# Environmental Impact Assessment (EIA) for the Floating Data Centre at Loyang, Singapore

Environmental Impact Assessment Report

**Keppel Data Centre Fund II**

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# Executive summary

Keppel Data Centre Fund II (Keppel) proposes the development of a Floating Data Centre at Loyang, Singapore. As part of the planning approval process, an Environmental Impact Assessment (EIA) was conducted to evaluate potential environmental impacts from both construction and operational phases. This assessment aligns with Singapore's environmental regulations and incorporates feedback from key agencies.

**Project Overview**

The proposed Floating Data Centre (FDC) development comprises a modular Floating Data Centre Module (FDC) Module and associated shoreside infrastructure, occupying approximately 9,870 m² of land and 7,580 m² of sea space at the Loyang. The site is zoned "Business 2" under the URA Master Plan 2019.

The FDCM is a four-storey floating structure designed to support up to 19.2 MW of IT load, incorporating seawater-cooled chillers, onboard cooling infrastructure, and a retention pile mooring system for stability. The facility will operate a closed-loop seawater cooling system, utilise low-GWP refrigerants, and include bunded underground diesel storage to ensure environmental safeguards are met.

The shoreside infrastructure will support FDCM operations and comprises substations, offices, diesel storage tanks, pipe racks, photovoltaic panels, walkways, and administrative facilities. All components have been designed in accordance with PUB's platform height requirements and follow best practices for environmental integrity and operational efficiency.

**Scope of Works**

The EIA has been conducted to assess the potential environmental impacts during both the construction and operational phases. As part of the EIA, baseline surveys were conducted following the completion of the scoping exercise with the Technical Agencies. The assessment evaluates potential impacts on air quality, noise levels, sediment plumes, sedimentation, thermal and chlorine plumes, as well as direct impacts. The EIA identifies appropriate mitigation, monitoring, and management measures to be implemented. These measures are designed to minimize environmental impacts and ensure that any realized impacts comply with the Project's environmental quality objectives.

**Approach and Methodology**

As part of this EIA, field data collection, numerical modelling, impact evaluation, and stakeholder engagement were undertaken to establish baseline environmental conditions and assess the potential impacts arising from the proposed development. The key components of the EIA methodology are summarised below:

- **Scoping**
  A preliminary scoping exercise was conducted in consultation with relevant Technical Agencies to define the scope of the EIA, identify key environmental receptors, and determine the requirements for baseline surveys and impact assessment.
- **Baseline Environmental Surveys**

Comprehensive baseline surveys were undertaken to characterise the existing biotic and abiotic conditions within the study area. These include assessments of marine water quality, sediment characteristics, intertidal, and key ecological receptors.

- **Numerical Modelling Simulations**

  Numerical modelling tools were used to simulate the potential spatial and temporal extent of environmental impacts during both construction and operational phases. These include sediment plume modelling for dredging activities and dispersion modelling for thermal and chlorine discharges from the cooling water system.

- **Impact Assessment and Significance Evaluation**

  Identified environmental pressures were assessed using a receptor-based framework. The Rapid Impact Assessment Matrix (RIAM) was applied to evaluate the magnitude, extent, duration, and significance of each pressure-impact pathway for both construction and operational scenarios.

- **Development of Mitigation and Monitoring Measures**

  Based on the impact assessment findings, appropriate mitigation and monitoring measures were developed to prevent, reduce, or manage potential adverse effects. These measures are consolidated in the Environmental Management and Monitoring Plan (EMMP), which outlines monitoring protocols and responsibilities across pre-construction, construction, and operational phases.

**Key Environmental Pressures**

This EIA has evaluated the potential environmental risks associated with both the construction and operational phases of the proposed Project. The assessment identified key environmental pressures, characterised their potential short-term and long-term impacts, and recommended mitigation measures to manage or avoid significant environmental harm. The following table provides a summary of the key environmental pressures and potential impacts identified during the assessment:

| Environmental Domain | Construction Phase (Short-Term Impacts) | Operational Phase (Long-Term Impacts) |
|---|---|---|
| Ecological | • Sediment plume and sedimentation impacts on marine biodiversity from dredging activities. | • Thermal and residual chlorine plume impacts on marine biodiversity from cooling water discharge. |
| Socioeconomic | • Increased suspended solids affecting seawater intakes.<br>• Potential disruption to aquaculture activities.<br>• Risk of transboundary sediment dispersal near international boundaries.<br>• Short-term air and noise pollution affecting human receptors.<br>• Potential impact on navigation and marine infrastructure from trenching works. | • Alteration of local hydrodynamics from intake/outfall structures.<br>• Risk to aquaculture facilities from thermal and chlorine discharge.<br>• Ongoing air and noise emissions.<br>• Changes to navigational conditions due to altered flow patterns. |
| Physicochemical | • Degradation of water quality due to suspended sediment mobilisation.<br>• Localised disruption of coastal dynamics due to seabed intervention. | • Deterioration of marine water quality from thermal and chlorine discharges. |

During the **construction phase**, key environmental concerns are linked to seabed dredging, which generates suspended sediments that form sediment plumes. These plumes can be transported by tidal currents and waves, potentially reaching nearby sensitive receptors. The extent and magnitude of these impacts were assessed using hydrodynamic and sediment dispersion modelling under representative seasonal conditions.

During the **operational phase**, long-term impacts primarily stem from the discharge of heated and chlorinated effluent from the cooling water system of the floating data centre. Numerical modelling was conducted to predict thermal dispersion and chlorine concentrations under both average and conservative hydrodynamic scenarios.

**Baseline Environmental and Ecological Conditions**

Key surveys were conducted across various biotic and abiotic parameters:

1. Biotic Surveys:
   - Intertidal Seagrass Habitat: Survey was conducted at four (4) transects from 19 Oct 2024 to 20 Oct 2024
   - Mangroves: Survey of mangrove was carried out from 18 Oct 2024 to 22 Oct 2024
   - Soft-Bottom Macrobenthos: Survey was conducted at three (3) stations on 4 Oct 2024
   - Phytoplankton and Zooplankton: Survey at four (4) stations on 3 Oct 2024
2. Abiotic Surveys:
   - Marine Seabed Sediment Quality: Survey was conducted at three (3) stations on 4 Oct 2024
   - Marine Water Quality: Survey was conducted at four (4) stations on 3 Oct 2024
   - Ambient Air Quality: Ambient air measurements were collected at one (1) station from 25 Sep 2024 to 2 Oct 2024
   - Airborne Noise Quality: Noise measurements were collected at two (2) stations from 25 Sep to 2 Oct 2024

Air quality monitoring recorded Particulate Matter (PM2.5, PM10), Sulphur Dioxide ($SO_2$), Nitrogen Dioxide ($NO_2$), Carbon Monoxide (CO), and Ozone ($O_3$) levels within Singapore's long-term standards. Noise monitoring indicated that daytime levels were within permissible limits, with an isolated nighttime exceedance attributed to nearby industrial activities.

Marine water quality surveys area, covering the project boundary and adjacent areas, including Pasir Ris Park, involved both in-situ and ex-situ assessments during spring flood and ebb tides. The survey focused on physical, chemical, and biological parameters. Overall, the findings suggest no significant environmental concerns in the project area. While, the sediment quality assessment conducted at the Project sites revealed variable concentrations of key contaminants. While most heavy metals, including arsenic, cadmium, chromium, mercury, and nickel, were within acceptable limits according to MPA guidelines, elevated levels of lead, copper and zinc were observed at SQ02. TPH levels were recorded below relevant guidelines, indicating a lower risk to aquatic biota, and the TOC levels were also within safe limits.

The ecological and biodiversity survey covered intertidal seagrass communities, mangroves, plankton, and macrobenthos assemblages within the Project area and along Pasir Ris Park. No critically endangered species were identified during the survey.

**Modelling and Impact Assessment**

To assess the potential environmental impacts of the proposed development, a suite of numerical models was undertaken. These included simulations of tidal hydrodynamics, sediment dispersion from construction activities, and the dispersion of thermal and chlorine plumes from the seawater cooling system. Additional evaluations were carried out for air emissions from standby generators and noise generated during both construction and operation. The EIA considered impacts on a range of environmental receptors, including seagrass habitats, mangroves, soft-bottom macrobenthos, aquaculture facilities, water intakes, recreational areas, marine infrastructure, and cross-border marine waters.

- **Hydrodynamic Modelling**
  A site-specific three-dimensional hydrodynamic model was developed to simulate tidal flows, water levels, and current patterns across the project area. Simulations were conducted for the Northeast monsoon, Southwest monsoon, and inter-monsoon periods, each spanning a 14-day duration to cover a complete tidal cycle. Based on the results, the project design does not obstruct or significantly modify ambient flow patterns. While some localised scouring is expected near structural features, the overall hydrodynamic regime remains unaltered. No measurable change in water movement or tidal flushing is anticipated.

- **Sediment Transport Modelling**
  Sediment transport modelling was conducted to predict Suspended Sediment Quality (SSC) and deposition patterns associated with dredging activities. Both average daily production and maximum daily production scenarios were assessed under spring and neap tidal conditions. Model results showed that sediment plumes are highly localised, with SSC levels attenuating rapidly due to tidal dispersion. Deposition at ecologically sensitive areas, including seagrass/ interitdal area, mangroves, and aquaculture sites, remains below tolerance thresholds. Construction-related sedimentation is therefore expected to result in temporary, site-confined effects with no significant ecological consequences.

- **Thermal Dispersion Modelling**
  Thermal plume modelling assessed the dispersion of heated effluent discharged from the cooling water system under normal operational conditions. The model assumed continuous discharge based on maximum design heat load. Results indicate that excess temperature dissipates rapidly in the receiving waters. Sensitive receptors like seagrass/ intertidal areas and mangroves are located outside the thermal mixing zone. The operational discharge is therefore not expected to cause thermal stress or adverse ecological impacts.

- **Chlorine Dispersion Modelling**

  Chlorine modelling simulated the dispersion of residual biocides used in the seawater cooling system, based on conservative dosing assumptions. Results indicate rapid dilution and degradation of chlorine within the near-field zone, with predicted concentrations falling below the 0.012 mg/L threshold at all sensitive receptor like seagrass/ intertidal area and mangroves. No accumulation or exceedance was observed near seagrass, aquaculture facilities, or mangrove area. As such, no adverse ecological effects are anticipated from chlorine discharge.

- **Air Emissions Modelling**
  Air dispersion modelling was conducted to evaluate the potential impact of exhaust emissions from backup diesel generators during construction and emergency operational scenarios. Using worst-case meteorological data and stack release parameters, the model predicted that short-term exceedances of ambient air quality guidelines could occur during generator testing if no flue extension is applied. However, with the proposed flue height of 35.8 m SHD, dispersion is significantly improved and compliance with NEA air quality standards is achieved, resulting in only a slight residual impact on local air quality.

- **Noise Modelling**
  Noise modelling was undertaken to estimate sound levels from both construction activities and operational equipment such as cooling pumps and generators. Construction noise is expected to be intermittent and limited to standard working hours, with impact levels within regulatory thresholds. During operation, most equipment will be housed within the hull of the floating structure, and sound attenuation will be achieved through enclosure, insulation, and vibration isolation. As a result, both construction and operational noise are expected to remain within permissible limits and pose no significant impact to surrounding human or ecological receptors.

- **Biodiversity Impact Assessment**
  During the construction phase, sediment plume and sedimentation modelling confirmed that SSC and deposition levels remained within acceptable ecological thresholds for key receptors, including seagrass beds and mangrove habitats. At these sensitive locations, SSC values did not exceed species-specific tolerance limits, and sediment deposition remained below the 10 mm threshold associated with smothering risks for flora and benthic invertebrates. Consequently, the impacts of SSC and sedimentation on seagrass and mangroves were assessed as **no change / impact**. Direct habitat loss resulting from the dredging work was confined to small patches of soft-bottom benthic habitat, and this was assessed as a **slight negative change/ impact** due to the localised nature of the disturbance, which is expected to be temporary and reversible following natural recovery post-construction.

  Operational phase impacts from thermal and chlorine discharges were also assessed. Thermal dispersion modelling showed that temperature elevations beyond 100 to 150 m from the outfall remained below 1°C, while chlorine concentrations did not exceed the chronic exposure threshold of 0.012 mg/L for marine organisms. These findings indicate that thermal and chemical discharges are unlikely to cause ecological harm. Accordingly, impacts to seagrass, mangroves, and soft-bottom benthic communities during the operational phase due to thermal discharge and residual chlorine were also assessed as **no change / impact.**

Underwater noise impacts during construction, particularly from piling, are anticipated to generate sound pressure levels between 180 and 220 dB re 1 μPa at 1 metre, potentially triggering short-term avoidance behaviour in marine fauna. Although assessed qualitatively, the implementation of mitigation measures including soft-start piling procedures, deployment of low-noise equipment, and marine fauna observation, this could reduces the risk of adverse effects. Therefore, underwater noise during construction was also assessed as **no change / impact**. Operational underwater noise is expected to be negligible, due to acoustic insulation and the use of a double-hull structure, with **no measurable ecological** effects anticipated.

- **Fuel and Oil Spill Impact Assessment**

  The risk of accidental spills from diesel, lubricants, or cleaning agents was assessed for both construction and operational phases. Potential environmental effects include surface slick formation, light reduction, and hydrocarbon toxicity, particularly for seagrass, plankton, and filter-feeding organisms. For unmitigated spill scenarios ranged from **minor negative change / impact** to **slight negative change/ impact** across seagrass, mangroves, aquaculture, and intake receptors. With mitigation measures such as bunded double-walled storage, designated refuelling zones, and the availability of emergency response kits, all residual spill-related impacts were effectively reduced to **slight negative change/ impact**. These measures ensure that even under worst-case conditions, the environmental consequences of minor spills will be localised and short-term, with no long-term degradation anticipated.

- **Marine Infrastructure**

  During the operational phase, the presence of the floating data centre and its associated mooring infrastructure is not expected to obstruct existing shipping lanes or interfere with port operations. The cooling water intake and outfall structures are designed to be strategically located outside designated navigation channels and marine traffic corridors. Hydrodynamic modelling confirmed that the development will not result in any significant changes to ambient flow regimes that could affect vessel manoeuvrability or safety. In accordance with the RIAM evaluation, impacts to marine infrastructure were rated as **no change / no impact**.

  A potential for localised scouring around the mooring piles was identified during the operational phase. This is a common occurrence for fixed marine structures in areas with moderate tidal flows. However, this risk is considered manageable and will be addressed through appropriate engineering design measures, such as scour protection layers or structural reinforcement, to maintain seabed stability and protect surrounding infrastructure. **No change/ No impact** is expected on existing coastal or marine infrastructure with these safeguards in place.

- **Socio-Economic Receptors**

  Socio-economic receptors assessed in the EIA include aquaculture facilities, recreational users, and human health receptors potentially exposed to air and noise emissions. During the construction phase, sediment transport modelling indicated that SSC at the nearest aquaculture farms remained within tolerable limits, and the impact was assessed as **no change / impact**. Similarly, recreational areas within the vicinity of the project site were also assigned no change/ impact under the RIAM framework. The risk of accidental spills affecting marine intakes or aquaculture operations was assessed as a **slight negative change/ impact**, after the implementation of effective spill response protocols and containment measures.

  Operational phase modelling showed that both thermal and chlorine discharges from the seawater cooling system remained within applicable water quality guidelines for aquaculture. Consequently, impacts to aquaculture receptors during operation were also assessed as **no change / impact**.

  Air dispersion modelling for emergency generator emissions initially indicated a moderate negative change under conservative, unmitigated conditions. However, the adoption of a 35.8 m exhaust stack significantly improved pollutant dispersion, reducing the residual impact to a **slight negative change**. Noise exposure from periodic testing of emergency gensets was assessed as **no change / impact**, as testing is restricted to daytime hours and all equipment is acoustically enclosed within the hull structure.

**Environmental Management and Monitoring Plan (EMMP)**

An Environmental Management and Monitoring Plan (EMMP) and mitigation measures are recommended for the Project to ensure that potential impacts are effectively reduced and mitigated to acceptable levels. The EMMP outlines specific actions, monitoring protocols, and management strategies to address identified environmental concerns throughout the Project's construction and operational phases.

Based on the assessment and the proposed mitigation measures, the Project is considered to have no significant negative impacts on the environment. Therefore, it is deemed feasible from an environmental perspective.

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# Figures

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# Table of Abbreviations

| | |
|---|---|
| Al | Aluminium |
| ANZECC | Australian and New Zealand guidelines for fresh and marine water quality |
| AR6 | 6th Assessment Report |
| As | Arsenic |
| ASEAN MWQC | Association of Southeast Asian Nations Marine Water Quality Criteria |
| AQ | Air Quality |
| $BOD_5$ | Biochemical Oxygen Demand |
| CAFHI | Changi Airport Fuel Hydrant Installation |
| CBD | Convention On Biological Diversity |
| CCRS | Centre for Climate Research Singapore |
| Cd | Cadmium |
| CD | Chart Datum |
| CEMMP | Construction Environmental Management and Monitoring Plan |
| CITES | Convention on International Trade in Endangered Species of Wild Fauna and Flora |
| CO | Carbon Monoxide |
| CPFT | Changi Point Ferry Terminal |
| Cr | Chromium |
| CR | Critically Endangered |
| Cu | Copper |
| DD | Data Deficient |
| DO | Dissolved Oxygen |
| ECM | Erosion Control Measures |
| ECO | Environment Control Officer |
| ECMO | Earth Control Measures Officer |
| EIA | Environmental Impact Assessment |
| EMMP | Environmental Management and Monitoring Plan |
| EN | Endangered |
| ES | Environmental Score |
| ETLs | Environmental Tolerance Limits |
| EQOs | Environmental Quality Objectives |
| EX | Globally Extinct |
| FDCM | Floating Data Centre Module |
| Hg | Mercury |
| IES | Institution of Engineers Singapore |
| IM | Inter-Monsoon |
| IFC | International Finance Corporation |

| | |
|---|---|
| IT | information technology |
| IT | Intertidal |
| IPCC | Intergovernmental Panel on Climate Change's |
| IUCN | International Union for Conservation of Nature |
| LC | Least Concern |
| LOSB | Loyang Offshore Supply Base |
| MB | Macrobenthos |
| M&E | Mechanical and Electrical |
| MPA | Maritime and Port Authority of Singapore |
| MW | Megawatt |
| NA | Not Applicable |
| NE | Not Evaluated |
| Nex | Presumed Nationally Extinct |
| NE | Northeast |
| NEA | National Environment Agency |
| NT | Near Threatened |
| Ni | Nickel |
| $NO_2$ | Nitrogen Dioxide |
| NParks | National Parks Board |
| NQ | Noise Quality |
| $O_3$ | Ozone |
| O&G | Oil and Grease |
| Pb | Lead |
| PCG | Police Coast Guard |
| PCS | Pollution Control Study |
| PM | Particulate Matter |
| PRO | Public Relations Officer |
| QECP | Qualified Erosion control Professional |
| SECS | Singapore Environmental Consultancy and Solutions Pte Ltd |
| SFA | Singapore Food Authority |
| $SO_2$ | Sulphur Dioxide |
| SSP | Shared Socioeconomic Pathway |
| SS | Singapore Standard |
| SQ | Sediment Quality |
| SW | Southwest |
| TAs | Technical Agencies |
| TN | Total Nitrogen |
| TOC | Total Organic Carbon |
| TP | Total Phosphorus |

| | |
|---|---|
| TPH | Total Petroleum Hydrocarbons |
| TSS | Total Suspended Solids |
| UKC | Under Keel Clearance |
| UNFCCC | United Nations Framework Convention on Climate Change |
| UG | underground |
| URA | Urban Redevelopment Authority |
| USEPA | United States Environmental Protection Agency |
| VU | Vulnerable |
| VCO | Vector Control Operator |
| WBGT | West Bulb Globe Temperature |
| WQ | Water Quality |
| Zn | Zinc |

# 1

# Introduction

# 1 Introduction

Singapore Environmental Consultancy and Solutions Pte Ltd (SECS) has been engaged by Keppel Data Centre Fund II (Keppel) to undertake an Environmental Impact Assessment (EIA) for the development of a Floating Data Centre at Loyang (referred to as the “Project").

The EIA has been conducted in compliance with Singapore's legal framework and through consultations with relevant Technical Agencies (TAs). This report assesses the potential environmental impacts of both the construction and operational phases of the Project. It includes baseline environmental conditions, impact assessments, proposed mitigation measures, and management plans, alongside monitoring recommendations.

## 1.1 Study Objectives

The aim of the EIA is to evaluate the potential environmental impacts arising from the proposed Project and to identify measures to prevent or minimise these impacts. The objectives of this EIA are as follows:

- To establish the baseline conditions prior to construction of the Project.
- To analyse all relevant Project induced impacts on coastal dynamics.
- 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 dredging activity in relation to sediment spill and sedimentation on receptors of concern.
- To develop mitigation measures to avoid or minimise predicted environmental impacts.
- To consult relevant government agencies and stakeholders, securing approval for the environmental study of the proposed development.

## 1.2 Scope of Works

The scope of assessment for this EIA has been determined through engagement with the Urban Redevelopment Authority (URA) and key Technical Agencies, namely the National Parks Board (NParks), National Environment Agency (NEA), Maritime and Port Authority of Singapore (MPA), and Singapore Food Authority (SFA). Based on this consultation, this EIA will cover the following aspects during both the construction and operational phases:

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

| Scope | Report Reference |
|---|---|
| Current Impact | Section 9.1 |
| Sediment plume | Section 9.2 |
| Thermal plume | Section 9.3 |
| Chlorine plume | Section 9.4 |
| Underwater noise impact | Section 9.5 |
| Light Pollution | Section 9.6 |
| Direct impact | Section 9.7 |

| Scope | Report Reference |
|---|---|
| Air quality impact | Section 9.8 |
| Noise quality impact | Section 9.9 |

## 1.3 Assumption and Limitation

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

- SECS has conducted this EIA Study to primarily meet local regulations and standards, with the focus on assessing potential impacts to the marine environment arising from construction and operational activities, as well as impacts on air and noise quality, in accordance with the agreement with Keppel and the Technical Agencies.
- The information, assessments, and professional advice provided in this report were intended solely for assessing the Project's environmental impacts as part of URA's planning approval process, and SECS does not accept liability if the report is used for purposes other than those agreed upon.
- All conclusions and recommendations in this report reflect the professional opinion of the SECS personnel involved with the Project.
- Unless otherwise specified, the assessments in this report assume that the site and associated infrastructure will continue to be used for their intended purpose without significant change.
- Field investigations were conducted to the necessary level of detail to meet the objectives of this assessment. Results from measurements may vary temporally or spatially, and further investigations may be required if there is a significant delay in utilising this report. Consequently, SECS provides the results as an indication of possible impacts rather than definitive.
- A full Pollution Control Study (PCS) is not included as part of this EIA. The air and noise impact assessments for the operational phase were conducted solely to meet the Project's environmental evaluation requirements and is not intended to serve as the formal PCS submission to regulatory authorities.
- The Project is currently in the preliminary design stage at the time of writing and detailed engineering will be undertaken at the later phase. Thus, this EIA does not include specific assessments related to finalised construction methods, as these details remain subject to future refinement if applicable.

# 2

## Project Description

# 2 Project Description

## 2.1 Overview of Development

The proposed development at Loyang covers approximately 9,870 m² on land and 7,580 m² of sea space, positioned along the existing wharf, as shown in Figure 2-1. The development consists of two main components: the Floating Data Centre Module (FDCM) and shoreside infrastructure, as shown in Figure 2-2.


**Figure 2-1: Site Location**

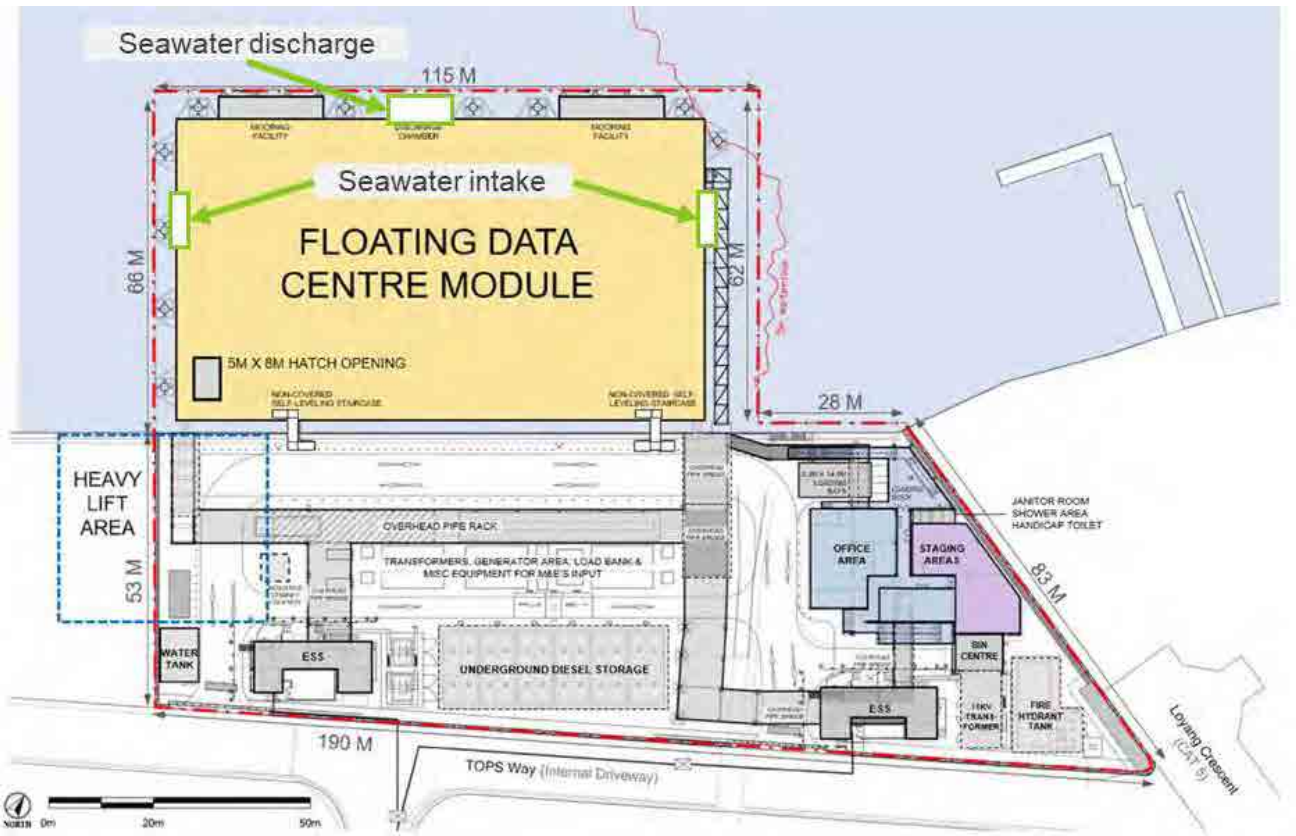



**Figure 2-2: Floating data centre module and shoreside site plan**

The FDCM houses four levels of data halls, with the associated Uninterruptible Power Supply (UPS) rooms located on Levels 1 to 4, ensuring a constant power supply for critical operations. The Level 1 floor also contains battery rooms designed to comply with Singapore Civil Defence Force (SCDF) safety standards, providing secure energy storage to back up data centre systems. Essential mechanical and electrical plant rooms, including the seawater-cooled chillers, are primarily located within the hull level and the shoreside area. These chillers form a core part of the FDCM's cooling system, leveraging seawater as a natural coolant, which significantly reduces the water consumption required for traditional air conditioning systems typically used in land-based data centres.

While the shoreside facilities are designed to complement and support the FDCM operations. They include auxiliary buildings that house office spaces, a Network Operations Centre, Fire Command Centre, staging areas, and loading/unloading zones. Additionally, shoreside infrastructure supports the main power distribution through substations and includes vital equipment such as pipe racks and M&E (mechanical and electrical) facilities that serve as a backbone to the data centre's operations. These shore facilities also provide secure access points, driveways, gates, and security systems, ensuring controlled, and secure site management.

The entire development is engineered to support an IT load capacity of approximately 19.2 MW, sufficient to power extensive data processing and storage operations. An artist's impression of the FDCM is provided in Figure 2-3 to visually illustrate the overall design and structure.

**Figure 2-3: Artist Impression of the Overall Floating Data Centre Module**

## 2.2 Statement of Need

Singapore faces increasing challenges in land scarcity, energy efficiency, and sustainable digital infrastructure. As the demand for data centres continues to grow, driven by advancements in cloud computing, artificial intelligence (AI), and 5G technologies, it is essential to explore alternative solutions that optimize space and reduce environmental impact.

Floating Data Centre Modules (FDCMs) present a viable and sustainable approach by leveraging seawater cooling technology to enhance energy efficiency while minimizing land use. Unlike traditional land-based data centres, FDCMs make use of coastal and offshore spaces, helping Singapore preserve its limited land resources while reducing its carbon footprint.

The proposed Floating Data Centre aligns with Singapore's commitment to sustainable urban planning and green data centre development, providing a scalable, energy-efficient, and environmentally responsible solution for the nation's growing digital economy.

## 2.3 Rationale and Benefits

The deployment of the Floating Data Centre offers several key advantages in terms of space efficiency, sustainability, and digital infrastructure enhancement:

1. Optimizing space and land resources
   - Utilizes coastal waters instead of land, preserving Singapore's scarce urban space for other critical developments.
   - Supports long-term urban planning goals by reducing pressure on land-based infrastructure.
2. Supporting Singapore's digital economy
   - Addresses the rising demand for high-performance data centres.
   - Enhances Singapore's position as a global hub for digital services and innovation.
3. Advancing Singapore's sustainability goals
   - Reduces the carbon footprint by incorporating seawater cooling, a more water-efficient alternative to conventional air-cooled systems.
   - Lowers reliance on treated water, contributing to national water conservation efforts.
   - Aligns with Singapore's Green Data Centre and Smart Nation initiatives.
4. Environmental and operational advantages
   - Minimizes dredging activities by selecting a site with good amount of water depth, reducing potential marine ecological impact.
   - Strategic location near existing data centres ensures efficient network integration and reduces underground construction disturbances.
   - Facilitates future scalability as Singapore continues expanding its data infrastructure

## 2.4 Site Selection

The proposed location for the Floating Data Centre at Loyang has been carefully evaluated based on environmental, technical, and operational feasibility factors:

1. Water depth and minimal dredging requirements
   - The LOSB site offers sufficient water depth, allowing for permanent mooring of the FDCM without the need for extensive dredging activities.
   - By minimizing dredging, the project reduces potential impacts on marine habitats, sediment transport, and water quality.
2. Availability of seawater cooling
   - The offshore location enables direct access to seawater for cooling purposes, reducing reliance on treated water.
   - This contributes to water conservation efforts and aligns with Singapore's initiatives for resource-efficient infrastructure development.
3. Proximity to existing data centres and underground infrastructure
   - The site's close proximity to surrounding data centres enables efficient deployment of submarine cable and underground network infrastructure.
   - This strategic positioning improves data transmission efficiency and latency performance, while minimizing disruption to the surrounding environment during construction and operation.

## 2.5 Project Design and Components

The data centre includes the following main components, along with additional auxiliary systems, outlined as follows:

| Floating Data Centre Module (FDCM) |
|---|
| The FDCM building consists of a four-storey superstructure atop a substructure, which includes a basement hull. The hull is designed as a barge-shaped, rectangular floating structure constructed from shipbuilding-grade mild steel. It is secured in place by a retention pile system with rollers, allowing vertical movement with tidal variations while restraining lateral displacement. The preliminary hull dimensions are approximately 101 meters in length, 57 meters in width, and 7 meters in depth, with a maximum draft of 4.0 meters. This design ensures a minimum average Under Keel Clearance (UKC) of 2 meters from the hull's bottom to the seabed at the design extreme low tidal level.<br>Additionally, the intake and outfall for the cooling water system will be constructed on the floating structure. Seawater will be drawn through the intake, circulated to cool the data centre, and then discharged back into the sea via the outfall. To protect against corrosion and prevent marine growth, inhibitors such as chlorine may be injected into the cooling system. As part of the biofouling control strategy, anti-fouling agent will be dosed into the system to prevent the accumulation of marine organisms in the intake pipes and heat exchangers. Several anti-fouling agent options were evaluated with respect to operational performance, compatibility with marine conditions, and environmental regulations. No other industrial discharges are anticipated from the FDCM beyond the managed cooling water discharge. |
| **Shoreside Infrastructure** |
| The shoreside facilities include:<br>1. Ancillary Buildings: Essential spaces such as office areas, a Network Operation Centre, Fire Command Centre, server rooms, loading/unloading areas, staging rooms, guardhouses, and a bin centre.<br>2. Substations: Providing electrical support for the development's operations.<br>3. Pipe Racks and Bridges: To facilitate the routing of utilities and connect systems between the FDCM and shoreside facilities.<br>4. Mechanical and Electrical (M&E) Facilities and Equipment: Housing necessary mechanical and electrical systems.<br>5. Driveways, Road Blockers, Gates, and Security Rooms: Ensuring secure access and safety for the development. |

## 2.6 Consideration of Anti-fouling Agent Use in the Seawater Cooling System

To manage biofouling within the seawater cooling system of the Floating Data Centre, a chemical anti-fouling agent is required to prevent the accumulation of marine organisms in the intake pipes, heat exchangers, and circulation systems. As part of this EIA, a review of commonly used marine anti-fouling agents were undertaken, considering technical effectiveness, environmental compatibility, safety, and regulatory alignment.

Sodium hypochlorite (NaOCl) is commonly used in industrial cooling systems; however, in seawater, it reacts readily with naturally occurring organic matter and ammonia, leading to the formation of disinfection by-products such as trihalomethanes (THMs), haloacetic acids (HAAs), and chloramines. These by-products are of environmental concern due to their toxicity to marine life, potential for bioaccumulation, and their classification as regulated pollutants in various environmental frameworks.

