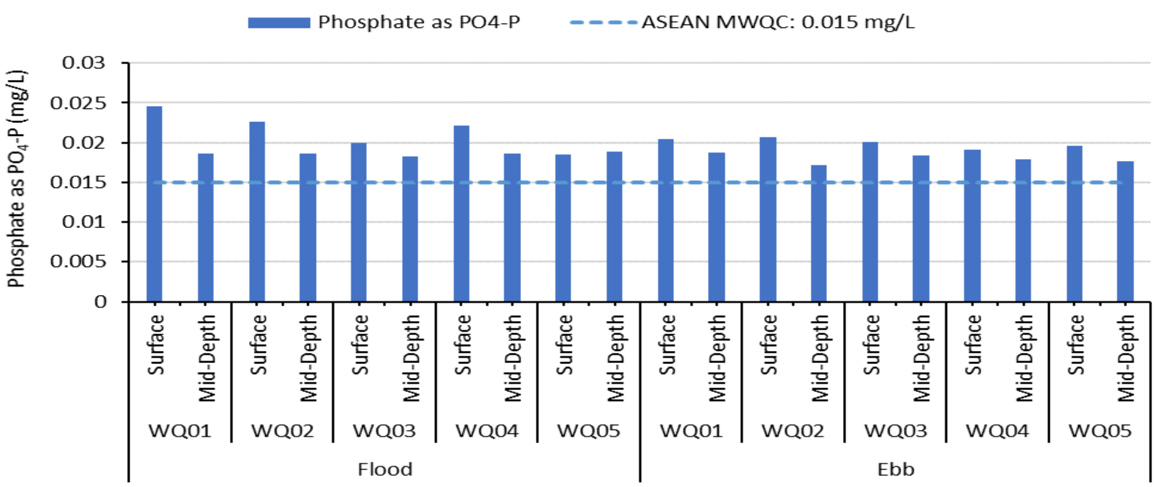



*Figure 7-32: Phosphate recorded during water quality survey*

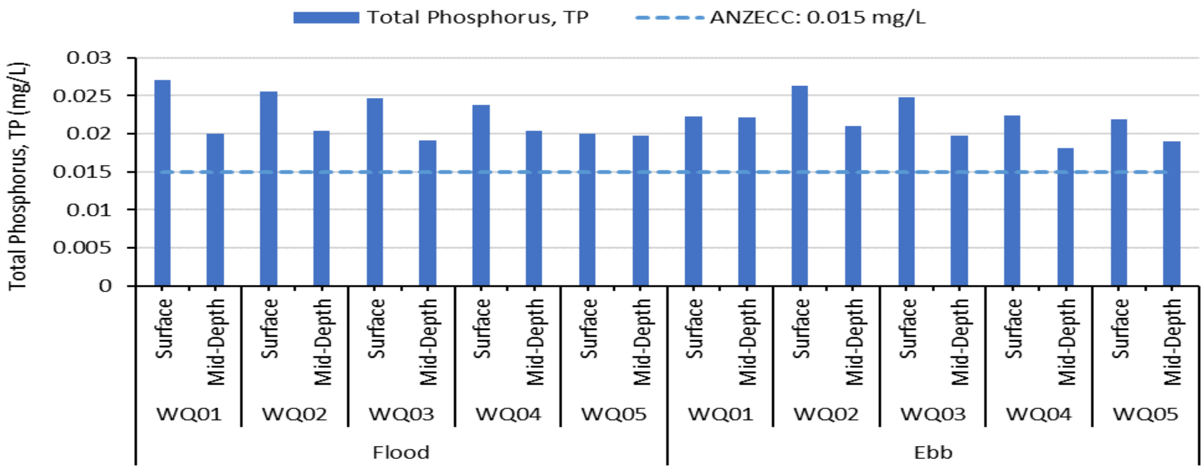



*Figure 7-33: Total phosphorus recorded during water quality survey*

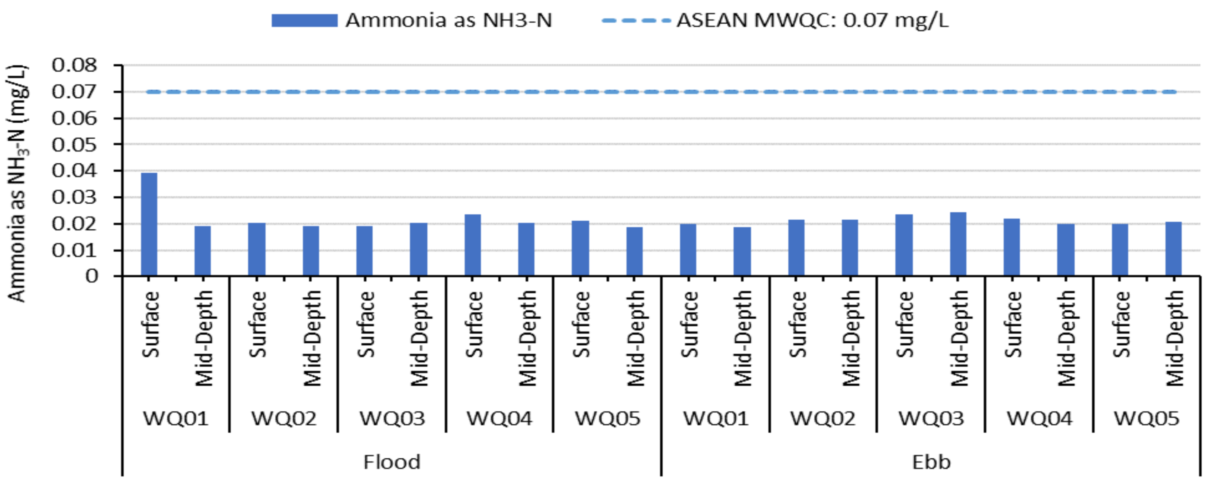



*Figure 7-34: Ammonia recorded during water quality survey*

**Chlorophyll-a**

Chlorophyll-a is a plant pigment used as a proxy for algal biomass presents in the water column. Chlorophyll a concentration are an indicator of phytoplankton abundance and biomass in coastal and estuarine waters. They can be an effective measure of trophic status, are potential indicators of maximum photosynthetic rate. High levels often indicate poor water quality and low levels often suggest good conditions. Chlorophyll-a concentrations are used as indicators of pollution and water quality in waterbodies, as well as indicators of phytoplankton and plant biomass and abundance (ANZECC/ARMCANZ, 2000). High concentrations of Chl-a can result in an increase in pH levels and fluctuations in DO concentrations (OzCoasts, n.d.). The Chlorophyll-a concentrations were above the detection limit at all survey stations, ranging between 0.30 µg/L and 1.73 µg/L. There is no ASEAN MWQC for Chlorophyll-a, however, the chlorophyll-a concentrations exceeded the ANZECC MWQC envelope upper range of 1.4 µg/L at several survey stations. The detection of chlorophyll-a is not of a concern given that the secchi disc depth and DO readings were above the ASEAN MWQC of 1.2 m and 4.0 mg/l respectively, at all stations. Furthermore, according to literature review, higher concentration of chlorophyll-a is reported at the Singapore Straits ranging from 0.4 to 10 ug/l, although shallow protected waterbodies in the Johor Strait have been observed to sustain chlorophyll-a at concentrations of up to 78 ug/l.

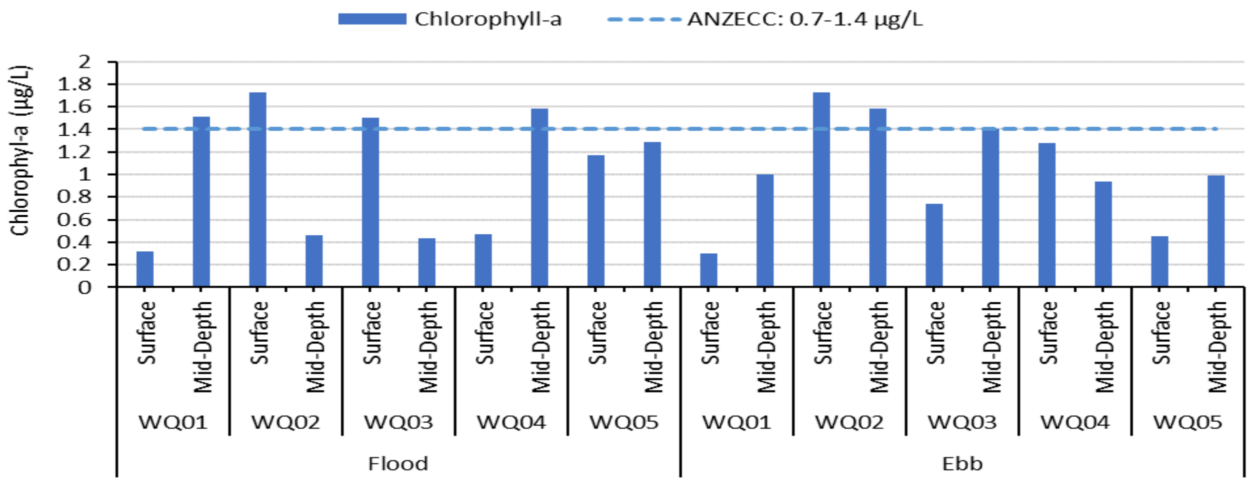



*Figure 7-35: Chlorophyll-a recorded during water quality survey*

**Biochemical Oxygen Demand ($BOD_5$)**

$BOD_5$ is the amount of oxygen needed to consume for breaking down waste in bacteria in water sources. Hence, $BOD_5$ is an indicator for the presence of organic pollutants. High biomass can promote rapid bacteriological growth resulting in depletion of dissolved oxygen which may create detrimental consequences to the aquatic biota. The $BOD_5$ readings were all below the detection limit of 1 mg/L across all the survey stations for both flood and ebb tides.

**Microbiological Contaminants**

The readings *Escherichia coli* (*E.Coli*) are below detection limits across the stations, tides, and depths. For Faecal Coliform, majority of the readings are below detection. The Faecal coliform ranged between 2 MPN/ 100ML and 13 MPN/ 100ML. Overall, detected concentrations of Faecal coliform were of no concern as the waters around the stations are not for recreational use and purposes. Therefore, there are no risks posed on human health.

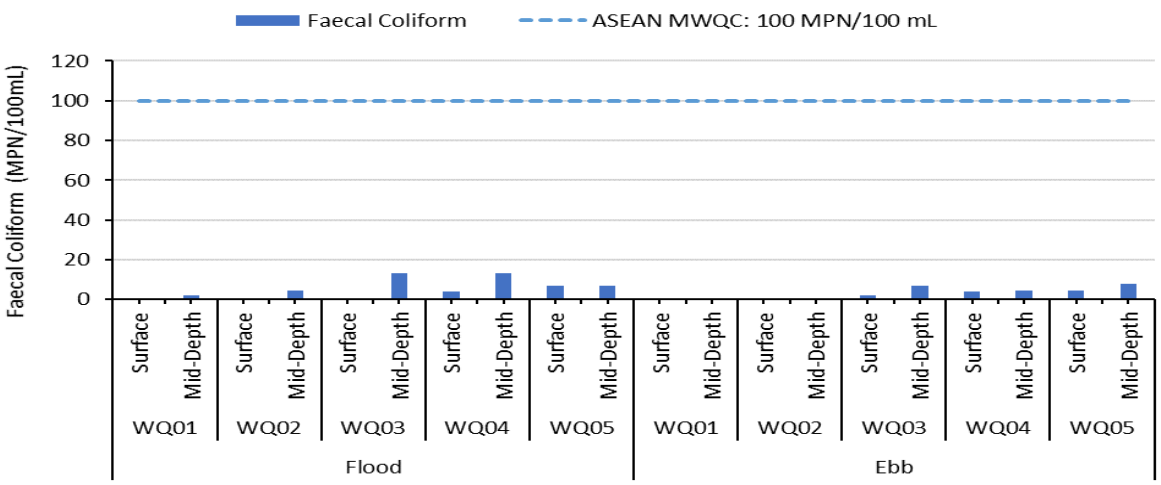



*Figure 7-36: Faecal coliform recorded during water quality survey*

**Oil and Grease**

Oil and grease (O&G) readings for all samples were below the detection limit of 0.1 mg/l and below the ASEAN MWQC of 0.14 mg/L across all stations.

**Dissolved Metals**

Dissolved metals including aluminum, arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc were analysed throughout the monitoring period. The dissolved metals are detected at certain survey stations, either during flood and/ or ebb tides.

During flood tide, the nickel and mercury readings were below the detection limit. While at ebb tide, the nickel and mercury concentrations were all below the detection limit, with the exception of WQ02 (ebb tide-surface) for nickel and WQ01 (ebb tide-surface) for mercury. The mercury concentrations were compliant with the ASEAN MWQC (0.16 µg/L). There is no ASEAN MWQC for nickel, however it was compliant with the ANZECC of 70 µg/L.

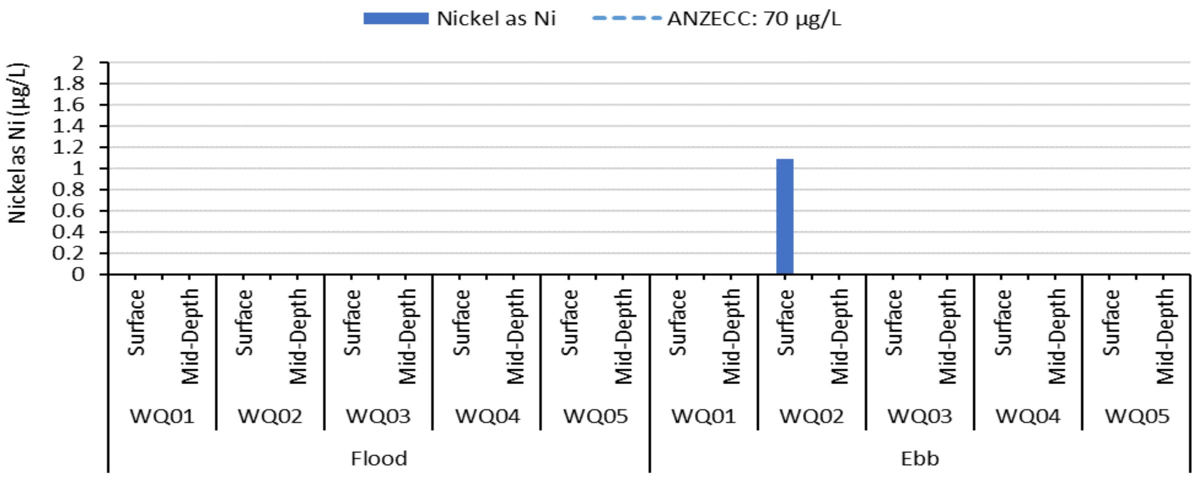



*Figure 7-37: Nickel recorded during water quality survey*

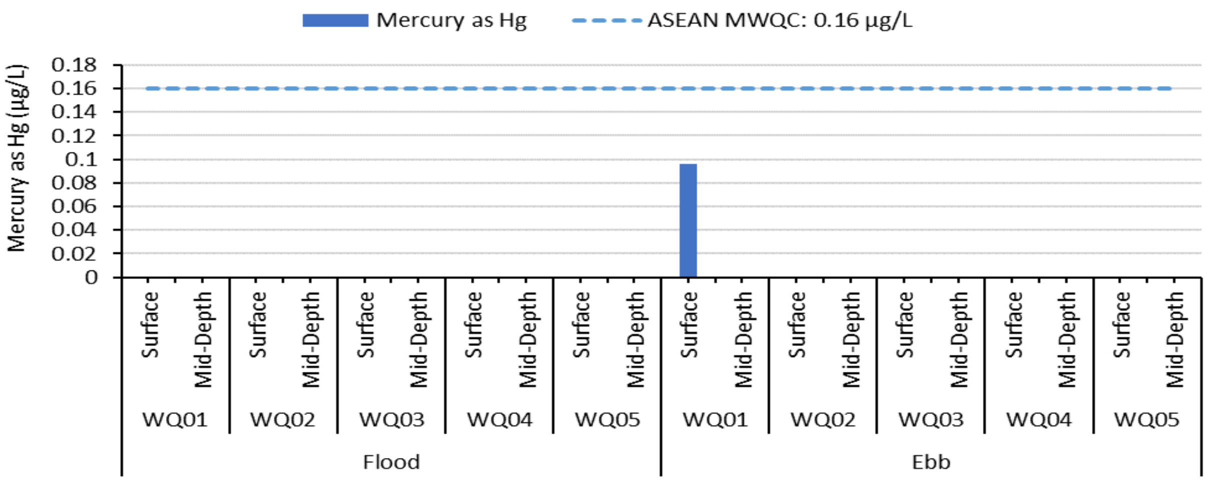



*Figure 7-38: Mercury recorded during water quality survey*

Cadmium, lead, and chromium were also detected during the baseline study; however, it was compliant with ASEAN MQQC of 10 µg/L, 8.50 µg/L, and 50 µg/L respectively. For cadmium, majority of the cadmium readings were below the detection limit, and it was only detected at WQ03 at mid-depth during flood tide and WQ05 at mid-depth during ebb tide. While for chromium, the concentrations ranged between 3.606 µg/L and 4.63 µg/L, with the highest reading recorded during flood tide at WQ05. The lead concentrations ranged between 0.13 µg/L to 0.322 µg/L.

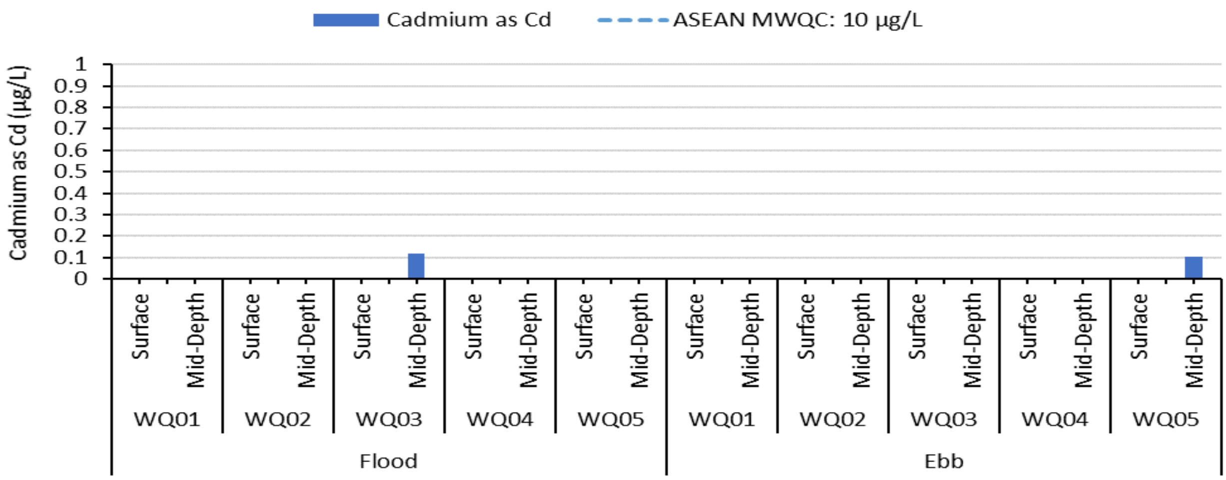



*Figure 7-39: Cadmium recorded during water quality survey*

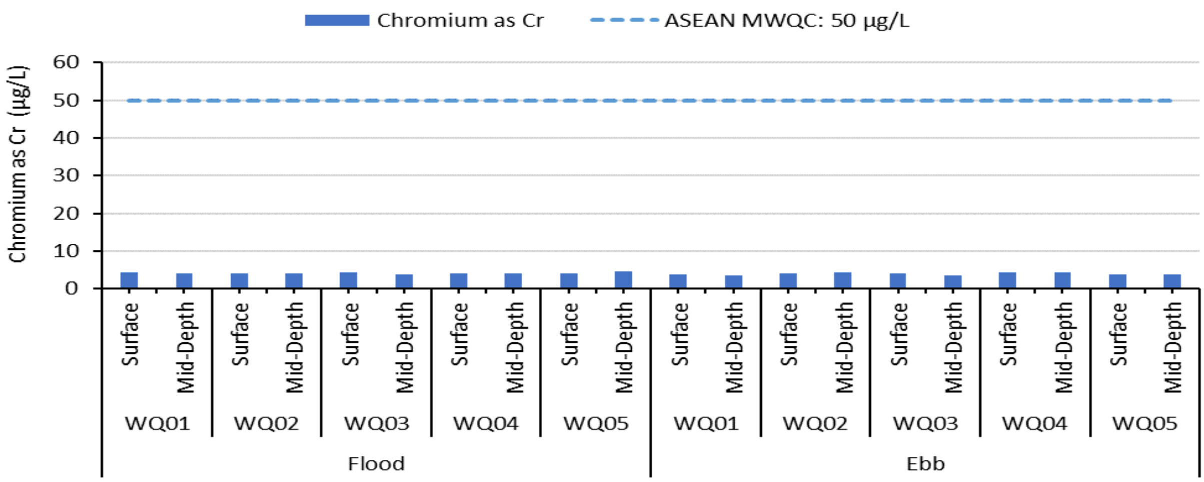



*Figure 7-40: Chromium recorded during water quality survey*

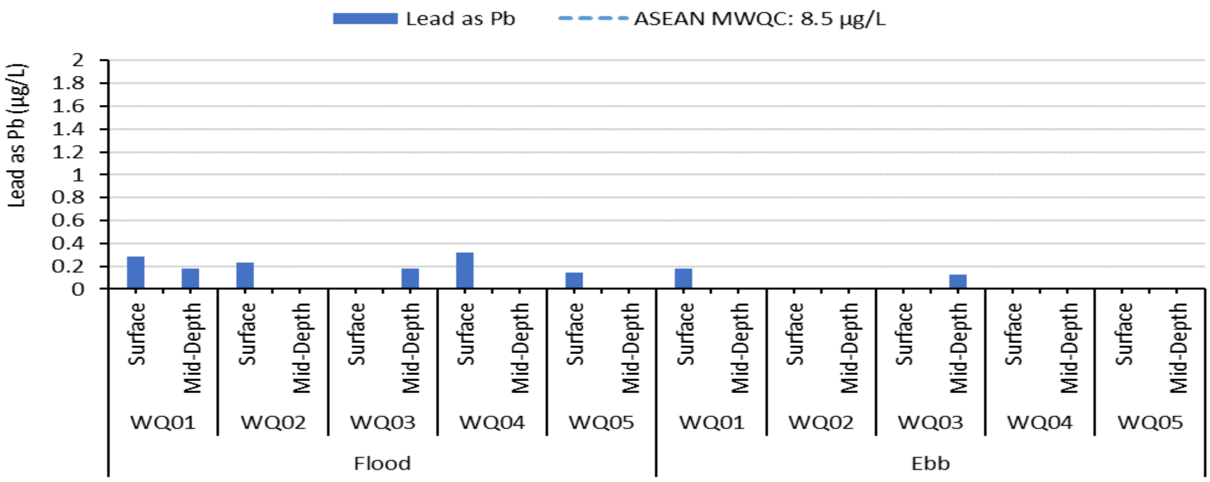



*Figure 7-41: Lead recorded during water quality survey*

Copper concentrations exceeded the ASEAN MWQC of 8 mg/L for both ebb and flood tides at all stations. The copper concentrations ranged between 8.00 µg/L and 17.087 µg/L, with the highest reading recorded during flood tide at the surface of WQ01. Possible sources of copper, exceedances include industrial or urban run-offs and/or antifouling paint from passing marine vessels (Comber, et al., 2022).

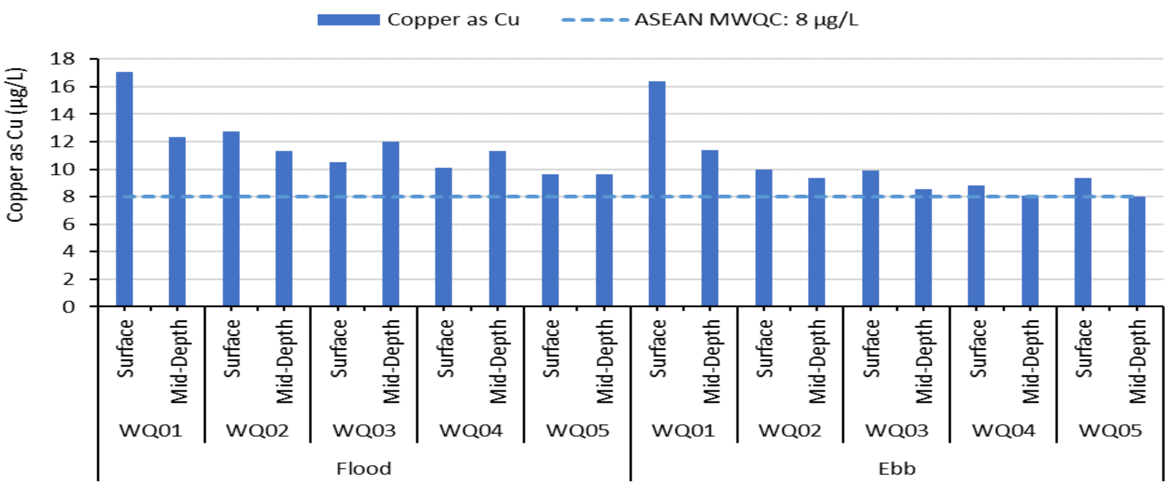



*Figure 7-42: Copper recorded during water quality survey*

For aluminum, the concentrations varied from 1.42 µg/L to 16.01 µg/L. While for arsenic, arsenic across the survey stations ranged between 1.689 µg/L and 2.623 µg/L. There is no ASEAN MWQC for aluminum and arsenic. The zinc concentrations recorded across the survey stations ranged between 8.432 µg/L and 23.496 µg/L, with some observations that were higher than the ANZECC MWQC of 15 µg/L. Despite being an essential trace element in aquatic waters, it has a harmful impact on aquatic life (toxicity) and human health if the measured concentrations are above 50 µg/L and 1,250 µg/L respectively (ASEAN MWQC 2008). Possible sources of Zinc exceedances include industrial discharge or sacrificial anodes, paint (Neff, 2002) and bilge water discharge from passing vessels (Hermansson, Hassellov, Jalkanen, & Ytreberg, 2023). Toxicity of Zn also increases at low DO concentrations and decreasing salinity (ANZECC & ARMCANZ, 2000). The detection of zinc is not a concern given by the DO and salinity are within the limits.

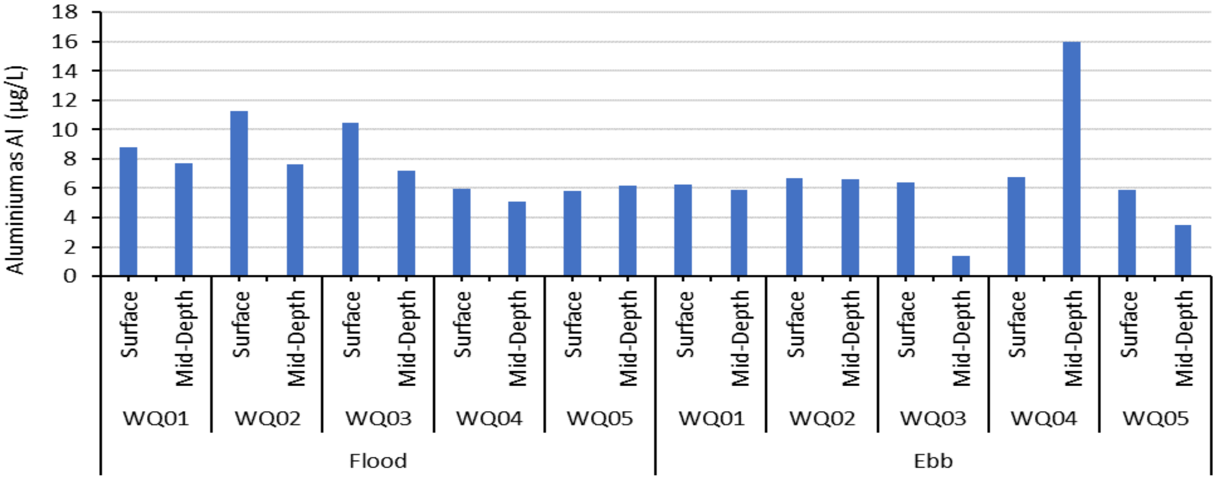



*Figure 7-43: Aluminum recorded during water quality survey*

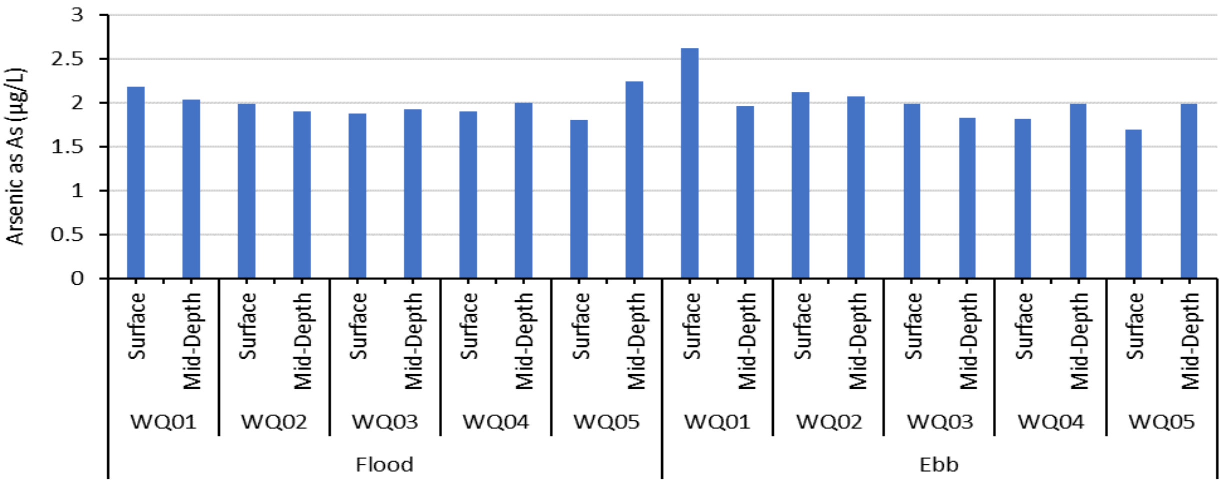



*Figure 7-44: Arsenic recorded during water quality survey*

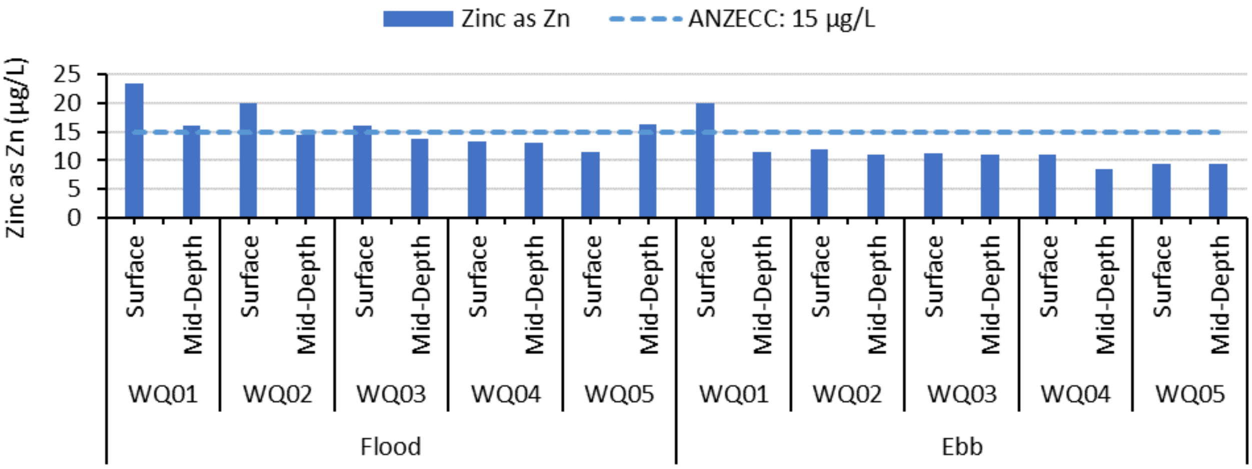



*Figure 7-45: Zinc recorded during water quality survey*

*Table 7-12: Ex-situ marine water quality results during Flood tide on 24 Nov 2022*

| Test Parameters | Units | WQ01 | | WQ02 | | WQ03 | | WQ04 | | WQ05 | | MDL | ASEAN MWQC | ANZECC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Surface | Mid depth | Surface | Mid depth | Surface | Mid depth | Surface | Mid depth | Surface | Mid depth | | | |
| Total Suspended Solids, TSS | mg/L | 5.80 | 5.90 | 5.80 | 3.00 | 7.90 | 4.10 | 4.70 | 6.50 | 7.20 | 6.40 | 1 | <10% increase over seasonal average | N.A. |
| Total Nitrogen, TN | mg/L | 0.231 | 0.240 | 0.312 | 0.220 | 0.390 | 0.331 | 0.464 | 0.349 | 0.489 | 0.268 | 0.01 | N.A. | N.A. |
| Nitrate as $NO_3$-N | mg/L | 0.064 | 0.074 | 0.097 | 0.062 | 0.059 | 0.067 | 0.081 | 0.070 | 0.061 | 0.073 | 0.01 | 0.06 mg/l | N.A. |
| Phosphate as $PO_4$-P | mg/L | 0.025 | 0.019 | 0.023 | 0.019 | 0.020 | 0.018 | 0.022 | 0.019 | 0.018 | 0.019 | 0.01 | 0.015 mg/L | N.A. |
| Total Phosphorus, TP | mg/L | 0.027 | 0.020 | 0.026 | 0.020 | 0.025 | 0.019 | 0.024 | 0.020 | 0.020 | 0.020 | 0.01 | N.A. | 0.015 mg/L |
| Ammonia as $NH_3$-N | mg/L | 0.039 | 0.019 | 0.020 | 0.019 | 0.019 | 0.020 | 0.024 | 0.020 | 0.021 | 0.019 | 0.01 | 0.07 mg/l | N.A. |
| Aluminum as Al | µg/L | 8.77 | 7.68 | 11.30 | 7.64 | 10.44 | 7.23 | 5.94 | 5.11 | 5.80 | 6.18 | 0.1 | N.A. | N.A. |
| Arsenic as As | µg/L | 2.18 | 2.03 | 1.99 | 1.91 | 1.88 | 1.93 | 1.90 | 1.99 | 1.80 | 2.24 | 0.1 | N.A. | N.A. |
| Cadmium as Cd | µg/L | ND | ND | ND | ND | ND | 0.119 | ND | ND | ND | ND | 0.1 | 10 µg/L | N.A. |
| Chromium as Cr | µg/L | 4.224 | 4.06 | 3.98 | 4.16 | 4.27 | 3.89 | 4.00 | 4.09 | 4.19 | 4.63 | 0.1 | 50 µg/L | N.A. |
| Copper as Cu | µg/L | 17.09 | 12.33 | 12.71 | 11.29 | 10.51 | 12.02 | 10.12 | 11.32 | 9.66 | 9.65 | 0.5 | 8 µg/L | N.A. |
| Lead as Pb | µg/L | 0.28 | 0.18 | 0.23 | ND | ND | 0.18 | 0.32 | ND | 0.14 | ND | 0.1 | 8.5 µg/L | N.A. |
| Mercury as Hg | µg/L | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.05 | 0.16 µg/L | N.A. |
| Nickel as Ni | µg/L | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 1 | N.A. | 70 µg/L |
| Zinc as Zn | µg/L | 23.5 | 16.1 | 19.9 | 14.5 | 16.1 | 13.7 | 13.3 | 13.1 | 11.6 | 16.2 | 0.5 | N.A. | 15 µg/L |
| Biochemcial Oxygen Demand, $BOD_5$ | mg/L | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 1 | N.A. | N.A. |
| Chlorophyll-a | µg/L | 0.32 | 1.51 | 1.73 | 0.46 | 1.51 | 0.44 | 0.47 | 1.58 | 1.17 | 1.28 | 0.1 | N.A. | 0.7-1.4 µg/L |
| Oil & Grease | mg/L | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.1 | 0.14 mg/L | N.A. |
| Faecal Coliform | MPN/100mL | ND | 2 | ND | 4.5 | ND | 13 | 4 | 13 | 6.8 | 6.8 | 1.8 | 100 MPN/100 mL | 150 MPN/100 mL |
| E.Coli | MPN/100mL | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 1 | N.A. | N.A. |

**Note:**
(1) [pink box] – Exceedance of ASEAN MWQC
(2) [yellow box] – Exceedance of ANZECC
(3) N.A – Not Available

*Table 7-13: Ex-situ marine water quality results during Ebb tide on 24 Nov 2022*

| Test Parameters | Units | WQ01 | | WQ02 | | WQ03 | | WQ04 | | WQ05 | | MDL | ASEAN MWQC | ANZECC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Surface | Mid depth | Surface | Mid depth | Surface | Mid depth | Surface | Mid depth | Surface | Mid depth | | | |
| Total Suspended Solids, TSS | mg/L | 23.70 | 5.20 | 4.30 | 3.40 | 6.90 | 5.30 | 1.20 | 6.00 | 12.00 | 1.90 | 1 | <10% increase over seasonal average | N.A. |
| Total Nitrogen, TN | mg/L | 0.493 | 0.343 | 0.623 | 0.270 | 0.310 | 0.281 | 0.299 | 0.243 | 0.427 | 0.211 | 0.01 | N.A. | N.A. |
| Nitrate as $NO_3$-N | mg/L | 0.059 | 0.068 | 0.053 | 0.056 | 0.054 | 0.054 | 0.059 | 0.057 | 0.063 | 0.068 | 0.01 | 0.06 mg/l | N.A. |
| Phosphate as $PO_4$-P | mg/L | 0.020 | 0.019 | 0.021 | 0.017 | 0.020 | 0.018 | 0.019 | 0.018 | 0.020 | 0.018 | 0.01 | 0.015 mg/L | N.A. |
| Total Phosphorus, TP | mg/L | 0.022 | 0.022 | 0.026 | 0.021 | 0.025 | 0.020 | 0.022 | 0.018 | 0.022 | 0.019 | 0.01 | N.A. | 0.015 mg/L |
| Ammonia as $NH_3$-N | mg/L | 0.020 | 0.019 | 0.021 | 0.021 | 0.023 | 0.024 | 0.022 | 0.020 | 0.020 | 0.021 | 0.01 | 0.07 mg/l | N.A. |
| Aluminum as Al | µg/L | 6.25 | 5.87 | 6.71 | 6.62 | 6.38 | 1.42 | 6.77 | 16.01 | 5.91 | 3.46 | 0.1 | N.A. | N.A. |
| Arsenic as As | µg/L | 2.62 | 1.96 | 2.13 | 2.07 | 1.99 | 1.82 | 1.82 | 1.99 | 1.69 | 1.99 | 0.1 | N.A. | N.A. |
| Cadmium as Cd | µg/L | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.104 | 0.1 | 10 µg/L | N.A. |
| Chromium as Cr | µg/L | 3.92 | 3.61 | 4.00 | 4.34 | 4.08 | 3.62 | 4.46 | 4.36 | 3.81 | 3.73 | 0.1 | 50 µg/L | N.A. |
| Copper as Cu | µg/L | 16.42 | 11.37 | 9.98 | 9.35 | 9.91 | 8.57 | 8.85 | 8.06 | 9.39 | 8.00 | 0.5 | 8 µg/L | N.A. |
| Lead as Pb | µg/L | 0.18 | ND | ND | ND | ND | 0.13 | ND | ND | ND | ND | 0.1 | 8.5 µg/L | N.A. |
| Mercury as Hg | µg/L | 0.096 | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.05 | 0.16 µg/L | N.A. |
| Nickel as Ni | µg/L | ND | ND | 1.09 | ND | ND | ND | ND | ND | ND | ND | 1 | N.A. | 70 µg/L |
| Zinc as Zn | µg/L | 20.0 | 11.5 | 12.0 | 10.9 | 11.1 | 11.0 | 10.9 | 8.43 | 9.44 | 9.35 | 0.5 | N.A. | 15 µg/L |
| Biochemcial Oxygen Demand, BOD5 | mg/L | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 1 | N.A. | N.A. |
| Chlorophyll-a | µg/L | 0.30 | 1.00 | 1.73 | 1.58 | 0.74 | 1.40 | 1.27 | 0.93 | 0.45 | 0.99 | 0.1 | N.A. | 0.7-1.4 µg/L |
| Oil & Grease | mg/L | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.1 | 0.14 mg/L | N.A. |
| Faecal Coliform | MPN/100mL | ND | ND | ND | ND | 2 | 6.8 | 4 | 4.5 | 4.5 | 7.8 | 1.8 | 100 MPN/100 mL | 150 MPN/100 mL |
| *E. Coli* | MPN/100mL | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 1 | N.A. | N.A. |

**Note:**
(4) [pink box] – Exceedance of ASEAN MWQC
(5) [yellow box] – Exceedance of ANZECC
(6) N.A – Not Available

## 7.2 Ecological Environment

### 7.2.1 Plankton Assemblage

Plankton are the diverse collection of organisms found in the water and form the base of most marine food webs, providing food directly and indirectly for nearly every marine organism. Marine phytoplankton are the autotrophs component of the plankton community, and they are basis of the whole marine ecosystems (Wang and Liu, 2022), they are the primary producers in the marine ecosystem, and they fix solar energy by photosynthesis, use carbon dioxide, nutrients and trace elements for production and growth. Zooplankton on the other hand, are the animal component of the plankton community. Zooplankton encompass an array of macro and microscopic animals and comprise representative of almost all major taxa and plays a vital role in the marine food chain.