Based on the review, a stabilised oxidant has been identified as the preferred anti-fouling agent for this project. The selected product offers broad-spectrum antimicrobial efficacy and demonstrates reliable performance under marine pH conditions. It is particularly effective in controlling biofilm formation and reduces the risk of biofouling within the cooling system. Compared to sodium hypochlorite, the stabilised oxidant produces fewer persistent halogenated by-products. Unlike the more persistent chlorinated by-products of sodium hypochlorite, the degradation products of the stabilised oxidant are less persistent and undergo more rapid breakdown in seawater through natural degradation processes.

In stabilised oxidants, trace amounts of free chlorine or chlorinated residuals may still be present as breakdown products. These residuals are expected to dissipate rapidly in open marine waters. However, in areas with limited water exchange or reduced flushing capacity, localised exposure to residual oxidants may pose risks to sensitive marine organisms. Given the hydrodynamic conditions at the discharge location and the low concentration of residual free chlorine, these substances are not expected to accumulate, and the overall environmental risk to marine biodiversity is assessed to be low.

For the purpose of environmental risk evaluation, free chlorine was used as the basis for modelling chlorine plume dispersion (See Section 9.4 for chlorine plume assessment). This was selected due to the availability of regulatory benchmarks, which is more established for free chlorine. While the proposed stabilised oxidant has different chemical behaviour and typically degrades more rapidly while producing fewer harmful by-products, the use of free chlorine provides a conservative approach that ensures predicted environmental concentrations remain within acceptable limits. Predicted concentrations were compared against international guidelines, including the Australian Marine Water Quality Guidelines for the protection of marine aquatic life (see Section 8.2.3.4).

Several mitigation and management measures are proposed to minimise environmental impacts (refer to Section 16). These include the use of automated control systems to monitor the anti-fouling agent levels in real time. The final dosing and discharge strategies will be refined during the detailed design phase and reviewed in consultation with relevant Technical Agencies. Environmental monitoring will be conducted throughout operations to ensure compliance with applicable Environmental Quality Objectives (EQOs), Environmental Threshold Limits (ETLs), and relevant statutory standards, while safeguarding marine biodiversity. Although the project is still in the design stage, the adoption of a stabilised oxidant remains a key component of the overall strategy to minimise ecological risks and ensure adherence to the adopted discharge thresholds for chlorine.

## 2.7 Project Activities

### 2.7.1 Construction

The main construction activities at this stage of development are:

- **Floating module installation**
  - Shipyard Construction: The floating module will be constructed either in Singapore (e.g., local shipyard) or overseas (e.g., Batam, China). Hull equipment will be installed at the shipyard, while the final fit-out will take place at the deployment site.
  - Towing and Positioning: The prefabricated module will be towed to the site by tugboats and positioned.
  - Anchoring and Installation: Once anchored with piles, the installation of supporting equipment will proceed sequentially until construction is complete.
- **Mooring piling and boardwalk**
  - Pre-Dredging: Prior to mooring pile installation, dredging will be carried out.
  - Mooring Pile Installation: A total of 75 mooring piles are planned, with 28 piles installed on the west side. The remaining 47 piles on the north side will be installed after the FDCM has arrived and is moored in place.
  - Boardwalk Installation: Boardwalk construction will commence only after the FDCM is securely moored in position.
- **Shoreside construction**
  - Piling: Initial activity involves installing approximately 450 RC micro piles over 6 to 8 months.
  - Fuel Tank and Building Construction: After piling, underground (UG) fuel tank and shoreside building construction will commence.

- Structural Installation: Structural elements will be prefabricated off-site and installed with cranes and other lifting equipment.
- Shoreside Infrastructure:
  - Walkways: A boardwalk will be constructed to connect the land to the FDCM. In addition to the boardwalk, two additional walkways will be provided to ensure human access to the FDCM.
  - The FDCM will be connected to the shore via a boardwalk system designed for equipment deliveries. Additionally, there will be two self-levelling staircases for human access: one covered staircase for regular circulation and one uncovered staircase designated for fire escape and fire-fighting operations
  - Facilities: This includes ancillary and storage buildings, loading bay, bin centres, pipe racks/bridges, fencing, and utility facilities (electrical substations, transformers, generators with chimney stacks, UG diesel tanks, drains, fire accessways, fire water tanks, and cable tray/trench systems) to support the FDCM.
    - Office and Staging Spaces: Office space will be built on the existing wharf structure, with staging rooms on the hardstand area, using lightweight materials such as steel, prefabricated concrete panels, and metal cladding, with roofs incorporating photovoltaic panels, and the finish floor level will be raised to +4.5m SHD to meet PUB's Minimum Platform Level, while a separation joint will prevent structural stress between the office and staging buildings, allowing for differential settlement.
    - Pipe Racks and Bridges: Pipe racks (min. headroom of 3m) and pipe bridges (min. headroom of 4.5m) will be installed across the wharf and hardstand areas, with columns on the wharf resting on existing piles and those on the hardstand supported by new micro pile foundations.
    - Diesel Storage Tanks: An underground reinforced concrete storage tank with a micro pile-supported mat foundation will hold diesel storage ISO tanks, featuring waterproof and petroleum-compatible membranes for leak containment, while above-ground diesel day tanks will be double-walled with leak detectors for early detection.
    - Transformers: Weatherproof, oil-type transformers will be equipped with containment systems to prevent leakage.
    - Drainage System: A surface drainage system will direct runoff to the sea via ground slopes.

### 2.7.2 Operational

The development is designed to function as a standard data centre, utilising seawater for cooling. The operation of the data centre will be supported by the following key sub-systems:

1. **Seawater Cooling System**:
   - The seawater cooling system ensures efficient cooling by utilising seawater as the primary cooling medium. Seawater will be drawn in through two fully independent sea chests, configured in a 2N setup, and filtered by a strainer before being directed into the seawater intake pipes. The water is then pumped to the seawater pumps and subsequently to the chillers. The chillers cool the water, producing chilled water that is distributed throughout various parts of the FDCM, including Fan Wall Units, Fan Coil Units, and other cooling components via the supply risers. The heated chilled water returns to the chillers through the return risers to be cooled again, forming a closed-loop chilled water circuit.
   - In the process of producing cooled chilled water, heat is transferred to the seawater within the chillers. The heated seawater is then discharged back into the surrounding marine environment via the outfall pipes. The cooling water intake and outfall will be positioned directly from the hull of the floating data centre. Therefore, no dredging is required for the development of the cooling water system.

- The cooling system is designed to include one outfall and two intake points. Under normal operating conditions, both intake points will function simultaneously, with each operating at 50% capacity. However, during maintenance activities, one intake point will operate at 100% capacity while the other is offline.

2. **Chilled Water Distribution**: Ensures the distribution of chilled water to various components within the facility for temperature regulation.
3. **Fire Protection System**: Offers safety measures to prevent and control fire incidents within the premises.
4. **Mechanical Ventilation System**: Maintains air circulation and ventilation throughout the facility to support operational requirements.
5. **Potable Water System**: Supplies clean and safe water for human use and facility needs.
6. **Sanitary and Drainage System**: Facilitates waste management and drainage to maintain hygiene and compliance.
7. **Water Leak Detection System**: Monitors and identifies potential leaks to prevent water wastage and structural damage.
8. **OT-IT System**: Integrates operational technology (OT) with information technology (IT) for seamless facility management.

### 2.7.3 Operational Overview – Environmental Pollution Control Measures

The development has adopted measures to control environmental pollution and minimise potential impacts:

- **Environmental Monitoring and Management Plan (EMMP):** In alignment with best practices and regulatory requirements, an Environmental Monitoring and Management Plan (EMMP) will be established, if deemed necessary, to manage and monitor identified environmental impacts during the construction and operational phases of the project.
- **Refrigerant Selection and Compliance:** The chiller units will be fabricated to meet marine application standards and will utilise a refrigerant with "zero" Ozone Depletion Potential (ODP = 0) and a Global Warming Potential (GWP < 15) in accordance with the National Environment Agency (NEA) requirements. The selected refrigerant will comply with local regulations and ensure minimal environmental impact.
- **Refrigerant Leak Detection System**: A fixed-point refrigerant leak detection system will be installed to monitor leakage across multiple zones. Upon detecting a leak, an alarm will be activated, and the system can be shut down either automatically or manually using isolation valves incorporated into the refrigerant system.
- **Underground Diesel Tanks**: The underground diesel tanks used in this development will be double walled with leak sensors installed between the tank walls to detect any leakage.
- **Seawater Discharge:** The temperature of discharged seawater will be maintained within acceptable limits as stipulated by the EIA findings to mitigate thermal pollution.

## 2.8 Project Schedule

Based on information provided by Keppel, the proposed construction schedule to commence in Sep 2025, and the breakdown in Table 2-1.

**Table 2-1: Proposed schedule**

| Task Name | Start* |
|---|---|
| Tender and Procurement | Dec 2024 |
| Start of Design and Build | Apr 2025 |

| Task Name | Start* |
|---|---|
| Design under Main Contractor | Apr 2025 |
| Authority Submissions | Apr 2025 |
| Construction | Sep 2025 |
| Testing and Commissioning | May 2027 |
| Integrated System Testing | May 2027 |
| Ready for Service | Jul 2027 |

* The dates listed are indicative timeline only and are subjected to change depending on EIA approval.

# 3

# Environmental Impact Assessment Context and Legal Framework

# 3 Environmental Impact Assessment Context and Legal Framework

## 3.1 Applicable Legislation, Laws, and Standards

A review of applicable environmental regulations, standards, and policies has been carried out for this project. This includes both Singapore and international laws relevant to environmental protection. The most up-to-date regulations in Singapore can be accessed through the Singapore Statutes Online website (https://sso.agc.gov.sg). While the list of applicable regulations presented below is not exhaustive, and additional specific standards and guidelines may be referenced throughout the relevant sections of this EIA report as necessary.

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

The applicable Singapore legislation, standards, and guidelines are listed in the following sections.

#### 3.1.1.1 General

- Environmental Protection and Management Act 1999, 2020 revised edition
- Environmental Public Health Act 1987, 2020 revised edition
- SS 593:2013 Singapore Standard on Code of Practice for Pollution Control
- Code of Practice on Environmental Health
- Energy Conservation Act 2012
- Radiation Protection Act 2007
- Code of Practice for the Control of Legionella Bacteria in Cooling Towers

#### 3.1.1.2 Air Quality

- Environmental Protection and Management Act 1999, 2020 revised edition, Part IV on Air Pollution Control
- Environmental Protection and Management (Vehicular Emissions) Regulations, 2008 revised edition
- Environmental Protection and Management (Off-Road Diesel Engine Emissions) Regulations, 2012
- Environmental Protection and Management (Prohibition on Use of Open Fires) Order, 2008 revised edition
- Environmental Protection and Management (Air Impurities) Regulations, 2008 revised edition
- SS 593:2013 Singapore Standard on Code of Practice for Pollution Control

#### 3.1.1.3 Biodiversity

- Wildlife Act 1965, 2020 revised edition
- Parks & Trees Act 2005, 2020 revised edition

- Singapore Red Data Book, second edition, 2008
- Singapore Red Data Book, third edition, 2023
- Biodiversity Impact Assessment (BIA) Guidelines, NParks, revised version May 2024

#### 3.1.1.4 Chemical Substance

- Environmental Protection and Management (Hazardous Substances) Regulations, 2008 revised edition
- SS 603:2014 Singapore Standard on Code of Practice for Hazardous Waste Management
- Fire Safety Act 1993, 2020 revised edition
- SS 532:2007 Singapore Standard on Code of Practice for the Storage of Flammable Liquids
- Fire Safety (Petroleum and Flammable Materials) Regulations, 2008 revised edition

#### 3.1.1.5 Noise

- Environmental Protection and Management Act 1999, 2020 revised edition, Part VIII Noise Control
- Environmental Protection and Management (Control of Noise at Construction Sites) Regulations, 2008 revised edition
- Environmental Protection and Management (Boundary Noise Limits for Factory Premises) Regulations, 2008 revised edition
- SS 593:2013 Singapore Standard on Code of Practice for Pollution Control
- SS 602:2014 Singapore Standard on Code of Practice for Noise Control on Construction and Demolition Sites

#### 3.1.1.6 Surface Water Quality

- Sewerage and Drainage Act 1999, 2020 revised edition
- Sewerage and Drainage (Surface Water Drainage) Regulations, 2007 revised edition
- Sewerage and Drainage (Trade Effluent) Regulations, 2007 revised edition
- Environmental Protection and Management Act 1999, 2020 revised edition, Part V on water pollution control
- Environmental Protection and Management Act (Trade Effluent) Regulations, 2008 revised edition
- PUB's Code of Practice on Surface Water Drainage (2018) with Amendment under Addendum No. 1 – April 2021
- PUB's Handbook on Managing Urban Runoff (2013)
- SS 593:2013 Singapore Standard on Code of Practice for Pollution Control
- PUB's Guidebook on Erosion and Sediment Control at Construction Sites (2018)

#### 3.1.1.7 Sediment Quality

- General guidelines on the requirements for application on dredging and dumping works

#### 3.1.1.8 Waste Management

- Environmental Protection and Management Act 1999, 2020 revised edition, Part VII on Hazardous Substances
- Environmental Protection and Management (Hazardous Substances) Regulations, 2008 revised edition
- Environmental Public Health (General Waste Collection) Regulations, 2000 revised edition
- Environmental Public Health (Toxic Industrial Waste) Regulations, 2000 revised edition
- SS 593:2013 Singapore Standard on Code of Practice for Pollution Control
- SS 603:2014 Singapore Standard on Code of Practice for Hazardous Waste Management

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

#### 3.1.2.1 General

- World Bank Group (WBC)'s Environmental, Health and Safety Guidelines
- International Financial Corporation (IFC)'s Performance Standards
- International Financial Corporation (IFC)'s Environmental, Health, and Safety (EHS) Guidelines for Thermal Power Plants

#### 3.1.2.2 Ambient Air Quality

- United Nations Framework Convention on Climate Change (UNFCCC)

#### 3.1.2.3 Biodiversity

- International Union for Conservation of Nature (IUCN) Red List of Threatened Species, version 2022-2
- CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora, 1983
- Convention on Biological Diversity (CBD)
- United States Environmental Protection Agency (USEPA) R.E.D. FACTS Chlorine gas

#### 3.1.2.4 Marine Water Quality

- Association of Southeast Asian Nations Marine Water Quality Criteria (ASEAN MWQC) (ASEAN 2008)
- Australian and New Zealand guidelines for fresh and marine water quality (ANZECC, 2000)

#### 3.1.2.5 Marine Seabed Quality

- Canadian Sediment Quality Guidelines (2008) were adopted in this Study
- Netherlands Soil Quality Standards (2012) were adopted in this Study.
- ANZECC/ARMCANZ Sediment Quality Guidelines (2000)

## 3.2 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. These tolerance limits served as benchmarks for assessing potential environmental impacts and ensuring that the proposed activities remained within acceptable limits of environmental change. The tolerance limits and compliance criteria used in this study were developed by a combination of quantitative numerical modelling, relevant regulatory standards, and technical guidance documents, along with SECS' experience in marine and coastal studies in Singapore. Where applicable, international best practices were also referenced to support the robustness of the assessment.

These thresholds were tailored to reflect the site-specific environmental sensitivities and the proposed development and guided the assessment of impact significance across various environmental aspects. Further details on the evaluation framework, including the tolerance limits applied were provided within the respective impact assessment sections of the EIA report.

# 4

# Study Approach and Methodology

# 4 Study Approach and Methodology

This assessment will cover both the construction and post-construction phases of the proposed development. The key activities undertaken by SECS include:

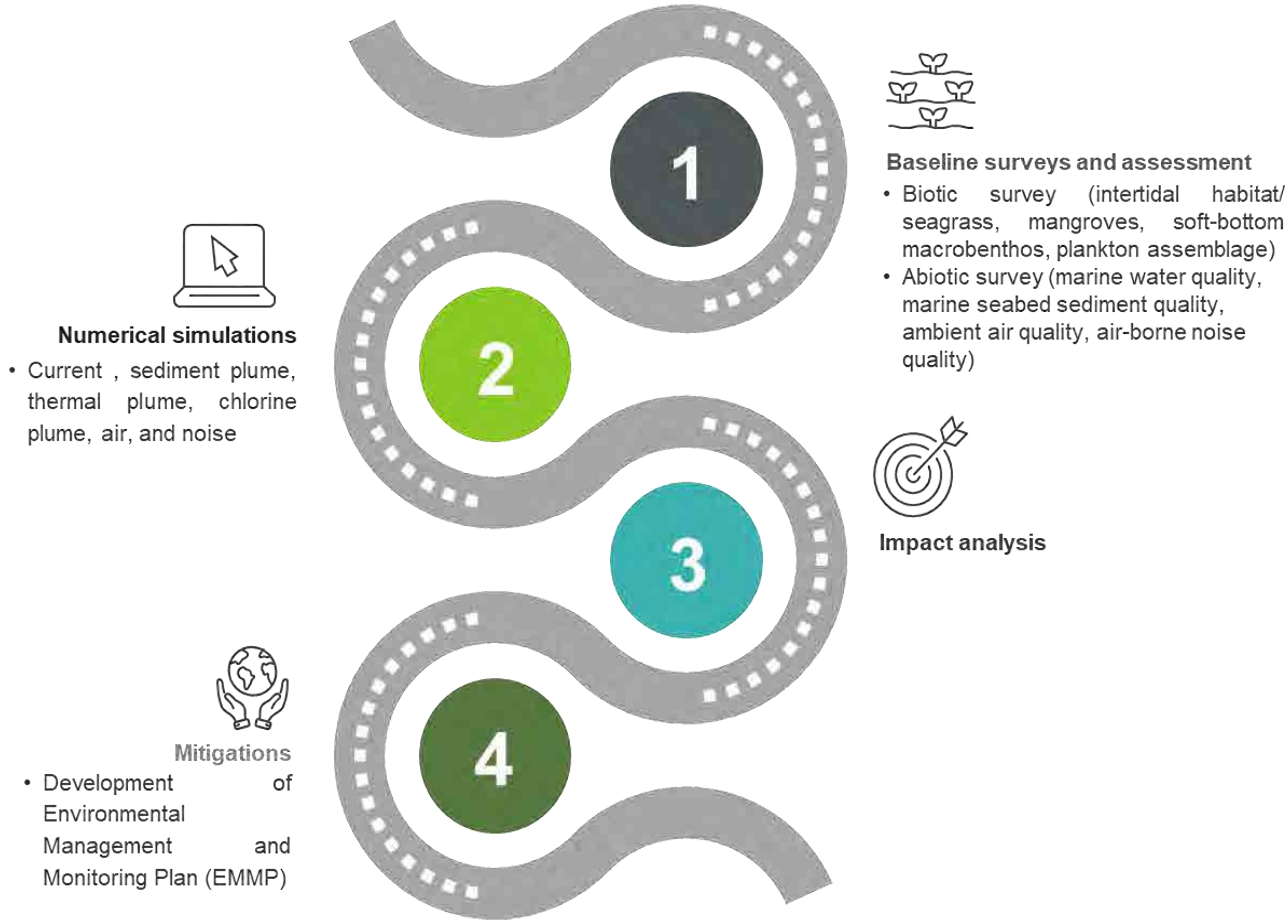



**Figure 4-1: Overview of key activities**

## 4.1 EIA Scoping

The scope of work undertaken by SECS was based on the outcomes of the scoping exercise conducted in consultation with relevant Technical Agencies. This section outlines the EIA scope established during the meeting, focusing on both the construction and post-construction phases of the development.

The Project was anticipated to result in various changes impacting the physicochemical, ecological, and socio-economic environments. Consequently, there was potential for the Project to have effects on sensitive environmental receptors located within the vicinity of the Project area.

The EIA aims to evaluate impacts over two distinct timeframes: short-term impacts during construction and long-term impacts during the post-construction or operational phase. During the construction phase, the assessment will focus on examining the effects of construction activities over a short-term period. In the post-construction phase, the emphasis will shift to monitoring and evaluating long-term environmental effects, particularly concerning cooling water discharge and air and noise emissions. Please note that this EIA does not cover compliance with Pollution Control Study (PCS) report requirements.

Table 4-1 provides a detailed summary of the key receptors and associated environmental aspects for both construction (short-term) and operational (long-term) phases.

**Table 4-1: Summary of the Impact**

| Environmental Aspects | Impact | Receptor | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Intertidal habitat/ seagrass | Mangrove habitat | Soft-bottom macrobenthos | Plankton | Jetties | Navigation | Aquaculture farm | Recreational facilities | Water intake | Cross border | Human health |
| Physical disturbance | Direct impact due to dredging activity within the Project footprint | Grey | Grey | Yellow | Yellow | Grey | Grey | Grey | Grey | Grey | Grey | Grey |
| Currents | Changes in current speed due to intermediate and final hull construction | Grey | Grey | Grey | Grey | Red | Red | Grey | Grey | Grey | Grey | Grey |
| Warm water discharge | Thermal water discharge from cooling water discharge | Orange | Orange | Orange | Grey | Grey | Grey | Orange | Grey | Orange | Grey | Grey |
| Chlorinated discharge | Chlorinated water discharge from cooling water discharge | Orange | Orange | Orange | Grey | Grey | Grey | Orange | Grey | Orange | Grey | Grey |
| Suspended sediments | Sediment plume dispersion due to dsiturbance of seabed during dredging activity | Yellow | Yellow | Grey | Yellow | Grey | Grey | Yellow | Yellow | Yellow | Yellow | Grey |
| Sedimentation | Sedimentation / sediment accummulation due to dredging activity | Yellow | Grey | Yellow | Grey | Yellow | Yellow | Grey | Yellow | Grey | Yellow | Grey |
| Sediment quality | Bioaccumulation from seabed polution released from dreding | Grey | Grey | Grey | Grey | Grey | Grey | Yellow | Grey | Grey | Grey | Grey |
| Air quality | Increases in traffic during construction activity<br>Emission during operation phase | Grey | Grey | Grey | Grey | Grey | Grey | Grey | Grey | Grey | Grey | Red |
| Noise level | Increase of noise level from consruction work<br>Increase noise level generated from the component during operation phase | Grey | Grey | Grey | Grey | Grey | Grey | Grey | Grey | Grey | Grey | Red |

**Note:**

- (Grey) No impact
- (Yellow) Short-term construction impacts
- (Orange) Long-term post-construction impacts
- (Red) Short and long-term construction impacts

## 4.2 Baseline Surveys

The purpose of the baseline assessment was to identify and establish the initial environmental characteristics and conditions of the area of interest prior to the commencement of any development activities. The data collected and analysed by SECS are presented in Table 4-2 and the survey locations were illustrated in Figure 4-2.

**Table 4-2: Summary of baseline parameter**

| Parameter | Descriptions | Report Section |
|---|---|---|
| **Biotic** | | |
| Intertidal seagrass habitat | Survey was carried out at four (4) transects from 19 Oct 2024 to 20 Oct 2024. | Section 7.8.1 |
| Soft-bottom macrobenthos | Survey was carried out at three (3) stations on 4 Oct 2024. | Section 7.8.3 |
| Mangroves | Survey was carried out on from 18 Oct 2024 to 22 Oct 2024. | Section 7.8.2 |
| Phytoplankton and zooplankton survey | Survey was carried out at four (4) stations on 3 Oct 2024. | Section 7.8.4 |
| **Abiotic** | | |
| Marine seabed sediment quality | Survey was carried out at three (3) stations on 4 Oct 2024. | Section 7.7 |
| Marine water quality | Survey was carried out at four (4) stations on 3 Oct 2024. | Section 7.6 |
| Ambient air quality | Primary data collection was conducted at one (1) station over a period of seven (7) days to measure particulate matter ($PM_{2.5}$ and $PM_{10}$), Nitrogen Dioxide ($NO_2$), Carbon Monoxide (CO), Sulphur Dioxide ($SO_2$), and Ozone ($O_3$) as identified in NEA's Singapore Ambient Air Quality Targets. The measurement was successfully completed from 25 Sep 2024 to 2 Oct 2024 | Section 7.4 |
| Air-borne noise quality | Primary data collection was conducted at two (2) stations over a period of seven (7) days and the measurement was successfully completed from 25 Sep 2024 to 2 Oct 2024 | Section 7.5 |

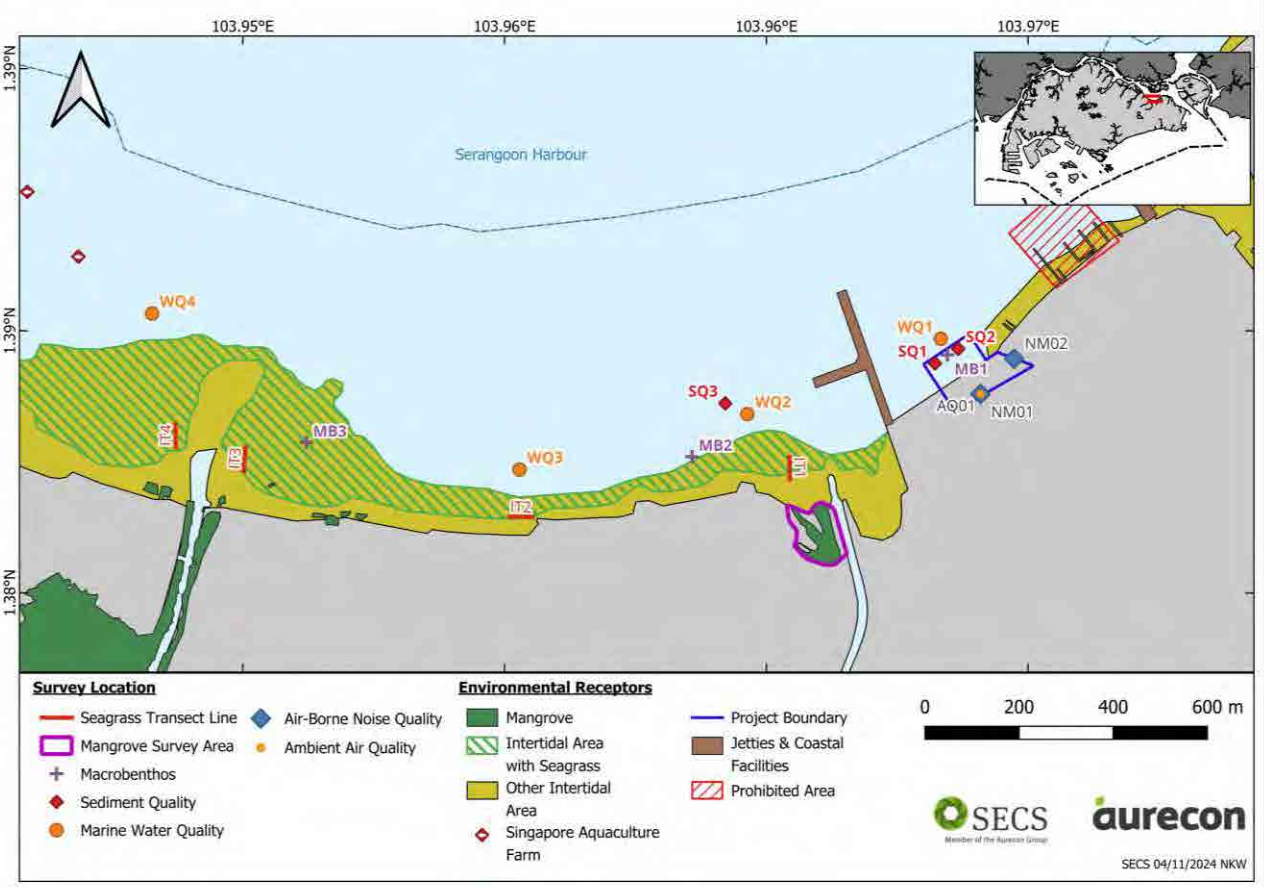



**Figure 4-2: Baseline survey locations**

## 4.3 Numerical Simulations

Multiple model simulations were performed to evaluate the environmental impacts associated with both the construction (short term impact) and operational phases (long-term impact) of the Project. The short-term and long-term impacts are defined as follows:

- **Short-term impacts** were temporary environmental effects that occur during the construction or early stages of the Project. These impacts typically last only for the duration of construction activities or initial phases and generally diminish or disappear once construction is completed or when mitigation measures are implemented. For this project, short-term impacts include sediment spills generated during dredging activities. These spills may create sediment plumes that can potentially reach sensitive sites and receptors. The assessment of these impacts has been conducted for different representative seasonal conditions.
- **Long-term impacts** refer to environmental effects that occur during the operational phase of the Project and may persist over an extended period or even permanently. These impacts were associated with ongoing activities or infrastructure related to the project and may require continuous monitoring or mitigation to minimise environmental effects. For this project, long-term impacts have been assessed in relation to:
  - Warm water discharge
  - Chlorinated water discharge
  - Air emissions
  - Noise emissions

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. The findings from these simulations will be incorporated into this EIA report.

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

This assessment was designed to evaluate impacts in terms of Impact Significance, relying on information gathered from field surveys, laboratory sample analyses, and modelling results. For this EIA, the Rapid Impact Assessment Matrix (RIAM) framework has been adopted. This tool quantifies, whenever possible, the key changes to the physicochemical, ecological, and socio-economic environments anticipated during the construction and operational phases.

Using the RIAM tool, the impacts resulting from project activities are assessed against various environmental components. For each component, a score was assigned based on established criteria. The significance of an impact is determined by converting the Environmental Score (ES) into categories such as 'Slight,' 'Minor,' 'Moderate,' etc., using a predetermined list of impact levels that correspond to a range of ES values. The formula for calculating the ES is expressed as follows:

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

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
- **Cumulative Impact (C)** – A score is defined based on the cumulative potential of an impact.

The impact assessment focuses on analysing the 'Magnitude of Change' (M), which is classified according to the defined parameters outlined in Table 4-3. The scale of negative changes for various receptors were quantitatively assessed based on well-established or industry-recognised tolerance limits, alongside the modelling results generated for this study.

**Table 4-3: Impact assessment severity categories**

| Severity | Definition |
|---|---|
| No Impact | Compliance with standard, guidelines or benchmarks does not change due to project or, in the relation to tolerance limits, magnitudes are below the level of model reliability or are significantly below recognised tolerance levels so that no change to the quality or functionality of a receptor will occur. |
| Slight Impact | Slight changes can be resolved by numerical models but are unlikely to be detectable in the field as typically Slight negative changes are associated with changes that may cause limited stress (e.g. ecosystems) |
| Minor Impact | Minor negative change is realised when there is a limited non-compliance with established standards, guidelines or benchmarks. In relation to Tolerance Limits, minor negative magnitudes of change are identifiable by the predictive modelling tools (e.g. intense stress or mortality) and would also be identifiable in the field but are limited in spatial extent and severity. |
| Moderate Impact | Moderate negative change is evident when an analysed deviation exceeds established standards, guidelines or benchmarks. The non-compliance is locally relevant and would require alterations to project design and/or operational management to ensure general compliance. In relation to Tolerance Limits, Moderate magnitudes of change are clearly and readily evident with predictive modelling tools (e.g. mortality, or excessive mean TSS concentrations) and can be readily identified in the field. |

| Severity | Definition |
|---|---|
| Major Impact | Major negative changes involve exceedance of established standards, guidelines, benchmark or tolerance limits well beyond project boundaries or when a complete loss of local habitat is evident. Depending on significance, impacts of this nature may be considered unacceptable and require substantial design-related mitigation measures to remediate negative impacts on the physical, ecological or social environment. |

The scales for the importance, magnitude, permanence, reversibility, and cumulatively specified in Table 4-4.

**Table 4-4: 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 |
| 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 | 2 |
| | Presence of obvious cumulative/cascading effect that will affect other Developments or activities or trigger secondary impacts | 3 |

For each identified potential environmental impact affecting a sensitive receptor, an ES will be calculated. The ESs are then banded together and ranked in range bands as presented in Table 4-5, which are then translated to Impact Significance and presented in the EIA report.

**Table 4-5: Range bands used in RIAM**

| Range Bands for RIAM ES | Impact Indicators according to Range Band | | Description of Range Value |
|---|---|---|---|
| | Range Value (alphabetical) | Range Value (numeric) | |
| 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 | Minor positive change/ minor 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 | Minor negative change/ minor negative impact |
| - 81 to - 115 | - C | -3 | Moderate negative change/ moderate negative impact |
| - 116 to - 180 | - D | -4 | Major negative change/ major negative impact |

# 5

# Receptors

# 5 Receptors

Environmental receptors include components of both the natural environment, such as water, air, flora, and, as well as elements of the built environment, such as facilities, jetties, and recreational areas. These receptors represent various user groups or communities that may be exposed to, or impacted by, construction activities and post-construction or operational activities associated with the proposed development.

Characterisation of the marine environment in the region has been based on available secondary data, supplemented by further baseline surveys undertaken for this EIA. This information forms the foundation for understanding the marine and ecological ecosystem status prior to construction, supporting the development of management strategies and monitoring programs.

An overview of marine-related receptors is shown in Figure 5-1, with Figure 5-2 providing a close-up view of the receptors identified in and around the Project area. Figure 5-3 to Figure 5-6 illustrate the receptors of concern, along with the overlay of the Project area on the nautical chart (Figure 5-7).