Surveys for both phytoplankton and zooplankton were carried out alongside the water quality sampling survey. Phytoplankton samples were collected using a water sampler at 1 m depth and for zooplankton, a vertical plankton tow was used to sample the water column. The results are presented in the following sections.

#### 7.2.1.1 Phytoplankton

During the phytoplankton sampling on the 24 Nov 2022, phytoplankton observed were low, with a total abundance ranging from 2.00 cells/ mL to 14.00 cells/ mL. With the most dominant species observed was *Chaetoceros* sp. observed at WQ01 andWQ02 during flood tide and at WQ02 and WQ03 during ebb tide. No harmful phytoplankton have been observed and recorded during the 24-Nov-2022 sampling.

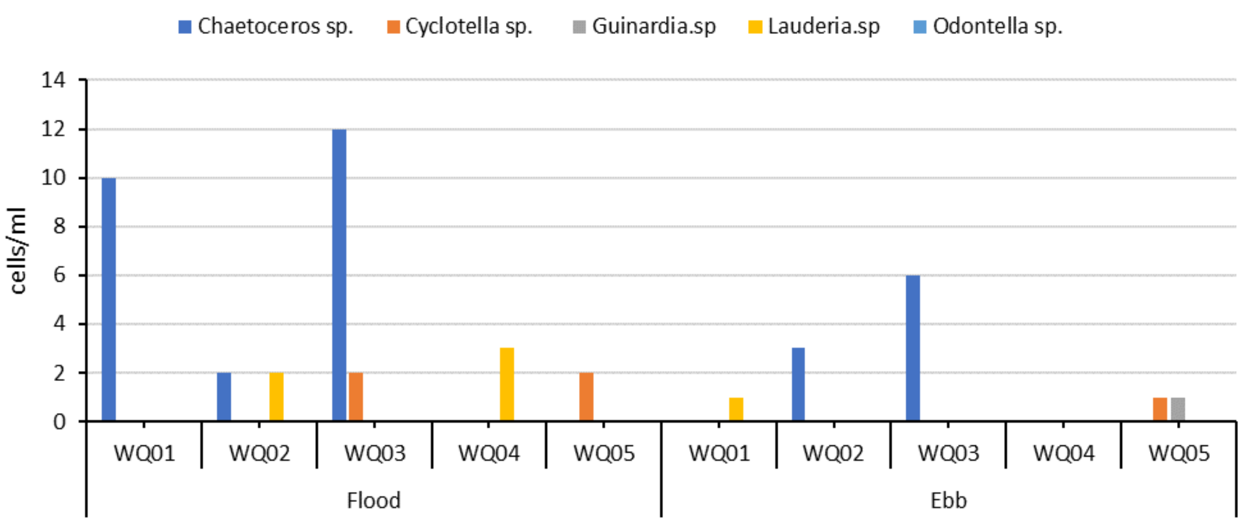



*Figure 7-46: Phytoplankton observed during the water quality sampling*

#### 7.2.1.2 Zooplankton

The abundance of zooplankton abundance during the 24 Nov 2022 sampling varied from 0.47 org/m$^3$ (WQ05, ebb tide) to 5,872.07 org/m$^3$ (WQ01, flood tide), with the most abundant organism observed are the *Copepod nauplii, Oithona* sp., and *F.Paracalanidae copepod.* No harmful zooplankton have been observed and recorded during the 24 Nov 2022 sampling.

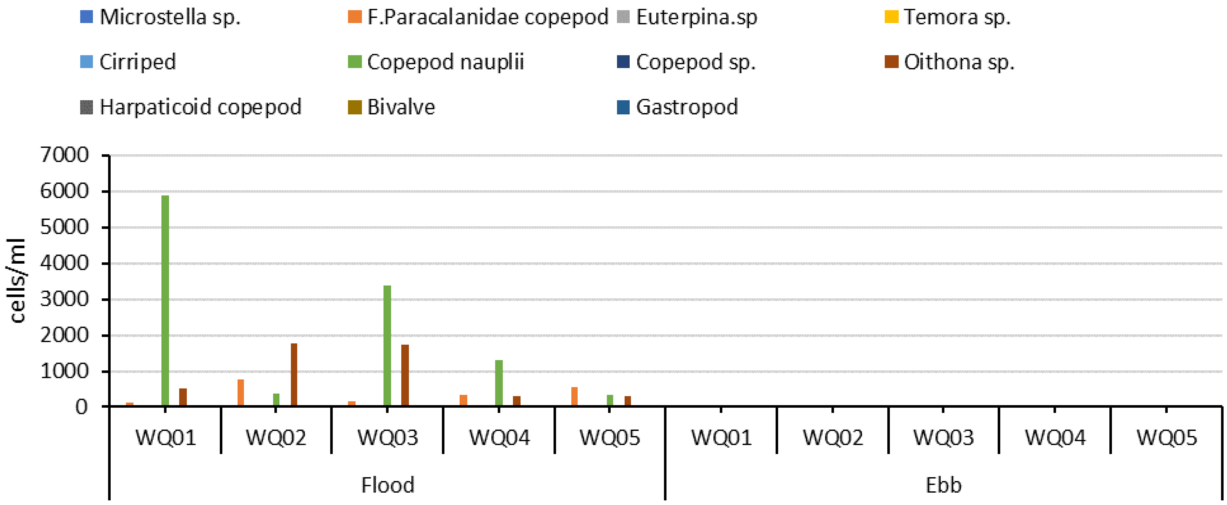



*Figure 7-47: Zooplankton observed during the water quality sampling*

### 7.2.2 Terrestrial Biodiversity

For terrestrial biodiversity, the two (2) primary Acts in Singapore are the Parks and Trees Act 2005 (2020 revised edition) and Wildlife Act 1965 (2020 Revised edition).

#### 7.2.2.1 Flora

The Parks and Trees Act 2005 (2020 revised edition) is an Act is under the NParks purview, to provide for protection of biodiversity, habitats, and planting, maintenance and conservation of trees and plants within national parks, nature reserves, tree conservation areas, heritage road green buffers and other specified areas.

Applicable aspects of the Parks and Trees Act 2005 (2020 revised edition) are as follows:

- Relating to the removal of trees on vacant land (whether within or outside a tree conservation area) that are greater than 1 m in girth or any trees in the Tree Conservation Area (TCA). Special permission may be required from the NParks commissioner of parks and recreation if it falls within this category; and
- Relating to restricted activities carried out in nature reserves.

A tree inventory was established and was outlined in Table 7-14 and Figure 7-48.

*Table 7-14: List of species*

| Latin Name | Common Name | Origin | Conservation Status[2,3] |
|---|---|---|---|
| *Acacia auriculiformis* | Ear-leaf Acacia | Exotic | Not Applicable |
| *Casuarina equisitifolia* | Casuarina Tree | Native | Least Concern |
| *Spathodea campanulata* | African Tulip Tree | Exotic | Not Applicable |
| *Elaeis guineensis* | Oil Palm | Exotic | Not Applicable |
| *Terminalia catappa* | Sea almond | Native | Least Concern |

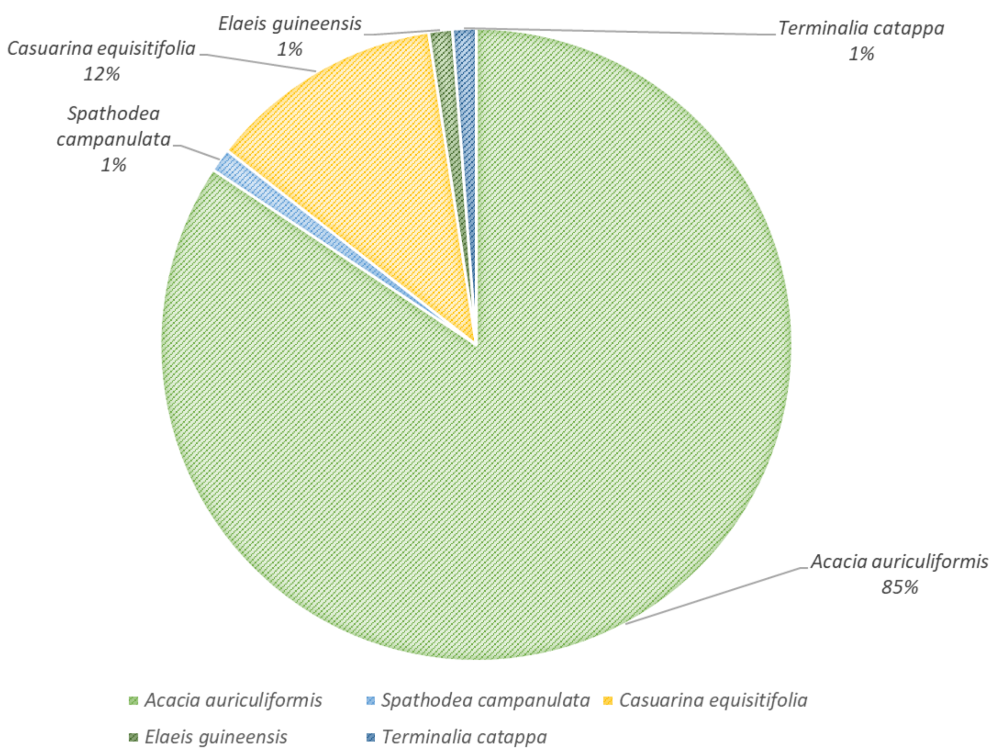



*Figure 7-48: Trees identified within the Project footprint and boundary*

All living trees with a trunk girth or circumference of more than 30cm were mapped. This had been carried out in accordance with the Land Surveyors Board (LSB) directive Section 6.5. In total, 83 trees were observed

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[2] Conservation Status of the species is referenced from "Singapore Red Data Book 3rd Ed, 2023"

[3] Status of non-native species as referenced from "Flora of Singapore: Checklist and bibliography, 2022" (Lindsay, et al., (2022))

| Latin Name | Status |
|---|---|
| *Acacia auriculiformis* | Naturalised |
| *Spathodea campanulata* | Naturalised |
| *Elaeis guineensis* | Casual |

during survey within the Project footprint and roadside. *Acacia auriculiformis* (Ear-leaf Acacia) (85%) was the most encountered species throughout the project study area, followed by *Casuarina equisitifolia* (Casuarina Tree) (12%), *Spathodea campanulata* (African Tulip Tree) (1%), *Elaeis guineensis* (Oil Palm) (1%), and *Terminalia catappa* (sea almond) (1%).

7 trees are proposed to be retained, and 76 trees identified within the Project footprint are proposed to be removed (Figure 7-49). Of these 76 trees, 19 trees have girth of more than 1 m, with majority species being *Acacia auriculiformis* and *Casuarina equisitifolia*. Example of land vegetation found within, and roadside of the Project can be seen in Figure 7-50. Approval was obtained from NParks for the tree felling activities during the preparation of the EIA report. In accordance with the requirements for this approval, a tree survey on the project site was conducted for the tree-felling submission and the designated trees to be felled were visibly tagged prior to the commencement of tree felling operations. Additionally, a pre-felling fauna survey had been conducted to confirm that there were no fauna, active nests, or burrows on the trees and within the vicinity, before any tree felling activities take place.

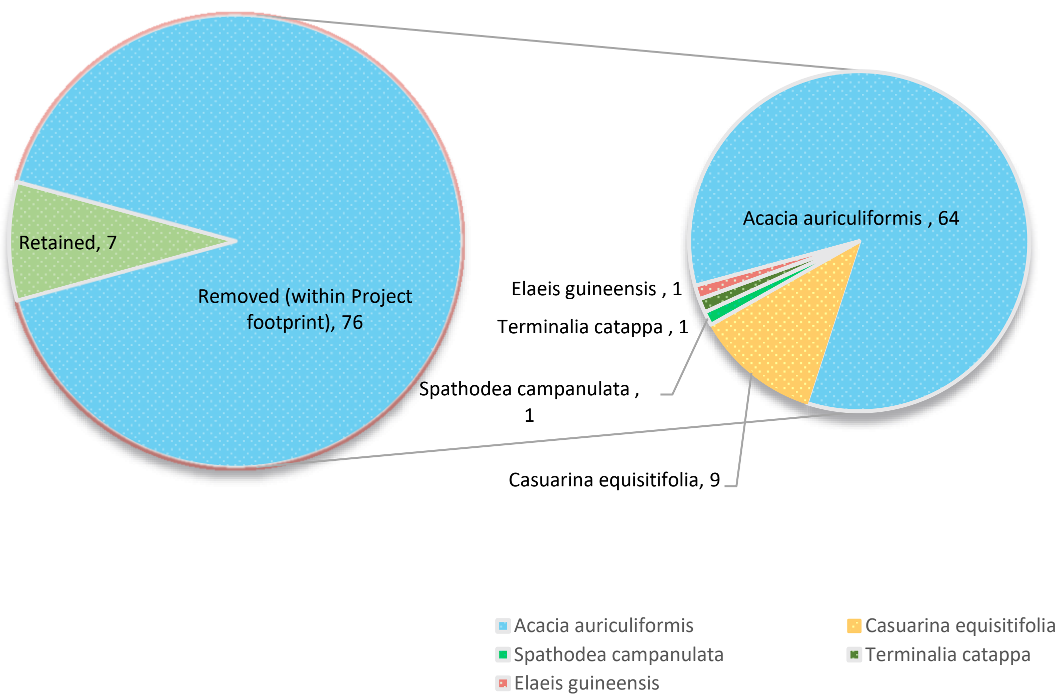



*Figure 7-49: Trees proposed to be removed and retained*

*Casuarina equisitifolia*

*Acacia auriculiformis*

*Spathodea campanulata*

*Elaeis guineensis*

*Figure 7-50: Example of trees found within the Project footprint and roadside*

#### 7.2.2.2 Wildlife

Wildlife Act 1965 (2020 revised edition) is an Act for the protection, preservation, and management of wildlife for the purposes of maintaining a healthy ecosystem and safeguarding public safety and health, and for related matters. The act prohibits feeding of wildlife, releasing of wildlife, killing, trapping, taking, or keeping of wildlife, etc.  many more.

While no terrestrial wildlife was noted during the tree inventory process, this does not preclude the potential occurrence of wildlife within the site. Therefore, mitigating measures are recommended for the construction phase, including checking for wildlife presence during site clearance activities to ensure that wild animals and birds are no longer present. NParks (Wildlife Management Division) should be consulted on action(s) to be taken if wildlife is encountered on site. Should any fauna be encountered within the work site, they are to be relocated to suitable locations as advised by NParks.

## 7.3 Socioeconomics

Socioeconomic environment refers to a wide range of interrelated and diverse aspects and variables relating to or involving a combination of social and economic factors, and it helps to identify and evaluate the potential socio-economic and cultural impacts of a proposed development on the lives and circumstances of people, and communities.

### 7.3.1 Economy

The proposed development Project is located along Sakra Avenue in Jurong Island, Singapore.  Jurong Island is a manmade island formed through successive land reclamation works that joined up several island and is transformed into a designated industrial zone. Jurong Island is Singapore’s designated petrochemical hub, serving as a base of operations for over 100 leading chemical and energy companies.

### 7.3.2 Land and Marine Environment

As illustrated in Figure 7-51, the land uses within the 3 km buffer radius from the Project site primarily used for industrial purpose. As stated in the URA Masterplan 2019, the land use is classified under Business 2. The choice of an offshore location like Jurong Island to host special industries helped ensure adequate buffer distances between residential and industrial land use, therefore establishing a precedence of minimising nuisances. The land use at the immediate adjacent to the Project are indicated in Table 7-15. As the site is located at the industrial area, there are no residential and buildings/ structure of cultural heritage importance within the 3 km radius.

The marine environment receptors for this project that is located close to the Project development comprised primarily of navigational areas (e.g., fairways) and various marine facilities (e.g., jetties, terminals, industrial, and intakes) within 2.71 km.

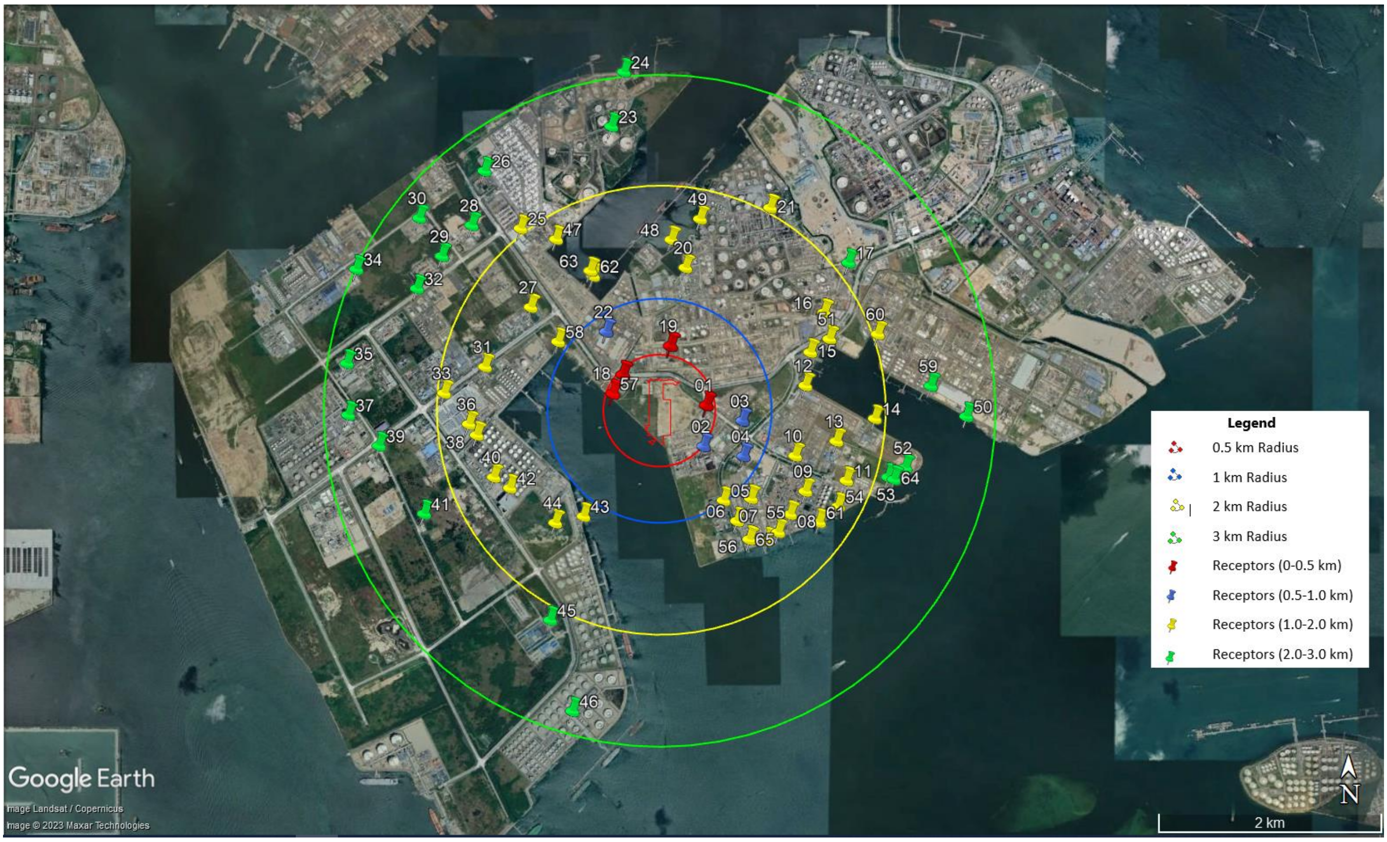



*Figure 7-51:Location of receptors within the 0.5 km, 1km, 2km and 3km radius*

*Table 7-15: List of receptors within the 0.5 km, 1km, 2km and 3km radius*

| ID | Receptor | Distant (km) | Direction from the Project boundary |
|---|---|---|---|
| **500 m** | | | |
| 1 | Mitsui Phenols | 0.37 km | East |
| 18 | Underground Storage (extension of Jurong Rock Caverns Singapore) | 0.44 km | Northwest |
| 57 | EM Banyan 1 Outfall | 0.46 km | West |
| 19 | ExxonMobil Chemical Plant | 0.48 km | North |
| **500 m – 1km** | | | |
| 2 | Asahi Kasei Plastics | 0.54 km | Southeast |
| 3 | Chemical Industries (Far East) | 0.72 km | Southeast |
| 22 | Tanjong Pangkong | 0.78 km | Northwest |
| 4 | Acez Instruments | 0.89 km | Southeast |

| ID | Receptor | Distant (km) | Direction from the Project boundary |
|---|---|---|---|
| **1km to 2km** | | | |
| 5 | SembCorp EFW | 1.05 km | Southeast |
| 58 | EM Banyan 2 Outfall | 1.07 km | Northwest |
| 20 | Infineum Singapore | 1.14 km | North |
| 7 | Chevron Oronite | 1.17 km | Southeast |
| 12 | Sumitomo Chemical | 1.22 km | East |
| 62 | EM Pesek 1 Intake | 1.25 km | Northwest |
| 6 | SembCorp Gas | 1.27 km | Southeast |
| 10 | Lucite International | 1.27 km | Southeast |
| 43 | Bayan Storage Services | 1.29 km | Southwest |
| 63 | EM Pesek 2 Intake | 1.31 km | Northwest |
| 15 | Oasis @ Sakra | 1.34 km | Northeast |
| 27 | SI Group – Singapore/ BASF | 1.40 km | Northwest |
| 48 | EM Pesek 3 Outfall | 1.41 km | North |
| 56 | Chevron Oronite Outfall | 1.46 km | Southeast |
| 9 | Celanese (S) VAM | 1.49 km | Southeast |
| 44 | Jurong Rock Caverns Singapore | 1.49 km | Southwest |
| 8 | Sembcorp Cogen | 1.50 km | Southeast |
| 51 | Selat Sakra Outfall | 1.57 km | Northeast |
| 55 | SembCorp 2 Outfall | 1.57 km | Southeast |
| 65 | Chevron Oronite Intake | 1.57 km | Southeast |
| 13 | Evonik | 1.59 km | Southeast |
| 16 | Air Liquide J8 | 1.60 km | Northeast |
| 31 | Vopak Terminals Singapore | 1.63 km | Northwest |
| 49 | EM Pesek 2 Outfall | 1.63 km | North |
| 42 | LTH Logistics Singapore | 1.65 km | Southwest |
| 47 | EMC I Outfall | 1.72 km | Northwest |
| 40 | 121 Banyan Dr | 1.74 km | Southwest |
| 36 | Katoen Natie Singapore (Jurong) | 1.76 km | Southwest |
| 38 | U&P Jurong Island | 1.77 km | Southwest |

| ID | Receptor | Distant (km) | Direction from the Project boundary |
|---|---|---|---|
| 61 | SembCorp Industries Intake | 1.77 km | Southeast |
| 11 | Vopak Singapore – Sakra Terminal | 1.80 km | Southeast |
| 54 | SembCorp 1 Outfall | 1.83 km | Southeast |
| 14 | Unimatec Singapore | 1.89 km | Southeast |
| 21 | ExxonMobil Asia Pacific | 1.93 km | Northeast |
| 60 | PCS A Intake | 1.99 km | Northeast |
| **2km to 3km** | | | |
| 17 | Exxon PAC | 2.02 km | Northeast |
| 25 | Pulau Pesek Kecil | 2.02 km | Northwest |
| 33 | Resin & Pigment Technologies | 2.03 km | West |
| 53 | Invista 2 Outfall | 2.13 km | Southeast |
| 64 | Invista Intake | 2.18 km | Southeast |
| 45 | TSAnderco Dormitory | 2.20 km | Southwest |
| 52 | Invista 1 Outfall | 2.25 km | Southeast |
| 28 | KPW Singapore | 2.27 km | Northwest |
| 29 | Gashubunited Utility | 2.34 km | Northwest |
| 41 | Banyan Fire Station | 2.39 km | Southwest |
| 59 | PCS J Intake | 2.39 km | East |
| 32 | CCD Singapore | 2.41 km | Northwest |
| 23 | Pulau Pesek | 2.46 km | Northwest |
| 26 | Institute Of Sustainability for Chemicals, Energy and Environment | 2.56 km | Northwest |
| 39 | Sembcorp SUT | 2.57 km | Southwest |
| 30 | Cogent Jurong Island Logistics Hub | 2.70 km | Northwest |
| 50 | PCS D Outfall | 2.71 km | East |
| 37 | SAR-2 ExxonMobil Chemical | 2.82 km | West |
| 35 | Arlanxeo Singapore | 2.86 km | Northwest |
| 46 | Jurong Port Universal Terminal | 2.86 km | Southwest |
| 24 | Pesek Control House | 2.92 km | Northwest |
| 34 | Triton Shoal | 3.05 km | Northwest |

# 8 Evaluation of Impacts

This section outlines the environmental issues associated with the Project's activities, throughout the construction and operation of the CCGT. The identified key issues are assessed to define the level of potential risk to the environment, and where necessary, proposed mitigation measure to reduce and/ or avoid the risk.

The following key environmental aspects are identified and are evaluated.

*Table 8-1: Key identified environmental aspects*

| Key environment | Construction (short term impact) | Operation (long term impact) |
|---|---|---|
| Ecological | • Sediment plume and sedimentation impacts on marine biodiversity due to trenching works. | • Thermal and chlorine plume impacts on marine biodiversity due to discharge from the CW system. |
| Socioeconomic | • Increase of suspended solid in water to intakes due to trenching activities<br>• Impacts to aquaculture facilities<br>• Impacts to international boundary<br>• Impact on human health<br>• Impacts to navigation and marine infrastructure due to increase of suspended solid sediment during trenching | • Impacts to hydrodynamic due to development of CW intake/ outfall<br>• Impacts on aquaculture facilities from the CW discharge<br>• Impact on human health<br>• Impacts to navigation due to change of local hydrodynamic |
| Physico-chemical | • Deterioration of water quality due to increase of suspended sediments in the water column due to trenching works<br>• Localized impact to coastal dynamics from trenching activities | • Deterioration of water quality due to CW discharge |

Short-term or temporary impacts are generated during the construction period when the trenching-induced sediment spill is transported and dispersed by currents and waves, generating sediment plumes which potentially can reach sensitive sites and receptors. The assessment is carried out for different representative seasonal conditions.

Long-term impacts are related to the long-term changes after the proposed development is in place and remained after the project is completed. At present, the long-term changes induced by the proposed development have been assessed for the following components:

- Excess seawater temperature; and
- Excess chlorine concentration.

Modelling is then used to quantify the impacts for the proposed Project using a range of specific models. The impacts are then translated and assessed using the RIAM tool. Detailed evaluations are presented in the following sections.

# 9 Coastal Dynamic

The coastal environment is governed by natural processes i.e., tides, surges, waves, and sediment transport that take place over a range of time scales. Any changes to the existing marine environment may alter the coastal dynamics and thus, numerical simulations are required to predict, quantify, and assess the impacts.

In view of the development of CW system, a coastal modelling is required to evaluate the potential long term and short-term impacts to the environment.

The once through CW system draws 105,000 $m^3$/ hr of seawater continuously and subsequently released back into sea via an outfall. A submerged intake head is to be installed at approximately 60 m seaward from shore where the seabed is -9.5 mCD. On the other hand, the outfall will be placed in a water depth of about -0.2 mCD, approximately 24 m from the shore.

The CW system design criteria and construction activities (trenching) indicated in Table 9-1 is used for coastal modelling.

*Table 9-1: Cooling water system design criteria*

| Parameter | Intake | Outfall |
|---|---|---|
| Location | 12328 Easting; 27048 Northing | 12291 Easting; 27138 Northing |
| Seabed level at head (mCD) | -9.5 | -0.2 |
| Flow rate ($m^3$/hr) | 105,000 | 105,000 |
| Residual chlorine concentration (ppm) | N.A. | Normal dosing: 0.25ppm<br>Shock dosing: 0.5ppm |
| Design discharge excess temperature increase (°C) | N.A. | +7 °C |
| Distance from shoreline (m) | 56 | 8 |

In carrying out the assessment, the following primary and secondary information are included in the model and more details can be found in Appendix B and Appendix C:

- Bathymetrical data;
- Wind data;
- ADCP current transect;
- Seabed sediment characteristics at selected locations;
- Tidal and wave data;
- Temperature and salinity data;
- Information on design criteria; and

- Information of the existing intake and outfall from Worley's past experience.

The details of the modelling tools, simulation scenarios, evaluation criteria, results, and assessment for each model assessment are described in following sections.

## 9.1 Evaluation Framework and Methodology

### 9.1.1 Modelling Tools

The following simulation tools and scenarios is applied to determine the impacts to the receptors.

*Table 9-2: Numerical model simulation tools*

| Item | Model used |
|---|---|
| Current | 3D MIKE3 HD-FM |
| Waves | MIKE21 SW |
| Sediment plume & sedimentation | 3D MIKE3 MT |
| Water Quality (thermal, chlorine) | 3D MIKE3 HD-FM +AD |

#### 9.1.1.1 Hydrodynamic Model

A three-dimensional (3D) modelling framework has been adopted to represent both horizontal and vertical circulation. The hydrodynamic (HD) model adopted the MIKE3 HD module for Worley's Hydrodynamic Model. Worley has built this local hydrodynamic model to provide the hydrodynamic conditions for the project site. This model has been extensively calibrated and validated with site measurements. This built hydrodynamic model has been used for a range of projects in the vicinity of the areas. For this project, the model was refined and further validated with the latest site measurements. The details of the model setup adopted sigma system, and input and calibration can be found in Appendix B and Appendix C.

#### 9.1.1.2 Wave Model

Wave modelling applied MIKE21 Spectral Wave (SW), which is a third-generation spectral wind-wave model based on unstructured mesh, which is particularly useful as it allows areas of interest to be refined in great detail whilst minimising computational demand. The model enables full time domain simulations, which are important for the present development site. MIKE21 SW allows for the simulation of growth, decay and transformation of wind-generated waves and swells in offshore and coastal areas. The fully spectral formulation is based on the wave action conservation equation, where the directional-frequency wave action spectrum is the dependent variable. Worley modified the existing Singapore Local Wave Model using MIKE21 SW modelling suite to incorporate the available bathymetric survey data and CMAP digital data into the model mesh refining the areas near the development to ensure the appropriate wave transferring to the development site. The details of the model setup and input and calibration can be found in Appendix B and Appendix C.

#### 9.1.1.3 Sediment Plume Model

The dispersion, transport and deposition of sediment from the Construction Works is being simulated with Worley's sediment plume model, coupled with Worley's validated Hydrodynamic model for the Project. The sediment plume model applies the MIKE3 coupled flexible mesh hydrodynamic modelling system to simulate the plume dispersion process, which the model utilises the MIKE3 MT multi fraction cohesive sediment transport module.

The MIKE3 MT module describes erosion, transport and deposition of mud or sand/mud mixtures under the action of currents, wind and waves. The bed is described as layered and characterised by the density and critical shear strength for erosion. For the sediment plume study, a one-layer approach has been applied to represent sedimentation from the plume.

As the MIKE3 MT model is dynamically coupled with the hydrodynamic model (MIKE3 HD) the sediment plume model adopts the same model domain as that used in the hydrodynamic model. The details of the model setup and input and calibration can be found in Appendix B.

#### 9.1.1.4 Thermal Plume Model

The thermal plume dispersion has been simulated using the further validated three dimensional (3D) Hydrodynamic Model. The large model domain allows an accurate representation of regional tides within the model, integral to ensuring that the tidal hydrodynamics in the Banyan Basin area are correctly characterised. Local winds and heat exchange between the ocean and atmosphere are also incorporated as model drivers. The Thermal Plume Model utilised the Advection-Dispersion module of the MIKE3 HD numerical modelling software package, run in temperature mode. The details of the model setup and input and calibration can be found in Appendix B.

#### 9.1.1.5 Chlorine Plume Model

The dispersion and transport of process water discharge from the outfall is simulated with Worley water quality model, coupled with Worley's validated Hydrodynamic model for the Project. The details of the model setup and input and calibration can be found in Appendix B.

### 9.1.2 Simulation Scenario

The project site is located within Basin or semi enclosed environment, and the nearshore current is influenced by local winds and regional flows. To capture the possible scenarios given by limited seasonal influence, the simulations are made over a 14-day peak spring-neap period during the Southwest (SW) monsoon. The SW monsoons given by the stronger wind condition is selected for modelling as the worst-case scenario. We have also performed additional modelling for the Northeast (NE) monsoon, which is included in this report.

It is expected that the findings of sediment plume, thermal, and chlorine model assessment during inter-monsoon period, will not be worse off than the findings presented for SW monsoon if simulated as shown in the memorandum of Hydrodynamic condition comparison between worst case scenario (SW monsoon) and inter-monsoon scenario (Appendix H). Thus, inter-monsoon scenario was not included for the present modelling study.

To capture the possible scenarios given by limited seasonal influence, the simulations are made over a 14-day peak spring-neap period during the NE and SW monsoon.

- Northeast (NE) monsoon: 10 Dec 2016 to 23 Dec 2016; and
- Southwest (SW) monsoon: 16 Jul 2016 to 29 Jul 2016.

The year 2016 is selected for simulation using a measured wind and air temperature data. Typically, compared to the wind data collected inland, the wind data from an open marine water/sea would be directly applied as a forcing input to the hydrodynamic model. It is because the inland wind including speed and direction will be affected by physical interference due to land/human-made objects. Based on our assessment, the wind data recorded at Semakau wind station is suitable and is applied in our simulation as it reflects the wind force over marine water.