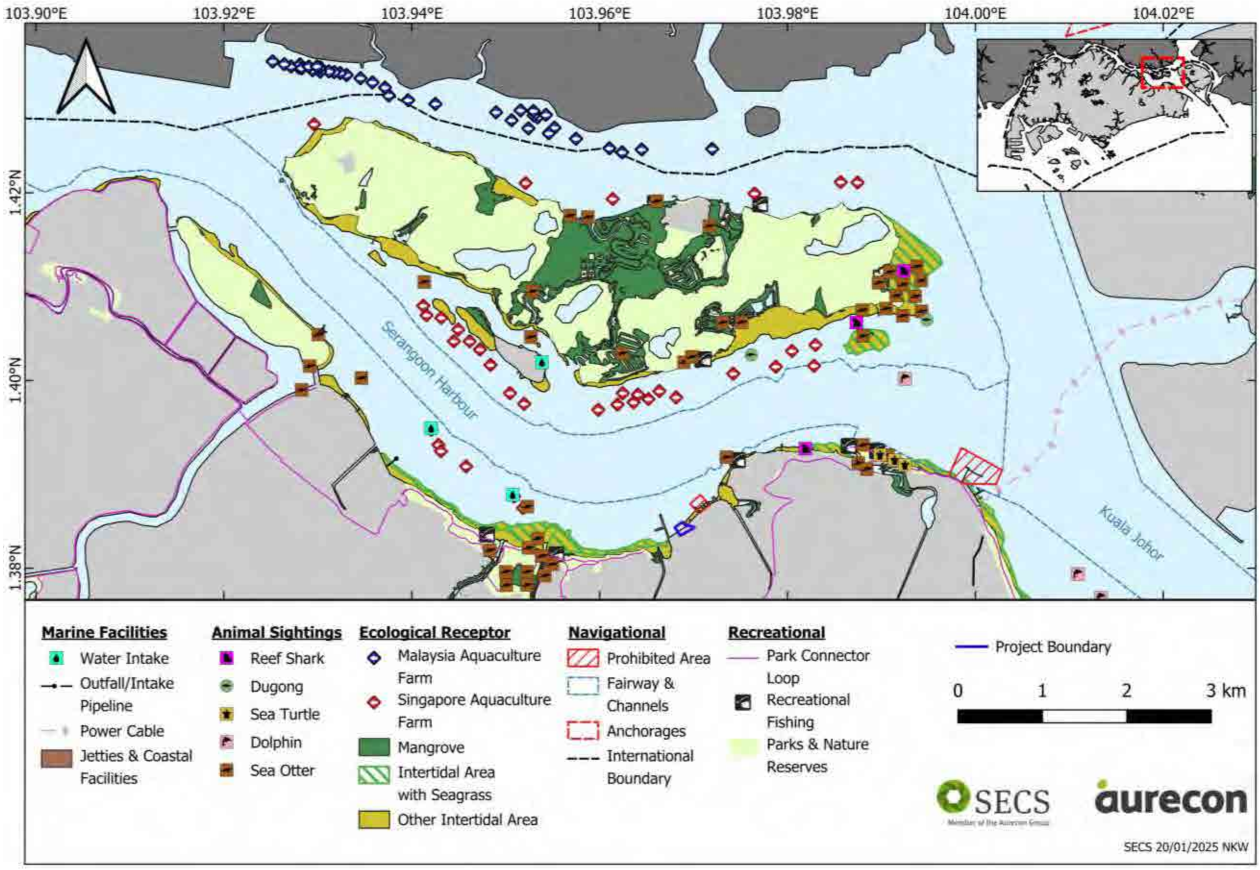



**Figure 5-1: Overview of the known marine environmental receptor around the vicinity of the proposed development**

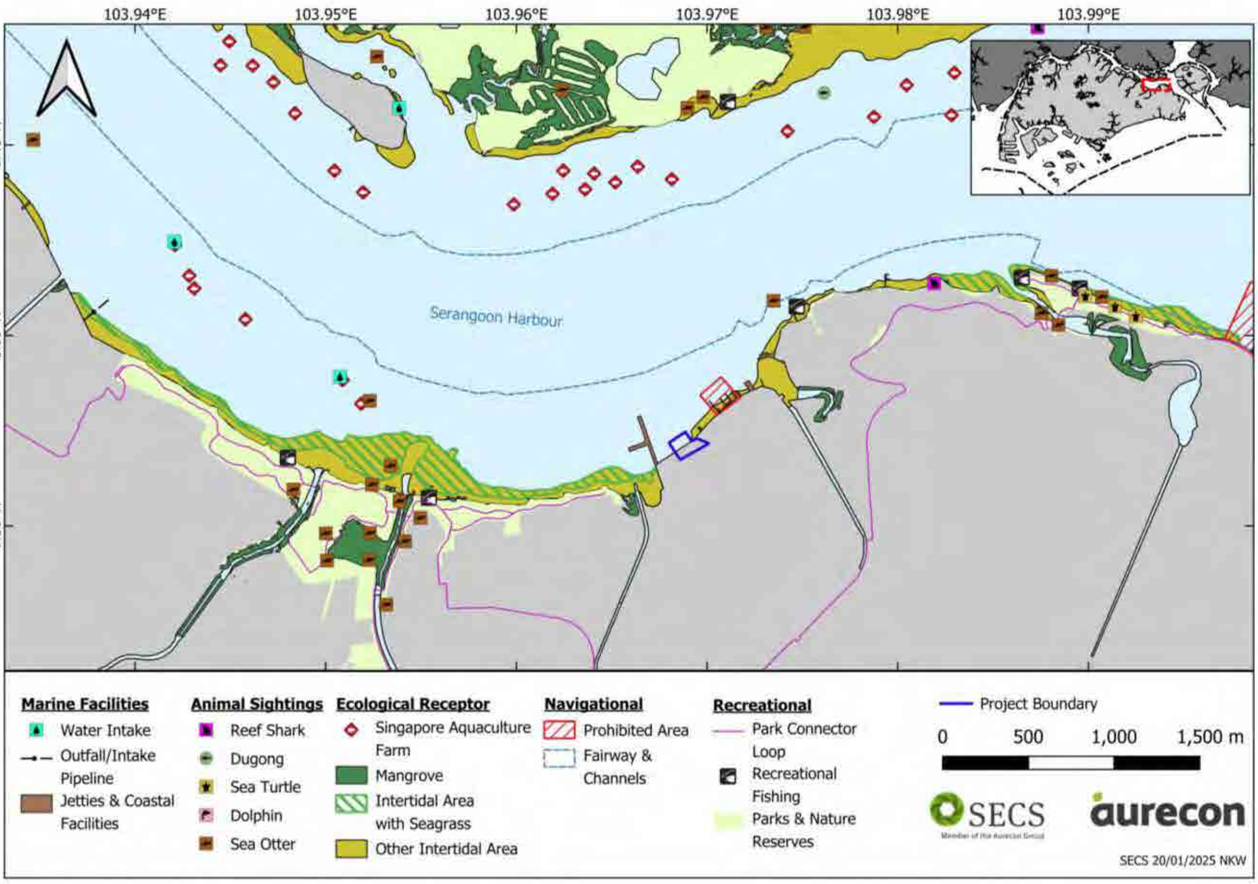



**Figure 5-2: Close-up view of known marine environmental receptor around the vicinity of the proposed development**

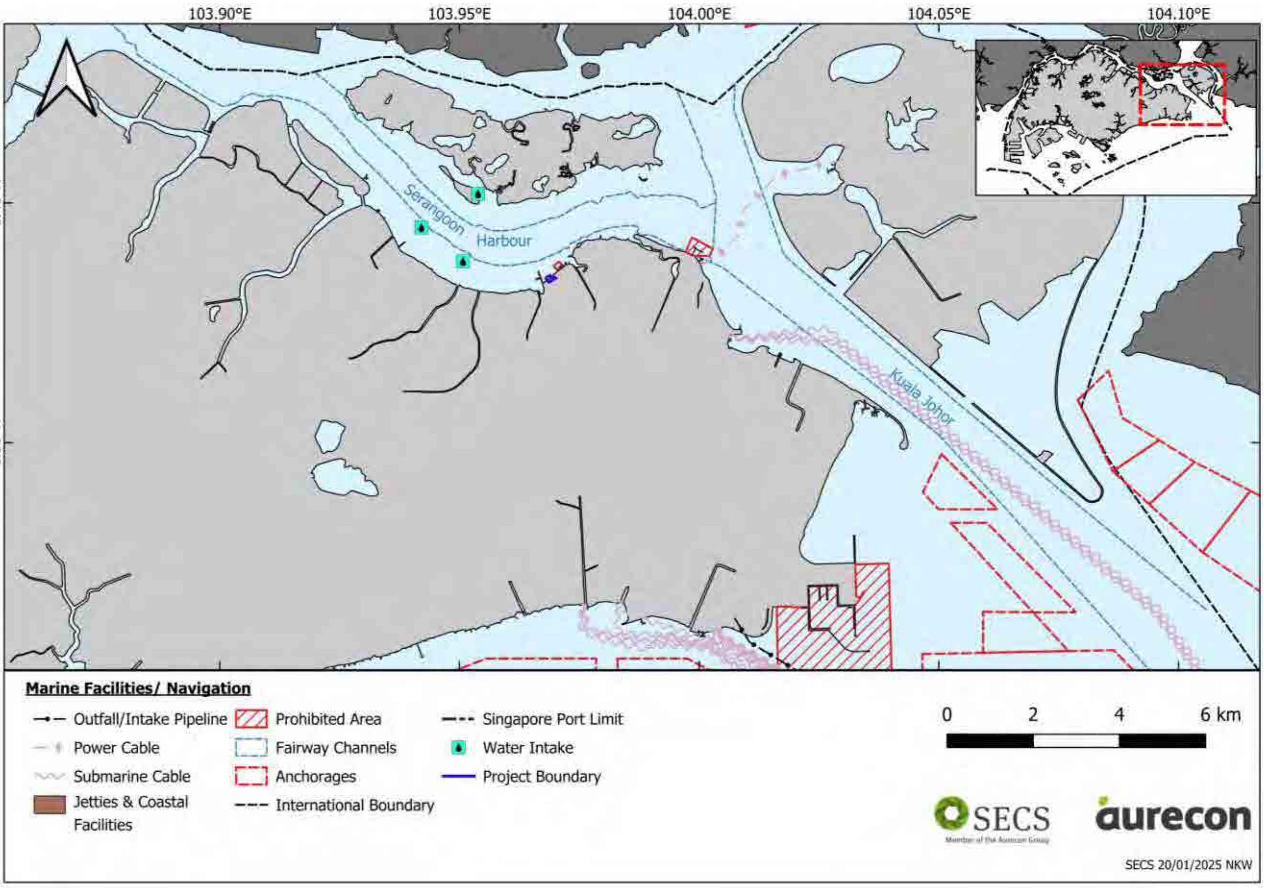



**Figure 5-3: Known marine facilities around the vicinity of the proposed development**

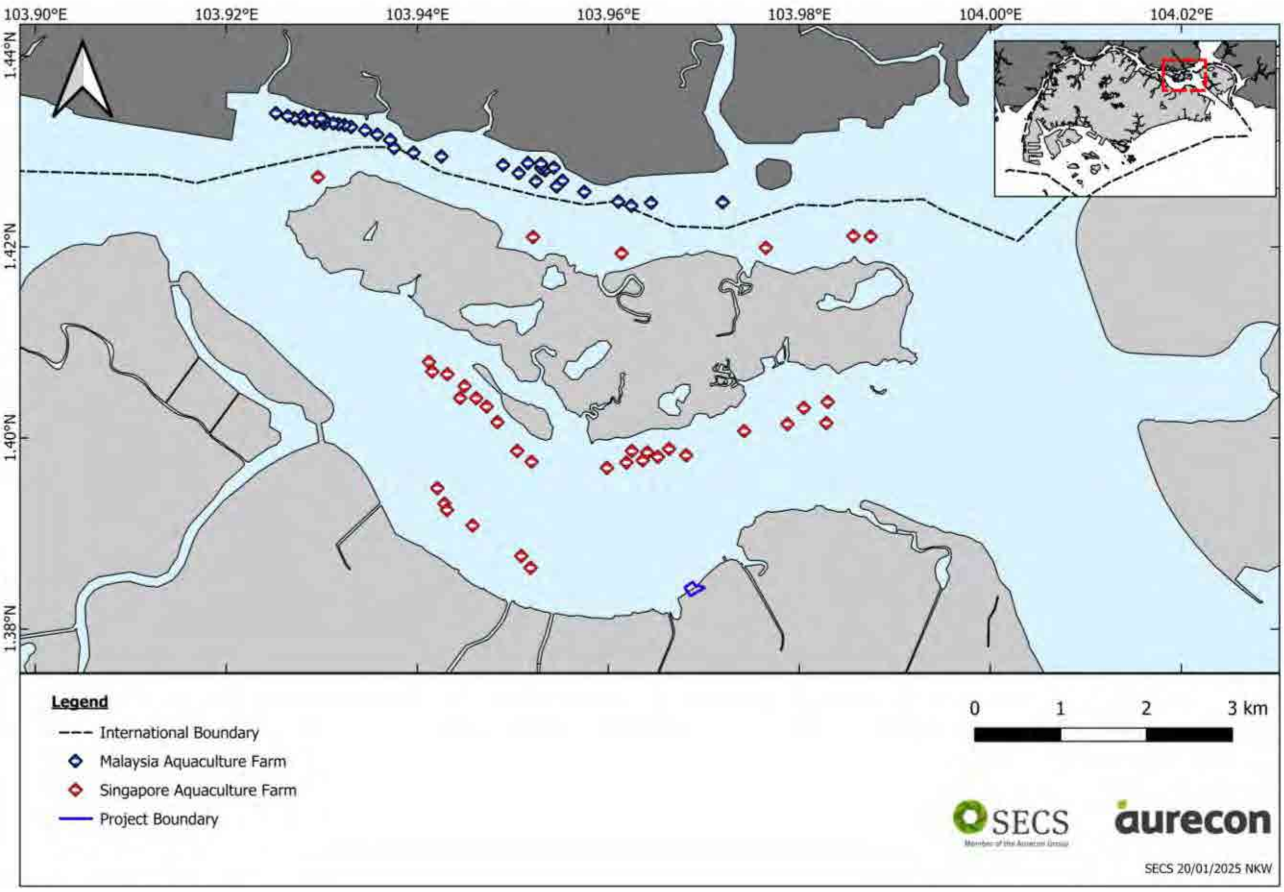



**Figure 5-4: Known aquaculture facilities around the vicinity of the proposed development**

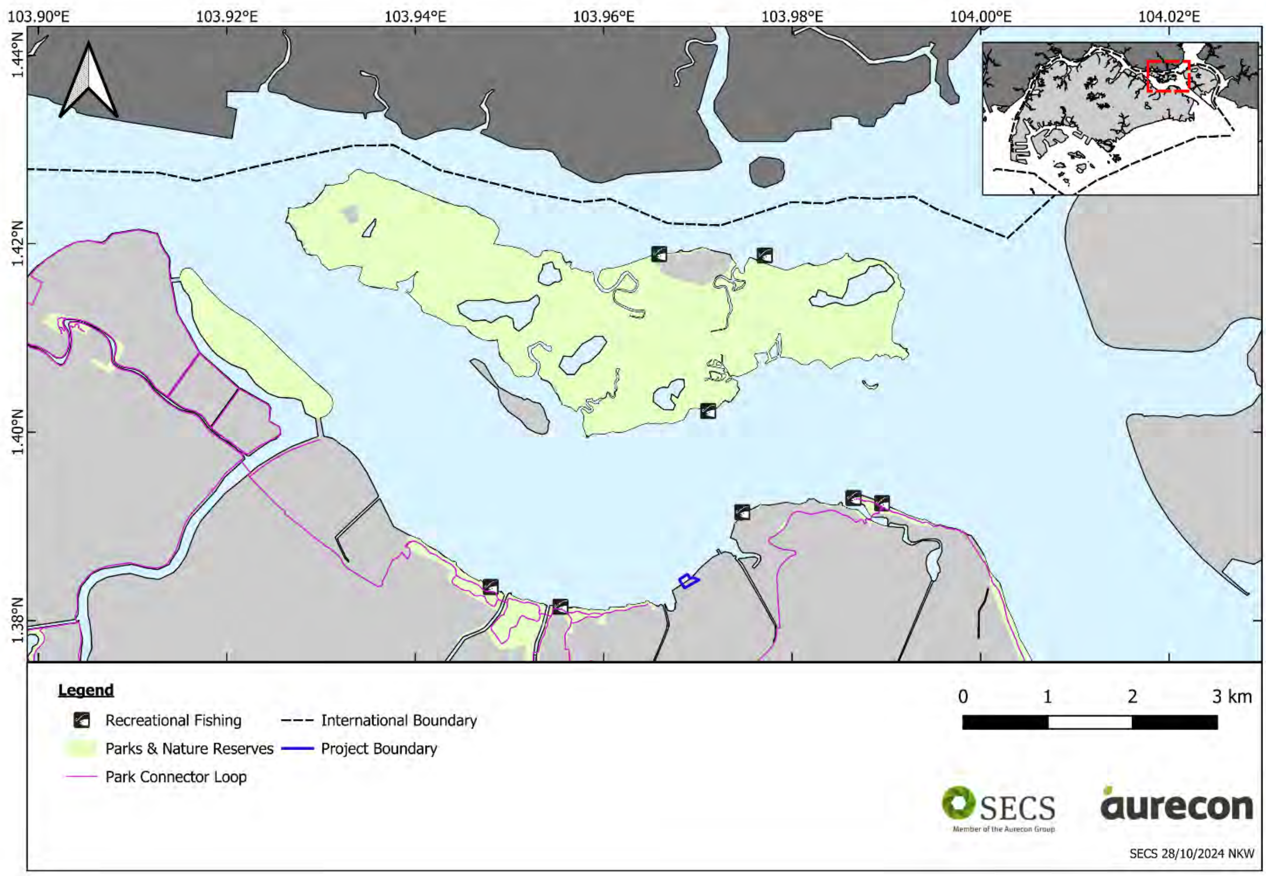



**Figure 5-5: Known recreational facilities around the vicinity of the proposed development**

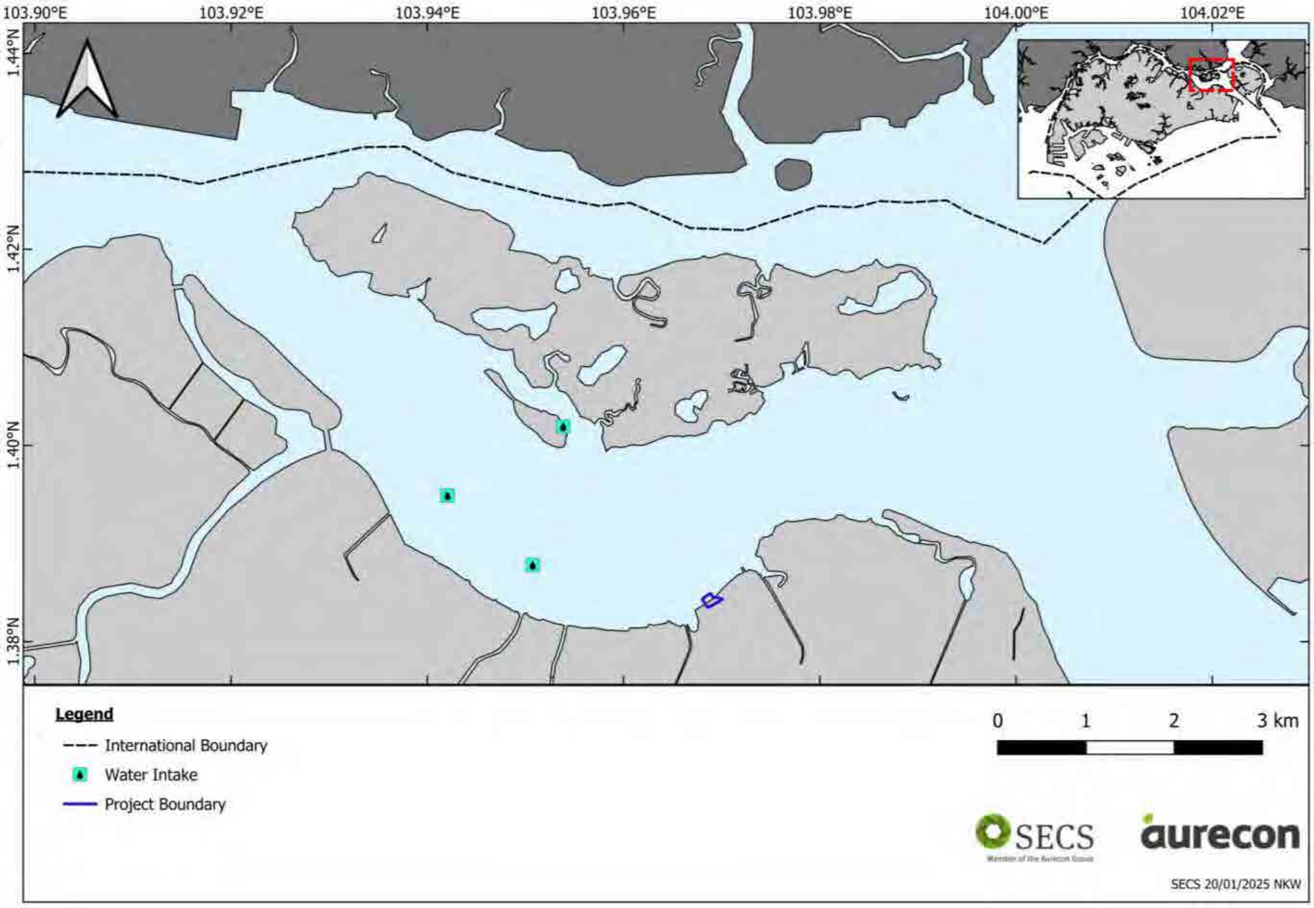



Figure 5-6: Known water intake around the vicinity of the proposed development, including cross-border

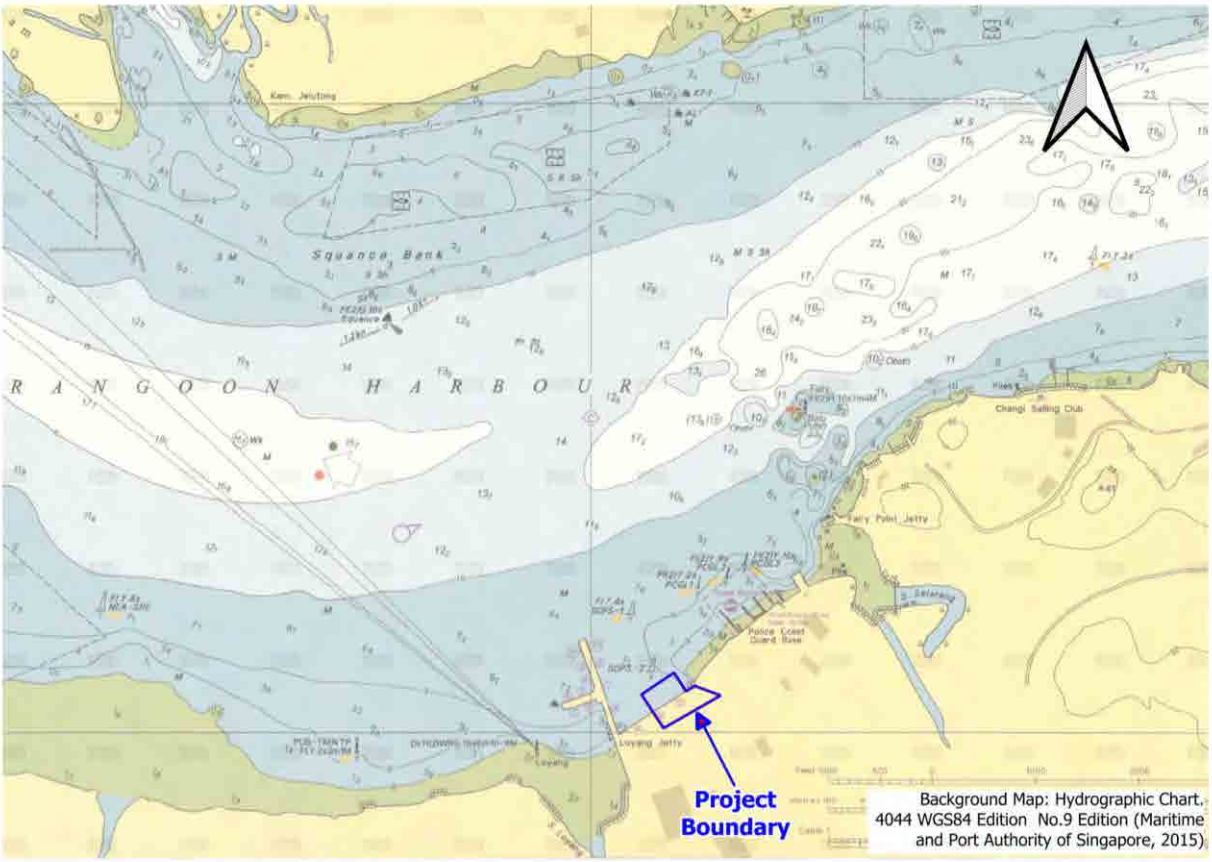



**Figure 5-7: Location of the Floating Data Centre overlay on the nautical chart**

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

**Table 5-1: Summary of known receptor**

| Receptor | Description |
|---|---|
| Seagrass | Seagrass habitats are present in areas near the project site, including:<br>• Adjacent to the Project site shoreline<br>• Pasir Ris Park shoreline<br>• Changi Boardwalk shoreline, approximately 2 km Northeast of the Project site<br>• Changi Beach Park, approximately 2 km Northeast of the Project site<br>• Pulau Sekudu, approximately 3 km Northeast of the Project site<br>• Chek Jawa, approximately 3 km Northeast of the Project site |
| Mangrove | Mangrove habitats are found in the following locations:<br>• Adjacent to the Project site<br>• Selarang River, approximately 1 km Southwest of the Project site<br>• Pasir Ris Park, approximately 1.3 km Southwest of the Project site<br>• Sungei Jelutong, approximately 2 km Southwest of the Project site<br>• Sungei Api-api, approximately 2 km Southwest of the Project site |
| Coral | Coral habitats are located approximately 8 km East of the Project site, beyond the potential impact zone. |
| Megafauna | Key megafauna species identified in the vicinity of the Project site include:<br>• Sea otters: Found at Pasir Ris Park, located 1.3 km Southwest of the Project site<br>• Sea turtles: Sighted at Changi Beach Park, approximately 3 km East of the Project site<br>• Other megafauna: Occasional sightings of dolphins, dugongs, and reef sharks have been reported around the Project site, although these sightings are sparse and infrequent. |
| Aquaculture facilities | Aquaculture facilities are located at the following locations:<br>• Serangoon Harbour, with the nearest aquaculture facility approximately 2 km west of the Project site<br>• Around Pulau Ubin |
| Water intake | The closest marine intakes are sea-based farms in Serangoon Harbour as indicated in Figure 5-6. |

| Receptor | Description |
|---|---|
| Navigation channel | Navigation features include harbours, channels, anchorages, and prohibited/restricted areas:<br>• The nearest waterways include Serangoon Harbour and Kuala Johor Channel.<br>• Four anchorages are situated in proximity to the Project area: Changi Barge Temporary Holding Anchorage (ACBTH), Changi General Purpose Anchorage (ACGP), Man-of-War Anchorage (AMOW), and Eastern Bunkering A Anchorage (AEBA). However, these anchorages are located outside the designated impact zone.<br>• Prohibited and restricted areas within the study area include the Police Coast Guard - Loyang Police, Changi Airport Fuel Hydrant Installation (CAFHI), and Chek Jawa Wetlands. Access to these areas is strictly controlled, with no vessels allowed except those authorized by the Commander of the Police Coast Guard for purposes such as anchorage, passage, or other activities. The prohibited and restricted area closest to the immediate construction footprint is the Police Coast Guard - Loyang Police. |
| Marine jetties | The marine jetties in the vicinity of the Project area were located at the following locations:<br>• Loyang Offshore Supply Base Jetty<br>• Fugro's Jetty<br>• Police Coast Guard Loyang Regional Base Jetty<br>• Changi Point Ferry Terminal (CPFT)<br>• Singapore Armed Forces (SAF) Ferry Terminal<br>The marine facilities closest to the immediate construction footprint is the Loyang Offshore Supply Base Jetty, Fugro's Jetty, and Police Coast Guard Loyang Regional Base Jetty. Other marine facilities are anticipated to remain unaffected by the Project development. |
| Recreational Facilities | Within the study area, several recreational facilities are identified, including coastal public parks, beaches, leisure boating areas, and waterfront attractions. The key recreational facilities in the vicinity of the Project site are as follows:<br>• Recreational facilities at Pasir Ris Park, Changi Beach Park, as well as Jelutong Campsite and Chek Jawa Boardwalk on Pulau Ubin. Pasir Ris Park is the nearest recreational facilities and recreational fishing from the construction footprint.<br>• Recreational activities such as recreational fishing and camping at Pasir Ris Park, Jelutong Campsite, Changi Beach Park |
| Cross-Border | Cross-border features are located within the border of other countries. The closest country to the Project area outside Singapore was Malaysia. |

# 6

# Environmental Quality Objectives (EQOs)

# 6 Environmental Quality Objectives (EQOs)

The Environmental Quality Objectives (EQOs) adopted for the project are outlined below for both the construction and post-construction (operational) phases. These objectives were developed in consultation with the Technical Agencies.

During the construction phase, the primary environmental concerns are associated with dredging activities, particularly sediment suspension and sedimentation. In the operational phase, the focus shifts to potential impacts from chlorine and thermal discharges related to the cooling water system.

The EQOs established for the project are as follows:

Construction Phase

The primary environmental impacts during construction were associated with dredging activities, with key concerns including sediment suspension and sedimentation.

- No impact on seagrass and mangroves.
- No impact on aquaculture facilities.
- No impact on key receptors outside the immediate project area, including marine intake points, marine infrastructure, and navigation routes.
- No cross-border impacts.

Operational Phase

During the operational phase, the primary environmental concerns were related to chlorine and thermal discharges from the cooling water system. The EQOs for this phase include:

- No impact on seagrass and mangroves.
- No impact on aquaculture facilities.

# 7

# Environmental Baseline Settings

# 7 Environmental Baseline Settings

This section provides an overview of the existing environmental conditions in the Project area prior to the commencement of any proposed activities. The baseline data collected will serve as a reference point for assessing potential impacts from the proposed Project on the surrounding environment.

The baseline data were composed of both primary and secondary data collection. Primary data was gathered through a series of field campaigns, while secondary data was sourced from existing literature, reports, and databases where available.

## 7.1 Site Feature

The Project site comprised a plot of land along the existing wharf and extended into the adjacent sea area, where the floating data centre was proposed to be constructed. According to the prevailing land lot plan, the site formed part of Lots MK31-04684C and MK31-04865P.

The existing land uses and planned users that may be impacted by the Project during construction and operational phases were identified through available secondary data, utilising online resources such as street directories, satellite imagery, and government databases. These identified land uses are depicted in Figure 7-1.

The site was classified as "Business 2" under the URA Master Plan 2019. In accordance with URA's land use zoning, the site and its immediate surroundings fell within the Pasir Ris Planning Area, specifically within the Loyang West Planning Subzone, and were designated for "Business 2" industrial use. This zoning category accommodates clean industry, light industry, general industry, warehousing, public utilities, telecommunication facilities, and other forms of public infrastructure. The base consists of port facilities, offices, warehouses, storage facilities, logistics, and workshops.

The Project site is located within an industrial area, with no heritage buildings or culturally significant structures in the immediate vicinity. Adjacent facilities include Fugro House, as well as the Police Coast Guard (PCG) – Loyang Base and the Loyang Marine Fire Post, as shown in Figure 7-2. Both Fugro and the PCG have been engaged and consulted during the scoping exercise as part of the study.

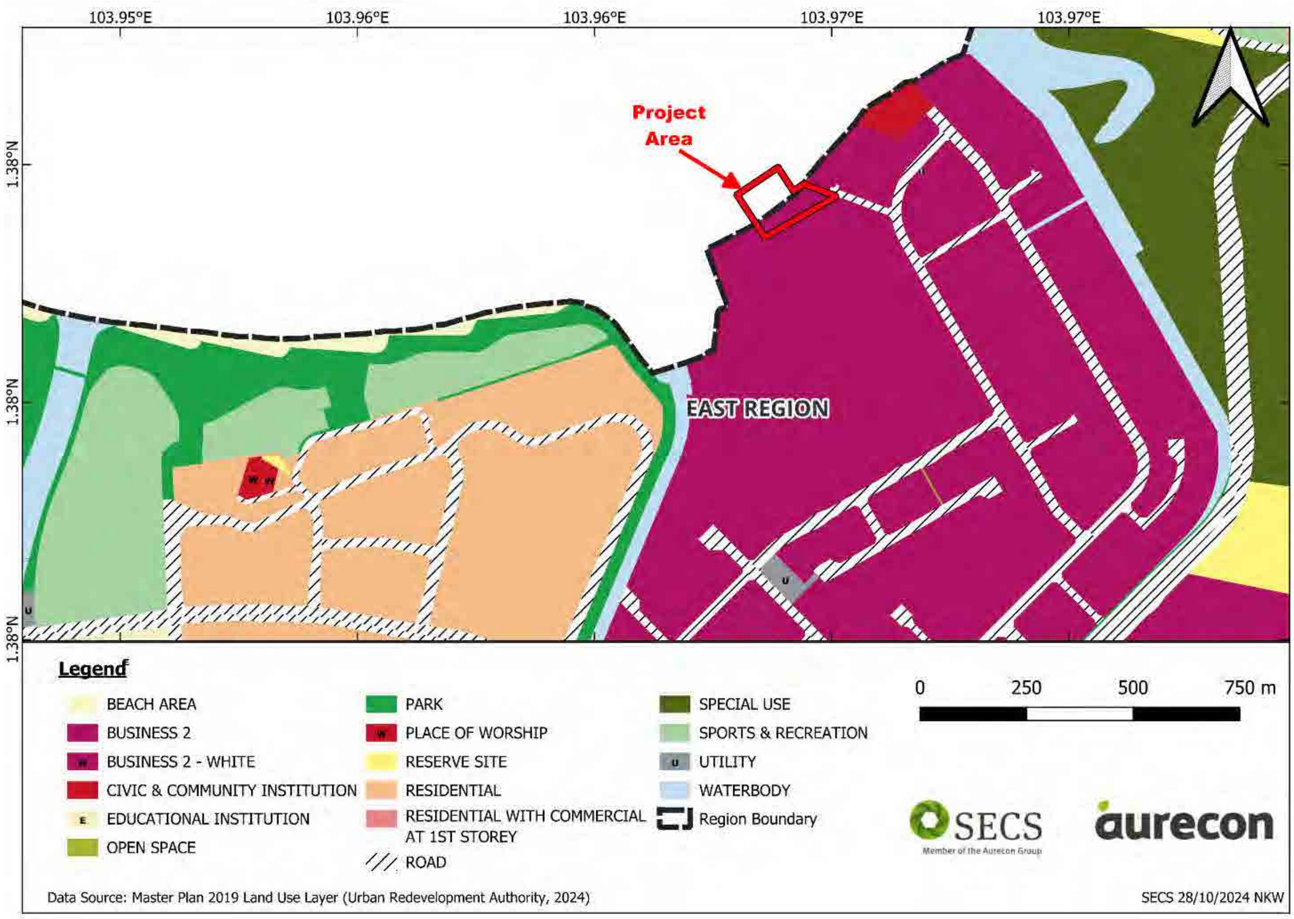



**Figure 7-1: Location of the Floating Data Centre within URA Master Plan 2019**


**Figure 7-2: Adjacent facilities within the development footprint**

## 7.2 Climate and Meteorology

### 7.2.1 Climate

Singapore is located near the equator, at the confluence of two major tidally influenced water bodies: the South China Sea and the Indian Ocean. These bodies converge in the Malacca and Singapore Straits. The country experiences a tropical climate, characterized by consistently high temperatures, abundant rainfall, and elevated humidity throughout the year.

Precipitation patterns are significantly influenced by the Asian monsoon, which features two distinct monsoons separated by inter-monsoon seasons occurring during the following periods (NEA, 2016):

- March - May (Inter-monsoon): During this time, elevated temperatures lead to hot weather, occasionally interrupted by intense afternoon thunderstorms.
- June - September (Southwest Monsoon): This period is marked by a change in wind patterns from the south and southeast, along with occasional Sumatra squalls, resulting in high wind speeds of 40-80 km/h during early mornings to midday. Afternoon thunderstorms are also common.
- October - November (Inter-monsoon): Light and variable winds, along with afternoon thunderstorms, contribute to a greater number of rainfall events compared to the previous inter-monsoon period.
- December - April (Northeast Monsoon): Characterized by monsoon surges, this period sees moderate to heavy rainfall and strong northeasterly winds of 25-35 km/hour. The latter part of this season typically experiences sustained winds and reduced rainfall.

The monsoonal dynamics lead to inflows in the Singapore Strait from the South China Sea during the Northeast Monsoon (resulting in a net westerly flow) and from the Java Sea and Malacca Strait during the Southwest Monsoon.

### 7.2.2 Meteorological

This section provides an overview of the key climatic factors (wind, rainfall, temperature, and humidity) in Singapore. Singapore's climate is primarily influenced by its equatorial position, with prevailing winds shaped by the Northeast and Southwest Monsoons, as well as consistent rainfall and stable temperatures year-round. The data presented in the following sections is derived from long-term climate records (1991-2020) and more recent observations from Changi and Pasir Ris weather stations in 2023.

Overall, Singapore's tropical climate is characterized by consistent temperatures, high humidity, and significant rainfall throughout the year, with minimal seasonal temperature variations. The prevailing winds from the Northeast and Southwest Monsoons, along with frequent thunderstorms, play a crucial role in shaping local wind conditions. Rainfall is plentiful, with December experiencing the highest levels, while February is the driest month. The sea's moderating influence and natural weather phenomena such as sea breezes, monsoon surges, and Sumatra squalls also contribute to the local climate. The weather patterns observed in 2023 at Pasir Ris and Changi weather stations confirm these general trends, demonstrating Singapore's predictable yet dynamic tropical environment.

#### 7.2.2.1 Wind

In Singapore, prevailing winds mainly originate from the northeast and the south, reflecting the influence of the region's dominant monsoons. Typically, daily wind patterns follow the prevailing monsoon flow, although they can be affected by local terrain and weather events such as showers, thunderstorms, or land and sea breezes. During the Northeast Monsoon season, from December to March, winds predominantly come from the northerly to northeasterly directions. In contrast, the Southwest Monsoon, occurring from June to September, generally brings winds from the southeasterly to southerly directions.

Wind data collected from Changi Weather Station in 2023 shows that average wind speeds reached up to 12.97 km/h in September. For a more comprehensive view, data from Changi Climate Station between 1991 and 2020 indicates that winds are generally light, with an average surface wind speed of approximately 2 m/s.

Stronger winds are observed during the Northeast Monsoon, particularly in January and February, when monsoon surges can increase mean wind speeds to 10 m/s or higher. Thunderstorms also contribute to stronger winds, with surface gusts often triggered by downdrafts or the passage of Sumatra squalls, which can produce gusts of up to 80 km/h.

#### 7.2.2.2 Rainfall

Singapore experiences no distinct wet or dry seasons, but there are noticeable monthly variations in rainfall. The wettest period typically occurs from November to January during the wet phase of the Northeast Monsoon, while February, the driest month, falls within the monsoon's dry phase, as the rain-belt shifts southward toward Java (NEA, 2016).

Rainfall is abundant in Singapore, with an average of 171 rainy days annually. The long-term average annual rainfall from 1991 to 2020 stands at 2,113.3 mm (NEA, 2016). In terms of spatial distribution, higher rainfall is generally recorded in the central and western regions of Singapore, gradually decreasing towards the eastern areas (Figure 7-3).

In addition, based on the climate data from 1991 to 2020 for northeastern Singapore (Figure 7-4), December exhibits higher rainfall levels.


**Figure 7-3: Annual average rainfall distribution (1991-2020)**

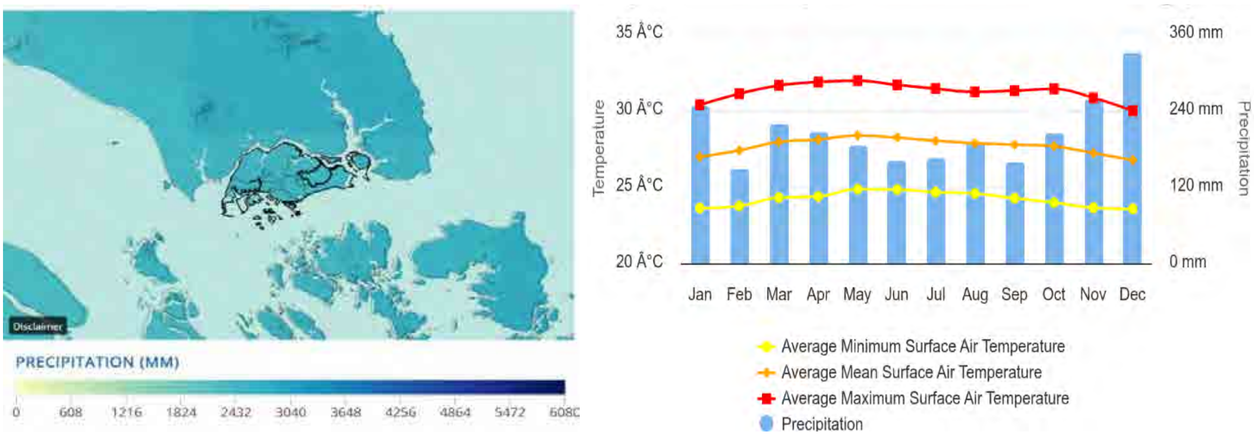



**Figure 7-4: Observed precipitation at Northeast Singapore from 1991 to 2020 (left) and monthly precipitation in 1991 to 2020 at Northeast Singapore (right)**

## 7.2.2.3 Temperature and Humidity

Temperatures in Singapore show little variation throughout the year compared to temperate regions, with daily lows generally between 23-25°C at night and highs of 31-33°C during the day. May tends to be the warmest month, with an average temperature of 28.6ºC, while December and January are the coolest, with a 24-hour mean of 26.8°C. As an island, Singapore experiences a coastal climate, with the nearby sea having a moderating effect on temperatures due to its higher heat capacity compared to land. This effect, along with sea breezes during the afternoon, helps alleviate the tropical heat. Wind, rainfall, and cloud cover are also key natural factors that reduce heat intensity.

The long-term average daily temperature from 1991 to 2010 was around 27.5°C, with a maximum of 31.5°C and a minimum of 24.7°C. The average annual rainfall during this period was approximately 2,166 mm (Figure 7-5). The 1981 – 2010 long-term average daily temperature was about 27.5°C, with an average daily maximum of about 31.5°C and an average daily minimum of about 24.7°C. While, for 2023, temperature data collected from the Changi Weather Station shows average monthly temperatures ranging from 26.54ºC to 29.45ºC.

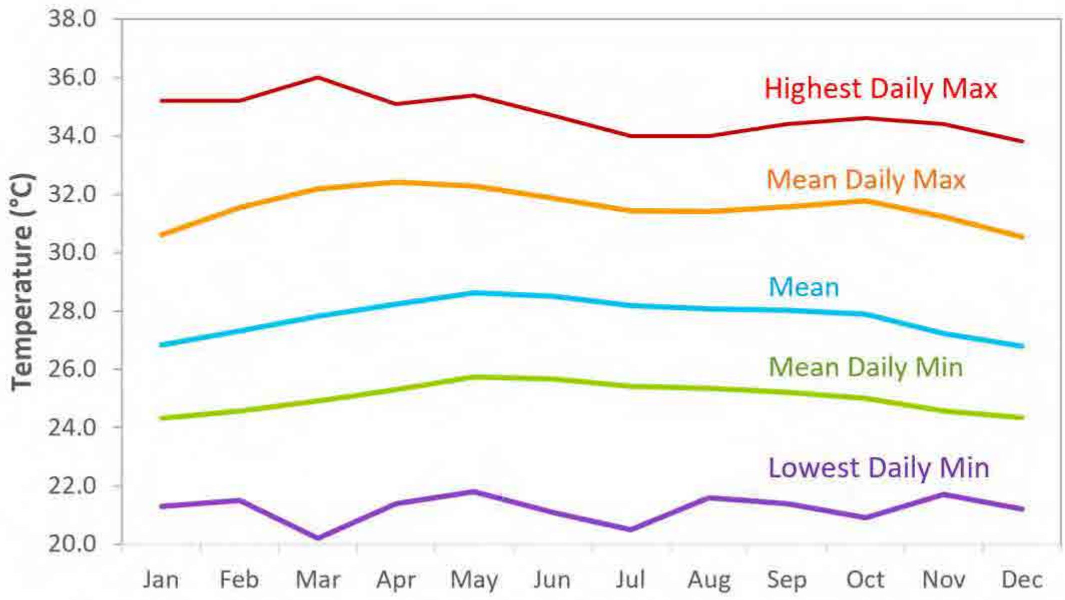



**Figure 7-5: Mean monthly temperature variation (ºC) (1991-2020)**

## 7.3 Coastal Hydraulic

### 7.3.1 Bathymetry

A bathymetric survey of the project area was provided by the client to enhance the understanding of the site. Table 7-4 illustrates the surveyed seabed depths, which range from -1.2 mCD to -10.5 mCD. The deepest areas were located near the jetties, while the shallowest sections were found along the coastline. Overall, the depth within the Project boundary can be classified as shallow, with an average seabed depth varying between -3.3 mCD and -7.7 mCD.

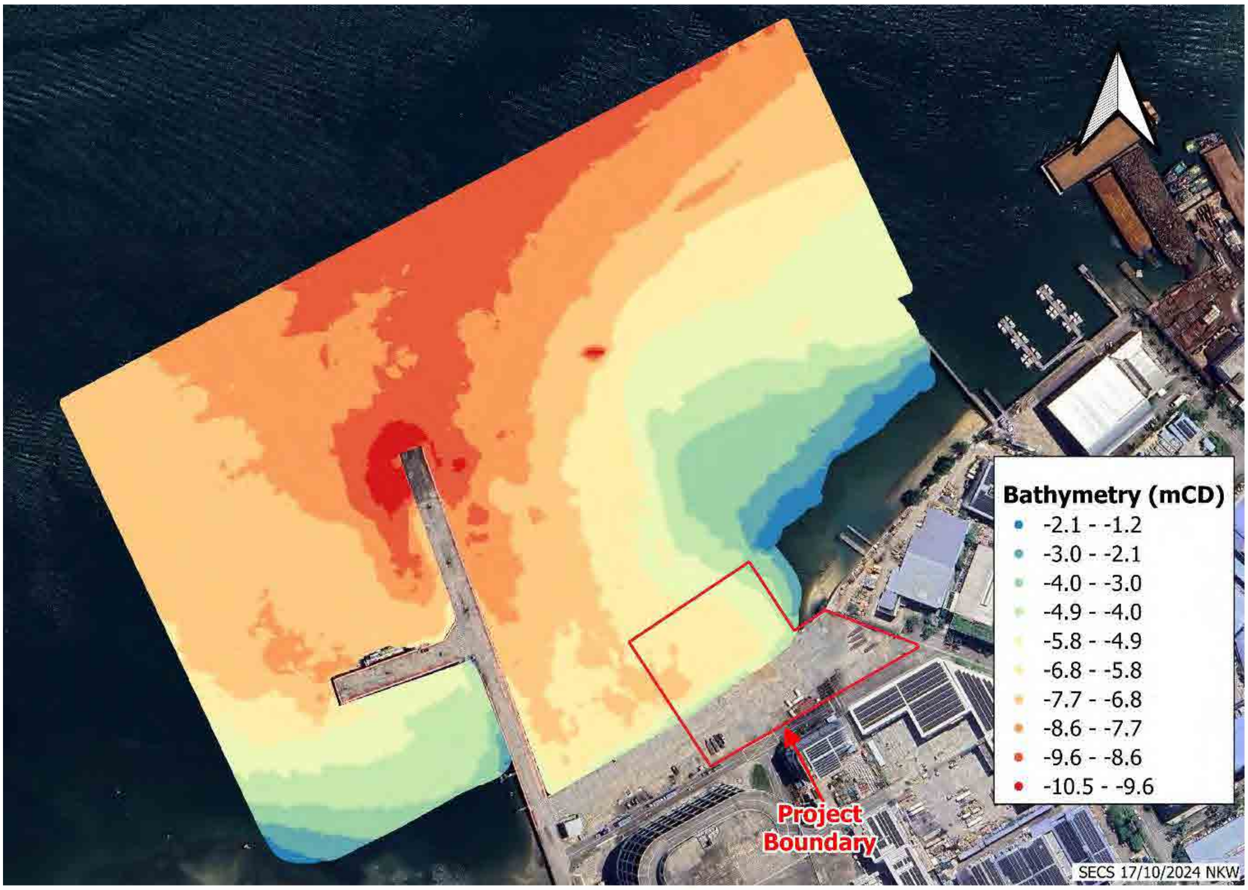



**Figure 7-6: Bathymetry around project site**

### 7.3.2 Current

The hydraulic conditions at the Project site across three seasonal periods, namely Southwest Monsoon, Northeast Monsoon, and Inter-monsoon were studied in this EIA report. Figure 7-7, Figure 7-8, and Figure 7-9 illustrate the depth-averaged current speeds at peak flood and ebb tides for each respective monsoon condition.

During ebb tide, currents flow from Serangoon Harbour toward the Kuala Johor Channel, while during flood tide, the flow reverses into Serangoon Harbour from Kuala Johor Channel.

Currents within the Project area, situated in a sheltered nearshore zone, were observed to be weaker compared to those in the main Serangoon Harbour channel. At peak ebb tide during the Northeast Monsoon, Southwest Monsoon, and Inter-monsoon, the current speeds within the Project footprint range from 0.03 m/s to 0.15 m/s, 0.03 m/s to 0.15 m/s, and 0.04 m/s to 0.17 m/s, respectively, with an eastward flow. Conversely, during peak flood tide in the Northeast Monsoon, Southwest Monsoon, and Inter-monsoon, the current speeds within the Project footprint range from 0.01 m/s to 0.09 m/s, 0.01 m/s to 0.08 m/s, and 0.01 m/s to 0.06 m/s, respectively, with a westward flow.

The sheltered nature and nearshore location of the Project area contribute to generally lower current strengths within the footprint. The currents were primarily influenced by the site's profile and prevailing wind conditions. This flow regime, which varies subtly with monsoon and tidal conditions, was anticipated to affect sediment transport and other hydrodynamic processes in the vicinity of the Project area.

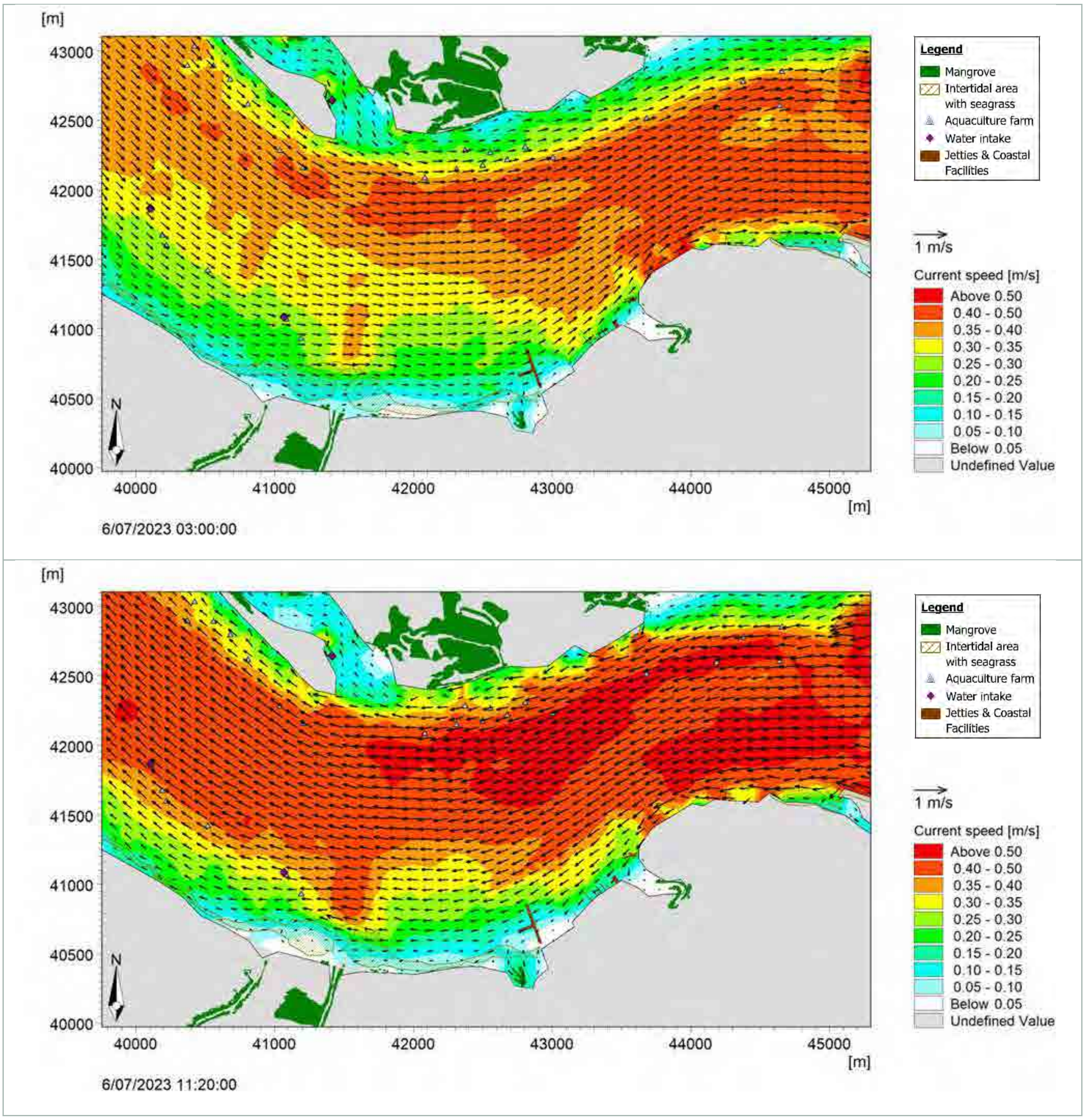



**Figure 7-7: Depth averaged current speed at peak ebb (top) and flood (bottom) during Southwest Monsoon**

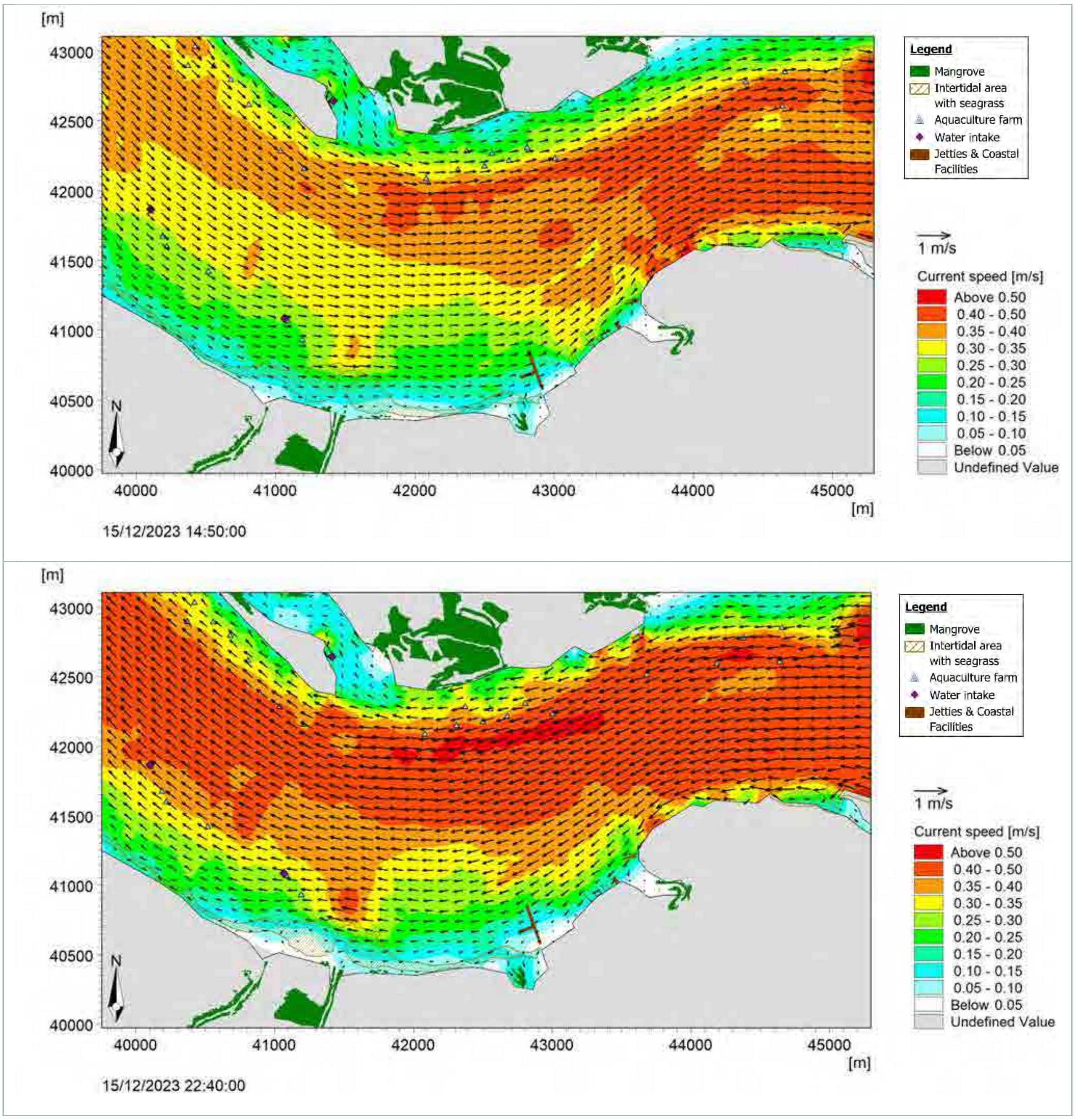



**Figure 7-8: Depth averaged current speed at peak ebb (top) and flood (bottom) during Northeast Monsoon**

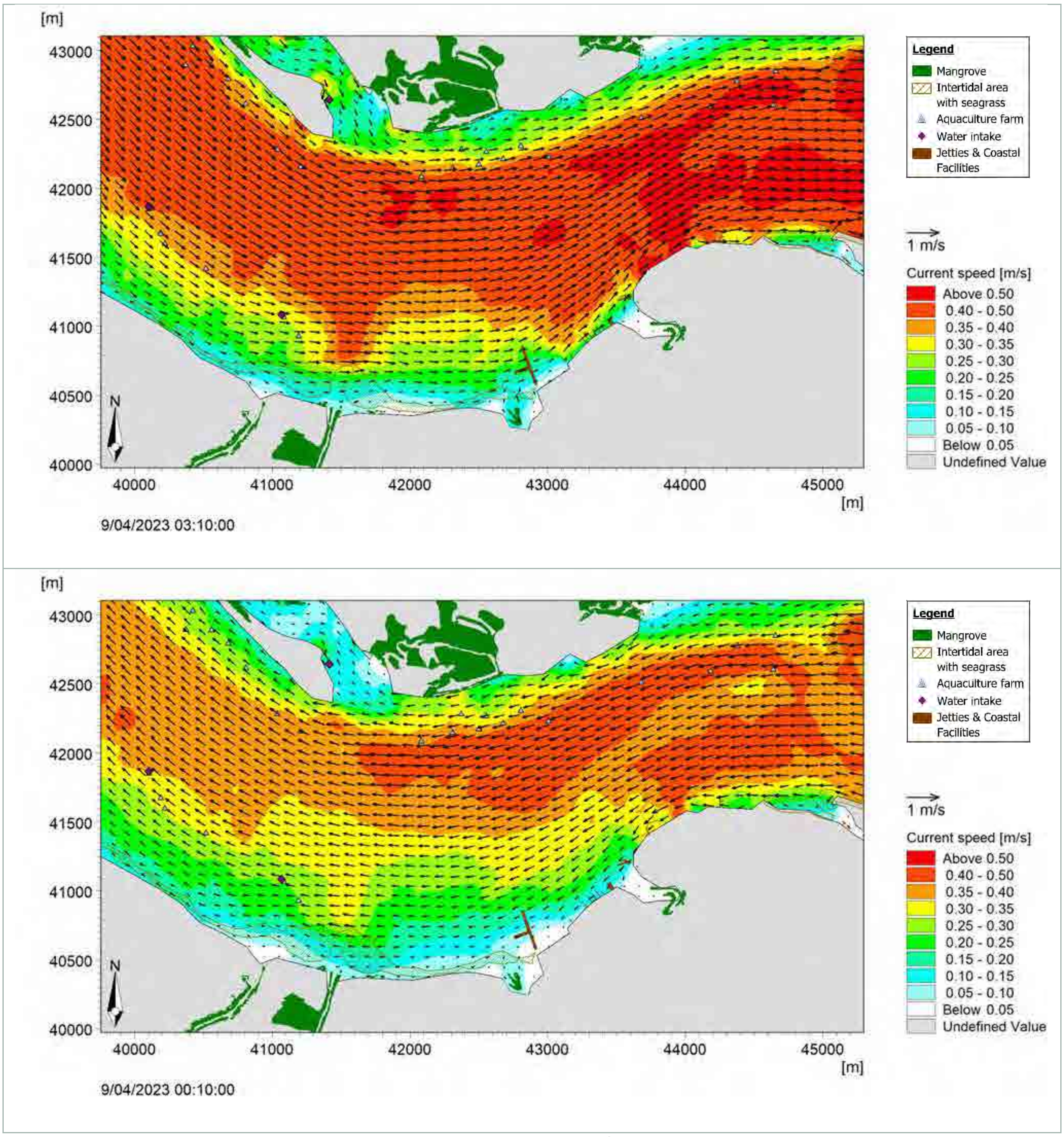



**Figure 7-9: Depth averaged current speed at peak ebb (top) and flood (bottom) during Inter-monsoon**

## 7.4 Ambient Air Quality

### 7.4.1 Baseline Ambient air

An ambient air quality monitoring station has been proposed and implemented, as detailed in Table 7-1 and illustrated in Figure 7-10. The air quality monitoring station, AQ01, was deployed at the Project site for at least seven (7) days, from 25 Sep 2024 to 1 Oct 2024. A photograph of the monitoring station is provided in Figure 7-11.

**Table 7-1: Description of ambient air quality monitoring station**

| Station | Description | Coordinates | | Justification |
|---|---|---|---|---|
| | | Latitude | Longitude | |
| AQ01 | Project site | 1° 23.023' | 103° 58.142' | Establish baseline air quality conditions for the project site. |

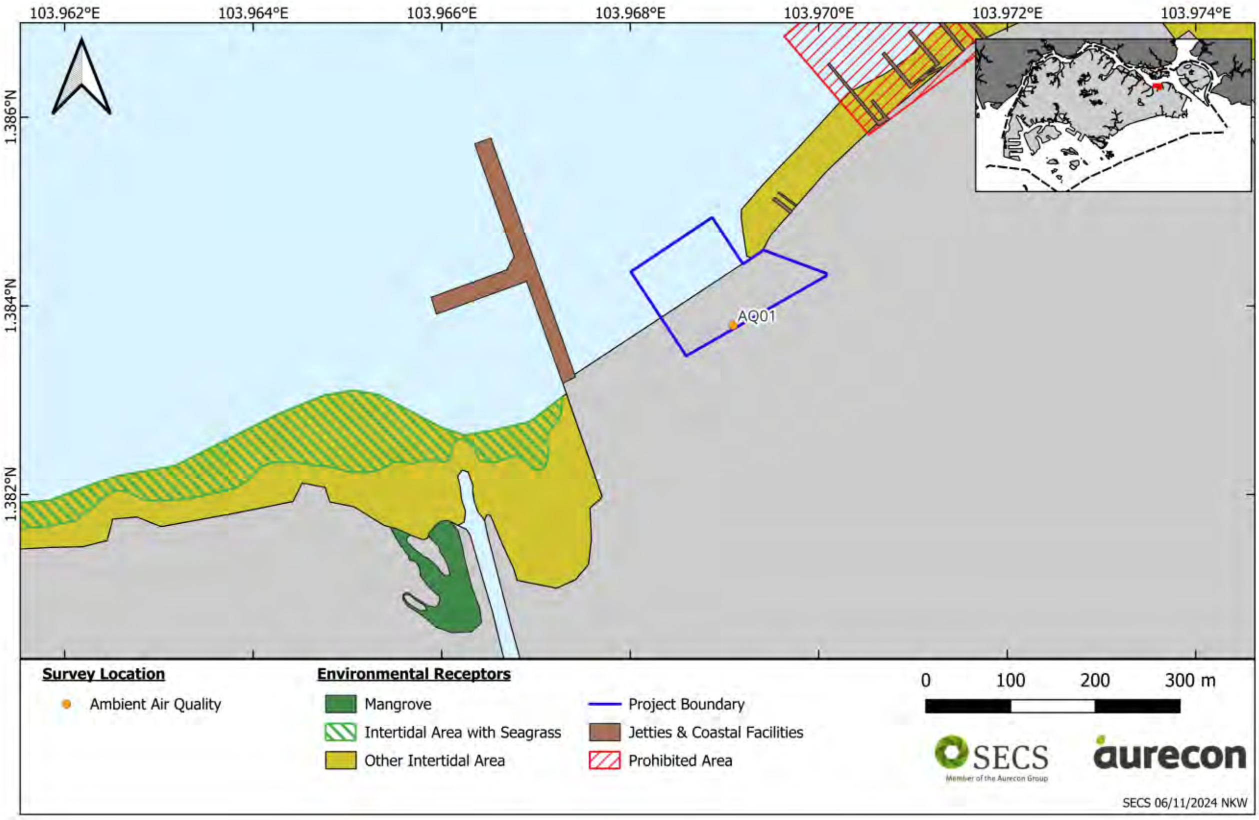



**Figure 7-10: Ambient air quality measurement location**


**Figure 7-11: Ambient air quality monitoring station photo at AQ01**

The monitoring program focused on key air quality indicators, including sulphur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), carbon monoxide (CO), ozone ($O_3$), and particulate matter ($PM_{2.5}$ and $PM_{10}$). The results are presented in Table 7-2 and have been compared against Singapore's long-term ambient air quality standards. All monitored pollutants were found to be within acceptable limits. For detailed results, refer to Appendix A.

**Table 7-2: Baseline ambient air quality results**

| Parameter | Unit | Baseline Result | Singapore's Ambient Air Quality Long Term Targets |
|---|---|---|---|
| Particulate Matter ($PM_{2.5}$) | µg/m$^3$ | 2.7 to 6.7 | 24-hour mean: 25 |
| Particulate Matter ($PM1_{10}$) | µg/m$^3$ | 7.5 to 16.7 | 24-hour mean: 50 |
| Sulphur Dioxide ($SO_2$) | µg/m$^3$ | 1.31 to 10.37 | 24-hour mean: 20 |
| Carbon Monoxide (CO) | µg/m$^3$ | 0.11 to 0.27 | 8-hour mean: 10 |
| | µg/m$^3$ | 0.20 to 0.36 | 1-hour mean: 30 |
| Nitrogen Dioxide ($NO_2$) | µg/m$^3$ | 20.52 to 36.51 | 1-hour mean 200 |
| Ozone ($O_3$) | µg/m$^3$ | 2.99 to 30.81 | 8-hour mean: 100 |

## 7.5 Air-Borne Noise Quality

### 7.5.1 Baseline noise

Two (2) noise level monitoring stations were deployed with the location shown in Table 7-3 and Figure 7-12. The noise meter, NM01 and NM02, were deployed at the Project site for at least seven (7) days, from 25 Sep 2024 to 2 Oct 2024. A photograph of the monitoring station is provided in Figure 7-13.