#### 9.1.2.1 Hydrodynamic Model

The changes on current and its impact due to the construction have been investigated by comparing pre-construction and post-construction phase. Hydrodynamic model simulation scenarios are summarized in Table 9-3.

*Table 9-3: Hydrodynamic model simulation scenarios*

| Case | Monsoon | Simulation period | Remarks |
|---|---|---|---|
| Pre-construction | NE | 10 Dec 2016 to 23 Dec 2016 | Exclude the proposed intake/outfall flow |
| Pre-construction | SW | 16 Jul 2016 to 29 Jul 2016 | Exclude the proposed intake/outfall flow |
| Post-construction | NE | 10 Jul 2016 to 23 Dec 2016 | Include the proposed intake/outfall flow |
| Post-construction | SW | 16 Jul 2016 to 29 Jul 2016 | Include the proposed intake/outfall flow |

##### 9.1.2.1.1 Thermal Plume Model

The development of CW outfall causes thermal release impact to the surrounding due to the heated water discharge via the outfall.

The designed outfall discharge flow rate is 105,000 $m^3$/ hr with the maximum temperature rise in the CW system not exceeding 7 °C of the ambient seawater temperature. The CW system key information of the pipeline information as described in Table 9-4 is incorporated into the model.

The quantification of thermal impacts is presented as the increase of the excess temperature (i.e., temperature in excess of the ambient values) associated to the project-related release, as well as cumulative thermal release from outfall within the Basin.

The modelling results presents the thermal plume excursion as mean excess temperature calculated at surface and bottom layer. The water temperature nearer to the surface varies greater than the water temperature at the bottom layer due to a number of factors such as influences from solar radiation, wind, humidity and other meteorological conditions.

*Table 9-4: Intake and outfall information*

| Parameter | Intake | Outfall |
|---|---|---|
| Seabed level at head (mCD) | -9.5 | -0.2 |
| Flow rate ($m^3$/hr) | 105,000 | 105,000 |

| Parameter | Intake | Outfall |
|---|---|---|
| Design discharge excess temperature increase (°C) | - | +7 °C |
| Distance from shore (m) | 56 | 8 |

The impacts of the dispersal of the warm water discharge from the outfall have been analyzed for the design release flow rates of the proposed development. The following scenarios indicated in Table 9-5 are simulated.

*Table 9-5: Thermal plume model scenarios*

| Case | | Monsoon | Simulation period | Remarks |
|---|---|---|---|---|
| Pre-construction | | NE | 10 Dec 2016 to 23 Dec 2016 | Exclude the proposed intake/outfall flow |
| Pre-construction | | SW | 16 Jul 2016 to 29 Jul 2016 | Exclude the proposed intake/outfall flow |
| Post-construction | | NE | 10 Jul 2016 to 23 Dec 2016 | Include the proposed intake/outfall flow |
| Post-construction | | SW | 16 Jul 2016 to 29 Jul 2016 | Include the proposed intake/outfall flow |

#### 9.1.2.2 Chlorine Plume Model

Seawater is pumped from the seawater intake through the condenser of the open cycle CW system and discharged directly back to the sea at the outfall structure. A dedicated CW eletrochlorination system provided at the intake is to prevent biological growth and to maintain the desired water chemistry.

The ambient chlorine concentration is assumed to be 0 ppm and the model output is evaluated as the excess chlorine concentration above the ambient concentration.

The residual chlorine discharge key information of the pipeline is incorporated into the model includes:

*Table 9-6: Residual chlorine discharge information*

| Parameter | Value |
|---|---|
| Flow rate | 105,000 $m^3$/ hour |
| Residual chlorine release at discharge | Continuous: dosing during normal operation: 0.25 ppm/hour<br>Shock dosing: 0.5 ppm/hour for 20 minutes (maximum) |

Shock dosing is applied to prevent fouling species from adapting to the continuous chlorination. The residual chlorine concentration under normal and shock dosing concentration complies with the Singapore's Environmental Protection and Management (Trade Effluent) Regulations 2008 and USEPA (R.E.D. FACTS Chlorine gas).

The potential chlorine impact on the marine environment has been assessed by considering a constant outfall flow rate of 105,000 $m^3$/ hr, releasing:

- A 24-hour residual chlorine concentration of 0.25 ppm/hr (daily); and

- A 24-hour residual chlorine concentration of 0.5 ppm/hr (worst case/ conservative approach).

The impacts of the dispersal of the residual chlorine discharge from the outfall have been analyzed for the design release flow rates of the proposed development. The following four (4) scenarios indicated in Table 9-7 are simulated.

*Table 9-7: Chlorine plume model scenarios*

| Case | Monsoon | Simulation period | Remarks |
|---|---|---|---|
| Post-construction | NE | 10 Dec 2016 to 23 Dec 2016 | Include the proposed intake/outfall flow |
| Post-construction | SW | 16 Jul 2016 to 29 Jul 2016 | Include the proposed intake/outfall flow |
| Post-construction | NE | 10 Jul 2016 to 23 Dec 2016 | Include the proposed intake/outfall flow |
| Post-construction | SW | 16 Jul 2016 to 29 Jul 2016 | Include the proposed intake/outfall flow |

#### 9.1.2.3 Sediment Plume Model

Sediment plume impacts have primarily focused on the excursion of spill generated from the trenching activities. For the construction of CW system, trenching works are required for the construction of intake and therefore, it is considered in the sediment plume simulation. The construction of intake pipeline routes may cause generation of sediment plume.

The spill materials will be dispersed by the currents from the source points to the surrounding environment. The sediment spill is simulated as continuous and defined as moving near-bed source along the trench. The modelling has assumed that no mitigation is considered during the trenching works as a conservative estimate and the simulations carried out in excess concentrations with no inclusion of the background levels. Generally, the impacts associated with the trenching activities are considered short term and temporary.

The outfall structure is not considered in this assessment as the outfall will be constructed as a reinforced concrete (RC) boxed culvert at the shoreline of Banyan Bay, with no trenching activities.

The key information indicated in Table 9-8 for the pipeline is incorporated into the model.

*Table 9-8: Trenching work information*

| Parameter | Value |
|---|---|
| Trenching hours | 24 hours for 7 days per week |
| Volume per day | Daily Average: 1000$m^3$/day<br>Maximum: 5000$m^3$/day |
| Percentage of sediment fines (%) | 87.5 |
| Sediment wet density (T/$m^3$) | 1.91 |
| Spill rate | Grab dredger: 2.5%<br>Backfilling: 6% |

As a conservative approach, the trenching works are assumed to be carried out along the trench by using one (1) grab dredger (dredger bucket between 8 $m^3$ and 10 $m^3$) and the dredged material will be transfer out from site using hopper barge to dump at approved dumping ground. The pipeline will then be laid down in the trench and will be backfilled to cover the pipeline. The maximum production rate is 5,000$m^3$/day and we assume the backfilled volume is approximately 20,500$m^3$. This corresponds to 4.1 days of dredging and infilling work respectively; hence, the dredging and infilling work is likely to complete within 10.2 days based on equipment maximum daily rate.

The simulation was run over 14 days covering peak spring, ebb and intermediate tide during NE and SW monsoon, which deemed to cover the worst-case period for the construction activity. Should the construction period extend beyond 14 days, results will be unlikely to be worse off than results presented section 9.2.5.

The key information indicated in Table 9-9 for the trenching scenarios were incorporated into the model.

*Table 9-9: Sediment plume model scenarios*

| Case | Monsoon | Simulation period | Remarks |
|---|---|---|---|
| Typical daily production rate case | NE | 10 Dec 2016 to 23 Dec 2016 | • Daily production rate: 1000 m3 for dredging<br>• Daily working duration: 24 hours continuously 7 days a week for 20.5 number of days<br>• Simulation period: Model runs for 14 days (one spring-neap cycle) |
| Typical daily production rate case | SW | 16 Jul 2016 to 29 Jul 2016 | • 1000 m3 Daily as planned. Model runs for 14 days (one spring-neap cycle) |
| Maximum daily production rate | NE | 10 Dec 2016 to 23 Dec 2016 | • Model runs for 14 days = (4.1 days trenching at 5000m3/day +5.8 days deploying pipeline + 4.1 days backfilling at 5000m3/day) |
| Maximum daily production rate | SW | 16 Jul 2016 to 29 Jul 2016 | • Model runs for 14 days = (4.1 days trenching at 5000m3/day +5.8 days deploying pipeline + 4.1 days backfilling at 5000m3/day) |

### 9.1.3 Adopted Evaluation Criteria

#### 9.1.3.1 Current Model

The simulation results for the construction of outfall and intake pipeline routes are presented in the following section, which comprise of the:

- Change in current field
  - It is the instantaneous current speed at the peak ebb and flood of each tidal stage
  - The change in current speed is the product of post-construction – pre-construction

  - One of the most important assessments of changes in current conditions is that of the change in current fields. In particular, the generation of changes in the form of shear zones and eddies, is a key indicator of potential negative impacts to navigation.
- Mean current speed
  - It is the numerical mean of the 10-minutes current speeds at any given point over the 14-day peak spring-neap tidal cycle. Changes in mean current speed less than 0.05m/s are typically considered as 'No Change.'
  - The change in current speed is the product of post-construction – pre-construction
- Representative current speeds at 2 knots and 3.5 knots
  - The choice of representative current speed in the present context is as per MPA berthing and Fairway limit setting, respectively, which is recommended by Port designer's handbook, ICE (2018).
  - Exceedance is defined as the percentage of the time over the 14-day tide cycle, that the current speed (instantaneous 10-minutes stored value) is higher than the defined representative value, for example, the current is stronger than 2 knots and 3.5 knots.
  - The impact on percentage exceedance is defined as follows:

*Difference in exceedance (%) = % exceedance Post-Construction Case - % exceedance Pre-Construction Case*

#### 9.1.3.2 Thermal Plume Model

For assessing the thermal impacts to the environment, the following guidelines presented in Table 9-10 are adopted.

At the point of discharge, the maximum absolute effluent temperature must not be more than 45°C at point of its entry to watercourse based on the Singapore's Environmental Protection and Management (Trade Effluent) Regulations 2008. Prior to discharge, there are monitoring sensors established to ensure temperature does not exceed the criteria.

While for the receiving water, the ASEAN Marine Water Quality Criteria (MWQC) is adopted, in which the temperature shall not be more than 2°C over maximum ambient temperature

*Table 9-10: Water temperature impact criteria*

| Description | Guideline |
|---|---|
| **Point of discharge** | |
| Temperature shall not exceed 45°C at point of its entry to watercourse | Singapore's Environmental Protection and Management (Trade Effluent) Regulations 2008 |
| ASEAN MWQC | |
| The excess temperature increases not more than 2°C above the maximum ambient temperature | ASEAN MWQC |

#### 9.1.3.3 Chlorine Plume Model

To assess the potential impact associated with the chlorine release on environmental receptors, the impact criteria mentioned in Table 9-11 adopted.

*Table 9-11: Free chlorine impact criteria*

| Parameter | Description | Guideline |
|---|---|---|
| Free chlorine | Point of discharge<br>• Concentration of free chlorine shall not exceed 1mg/L at point of entry to watercourse | Singapore's Environmental Protection and Management (Trade Effluent) Regulations 2008 |
| | Receiving environment<br>• Level of concern for estuarine/marine organisms is 0.013 ppm | USEPA |

#### 9.1.3.4 Sediment Plume Model

To assess the potential impact associated with the sediment plume to environment, the impact criteria mentioned in Table 9-12 adopted.

*Table 9-12: Sediment plume impact criteria*

| Proposed Environmental Quality Objectives (EQOs) and Environmental Tolerance Limits (ETLs) based on receptors of concerned | | |
|---|---|---|
| **Environmental Receptor** | **EQO** | **ETL** |
| International boundary | No impact | • SSC > 10mg/L for less than 5% of the (12-hour daylight period) |
| Corals | No impact | • SSC > 5mg/L for less than 5% of the time<br>• Sedimentation < 1.7mm/14 days |
| Seagrass | No impact | • SSC > 5mg/L for less than 20% of the time<br>• Sedimentation < 0.25mm/day |
| Aquaculture facilities | No impact | • SSC > 5mg/L for less than 5% of the time<br>• Sedimentation < 1.7mm/14 days |
| Recreational Facilities | No impact | • SSC > 5mg/L for less than 2.5% per day (12-hour daylight period) |
| Marine facilities | No impact | • Sedimentation < 50mm/year or equivalent to 1.92 mm/ 14 days |

## 9.2 Impacts Assessment

### 9.2.1 Current Model

The quantification of the current impacts is presented as:

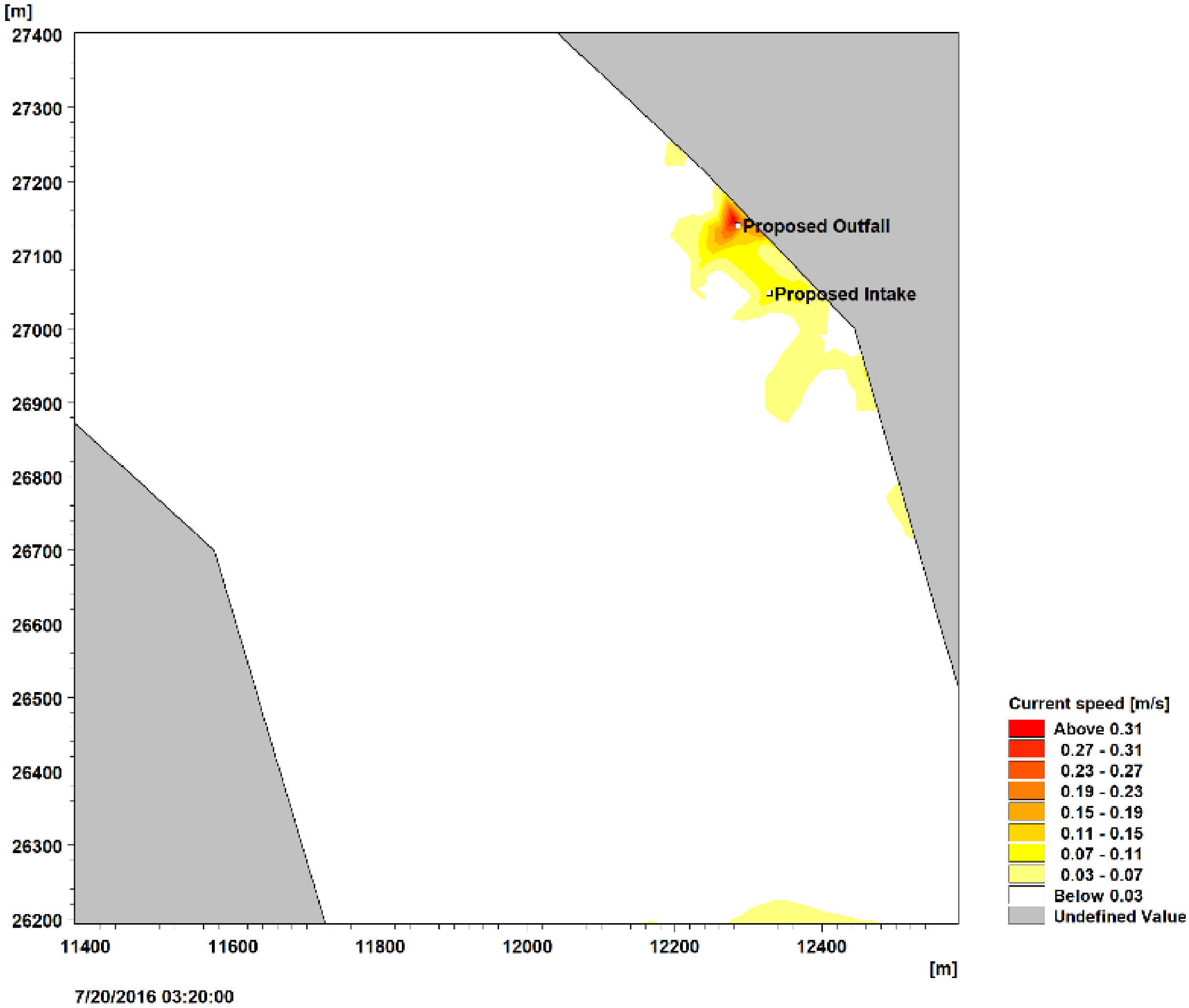
- Change in current field;
- Mean current speed; and
- Representative current speeds at 2 knots and 3.5 knots.

Based on the simulation results, it is observed that:

**Change in Current Field**

- For peak flood tide during the NE monsoon (Figure 9-1), the current patterns for pre-construction and post-construction cases are similar. There are no changes on currents along the Sinki Fairway, and the three (3) anchorages at the vicinity of the Project area, namely Selat Pauh Anchorage, Raffles Petroleum Anchorage, and Raffles Reserved Anchorage. The peak current changes are observed near the immediate areas of intake (up to 0.19 m/s) and outfall (up to 0.48 m/s). Such impact on currents is localized and impact areas are limited.
- For peak ebb tide during the NE monsoon (Figure 9-2), the current patterns for pre-construction and post-construction cases are similar. There are no changes on currents along the Sinki Fairway, and the three anchorages at the vicinity of the Project area, namely Selat Pauh Anchorage, Raffles Petroleum Anchorage, and Raffles Reserved Anchorage. The peak current changes are observed near the immediate areas of intake (up to 0.22 m/s) and outfall (up to 0.48 m/s). Such impact on currents is localized and impact areas are limited.

- During the SW monsoon (Figure 9-3 and




- Figure 9-4), the current changes are similar to the results of NE monsoon. There are no changes on currents along the Sinki Fairway, and the three anchorages at the vicinity of the Project area, namely Selat Pauh Anchorage, Raffles Petroleum Anchorage, and Raffles Reserved Anchorage. The current pattern changes are observed near the immediately areas of intake and outfall. The current impact is localized, and impact areas are limited.
- Within the Basin, eddy is expected to be formed around the intake and outfall area due to the higher discharge velocities from the outfall compared to the existing current flow. However, the eddy current magnitude is weaker and such impact on currents is localized, with impact areas limited and will not cause an impact on the navigation safety within Banyan Basin.

**Mean Current Speed**

- In order to provide an initial overview of the spatial impacts, it is productive to consider the effect of the development on the mean current conditions.
- The mean current speed (Figure 9-5 and Figure 9-6) is the numerical mean of the instantaneous (10 minute stored) current speeds, for each grid point of the model domain, over the 14-day modelled time frame.

- After completion of the intake and outfall development, the mean current speeds over 14-day have increased near the outfall and intake up to 0.23 m/s and 0.15 m/s respectively. However, such impact on currents is localized and impact areas are limited. There is essentially no impact on the mean current speed along the Sinki Fairway, and the three anchorages at the vicinity of the Project area, namely Selat Pauh Anchorage, Raffles Petroleum Anchorage, and Raffles Reserved Anchorage.

**Representative Current Speeds**

- Although current pattern and mean current speed provides appropriate measures to overview the spatial impacts caused by intake and outfall development, an alternative measure of the impact is provided by the exceedance of representative currents speeds as this introduces the important measure of duration of impact, which is judgement on navigation and anchorage impact assessment for vessels.
- Figure 9-7 and Figure 9-8 indicate that there are no impacts on the exceedance of 2 knots near the intake and outfall area, as well as along the Sinki Fairway, and the three anchorages at the vicinity of the Project area, namely Selat Pauh Anchorage, Raffles Petroleum Anchorage, and Raffles Reserved Anchorage.
- Figure 9-9 and Figure 9-10 indicate that there are no impacts on the exceedance of 3.5 knots near the intake and outfall area, as well as along the Sinki Fairway, and the three anchorages at the vicinity of the Project area, namely Selat Pauh Anchorage, Raffles Petroleum Anchorage, and Raffles Reserved Anchorage.

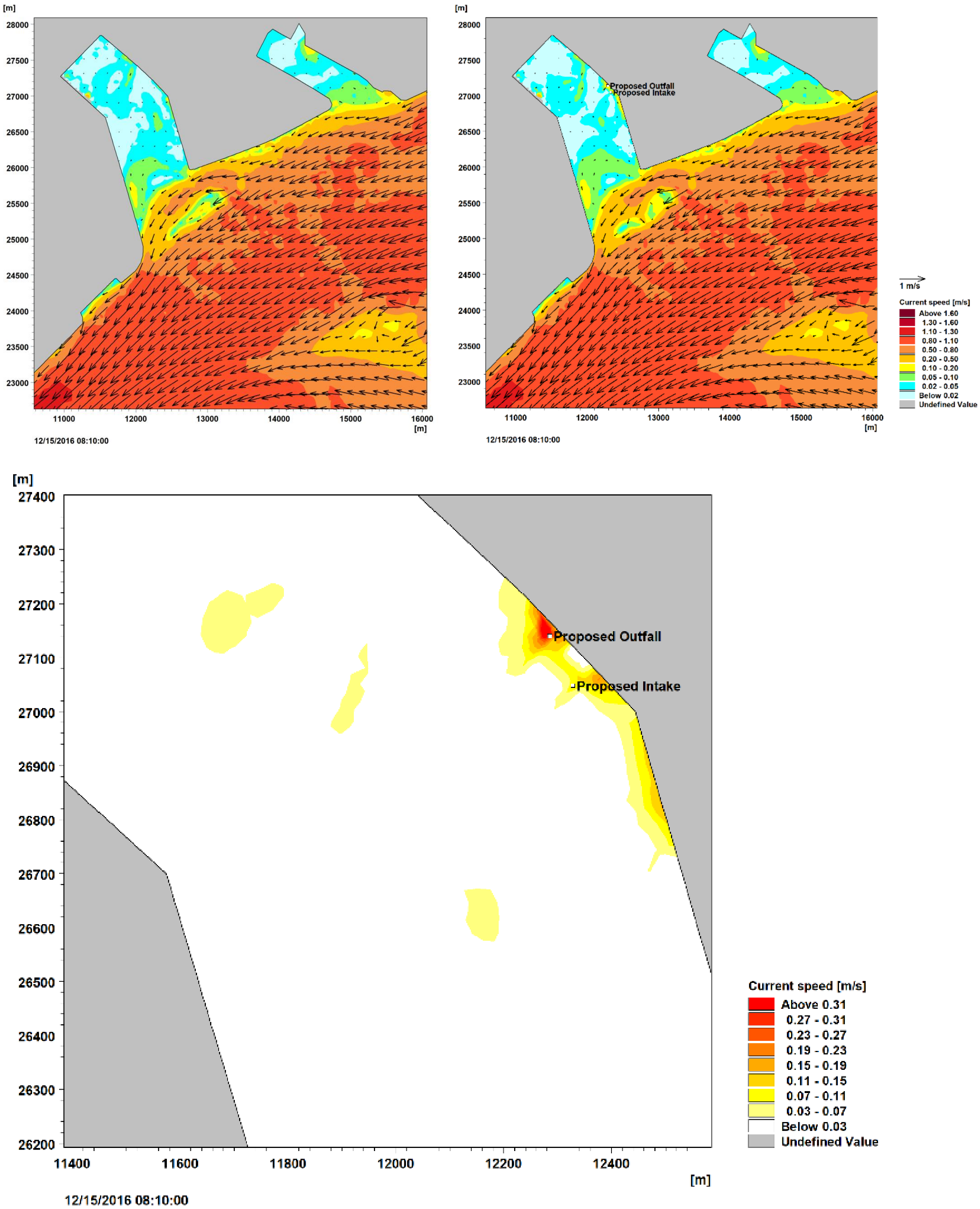



*Figure 9-1: Impact on current field, NE monsoon during peak flood tide. Top Left: Pre-construction Case, Top Right: Post-construction Case, Bottom: difference in current speed (Post-construction – Pre-construction)*

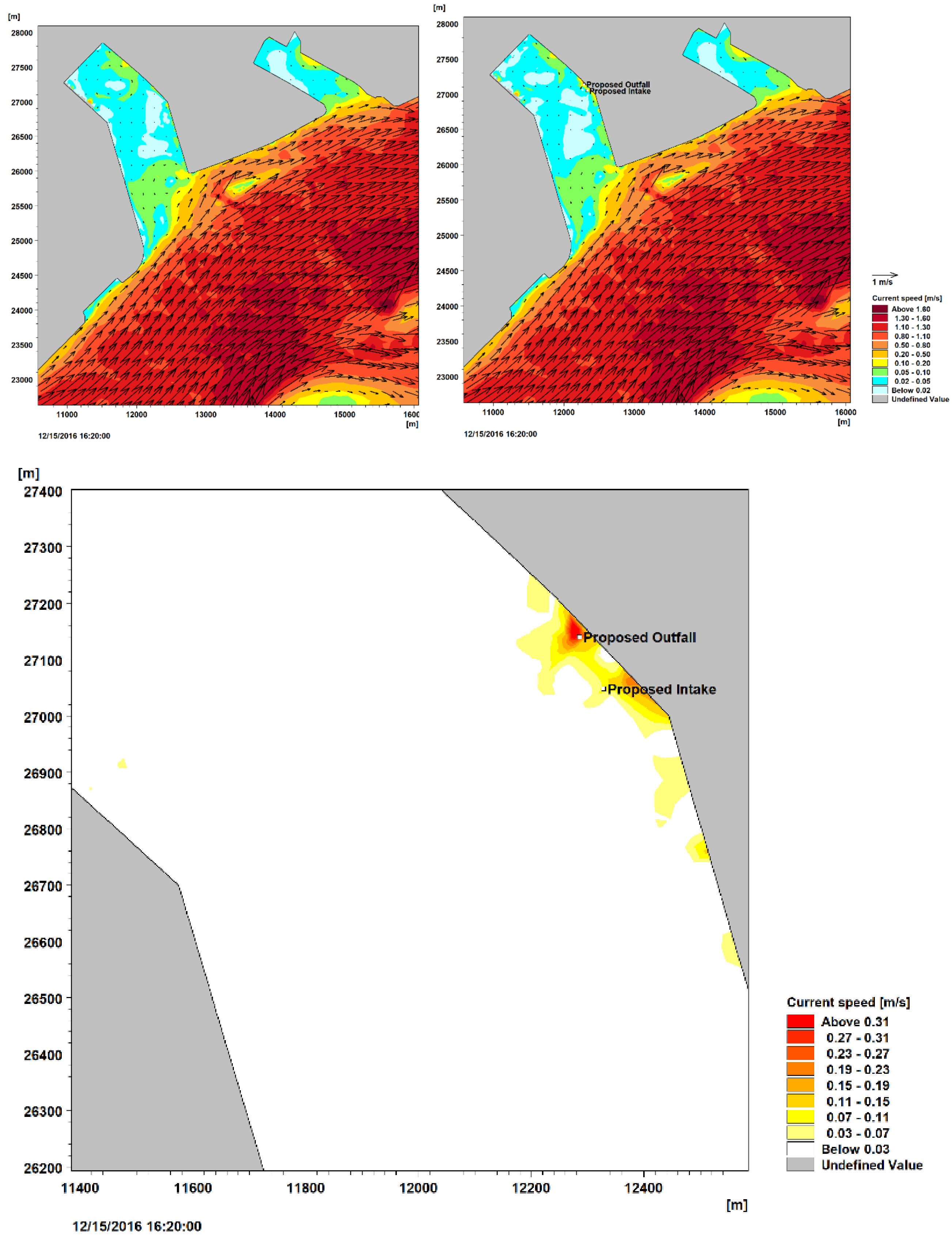



*Figure 9-2 Impact on current field, NE monsoon during Peak ebb tide. Top Left: Pre-construction Case, Top Right: Post-construction Case, Bottom: difference in current speed (Post-construction – Pre-construction)*

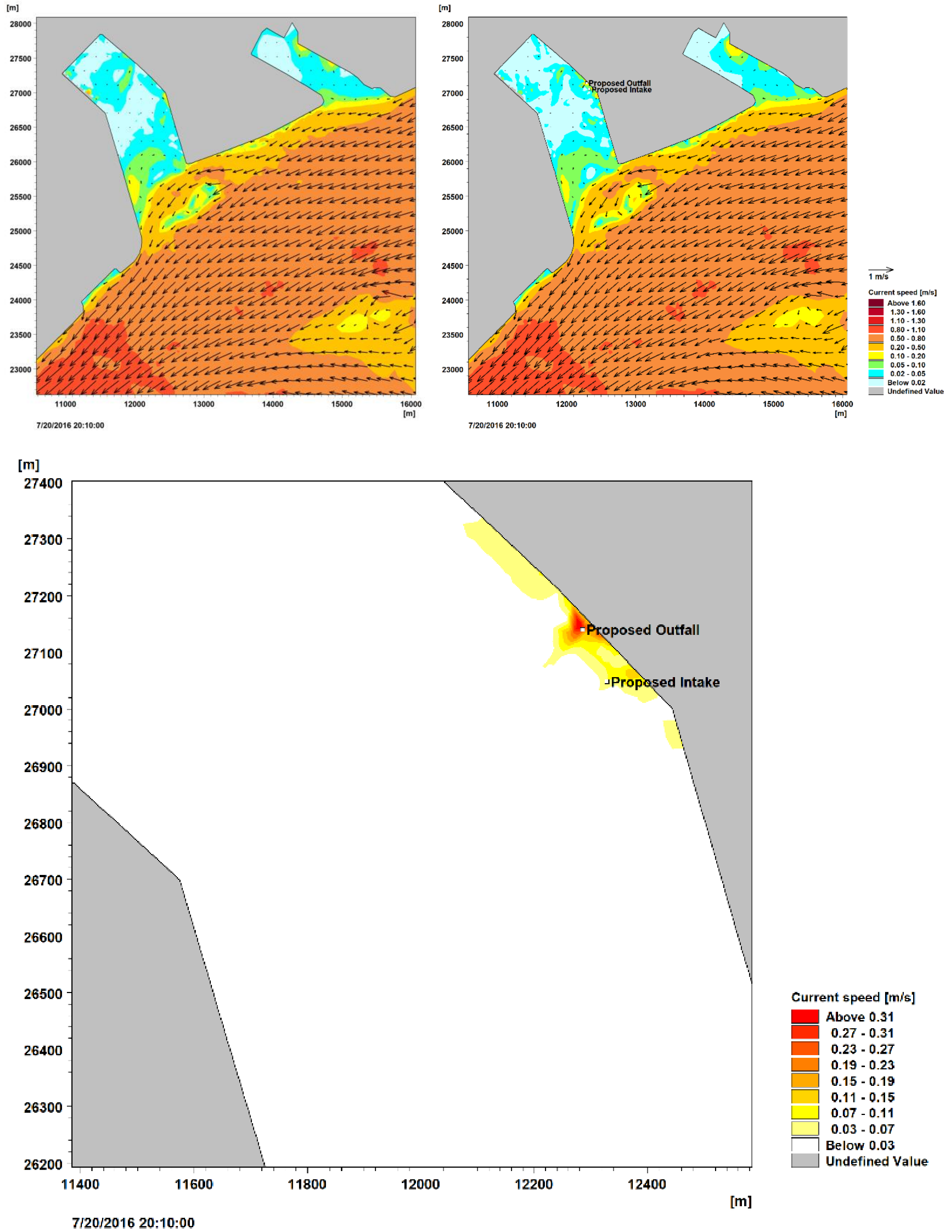



*Figure 9-3 Impact on current field, SW monsoon during peak flood tide. Top Left: Pre-construction Case, Top Right: Post-construction Case, Bottom: difference in current speed (Post-construction – Pre-construction)*

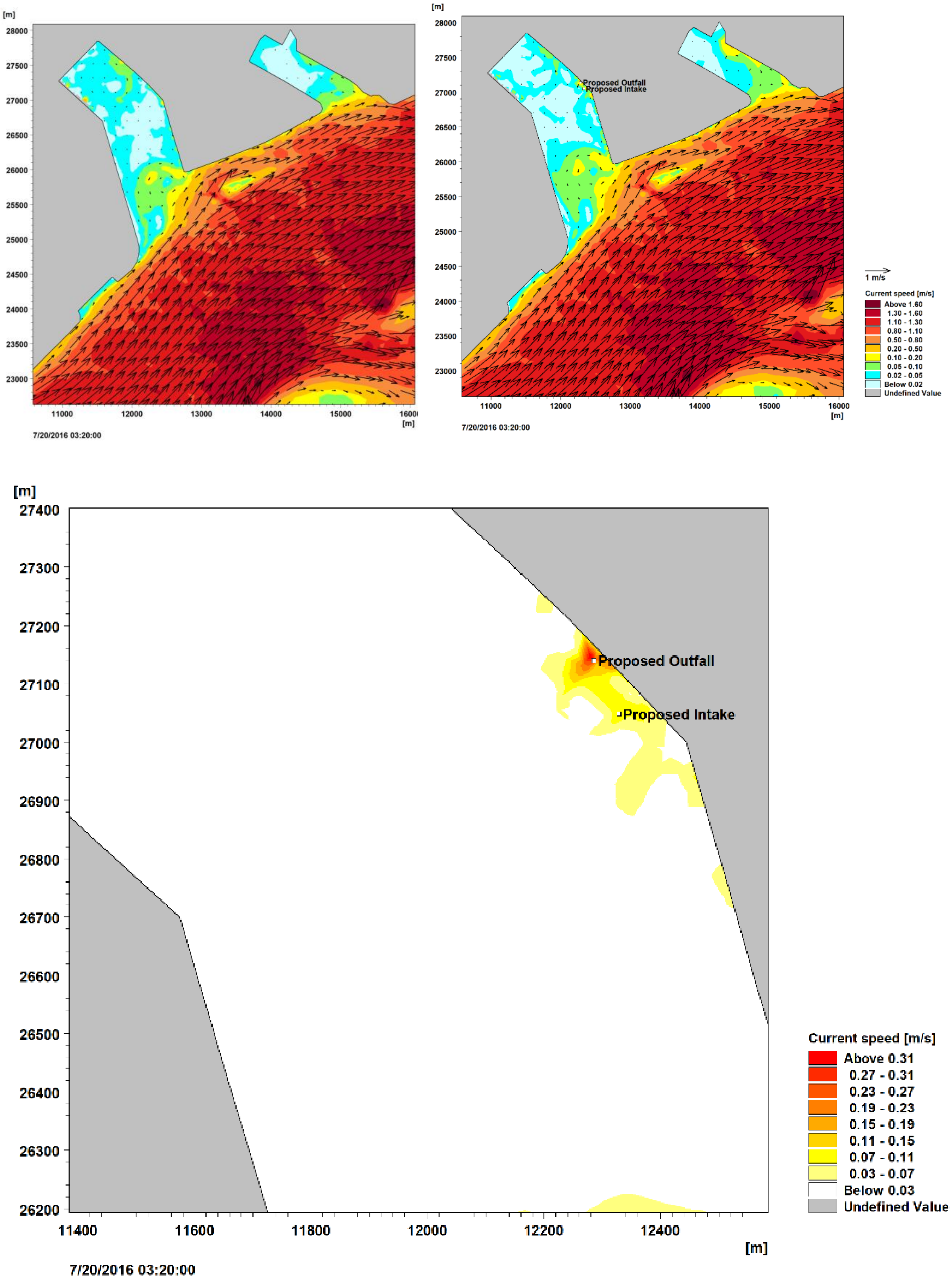



*Figure 9-4 Impact on current field, SW monsoon during Peak ebb tide. Top Left: Pre-construction Case, Top Right: Post-construction Case, Bottom: difference in current speed (Post-construction – Pre-construction)*

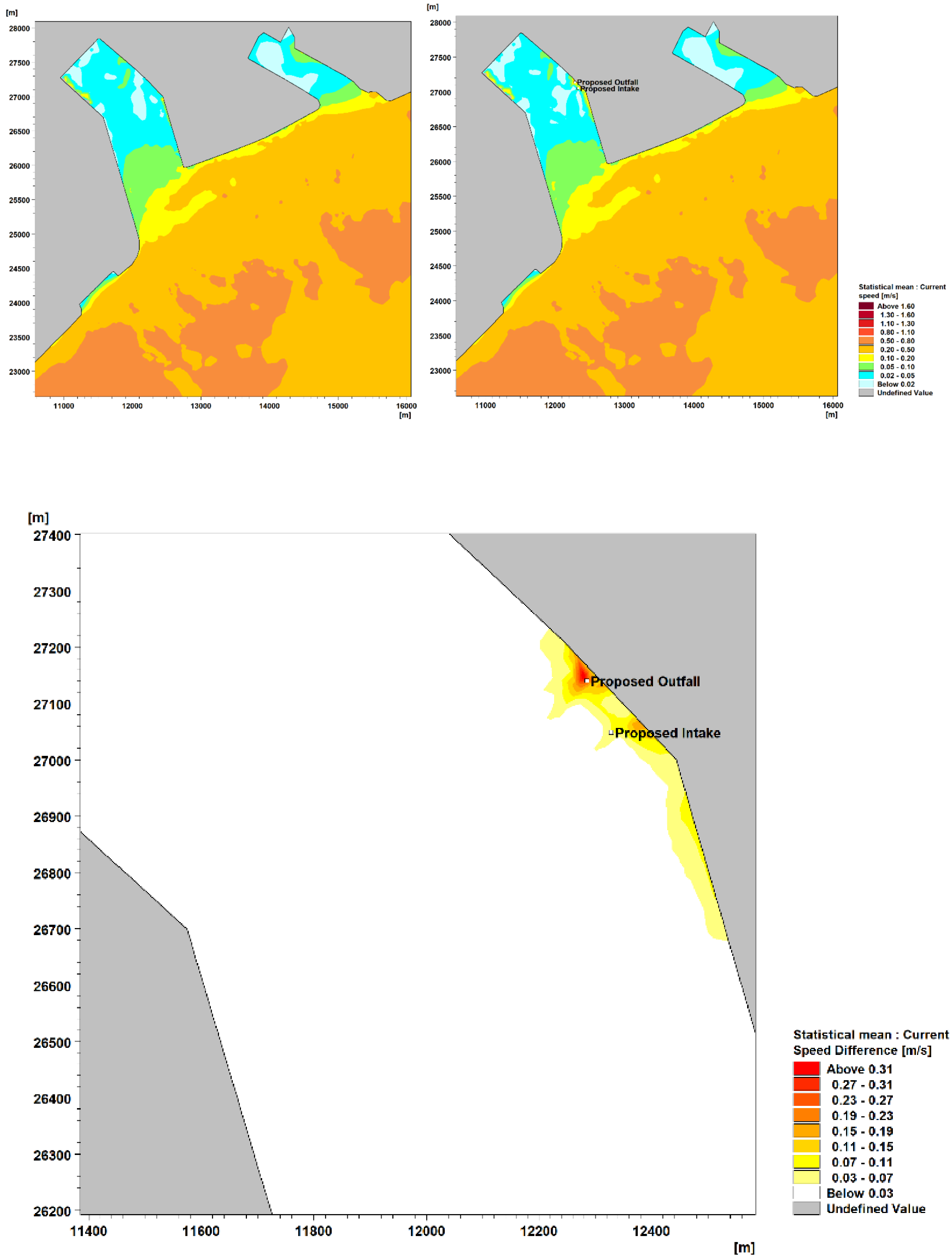



*Figure 9-5: Mean current for 14 days during NE monsoon. Top Left: Pre-construction Case, Top Right: Post-construction Case, Bottom: difference in mean current speed (Post-construction – Pre-construction)*

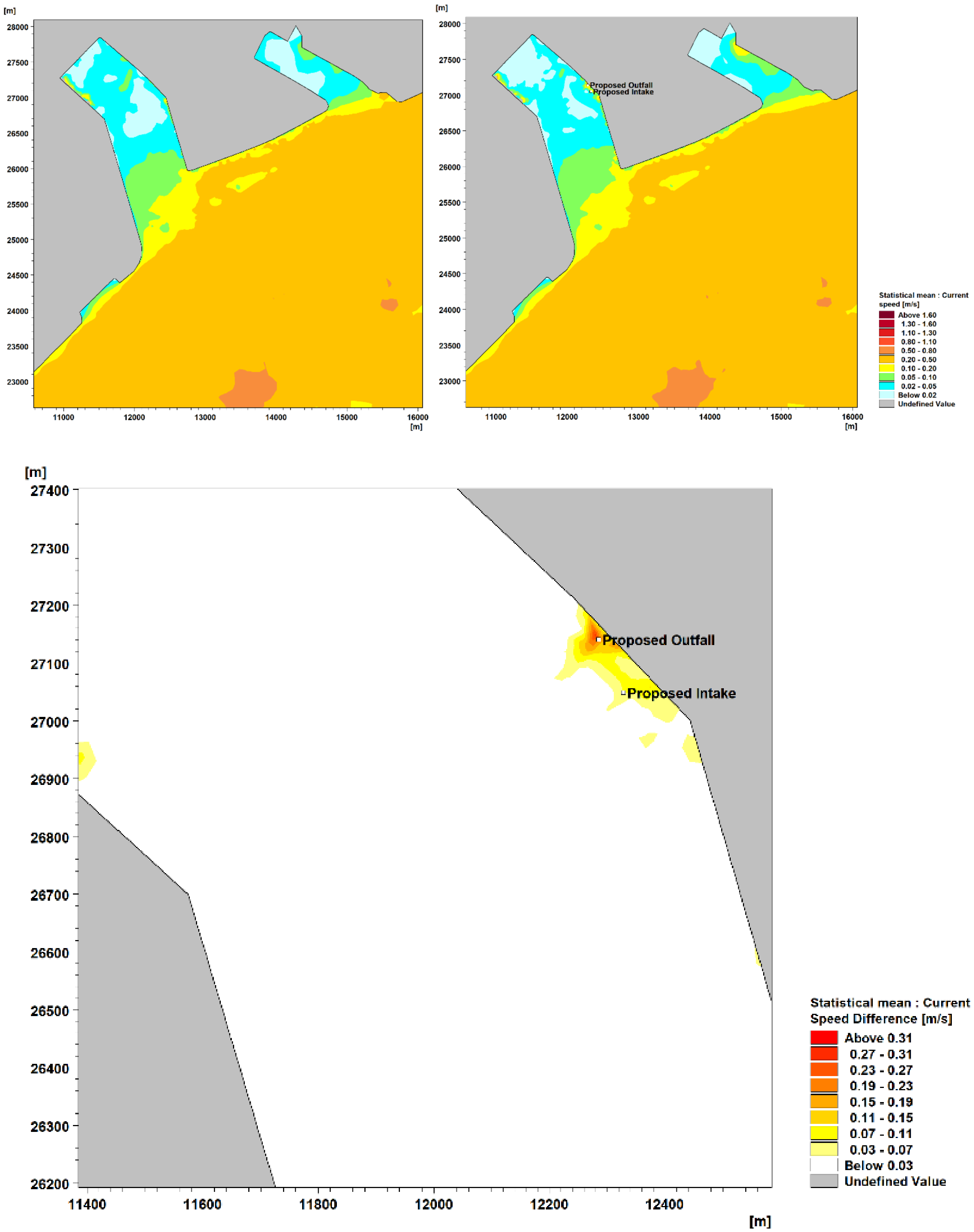



*Figure 9-6: Mean current for 14 days during SW monsoon. Top Left: Pre-construction Case, Top Right: Post-construction Case, Bottom: difference in mean current speed (Post-construction – Pre-construction)*

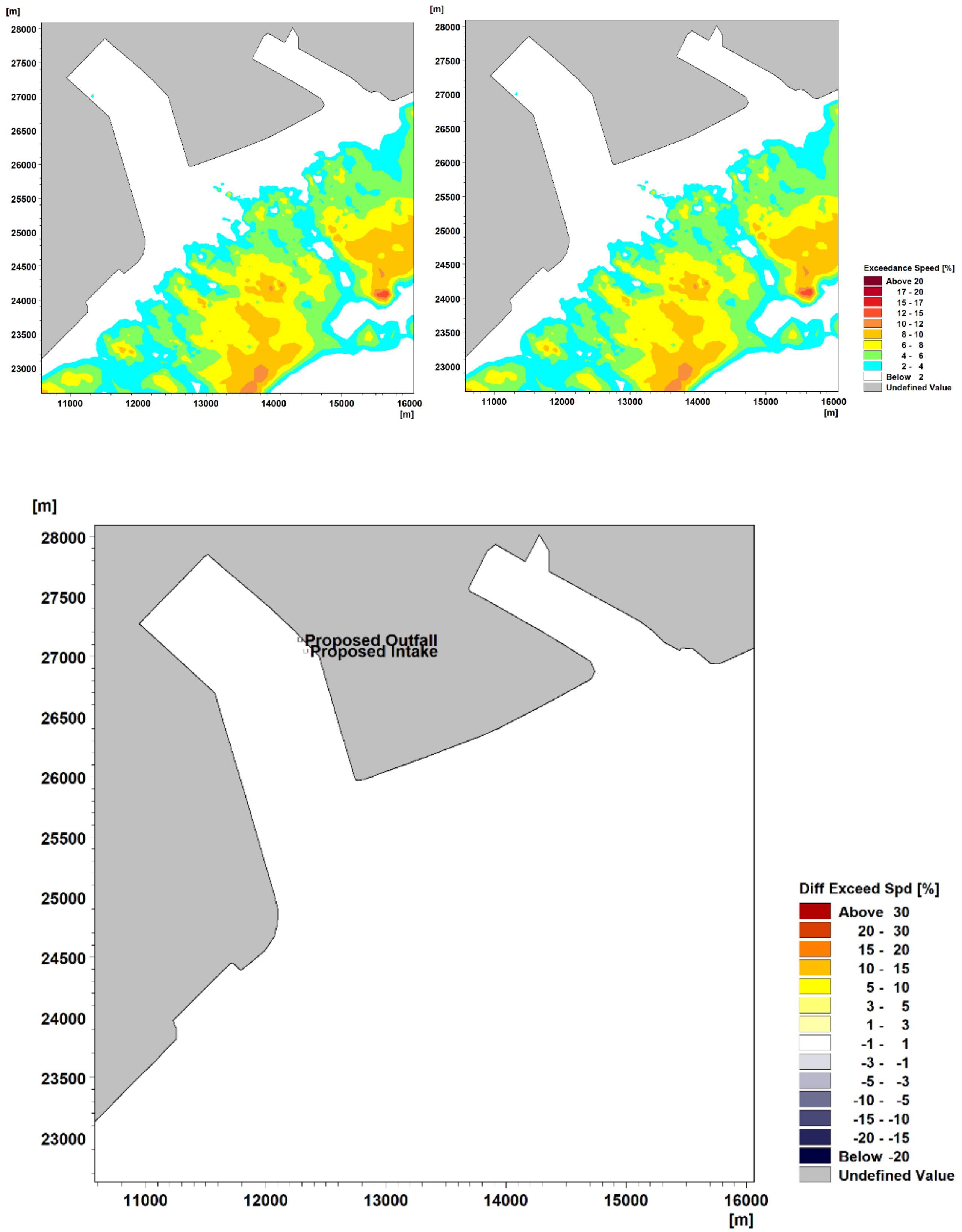



*Figure 9-7: Impact on exceedance of 2 knots, NE monsoon. Top Left: Pre-construction, Top right: Post-construction, bottom: Difference (percentage of time) in exceedance of 2 knots*

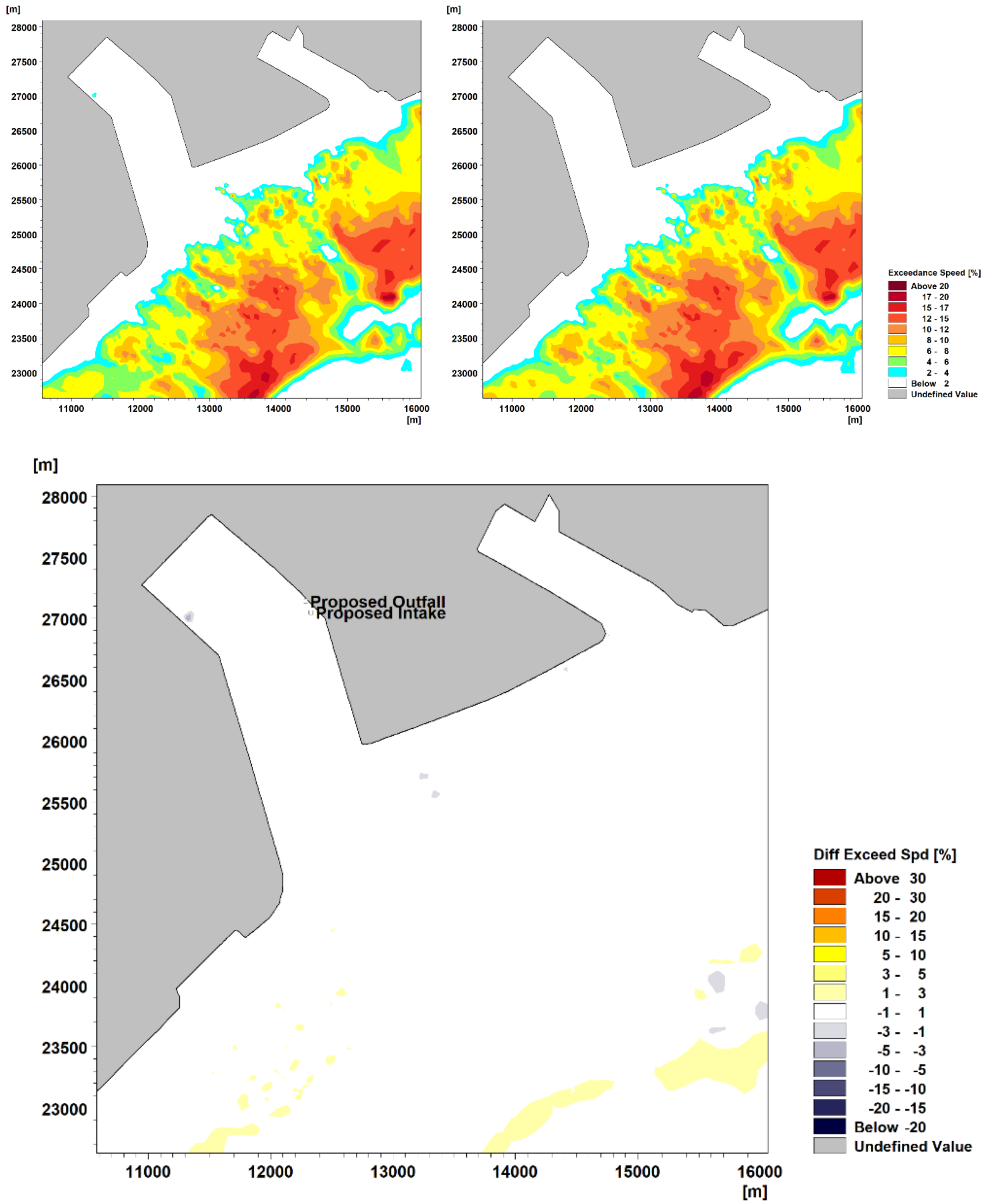



*Figure 9-8: Impact on exceedance of 2 knots, SW monsoon. Top Left: Pre-construction, Top right: Post-construction, bottom: Difference (percentage of time) in exceedance of 2 knots*

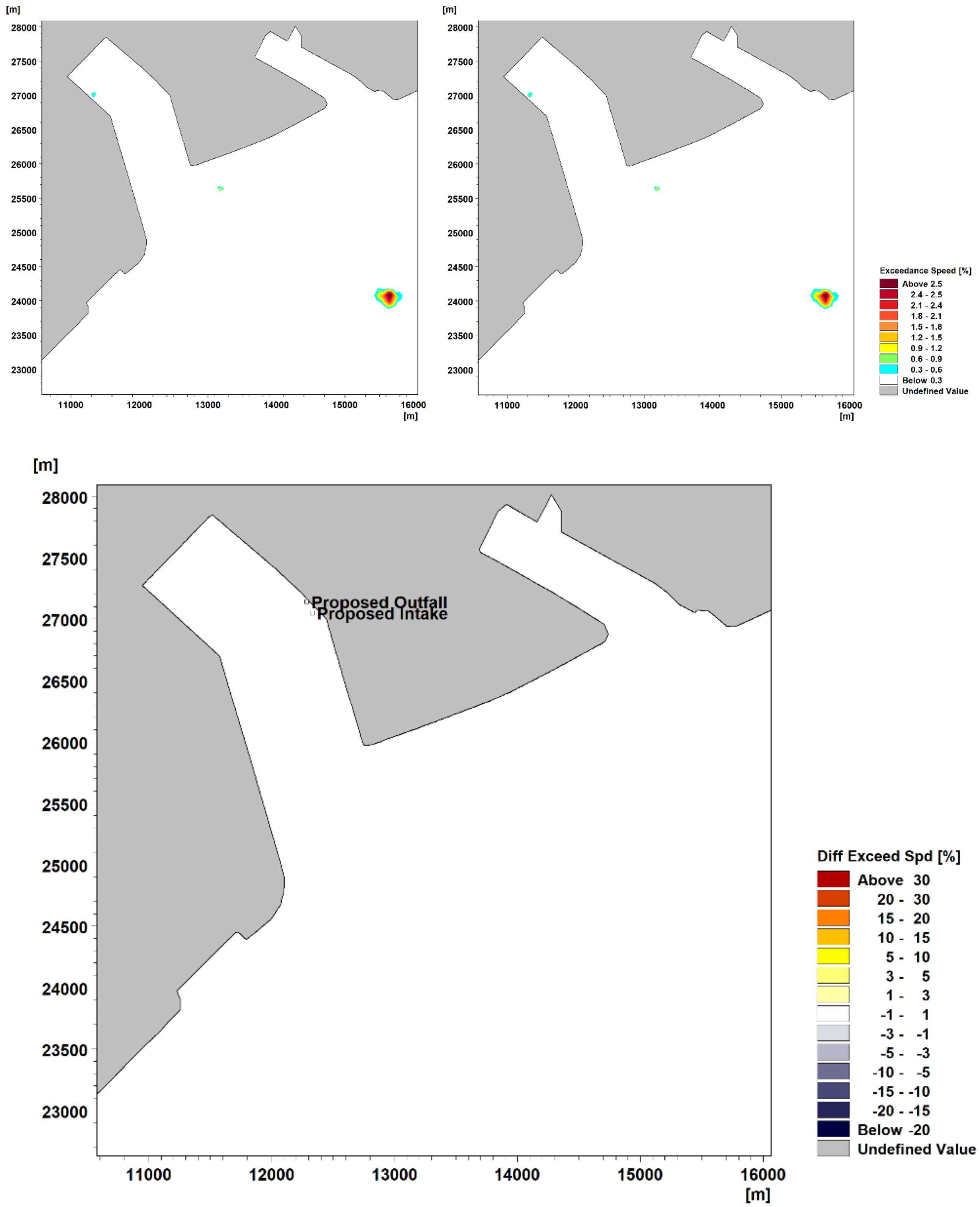



*Figure 9-9: Impact on exceedance of 3.5 knots, NE monsoon. Top Left: Pre-construction, Top right: Post-construction, bottom: Difference (percentage of time) in exceedance of 3.5 knots*

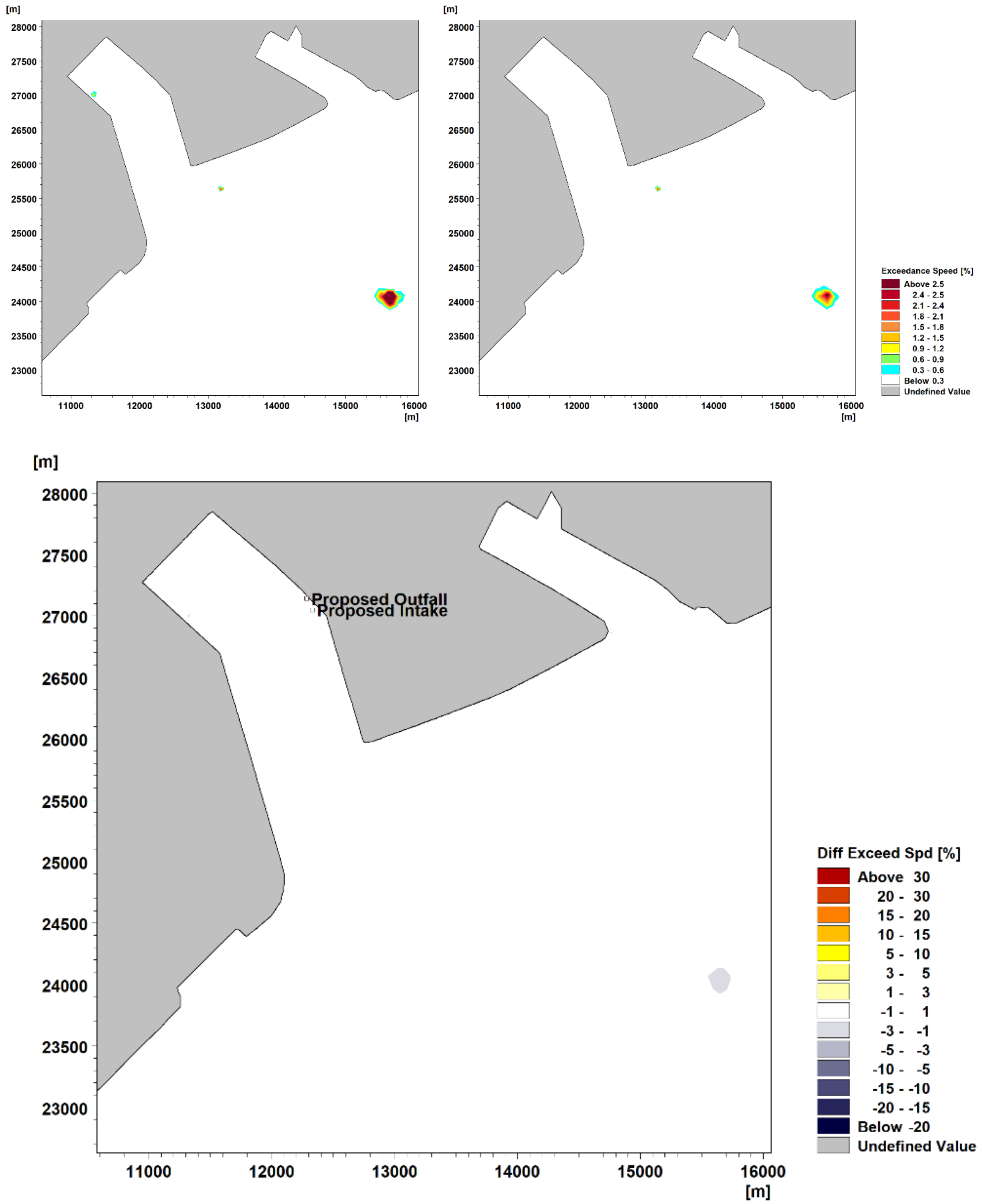



Figure 9-10: Impact on exceedance of 3.5 knots, SW monsoon. Top Left: Pre-construction, Top right: Post-construction, bottom: Difference (percentage of time) in exceedance of 3.5 knots

#### 9.2.1.1 Impacts Summary

Based on hydrodynamic modelling and assessment, model results indicated that the current changes are limited within the areas near the intake and outfall due to the formation of eddy. However, the eddy current magnitude is weak and such impact on currents is localized, with impact areas limited and will not cause an impact on the navigation safety within Banyan Basin. That being said, slight increase in current may generate local scour immediately near the structures. Engineering design of the intake and outfall structures has taken into account the impact of such eddy currents, with the addition of armoured stones on the seabed to disrupt the circular flow of the eddies (refer to Appendix C for design of intake and outfall structures). No impact to the navigation is anticipated.

*Table 9-13: Hydrodynamic model impact summary*

| Impacts | Predicted Impacts | | | | | | | Mitigation measures | Mitigated impact |
|---|---|---|---|---|---|---|---|---|---|
| | Potential impact | ES | I | M | P | R | C | | |
| **Operational** | | | | | | | | | |
| Current | Slight negative change/ slight negative impact | -7 | 1 | -1 | 3 | 3 | 1 | Mitigation at engineering design phase | No change/ no impact |

### 9.2.2 Wave Model

#### 9.2.2.1 Impacts Summary

Worley has investigated all the modelled scenarios of the extreme wave conditions using constant wind forcing (100-year RP) and presented the spatial extreme wave heights for 100-year RP (shown in Figure 9-11). The significant wave height at the Project site is 0.5 m for 100-year RP. There is no impact on wave conditions are expected due to the development of the intake and outfall.

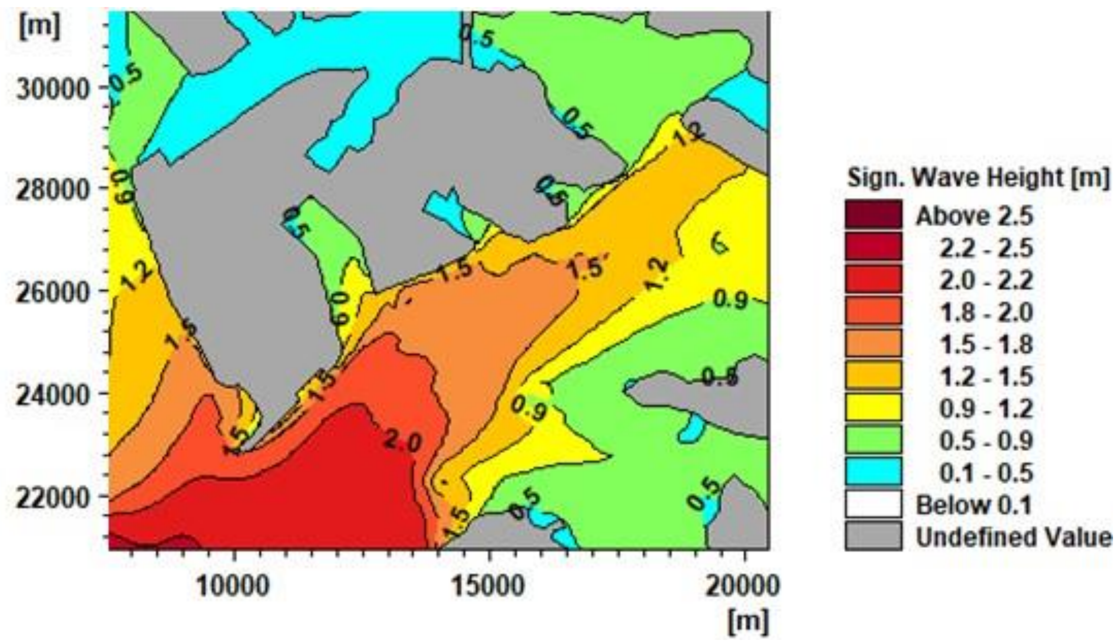



*Figure 9-11 Spatial Extreme Significant Wave Heights for 100-year RP*

Based on wave modelling and assessment, as a result of the dredged trench to be backfilled after postconstruction, it was concluded that there are no wave condition changes after post-construction. Therefore, the potential morphology chance is limited within the proposed intake and outfall areas. Such localize changes mean that there is no morphology impact on the existing jetties, channel, and anchorage areas.

*Table 9-14: Wave model impact summary*

| Impacts | Predicted Impacts | | | | | | | Mitigation measures | Mitigated impact |
|---|---|---|---|---|---|---|---|---|---|
| | Potential impact | ES | I | M | P | R | C | | |
| **Operational** | | | | | | | | | |
| Morphology | No change/ impact | 0 | 0 | 0 | 3 | 3 | 1 | None required | No change/ no impact |

### 9.2.3 Thermal Plume Model

Before carrying out the thermal impact assessment, validation of temperature depth-profile has been carried out by comparing modelled temperature against measured temperature data collected on 24 November 2022, as described in section 7.1.8.1.

There are no standard guidelines to conduct the modelled temperature for validation purpose. Compared to the hydrodynamic model validation assessment for tidal currents (Appendix C), the dynamic nature of water temperature variations in the marine environment makes it difficult to establish standard guidelines for validating modeled temperature. There are many factors (Ocean currents, wind, salinity, cloud cover, air temperature, etc.,) that can affect temperature variation, in addition to hydrodynamic conditions. These factors are interconnected and can influence each other in complex ways. Thus, the visual comparison presented is deemed sufficient as validation of the thermal plume model in Singapore which is a normal industry practice to use in Singapore.

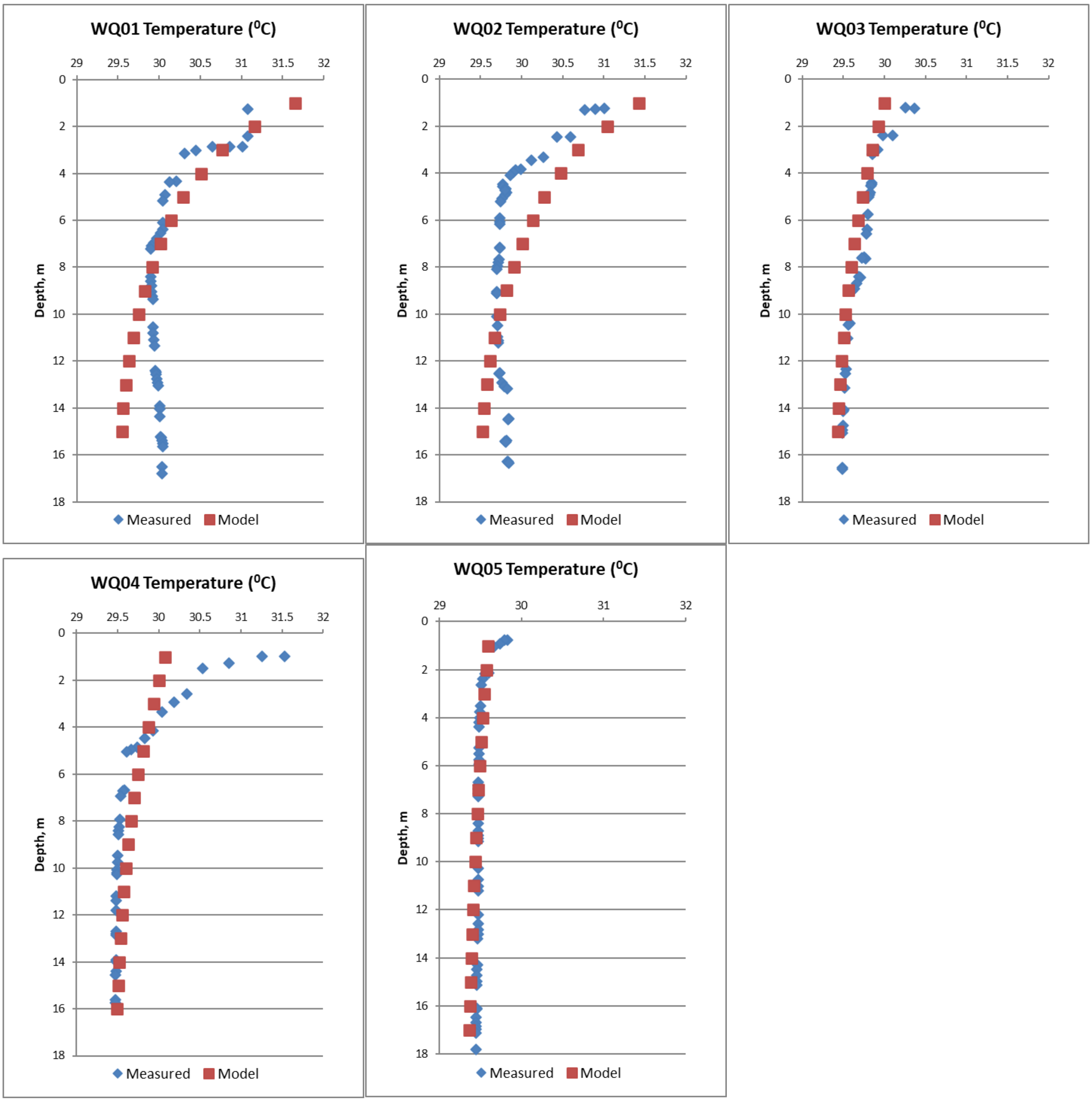



*Figure 9-12 Comparison of Modelled and Measured Temperature at 5 water quality sampling locations*

Based on the presented plots, measured temperature profiles indicate thermal stratification, whereby higher temperatures are observed in the top few meters, before rapidly decreasing to a more constant temperatures below the surface layer. It is shown that the model is able to capture measured temperature depth-profile reasonably well. It can be concluded that the model is sufficient for further thermal impacts assessment presented further in this report.

Figure 9-13 presents the temperature time series extracted at a location near the location of Project's outfall. The time series plot indicates that there are no obvious upwards/downwards trend and hence the warm up period adopted is deemed sufficient.

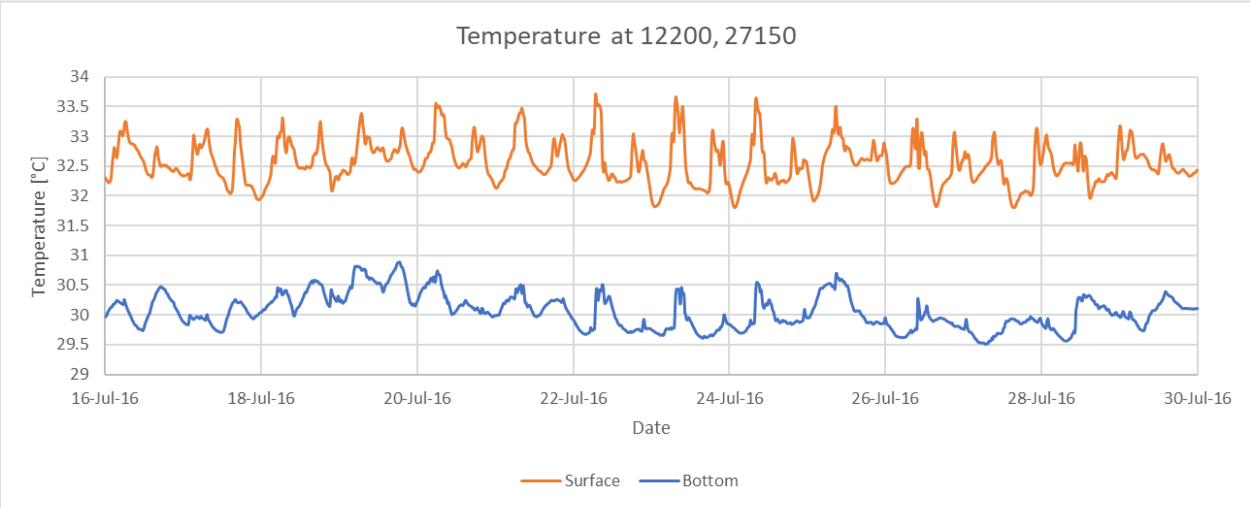



*Figure 9-13 Temperature time series at surface and bottom layer at location near Project's outfall*

The quantification of thermal impacts is presented as the increase of the excess temperature (i.e., temperature in excess of the ambient values) associated to the project-related release, as well as cumulative thermal release from outfall within the Basin. The results are assessed and presented in terms of:

- Instantaneous excess temperature calculated at surface and bottom layer for NE monsoon (peak flood and ebb tide) and SW monsoon (peak flood and ebb tide) (Figure 9-14 and Figure 9-15);
- Mean excess temperature calculated at surface and bottom layer ( Figure 9-16); and
- Percentage exceedance plot for 2°C excess temperature (Figure 9-17).

Based on the simulation results, it is observed that:

- The maximum temperature changes over 14-day (NE and SW monsoon) are observed near the Project's outfall (up to 3.2°C at surface and up to 3.3°C at bottom) post-development.
- The mean temperature changes over 14-day (NE and SW monsoon) of up to 3.0 °C (surface) and 3.3 °C (bottom) are observed near the Project's outfall post-development.
- The maximum mean temperature changes observed at Project's intake are up to 1.71 °C at surface and up to 0.49 °C at bottom post-development.
- Spatial extent of temperature changes is also observed to be contained within the Banyan basin, with wider temperature change extent observed for surface layer compared to bottom layer.

- A relatively larger plume excursion is observed over the surface than the bottom layer due to the tendency of the positive buoyant effluents to disperse upwards (towards water surface).

- Extent of thermal plume does not vary significantly among the considered monsoonal scenarios.

- The percentage exceedance plots at 2°C indicates that the thermal plume is generally localized within the point of discharge. The thermal plume is also predicted not to disperse significantly towards the Basin's mouth. Due to the localized exceedance of the 2oC guidelines, a slight negative impact/ change is observed. However, the probability of occurrence of marine cyanobacteria bloom is considered rare. Therefore, the conclusion of the study is that there is no impact to the environment anticipated due to the development of outfall.

- The ambient temperature of 31°C (rounding off to nearest integer from 31.37°C) is applied for the modelling which has been based on the maximum instantaneous temperature recorded around the proposed project site (i.e., WQ01 and WQ02). In this case, the maximum total temperature is calculated as 38°C (high ambient temperature 31°C + maximum power plant increase 7°C), leaving a safety margin of 7°C for recirculation to take effect. It complies with Singapore's Trade Effluent Discharge Limits that the maximum absolute effluent temperature must not more than 45°C before discharging from the site.