**Table 7-3: Description of ambient air quality monitoring station**

| Station | Description | Coordinates | | Justification |
|---|---|---|---|---|
| | | Latitude | Longitude | |
| NM01 | Project site | 1° 23.023' | 103° 58.142’ | Establish baseline noise quality conditions for the Project site. |
| NM02 | Vicinity of Fugro | 1° 23.070' | 103° 58.179’ | Establish noise quality conditions to the neighbouring stakeholder at the West from the Project |

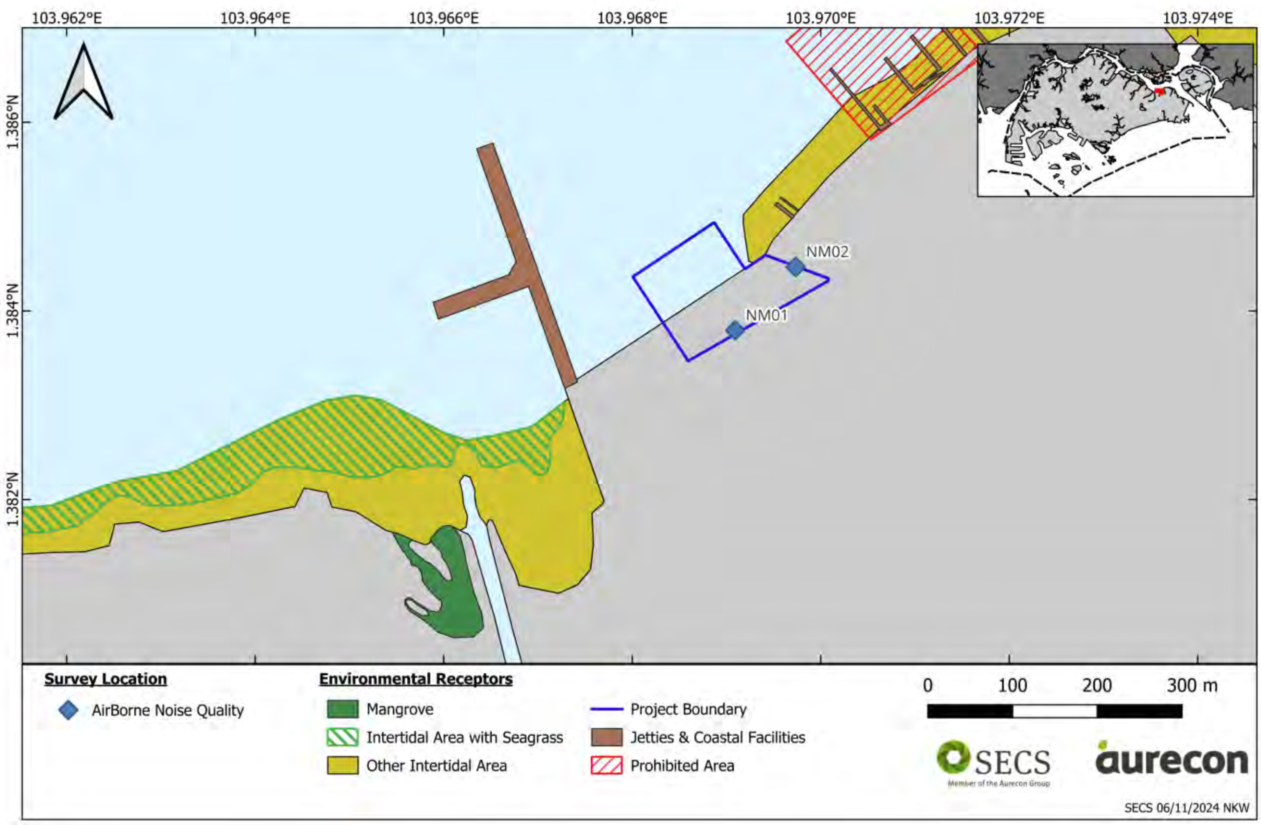



**Figure 7-12: Air-borne noise measurement stations**


**Figure 7-13: Noise quality monitoring station photo at NM01 (left) and NM02 (right)**

The sound level meter was calibrated prior to the monitoring, and the calibration certificate is attached in Appendix B. Monitoring was conducted using a data-logging sound level meter over a 24-hour period. Daytime readings were recorded from 7:00 AM to 7:00 PM, while nighttime readings were taken from 7:00 PM to 7:00 AM.

The following parameters were monitored

- $L_{Aeq,\ 5\ mins}$: It is the equivalent of contonours sound pressure lelve over a 5-minute measuremenet period
- $L_{Aeq,\ 12\ hours}$: It is the equivalent of contonours sound pressure lelve over a 12-hour measuremenet period

Results are presented in Table 7-4 and the results were compared to the permissible noise limits set by NEA under the Environmental Protection and Management (Control of Noise at Construction Sites) Regulations.

**Table 7-4: Summary of the noise level monitoring results**

| Date and Time | Station | Limits | | Baseline Results | |
|---|---|---|---|---|---|
| | | $L_{Aeq,\ 12hour}$ | $L_{Aeq,\ 5\ mins}$ | $L_{Aeq,\ 12hour}$ | $L_{Aeq,\ 5\ mins}$ |
| Day (7am to 7pm) | NM01 | 75 dBA | 90 dBA | 48.7 – 64.1 | 41.9 – 74.6 |
| | NM02 | | | 57.8 – 62.7 | 40.9 – 77.4 |
| Night (7pm to 7am) | NM01 | 65 dBA | 70 dBA | 43.1 – 55.1 | 39.9 – 74.8 |
| | NM02 | | | 53.7 – 62.8 | 38.90 – 67.4 |

Based on the measurements, the daytime noise levels at all stations were within permissible limits, except for nighttime readings at NM01, where the $L_{Aeq,\ 5\ mins}$ exceeded the limit. The exceedance at NM01 during nighttime at 4:00 AM for the $L_{Aeq,\ 5\ mins}$ can be attributed to several potential factors, including nighttime industrial activities or nearby vessel operations berthing at the Loyang Offshore Supply Base. Given the industrial nature of the surrounding area, intermittent activities could have contributed to short bursts of elevated noise levels. The exceedance likely resulted from a one-time or isolated event, and given its short duration, it may not accurately reflect the typical noise levels at this location. Full measurement details can be found in Appendix C.

## 7.6 Marine Water Quality

Marine water quality surveys were conducted on 3 Oct 2024 at four (4) survey locations as shown in Figure 7-14 with coordinates shown in Table 7-5. WQ01 was located directly within the Project boundary close to Loyang Offshore Supply Base, while WQ02 was positioned adjacent to it. WQ03 and WQ04 were situated along the Pasir Ris Park, providing broader spatial coverage to assess potential influences from the Project on the surrounding marine environment.

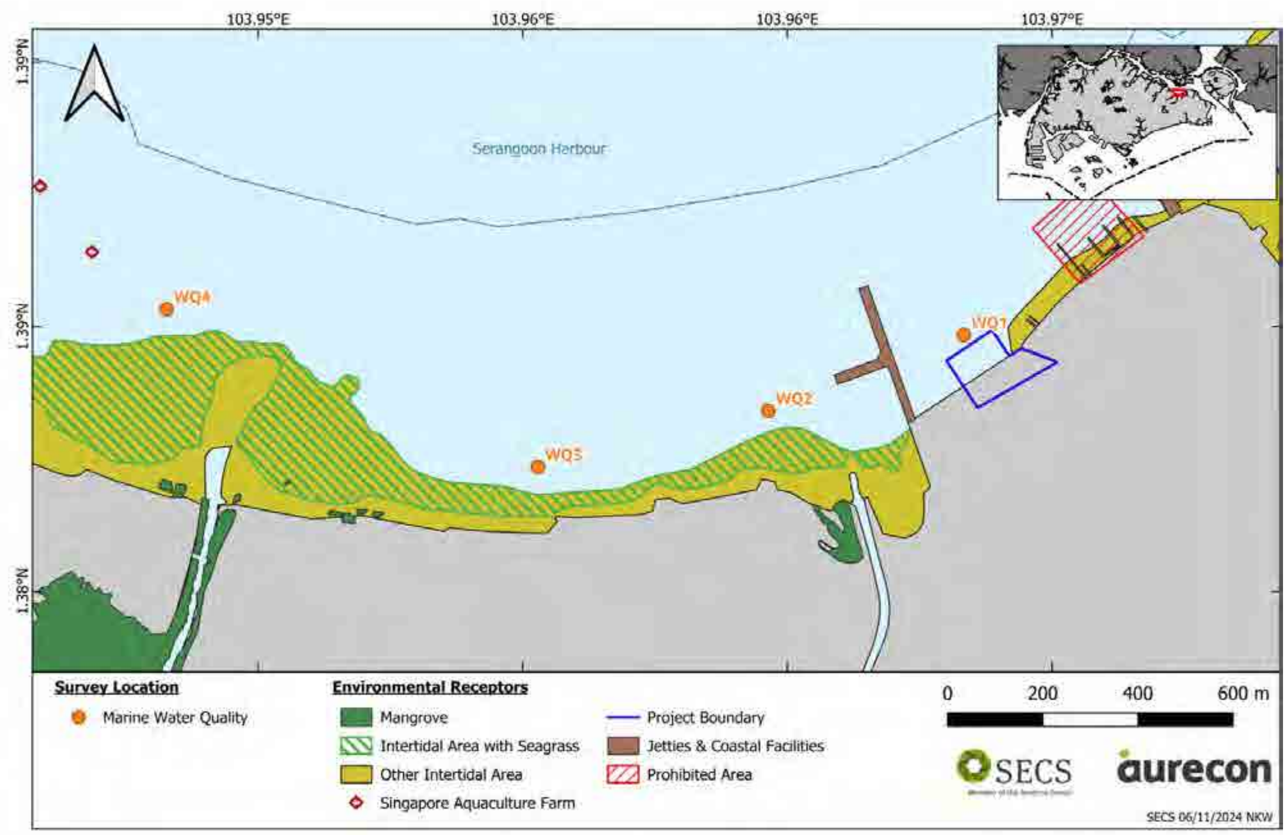



Figure 7-14: Marine water quality survey stations

Table 7-5: Water quality survey stations coordinates

| Station ID | Coordinates | | Location | Survey Date |
|---|---|---|---|---|
| | Latitude (N) | Longitude (E) | | |
| WQ01 | 1.384848° | 103.968333° | Loyang Shore Front | 3 Oct 2024 |
| WQ02 | 1.383413° | 103.964638° | Pasir Ris Beach Front | |
| WQ03 | 1.382353° | 103.960287° | | |
| WQ04 | 1.385331° | 103.953270° | | |

The marine water quality surveys were carried out during spring flood and ebb tides. The surveys include water samples collection for laboratory analysis (ex-situ) and in-situ measurements. The in-situ and ex-situ assessments aim to evaluate the baseline conditions of the marine environment prior to the development of the Project.

### 7.6.1 Compliance Criteria

The compliance assessment of the water quality monitoring program, for both in-situ and ex-situ measurements, is reported based on the guidelines or criteria listed in Table 7-7 and Table 7-11. The guidelines referenced include:

- Association of Southeast Asian Nations Region Marine Water Quality Criteria (ASEAN MWQC, 2008)
- National Environment Agency, 2008 (NEA, 2008)
- Australian and New Zealand guidelines for fresh and marine water quality (ANZECC, 2000)

**Table 7-6: In-situ water quality criteria**

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

**Note:**

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

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

| Parameters | Unit | Water Quality Criteria | | Detection Limit | Sampling Depth |
|---|---|---|---|---|---|
| | | ASEAN MWQC | ANZECC (1) | | |
| Total Suspended Solids, TSS | mg/L | <10% increase over seasonal average | N.A. | 1 | Surface & Mid depth |
| Total Nitrogen, TN | mg/L | N.A. | 0.1 | 0.01 | Surface & Mid depth |
| Total Phosphorus, TP | mg/L | N.A. | 0.015 | 0.01 | Surface & Mid depth |
| Ammonia as NH3-N | mg/L | 0.07 | N.A. | 0.01 | Surface & Mid depth |
| Nitrate as NO3-N | mg/L | 0.06 | N.A. | 0.01 | Surface & Mid depth |
| Phosphate as PO4-P | mg/L | 0.015 | N.A. | 0.01 | Surface & Mid depth |
| Oil & Grease | mg/L | 0.14 | N.A. | 1 | Surface & Mid depth |
| Chlorophyll-a | µg/L | N.A. | 0.7-1.4 | 1 | Surface & Mid depth |
| Arsenic as As | µg/L | 120 | N.A. | 0.1 | Surface & Mid depth |

| Parameters | Unit | Water Quality Criteria | | Detection Limit | Sampling Depth |
|---|---|---|---|---|---|
| | | ASEAN MWQC | ANZECC (1) | | |
| Aluminum as Al | µg/L | N.A. | N.A. | 0.1 | Surface & Mid depth |
| Cadmium as Cd | µg/L | 10 | N.A. | 0.1 | Surface & Mid depth |
| Chromium as Cr | µg/L | 50 | N.A. | 0.1 | Surface & Mid depth |
| Copper as Cu | µg/L | 8 | N.A. | 0.5 | Surface & Mid depth |
| Mercury as Hg | µg/L | 0.16 | N.A. | 0.05 | Surface & Mid depth |
| Nickel as Ni | µg/L | N.A. | 70 | 0.5 | Surface & Mid depth |
| Lead as Pb | µg/L | 8.5 | N.A. | 0.1 | Surface & Mid depth |
| Zinc as Zn | µg/L | N.A. | 15 | 0.5 | Surface & Mid depth |
| Biochemical Oxygen Demand, $BOD_5$ | mg/L | N.A. | N.A. | 1 | Surface & Mid depth |
| Faecal Coliform | MPN/100mL | 100 | 150 | 1.8 | Surface & Mid depth |
| Enterococcus | cfu/ 100mL | 35 | 35 | 1 | Surface & Mid depth |
| Escherichia coli (*E. Coli*) | MPN/100mL | N.A. | N.A. | 1.8 | Surface & Mid depth |
| Phytoplankton (Total) | cell/mL | N.A. | N.A. | 1 | Surface |
| Zooplankton (Total) | org/m3 | N.A. | N.A. | 1 | Water profile |

**Note:**

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

### 7.6.2 In-situ and Ex-situ Marine Water Quality Assessment

As part of the EIA, both in-situ and ex-situ water quality surveys were conducted to evaluate baseline conditions.

For the in-situ water quality surveys, temperature, salinity, turbidity, pH, and dissolved oxygen (DO) were measured at 1-meter intervals throughout the water column, using a calibrated multiparameter Sonde (In-situ AT-500). Measurements were collected during both flood and ebb tides at four (4) survey stations. Detailed in-situ results are provided in Appendix D.

Concurrently, ex-situ surveys were conducted, involving the collection of water samples during both flood and ebb tides at surface, mid-depth, or throughout the entire water column. The detailed laboratory results are presented in Appendix E. Table 7-8 and Table 7-9 summarize the in-situ and ex-situ water quality results, respectively.

**Table 7-8: Summary of in-situ water quality results**

| Parameter | Unit | Compliance Criteria | WQ01 | WQ02 | WQ03 | WQ04 | WQ01 | WQ02 | WQ03 | WQ04 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Flood | | | | Ebb | | | |
| Turbidity | NTU | ANZECC: < 20 NTU | 6.10 | 9.61 | 10.51 | 4.78 | 7.65 | 6.73 | 5.50 | 4.14 |
| Secchi | m | ≥1.2m (recreational waters)<br>≥0.5m (non-recreational waters) | 1.1 | 1.4 | 1 | 1.4 | 1.3 | 1.3 | 1.1 | 1.2 |

| Parameter | Unit | Compliance Criteria | WQ01 | WQ02 | WQ03 | WQ04 | WQ01 | WQ02 | WQ03 | WQ04 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Flood | | | | Ebb | | | |
| Temperature | °C | ASEAN MWQC: ≤ 2°C above the maximum ambient temperature | 30.65 | 30.68 | 30.63 | 30.71 | 30.57 | 30.59 | 30.39 | 30.44 |
| Salinity | ppt | ANZECC: 8.5 | 26.93 | 27.04 | 27.10 | 26.80 | 27.48 | 26.74 | 27.07 | 26.91 |
| pH | - | N.A. | 7.90 | 7.90 | 7.92 | 7.94 | 7.91 | 7.98 | 7.88 | 7.89 |
| Dissolved oxygen | mg/L | ASEAN MWQC: > 4 mg/L | 5.71 | 5.82 | 5.37 | 6.03 | 5.47 | 6.37 | 6.26 | 6.27 |

**Table 7-9: Summary of ex-situ water quality results**

| Parameter | Unit | Compliance Criteria | | MDL | WQ01 | WQ02 | WQ03 | WQ04 | WQ01 | WQ02 | WQ03 | WQ04 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Surface | | | | Mid-depth | | | |
| | | ASEAN MWQC | ANZECC | | | | | | | | | |
| **Flood** | | | | | | | | | | | | |
| Total suspended solid | mg/L | <10% increase over seasonal average | N.A. | 1 | 9.5 | 5.9 | 8.15 | 5 | 13.5 | 9.1 | 7.2 | 4.3 |
| Total Nitrogen, TN | mg/L | N.A. | 0.1 | 0.01 | 0.44 | 0.4 | 0.43 | 0.37 | 0.42 | 0.48 | 0.39 | 0.39 |
| Total Phosphorus, TP | mg/L | N.A. | 0.015 | 0.01 | 0.068 | 0.07 | 0.083 | 0.061 | 0.071 | 0.056 | 0.059 | 0.066 |
| Ammonia as NH3-N | mg/L | 0.07 | N.A. | 0.01 | 0.019 | 0.011 | 0.023 | 0.039 | 0.045 | 0.032 | 0.045 | 0.048 |
| Nitrate as NO3-N | mg/L | 0.06 | N.A. | 0.01 | 0.073 | 0.05 | 0.064 | 0.065 | 0.064 | 0.053 | 0.066 | 0.064 |
| Phosphate as PO4-P | mg/L | 0.015 | N.A. | 0.01 | ND | 0.029 | 0.012 | 0.012 | 0.016 | 0.01 | 0.016 | 0.016 |
| Oil and grease | mg/L | 0.14 | N.A. | 1 | ND | ND | ND | ND | ND | ND | ND | ND |
| Biochemical Oxygen Demand ($BOD_5$) | mg/L | N.A. | N.A. | 1 | ND | ND | ND | ND | ND | ND | ND | ND |
| Arsenic as As | mg/L | 120 | N.A. | 0.1 | 19.2 | 12.3 | 32.2 | 30.8 | 16.1 | 65.2 | 35.6 | 63.3 |
| Aluminium as Al | µg/L | N.A. | N.A. | 0.1 | 2.77 | 2.75 | 2.83 | 2.99 | 3.04 | 2.98 | 3.21 | 2.66 |
| Cadmium as Cd | µg/L | 10 | N.A. | 0.1 | ND | ND | ND | ND | ND | ND | ND | ND |
| Chromium as Cr | µg/L | 50 | N.A. | 0.1 | 1.1 | 0.86 | 0.92 | 0.9 | 2.2 | 1.01 | 1.14 | 0.88 |
| Copper as Cu | µg/L | 8 | N.A. | 0.5 | 3.42 | 2.86 | 2.2 | 2.25 | 2.26 | 3.39 | 2.88 | 2.05 |
| Mercury as Hg | µg/L | 0.16 | N.A. | 0.05 | ND | ND | ND | ND | ND | ND | ND | ND |
| Nickel as Ni | µg/L | N.A. | 70 | 0.5 | 1.28 | 1.19 | 1.25 | 1.12 | 2.1 | 1.51 | 1.37 | 1.03 |
| Lead as Pb | µg/L | 8.5 | N.A. | 0.1 | 1.07 | 0.18 | 0.16 | 0.11 | 0.46 | 0.33 | 0.15 | 0.14 |
| Zinc as Zn | µg/L | N.A. | 15 | 0.5 | 7.09 | 1.54 | 2.56 | 1.13 | 1.44 | 6.62 | 1.76 | 2.46 |
| Faecal Coliform | MPN/100mL | 100 | 150 | 1.8 | 22 | 6.8 | 1.8 | ND | 4.5 | 6.8 | ND | 4.5 |
| Enterococcus | cfu/ 100mL | 35 | N.A. | 1 | ND | ND | ND | ND | ND | 2 | 3 | ND |
| E. *Coli* | MPN/100mL | N.A. | N.A. | 1.8 | 2 | ND | ND | ND | ND | ND | ND | ND |

| Parameter | Unit | Compliance Criteria | | MDL | WQ01 | WQ02 | WQ03 | WQ04 | WQ01 | WQ02 | WQ03 | WQ04 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ASEAN MWQC | ANZECC | | Surface | | | | Mid-depth | | | |
| **Ebb** | | | | | | | | | | | | |
| Total suspended solid | mg/L | <10% increase over seasonal average | N.A. | 1 | 12.1 | 1.8 | 7.1 | 24.3 | 9.8 | 5.8 | 6.4 | 36.8 |
| Total Nitrogen, TN | mg/L | N.A. | 0.1 | 0.01 | 0.34 | 0.39 | 0.37 | 0.37 | 0.51 | 0.48 | 0.44 | 0.38 |
| Total Phosphorus, TP | mg/L | N.A. | 0.015 | 0.01 | 0.06 | 0.056 | 0.051 | 0.063 | 0.048 | 0.054 | 0.072 | 0.069 |
| Ammonia as NH3-N | mg/L | 0.07 | N.A. | 0.01 | 0.036 | 0.038 | 0.02 | 0.045 | 0.042 | 0.043 | 0.054 | 0.035 |
| Nitrate as NO3-N | mg/L | 0.06 | N.A. | 0.01 | 0.06 | 0.051 | 0.048 | 0.077 | 0.058 | 0.057 | 0.06 | 0.055 |
| Phosphate as PO4-P | mg/L | 0.015 | N.A. | 0.01 | ND | 0.011 | ND | 0.015 | 0.012 | 0.013 | 0.017 | 0.011 |
| Oil and grease | mg/L | 0.14 | N.A. | 1 | 1.03 | ND | ND | ND | ND | ND | ND | ND |
| Biochemical Oxygen Demand ($BOD_5$) | mg/L | N.A. | N.A. | 1 | 3.35 | 9.24 | 13 | 7.83 | 3.34 | 7.01 | 5.76 | 4.94 |
| Arsenic as As | mg/L | 120 | N.A. | 0.1 | 49.2 | 39.5 | 13.5 | 98.9 | 36.5 | 29.4 | 40.2 | 26.1 |
| Aluminium as Al | μg/L | N.A. | N.A. | 0.1 | 2.82 | 2.82 | 3.14 | 2.74 | 2.76 | 2.67 | 2.97 | 2.86 |
| Cadmium as Cd | μg/L | 10 | N.A. | 0.1 | ND | ND | 0.11 | ND | ND | ND | ND | ND |
| Chromium as Cr | μg/L | 50 | N.A. | 0.1 | 0.93 | 0.9 | 0.92 | 1.13 | 0.9 | 0.89 | 1.54 | 1.54 |
| Copper as Cu | μg/L | 8 | N.A. | 0.5 | 3.14 | 2.32 | 2.56 | 2.13 | 3.34 | 2.18 | 2.2 | 2.08 |
| Mercury as Hg | μg/L | 0.16 | N.A. | 0.05 | ND | ND | ND | ND | ND | ND | ND | ND |
| Nickel as Ni | μg/L | N.A. | 70 | 0.5 | 0.94 | 1.03 | 1.12 | 1.49 | 1.13 | 1.1 | 1.38 | 1.62 |
| Faecal Coliform | MPN/100mL | 100 | 150 | 1.8 | 4 | 2 | ND | ND | 49 | 2 | 2 | 2 |
| Enterococcus | cfu/ 100mL | 35 | N.A. | 1 | ND | 2 | 2 | ND | 12 | 4 | 3 | ND |
| E. *Coli* | MPN/100mL | N.A. | N.A. | 1.8 | ND | ND | ND | ND | 2 | ND | ND | ND |

The data obtained from both in-situ and ex-situ surveys were categorized into three key groups: physical, chemical, and biological characteristics, as illustrated in Figure 7-15.

| Physical | Chemical | Biological |
|---|---|---|
| • Turbidity<br>• Total suspended solid<br>• Secchi disc depth<br>• Temperature<br>• Salinity | • pH<br>• Dissolved oxygen<br>• Nutrients<br>• Oil and grease<br>• Biochemical Oxygen Demand ($BOD_5$)<br>• Dissolved heavy metals | • Chlorophyll-a<br>• Microbial contaminants<br>• Plankton (phytoplankton and zooplankton) (1) |

**Figure 7-15: Categorization of water quality parameters by characteristics**

Note:

(1) The assessment for plankton is covered under the marine biodiversity section, as discussed in Section 7.8.4.

### 7.6.2.1 Physical

The physical parameters include temperature, salinity, turbidity, total suspended solids (TSS), and Secchi disc depth. Further details on each parameter are provided in the sections below.

***Turbidity***

The mean turbidity readings ranged from 4.14 NTU to 10.51 NTU regardless of tides. There was 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.

***Total Suspended Solid***

The highest recorded TSS concentration of 36.8 mg/L was observed at WQ04 during ebb tide at mid-depth. The associated turbidity readings indicated that the observed TSS levels remained within permissible limits, posing no significant concerns for water quality. These findings confirm that the TSS levels did not represent a risk to the marine environment.

***Secchi Depth***

Secchi depth readings were influenced by the presence of suspended or dissolved materials in the water. The recommended target depths by NEA were >0.5 m for non-recreational waters and >1.2 m for recreational waters. The Secchi disc readings met the NEA's target depth of 0.5 m for non-recreational waters at all monitoring stations. However, the readings did not achieve the 1.2 m target for recreational waters at WQ02 (ebb), WQ01 (flood), and WQ03 (flood). On the day of the survey, weather conditions were unstable, with alternating periods of sun, high cloud cover, and light rain. Cloud cover reduces light penetration, which limits visibility in the water and may result in lower Secchi depth readings at some stations. Although the Secchi depth measurements for recreational waters did not meet the recommended target, the turbidity levels remained within the limits.

***Temperature***

Temperature readings during the in-situ baseline survey were relatively stable across the depth profile at both flood and ebb tides. The water temperature profile of the water quality stations ranges from 30.39°C to 30.71°C across stations and tides.

***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 – 32 ppt (Din et. al., 1996) and Behera et. al.

(2013) observing salinities of up to 34.5 ppt. During the in-situ survey, salinity readings ranged from 26.74 ppt to 27.48 ppt, which was slightly below the typical lower limit, likely due to rainfall which lowers the salinity by introducing freshwater. However, the salinity levels did not exceed the upper limit of 34.5 ppt.

#### 7.6.2.2 Chemical

Chemical parameters encompass pH, dissolved oxygen (DO), nutrients (total nitrogen, total phosphorus, nitrate, phosphate, ammonia), oil and grease (O&G), biochemical oxygen demand ($BOD_5$), and dissolved heavy metals. Details on each parameter are provided in the sections below.

***pH***

pH readings during the in-situ baseline survey were relatively uniform across the depth profile at both flood and ebb tides. The mean pH readings ranged from 7.88 to 7.98. There was no ASEAN MWQC for pH. However, in comparison to the ANZECC guideline criterion of 8.50, the mean pH values across all monitoring stations were below the ANZECC threshold.

***Dissolved Oxygen***

Dissolved Oxygen (DO) concentrations are a key indicator of water's ecological health, maintained by physical processes like wind-driven surface agitation, tidal exchange, and biological activities such as photosynthesis from aquatic flora (e.g., algae, seagrass, and phytoplankton). During both flood and ebb tides, the mean DO levels ranged from 5.47 mg/L to 6.37 mg/L, exceeding the ASEAN MWQC threshold of ≥ 4.00 mg/L. This indicates that the water within the project area is generally well oxygenated.

***Nutrients***

Currently, no ASEAN MWQC have been established for Total Nitrogen (TN) and Total Phosphorus (TP). During the survey, TN concentrations recorded during flood and ebb tides were 0.37 mg/L and 0.48 mg/L, and 0.34 mg/L and 0.51 mg/L, respectively. While TP concentrations during the flood and ebb tide surveys ranged from 0.059 mg/L to 0.071 mg/L and from 0.048 mg/L to 0.069 mg/L, respectively.

Ammonia concentrations recorded at all survey stations during both flood and ebb tides were below the ASEAN MWQC limit of 0.07 mg/L, ranging from 0.02 mg/L to 0.054 mg/L, irrespective of tidal conditions, depth, or station location.

Nitrate and phosphate concentrations exceeded the ASEAN MWQC of 0.06 mg/L and 0.015 mg/L at several stations. During flood tide, nitrate concentrations ranged from 0.05 mg/L to 0.073 mg/L, while during ebb tide, they ranged from 0.06 mg/L to 0.077 mg/L. Phosphate concentrations recorded during the survey ranged from 0.01 mg/L to 0.029 mg/L during flood tide and from 0.011 mg/L to 0.017 mg/L during ebb tide.

Literature review indicates that baseline nutrient concentrations in Pasir Ris are significantly higher, with reported nitrate levels of 0.242 mg/L and phosphate-phosphorus levels of 0.103 mg/L (Water Quality in Singapore, 2011). Additionally, Zheng H. et al. (2010) observed that ammonia concentrations at shallow locations were higher than at deeper points, likely due to acidic precipitation or nutrient runoff from grass-covered areas. These nutrients are transported through storm drains, ultimately being deposited into the Strait of Johor. As the Project does not involve the discharge of nutrients, no impact on nutrient levels is anticipated.

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

Biochemical Oxygen Demand ($BOD_5$) 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.

**_Oil and Grease_**

Oil and grease (O&G) concentrations across all sampling stations were below the detection limit of 0.1 mg/L and met the ASEAN MWQC of 0.14 mg/L, except at station WQ01 during ebb tide, where an elevated concentration of 1.03 mg/L was recorded.

This exceedance is considered an isolated occurrence, as WQ01 is located within the Project footprint and near the Loyang Offshore Supply Base jetty. Despite the recorded level, no visible oil or grease was observed on the water surface at the time of the survey. Additionally, water quality data from downstream locations did not indicate any presence of oil or grease, further supporting the localized nature of the exceedance.

Given WQ01's proximity to the Loyang Offshore Supply Base jetty, the elevated O&G levels may have been influenced by vessels docked at the jetty or moving vessels in the area. This will be further assessed and monitored during the construction phase to determine any potential project-related impacts.

**_Heavy Metals_**

At the four (4) water quality stations (WQ01, WQ02, WQ03, and WQ04), a total of nine (9) heavy metals were analysed, namely Arsenic (As), Aluminium (Al), Cadmium (Cd), Chromium (Cr), Copper (Cu), Mercury (Hg), Nickel (Ni), Lead (Pb) and Zinc (Zn). Mercury was not detected at any station, regardless of tide, station, or depth. Other dissolved metals were detected at certain survey stations during either flood or ebb tides.

Cadmium was detected only at ebb tide at WQ03, with a concentration of 0.11 µg/L, which was well below the ASEAN MWQC limit of 10 µg/L. Chromium, copper, and lead concentrations remained within the limits, demonstrating compliance with the ASEAN MWQC standards. The highest chromium concentration recorded was 1.54 µg/L at WQ03 and WQ04 during ebb tide at mid-depth. Copper concentrations ranged from 2.05 µg/L (WQ04, mid-depth) to 3.42 µg/L (WQ01, surface) during flood tide and from 2.08 µg/L (WQ04, mid-depth) to 3.34 µg/L (WQ01, mid-depth) during ebb tide. Lead concentrations during flood tide ranged from 0.11 µg/L (WQ04, surface) to 1.07 µg/L (WQ01, surface) and during ebb tide from 0.12 µg/L (WQ04, both surface and mid-depth) to 2.08 µg/L (WQ01, surface).

Zinc and arsenic concentrations recorded at the monitoring stations did not exceed the ASEAN MWQC. The highest zinc concentration was 7.09 µg/L at WQ01, while the lowest was 1.13 µg/L at WQ04. Arsenic concentrations ranged from 13.5 µg/L to 98.9 µg/L during both flood and ebb tides.

Nickel was detected at all monitoring stations, with the highest concentration recorded at WQ01 (2.1 µg/L). Although there is no ASEAN MWQC for nickel, the concentrations were well below the ANZECC guideline of 70 µg/L. For aluminium, although there were no established ASEAN MWQC and ANZECC criteria, the recorded aluminium concentrations ranged from 2.67 µg/L to 3.14 µg/L.

### 7.6.2.3 Biological

Biological parameters encompass chlorophyll-a and microbial indications (*E. coli*, faecal coliform, enterococcus). Details on each parameter are provided in the sections below.

**_Chlorophyll-a_**

Chlorophyll-a concentrations recorded at all survey stations were above the detection limit, ranging from 2.89 µg/L to 7.39 µg/L during flood tide and from 3.34 µg/L to 13 µg/L during ebb tide. While there are no ASEAN MWQC standards for Chlorophyll-a, these concentrations exceeded the upper range of the ANZECC MWQC guideline of 1.4 µg/L at all stations. However, this exceedance is not a concern as DO levels were consistently above the ASEAN MWQC threshold of 4.0 mg/L across all stations.

In the sheltered waters of the Johor Strait, chlorophyll-a concentrations have been observed to reach much higher levels, with values up to approximately 78 µg/L and an average concentration of 21.5 µg/L (Karina Y.H., Lin X., Zhang S., 2000). These elevated concentrations are primarily influenced by anthropogenic activities and show limited seasonal variation due to monsoon patterns (Zheng H., et al, 2010). Given that the Project will not discharge nutrients, no significant impact on chlorophyll-a levels is expected.

***Microbiological Contaminants***

Enterococcus readings were below detection limits during flood tide at all stations, but detectable levels were found during ebb tide at most stations, except WQ04 (surface and mid-depth) and WQ01 (surface). The highest concentration observed was 12 cfu/100 mL at WQ01 (mid-depth), which is below the ASEAN MWQC and ANZECC criteria of 35 cfu/100 mL. As WQ01 is located near the Loyang Offshore Supply Base and is not a recreational area, these levels are not of concern.

For *E. coli*, most readings were below detection limits, with a maximum concentration of 2 MPN/100 mL recorded at WQ01 during both flood and ebb tides. Although there are no ASEAN MWQC or ANZECC criteria for *E. coli*, the values are not of concern as WQ01 is not for recreational use.

Faecal coliform concentrations ranged from 2 MPN/100 mL to 49 MPN/100 mL, with the highest value recorded at WQ01. These levels are well below the ASEAN MWQC and ANZECC thresholds of 100 MPN/100 mL and 150 MPN/100 mL, respectively.

## 7.7 Seabed Sediment Quality

Sediment quality surveys were conducted on 4 Oct 2024, at three (3) survey locations, as shown in Figure 7-16. Locations SQ01 and SQ02 were located directly within the Project boundary, while SQ03 was positioned adjacent to it, near the nearest seagrass area. These samplings aimed to assess the seabed conditions prior to construction, providing information on the chemical and heavy metals bound on the seafloor sediment, sediment grading, as well as necessary inputs for the sediment transport model.