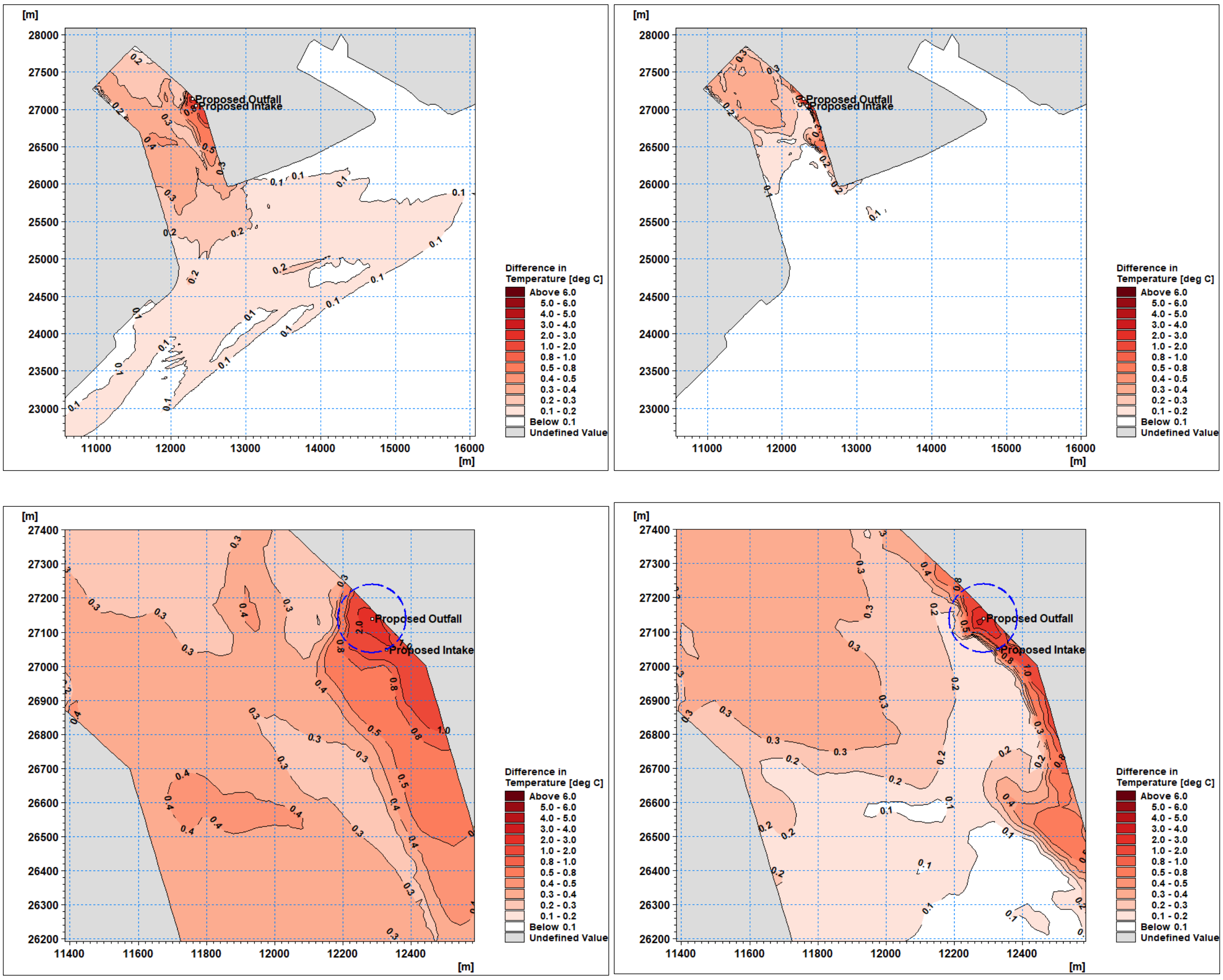



*Figure 9-14: Maximum excess temperature for at surface (left) and bottom layer (right) during NE monsoon*

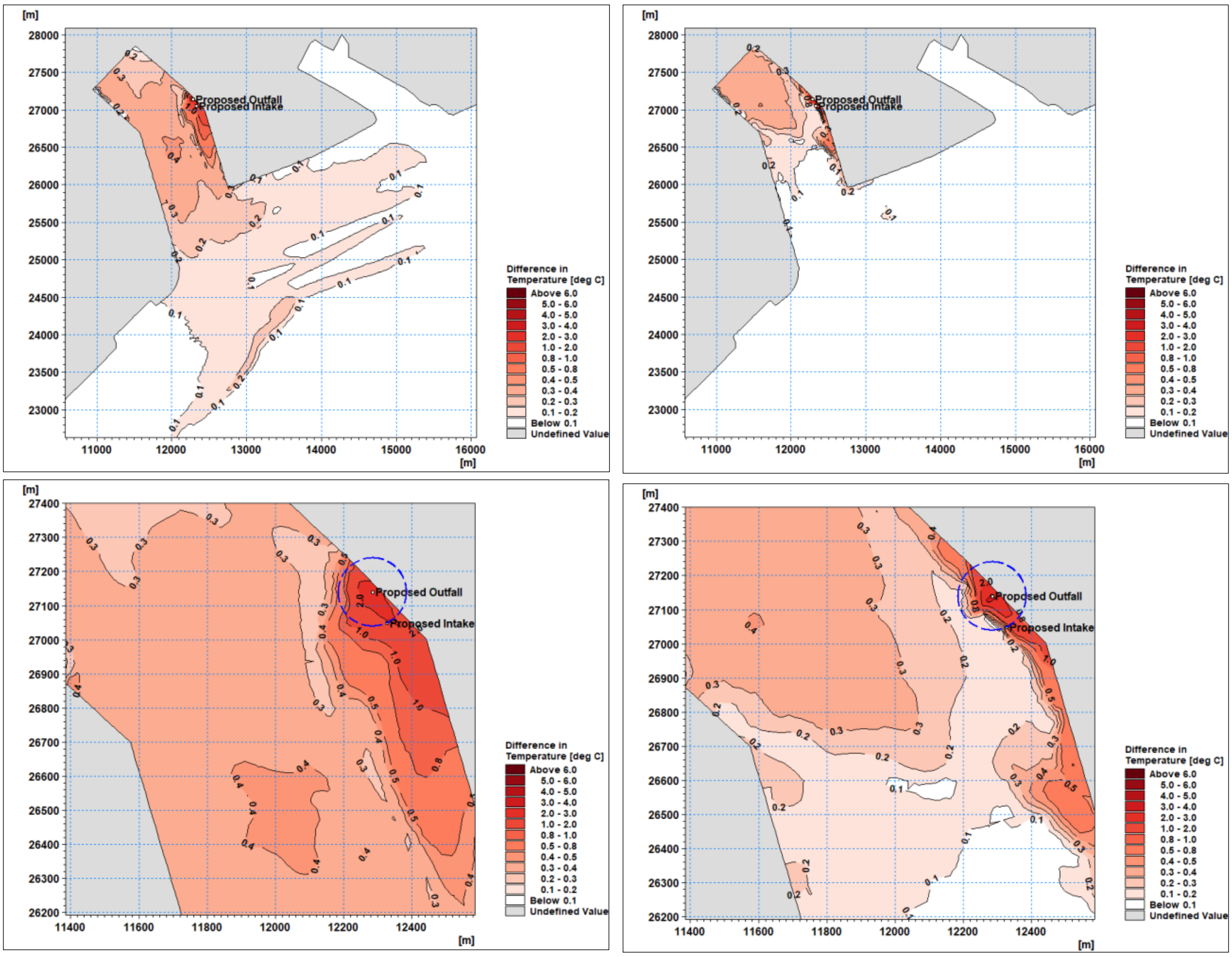



*Figure 9-15: Maximum excess temperature for at surface (left) and bottom layer (right) during SW monsoon.*

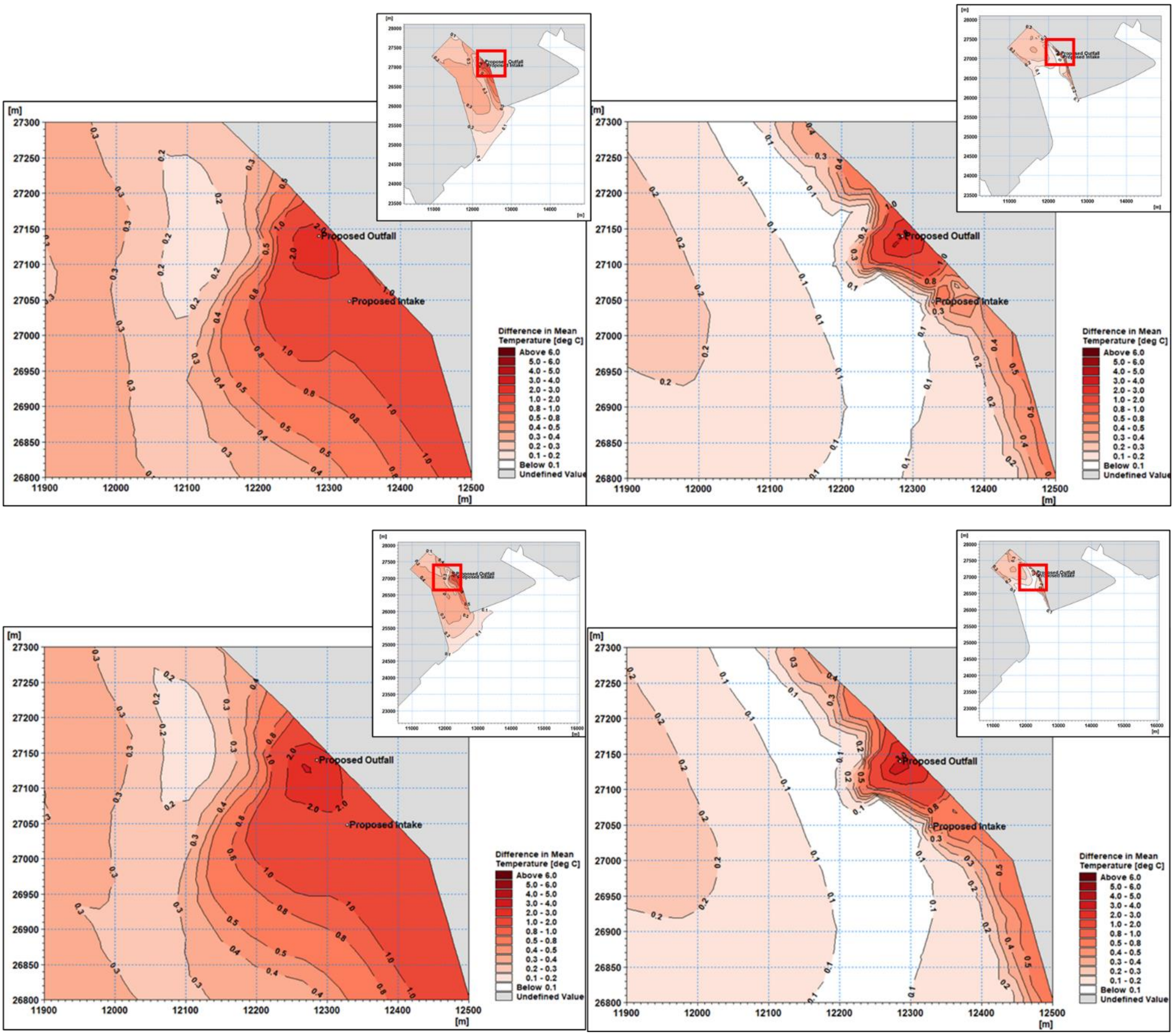



*Figure 9-16: Mean excess temperature at surface layer (top, left) and bottom layer (top, right) during NE monsoon and mean excess temperature at surface layer (bottom, eft) and bottom layer (bottom, right) during SW monsoon*

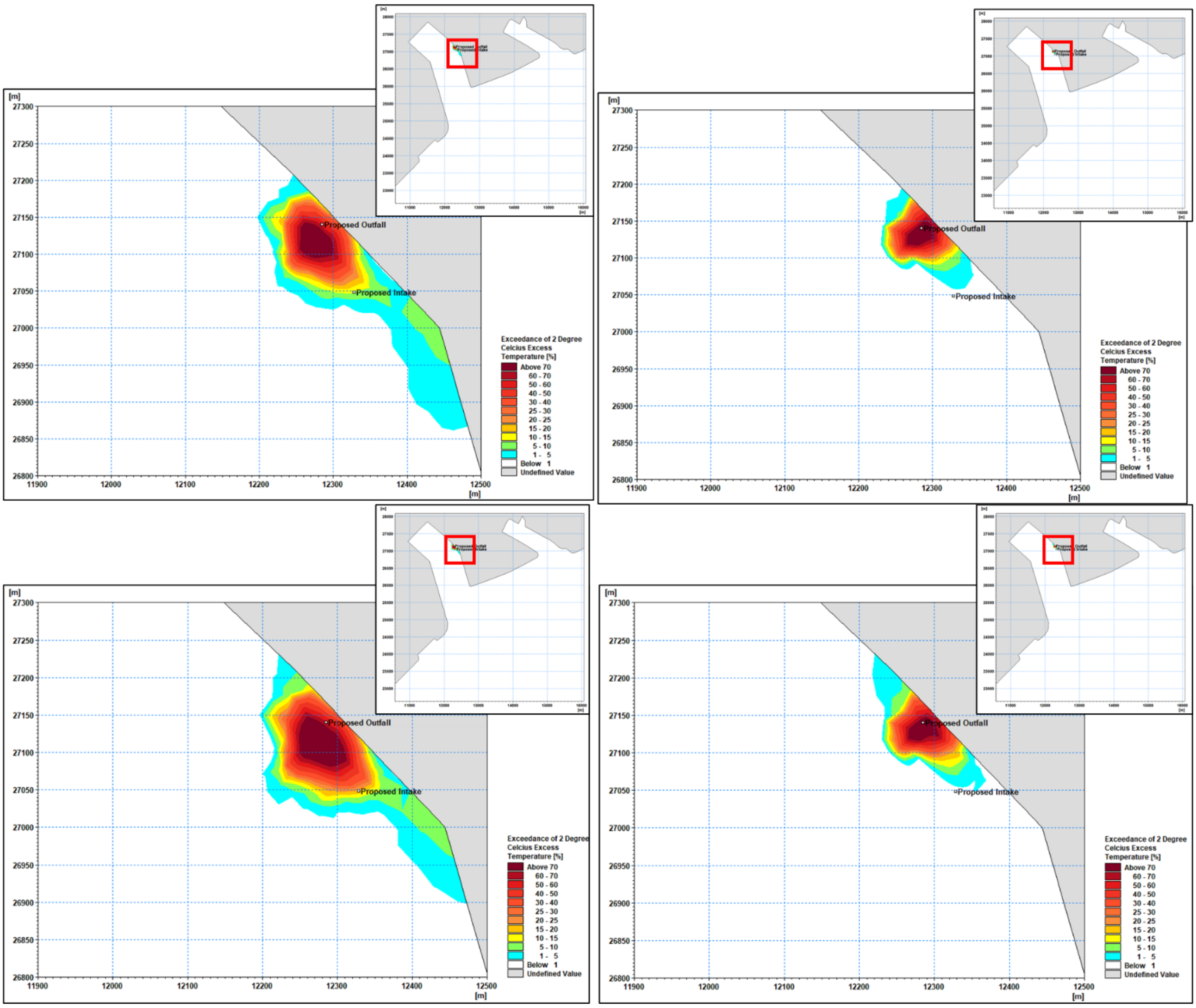



*Figure 9-17: Percentage time of excess temperature above +2°C at surface layer (top, left) and bottom layer (top, right) during NE monsoon and above +2°C at surface layer (bottom, left) and bottom layer (bottom, right) during SW monsoon*

#### 9.2.3.1 Impacts Summary

The model predictions on the generated thermal plume from the 105,000 m3/ hr released of heated water of +7 °C via the outfall are below the Singapore's Environmental Protection and Management (Trade Effluent) Regulations 2008 (Table 9-15).

Based on the thermal plume model results, the percentage exceedance plots at 2 °C indicates that the thermal plume is generally localized at the point of discharge. The thermal plume is also predicted not to disperse significantly towards the Basin's mouth.

The thermal plume impacts to the receiving water are assessed against the ASEAN MWQC using the RIAM framework. Refer to Table 9-16 for the results of the assessment. Due to the localized exceedance of the 2°C guidelines, a study on the impact to the marine environment caused by the thermal discharge of power plant was carried out. According to literature reviews, it is found that when the environmental temperature is above 25°C, an increase in temperature inhibits the growth of algae (except cyanobacteria). When the temperature is above 30°C, a further increase in temperature can significantly reduce the population of algal (Jiang & Hou, 2015). For cyanobacteria, cyanobacteria blooms can form in warm and slow-moving waters that are rich in nutrients from sources such as fertilizer runoff or septic tank overflows. Cyanobacteria blooms need nutrients to survive. Generally, not all algal bloom is toxic and cause harm to human health and aquatic life. Most harmful algal bloom-forming and toxin-producing cyanobacteria (cyanoHABs) are freshwater species ( (Berg.,M. & Sutula, M. , 2015)Berg, L. & Sutulua, M., 2015). In contrast, marine cyanobacteria such as *Prochlorococcus, Synechococcus* sp. and *Trichodesmium* sp. are non-toxic and do not form cyanoHABs. For the marine cyanobacteria, nutrient pollution is the leading cause of cyanobacteria blooms (Bennett, 2017). Given that there will be no nutrients discharge from the outfall, the probability of occurrence of marine cyanobacteria bloom is considered rare[4]. Additionally, based on Worley's past experience, there are no environmental concerns in Banyan Basin when other outfall discharge water at temperatures close to 45°C. No algal bloom or eutrophication was sighted at the time of baseline survey and no eutrophication or algal bloom sightings have been reported or found in public domain. Therefore, the conclusion of the study is that there is no impact to the environment anticipated due to the development of outfall.

Despite the rare probability of cyanobacteria/ algal bloom, the developer is committed to the protection of the environment. As such, visual observation will be carried out to identify sightings of algal bloom or eutrophication or fish-kill at the outfall during the operation phase. Sampling of algal will also be carried out when there is presence of algal bloom or eutrophication, or fish-kill at the outfall.

*Table 9-15: Compliance summary for thermal plume*

| Description | Guideline | Compliance |
|---|---|---|
| **Point of discharge** | | |
| Temperature shall not exceed 45°C at point of its entry to watercourse | Singapore's Environmental Protection and Management (Trade Effluent) Regulations 2008 | √ |
| **Receiving environment** | | |

[4] Rare is defined as event may occur only in exceptional circumstances, i.e., below 5% chance or likelihood (probability) of occurring.

| Description | Guideline | Compliance |
|---|---|---|
| The excess temperature increases not more than 2°C above the maximum ambient temperature | ASEAN MWQC | √ (with mitigation measures detailed in Section 13.5)[5] |

*Table 9-16: RIAM results for thermal plume impacts during operation phase*

| Impacts | Predicted Impacts | | | | | | | Mitigation measures | Mitigated impact |
|---|---|---|---|---|---|---|---|---|---|
| | Impact Significance | ES | I | M | P | R | C | | |
| **Operation** | | | | | | | | | |
| Thermal release from outfall to the seawater | Slight negative change/ impact | -12 | 1 | -2 | 2 | 2 | 2 | Regular visual observation and sampling | No change/ no impact |

[5] Slight localised negative change/ impact at the outfall was identified as illustrated in Table 9-16. Despite the rare probability of cyanobacteria/ algal bloom, the developer is committed to provide the protection of the environment. Mitigation measures have been put in place as presented in Table 13-5 to avoid the impacts to the marine environment.

### 9.2.4 Chlorine Plume Model

Figure 9-18 presents the depth averaged excess chlorine time series extracted at a location near the location of Project's outfall. The time series plot indicates that there are no obvious upwards/downwards trend and hence the warmup period adopted is deemed sufficient.

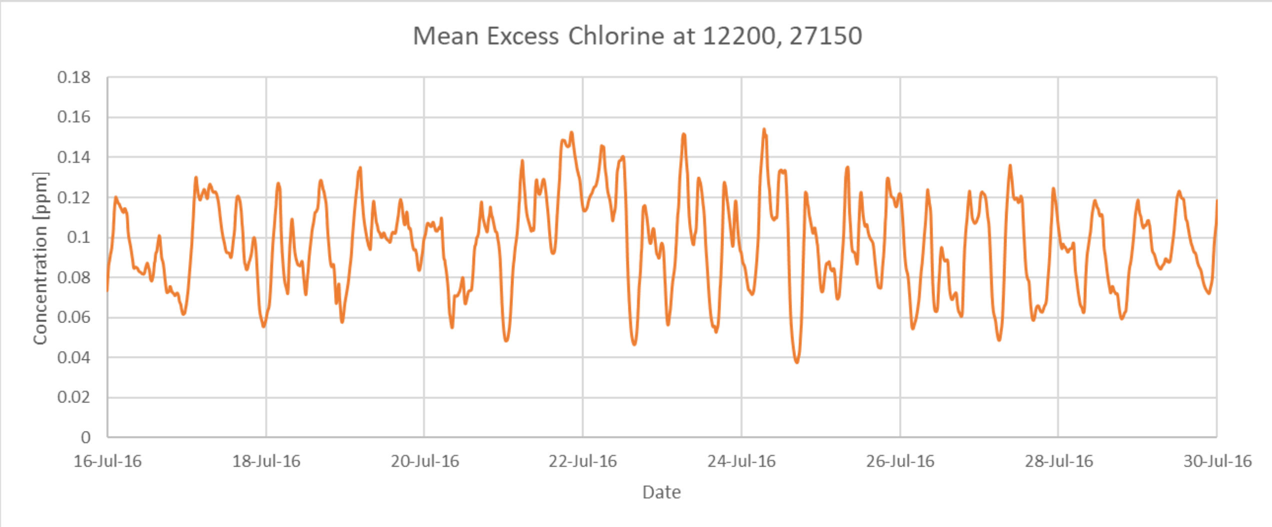



*Figure 9-18: Extracted mean excess chlorine time series*

The quantification of chlorine impacts is presented in excess. The results are assessed and presented in terms of:

- Map of mean chlorine concentration (Figure 9-19)
- Map of maximum chlorine concentration (Figure 9-20 and Figure 9-21)
- Map of percentage exceedance of 0.013ppm of excess chlorine concentration (Figure 9-22)

The observation based on the results:

- Mean excess chlorine over 14 days (NE and SW monsoon) of up to 0.20 – 0.40 ppm are observed to be localized near Project's outfall post development during normal dosing operations at 0.25 ppm.
- Mean excess chlorine over 14 days (NE and SW monsoon) of up to 0.40 – 0.60 ppm are observed to be localized near Project's outfall post development during shock dosing operations at 0.5 ppm.
- Spatial extent of mean excess chlorine is observed to be mostly contained within the Banyan basin for both normal and shock dosing operations at 0.25 ppm and 0.5 ppm, respectively.
- Extent of Chlorine plume does not vary significantly among the considered monsoonal scenarios. The mean excess chlorine discharge from the outfall is primarily confined within Banyan basin and localized.
- Maximum excess chlorine over 14 days (NE and SW monsoon) of up to 0.20 – 0.40 ppm are observed to be within Banyan Basin post development during both normal dosing and shock dosing operations.

- Percentage exceedance of 0.013 ppm excess chlorine over 14 days (NE and SW monsoon) of up to above 90 percent are observed near Project's outfall post development during normal dosing operations at 0.25 ppm.
- Percentage exceedance of 0.013 ppm excess chlorine over 14 days (NE and SW monsoon) of up to above 90 percent are observed near Project's outfall post development to inner half of Banyan Basin during shock dosing operations at 0.5 ppm.
- In terms of potential impact to the sensitive receptors, the exceedance of 0.013 ppm is deemed compliance given by no sensitive receptors within the discharge footprint.

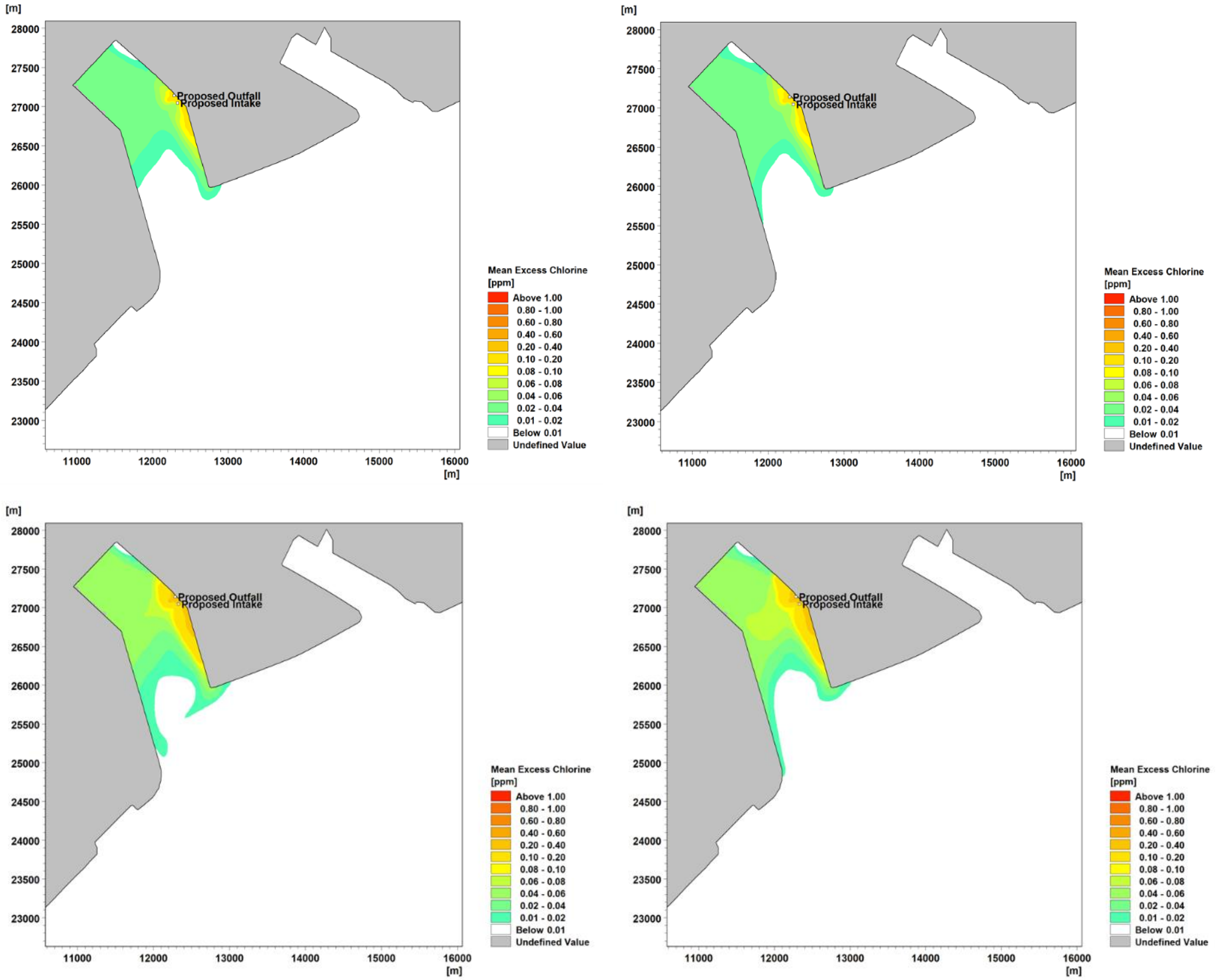



*Figure 9-19: Mean excess chlorine for 0.25 ppm during normal dosing operation during NE (top, left) and SW (top, right)* and mean excess chlorine at 0.5 ppm during shock dosing operation during NE (*bottom, left) and SW (*bottom, right) *monsoon*

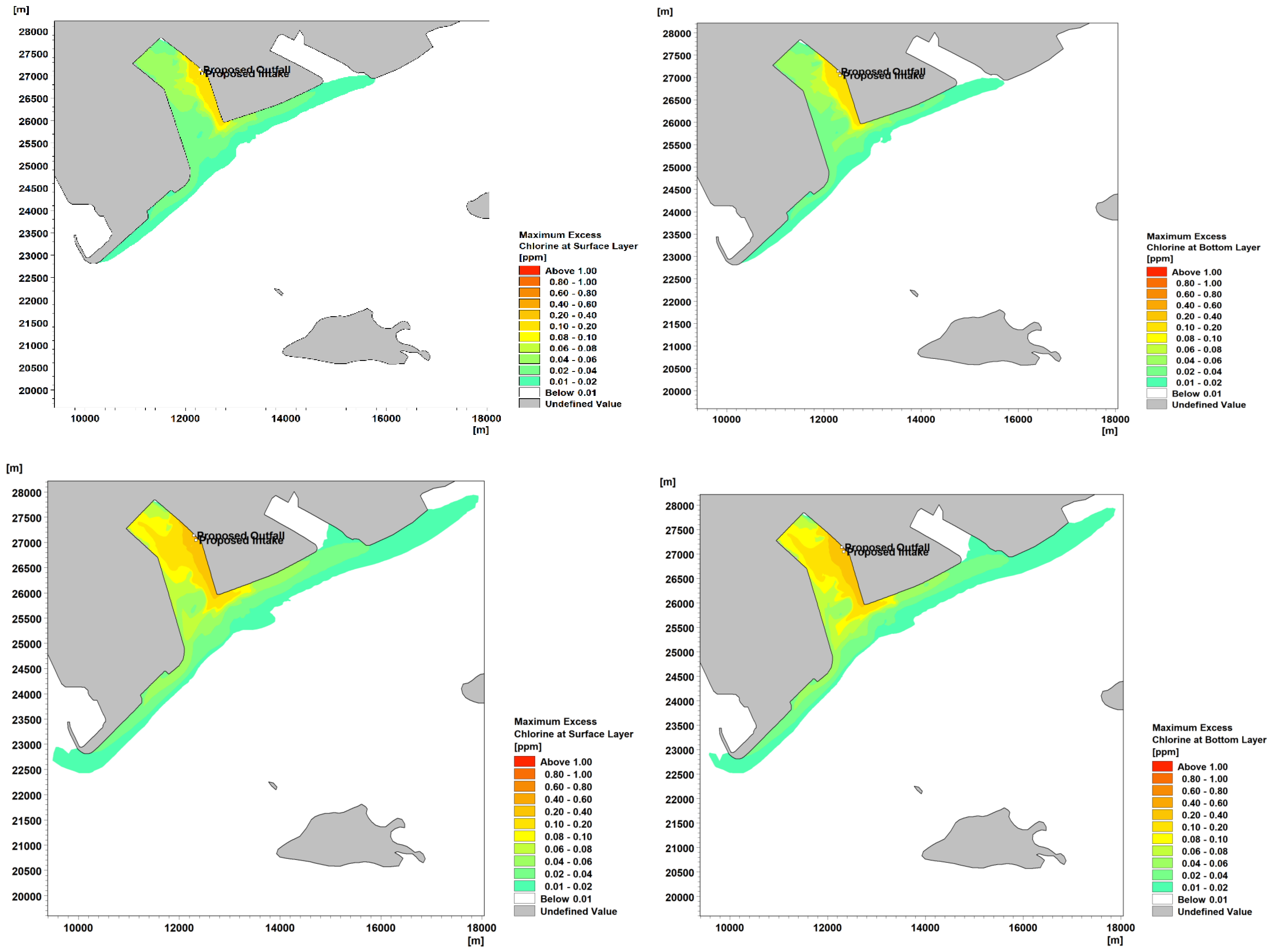



*Figure 9-20: Maximum excess chlorine for 0.25 ppm during normal dosing operation at surface* (top, *left) and bottom layer* (top, *right)* and maximum *excess chlorine at 0.5 ppm during shock dosing operation at surface* (bottom, *left) and bottom layer* (bottom, *right) during NE monsoon*

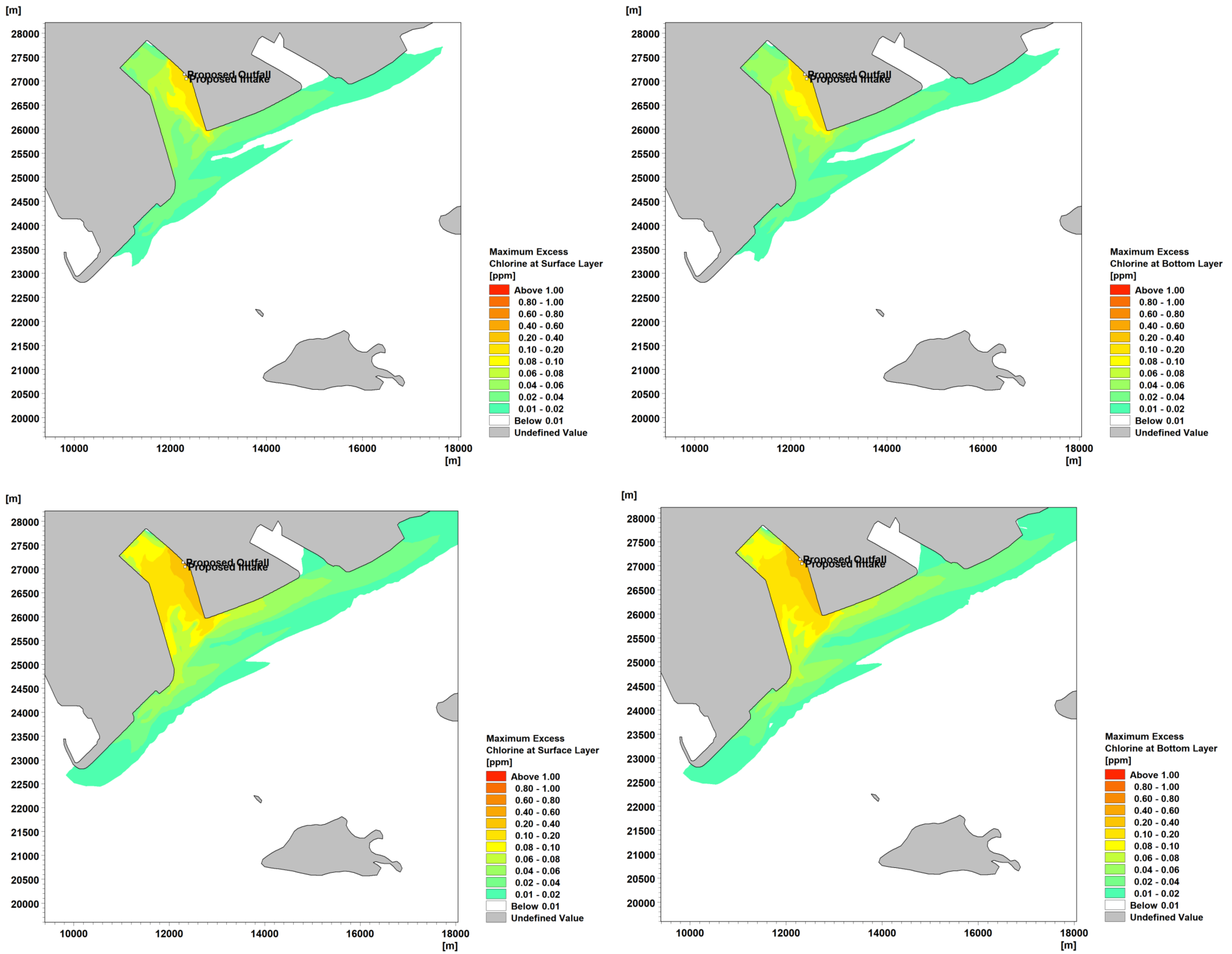



*Figure 9-21: Maximum excess chlorine for 0.25 ppm during normal dosing operation at surface (top, left) and bottom layer (top, right) and maximum excess chlorine at 0.5 ppm during shock dosing operation at surface (bottom, left) and bottom layer (bottom, right) during SW monsoon*

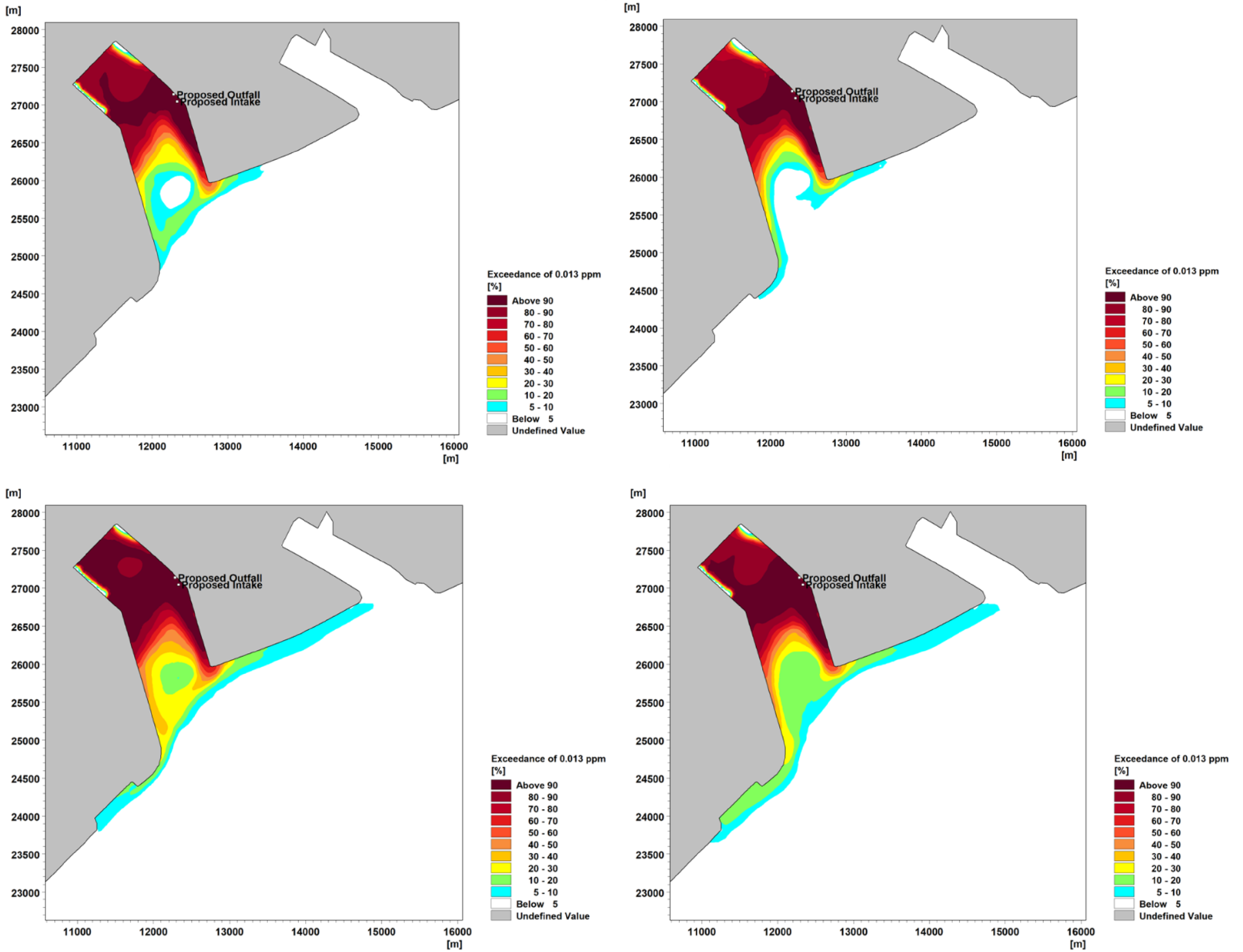



*Figure 9-22: Percentage exceedance of 0.013ppm of excess chlorine for 0.25 ppm during normal dosing operation during NE (top, left) and SW (top, right) and mean excess chlorine at 0.5 ppm during shock dosing operation during NE (bottom, left) and SW (bottom, right) monsoon*

##### 9.2.4.1 Impacts Summary

Using the Singapore's Environmental Protection and Management (Trade Effluent) Regulations 2008 and USEPA (R.E.D. FACTS Chlorine gas), the chlorine plume from the 105,000 $m^3$/ hr release of 0.25 ppm and 0.5 ppm concentration demonstrated no potential impact on the nearby sensitive receptors (Table 9-17). The dispersion is generally confined within the Basin and no dispersion to the sensitive receptors are observed. Therefore, no impact to the environment is anticipated due to the development of outfall.

*Table 9-17: Compliance summary for chlorine plume*

| Description | Guideline | Compliance |
|---|---|---|
| Point of discharge:<br>• Concentration of free chlorine shall not exceed 1mg/l at point of entry to watercourse | Singapore's Environmental Protection and Management (Trade Effluent) Regulations 2008 | √ |
| Receiving environment<br>• Level of concern for estuarine/marine organisms is 0.013 ppm | USEPA | √ |

*Table 9-18: RIAM results for chlorine plume impacts during operation phase*

| Impacts | Predicted Impacts | | | | | | | Mitigation measures | Mitigated impact |
|---|---|---|---|---|---|---|---|---|---|
| | Impact Significance | ES | I | M | P | R | C | | |
| **Operation** | | | | | | | | | |
| Chlorine release from outfall to the seawater | No change/ no impact | 0 | 3 | 0 | 1 | 1 | 1 | None required | No change/ no impact |

### 9.2.5 Sediment Plume Model

The quantification of sediment plume impacts is presented in excess. The results are assessed and presented in terms of:

- Mean Suspended Solid Concentration (SSC);
- Maximum Suspended Solid Concentration (SSC);
- Exceedance of Suspended Solid Concentration (SSC) at 5mg/L, 10mg/L, and 25mg/L; and
- Sedimentation.

Based on the modelling results, it is observed that:

- Sediment plume generated from dredging and infilling activity is confined within Banyan basin.
- The 5 mg/L exceedance concentration exceeded 10% of the time extending < 1km from the source. The footprint of the 10 mg/L, and 25 mg/L exceedance concentration exceeding 5% of the time is expected to reduce and localized.
- The sedimentation due to dredging and infilling activity is localized, and such sedimentation material will be backfilled to the trench during the construction phase.

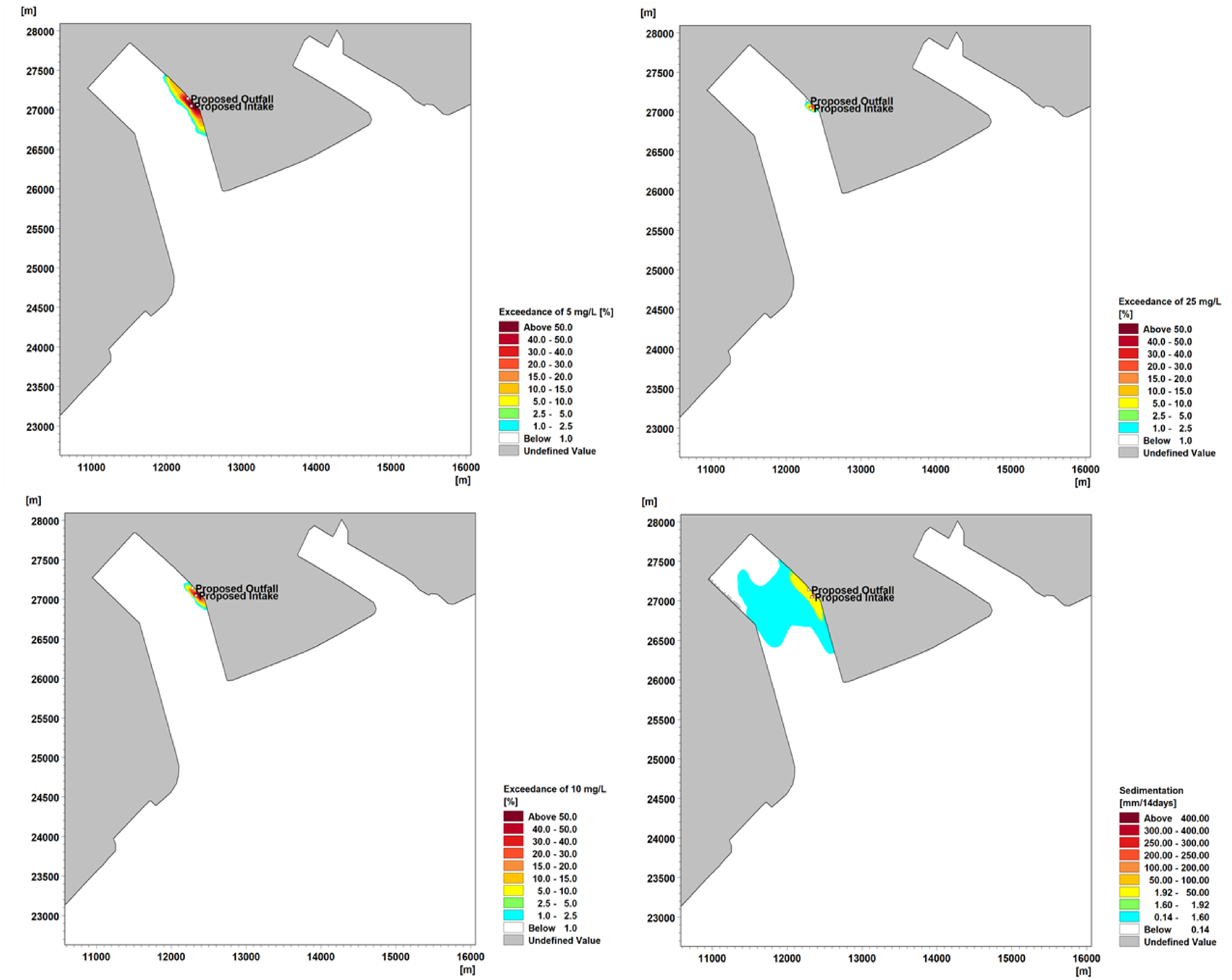



*Figure 9-23: Percentage exceedance of 5mg/L (top left), 10 mg/L (bottom left), 25 mg/L (top right) and sedimentation (bottom right) 1000 m$^3$/ day during NE monsoon*

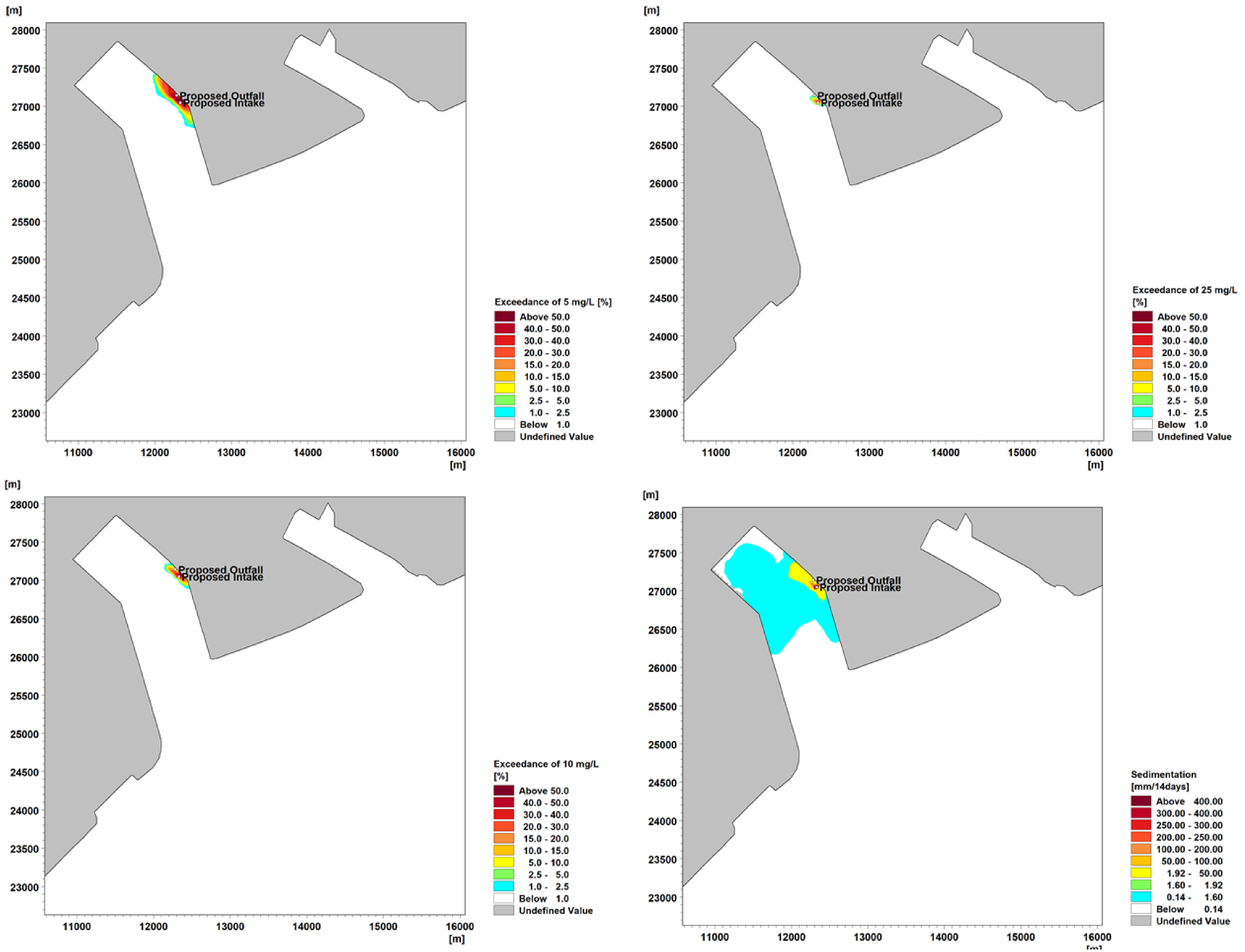



*Figure 9-24: Percentage exceedance of 5mg/L (top left), 10 mg/L (bottom left), 25 mg/L (top right) and sedimentation (bottom right)* 1000 $m^3$/ day during SW monsoon

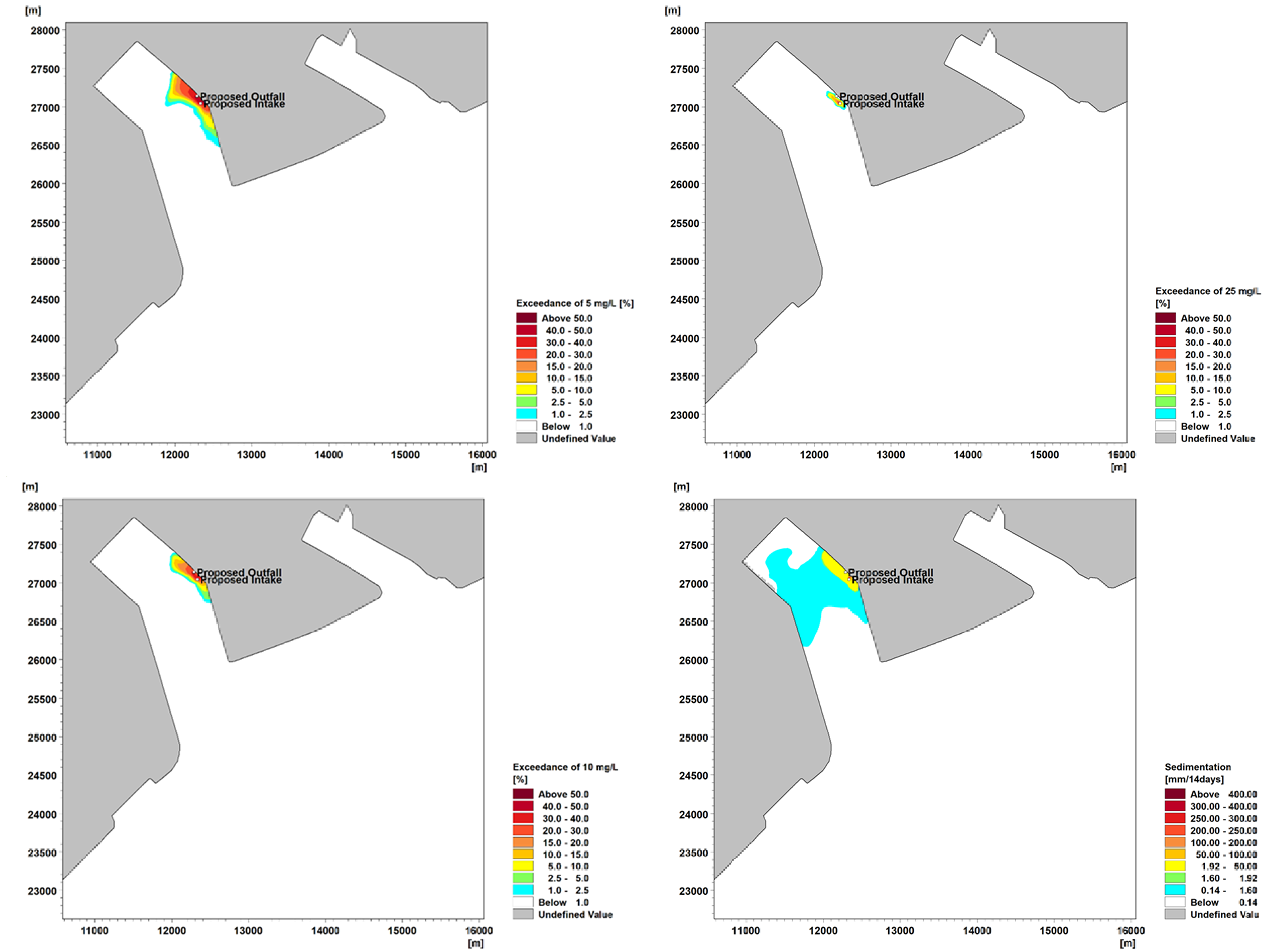



*Figure 9-25: Percentage exceedance of 5mg/L (top left), 10 mg/L (bottom left), 25 mg/L (top right) and sedimentation (bottom right)* 5000 m$^3$*/ day during NE monsoon*

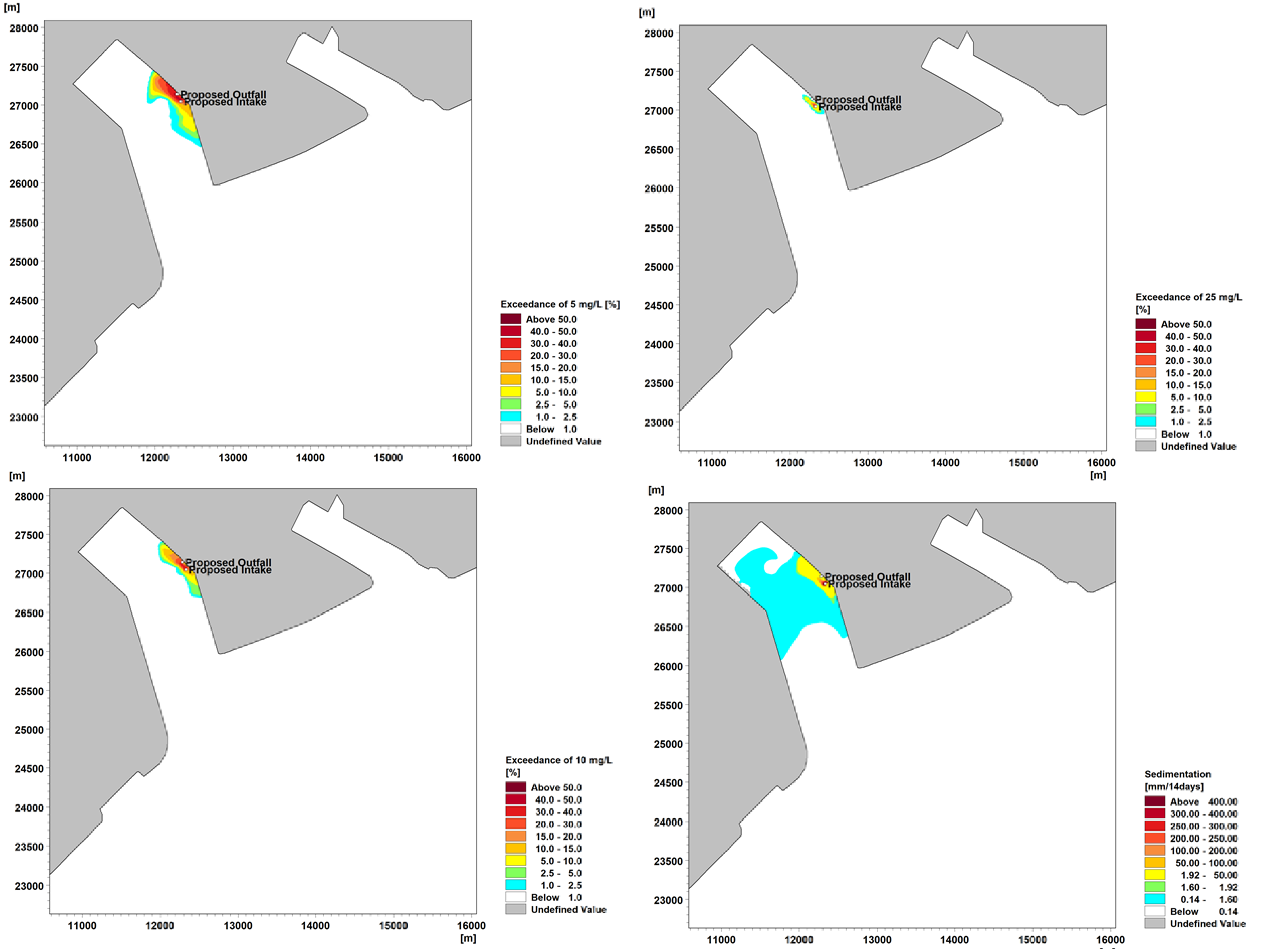



*Figure 9-26: Percentage exceedance of 5mg/L (top left), 10 mg/L (bottom left), 25 mg/L (top right) and sedimentation (bottom right) 5000 m³/ day during SW monsoon*

ASEAN MWQC states that total suspended solids (TSS) criteria permissible is 10% maximum increase over seasonal average concentrations. The long term TSS monitoring data at this EIA stage are not available in this region to derive the seasonal average concentration. As a preliminary assessment for the study, the baseline TSS values could be derived from analysed water quality samples at five (5) locations collected on 22nd November 2022. As the preliminary assessment requirements, single baseline TSS value at surface and mid-depth are derived by averaging the TSS value measured at the respective depth. For example, the average measured TSS at surface layer is calculated to be $\frac{(23.7+4.3+6.9+1.2+12)\ mg/L}{5} = \ 9.62\ mg/L.$

To assess the sediment plume level due to the dredging, the maximum modelled suspended sediment concentration (SSC) value over 14 days during SW/ NE monsoon will be extracted at same coordinates as the five (5) water quality sampling locations at surface and mid-depth, before averaging and compared to the baseline value as tabulated in Table 9-19. For example, the percentage increase in TSS at surface layer compared to baseline TSS value for 1000m$^3$/day dredging during NE monsoon scenario is calculated as $\frac{\frac{(0.56+0.55+0.05+0.05+0.05)\frac{mg}{L}}{5}}{9.62\ mg/L} = 2.62\ \%.$

It should be noted that the model TSS values extracted are purely due to the project's dredging and infilling works, and do not take into account of the natural variation of background TSS.

The assessed results indicate increased TSS values are below 10 percent increase over the baseline TSS for all scenarios, except for 5000m$^3$/day dredging scenarios at mid depth. Silt curtains will be deployed during the actual trenching works to limit the release of sediment into the surrounding waterbody where further details are provided in Table 13-4 of the Construction EMMP at Section 13.4.

It should be noted that these results should not be used as indication of conformity/non-conformity to ASEAN MWQC criteria, as the practice of using baseline value derived from single event measurement is not representative of the seasonal average concentration, which needs to be derived using long-term monitoring TSS data.

*Table 9-19: Modelled TSS value (red shading) compared to measured TSS value (blue shading) from water quality station locations*

| | | | Water Quality Station | | | | | Average TSS, mg/L | % above average TSS |
|---|---|---|---|---|---|---|---|---|---|
| | | | WQ01 | WQ02 | WQ03 | WQ04 | WQ05 | | |
| | Surface Measured TSS, mg/L | | 23.7 | 4.3 | 6.9 | 1.2 | 12 | 9.62 | - |
| | Mid depth Measured TSS, mg/L | | 5.2 | 3.4 | 5.3 | 6.0 | 1.9 | 4.36 | - |
| NE monsoon | Surface Model TSS, mg/L | 1000m$^3$/day dredging | 0.56 | 0.55 | 0.05 | 0.05 | 0.05 | 0.25 | 2.62 |
| | | 5000m$^3$/day dredging | 1.13 | 1.07 | 0.14 | 0.28 | 0.25 | 0.57 | 5.97 |
| | Mid Depth Model TSS, mg/L | 1000m$^3$/day dredging | 0.79 | 0.67 | 0.06 | 0.06 | 0.05 | 0.33 | 7.48 |
| | | 5000m$^3$/day dredging | 1.30 | 1.16 | 0.16 | 0.29 | 0.26 | 0.63 | 14.54 |
| SW monsoon | Surface Model TSS, mg/L | 1000m$^3$/day dredging | 0.61 | 0.44 | 0.14 | 0.10 | 0.10 | 0.28 | 2.89 |
| | | 5000m$^3$/day dredging | 1.19 | 1.37 | 0.39 | 0.40 | 0.39 | 0.75 | 7.78 |
| | Mid Depth Model TSS, mg/L | 1000m$^3$/day dredging | 0.78 | 0.53 | 0.14 | 0.11 | 0.1 | 0.33 | 7.61 |
| | | 5000m$^3$/day dredging | 1.28 | 1.61 | 0.33 | 0.4 | 0.39 | 0.80 | 18.39 |

Note: The model TSS values extracted are purely due to the project's dredging and infilling work only

#### 9.2.5.1 Impact Summary

The excess SSC and sedimentation generated from the trenching activities is primarily confined within Banyan basin and localized. Overall, there are no SSC and sedimentation impacts forecasted due to the construction of intake pipeline with the recommended production rate. Therefore, SSC and sedimentation impacts to the environment is no impact.

*Table 9-20: RIAM results for sediment plume impacts during construction phase*

| Impacts | Predicted Impacts | | | | | | | Mitigation measures | Mitigated impact |
|---|---|---|---|---|---|---|---|---|---|
| | Potential impact | ES | I | M | P | R | C | | |
| **Construction** | | | | | | | | | |
| Suspended Sediment concentration (SSC) from trenching works | No change/ no impact | -6 | 1 | -1 | 2 | 3 | 1 | None required | No change/ no impact |

# 10 Marine Biodiversity

The marine biodiversity environment for this Project composed of coral reef habitat and seagrass/ intertidal habitat. The coral reef habitat found in the area are classified to primary reef areas and secondary reef areas. Primary reef areas are areas of natural and original reefs, where corals and its associated reef flora and fauna had grown and thrive from its original and natural environment (e.g., natural coral reef area's), while secondary reefs areas are areas where corals and its associated reef flora and found had grown and thrive from a modified environment (e.g., seawalls, rock bunds, artificial reefs).

Worley
energy | chemicals | resources

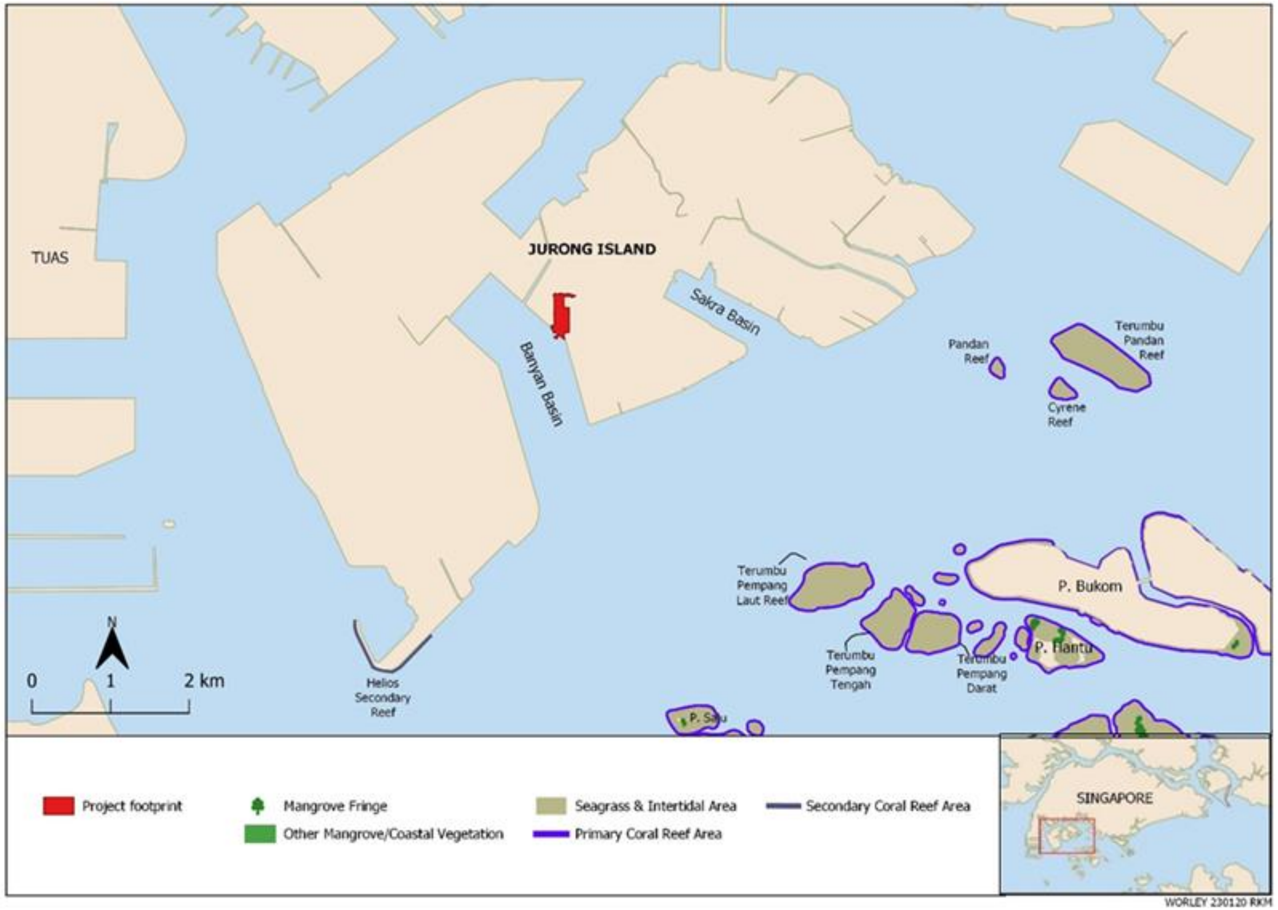



*Figure 10-1: Known ecological receptors around the vicinity of the proposed construction site*

The Project's activities as described in Table 10-1 will potentially affect the coral reefs and seagrass.

*Table 10-1: Summary of proposed project activities with potential to affect marine ecology*

| Activity | | Potential to affect marine biodiversity |
|---|---|---|
| Construction | Offshore trenching works | • Resuspension and dispersion of sediments<br>• Deposition of sediments (sedimentation) |
| Operation | CW system outfall | • Thermal plume dispersion<br>• Chlorine plume dispersion |

## 10.1 Evaluation Framework and Methodology

To assess the potential impact associated with the sediment, thermal, and chlorine plume on coral reefs and seagrass/ intertidal habitat, it is required to establish tolerance limits for these sensitive receptors at risk. The tolerance limits for coral reef and seagrass/ intertidal are likely to vary both with species and from site to site depending on ambient conditions and existing stress levels.

The impacts to coral reefs and seagrass are inferred based on the sediment plume, thermal plume, and chlorine plume dispersion model results, along with the adopted evaluation criteria.

### 10.1.1 Adopted Evaluation Criteria

The evaluation of impact to marine biodiversity is based on consideration of protected and threatened species, designated areas of conservation (if any), environmental criteria, and guidelines, as well as established tolerance limits. This assessment is also supported by *other studies (if available), including*:

The tolerance limits and compliance criteria developed for this study is based on quantitative numerical modelling, relevant standards, limits, guidance, and Worley's experience in dredging and reclamation project in Singapore, as well as industry best practices. The receptors of concern for the study are coral reefs and seagrass/ intertidal.

#### 10.1.1.1 Coral Reefs

The coral reefs in Singapore are found skirting many of the islands south of mainland Singapore. The risk and severity impact of corals primarily related to the intensity, duration, and frequency of exposure to increase suspended sediments concentration and sedimentation in water column. Tolerance limits related to coral receptors are described in Table 10-2.

There is no specific reference limits or threshold available for assessing thermal and chlorine impacts to corals. However, the ASEA MWQC, IFC, and USEPA are applied in this study. For the thermal and chlorine plume impact assessment, the excess temperature of 2°C from the ASEAN MWQC, as well as residual chlorine of 0.013 ppm from the UESPA are adopted.

*Table 10-2: Coral reefs tolerance limits to suspended sediments and sedimentation*

<table>
<tr><th>Tolerance Limit</th><th>Description</th></tr>
<tr><td>Suspended sediments</td><td>Dredging and infilling releases sediment into the water column, creating sediment plume which can be transported from the initial activity to nearby environmental receptor. Suspended sediments typically comprise of small particles such as silt and clay and will remain in suspension for an extended period with limited water turbulence. Corals experience stress when the suspended sediments concentration in water column are high and this reduces irradiance, restrict photosynthesis and therefore reduces coral growth. The amount of light attenuation that occurs in a plume depends on depth, as well as the sediment concentration and its scattering and absorption properties including colour, composition, and particle size (Storlazzi et al., 2015). The corals required minimal light ranging from less than 1% to 60% of surface irradiance and capable to tolerate suspended sediment concentration ranging from less than 10 mg/L for pristine reef areas to between 40 mg/L and 165 mg/L for marginal nearshore reefs (Paul L.A. et al, 2012). The ability for corals to cope to tolerate higher suspended sediment concentration varies between species as a function of root architecture. stipulates the matrix[4, 3] of corals tolerance to SSC.
Table 10-3: Impact Severity Matrix for Suspended Sediment Impact to Corals
<table>
<tr><th>Severity</th><th>Definitions</th></tr>
<tr><td>No Impact</td><td><ul><li>SSC > 5mg/L for less than 5% of the time</li></ul></td></tr>
<tr><td>Slight impact</td><td><ul><li>SSC > 10mg/L for more than 5% of the time; or</li><li>SSC > 5mg/L for less than 20% of the time</li></ul></td></tr>
<tr><td>Minor impact</td><td><ul><li>SSC > 10mg/L for less than 20% of the time; or</li><li>SSC > 5mg/L for more than 20% of the time</li></ul></td></tr>
<tr><td>Moderate impact</td><td><ul><li>SSC > 25mg/L for more than 5% of the time; or</li><li>SSC > 10mg/L for less than 20% of the time</li></ul></td></tr>
<tr><td>Major impact</td><td><ul><li>SSC > 100mg/L for more than 1% of the time; or</li><li>SSC > 25mg/L for more than 20% of the time</li></ul></td></tr>
</table>
</td></tr>
<tr><td>Sedimentation</td><td>Increase sedimentation may cause smothering and burial of coral polyps and affect the structure and function of the coral reef ecosystem. Based on available study and research, the duration in which the coral is capable to survive high sedimentation rates range from less than 24 hours for sensitive species to few weeks (more than 4 weeks of high sedimentation or more than 14 days for complete burial) for very tolerant species (Erftermeijer, Riegl, Hoeksema, & Todd, 2012).
Table 10-4 stipulate the matrix1, 2 of corals tolerance to sedimentation. </td></tr>
</table>

<table>
<tr><th>Tolerance Limit</th><th>Description</th></tr>
<tr><td></td><td>
Table 10-4: Impact Severity Matrix for Sedimentation Impact to Corals
<table>
<tr><th>Severity</th><th>Definitions</th></tr>
<tr><td>No Impact</td><td>Sedimentation < 1.7 mm/14 day</td></tr>
<tr><td>Slight impact</td><td>Sedimentation < 3.5 mm/14 day</td></tr>
<tr><td>Minor impact</td><td>Sedimentation < 7.0 mm/14 day</td></tr>
<tr><td>Moderate impact</td><td>Sedimentation < 17.5 mm/14 day</td></tr>
<tr><td>Major impact</td><td>Sedimentation > 17.5mm/14 day</td></tr>
</table>
</td></tr>
</table>

*[1] The tolerance limit adopted has been validated based on Worley's past experience in EMMP and habitat monitoring experiences within the region, as well as best industry practices.*

*[2] These set of tolerance limits have been applied in Singapore based on recognized study* (Doorn-Groen & Foster, 2007).

#### 10.1.1.2 Seagrass

Suspended sediments and sedimentation tolerance limits related to seagrass receptors are described in Table 10-5. There is no specific reference limits or threshold available for assessing thermal and chlorine impacts to seagrass. However, the ASEA MWQC, IFC, and USEPA are applied in this study. For the thermal and chlorine plume impact assessment, the excess temperature of $2^{\circ}C$ from the ASEAN MWQC, as well as residual chlorine of 0.013 ppm from the UESPA are adopted.

*Table 10-5: Seagrass tolerance limits to suspended sediments and sedimentation*

<table>
<tr><th>Tolerance Limit</th><th>Description</th></tr>
<tr><td>Suspended sediments</td><td>
Light is one of the most important factors in the regulation of seagrass distribution as seagrass required light to drive photosynthesis. Lights generally attenuates exponentially with increasing water turbidity and higher suspended solid concentration (SSC). Therefore, changes in water quality will affect the adequacy of irradiance. Based on the available study (Duarte, 1991), seagrass have a minimum requirement for light of approximately 10 % of the surface irradiance. Deterioration of water quality may occur from the disturbance of seabed sediment (higher SSC) during dredging and infilling construction works, which may result in temporary impact to seagrass. The impact can be managed by an EMMP. Table 10-6 stipulates the matrix of seagrass tolerance[6] to SSC.<br>
Table 10-6: Impact severity matrix for suspended sediment impact to seagrass
<table>
<tr><th>Severity</th><th>Definitions</th></tr>
<tr><td>No Impact</td><td>• SSC > 5mg/L for less than 20% of the time</td></tr>
</table>
</td></tr>
</table>

[6] The tolerance limit adopted has been validated based on Worley's past experience in EMMP and habitat monitoring experiences within the region, as well as best industry practices.

<table>
<tr><th>Tolerance Limit</th><th>Description</th></tr>
<tr><td></td><td>
<table>
<tr><td>Slight impact</td><td>• SSC > 5mg/L for more than 20% of the time<br>• SSC > 10mg/L for less than 20% of the time</td></tr>
<tr><td>Minor impact</td><td>• SSC > 25mg/L for less than 5% of the time</td></tr>
<tr><td>Moderate impact</td><td>• SSC > 25mg/L for more than 20% of the time<br>• SSC > 75mg/L for less than 1% of the time</td></tr>
<tr><td>Major impact</td><td>• SSC > 75mg/L for more than 20% of the time</td></tr>
</table>
</td></tr>
<tr><td>Sedimentation</td><td>The seabed sediment will be disturbed, particularly during dredging and infilling operations. Depending on the size, the sediment will be transported to other area, and eventually deteriorate the water quality and also, burial or sedimentation which hinder seagrass growth. Similar to the suspended solid concentration factor, the disturbance to seagrass may be temporary. The impact can be managed by an EMMP. The impact severity matrix [6] for sedimentation impact to seagrass is presented in Table 10-7.<br><br>Table 10-7: Impact severity matrix for sedimentation to seagrass<br>
<table>
<tr><th>Severity</th><th>Definitions</th></tr>
<tr><td>No Impact</td><td>Sedimentation < 0.25mm/day</td></tr>
<tr><td>Slight impact</td><td>Sedimentation < 0.63mm/day</td></tr>
<tr><td>Minor impact</td><td>Sedimentation <1.25mm/day</td></tr>
<tr><td>Moderate impact</td><td>Sedimentation < 2.5 mm/day</td></tr>
<tr><td>Major impact</td><td>Sedimentation > 2.50mm/day</td></tr>
</table>
</td></tr>
</table>

## 10.2 Impact Assessment

The sediment plume, thermal plume, and chlorine plume results are assessed and presented in terms of:

- Exceedance of Suspended Solid Concentration (SSC) at 5mg/L, 10mg/L, and 25mg/;
- Sedimentation;
- Percentage exceedance plot for 1°C and 2°C, and 3°C excess temperature; and
- Percentage exceedance plot for 0.013 ppm excess chlorine concentration.

It is observed that:

**Construction**

- During the construction phase, an increase in SSC would occur due to potential spilling of fine sediments into the sea during the excavation of trenches to install the intake pipeline. The plume is generally confined and deposited in the basin.
- The percentage exceedance of SSC above 5 mg/L for than more 5 % of the time is < 1km from the spill source at both production volume of 1000 $m^3$/day and 5000 $m^3$/day. The percentage exceedance of SSC above 5 mg/L for more than 20% of the time are localised at the trench.