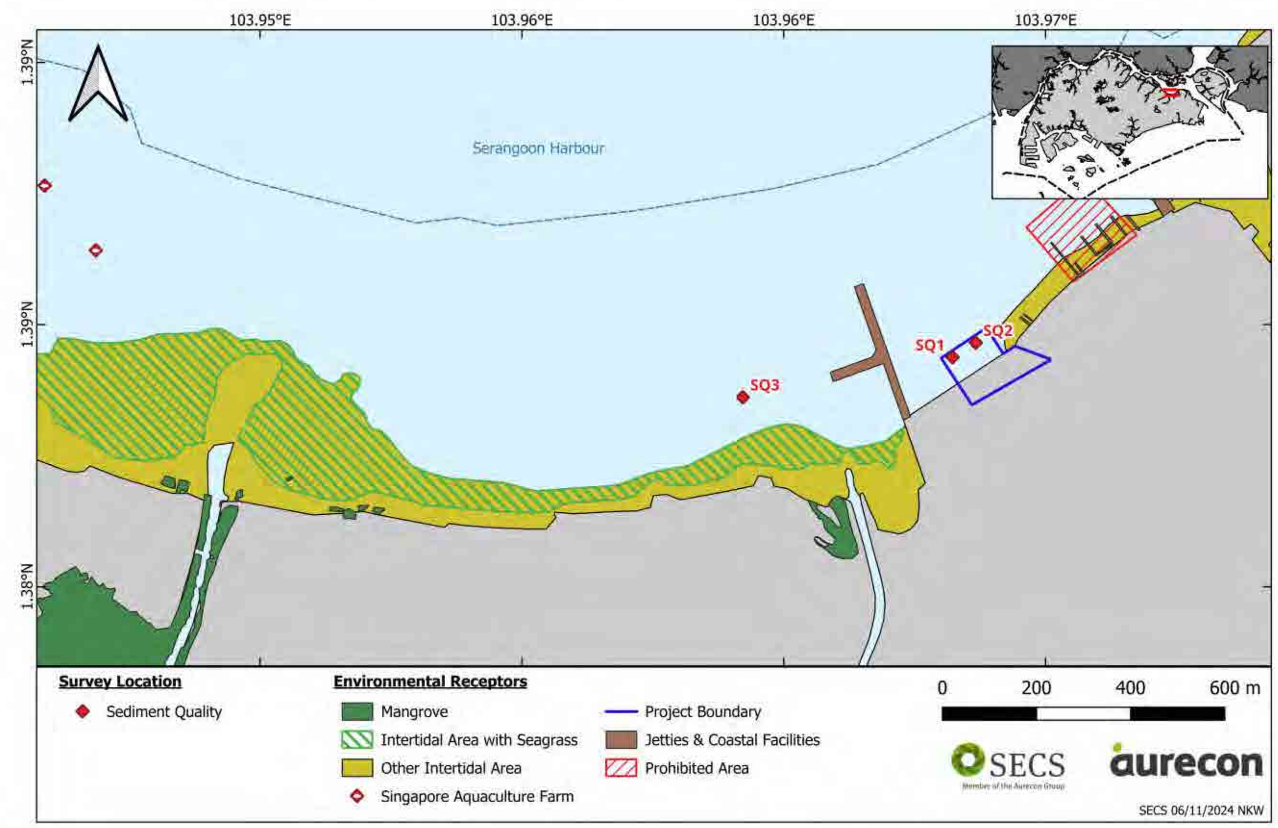



**Figure 7-16: Sediment quality survey stations**

**Table 7-10: Coordinates of sediment quality survey stations**

| Station ID | Coordinates | | Location | Survey Date |
|---|---|---|---|---|
| | Latitude (N) | Longitude (E) | | |
| SQ01 | 1.384379° | 103.968223° | Loyang Shore Front | 4 Oct 2024 |
| SQ02 | 1.384656° | 103.968666° | | |
| SQ03 | 1.383617° | 103.964217° | Pasir Ris Beach Front | |

### 7.7.1 Compliance Criteria

At the three (3) survey stations, sediments were collected using a Van Veen grab sampler to determine the parameters outlined in Table 7-11, including heavy metals, Total Organic Carbon (TOC), and Total Petroleum Hydrocarbons (TPH) levels. The compliance assessment of the sediment quality was compared against the MPA Guidelines for Dredging and Dumping Works on Chemical Characteristics of Dredged Material (2014). As TPH and TOC are not included in the MPA Dumping Guidelines, the Netherlands Soil Quality Standards (2012) were used to assess TPH, and the Canadian Sediment Quality Guidelines (2008) were applied for TOC.

**Table 7-11: Seabed sediment quality parameter**

| Parameter | MPA Guidelines (MPA, 2014) | Unit |
|---|---|---|
| Arsenic | 30.00 | mg/kg |
| Copper | 55.00 | mg/kg |
| Cadmium | 1.00 | mg/kg |
| Chromium | 50.00 | mg/kg |
| Lead | 65.00 | mg/kg |
| Mercury | 0.80 | mg/kg |
| Zinc | 150.00 | mg/kg |
| Nickel | 35.00 | mg/kg |
| Total Organic Carbon (TOC) | Lowest effect: 1(1)<br>Severe effect: 10(1) | mg/kg |
| Total Petroleum Hydrocarbon (TPH) | Residential use: 190(2)<br>Industrial use: 500(2) | % |
| Percentage Fines | - | mg/kg |

**Note:**

(1) Canadian Sediment Quality Guidelines (2008) were adopted in this Study

(2) Netherlands Soil Quality Standards (2012) were adopted in this Study.

### 7.7.2 Sediment Quality Assessment

The sediment collected at the three (3) locations was used to determine sediment grading, particle size distribution, and the analysis of chemical components, including heavy metals, Total Organic Carbon (TOC), and Total Petroleum Hydrocarbons (TPH).

The sediment quality assessment conducted at the Project sites revealed variable concentrations of key contaminants. While most heavy metals, including arsenic, cadmium, chromium, mercury, and nickel, were within acceptable limits according to MPA guidelines, elevated levels of lead, copper and zinc were observed at SQ02. TPH levels were recorded below relevant guidelines, indicating a lower risk to aquatic biota, and the TOC levels were also within safe limits.

The sediment samples predominantly consisted of silt, which is known to retain contaminants due to its fine particle size and larger surface area. However, despite the presence of these contaminants, the overall sediment quality remains within acceptable thresholds.

Further details are presented in the following section.

#### 7.7.2.1 Sediment Grading

Bioavailability and toxicity of contaminants is influenced by sediment grain size. The contaminant binding capacity of sediments decreases with increasing grain size, and this results in the concentration of contaminants typically being greater in the finer sediment fractions.

The composition of the sediments (gravel, sand, silt, and clay) from the survey stations is detailed in Table 7-12 and Figure 7-17. Clay content ranged from 34% to 71%, with the highest levels at SQ01 and SQ03. In contrast, SQ02 exhibited a more evenly distribute sediment types, comprising gravel, sand, and silt at 25%, 28%, and 34%, respectively. At both SQ01 and SQ03, the sediment was predominantly composed of silt, followed by clay and sand, with small percentages of gravel. Particle size distribution curves are presented in

Appendix F. In addition, the results indicate variability in fine content, particularly in the clay and silt fractions, which were most likely to form lasting sediment plumes.

**Table 7-12: Results of sediment grading**

| Station | Clay (<0.002 um) | Silt (0.002 to 0.063 mm) | Sand (0.063 to 1.18 mm) | Gravel (>1.18mm) |
|---|---|---|---|---|
| SQ1 | 19 | 70 | 8 | 3 |
| SQ2 | 13 | 34 | 28 | 25 |
| SQ3 | 21 | 63 | 14 | 2 |

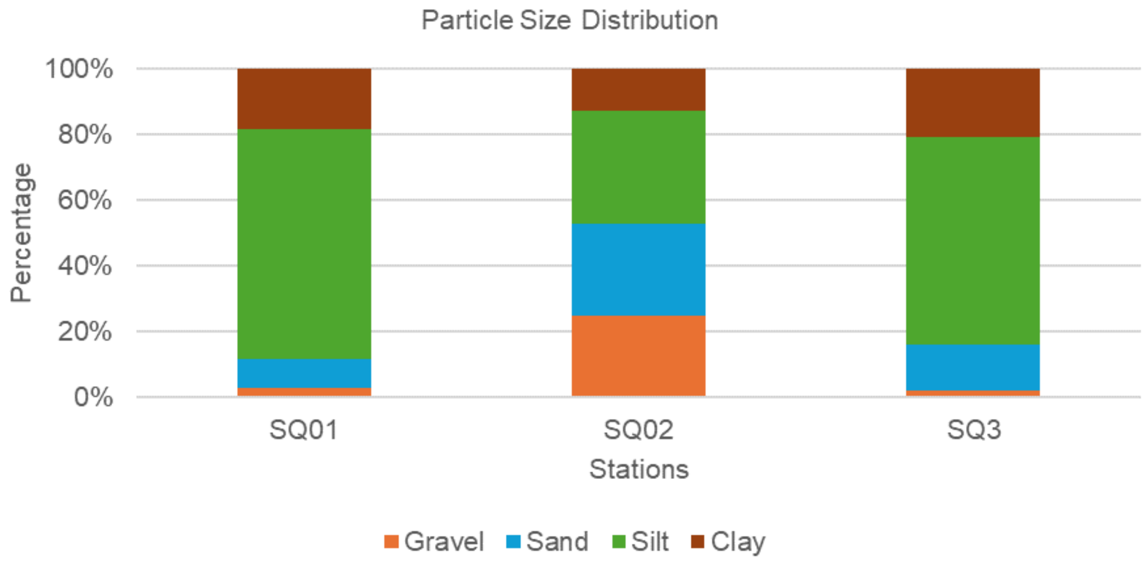



**Figure 7-17: Particle size analysis results**

### 7.7.2.2 Sediment Chemical Parameter

The results of the sediment quality survey are used to provide information on the chemicals and heavy metals bound to the seafloor sediments. The parameters tested are listed in Table 7-13.

**Table 7-13: Baseline survey results for the heavy metal analysis**

| Parameter | MPA Guidelines (MPA, 2014) | Unit | SQ1 | SQ2 | SQ3 |
|---|---|---|---|---|---|
| Arsenic | 30.00 | mg/kg | 8.76 | 10.3 | 11.2 |
| Copper | 55.00 | mg/kg | 27.5 | **55.5** | 32.9 |
| Cadmium | 1.00 | mg/kg | ND | 0.55 | 0.56 |
| Chromium | 50.00 | mg/kg | 23.1 | 20.3 | 26.0 |
| Lead | 65.00 | mg/kg | 24.3 | **118** | 31.3 |
| Mercury | 0.80 | mg/kg | 0.27 | 0.16 | 0.19 |
| Zinc | 150.00 | mg/kg | 107 | **205** | 129 |
| Nickel | 35.00 | mg/kg | 15 | 11.8 | 15.1 |

| Parameter | MPA Guidelines (MPA, 2014) | Unit | SQ1 | SQ2 | SQ3 |
|---|---|---|---|---|---|
| Total Organic Carbon (TOC) | Lowest effect: 1[(1)]<br>Severe effect: 10[(1)] | % | 1.48 | 1.33 | 1.39 |
| Total Petroleum Hydrocarbon (TPH) | Residential use: 190[(2)] Industrial use: 500[(2)]<br>Default guideline values (DGVs): 280 [(3)] | mg/kg | 134 | 108 | 120 |
| Percentage Fines | - | % | 98.6 | 52.1 | 98.4 |

**Note:**

(1) Canadian Sediment Quality Guidelines (2008) were adopted in this study

(2) Netherlands Soil Quality Standards (2012) were adopted in this study

***Metals***

Analysis of sediment samples indicated that arsenic, cadmium, chromium, mercury, and nickel levels were within the MPA Guidelines for Dredging and Dumping Works (2014) at all three (3) stations, with the exception of copper, lead, and zinc. At Station SQ02, concentrations of copper (55.5 mg/kg), lead (118 mg/kg), and zinc (205 mg/kg) exceeded the guideline thresholds of 55.5 mg/kg, 65 mg/kg, and 150 mg/kg respectively. The elevated concentrations observed at SQ02 were likely attributed to marine industrial activity, particularly the use of antifouling paints, and were consistent with conditions typically found near active vessel berthing and maintenance areas (Costa et al., 2013; 2016). Although the values exceeded guideline thresholds, the affected area was limited to a single station within a jetty environment, where such elevations are not uncommon due to long-term industrial and maritime activities.

As indicated in the sedimentation results (Section 8), sedimentation was predicted to occur locally, thereby limiting the potential for wider dispersion of associated contaminants. In addition, scientific literature supports that heavy metals in marine sediments are typically adsorbed onto particulates and undergo natural attenuation through processes such as dilution, dispersion, adsorption, and resettlement into the sediment bed.

Based on the available data and site-specific physical conditions, the sediment quality within the project area was assessed to reflect localised anthropogenic influences typical of industrial waterfront settings. Furthermore, the short duration of dredging activities (approximately 9 to 14 days) further reduces the likelihood of sustained sediment-related impacts. To manage these risks, mitigation measures were proposed as part of the Environmental Monitoring and Management Plan (EMMP), including regular water quality monitoring during dredging and the deployment of silt curtains where necessary (Refer to Section 15). A detailed Construction Environmental Monitoring and Management Plan (CEMMP) would also be developed and submitted to the relevant agencies for review and approval prior to construction. All dredged materials would be managed and disposed of in accordance with the MPA guidelines, using designated and approved disposal facilities.

***Total Petroleum Hydrocarbon (TPH)***

Coastal environments are exposed to chemical contaminants from various anthropogenic activities, impacting marine ecosystems and their biota. TPH levels recorded at SQ01, SQ02, and SQ03 ranged from 108 to 134 mg/kg, with the highest concentrations at SQ01, followed by SQ03 and SQ02. All TPH concentrations were below the Netherlands Guidelines for residential use, indicating no cause for concern as they remain within acceptable limits.

***Total Organic Carbon (TOC)***

TOC represents the amount of organic matter present in sediment and serves as an indicator of the sediment's potential to generate hydrocarbons. TOC levels recorded at the three (3) stations were compared against the Canadian Sediment Quality Guidelines. The detected TOC levels ranged from 1.33% to 1.48%, which was above the lowest effect threshold of 1% but remains below the severe effect level of 10%.

# 7.8 Marine Biodiversity

## 7.8.1 Intertidal Habitat/ Seagrass

The intertidal habitat/ seagrass survey locations and coordinates of the four (4) intertidal / seagrass transects are presented in Figure 7-18 and Table 7-14 respectively.

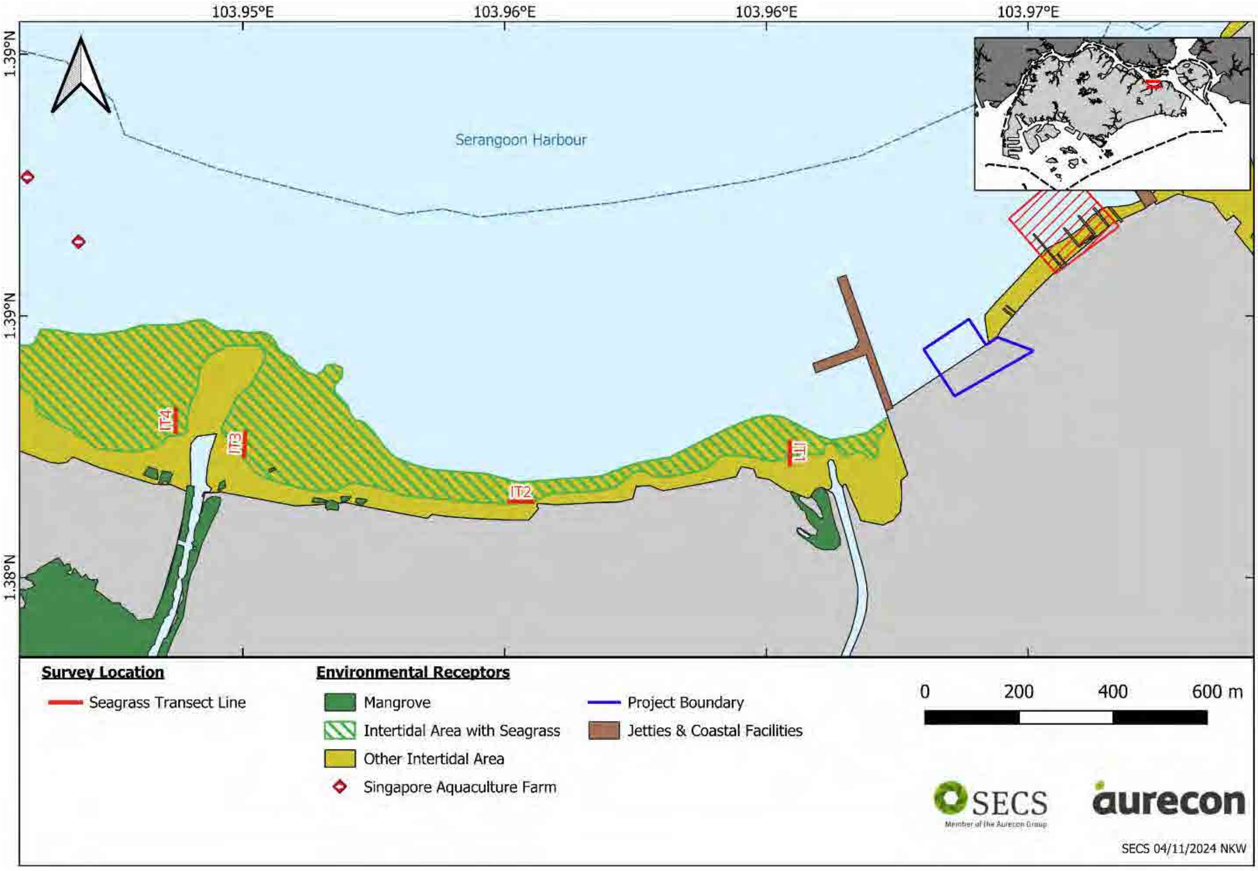



Figure 7-18: Intertidal/seagrass survey stations

Table 7-14: Survey coordinates and details of the intertidal survey transects

| Transect | | Coordinates | | Location | Survey Date |
|---|---|---|---|---|---|
| | | Latitude (N) | Longitude (E) | | |
| IT1 | Start | 1.382166° | 103.965449° | Pasir Ris Park Shoreline | 19 Oct 2024 |
| | End | 1.382594° | 103.965444° | | |
| IT2 | Start | 1.381446° | 103.960536° | | 19 Oct 2024 |
| | End | 1.381453° | 103.960093° | | |
| IT3 | Start | 1.382320° | 103.955020° | | 20 Oct 2024 |
| | End | 1.382770° | 103.955050° | | |
| IT4 | Start | 1.382780° | 103.953720° | | 20 Oct 2024 |
| | End | 1.383220° | 103.953720° | | |

#### 7.8.1.1 Survey Methodology

To quantify the intertidal habitat, quadrat sampling method was adopted (Loy et al., 2024; McKenzie, 2003) in accordance with NParks' Biodiversity Impact Assessment (BIA) guidelines (Figure 7-19). The quadrat sampling was conducted during spring low tides to evaluate the intertidal communities present in the area.

Four (4) transects, each measuring 50 m in length were laid out along the intertidal zone of the study area. Three replicate quadrats measuring 50 cm × 50 cm were placed at fixed intervals of every 5 m along the transect tape. Within these quadrats, measurements were taken on sediment composition, seagrass percent cover, species composition, and other relevant variables.

The quadrat surveys documented and characterized the seagrass and intertidal communities, focusing on the following aspects:

- Percentage cover of major benthic categories such as seagrass, macroalgae and abiotic substrate.
- Abundance of individual motile fauna.
- General biodiversity checklist of intertidal flora and fauna and their conservation status of flora based on The Singapore Red Data Book, Third Edition (SRDB 3) by Davison et.al., (eds.) 2024.

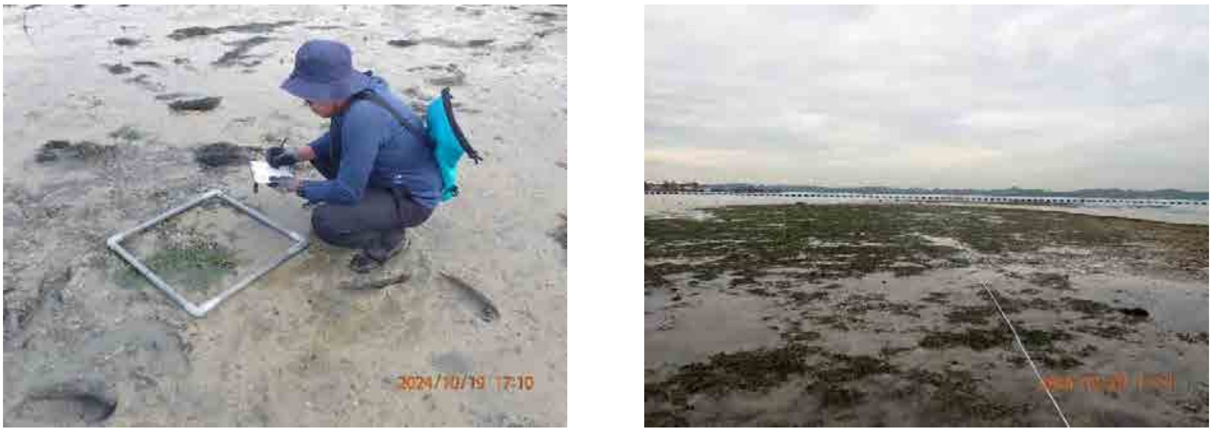



**Figure 7-19: SECS ecologist recording the intertidal community within a 50 cm x 50 cm quadrat (left); a 50 m intertidal survey transect (Right)**

**Table 7-15: Categories for various conservation significance status (SRDB 3)**

| Category | | Abbreviation | Remarks |
|---|---|---|---|
| Not Threatened | Least Concern | LC | Not approaching the criteria for being threatened |
| | Near Threatened | NT | Approaching but not yet reaching the threshold for being threatened |
| Threatened | Vulnerable | VU | |
| | Endangered | EN | |
| | Critically Endangered | CR | |
| Extirpation & Extinction | Presumed Nationally Extinct | Nex | The species is extinct (extirpated) within Singapore, but it still survives outside Singapore. |
| | Globally Extinct | EX | The species is extinct all over the world, both in the wild and in cultivation |
| Other Categories | Data Deficient | DD | Species eligible for assessment at the national level but with inadequate information to make an informed assessment |

| Category | | Abbreviation | Remarks |
|---|---|---|---|
| | Not Applicable | NA | Species that are not eligible for assessment at the national level (mainly introduced taxa and vagrants |
| | Not Evaluated | NE | Species that are possibly eligible for assessment but have not yet been evaluated against the criteria |
| | Not Listed | Not Listed | Species not listed in the records (in the IUCN Global Red List database, or the third edition Singapore Red Data Book – SRDB3) |

### 7.8.1.2 Survey Result

The intertidal habitat survey was conducted along the shoreline at Pasir Ris Park on 19 Oct 2024 and 20 Oct 2024 and is located at least 400 m to west of the proposed project footprint. Across the four (4) survey transects (Table 7-16), abiotic component such as sand and silt dominated the intertidal area with a combined average ranging from 45.03 % (IT3) to 90.58 % (IT1). The most abundant biotic cover was made up of green algae along IT1 and IT2 while seagrass dominated IT3 and IT4.

Based on available public information such as satellite image, previous study data and actual observations during the intertidal surveys, the seagrass habitat has been mapped and is shown in Figure 7-18. Seagrass habitat has been documented across the entire intertidal study area.

**Table 7-16 Summary of the major benthos recorded during the intertidal survey**

| Groups | IT1 | | IT2 | | IT3 | | IT4 | |
|---|---|---|---|---|---|---|---|---|
| | Mean (%) | SE | Mean (%) | SE | Mean (%) | SE | Mean (%) | SE |
| Seagrass | 2.09 | 0.71 | 2.73 | 1.00 | 39.73 | 4.11 | 30.88 | 5.22 |
| Macroalgae | 7.33 | 1.32 | 48.61 | 5.37 | 15.24 | 2.22 | 6.64 | 0.84 |
| Ascidian | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Anemone | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.03 |
| Hard coral | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Soft coral | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sponge | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Zoanthid | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Other Fauna | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Abiotic | 90.58 | 1.28 | 48.67 | 5.15 | 45.03 | 5.06 | 62.45 | 5.19 |
| **Total** | **100.00** | | **100.00** | | **100.00** | | **100.00** | |

The green macroalgae (*Ulva* sp.) was the most common algae observed across all transects. As for the seagrass, only the Spoon seagrass (*Halophila ovalis*) was recorded (Table 7-17). Seagrass cover ranged between 2.09 % at IT1 to 39.73 % at IT3. Outside of the survey transects, it was also noted that relatively high seagrass cover (comparable to IT3 and IT4) was observed within 200 m to the west from IT1.

**Table 7-17 Details of seagrass and macroalgae recorded during the intertidal survey**

| Summary | IT1 | IT2 | IT3 | IT4 |
|---|---|---|---|---|
| Total Seagrass Cover (%) | 2.09 | 2.73 | 39.73 | 30.88 |
| Total Number of Seagrass Species Observed | 1 | 1 | 1 | 1 |
| Seagrass Species | *Halophila ovalis* | *Halophila ovalis* | *Halophila ovalis* | *Halophila ovalis* |
| Total Algae Cover (%) | 5.52 | 46.97 | 14.58 | 6.64 |
| Most Common Macroalgae | Chlorophyta (Green Algae) | Chlorophyta (Green Algae) | Chlorophyta (Green Algae) | Chlorophyta (Green Algae) |
| Macroalgae Species | *Bryopsis* sp., *Caulerpa* sp., *Gracilaria* sp., *Ulva* sp. | | | |

Five classes of motile fauna were recorded along the transects (Table 7-18). The gastropod Bazillion snail (*Batillaria zonalis*) dominated IT1 (> 80 no./$m^2$) and substantial abundance at IT3 and IT4 (> 12 no./$m^2$). In addition, the tiny Tidal hermit crabs (*Diogenes* sp.) were observed across all transects and everywhere within the intertidal area with the highest abundance recorded at IT1 (> 40 no./$m^2$). Outside the survey transects, several motile fauna species (Table 7-19) were also observed including those with conservation significance (Davison et.al., (eds.) 2024). The conservation significant (CS) species (Figure 7-21) recorded are the following:

- *Goniodiscaster scaber* (Biscuit Sea star) – Vulnerable (VU)
- *Protoreaster nodosus* (Knobbly Sea star) – Endangered (EN)
- *Phyllophorella spiculata* (Tennis ball sea cucumber) – Vulnerable (VU)
- *Holothuria scabra* (Garlic bread sea cucumber) – Endangered (EN)
- *Cercondemas ancep* (Pink warty sea cucumber) – Vulnerable (VU)

Table 7-18: Summary of the major motile fauna recorded during the intertidal survey

| Class | | IT1 | | IT2 | | IT3 | | IT4 | |
|---|---|---|---|---|---|---|---|---|---|
| | | Density (No./m²) | SE | Density (No./m²) | SE | Density (No./m²) | SE | Density (No./m²) | SE |
| Polychaeta | Tubeworms | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Others | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Arachnida | Spiders | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Hexanauplia | Barnacles | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Malacostraca | Shrimps | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Crabs | 42.91 | 15.76 | 0.85 | 0.48 | 3.27 | 0.79 | 1.58 | 0.60 |
| Ostracoda | Mussel shrimps | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Asteroidea | Sea stars | 0.12 | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Echinoidea | Urchins | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Holothuroidea | Sea cucumbers | 0.00 | 0.00 | 0.12 | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 |
| Ophiuroidea | Brittle stars | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Bivalvia | Bivalves | 0.00 | 0.00 | 0.00 | 0.00 | 0.24 | 0.17 | 0.00 | 0.00 |
| Gastropoda | Nudibranchs | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Others | 88.24 | 19.84 | 0.97 | 0.46 | 12.36 | 1.74 | 19.88 | 3.13 |
| **Total** | | **131.27** | | **1.94** | | **15.88** | | **21.45** | |

Table 7-19: Checklist of motile fauna observed during the intertidal survey

| No. | Family | Scientific Name | Common Name | SRDB 3 |
|---|---|---|---|---|
| **1** | Oreasteridae | *Goniodiscaster scaber* | Biscuit sea star | Vulnerable |
| **2** | Oreasteridae | *Protoreaster nodosus* | Knobbly sea star | Endangered |
| **3** | Phyllophoridae | *Phyllophorella spiculata* | Tennis ball sea cucumber | Vulnerable |
| **4** | Holothuriidae | *Holothuria scabra* | Garlic bread sea cucumber | Endangered |
| **5** | Holothuriidae | *Cercodemas ancep* | Pink warty sea cucumber | Vulnerable |
| 6 | Diogenidae | *Clibanarius infraspinatus* | Orange-striped hermit crab | NA |
| 7 | Diogenidae | *Diogenes* sp. | Tidal hermit crab | NA |
| 8 | Menippidae | *Myomenippe hardwickii* | Stone/Thunder crab | Least Concern |
| 9 | Squillidae | *Harpiosquilla* sp. | Spearer mantis shrimp | NA |
| 10 | Boloceroididae | *Boloceroides mcmurrichi* | Swimming anemone | Least Concern |
| 11 | Stichodactylidae | *Stichodactyla haddoni* | Haddon's carpet anemone | Least Concern |
| 12 | Oulastreidae | *Oulastrea crispata* | Zebra coral | Least Concern |

| No. | Family | Scientific Name | Common Name | SRDB 3 |
|---|---|---|---|---|
| 13 | Batillariidae | *Batillaria zonalis* | Bazillion snail | NA |
| 14 | Muricidae | *Thais* sp. | Chunky drill | NA |
| 15 | Nassariidae | *Nassarius livescens* | Common whelk | Least Concern |
| 16 | Nassariidae | *Nassarius olivaceus* | Olive whelk | Least Concern |
| 17 | Chalinidae | *Haliclona* sp. | Sponge | - |
| 18 | Class Polychaeta | - | Gregarious tubeworms | - |
| 19 | Balanidae | *Balanus* sp. | Acorn barnacle | - |
| 20 | Chalinidae | *Haliclona* sp. | Sponge | - |

Representative photographs of the general intertidal community along the study area during the intertidal survey are presented in Figure 7-20.

Overview of IT1

Overview of IT2

Overview of IT3

Overview of IT4

Spoon seagrass (*Halophila ovalis*)

Green macroalgae (*Ulva* sp.)

Commonly observed Bazillion snails (*Batilaria zonalis*)

Encrusting Zebra coral (*Oulastrea crispata*)

Haddon's carpet anemone (*Stichodactyla haddoni*)

Thunder crab (*Myomenippe hardwickii*)

Catfish fishing during low tide

Members of the public collecting intertidal fauna

Park activities observed (kayaking)

Human debris (discarded tyre) seen along the shore

**Figure 7-20: Representative photographs of the intertidal community along the study area**

Knobbly Sea star (*Protoreaster nodosus*) - **EN**

Biscuit Sea star (*Goniodiscaster scaber*) - **VU**

Garlic bread sea cucumber (*Holothuria scabra*) - **EN**

Tennis ball sea cucumber (*Phyllophorella spiculata*) - **VU**

Pink warty sea cucumber (*Cercodemas anceps*) - **VU**

**Figure 7-21: Photographs of the various conservation significant fauna species recorded during the intertidal survey**

### 7.8.2 Mangroves

The survey locations and coordinates of the mangrove transects are presented in Figure 7-22 and Table 7-20 accordingly.

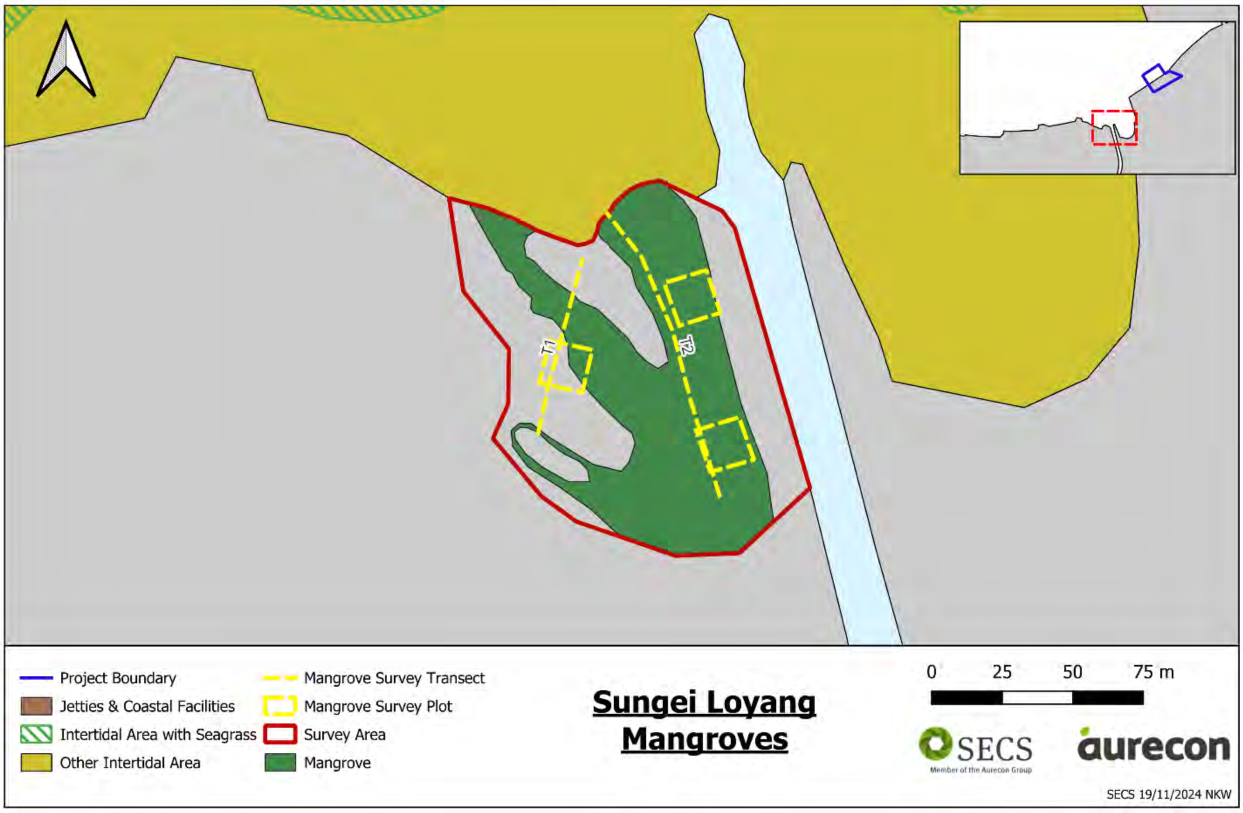



Figure 7-22: Mangrove survey locations

Table 7-20: Survey coordinates and details of the mangrove survey transects

| Transect ID | | Coordinates | | Location | Survey Date |
|---|---|---|---|---|---|
| | | Latitude (N) | Longitude (E) | | |
| T1 | Start | 1.381477 | 103.9658 | Sungei Loyang | 18 Oct 2024 and 22 Oct 2024 |
| | End | 1.380928 | 103.9657 | | |
| T2 | Start | 1.381622 | 103.9659 | | 19 Oct 2024 and 21 Oct 2024 |
| | End | 1.380728 | 103.9663 | | |

#### 7.8.2.1 Survey Methodology

The transect line plot method was utilised to assess the mangrove habitat in the vicinity of the project area (Figure 7-23). Two (2) transect lines were oriented perpendicular to the shoreline, with plots established within each vegetation zone (Figure 7-22). Surveys conducted within these plots yielded quantitative descriptions of the species composition and community structure of the mangrove forest.