**Operation Phase**

- According to the thermal plume model result, the simulated maximum mean temperature changes observed at Project's intake are up to 1.71 °C at surface and up to 0.49 °C at bottom post-development. Spatial extent of temperature changes are also observed to be contained within the Banyan basin, with wider temperature change extent observed for surface layer compared to bottom layer.
- Additionally, according to Seagrass-Watch HQ, short-term exposure to elevated temperatures above 40°C will cause leaf death in seagrass.
- Based on the chlorine plume model result, the percentage exceedance of 0.013 ppm excess chlorine over 14 days (NE and SW monsoon) of up to above 90 percent are observed near Project's outfall post development during normal dosing operations at 0.25 ppm (normal operation) and 0.5 ppm (shock dosing). Spatial extent of percentage exceedance of 0.013 ppm excess chlorine is observed to be mostly contained within Banyan basin and slightly extending out east and west close to Jurong Island for both normal and shock dosing operations at 0.25 ppm and 0.5 ppm, respectively. No chlorine plume is dispersed to the sensitive receptors.

### 10.2.1 Impacts Summary

The excess SSC, thermal and chlorine plume are localized and it is primarily confined within Banyan basin

Overall, there are

- no SSC and sedimentation impacts forecasted due to the construction of intake pipeline with the recommended production rate
- No impact thermal
- No impact of chlorine plume
- Using the Singapore's Environmental Protection and Management (Trade Effluent) Regulations 2008 and USEPA (R.E.D. FACTS Chlorine gas), the chlorine plume from the 105,000 $m^3$/ hr release of 0.25 ppm and 0.5 ppm concentration demonstrated no potential impact on the nearby sensitive receptors. The dispersion is generally confined within the Basin and no dispersion to the sensitive receptors are observed.
- Therefore, impacts to the marine biodiversity are assessed as "No impact".

*Table 10-8: EQO and EQL compliance for marine biodiversity impact assessment*

| Receptors of Concern | EQO | ETL | Compliance |
|---|---|---|---|
| Coral reefs | No impact | • SSC > 5mg/L for less than 5% of the time<br>• Sedimentation < 1.7mm/14 days<br>• Excess temperature of 2°C<br>• Excess chlorine of 0.013 ppm | √ |
| Seagrass | No impact | • SSC > 5mg/L for less than 20% of the time<br>• Sedimentation < 0.25mm/day<br>• Excess temperature of 2°C<br>• Excess chlorine of 0.013 ppm | √ |

*Table 10-9: RIAM results for marine biodiversity impact assessment*

| Impacts on receptor | | Predicted Impacts | | | | | | | Mitigation measures | Mitigated impact |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Potential impact | ES | I | M | P | R | C | | |
| **Construction** | | | | | | | | | | |
| Coral reefs | Excess sediment plume impacts | No change/ no impact | 0 | 3 | 0 | 1 | 1 | 1 | None required | No change/ no impact |
| Seagrass | Excess sediment plume impacts | No change/ no impact | 0 | 3 | 0 | 1 | 1 | 1 | None required | No change/ no impact |
| **Operation** | | | | | | | | | | |
| Coral reefs | Excess temperature impacts | No change/ no impact | 0 | 3 | 0 | 1 | 1 | 1 | None required | No change/ no impact |
| | Excess chlorine impacts | No change/ no impact | 0 | 3 | 0 | 1 | 1 | 1 | None required | No change/ no impact |
| Seagrass | Excess temperature impacts | No change/ no impact | 0 | 3 | 0 | 1 | 1 | 1 | None required | No change/ no impact |
| | Excess chlorine impacts | No change/ no impact | 0 | 3 | 0 | 1 | 1 | 1 | None required | No change/ no impact |

# 11 Socioeconomic

The receptors that may be influenced due to the Project development presented in Table 11-1. Figure 11-1 illustrates the socio-economic receptors in the vicinity of the Project development site

*Table 11-1: Summary of the marine environment receptors*

| Receptor | Location |
|---|---|
| Navigation | • Sinki Fairway<br>• ASPP Anchorage |
| Marine facilities | • Water intakes<br>• Jetties and berthing |
| Aquaculture facilities | • Aquaculture facilities in the Southern waters off western Pulau Semakau and eastern Pulau Senang |
| International Boundary | • Singapore – Indonesia boundary |
| Human health | • Workers |

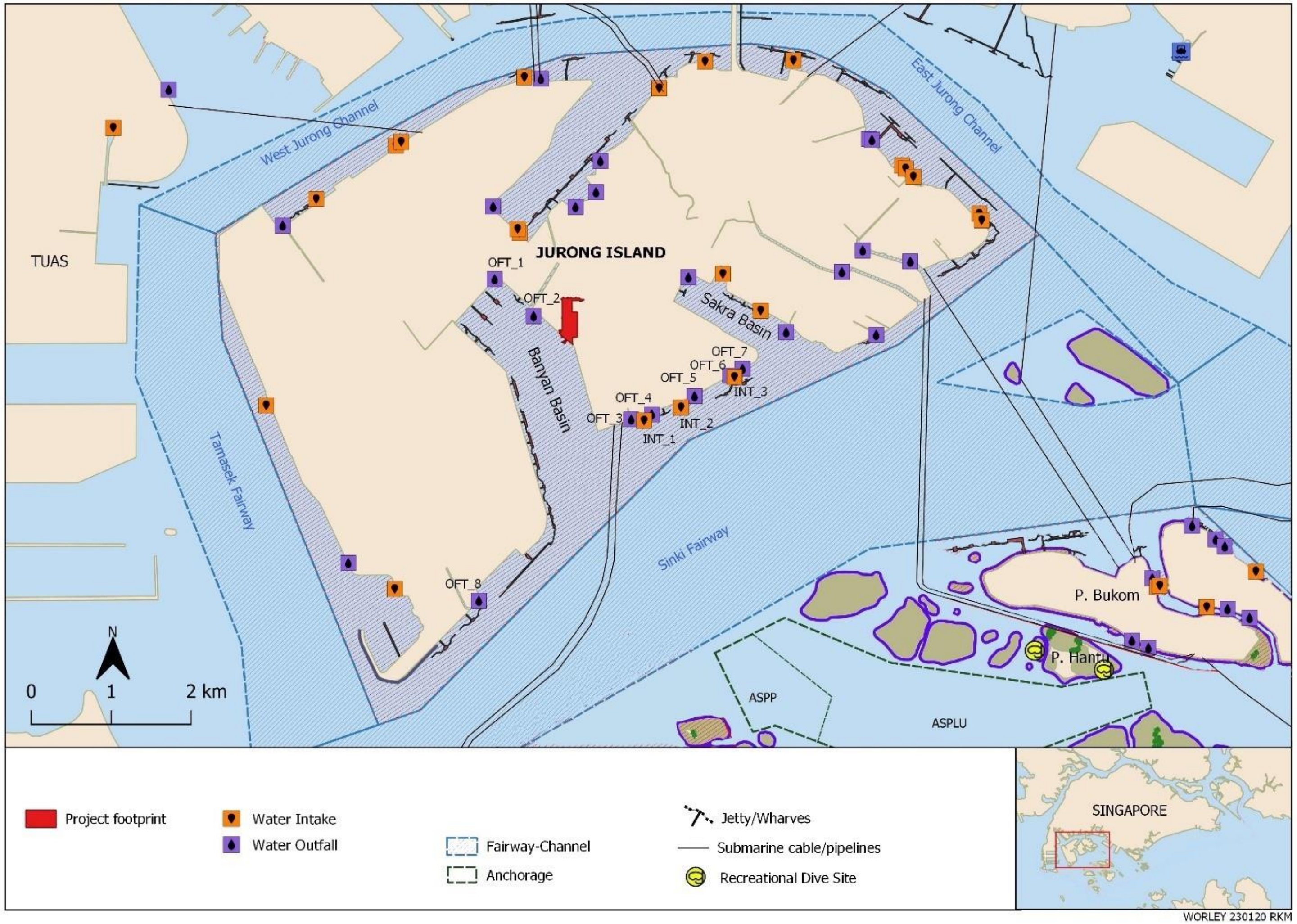



*Figure 11-1: Known marine environment receptors around the vicinity of the proposed construction site*

## 11.1 Evaluation Framework and Methodology

The impacts to the socio-economic aspects arising from the Project activities are assessed based on the legal framework that governs Singapore, as well as other applicable evaluation criteria. Additionally, tolerance limits are applied for the EIA analysis to supplement the relevant legislation.

### 11.1.1 Adopted Evaluation Criteria

#### 11.1.1.1 Human Health

The evaluation criteria used to assess the impact to human health are presented in Table 11-2.

*Table 11-2 Evaluation criteria for human health impact*

| Legislation | Description |
|---|---|
| Environmental Pollution Control Act | Provides national environmental standards and guidelines for pollution control and management. The Act includes the framework for managing and setting acceptable levels for parameters related to air, water, noise, land and hazardous waste pollution. |
| Singapore Code of Practice on Environmental Health | Singapore methods for ensuring environmental health. |
| ASEAN MWQC | Association of Southeast Asian Nations Marine Water Quality Criteria (ASEAN 2008) for assessing marine water quality. |
| IFC General EHS Guidelines 2007: 3.0 Community Health and Safety | Provides measures for the prevention of disease during large development projects. |

#### 11.1.1.2 Marine Infrastructure

Incremental sedimentation for the marine infrastructure like navigation, jetties, and berthing area were considered as a crucial issue as it would affect the operations of the marine infrastructure. Based upon recognized tolerance limits the sedimentation tolerance limits for marine infrastructure is indicated in Table 11-3.

*Table 11-3: Sedimentation tolerance limits[1,2] for marine infrastructure*

| Severity | Definitions |
|---|---|
| No Impact | Sedimentation < 50mm/ year |
| Slight impact | Sedimentation 50 to < 150 mm/ year |
| Minor impact | Sedimentation 150 to < 300 mm/ year |
| Moderate impact | Sedimentation 300 to < 500 mm/ year |
| Major impact | Sedimentation ≥ 500 mm/ year |

#### 11.1.1.3 Aquaculture Facilities

Based upon recognized tolerance limits, the matrix for aquaculture facilities tolerance to SSC are indicated in Table 11-4.

*Table 11-4: Impact Severity Matrix for suspended sediment impact to aquaculture*

| Severity | Definitions |
|---|---|
| No Impact | • SSC > 5mg/L for less than 5% of the time<br>• Sedimentation < 1.7 mm/ 14day |
| Slight impact | • SC > 10mg/L for more than 5% of the time; or<br>• SSC > 5mg/L for less than 20% of the time<br>• Sedimentation < 3.5 mm/ 14day |
| Minor impact | • SSC > 10mg/L for less than 20% of the time; or<br>• SSC > 5mg/L for more than 20% of the time<br>• Sedimentation < 7.0 mm/14 day |
| Moderate impact | • SSC > 25mg/L for more than 5% of the time; or<br>• SSC > 10mg/L for more than 20% of the time<br>• Sedimentation < 17.5 mm/14 day |
| Major impact | • SSC > 100mg/L for more than 1% of the time; or<br>• SSC > 25mg/L for more than 20% of the time<br>• Sedimentation > 17.5 mm/ 14 days |

#### 11.1.1.4 International Boundary

The international boundary impact is caused by the increased of suspended sediment leading to negative aesthetic impact. Impacts along the border or within international waters would be undesirable, particularly visual impacts. For visual impact assessment, a realistic measurable detection limit for non-recreational and recreational area would be assessing the plume over 12- hour daylight period. The adopted visual impact tolerance limits for this study are the SSC of 10 mg/L for no more than 5% of the time during 12-hour daylight period.

#### 11.1.1.5 Seawater Intakes

The incremental SSC to water intakes depends on the intake purpose. However, from Advising's experience in managing large-scale EMMPs in relation to dredging and impacts to seawater intake, a standard where suspended sediments generated from dredging activities do not exceed a concentration of 10 mg/l for more than 5% of the time.

#### 11.1.1.6 Extracted Mean Excess Temperature

The excess temperature is extracted at five (5) intakes.

The mean thermal impact to existing intakes is shown in Table 11-5. Model results indicate < 0.1°C mean temperature differences over 14-day (NE and SW monsoon) simulation period and across different water column layer. Model results indicate there are negligible temperature difference pre- vs post-development throughout 14 days of NE and SW monsoon simulation period.

The time series extracted at the intakes are illustrated in Figure 11-2 to Figure 11-6. The black lines show the temperature for pre-construction phase, while the red line represents the same parameter during post-construction phase.

*Table 11-5: Mean temperature differences for 5 existing intakes*

| Existing Intake | Layer | Mean Temperature [°C] | | | | | |
|---|---|---|---|---|---|---|---|
| | | NE monsoon | | | SW monsoon | | |
| | | Pre-Development | Post-Development | Difference | Pre-Development | Post-Development | Difference |
| 1.Invista | Surface | 29.9 | 29.9 | < 0.1 | 30.6 | 30.6 | < 0.1 |
| | Bottom | 29.8 | 29.8 | < 0.1 | 30.3 | 30.3 | < 0.1 |
| 2.SembCorp Industries | Surface | 29.8 | 29.9 | < 0.1 | 30.4 | 30.4 | < 0.1 |
| | Bottom | 29.5 | 29.6 | < 0.1 | 30.1 | 30.1 | < 0.1 |
| 3.Chevron Oronite | Surface | 29.9 | 30.0 | < 0.1 | 30.5 | 30.6 | < 0.1 |
| | Bottom | 29.5 | 29.6 | < 0.1 | 30.1 | 30.1 | < 0.1 |
| 4.SLNG | Surface | 29.4 | 29.5 | < 0.1 | 29.9 | 29.9 | < 0.1 |
| | Bottom | 29.3 | 29.4 | < 0.1 | 29.8 | 29.8 | < 0.1 |
| 5.SembCorp Intake (JI Westward) | Surface | 29.7 | 29.8 | < 0.1 | 30.1 | 30.2 | < 0.1 |
| | Bottom | 29.6 | 29.7 | < 0.1 | 30.1 | 30.1 | < 0.1 |

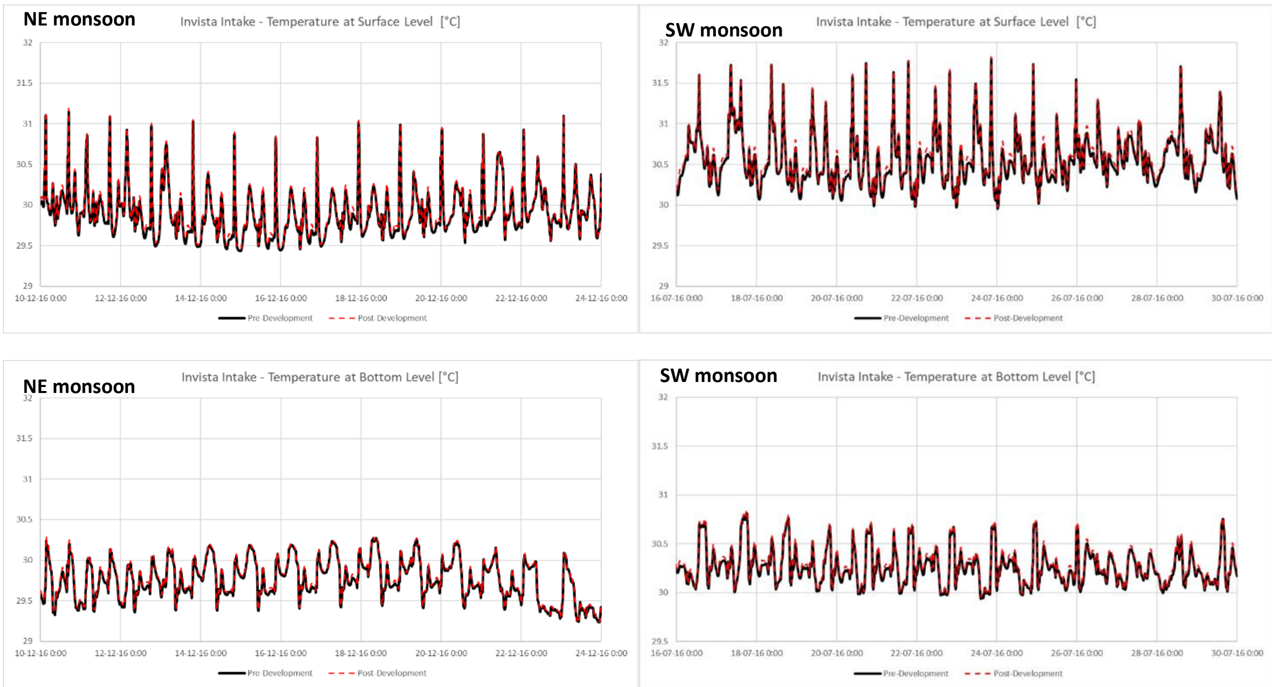



*Figure 11-2: Modelled temperature time series for Pre- and Post-Development during NE monsoon (left) and SW monsoon (right) at Invista Intake at Surface (top) and Bottom (bottom) layer*

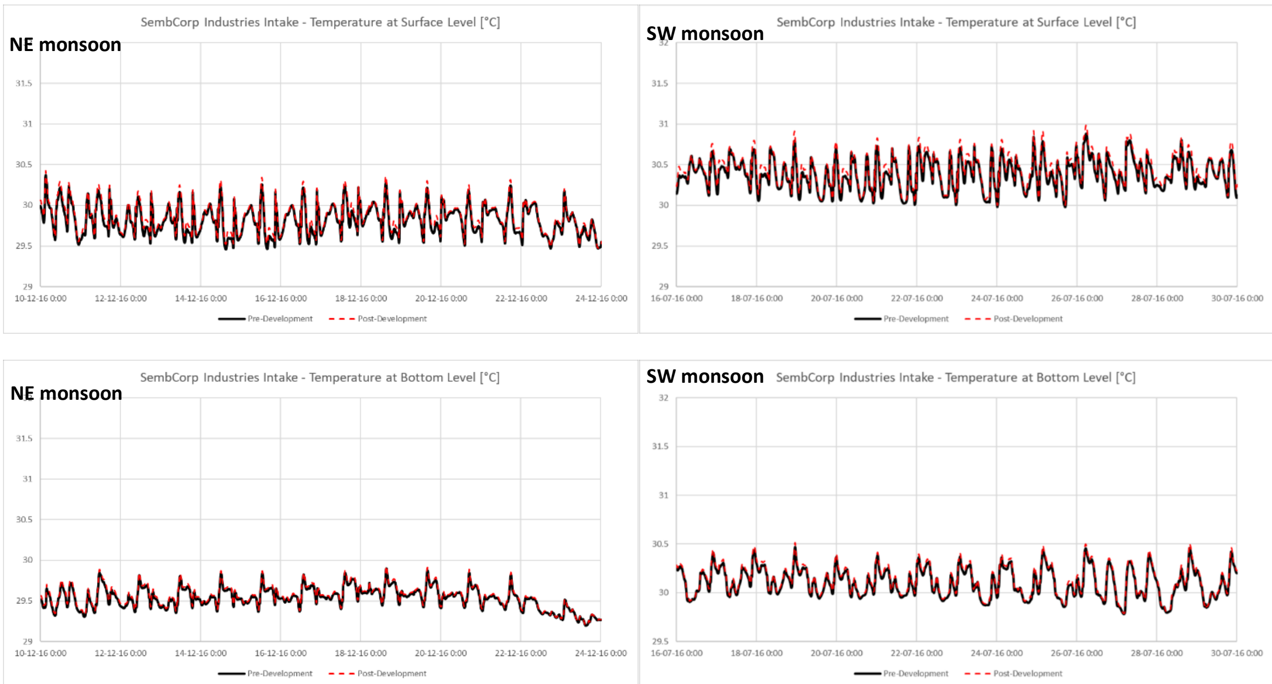



*Figure 11-3: Modelled temperature time series for Pre- and Post-Development during NE monsoon (left) and SW monsoon (right) at SembCorp Industries Intake at Surface (top) and Bottom (bottom) layer*

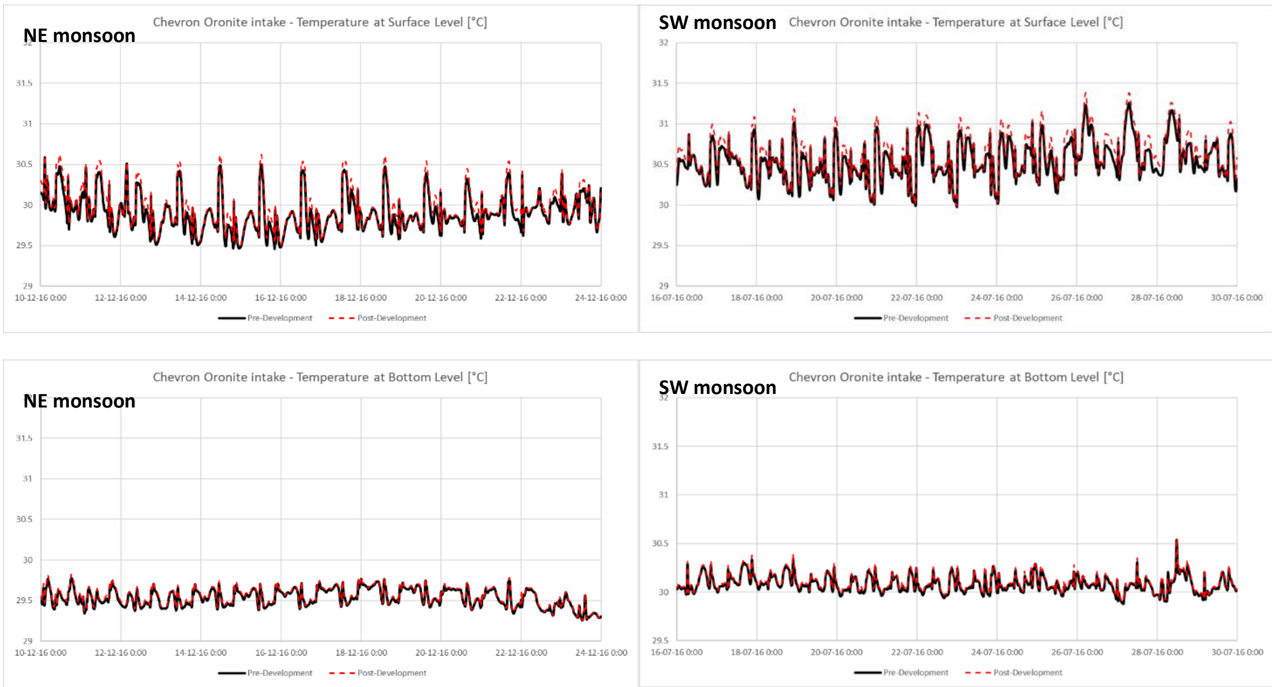



*Figure 11-4: Modelled temperature time series for Pre- and Post-Development during NE monsoon (left) and SW monsoon (right) at Chevron Oronite Intake at Surface (top) and Bottom (bottom) layer*

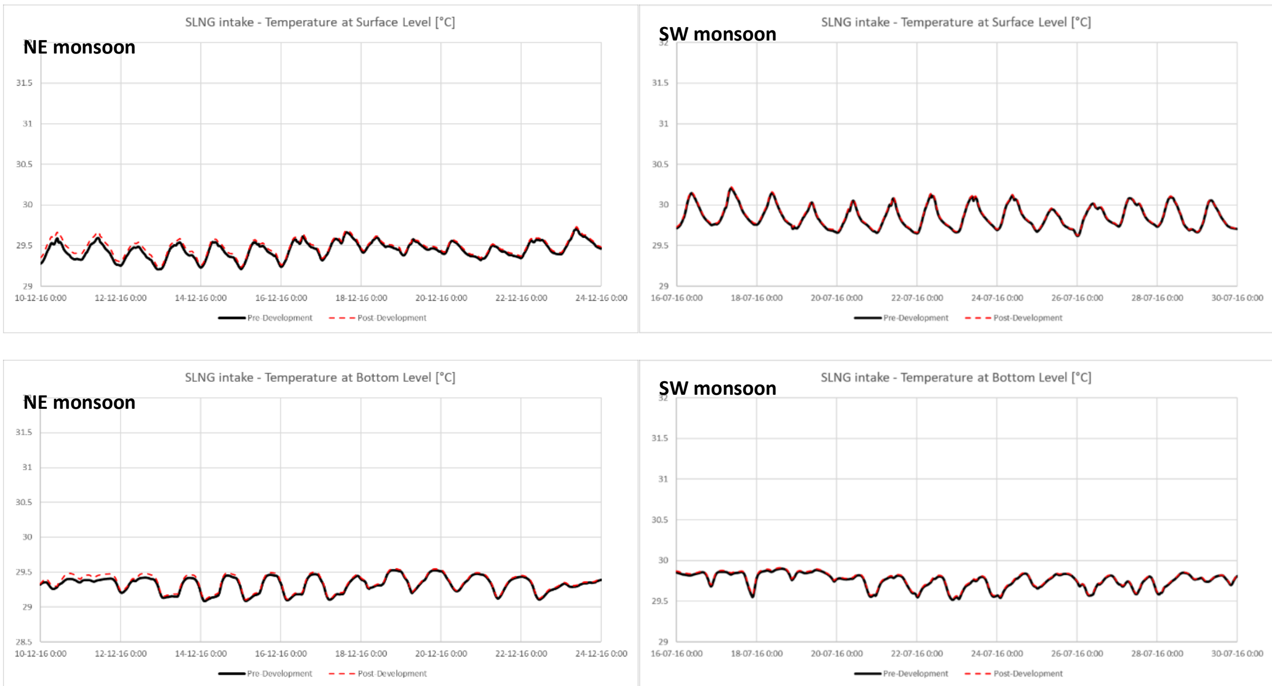



*Figure 11-5: Modelled temperature time series for Pre- and Post-Development during NE monsoon (left) and SW monsoon (right) at SNLG Intake at Surface (top) and Bottom (bottom) layer*

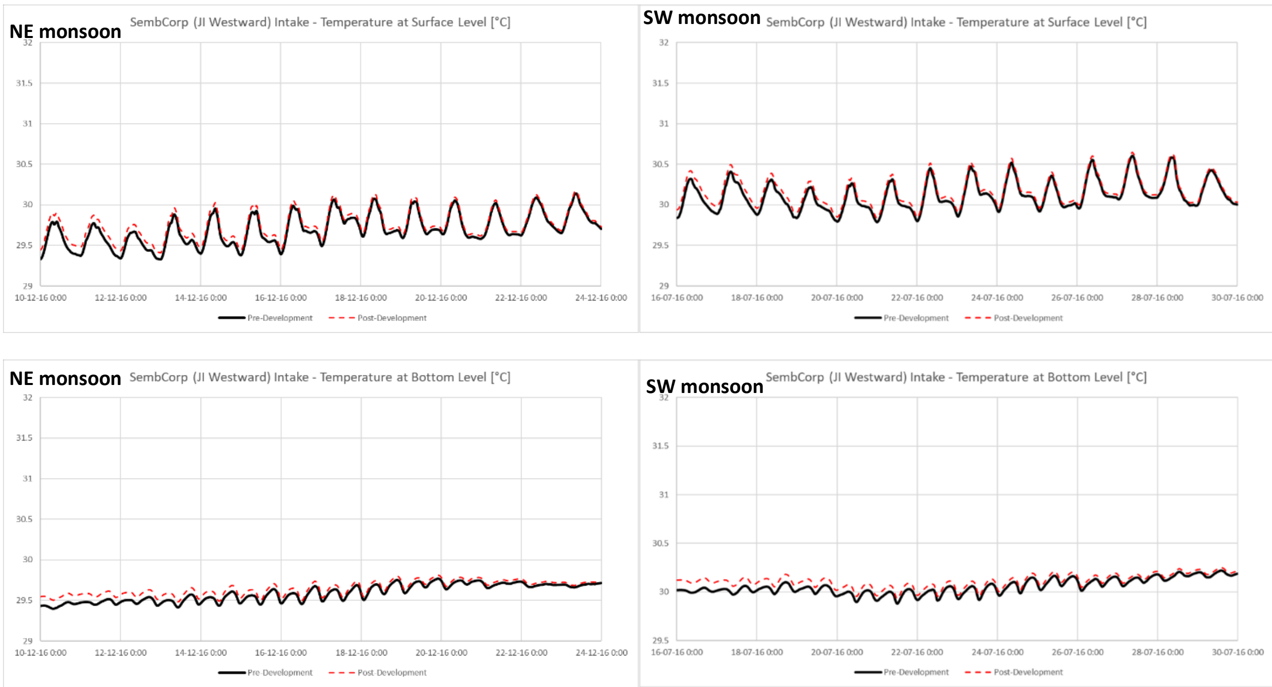



*Figure 11-6: Modelled temperature time series for Pre- and Post-Development during NE monsoon (left) and SW monsoon (right) at SembCorp (JI Westward) Intake at Surface (top) and Bottom (bottom) layer*

## 11.2 Impact Assessment

The sediment plume model results (Section 9.2.5) are assessed and presented in terms of:

- Exceedance of Suspended Solid Concentration (SSC) at 5mg/L, 10mg/L, and 25mg/L; and
- Sedimentation.

It is observed that:

**Construction**

- During the construction phase, an increase in SSC would occur due to potential spilling of fine sediments into the sea during the excavation of trenches to install the intake pipeline. The plume is generally confined and deposited in the basin.
- The percentage exceedance of SSC above 5 mg/L for than more 5 % of the time is < 1km from the spill source at both production volume of 1000 $m^3$/day and 5000 $m^3$/day. The percentage exceedance of SSC above 5 mg/L for more than 20% of the time are localised at the trench.

**Operation Phase**

- Based on the model result, the mean current speeds over 14-day have increased near the outfall and intake up to 0.23 m/s and 0.15 m/s respectively after completion of the intake and outfall development.

### 11.2.1 Impact Summary

Table 11-6 provide an overview of the impacts significant level for the socio-economic receptor.

#### 11.2.1.1 Human Health

Surrounding waters are also not used for drinking water. The impact to human health as a result of changes to water quality is therefore assessed to be "No impact".

#### 11.2.1.2 Marine Infrastructure

Based on hydrodynamic modelling and assessment, model results indicated that the current changes are limited within the areas near the intake and outfall. The increased current may generate local scour immediately near the structures, but engineering design have been factored in. There are no identifiable significant impacts to the navigation. Therefore, impacts to the marine infrastructure are assessed as "no impact".

The subsea cables and pipelines are all outside the direct impact zone of the pipeline replacement and hence the impact to them is anticipated to be negligible, assessed as "No impact".

#### 11.2.1.3 Aquaculture Facilities

Aquaculture facilities may be affected by changes in sediment plumes as a result of proposed construction works. Increases in suspended sediments may result in the clogging of fish gills. The aquaculture facilities are outside the direct impact zone and hence the impact to them is anticipated to be "No impact".

#### 11.2.1.4 International Boundary

The sediment plume does not cause impact to the international boundary. Based on the modelling results, it is unlikely that the dredging activities would cause any impact to this receptor. Therefore, impacts to the international boundary are assessed as "No impact".

#### 11.2.1.5 Seawater Intakes

Based on the modelling results, it is unlikely that the dredging activities would cause any impact to this receptor. Therefore, impacts to the seawater intakes are assessed as "No impact".

*Table 11-6: RIAM results for socio-economic impact assessment*

| Impacts on receptor | | Predicted Impacts | | | | | | | Mitigation measures | Mitigated impact |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Potential impact | ES | I | M | P | R | C | | |
| **Construction** | | | | | | | | | | |
| Marine Infrastructure and Navigation | Sedimentation to berthing and other marine facilities | No change/ no impact | 0 | 3 | 0 | 1 | 1 | 1 | None required | No change/ no impact |
| International boundary | SSC impact | No change/ no impact | 0 | 5 | 0 | 1 | 1 | 1 | None required | No change/ no impact |
| Aquaculture facilities | SSC impact | No change/ no impact | 0 | 4 | 0 | 1 | 1 | 1 | None required | No change/ no impact |
| Seawater intakes and outfalls | SSC impact | No change/ no impact | 0 | 3 | 0 | 1 | 1 | 1 | None required | No change/ no impact |
| Subsea cables and pipelines | SSC impact | No change/ no impact | 0 | 3 | 0 | 1 | 1 | 1 | None required | No change/ no impact |
| **Operation** | | | | | | | | | | |
| Marine Infrastructure and Navigation | Current impact to berthing and other marine facilities | No change/ no impact | 0 | 3 | 0 | 1 | 1 | 1 | None required | No change/ no impact |

# 12 Quantitative Risk Assessment

For this Project, a full scope of QRA was done by BMT Singapore Pte Ltd (BMT) in accordance with the Revised QRA Guidelines Criteria, August 2016, and the Revised QRA Technical Guidance, Nov 2016, both stipulated by NEA, with the objectives to:

- Identify hazards and quantify risks related to the storage and handling of hazardous materials within the site boundary;
- Determine hazards/risks due to possible fire, explosion and toxic release outcomes;
- Recommend measures to address major hazards / risks and to keep residual hazards / risks to as low as reasonably practicable (ALARP), if necessary; and
- Provide input to facilitate land planning decisions by evaluating the acceptability of the overall site risk profiles with respect to the Revised QRA Guidelines Criteria.

Scope of works mainly focused on assessment of risks to on-site occupied buildings and off-site populations arising from the operation of the proposed power plant, and the storage and handling of hazardous materials (natural gas, diesel, hydrogen, and Hydrochloric acid (37%)) on-site, based on the below methodology:

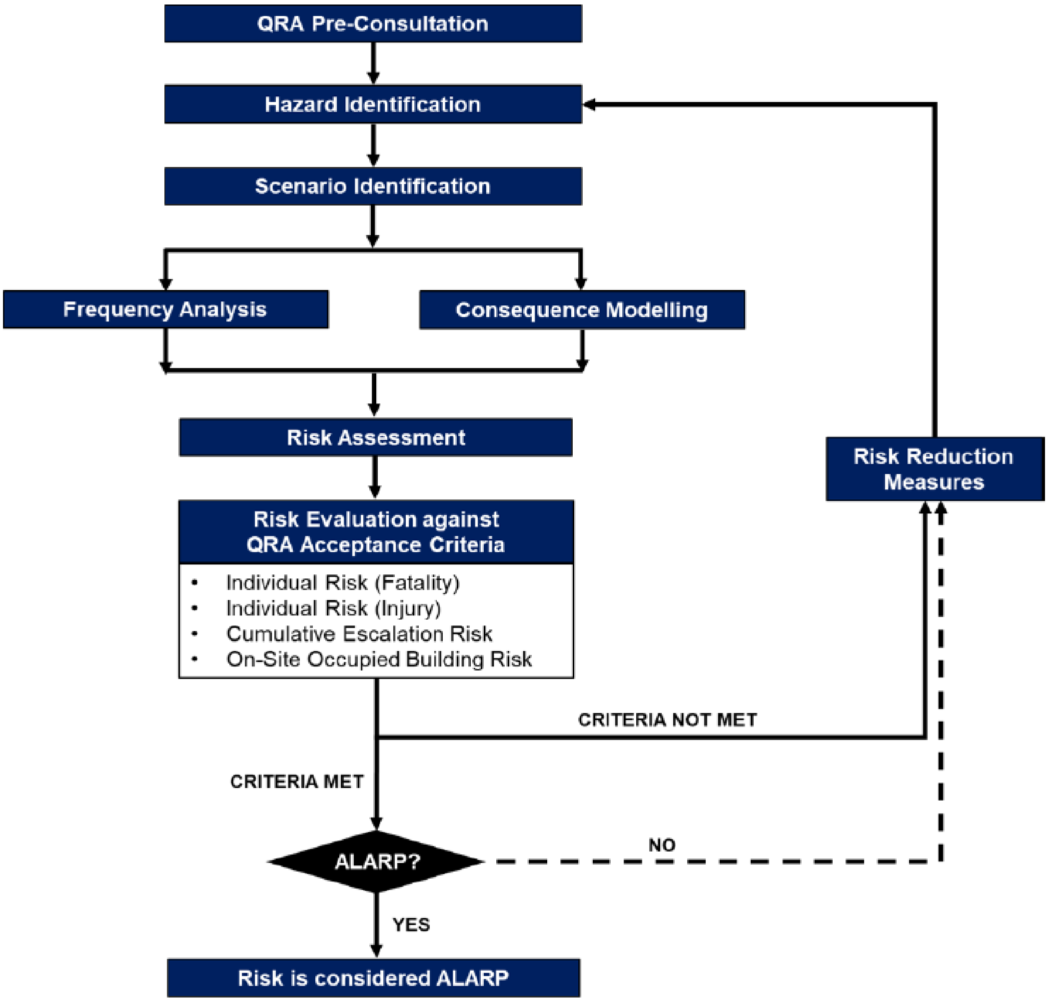



*Figure 12-1 QRA Methodology*

For this QRA, a pre-consultation was conducted with Major Hazards Department (MHD) which confirmed that a QRA study is required for the Project, as per email response on 28 March 2022. It was then followed by Hazard Identification then Scenario Identification. Both Frequency Analysis, that involved computation of the likelihood of occurrence of accident events and the likelihoods of various subsequent end events, and Consequence Modelling, that assessed the development of hazardous scenarios from the initial release event to the various end event outcomes, were conducted concurrently after Scenario Identification.

For Consequence Modelling, the following impacts were identified and assessed:

- Worst Case Scenarios (WCS) causing the largest absolute and off-site injury harm distances for fire, explosion and toxic dispersion outcomes;
- Cumulative Escalation (CE) scenarios causing the largest absolute and off-site harm distances for fire at 20 kW/m$^2$ and explosion at 2 psi levels;
- ERPG-2 harm footprints;
- Fireball zones; and
- Domino information.