Each plot covered a minimum area of 15 m × 15 m. The overall condition of the mangrove forest in the area interest was assessed based on the following criteria:

- Identification and recording of any tree larger than 4 cm in diameter at breast height (DBH), along with documentation of its girth.
- Recording of species and the number of saplings (diameter < 4 cm).

- Recording of seedlings (height < 1 m).
- Conservation status of flora based on SRDB 3


**Figure 7-23: SECS ecologists setting up survey transect (left); and measuring mangrove DBH (right)**

**Table 7-21: Categories for various conservation significance status (SRDB 3)**

| Category | | Abbreviation | Remarks |
|---|---|---|---|
| Not Threatened | Least Concern | LC | Not approaching the criteria for being threatened |
| | Near Threatened | NT | Approaching but not yet reaching the threshold for being threatened |
| Threatened | Vulnerable | VU | |
| | Endangered | EN | |
| | Critically Endangered | CR | |
| Extirpation & Extinction | Presumed Nationally Extinct | Nex | The species is extinct (extirpated) within Singapore, but it still survives outside Singapore. |
| | Globally Extinct | EX | The species is extinct all over the world, both in the wild and in cultivation |
| Other Categories | Data Deficient | DD | Species eligible for assessment at the national level but with inadequate information to make an informed assessment |
| | Not Applicable | NA | Species that are not eligible for assessment at the national level (mainly introduced taxa and vagrants |
| | Not Evaluated | NE | Species that are possibly eligible for assessment but have not yet been evaluated against the criteria |
| | Not Listed | Not Listed | Species not listed in the records (in the IUCN Global Red List database, or the first edition Singapore Red Data Book - RDB1 and second edition Singapore Red Data Book - RDB2) for whatever reason |

#### 7.8.2.2 Survey Result

The mangrove survey was conducted between 18 Oct 2024 to 21 Oct 2024 within the mangrove habitat observed near the mouth of Sungei Loyang and extending inland where non-mangrove species dominated (Figure 7-24). Along transect T1, a mixture of mangrove and non-mangrove species were observed while transect T2 runs through a mangrove dominated vegetation.

During the survey, 25 species of plants were recorded consisting of seven major mangroves species, 1 minor mangrove species, 5 mangrove associates and 12 non-mangrove species (Table 7-22). The mangrove forest mainly consisted of major mangroves of "Least Concern" (Davison et.al., (eds.) 2024) such as *Rhizophora apiculata*, *Rhizophora mucronata*, *Avicenia alba*, Bruguiera *cylindrica and Bruguiera gymnorhiza*. Several instances of *Nypa fruticans* (Vulnerable) were observed scattered sparsely throughout the study area. Various mangrove associates such as *Hibiscus tiliaceus*, *Derris trifoliata*, *Terminalia catappa* as well as the "Endangered" *Podocarpus polystachyus* were also recorded within the study area. The *Podocarpus polystachyus* recorded within the study area is likely to be progeny of mature instances of managed vegetation within Pasir Ris Park.

Based on previous records, the "Critically Endangered" major mangrove species *Bruguiera hainesii* was spotted at Loyang (Wild Shores of Singapore, 2024). In addition, the "Vulnerable" major mangrove species *Kandelia candel* was also recorded during previous surveys (Flora of Singapore, 2012). Furthermore, one mangrove associate (*Dalbergia candenatensis*) and three non-mangrove species were also previously recorded (Flora of Singapore, 2012) and were all assessed as *Least Concern.*

Representative photographs of the general intertidal community along the study area during the intertidal survey are presented in Figure 7-25.

Table 7-22: List of various flora species, along with their respective conservation significance status, recorded within the study area during the baseline surveys

| No. | Family | Species | Common Name | Classification | Type | Origin | Conservation Status (RDB 3) | Abundance | Location | T1 | T2 | Casual Sightings |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Acanthaceae | *Avicennia alba* | Api Api Putih | Major Mangrove | Tree | Native | Least Concern | 19 | Mangrove Forest | | √ | |
| **2** | **Arecaceae** | ***Nypa fruticans*** | **Nipah** | **Major Mangrove** | **Tree** | **Native** | **Vulnerable** | **9** | Mangrove Forest | | √ | |
| **3** | Lythraceae | *Sonneratia alba* | Perepat | Major Mangrove | Tree | Native | Least Concern | 1 | Mangrove Forest | | √ | |
| **4** | Rhizophoraceae | *Bruguiera cylindrica* | Bakau Putih | Major Mangrove | Tree | Native | Least Concern | 15 | Mangrove Forest | √ | √ | |
| **5** | Rhizophoraceae | *Bruguiera gymnorhiza* | Tumu Merah | Major Mangrove | Tree | Native | Least Concern | 5 | Mangrove Forest | | | √ |
| **6** | Rhizophoraceae | *Rhizophora apiculata* | Bakau Minyak | Major Mangrove | Tree | Native | Least Concern | 19 | Mangrove Forest | | √ | |
| **7** | Rhizophoraceae | *Rhizophora mucronata* | Bakau Kurap | Major Mangrove | Tree | Native | Least Concern | 18 | Mangrove Forest | | √ | |
| **8** | Meliaceae | *Xylocarpus granatum* | Nyireh Bunga | Minor Mangrove | Tree | Native | Least Concern | 1 | Mangrove Forest | | √ | |
| **9** | Combretaceae | *Terminalia catappa* | Ketapang | Mangrove Associate | Tree | Native | Least Concern | 4 | Regenerated Forest | √ | | |
| **10** | Fabaceae | *Caesalpinia crista* | Squirrel's Claws | Mangrove Associate | Climber | Native | Least Concern | 5 | Mangrove Forest | | | √ |
| **11** | Fabaceae | *Derris trifoliata* | Common Derris | Mangrove Associate | Climber | Native | Least Concern | 6 | Mangrove Forest | √ | | |
| **12** | Malvaceae | *Hibiscus tiliaceus* | Sea Hibiscus | Mangrove Associate | Tree | Native | Least Concern | 6 | Edge of Mangroves | √ | | |
| **13** | **Podocarpaceae** | ***Podocarpus polystachyus*** | **Sea Teak** | **Mangrove Associate** | **Tree** | **Native** | **Endangered** | **4** | **Pasir Ris Park (managed vegetation)** | | | √ |
| **14** | Arecaceae | *Caryota mitis* | Fishtail Palm | Non-mangrove | Tree | Native | Least Concern | 2 | Regenerated Forest | √ | | |

| No. | Family | Species | Common Name | Classification | Type | Origin | Conservation Status (RDB 3) | Abundance | Location | T1 | T2 | Casual Sightings |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **15** | Arecaceae | *Cocos nucifera* | Coconut | Non-mangrove | Tree | Non-native | NA-Naturalised | 1 | Pasir Ris Park (managed vegetation) | | | √ |
| **16** | Arecaceae | *Elaeis guineensis* | Oil Palm | Non-mangrove | Tree | Non-native | NA - Casual | 5 | Regenerated Forest | | | √ |
| **17** | Arecaceae | *Ptychosperma macarthurii* | MacArthur Palm | Non-mangrove | Tree | Non-native | NA - Naturalised | 14 | Regenerated Forest | √ | | |
| 18 | Aspleniaceae | *Asplenium nidus* | Bird's Nest Fern | Non-mangrove | Epiphyte | Native | Least Concern | 3 | Regenerated Forest | | | √ |
| **19** | Casuarinaceae | *Casuarina equisetifolia* | Common Rhu | Non-mangrove | Tree | Native | Least Concern | 3 | Regenerated Forest | | | √ |
| **20** | Fabaceae | *Andira inermis* | Cabbage Tree | Non-mangrove | Tree | Non-native | NA - Casual | 16 | Mangrove Forest | √ | | |
| **21** | Dilleniaceae | *Tetracera indica* | Mempelas | Non-mangrove | Climber | Native | Least Concern | 1 | Pasir Ris Park (managed vegetation) | | | √ |
| **22** | Fabaceae | *Falcataria falcata* | Albizia | Non-mangrove | Tree | Non-native | NA - Naturalised | 2 | Regenerated Forest | √ | | |
| **23** | Moraceae | *Artocarpus heterophyllus* | Jackfruit | Non-mangrove | Tree | Non-native | NA - Casual | 6 | Regenerated Forest | √ | | |
| **24** | Ochnaceae | *Ochna kirkii* | Mickey Mouse Plant | Non-mangrove | Shrub | Non-native | NA - Naturalised | 21 | Regenerated Forest | √ | | |
| **25** | Rubiaceae | *Morinda citrifolia* | Noni | Non-mangrove | Tree | Native | Least Concern | 1 | Edge of Mangroves | √ | | |

**Table 7-23: List of various flora species, along with their respective conservation significance status, recorded within the study area obtained from secondary data (Wild shores of Singapore, 2024*; Flora of Singapore, 2012+**

| No. | Family | Species | Common Name | Classification | Type | Origin | Conservation Status (RDB 3) | Source |
|---|---|---|---|---|---|---|---|---|
| 1 | Rhizophoraceae | *Bruguiera hainesii* | Bakau Mata Buaya | Major Mangrove | Tree | Native hybrid | Critically Endangered | Wild Shores of Singapore* |
| 2 | Rhizophoraceae | *Kandelia candel* | Pisang- pisang | Major Mangrove | Tree | Native | Critically Endangered | Flora of Singapore+ |
| 3 | Fabaceae | *Dalbergia candenatensis* | Indian Rosewood | Mangrove Associate | Climber | Native | Least Concern | Flora of Singapore+ |
| 4 | Fabaceae | *Dendrolobium umbellatum* | Dendulang | Non-mangrove | Tree | Native | Least Concern | Flora of Singapore+ |
| 5 | Flagellariaceae | *Flagerallia indica* | Common Flagellaria | Non-mangrove | Climber | Native | Least Concern | Flora of Singapore+ |
| 6 | Olacaceae | *Ximenia americana* | Bedara Laut | Non-mangrove | Shrub | Native | Least Concern | Flora of Singapore+ |

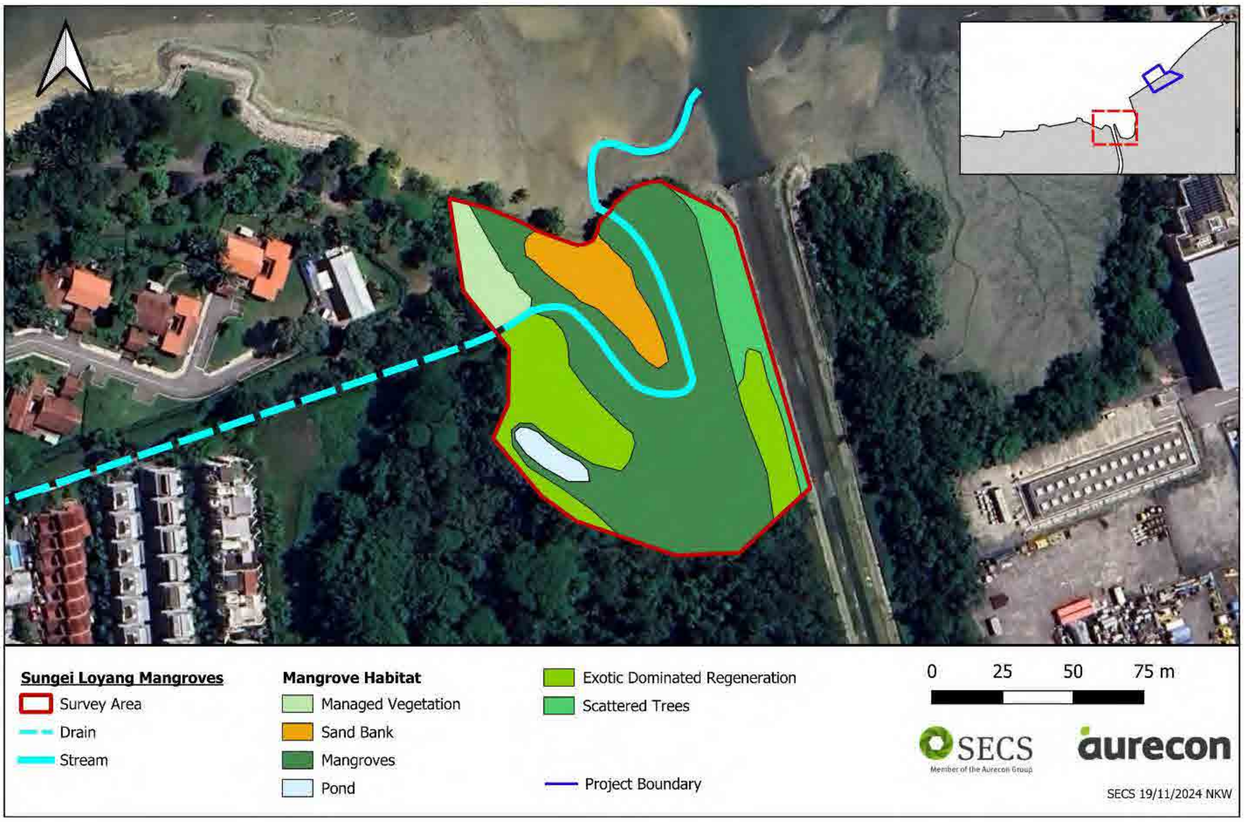



**Figure 7-24: Flora habitat map at the study area**

General overview of the study area at T1

General overview of the study area at T2

*Nypa fruticans* (Nipah) - **VU**


*Podocarpus polystachyus* (Sea teak) - **EN**

*Rhizophora apiculata* (Bakau minyak)


*Avicennia alba* (Api api putih) seedlings


*Casuarina equisetifolia* (Common Rhu)

*Ptychosperma macarthurii* (MacArthur palm)

*Ochna kirkii* (Mickey Mouse plant)

*Andira inermis* (Cabbage tree)

**Figure 7-25: Representative photographs of the mangrove community along the study Area**

## 7.8.3 Soft-bottom Macrobenthos

The survey locations and coordinates of the soft-bottom macrobenthos survey stations are presented in Figure 7-26 and Table 7-24 accordingly.

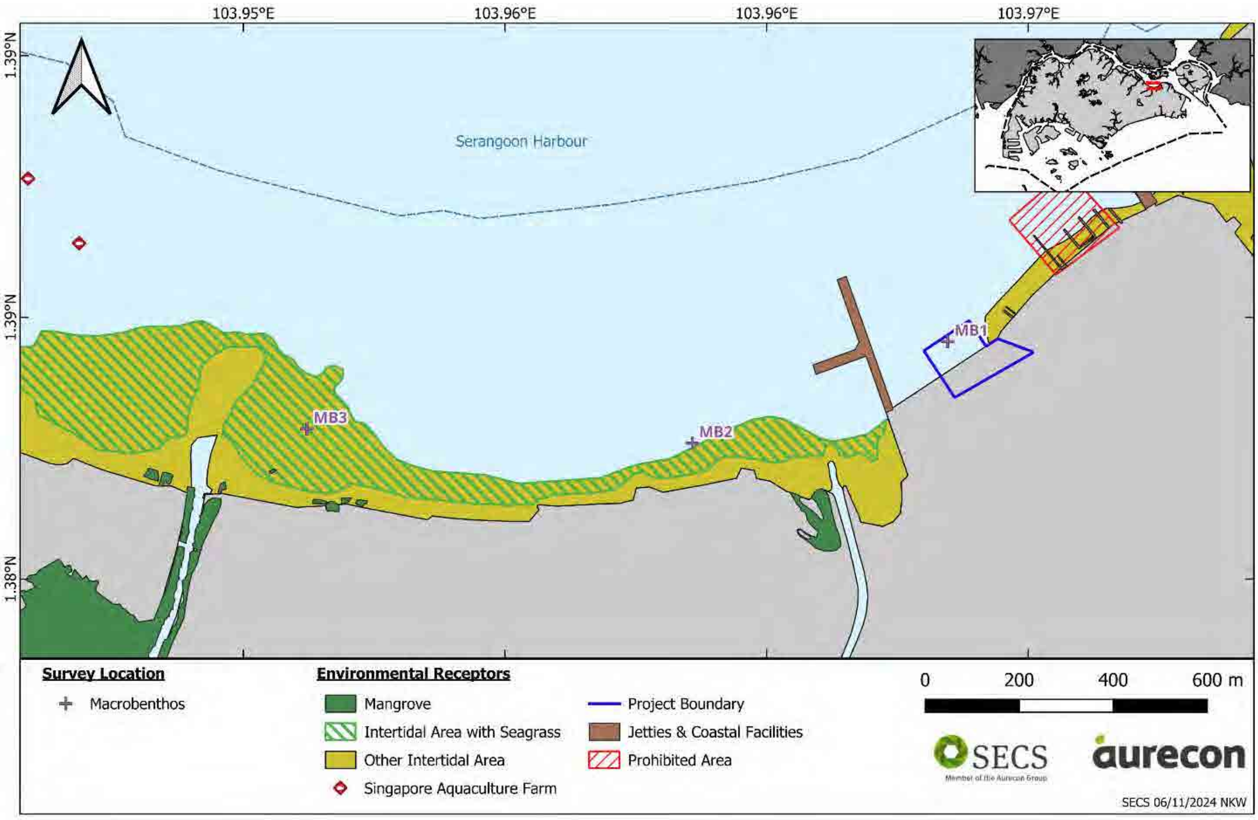



**Figure 7-26: Soft-Bottom macrobenthos survey stations**

**Table 7-24: Survey Coordinates of the soft-bottom macrobenthos survey stations**

| Station ID | Coordinates | | Location | Survey Date |
|---|---|---|---|---|
| | Latitude (N) | Longitude (E) | | |
| MB01 | 1.384540° | 103.968461° | Loyang | 4 Oct 2024 |
| MB02 | 1.382598° | 103.963581° | Pasir Ris Park Shoreline | |
| MB03 | 1.382872° | 103.956217° | | |

### 7.8.3.1 Survey Methodology

A Van Veen grab sampler was used to facilitate the capture of the benthic organisms at the bottom seabed. Grab sampling of the benthic organism was carried out at three (3) locations with the standard three (3) replicate samples each measuring an area of 0.063m$^2$, collecting samples from the upper 10 cm to 20 cm of the seabed at each location.

Each of the samples collected by the Van Veen grab was then sieved through 1 mm mesh-size test-sieve on board the sampling boat. Any marine macrofauna retained in the sieve were counted, sorted and preserved in labelled containers containing 70% ethanol (Tagliapietra and Sigovini, 2010). The collected samples were analysed and identified to the lowest taxonomic classification when possible. The seafloor soft bottom macrobenthos communities sampling was carried out at the same locations as the sediment quality sampling.

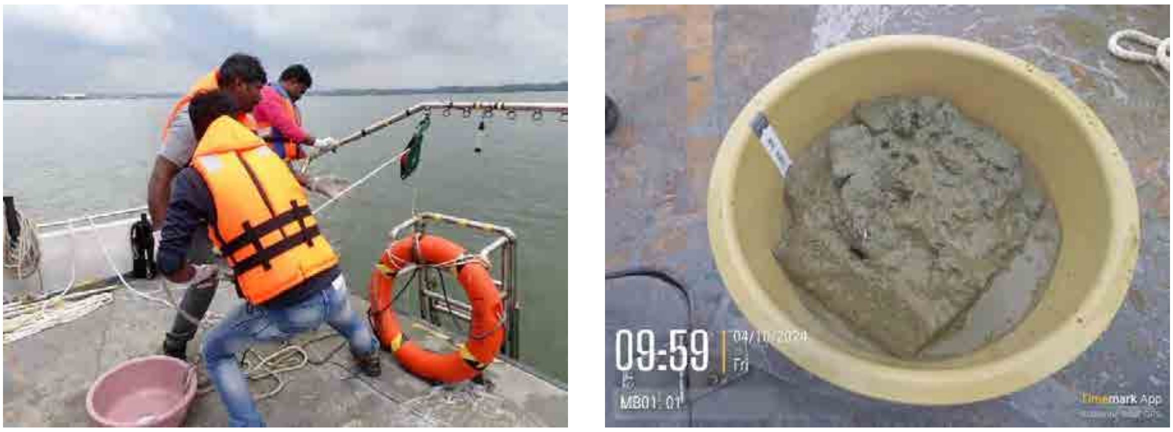



**Figure 7-27: Surveyors conducting grab sampling (left); sediment sample collected for sieving to retrieve macrobenthos samples (right)**

#### 7.8.3.2 Survey Result

The soft-bottom macrobenthos sampling was carried out along the shoreline at Pasir Ris Park and within the direct footprint on 4 October 2024. A total of 46 individual macrobenthic organisms were documented from the nine grab samples at the three survey stations within the study area, with an overall mean density of 81.13 individuals/m$^2$. Station MB03, which is the farthest from the proposed direct footprint of the proposed development, has the highest mean density of macrobenthic organisms at 95.24 individuals/m$^2$ and station MB02 has the lowest with 63.49 individuals/m$^2$ (Table 7-25).

Six soft-bottom macrobenthic classes were recorded from five phyla. Among the different classes recorded, brittle stars (Ophiuroidea) were the most abundant with a mean density of 52.91 individuals/m$^2$ and was observed at all three stations. Other macrobenthos observed were comprised of bivalves, hermit crabs, polychaetes, peanut and ribbon worms and were in a much lower density. These microbenthic species are commonly found in Singapore.

Representative photographs of the various macrobenthos classes during the baseline survey are presented in Figure 7-28.

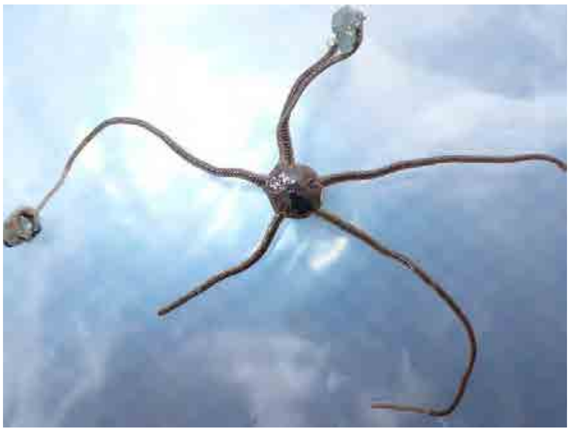
**Table 7-25: Soft-bottom macrobenthic organisms recorded within the study area**

| Phylum | Class | Density (individuals/m$^2$) | | | Mean | SD |
|---|---|---|---|---|---|---|
| | | MB01 | MB02 | MB03 | | |
| Arthropoda | Malacostraca | 5.29 | 0.00 | 5.29 | 3.53 | 7.00 |
| Annelida | Polychaeta | 0.00 | 0.00 | 15.87 | 5.29 | 15.87 |
| | Sipuncula | 0.00 | 10.58 | 0.00 | 3.53 | 7.00 |
| Echinodermata | Ophiuroidea | 63.49 | 26.46 | 68.78 | 52.91 | 42.00 |
| Mollusca | Bivalvia | 15.87 | 26.46 | 0.00 | 14.11 | 20.15 |
| Nemertea | - | 0.00 | 0.00 | 5.29 | 1.76 | 5.29 |
| **Mean** | | **84.66** | **63.49** | **95.24** | **81.13** | **53.50** |

Hermit crab (Malacostraca)

Polychaete worm (Polychaeta)

Peanut worm (Sipuncula)



Brittle star (Ophiuroidea)

Bivalve (Bivalvia)

Ribbon worm (Nemertea)

**Figure 7-28: Representative photographs of the six macrobenthos classes sampled during the baseline survey**

## 7.8.4 Plankton Assemblage

The survey locations and coordinates of the phytoplankton and zooplankton survey stations are presented in Figure 7-29 and Table 7-26 accordingly.

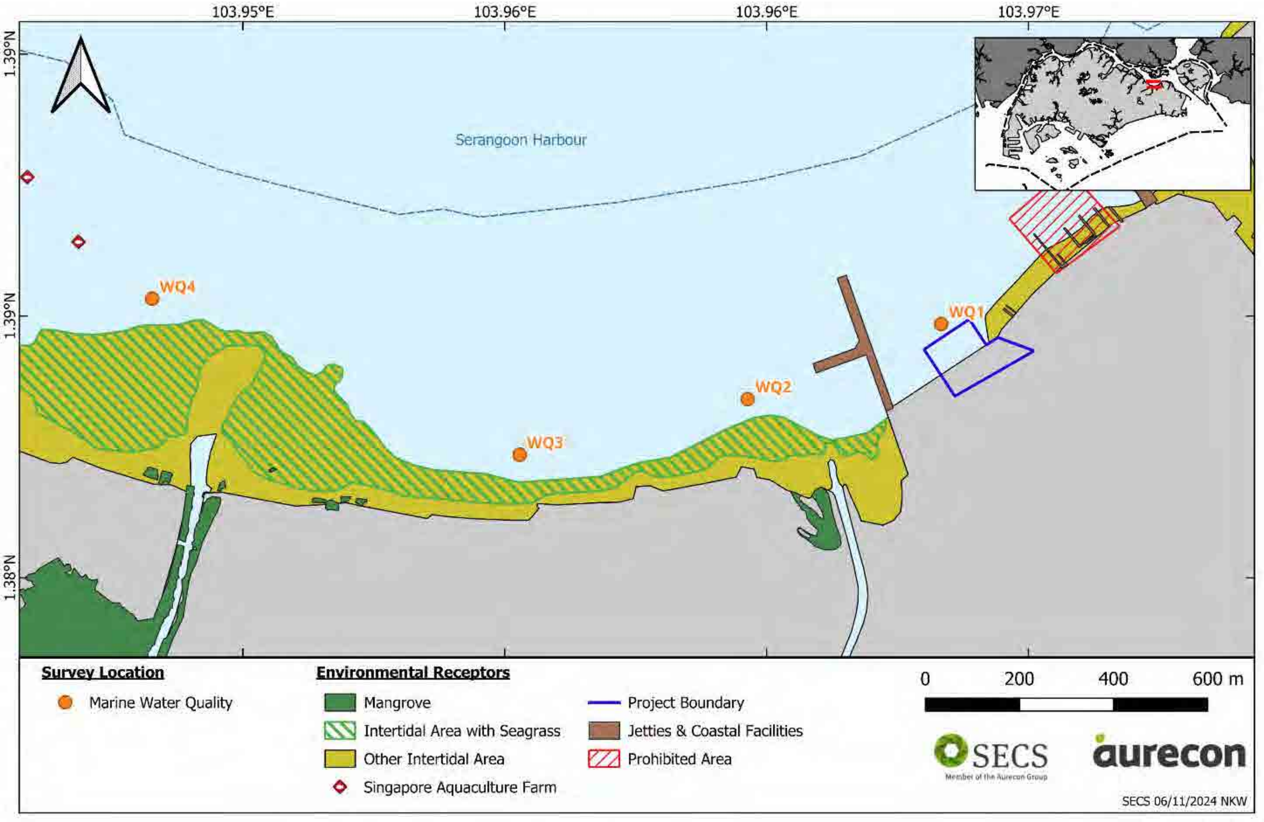



**Figure 7-29: Phytoplankton and zooplankton survey stations**

**Table 7-26: Survey coordinates of the phytoplankton and zooplankton survey stations**

| Station ID | Coordinates | | Location | Survey Date |
|---|---|---|---|---|
| | Latitude (N) | Longitude (E) | | |
| WQ01 | 1.384848° | 103.968333° | Loyang Shore Front | 3 Oct 2024 |
| WQ02 | 1.383413° | 103.964638° | Pasir Ris Beach Front | |
| WQ03 | 1.382353° | 103.960287° | | |
| WQ04 | 1.385331° | 103.953270° | | |

### 7.8.4.1 Survey Methodology

Phytoplankton samples were collected through discrete sampling at a depth of 1 meter from the water surface (Figure 7-30). The analysis encompassed both qualitative and quantitative evaluations to assess the following parameters:

- Distribution
- Composition
- Dominant genera

- Presence of potentially harmful species

Zooplankton samples were collected by vertically towing a plankton net with a mesh size of 125 µm throughout the water column, from 1 meter above the seabed to the water's surface (Figure 7-30). The collected samples were then sent for processing.

Both phytoplankton and zooplankton sampling took place at four (4) designated locations that coincide with the water quality sampling sites.

**Figure 7-30 Surveyors collecting zooplankton samples using a plankton net (left); water sample collection for phytoplankton analysis (right)**

### 7.8.4.2 Survey Result

#### 7.8.4.2.1 Phytoplankton

The phytoplankton sampling was carried out along Pasir Ris Beach and Loyang Shore Front on 3 Oct 2024. A total of five (5) phytoplankton genera from two phyla were found across the four water quality stations. Abundances of phytoplankton found were low, with a maximum of 222 cells/mL (Table 7-27). The genus *Chaetoceros* (diatoms) were the most abundant and were observed at all 4 stations. *Chaetoceros* are mostly found in marine habitats and arguably the most diverse genus of marine planktonic diatoms (De Luca et.al., 2021).

Comparing across the 4 sampling stations, WQ03 and WQ04 had the higher abundances of phytoplankton which are located further away from the proposed project footprint (Table 7-27).

**Table 7-27 Summary of phytoplankton recorded during the baseline survey**

| No. of plankton in cell/ml | | WQ01 | | WQ02 | | WQ03 | | WQ04 | |
|---|---|---|---|---|---|---|---|---|---|
| **Phylum** | **Lower Taxon** | **Flood** | **Ebb** | **Flood** | **Ebb** | **Flood** | **Ebb** | **Flood** | **Ebb** |
| Dinophyta | *Protoperidinium* sp. | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ochrophyta | *Coscinodiscus* sp. | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Chaetoceros* sp. | 200 | 70 | 217 | 201 | 105 | 195 | 197 | 204 |
| | *Rhizosolenia* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | *Skeletonema* sp. | 8 | 0 | 0 | 14 | 117 | 20 | 19 | 5 |
| **Total counted** | | **211** | **71** | **217** | **215** | **222** | **215** | **217** | **209** |

| No. of plankton in cell/ml | | WQ01 | | WQ02 | | WQ03 | | WQ04 | |
|---|---|---|---|---|---|---|---|---|---|
| Phylum | Lower Taxon | Flood | Ebb | Flood | Ebb | Flood | Ebb | Flood | Ebb |
| **No. of squares counted / µL counted** | | **200** | **200** | **200** | **116** | **63** | **87** | **105** | **103** |
| **No. of organism per 1 mL** | | **1,055** | **355** | **1,085** | **1,853** | **3,524** | **2,471** | **2,067** | **2,029** |

#### 7.8.4.2.2 Zooplankton

The zooplankton sampling was carried out along Pasir Ris Beach and Loyang Shore Front on 3 Oct 2024. A total of 3 zooplankton phyla were found during the baseline survey (Table 7-28). Mean abundance of zooplankton at each of the water quality stations ranged between 15,927 plankton/m$^3$ to 70,187 plankton/m$^3$ which are comparable to previous studies carried out within the area. Similar to phytoplankton, stations WQ03 and WQ04 had the higher abundance of zooplankton which are further away from the proposed project footprint.

Among the identified zooplanktons, majority are copepods belonging to phylum Arthropoda which are commonly observed in seawater. The copepods are mainly from various nauplii (larvae) as well as *Euterpina* and *Oithona* genera (Table 7-28).

**Table 7-28 Summary of zooplankton recorded during the baseline survey**

| No. of plankton per m$^3$ | | WQ01 | | WQ02 | | WQ03 | | WQ04 | |
|---|---|---|---|---|---|---|---|---|---|
| Phylum | Lower Taxon | Flood | Ebb | Flood | Ebb | Flood | Ebb | Flood | Ebb |
| Arthropoda | F. Paracalnidae copepod | 2,757 | 2,149 | 933 | 1,819 | 3,694 | 3,134 | 2,814 | 2,463 |
| | *Acartia* sp. | 0 | 0 | 311 | 0 | 0 | 0 | 0 | 0 |
| | *Euterpina* sp. | 3,063 | 6,089 | 5,284 | 2,729 | 16,007 | 8,507 | 8,441 | 6,567 |
| | Cirriped | 0 | 716 | 622 | 1,364 | 2,463 | 1,343 | 938 | 0 |
| | Copepod nauplii | 5,513 | 8,238 | 6,528 | 10,005 | 26,474 | 16,119 | 30,014 | 13,955 |
| | *Oithona* sp. | 1,531 | 1,433 | 5,284 | 1,819 | 7,388 | 10,299 | 9,848 | 5,746 |
| Ciliophora | Tintinnid species | 1,838 | 1,791 | 2,176 | 10,914 | 6,157 | 5,821 | 10,786 | 6,567 |
| Mollusca | Bivalve | 1,225 | 0 | 622 | 455 | 8,004 | 6,269 | 5,159 | 3,284 |
| | Gastropod | 0 | 716 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total** | | **15,927** | **21,132** | **21,759** | **29,105** | **70,187** | **51,493** | **68,001** | **38,582** |

### 7.8.5 Marine Megafauna

During the various baseline surveys carried out for this EIA, no marine mammals were observed, however, marine megafauna sightings have been observed in the vicinity of the study area from various instances. The smooth-coated otter (*Lutrogale perspicillata* - EN) has been spotted on multiple occasions (Wild Singapore, 2012). In addition, an estuarine crocodile (*Crocodylus porosus* - CR) was spotted along the intertidal area near Sungei Tampines (Ang, 2021). No actual sightings of dugongs

(*Dugong dugong* - CR) have been reported in the study area, nonetheless, dugong feeding trails have been observed along the seagrass beds at Pasir Ris (Wild Singapore, 2017).