The results from the above were later combined to give a measure of risk of each outcome. By summing the risk contributions of each hazardous event, the overall risk profiles for the Project were generated and presented as individual risk (IR) contours on a map of the site and surrounding vicinity in four (4) risk profiles as below:

- IR (Fatality);
- IR (Injury);
- Cumulative Escalation; and
- IR (Occupied Building).

The generated risk profiles for the Project were assessed against the QRA risk acceptance criteria stipulated in the Revised QRA Guidelines Criteria, as shown below:

*Table 12-1 QRA Risk Acceptance Criteria*

| Risk Criteria | Risk Level (per year) | Requirement |
|---|---|---|
| IR (Fatality) | 5 x $10^{-5}$ | Confined within site boundary |
| | 5 x $10^{-6}$ | Confined to industrial developments only |
| IR (Injury)* | 3 x $10^{-7}$ | Confined to commercial and industrial developments only and shall not reach sensitive receptors |
| Cumulative Escalation | 1 x $10^{-4}$ | Confined within site boundary |
| IR (Occupied Building) | 1 x $10^{-3}$ | Shall not be exceeded for any on-site occupied building |

**Note:**

* - Subject to JTC imposed criterion as the Project area is owned and managed by JTC

Should the level of risk be assessed to be unacceptable, risk reduction measures were recommended to reduce the risk to ALARP levels. The findings of this QRA study show that the IR (Fatality), IR (Injury), Cumulative Escalation and On-site Occupied Buildings risk profiles were in compliance with all risk acceptance criteria stipulated in the Revised QRA Guidelines Criteria. The salient findings of the QRA study are summarised in Table 12-2.

*Table 12-2 QRA Salient Findings*

| Risk Criteria | Risk Level (per year) | Maximum Off-site Distance (m) | Requirement |
|---|---|---|---|
| IR (Fatality) | $5 \times 10^{-5}$ | 0 | This contour is confined within site boundary |
| | $5 \times 10^{-6}$ | 11 | This contour is confined to industrial developments only |
| IR (Injury)* | $3 \times 10^{-7}$ | 27 | This contour is confined to commercial and industrial developments only and does not reach sensitive receptors |
| Cumulative Escalation | $1 \times 10^{-4}$ | - | This contour is not attainable |
| IR (Occupied Building) | $1 \times 10^{-3}$ | N/A | IR (Fatality) recorded at $1.17 \times 10^{-6}$ did not exceed the threshold for any on-site occupied building |

**Note:**

* - Subject to JTC imposed criterion as the Project area is owned and managed by JTC

N/A - Not applicable

In conclusion, all stipulated risk acceptance criteria in the Revised QRA Guidelines Criteria were met.

It was recommended that:

- Emergency Response Plan to be developed by the Project Owner when more detailed information on the site operating procedures is available prior to commencement of operations; and
- QRA study to be updated if there are any significant changes to the design basis, hazardous inventories or relevant assumptions for the site facilities and operations in future. For the full report, please refer to Appendix G.

# 13 Environmental Management Framework

The Environmental Management and Monitoring Plan (EMMP) is a systematic approach to mitigate environmental impacts and monitor the implementation of these mitigation measures to ensure that the Project implementation will not cause any significant adverse impact to the environment during construction and operation phases.

This EMMP will serve as an iterative dynamic document and shall be updated as and when deemed necessary to ensure that any changes to the Project's activities and layout, as well as new environmental requirements are updated accordingly.

The objective of the EMMP are as follows:

- To establish appropriate standards and procedures for mitigating and monitoring the impacts;
- To set up roles and responsibilities for the management of environmental qualities; and
- To monitor the effectiveness of the recommended mitigation measures to allow amendment or review of mitigation and establish corrective actions when necessary.

This EMMP framework consolidates the mitigation and monitoring strategy required for this Project based on the outcome from this EIA.

## 13.1 Environmental Management and Monitoring Plan

The coverage of the EMMP involves the environmental parameters that were assessed, namely air quality, noise, water quality, vector, wastewater, and waste management, as well as biodiversity. The scale and approach of the EMMP has been tailored to the specific nature of this proposed work and the following monitoring components are proposed. The various mitigation actions will be further refined in line with Technical Agencies' requirement.

*Table 13-1: EMMP application*

| Impacts | Applied during | |
|---|---|---|
| | Construction Phase | Operational Phase |
| Water Quality (ECM) | ✓ | X |
| Water Quality (Spill budget) | ✓ | X |
| Water Quality (General surface water runoff) | ✓ | ✓ |
| Water Quality (Trade effluent) | ✓ | ✓ |
| Air Quality | ✓ | ✓ |
| Noise Quality | ✓ | ✓ |
| Waste | ✓ | ✓ |
| Biodiversity | ✓ | ✓ |
| Vector control | ✓ | ✓ |

Following the discussion with the Technical Agencies, a quarterly EMMP report will be prepared and submitted to the relevant agencies in a quarterly basis during construction phase and during the first year of operation phase. The results of the inspections records and lab results, where relevant will be included in the EMMP report.

## 13.2 Roles and Responsibilities

The Contractor shall be responsible for implementing all the environmental requirements specified in this EIA report including CEMMP conditions as well as requirements mandated by the applicable regulations and relevant authorities. It is recommended that to implement the CEMMP, a team composed of qualified personnel shall be available throughout the construction period. The team should include but not limited to the following:

*Table 13-2: Roles and responsibilities of EMMP team during construction phase*

| Roles | Responsibilities | Qualifications |
|---|---|---|
| Environment Control Officer (ECO) | Responsible to advise the Contractor in the following main areas but not limited to:<br>• Control and maintain the of disease-bearing vectors and rodents;<br>• Ensure proper management and disposal of solid waste and liquid waste;<br>• Control of noise and dust pollution;<br>• Drainage control;<br>• General housekeeping; and<br>• Earth control measures. | Valid registration with the National Environment Agency (NEA) |
| Qualified Erosion control Professional (QECP) | • Responsible to plan, design, supervise and review a system of earth control measures (ECM) to meet the relevant requirements;<br>• Submit the detailed ECM proposal on behalf of the developer to the Public Utilities Board (PUB) prior to the commencement of works;<br>• Proposed discharge treatment system of the ECM; and<br>• Design Earth Control Measures (ECM). | Valid registration with the Institution of Engineers Singapore (IES) |
| Earth Control Measures Officer (ECMO) | • The ECMO is responsible to implement all ECM requirements in compliance with the ECM Plan approved by PUB. | Valid IES registration |

## 13.3 Compliance Limits

### 13.3.1 Trade Effluent Discharge

The allowable limits for trade effluent discharge under the Environmental Protection and Management (Trade Effluent) Regulations are outlined in Table 13-3. As the Project will be discharging trade effluent into the Banyan Basin, the permissible discharge limits for watercourse must be met.

In carrying the laboratory analysis, the trade effluent shall be analysed in accordance with the latest edition of 'Standard Methods for the Examination of Water and Wastewater' published jointly by the American Water Works Association and the Water Pollution Control Federation of the United States.

*Table 13-3: Trade effluent discharge limit*

| Items of Analysis | Unit | Watercourse | Controlled Watercourse |
|---|---|---|---|
| Temperature of discharge | °C | 45 | 45 |
| Colour | Lovibond | 7 | 7 |
| pH Value | - | 6- 9 | 6- 9 |
| BOD (5 days at 20°C) | | 50 | 20 |
| COD | mg/L | 100 | 60 |

| Items of Analysis | Unit | Watercourse | Controlled Watercourse |
|---|---|---|---|
| Total Suspended Solids | mg/L | 50 | 30 |
| Total Dissolved Solids | mg/L | - | 1000 |
| Chloride (as chloride ion) | mg/L | - | 250 |
| Sulphate (as $SO_4$) | mg/L | - | 200 |
| Sulphide (as sulphur) | mg/L | 0.2 | 0.2 |
| Cyanide (as CN) | mg/L | 0.1 | 0.1 |
| Detergents (linear alkylate sulphonate as methylene blue active substances) | mg/L | 15 | 5 |
| Grease and Oil | mg/L | 10 (Total Hydrocarbons) | 1 (Total) |
| Arsenic | mg/L | 0.1 | 0.01 |
| Barium | mg/L | 2 | 1 |
| Tin | mg/L | - | 5 |
| Iron (as Fe) | mg/L | 10 | 1 |
| Beryllium | mg/L | - | 0.5 |
| Boron | mg/L | 5 | 0.5 |
| Manganese | mg/L | 5 | 0.5 |
| Phenolic Compounds (expressed as phenol) | mg/L | 0.2 | Nil |
| *Cadmium | mg/L | 0.1 | 0.003 |
| *Chromium (trivalent and hexavalent) | mg/L | 1 | 0.05 |
| *Copper | mg/L | 0.1 | 0.1 |
| *Lead | mg/L | 0.1 | 0.1 |
| *Mercury | mg/L | 0.05 | 0.001 |
| *Nickel | mg/L | 1 | 0.1 |
| *Selenium | mg/L | 0.5 | 0.01 |
| *Silver | mg/L | 0.1 | 0.1 |
| *Zinc | mg/L | 1 | 0.5 |
| *Metals in Total | mg/L | 1 | 0.5 |
| Chlorine (Free) | mg/L | 1 | 1 |
| Phosphates (as $PO_4$) | mg/L | 5 | 2 |
| Total Nitrogen | mg/L | 10 | Nil |
| Calcium (as Ca) | mg/L | - | 150 |

| Items of Analysis | Unit | Watercourse | Controlled Watercourse |
|---|---|---|---|
| Magnesium (as Mg) | mg/L | - | 150 |
| Nitrate (as $NO_3$) | mg/L | - | 20 |

**Note:**

1. Controlled Watercourses refers to a watercourse from which water supplied by PUB under the Public Utilities Act is obtained but does not include a watercourse from which water is pumped into a main of the PUB.
2. Where two or more of the metals listed in the table are present in the trade effluent, the total concentration of the metals shall not exceed: (i) 1 milligram per litre, if discharged into watercourse other than controlled watercourse; and (ii) 0.5 milligrams per litre, if discharged into controlled watercourse.
3. "-" No specified maximum concentrations under the Regulations.
4. The total nitrogen discharge concentration shall not exceed 10 mg/L as recommended by NParks.

## 13.4 Construction EMMP

The appointed Contractor is required to establish a detailed Construction EMMP (CEMMP) prior to the commencement of construction works based on the recommended EMMP framework in this EIA report before initiating construction work and to strictly implement the CEMMP requirements throughout construction phase to ensure the development of this project in environmentally sensitive manner.

The CEMMP shall be submitted by the Contractors for the construction work. The Contractor shall be responsible to submit and obtain approval for CEMMP from PUB, NParks, and other relevant Technical Agencies before commencement of works.

Table 13-4 provides recommendations on the types of monitoring that should be implemented, but this is not necessarily an exhaustive list.

Table 13-4: EMMP during construction phase

| Impact | Monitoring Measures/ Plan | Monitoring Method/ verification method | Technique | Location | Standards/ criteria | Time/ Duration/ Frequency | Reporting | Implementation |
|---|---|---|---|---|---|---|---|---|
| **Noise quality** | | | | | | | | |
| Increase of noise level to the environment and human receptors (i.e., workers) | • Undertake ad-hoc spot checks of construction equipment to ensure that equipment is operating within its noise specification. | • Visual inspection and compliance check. | • On-site visual and compliance monitoring | • Project site | • Presence of noisy equipment | • During construction phase | • Inspection records | • Contractor<br>• ECO |
| | • Utilization of PPE (i.e., earmuff or ear plug) to construction personnel where the noise levels are more than 85 dB(A). | • Visual inspection and compliance check. | • On-site visual and compliance monitoring | • Project site | • Site walk to ensure the PPE is used by worker<br>• Workplace Safety and Health (Noise) Regulations 2011 | • During construction phase | • Safety walk down inspection records | • Contractor<br>• ECO |
| | • Noise monitoring to measure the noise level at the boundary of the plant. | • Measurement using Class 1 Sound Level Meters with valid calibration certificate. | • Physical monitoring | • Four (4) locations | • Compliance to the maximum permissible noise levels (five-minute limits) – boundary under the Environmental Protection and Management (Boundary Noise Limits for Factory Premises) Regulations 2008 | • One (1) post-commissioning survey | • Test report | • Contractor |
| **Water quality** | | | | | | | | |
| Deterioration of water quality due to runoff and siltation during site clearance | • All stockpiles and worksite entrances shall be located as far as practically possible from waterbodies<br>• Stockpiles should be covered to prevent leaching.<br>• Biodegradable erosion mats should be used.<br>• Scheduling of construction activities in sequence/ phase should be considered to reduce the amount and duration of soil exposed to erosion by wind, rain, runoff, and vehicle. | • Visual inspection and compliance check | • On-site visual and compliance monitoring | • Project site in particular earthworks and site clearance take place | • Site walk checklist | • During construction phase | • Inspection records | • Contractor<br>• ECO |
| Earth Control Measures (ECM) | • QECP is to submit the detailed ECM proposal on behalf of the developer, to the Public Utilities Board (PUB) before commencement of construction works.<br>• Verify implementation of ECM plan<br>• Strictly no silty water/ surface runoff prior to treatment should be discharged.<br>• Earth Control Measures Officer (ECMO) shall ensure that the implementation, maintenance, and inspection of ECM.<br>• Inspect the site ECM during and after rain event and take immediate rectification action in the event the silty water is flowing or seeping into any public drain. | • Visual inspection and compliance check | • On-site visual and compliance monitoring | • Within the project site and drains along project boundary, as well as discharge points | • Site walk checklist to ensure silt fence is in good condition and to ensure no blockage to the perimeters drain. | • During construction phase<br>• ECM audit check to be carried out within six (6) months upon the earthworks or within a period is one third of the Project construction period | • Inspection records<br>• ECM site audit forms | • Contractor<br>• ECO<br>• ECMO<br>• QECP |

| Impact | Monitoring Measures/ Plan | Monitoring Method/ verification method | Technique | Location | Standards/ criteria | Time/ Duration/ Frequency | Reporting | Implementation |
|---|---|---|---|---|---|---|---|---|
| | • Carry out ECM audit check | | | | | | | |
| | • Contractor is to submit the CCTV installation checklist to PUB and to provide web access of the CCTV system to PUB.<br>• Deploy total suspended solid (TSS) meter at all discharge points to monitor the quality of discharge. | • CCTV monitoring<br>• Continuous TSS monitoring | • On-site visual and compliance monitoring | • Final ECM discharge points | • COP of Surface Water Drainage<br>• Compliance to the TSS concentration at discharge point is not more than 50 mg/L to comply with the Sewerage and Drainage Surface Water Drainage Regulation (2007) | • During construction phase | • Ad-hoc CCTV snapshots of at least the past 15-day, 5-min interval snapshots upon request by PUB<br>• Automated measurement record | • Contractor<br>• ECO |
| Deterioration of surface water | • Vehicles transporting the excavated material shall be covered properly to prevent runoff.<br>• Wheel wash at exit points of site.<br>• Fuel storage tanks should be installed with physical barriers such as bund to contain any oil spills and leakages.<br>• Engine oils and grease, fuel oils, and other chemicals should be properly stored at designed area.<br>• A spill kit should be kept within the site in case of accidental spills<br>• Spent oil and grease shall be stored in steel drums, sealed and disposed accordingly. | • Visual inspection and compliance check | • On-site visual and compliance monitoring | • Project site | • Site walk checklist | • During construction phase | • Site walk record | • Contractor<br>• ECO |
| | • The hazardous materials should be stored in designated area.<br>• The storage's floor is recommended to be lined to minimize the impacts of chemical infiltrate into soil/groundwater.<br>• All chemicals should be properly labelled and manage during construction activities. Spill kit should be available and accessible on site to contain the spillage. The workers should be trained to handle in the event a spill occur.<br>• Storage of hazardous materials on site should be minimal as possible to minimize a spillage.<br>• Develop chemical inventory and emergency spill response plan | • Visual inspection and compliance check | • On-site visual and compliance monitoring | • Project site | • Site walk checklist | • During construction phase | • Site walk record | • Contractor<br>• ECO |
| Trade effluent discharge | • Approval must be obtained from PUB and/or NParks prior to discharge.<br>• Wastewater will be collected on three (3) separate instances and sent to an accredited laboratory for testing. | • Ex-situ water sampling | • Physical monitoring | • At discharge outlet | • Environmental Protection and Management (Trade Effluent) Regulations, 2008 (Refer to Table 13-3 for compliance limits) | • Pre-commissioning. | • Test report | • Contractor<br>• ECO |
| Deterioration of marine water quality | • Turbidity measurement across the water profile to obtain a depth averaged value, along with plume photography. | • Turbidity probe | • Physical monitoring | • Three (3) locations during trenching | • Compliance to the turbidity limits not exceeding 3.5 NTU as recommended by NParks | • Quarterly throughout the trenching works | • Turbidity records and plume photograph | • Contractor<br>• ECO |

| Impact | Monitoring Measures/ Plan | Monitoring Method/ verification method | Technique | Location | Standards/ criteria | Time/ Duration/ Frequency | Reporting | Implementation |
|---|---|---|---|---|---|---|---|---|
| due to trenching works | • The location, date, time, depth, turbidity measurement, and photos shall be collated in a meaningful manner.<br>• If exceeding the compliance limit, the Contractor is to notify the developer and determine if the plume is generated from the works. | • Measurement to be undertaken when the dredging operations occur during daylight (0700h to 1900h). | | operation (Figure 13-1) | | | | |
| | • Spill budget monitoring.<br>• If exceeding the proposed daily production volume, the Contractor is to notify the developer and undertake corrective actions. In the event that the Contractor's work method cannot meet the required spill budget, the Contractor's work method shall be refined until compliance is achieved | • Compliance check between the actual daily dredged volume and forecasted production volume. | • Compliance monitoring | • During trenching operation | • The production volume not exceeding 1,000 $m^3$/day (daily average) or 5,000 $m^3$/day (maximum)<br>• The trenching works are assumed to be carried out using one (1) grab dredger (dredger bucket size between 8 $m^3$ and 10 $m^3$). A re-assessment is required in the event there is a significant change in the dredging workplan. | • Daily | • Dredging and backfilling production volume records. | • Contractor<br>• ECO |
| | • Deployment of silt curtain. | • Visual inspection and compliance check. | • On-site visual and compliance monitoring | • Perimeter of the trenching works during the construction of seawater intake. | • Visual inspection to monitor the integrity of silt curtain. | • During the construction of seawater intake. | • Inspection records | • Contractor |
| **Air quality** | | | | | | | | |
| Deterioration of air quality due to fugitive dust emissions, dust from construction works, exhaust emission | • Watering to reduce dust emissions from exposed areas during dry season.<br>• Maintenance of vehicles and machineries<br>• Washing facility should be provided at the designated exit points to wash the away the dirt from tires prior leaving the sites.<br>• Implementation of vehicular speed limit<br>• Construction vehicles will be maintained to reduce black smoke emission.<br>• Transportation of the construction materials to and from the Project site should be covered. | • Visual inspection and compliance check | • On-site visual and compliance monitoring | • Project site | • No visible exhaust plume, and dark smoke<br>• Vehicular/ machinery smoke emissions | • During construction phase | • Inspection record | • Contractor<br>• ECO |
| **Biodiversity** | | | | | | | | |

| Impact | Monitoring Measures/ Plan | Monitoring Method/ verification method | Technique | Location | Standards/ criteria | Time/ Duration/ Frequency | Reporting | Implementation |
|---|---|---|---|---|---|---|---|---|
| Flora and fauna Impacts | • Hoarding to be erected prior to vegetation clearance to demarcate working boundaries. | • Visual inspection and compliance check | • On-site visual and compliance monitoring | • Project site | • Proper installation of temporary hoarding/ barriers around the Project perimeter. | • During construction phase | • Inspection record | • Contractor<br>• ECO |
| | • Develop procedure for monitoring, reporting, documenting, or emergency care for dead or injured birds found within and around the perimeter of the site. | • Check for presence of injured or dead birds within and around the perimeter of the plant site | • On-site visual and compliance monitoring | • Within Project site and perimeter of the Project site | • Sightings of birds be it resting, alive, injured, or dead | • During construction phase | • Inspection record | • Contractor<br>• ECO |
| | • Checks on the presence of fauna as part of pre-felling checks, and if any fauna is present, to consult NParks Wildlife Management Division on action to be taken, to ensure that fauna has been shepherded to a safe zone, and any nests are checked to ensure that they are no longer active, before felling works commence. | • Visual inspection and compliance check | • On-site visual and compliance monitoring | • Project site | • Checks for presence of fauna | • During construction phase | • Inspection record | • Developer<br>• Contractor |
| Otter sighting | During otter sighting in the vicinity of the Project site, the Contractor is required to:<br>• Stop work temporarily if there is any perceived danger or obstruction to the otters<br>• Report and inform NParks/ ACRES for next step, if necessary.<br>• No attempts shall be made by Contractor to handle the animal<br>• Contractor to take photograph of the animal if possible.<br>• Contractors shall allow the animal to leave the site without harassment / handling<br>• Work resumes after otter leaves the area | • Visual inspection | • On-site visual monitoring | • Project site | • No disturbance to otter | • Ad-hoc.<br>• The mitigation measure will only be activated when otters are sighted | • Sighting records | • Contractor<br>• ECO |
| **Vector Control** | | | | | | | | |
| Increase in the incidence of vectors and related diseases | • Regular checks of at least once a week shall be conducted on the construction site for mosquito breeding in worksites.<br>• It is not mandatory to conduct fogging at construction sites. Fogging treatment should only be done when there is a mosquito nuisance problem or disease outbreak. | • Visual inspection (presence / absence of vectors) | • On-site visual monitoring | • Project site | • Control of Vectors and Pesticides Act (2002)<br>• COP for ECO | • Weekly during construction phase | • Inspection record | • Contractor<br>• ECO |
| **Waste management** | | | | | | | | |
| Hazardous waste | • Engagement of NEA licensed waste collector for hazardous waste<br>• Record of waste disposal | • Compliance check | • Compliance monitoring | • Project site | • Environmental Public Health (Toxic Industrial Wastes) Regulation, 2000 | • During construction phase | • Inspection record | • Contractor<br>• ECO |

| Impact | Monitoring Measures/ Plan | Monitoring Method/ verification method | Technique | Location | Standards/ criteria | Time/ Duration/ Frequency | Reporting | Implementation |
|---|---|---|---|---|---|---|---|---|
| Construction waste | • Engagement of NEA licensed general waste collector<br>• Record of waste disposal | • Compliance check | • Compliance monitoring | • Construction waste storage location<br>• General waste storage location | • Environmental Public Health (General Waste Collection) Regulation, 2000 | • During construction phase | • Inspection record | • Contractor<br>• ECO |

## 13.5 Operation EMMP

Table 13-5 provides recommendations on the types of monitoring that should be implemented during operation phase, but this is not necessarily an exhaustive list.

*Table 13-5: EMMP during operation phase*

| Impact | Monitoring Measures/ Plan | Monitoring Method/ verification method | Techniques | Location | Standards/ criteria | Time/ Duration/ Frequency | Reporting | Implementation |
|---|---|---|---|---|---|---|---|---|
| **Air quality** | | | | | | | | |
| Degradation of ambient air quality | • Continuous measurement of the stack's emission. for CO, $NO_x$, particulate substances, and $SO_2$. | • Continuous reading via CEMS | • Physical monitoring | • Stacks | • Compliance to the Environmental Protection and Management (Air Impurities) (Amendment) Regulations 2015 for CO, NOx, particulate substances, and SO2. | • Continuous measurement throughout the plant lifecycle. | • Automated measurement of the emission on a continuous basis. | • Operation team |
| **Noise quality** | | | | | | | | |
| Disturbance to workers working at major noise sources | • Utilization of PPE (i.e., earmuff or ear plug) by workers where the noise levels are more than 85 dB(A). | • Safety site walk | • On-site visual monitoring | • Primarily at location with major noise source within the Plant | • Appropriate PPE worn by workers | • Throughout the plant lifecycle. | • Safety sites walk records | • Operation team |
| | • Noise monitoring at workplace | • Measurement using Class 1 Sound Level Meters with valid calibration certificate. | • Physical monitoring | • Measurement at major noise sources within the plant | • Compliance to the Workplace Safety and Health (Noise) Regulations 2011 | • Noise monitoring to be carried out at least once every three (3) years, or earlier if there is a change in machinery, equipment, process, operation, work, control or other condition. | • Once every three (3) years | • Operation team |
| **Water quality** | | | | | | | | |
| Degradation of marine water quality due to thermal and chlorine plume discharge | • Online monitoring of the cooling water temperature and chlorine concertation at the outfall.<br>• Stop work temporarily when the ambient seawater temperature is above the NEA's limit of 45° C and operation is to be resumed when the seawater temperature is below the NEA's limit.<br>• Visual observation for algal bloom/ eutrophication/ fish-kill. Sampling of algal will also be carried out when there is presence of algal bloom or eutrophication or fish-kill at the outfall. In addition, the temperature of the discharge water will be lowered during algal bloom or eutrophication or fish-kill event. | • Continuous reading via online monitoring system<br>• Visual observation | • Physical monitoring | • At the point of discharge. | • Compliance to the Singapore's Environmental Protection and Management (Trade Effluent) Regulations (2008), where the temperature and chlorine concentration at point of discharge not exceeding 45° C and 1mg/L respectively (Refer to Table 13-3 for the compliance limits) | • Continuous measurement throughout the plant lifecycle.<br>• Stop work temporarily is only required when the ambient seawater temperature is above the NEA's limit of 45° C. | • Automated measurement of the temperature and chlorin concentration at discharge. | • Operation team |
| Discharge of trade effluent from Power Plant | • Wastewater will be treated at the water treatment plant prior discharge.<br>• Collection of trade effluent to be tested for parameters stipulated in the regulation. The trade effluent shall be analyzed in accordance with the latest edition of Standard Methods for the Examination of Water and Wastewater. | • Ex-situ monitoring | • Physical monitoring | • At every discharge outlet | • Environmental Protection and Management (Trade Effluent) Regulations 2008 permissible discharge limits must be met (Refer to Table 13-3 for the compliance limits) | • Annual sampling | • Test report | • Operation team |

| Impact | Monitoring Measures/ Plan | Monitoring Method/ verification method | Techniques | Location | Standards/ criteria | Time/ Duration/ Frequency | Reporting | Implementation |
|---|---|---|---|---|---|---|---|---|
| **Waste management** | | | | | | | | |
| Hazardous chemicals, accidental spills and leaks during storage and handling of hazardous chemical | • Conduct regular check of the hazardous materials.<br>• Regular update of the chemical inventory<br>• Chemicals will be stored within the bund wall. When required, the storage area will be protected with sprinkler system and water will be directed to the drainage system and treated at neutralization pit prior discharge. | • Visual inspection and compliance check<br>• Record of inventory and waste record | • On-site visual and compliance monitoring | • Entire plant | • Site walk down | • Throughout the plant lifecycle | • Site walk down records | • Operation team |
| Toxic waste or toxic industrial waste generated from Power Plant | • Inspect scheduled waste storage areas.<br>• Regular update of the inventory of scheduled wastes. | • Visual inspection and compliance check<br>• Record of inventory and waste record | • On-site visual and compliance monitoring | • Entire plant | • Site walk down | • Throughout the plant lifecycle | • Site walk down records | • Operation team |
| **Biodiversity** | | | | | | | | |
| Otter sighting | During otter sighting in the vicinity of the Plant, the operation team is required to:<br>• Stop work temporarily if there is any perceived danger or obstruction to the otters.<br>• Report and inform NParks/ ACRES for next step, if necessary.<br>• No attempts shall be made by the workers to handle the animal.<br>• Operation team is to take photograph of the animal if possible.<br>• Operation team shall allow the animal to leave the site without harassment / handling.<br>• Work resumes after otter leaves the area | • Visual inspection | • On-site visual monitoring | • Entire plant | • No disturbance to otter | • Ad-hoc<br>• The mitigation measure will be activated during otter sighting. | • Sighting records | • Operation team |
| **Vector Control** | | | | | | | | |
| Increase in the incidence of vectors and related diseases | • Regular checks of at least once a week shall be conducted within the Plant for mosquito breeding.<br>• It is not mandatory to conduct fogging within the Plant. Fogging treatment should only be done when there is a mosquito nuisance problem or disease outbreak. | • Visual inspection (presence / absence of vectors) | • On-site visual monitoring | • Entire Plant | • Control of Vectors and Pesticides Act (2002) | • Throughout the plant lifecycle | • Inspection record | • Operation team |

## 13.6 Environmental Non-compliance Protocol

In the event of non-compliance with the requirements of the EMMP or observation of no-compliance to regulations, the following process is recommended:

*During Construction*

- The Contractor will be responsible for ensuring adequate follow-up activities and should consult with the Qualified Erosion Control Professional (QECP) / Vector Control Operator (VCO) / Public Relations Officer (PRO).
- The Contractor is to inform the developer a notice of non-compliance, stating the nature and magnitude of the contravention.
- The Contractor is to provide the developer with a written statement describing remedial actions to be taken to rectify the non-compliance and expected results of the actions.
- The Contractor to correct the non-compliance within a period that is stipulated by the developer, to provide the developer with documented evidence of the completed remedial actions and obtain the developer's approval for closure of the non-compliance notice.
- Reporting and consultation with the relevant authorities (e.g., NEA, NParks, PUB, etc), if necessary
- In the event of violation of relevant standards/regulations/compliant, the environmental management practices at site are to be reviewed immediately with appropriate mitigation actions taken immediately to reduce impacts to acceptable levels.
- If the Contractor fails to remedy the non-compliance within the predetermined timeframe or if the non-compliance gives rise to physical environmental damage, the developer may take action (e.g., impose a penalty, require specific remedial action to be undertaken or stop work) based on the conditions of contract.

*During operation phase*

1. Stop work temporarily depend on the type and severity of the non-conformance.
2. The operation team is to carry out investigation to determine the cause of such exceedance.
3. Corrective actions are to be carried by the operation team to eliminate the cause of a detected non-conformity.
4. All non-compliances are required to be documented.

## 13.7 Specific Management Plan

### 13.7.1 Water Quality Management Plan

The water quality management plan shall be put in place during the construction and operation phase. During construction phase, the potential impacts are primarily sediment plumes and the effect of incremental suspended sediments concentration in the marine environment due to the trenching activities. While during the operation phase, the potential impact are primarily chlorine and thermal discharge from the cooling water outfall. The objective of the water quality management plan is to minimise the impact to the marine environment. A summary of monitoring activities is included in Table 13-6.

*Table 13-6: Monitoring schedule*

| Parameter | Frequency | Remarks |
|---|---|---|
| Turbidity measured in Nephelometric Turbidity Units (NTU) | Quarterly measurement using turbidity probe | During trenching operation.<br>It is recognized that sampling can only occur when it is safe to do so and during daylight hours only (0700h to 1900h) unless alternative measures are put in place. |
| Cooling water discharge<br>• Chlorine measured in mg/L<br>• Temperature measured in degree Celsius | Real-time measurement | Continuous measurement throughout the plant lifecycle |

#### 13.7.1.1 Turbidity Monitoring

Turbidity monitoring is required during active trenching operations only. Turbidity should be measured progressively using a turbidity probe in line with the visual plume and current direction and the proposed monitoring stations are as follows:

- WQ01: 100 m downgradient from the construction area (compliance point)
- WQ02: 500 m downgradient from the construction area.
- WQ03: Background concentration (not affected by the trenching works)

The spatial coverage of monitoring sites (Figure 13-1) is to enhance its ability to detect changes in the outer reaches of any plume. A visual assessment of the plume (if any) should be conducted and confirmed in pictures. The location, date, time, depth and turbidity and pictures shall be collated in a meaningful manner.


*Figure 13-1: Proposed water quality monitoring stations*

For quarterly turbidity measurement, compliance level adopted for this Study is 3.5 NTU as recommended by NParks. Data should be processed by the Contractor and notification issued to the developer. In the event of exceedances, the following contingency measures are proposed.

(1) Contractor is to stop work temporarily when compliance limit (3.5 NTU) is exceeded.

(2) The Contractor is to notify the developer and determine if the plume is generated from the works.

(3) The Contractor should compare the measured data to both background and baseline as well to determine if there is a risk. Actions would be taken to bring the turbidity level down if the increase of turbidity is due to construction works.

(4) The Contractor should also compare the daily production against the allocated spill budget. If the daily production volume exceeds the spill budget, the Contractor is to notify the developer and undertake corrective actions. In the event that the Contractor's work method cannot meet the required spill budget, the Contractor's work method shall be refined until compliance is achieved.

(5) In the event both exceedance is due to external factors such as high precipitation, propeller wash and etc, the works is to be resumed.

(6) All non-compliance and turbidity records are required to be documented.

#### 13.7.1.2 Cooling Water Discharge

Continuous monitoring of temperature and chlorine concentration of the cooling water discharge quality is required to ensure its compliance to the Singapore's Environmental Protection and Management (Trade Effluent)

Regulations (2008), in which the temperature and chlorine concentration at point of discharge not exceeding 45° C and 1mg/L respectively. In the event of exceedances, the following contingency measures are proposed.

(1) The management response will be triggered in the event the chlorine concentration and temperature exceed the compliance limits.

(2) The operation team is to notify the developer.

(3) The operation team is to validate the performance of the temperature and chlorin probes/ sensors. Sampling of cooling water discharge quality should be carried out, if needed.

(4) The operation team is to carry out investigation to determine the cause of such exceedance. For example, assessment of the outfall operating conditions, dosing concentrations, and maintenance of the plant.

(5) Corrective actions are to be carried by the operation team to eliminate the cause of a detected non-conformity.

(6) All non-compliances are required to be documented.

### 13.7.2 Project Practices for Energy and Resource Conservation

The new project will draw electricity from the Singapore grid for plant start up based on the information provided by the Client, thereafter the Power Plant will be self-sufficient. The following recycling/ resources conservation initiatives have been adopted:

- The Power Plant uses a 701JAC GT, one of the latest GT with high energy efficiencies;
- Variable speed couplings are provided for fuel gas compressors, condensate extraction pumps for reducing auxiliary power consumption during startup;
- Solar panels will be installed on a number of buildings generating approximately 1 MW;
- HRSG blowdown water (HP and IP) heat is recovered; and
- Implementation of 3R's approach (4) to general waste and other recycling initiatives within the Power Plant, for materials such as paper, scrap metals, plastic pallets, e-waste.

# 14 Conclusion

Worley carried out the EIA with integration of findings, Soil Investigation Report – Offshore (Appendix A) and QRA Report (Appendix G) for the construction and operation of the Keppel's Advanced Gas Turbine Cogeneration Combined Cycle Power Plant on Jurong island to assess the baseline conditons and to forecast any potential impact to the environment. The construction impact (sediment plume impact) and operational impact (thermal plume, chlorine plume, and coastal dynamic impact) without and with mitigation measures have been summarized in Table 14-1.

*Table 14-1: Impact assessment summary*

| Aspects | Potential Impact | Significance of impacts (without mitigation) | Significance of impacts (with mitigation) |
|---|---|---|---|
| **Construction** | | | |
| Marine water quality | SSC and sedimentation from trenching activities | No impact | No impact |
| Marine biodiversity (corals and seagrass) | SSC and sedimentation from trenching activities | No impact | No impact |
| Aquaculture facilities | SSC and sedimentation from trenching activities | No impact | No impact |
| International boundary | SSC and sedimentation from trenching activities | No impact | No impact |
| Marine infrastructure (intakes, subsea, jetties, navigation channel) | Suspended solid concentration and sedimentation from trenching activities | No impact | No impact |
| Seawater intakes and outfalls | SSC from trenching activities | No impact | No impact |
| Subsea cables and pipelines | SSC from trenching activities | No impact | No impact |
| **Operation** | | | |
| Marine water quality | Chlorine plume discharge from the outfall | Slight negative impact | No impact |
| Marine water quality | Thermal plume discharge from the outfall | No impact | No impact |
| Marine biodiversity (corals and seagrass) | Thermal and chlorine plume discharge from the outfall | No impact | No impact |
| Aquaculture facilities | Thermal and chlorine plume discharge from the outfall | No impact | No impact |
| Current | Current impact from constructed intake and outfall | Slight negative impact | No impact |

| Aspects | Potential Impact | Significance of impacts (without mitigation) | Significance of impacts (with mitigation) |
|---|---|---|---|
| Wave | Wave impact from constructed intake and outfall | No impact | No impact |

Worley have proposed EMMP for both construction phase (Section 13.3) and operational phase (Section 13.5) to mitigate environmental impacts and monitor the implementation of these mitigation measures to ensure that the developent will not cause any significant adverse impact to the environment during construction and operation phases. Overall, the project is considered feasible and no significant impacts are predicted through this study. Further analysis should be conducted in the event a significant update or change to the concept design and construction method are being proposed by the developer.

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# Appendix A. Soil Investigation Report – Offshore

# Appendix B. Model Setup

# Appendix C. Navigation and Hydrodynamic Feasibility Study for the Advanced Gas Turbine Cogeneration Combined Cycle Plant on Jurong Island, Singapore

# Appendix D. EXO 2 Water Quality Sonde Calibration Report

# Appendix E. Marine Water Quality Survey Methodology and Result

# Appendix F. Marine Water Quality Ex-Situ Laboratory Result

# Appendix G. QRA Report

## Appendix H. Memorandum: Hydrodynamic condition comparison between worst case scenario (NE and SW monsoon) and inter-monsoon scenario

## Appendix I. Topography Map