# 7.9 Land Use, Community, and Marine Environment

## 7.9.1 Land Use and Community

The Project site is located within a Business 2 (B2) industrial zone and is surrounded primarily by industrial and port-related facilities. A review of land uses within a 2 km radius of the Project site identified several potentially sensitive receptors, including residential properties, recreational areas, educational institutions, places of worship, and healthcare facilities.

The closest sensitive land uses to the Project site include the eastern end of Pasir Ris Park and the Civil Service Club @ Loyang. These are located approximately 300 to 600 metres from the Project boundary and are zoned under the URA Master Plan for "Park" and "Sports & Recreation" use. No nature reserves or designated conservation areas were identified within 500 metres of the site.

Figure 7-31 and Table 7-29 presents a summary of receptors located within the 2 km radius of the Project. Receptors are categorised by type, including residential, recreational, civic, educational, and healthcare facilities, with their approximate distance and direction from the Project boundary noted.

**Residential Receptors**

Several residential developments are located to the west-southwest (WSW) and southwest (SW) of the Project site, including Aston Residence (0.6 km), Casa Pasir Ris (0.7 km), Ripple Bay Condominium (1.0 km), and The EdgeWater Condominium (0.6 km). A parcel of vacant land zoned for future residential use is also located approximately 0.6 km to the southwest.

**Recreational and Park Areas**

Pasir Ris Park and a future park connector are situated within 300 metres of the Project site. Other recreational features within the broader study area include Changi Beach Park (2.0 km ENE), Changi Boardwalk (0.8 km ENE), and various facilities under the Civil Service Club and Changi Beach Club umbrella, primarily situated between 0.6 km and 2.2 km east-northeast (ENE) of the Project boundary.

**Sports and Recreation Clubs**

Sports and leisure amenities near the site include the Civil Service Club @ Loyang (0.6 km WSW), Changi Sailing Club (1.2 km ENE), and various other chalets and recreational clubs located along the northeastern coastline.

**Hotels and Accommodation**

Several hotels and lodging facilities were identified within the 2 km study area, including Changi Cove (0.9 km ENE) and Village Hotel Changi (1.9 km ENE), both of which may host transient populations sensitive to construction-phase noise or visual impacts.

**Places of Worship**

Four places of worship were identified in the vicinity: Sree Ramar Temple (1.9 km ENE), Carmel Presbyterian Church (0.9 km WSW), Masjid Al-Istighfar (1.3 km SW), and Loyang Tua Pek Kong Temple (1.3 km SW). These sites typically serve a large local population and are considered moderately sensitive to air and noise disturbances.

**Healthcare Facilities**

Two nursing homes were recorded within the study area: Orange Valley Nursing Home (1.5 km ENE) and Apex Harmony Lodge Nursing Home (1.4 km SW). These facilities accommodate vulnerable groups and are therefore considered highly sensitive receptors under environmental assessment criteria.

**Civic and Educational Institutions**

The Police Coast Guard – Loyang Base is located approximately 200 metres ENE of the Project site and is the closest institutional receptor. Educational facilities include Odyssey the Global Preschool @ Loyang (0.6 km WSW) and Pasir Ris Primary School (1.2 km SW), which are considered sensitive to noise and air quality during school hours.

Overall, while the majority of receptors are located beyond the immediate construction impact zone, several sensitive land uses fall within 500 to 1000 metres of the Project boundary. These include schools, parks, residential developments, and recreational clubs.

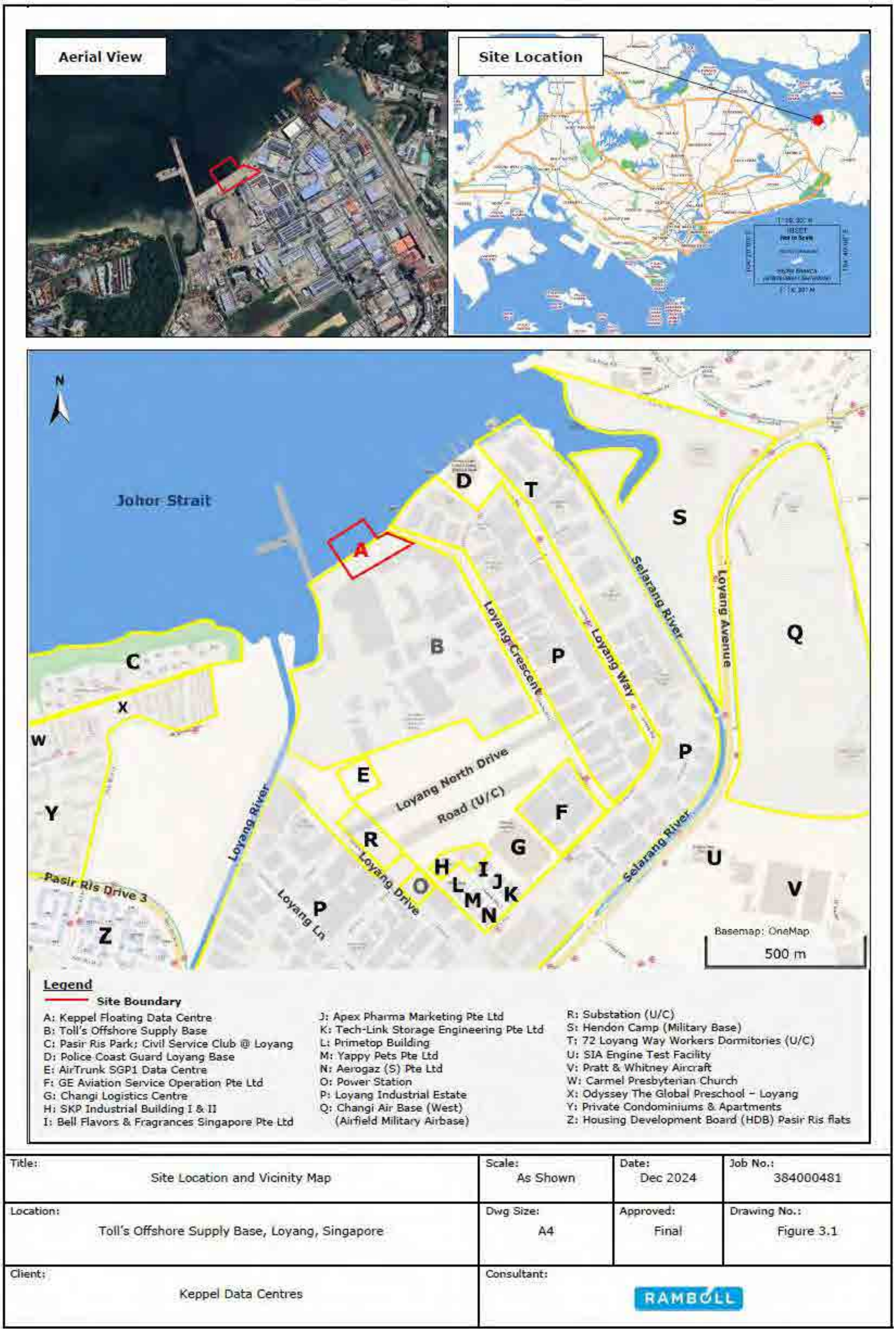



**Figure 7-31: Location of receptors within 2km radius**

**Table 7-29: List of receptors within the 2km radius**

| Receptor type | Receptor | Direction from the Project Boundary | Distant (km) |
|---|---|---|---|
| Residential | Aston Residence | WSW | 0.6 |
| | Casa Pasir Ris | WSW | 0.7 |
| | Ripple Bay Condominium | WSW | 1.0 |
| | The EdgeWater Condominium | WSW | 0.6 |
| | Vacant Land (Future Residential) | SW | 0.6 |
| Park | Changi Beach Park | ENE | 2.0 |
| | Pasir Ris Park & Future Park Connector | WSW | 0.3 |
| Sport & Recreation | Civil Service Club @Loyang | WSW | 0.6 |
| | Changi Beach Club | ENE | 0.8 |
| | Changi Sailing Club | ENE | 1.2 |
| | Changi Ferry Point Chalet | ENE | 0.7 |
| | Changi Boardwalk | ENE | 0.8 |
| | Civil Service Club @ Changi I | ENE | 1.9 |
| | Civil Service Club @ Changi II | ENE | 1.6 |
| | Changi Point Coastal Walk | ENE | 2.2 |
| Hotel | Changi Cove | ENE | 0.9 |
| | Village Hotel Changi | ENE | 1.9 |
| Place of Worship | Sree Ramar Temple | ENE | 1.9 |
| | Carmel Presbyterian Church | WSW | 0.9 |
| | Masjid Al-Istighfar | SW | 1.3 |
| | Loyang Tua Pek Kong Temple | SW | 1.3 |
| Health & Medical Care | Orange Valley Nursing Home | ENE | 1.5 |
| | Apex Harmony Lodge Nursing Home | SW | 1.4 |
| Civic & Community Institution | Police Coast Guard - Loyang Base | ENE | 0.2 |
| Educational Institution | Odyssey the Global Preschool @ Loyang | WSW | 0.6 |
| | Pasir Ris Primary School | SW | 1.2 |

### 7.9.2 Marine Environment

Marine receptors in the vicinity of the Project site included various features such as navigational routes, marine infrastructure, and water intake points. The area formed part of a commercially active marine environment, necessitating a careful assessment of potential interactions between the Project and existing marine users.

As described in Section 5, the nearest water intake facilities were associated with sea-based aquaculture farms located in Serangoon Harbour. These facilities were situated at a considerable distance from the Project site, and therefore, no direct impact was anticipated.

The local navigation network comprised harbours, fairways, anchorages, and restricted maritime zones. Key marine corridors in the study area included Serangoon Harbour and the Kuala Johor Channel. Several anchorages, namely Changi Barge Temporary Holding Anchorage, Changi General Purpose Anchorage, Man-of-War Anchorage, and Eastern Bunkering A Anchorage were identified, however, these lay outside the predicted zone of influence and were not expected to be affected by Project activities.

The jetties in closest proximity to the Project site were the Loyang Offshore Supply Base Jetty, Fugro's Jetty, and the Police Coast Guard Loyang Regional Base Jetty. These facilities were identified as sensitive receptors for the purposes of impact assessment. Other marine facilities in the surrounding area were located beyond the influence zone of the Project and were therefore expected to remain unaffected.

# 8

# Evaluation of Impacts

# 8 Evaluation of Impacts

This section outlined the environmental issues associated with the Project's construction and operational phases. The assessment identified potential short-term (construction-related) and long-term (operational) impacts arising from project activities, evaluated the magnitude of potential environmental change, and, where necessary, proposed mitigation measures to reduce or avoid environmental risks.

The following key environmental pressures and potential impacts were identified and evaluated as part of this EIA. Environmental pressures are defined as project-related activities, emissions, or stressors that may alter baseline environmental conditions and subsequently result in adverse impacts to ecological, socio-economic, or physicochemical receptors. These pressures form the foundation for the impact assessment presented in Table 8-1.

**Table 8-1: Key identified environmental pressures and potential impacts**

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

Short-term or temporary impacts are generated during the construction period when the dredging-induced sediment spill is transported and dispersed by currents and waves, generating sediment plumes which potentially can reach sensitive sites and receptors. These impacts were assessed under representative seasonal and tidal conditions using hydrodynamic and sediment plume modelling.

Long-term impacts were associated with the operation of the floating data centre, particularly the discharge of heated and chlorinated water from the cooling system. Modelling was conducted to estimate excess temperature and chlorine concentrations in the receiving waters under typical and conservative hydrodynamic conditions.

The results were interpreted through an impact evaluation framework, as described in the following sections.

## 8.1 Relevant Key Receptors

The assessment considered receptors across physical, ecological, and socio-economic domains.

### 8.1.1 Marine Receptors

The key receptors within the marine environment include:

- Physicochemical Environment
  - Water Quality
  - Sediment Quality
  - Current and water levels
- Ecological Environment
  - Intertidal habitat/ seagrass
  - Mangrove habitat
  - Marine Fauna (i.e., benthic communities, fish)
  - Plankton
  - Macrobenthos
- Socioeconomic and marine infrastructure
  - Aquaculture facilities
  - Marine navigation and facilities (i.e., jetties, water intake)
  - International Border

### 8.1.2 Human Receptors

Human receptors were identified with respect to potential air quality and noise-related impacts from the Project, both during construction and operations. These included:

- Residential Communities
- Educational Institutions
- Healthcare and Elderly Care Facilities
- Places of Worship
- Recreational Users

## 8.2 Evaluation Framework

The assessment of environmental impacts applies a standardised scoring framework to evaluate both the importance of the receptor and the magnitude of change induced by identified pressures. This standardised approach ensures comparability and coherence across the assessment of various environmental domains. Where available, tolerance thresholds or response limits specific to individual receptors have been referenced to support the scoring of impact magnitude.

The results of this evaluation contribute directly to the overall impact significance assessment using the RIAM methodology, as described in Section 4.4. This framework assessment of potential impacts, incorporating both the importance value of the receptor and the anticipated degree of change due to project activities.

### 8.2.1 Evaluation of Receptor of Importance

To assess the significance of receptors of concern for this project, a customised evaluation framework was developed. This approach draws from established environmental assessment methodologies but has been adapted to reflect the unique ecological and socio-environmental context of Singapore. The evaluation assigns levels of importance to each receptor based on criteria such as spatial distribution, ecological sensitivity, and socio-political relevance, ensuring that both environmental and stakeholder considerations are appropriately reflected in the impact assessment.

#### 8.2.1.1 Ecological Receptor

In assessing ecological receptors, the evaluation focused on key site-specific features such as biodiversity composition, habitat type, and conservation value. A tailored scoring framework was developed to reflect local ecological conditions and to ensure consistent application across the impact assessment process. This approach was informed by principles from the NParks Biodiversity Impact Assessment (BIA) Guidelines (2024) and aligned with adapted methodologies from RIAM. The evaluation framework was refined to suit the environmental setting of Singapore, recognising the varying ecological significance of natural areas. Table 8-2 outlines the receptor scoring and definitions used to categorise ecological importance across the study area.

**Table 8-2: Importance definition for ecological receptors**

| Score | Importance Definition | Customised Criteria Specific to Singapore's Ecological Context |
|---|---|---|
| 5 | Important to national/international interests | • Designated conservation areas of national or international importance, such as RAMSAR Sites, World Heritage Sites, Nature Reserves, Marine Protected Areas, and proposed heritage zones<br>• Critical water sources for daily living, including springs, swamps, lakes, and rivers<br>• Irreplaceable natural habitats supporting endemic species or species with limited distribution<br>• Areas supporting a significant number of Critically Endangered (CR) or Nationally Extinct (NEx) species listed in the Singapore Red Data Book<br>• Presence of species listed as CR, Endangered (EN), Vulnerable (VU), or Near Threatened (NT) on the IUCN Red List<br>• Ecologically sensitive sites where >10% of the habitat area is affected and no feasible alternatives for biodiversity relocation or compensation exist<br>• Ecologically sensitive benthic communities, including macrobenthos found in marine protected zones or supporting endangered species<br>• Extensive seagrass meadows or mangrove forests that serve as nurseries, shoreline stabilisers, and carbon sinks |

| Score | Importance Definition | Customised Criteria Specific to Singapore's Ecological Context |
|---|---|---|
| 4 | Important to regional/national interests | • Habitats of conservation priority, including those supporting species protected under the Wildlife Act or listed as Critically Endangered (CR) or Endangered (EN) in the Singapore Red Data Book<br>• Secondary forests or extensive natural vegetation outside protected areas that support a significant population of native species<br>• Key habitats forming part of wider ecological networks, such as mangrove-estuarine systems or intertidal zones within estuarine complexes<br>• Habitat areas with >20–30% impact within a regional ecological context, especially where species of national concern (EN/VU) are present<br>• Benthic zones with diverse macrobenthos assemblages or indicator species that contribute to regional biodiversity<br>• Mangrove-estuarine systems, tidal mudflats, or intertidal seagrass beds forming part of wider ecological networks |
| 3 | Important to areas immediately outside the local condition | • Habitats supporting Endangered (EN) and Vulnerable (VU) species listed in the Singapore Red Data Book<br>• Secondary forests or natural terrestrial vegetation outside protected areas, dominated by native species but of smaller extent or lower structural complexity<br>• Naturalised freshwater systems, such as streams or rivers with waterside vegetation, that provide local ecological functions (e.g., shelter, corridor)<br>• Areas where >30% of such habitat types are affected within the project's zone of influence, especially if contributing to local or regional biodiversity connectivity<br>• Subtidal or intertidal benthic habitats with moderate macrobenthos diversity and locally important ecological functions<br>• Small seagrass patches or fringing mangroves supporting juvenile fish or invertebrate refuge |
| 2 | Important to the local conditions (within a large direct impact area) | • Presence of species classified as Near Threatened (NT) or Least Concern (LC) in the Singapore Red Data Book<br>• Natural habitats with low biodiversity value, but potential for restoration or replacement<br>• Small patches of natural or secondary vegetation outside protected areas, with limited structural or ecological function<br>• Urban-edge vegetation or fragmented green corridors adjacent to forested or semi-natural areas<br>• Areas where >40% of the habitat is affected, but with moderate potential for ecological recovery or mitigation<br>• Macrobenthos communities dominated by pollution-tolerant species but with partial ecological function<br>• Scattered seagrass shoots or highly fragmented mangroves in non-reserve areas |

| Score | Importance Definition | Customised Criteria Specific to Singapore's Ecological Context |
|---|---|---|
| 1 | Important only to the local condition (within a small direct impact area) | • Species of no national conservation concern, commonly found across urban or disturbed environments<br>• Highly modified or degraded habitats with limited to no ecological value<br>• Common vegetation types or disturbed areas where >50% of the habitat is affected, but with minimal impact on biodiversity or ecosystem function<br>• Benthic zones with low macrobenthos abundance and dominated by opportunistic taxa<br>• Disturbed or artificial seagrass occurrences with poor coverage and resilience |
| 0 | No Importance | • Species not evaluated (NE), not listed (NL), or not applicable (NA) under the Singapore Red Data Book, and not classified as threatened under the IUCN Red List<br>• Habitats with no recognised ecological, conservation, or geographical importance, including highly urbanised or artificial environments<br>• Areas where the impact does not affect any ecologically recognised or sensitive area, and where natural features are negligible or absent<br>• No significant macrobenthos community, and absence of natural seagrass or mangrove features |

#### 8.2.1.2 Aquaculture Facilities

To assess the significance of aquaculture receptors, a receptor importance scoring system was developed based on internationally recognised EIA methodologies and adapted to Singapore's regulatory context. Table 8-3 presents the scoring criteria applied, drawing on FAO (2017), IFC Performance Standard 6 (2012), the European Commission (2016), and other guidance.

**Table 8-3: Importance definition for aquaculture facilities**

| Score | Importance Definition | Customised Criteria Specific for aquaculture facilities |
|---|---|---|
| 5 | Important to national/international interests | • Large-scale aquaculture zones contributing significantly to national food security or export economy.<br>• Facilities supporting nationally critical research, breeding programs, or species conservation.<br>• Sites designated under international development initiatives or bilateral agreements. |
| 4 | Important to regional/national interests | • Major fish farms or hatcheries supplying regional markets or forming part of national aquaculture development plans.<br>• High-investment farms with long-term leases or strategic importance to regional livelihoods.<br>• Clustered aquaculture areas supporting multiple operators or cooperative networks. |
| 3 | Important to areas immediately outside the local condition | • Medium-scale aquaculture farms serving district-level or local town demands.<br>• Facilities providing employment or economic support to surrounding communities beyond the immediate impact zone.<br>• Located in shared coastal resource zones (e.g., fishing communities, tourism corridors). |

| Score | Importance Definition | Customised Criteria Specific for aquaculture facilities |
|---|---|---|
| 2 | Important to the local conditions (within a large direct impact area) | • Small commercial aquaculture operations with localised market links and dependency.<br>• Facilities located within the project's influence zone but not dependent on sensitive species or water conditions.<br>• May experience operational stress but not critical financial or ecological disruption. |
| 1 | Important only to the local condition (within a small direct impact area) | • Subsistence-level or experimental farms with limited production volume and short-term operational planning.<br>• Sites operating intermittently or with alternative income sources.<br>• Minimal commercial value or impact to local food supply chains. |
| 0 | No Importance | • Abandoned or inactive aquaculture plots.<br>• Sites confirmed to be non-operational or excluded from marine spatial planning.<br>• No aquaculture activities in the zone of influence. |

#### 8.2.1.3 Marine Navigation and Facilities

The evaluation of receptor importance for marine facilities and navigation was based on standard definitions derived from the RIAM framework, as presented in Table 4-4. This framework provided a structured and consistent approach for assigning importance levels to receptors based on their functional role, regional relevance, and sensitivity to disturbance. The assessment considered potential impacts arising from construction activities, sediment dispersion, and the installation of marine infrastructure, including floating modules and associated intake and outfall systems.

#### 8.2.1.4 Cross Border

Cross-border receptors are classified as "Important to national or international interests" due to their transboundary relevance and potential for diplomatic, regulatory, or reputational implications. Even minor exceedances in sediment dispersion that cross jurisdictional boundaries may trigger heightened scrutiny or formal reporting obligations under international environmental cooperation agreements. As such, these receptors are assigned a high importance rating (score 5).

#### 8.2.1.5 Human Receptor

To evaluate potential impacts on human receptors in relation to air quality, noise, and sediment plume exposure, a tailored receptor importance framework was developed. It considers factors such as proximity to emission sources, exposure duration, population density, and regulatory protection status. Table 8-4 provides the scoring definitions applied for human receptors.

**Table 8-4: Importance definition for human receptors**

| Score | Importance Definition | Customised Criteria Specific to Human Receptor |
|---|---|---|
| 5 | Important to national/international interests | • Locations with national/international significance such as diplomatic zones, UNESCO sites, or major tourism areas.<br>• Residential areas near key government infrastructure or critical emergency response zones (e.g. hospitals, airports) with high occupancy and long-duration exposure<br>• Areas protected under national air/noise quality regulations or international treaties. |

| Score | Importance Definition | Customised Criteria Specific to Human Receptor |
|---|---|---|
| 4 | Important to regional/national interests | • Populated residential neighbourhoods, schools, and elderly care centres that are part of regional urban planning zones.<br>• Industrial or commercial hubs critical to national economy.<br>• Transport infrastructure hubs such as regional train/bus terminals and ports. |
| 3 | Important to areas immediately outside the local condition | • Community facilities such as parks, places of worship, or recreational areas with regular but non-intensive use.<br>• Sensitive land uses located near but not directly adjacent to impact sources.<br>• Commercial areas, mixed-use zones, or recreational facilities with moderate occupancy and regular exposure |
| 2 | Important to the local conditions (within a large direct impact area) | • Local residential areas, low-density housing, and general commercial premises located within the project's direct impact zone.<br>• Workers and users within the immediate construction or operation zone with prolonged exposure.<br>• Small residential clusters or worksites with limited occupancy or partial-day exposure |
| 1 | Important only to the local condition (within a small direct impact area) | • Isolated, low-use open areas, undeveloped land, or zones with intermittent short-term human presence.<br>• Temporary workspaces or construction laydown areas with restricted public access.<br>• Industrial zones or undeveloped land with low occupancy and infrequent exposure |
| 0 | No Importance | • Areas unoccupied or not expected to be impacted due to distance, topography, or barriers<br>• Areas with no expected human exposure to air emissions or noise (e.g. offshore zones, restricted buffer areas). |

### 8.2.2 Evaluation of Magnitude of Change

The magnitude of changes refers to the degree of alteration in physicochemical parameters or the extent of ecological and socio-economic receptor disruption arising from project-related pressures. This metric is a key component in evaluating the potential environmental impact and is used to determine the severity of change that may occur during both the construction and operational phases of the project.

#### 8.2.2.1 Ecological Receptor

The assessment of magnitude was guided by a combination of quantitative thresholds and expert judgment. Where available, numerical thresholds and legal standards were applied, while expert interpretation was used to supplement these in situations where site-specific data or standards were unavailable or incomplete.

The approach drew upon established international and national guidance, including Singapore's environmental regulatory standards, the International Finance Corporation's Performance Standard 6 (2012), the Chartered Institute of Ecology and Environmental Management's Ecological Impact Assessment Guidelines (2018), and Australia's EPBC Act Significant Impact Guidelines (2013).

Magnitude was evaluated in relation to key environmental pressures associated with the Project, such as elevated suspended sediment concentrations and sedimentation rates from dredging activities, thermal discharges from heated water, and chlorine concentrations in cooling water effluent.

**Table 8-5: Criteria for assessing magnitude of change for ecological receptors**

| Score | Magnitude of Change | Definition |
|---|---|---|
| -4 | Major impact | • Results in major population decline, local extinction, or irreversible disruption to critical life stages of species (e.g., breeding or migration).<br>• Introduction of persistent pollution, or structural habitat loss with no potential for natural recovery.<br>• Affects the entire habitat or a large proportion (>70%), resulting in permanent loss or a high likelihood of long-term decline in ecological function or biodiversity value. |
| -3 | Moderate impact | • Population-level changes or habitat disruption that are likely to recover but may require mitigation or restoration.<br>• Significant SSC, sedimentation, thermal and chlorine plume affecting the environment.<br>• Affects a significant portion of the habitat (40–70%), resulting in medium-term loss or degradation of ecosystem functions. |
| -2 | Minor impact | • Behavioural effects or physiological stress in fauna observed, but not affecting population sustainability.<br>• SSC, sedimentation, thermal and chlorine plume are slightly exceeding baseline but remain below ecological thresholds for mortality or severe disturbance.<br>• Affects a limited area of the habitat (10–40%), with short-term and reversible ecological consequences. |
| -1 | Slight impact | • No measurable change in population dynamics.<br>• SSC, sedimentation, thermal and chlorine plume slightly elevated but within natural variability.<br>• Affects a small area of the habitat (<10%), with temporary and negligible ecological consequence. |
| 0 | No Impact | • No observable impact on habitat area, species populations, or ecological functions.<br>• Environmental conditions remain within natural or background levels<br>• No measurable impact |

### 8.2.2.2 Human Receptor

To evaluate potential impacts, an impact significance framework was applied based on the magnitude, spatial extent, and duration of the predicted air quality changes.

**Table 8-6: Criteria for assessing magnitude of change for human receptors**

| Score | Magnitude of Change | Definition |
|---|---|---|
| -4 | 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. |

| Score | Magnitude of Change | Definition |
|---|---|---|
| -3 | 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. |
| -2 | 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. |
| -1 | 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.<br>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. |
| 0 | 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. |

### 8.2.3 Thresholds for Assessing Magnitude of Change

#### 8.2.3.1 Suspended Sediment Concentration (SSC) and Sedimentation

##### 8.2.3.1.1 Intertidal Habitat and Seagrass

Seagrass requires sufficient light for photosynthesis, with a minimum threshold of 10% surface irradiance (Duarte, 1991). Increased turbidity from elevated suspended solid concentration (SSC) can reduce light penetration, impacting seagrass growth. Additionally, dredging and infilling activities disturb seabed sediments, leading to sediment transport and deposition, which may degrade water quality and bury seagrass beds.

For intertidal habitats, particularly those supporting benthic organisms such as filter feeders, literature on suspended sediment and sedimentation tolerance remains limited. However, available studies indicate that sessile suspension feeders, such as sponges, are likely to be affected by fluctuations in sediment levels. Despite this, sponges exhibit adaptive capabilities, with certain species demonstrating tolerance and, in some cases, the ability to thrive in sedimented environments (Bell et al., 2015).

Given the knowledge gap regarding the tolerance of sessile suspension feeders to suspended sediments and sedimentation, seagrass is often used as an indicator of coastal ecosystem health. Seagrass habitats are widely recognized as ecosystem indicators because they integrate various environmental influences, including water quality, nutrient availability, and light penetration (Orth et al., 2006; Waycott et al., 2009). As such, changes in seagrass distribution and biomass can reflect shifts in ecosystem conditions, making seagrass a reliable biological indicator for assessing environmental impacts, particularly in response to SSC and sedimentation levels (Short, Short, & Novak, 2016).

The SSC and sedimentation thresholds relevant to seagrass and associated intertidal habitats are further detailed in the tables that follow.

**Table 8-7: Magnitude of change criteria based on SSC exposure for intertidal habitat/ seagrass**

| Severity | Definitions |
|---|---|
| No Impact | • SSC > 5mg/L for less than 20% of the time |
| Slight impact | • SSC > 5mg/L for more than 20% of the time<br>• SSC > 10mg/L for less than 20% of the time |
| Minor impact | • SSC > 25mg/L for less than 5% of the time |
| Moderate impact | • SSC > 25mg/L for more than 20% of the time<br>• SSC > 75mg/L for less than 1% of the time |
| Major impact | • SSC > 75mg/L for more than 20% of the time |

Note: The terms "Slight", "Minor", etc. in this table refer to the magnitude of change in SSC, which are then cross-referenced with the general magnitude of change criteria in Table 8-5.

**Table 8-8: Magnitude of change criteria based on sedimentation impact for intertidal habitat/ seagrass**

| Severity | Definitions |
|---|---|
| No Impact | Sedimentation < 0.25mm/day |
| Slight impact | Sedimentation < 0.63mm/day |
| Minor impact | Sedimentation <1.25mm/day |
| Moderate impact | Sedimentation < 2.50mm/day |
| Major impact | Sedimentation > 2.50mm/day |

Note: The terms "Slight", "Minor", etc. in this table refer to the magnitude of change in sedimentation, which are then cross-referenced with the general magnitude of change criteria in Table 8-5.

#### 8.2.3.1.2 Mangroves

Mangroves are generally resilient to a range of suspended sediment loads, as their intricate root systems aid in sediment trapping and stabilization. Mangroves, located at the intersection of terrestrial, marine, and freshwater environments, play a key role in trapping sediments through their complex root systems. Suspended sediments from dredging, seabed resuspension, and discharges can be transported to mangrove areas by tidal flows. While mangroves tolerate a range of sediment loads, no clear thresholds exist for sediment fluxes.

Suspended sediments generated from dredging or seabed resuspension can be transported by tidal currents into mangrove zones. Moderate sedimentation is typically beneficial, aiding in vertical accretion and helping mangroves keep pace with sea-level rise (Krauss et al., 2014). However, excessive accumulation (e.g., >10 cm for *Avicennia* sp.), may smother pneumatophores and other aerial roots, impeding gas exchange and potentially causing plant stress or mortality (Ellison, 1998; Alongi, 2002). Conversely, insufficient sediment supply can reduce nutrient availability and limit vertical growth, thereby making mangrove stands more vulnerable to erosion and sea-level rise (Field, 1995; Duke et al., 2007).

In terms of erosion, mild to moderate scouring may expose roots and affect respiration, while severe substrate loss exceeding 50–100 cm can lead to mangrove mortality. Overall, maintaining an optimal balance of sediment input is essential for the long-term viability of mangrove habitats. This balance supports not only the ecological functioning of the mangroves but also their ability to act as natural buffers against coastal erosion and water quality deterioration (UNEP, 2014; Duke et al., 2007).

#### 8.2.3.1.3 Corals

Coral reefs in Singapore are primarily found fringing the southern islands off the mainland. These ecosystems are highly sensitive to changes in water quality, particularly in relation to elevated suspended sediment concentrations and increased sedimentation rates resulting from coastal activities such as dredging and infilling.

The risk and severity of impacts on coral health are influenced by the intensity, duration, and frequency of exposure to suspended sediments. These fine particles, mainly silt and clay, can remain suspended in the water column for extended periods, especially under conditions of low turbulence. Elevated concentrations of suspended sediments reduce underwater light availability, which restricts photosynthesis and suppresses coral growth (Storlazzi et al., 2015). The degree of light attenuation within a sediment plume depends on water depth, sediment concentration, and particle characteristics such as size, composition, and optical properties.

Corals require a certain level of light irradiance to support photosynthetic processes via their symbiotic zooxanthellae. Their light requirements can vary widely by species and condition, ranging from less than 1% to 60% of surface irradiance. Similarly, coral tolerance to SSC varies according to species and reef condition. Pristine reef environments may tolerate less than 10 mg/L of SSC, whereas marginal or nearshore reefs, such as those in Singapore, have shown resilience at levels ranging between 40 mg/L and 165 mg/L (Paul et al., 2012). Coral tolerance is also affected by morphological features, including polyp and root architecture, which influence the ability to shed or resist sedimentation.

To evaluate potential effects of SSC exposure, a severity matrix is provided in Table 8-9.

**Table 8-9: Magnitude of change criteria based on SSC exposure for corals**

| Severity | Definitions |
|---|---|
| No Impact | • SSC > 5mg/L for less than 5% of the time |
| Slight impact | • SSC > 5mg/L for less than 20% of the time<br>• SSC > 10mg/L for more than 5% of the time |
| Minor impact | • SSC > 5mg/L for more than 20% of the time<br>• SSC > 10mg/L for less than 20% of the time |
| Moderate impact | • SSC > 10mg/L for more than 20% of the time<br>• SSC > 25mg/L for more than 5% of the time |
| Major impact | • SSC > 25mg/L for more than 20% of the time<br>• SSC > 100mg/L for more than 1% of the time |

Note: The terms "Slight", "Minor", etc. in this table refer to the magnitude of change in SSC, which are then cross-referenced with the general magnitude of change criteria in Table 8-5.

In addition to suspended sediments, sedimentation can also have significant effects on coral health. Excessive sediment deposition may lead to the smothering of coral polyps, impairing respiration and feeding, and potentially leading to mortality. While certain coral species can tolerate short periods of high sedimentation, prolonged exposure or complete burial can severely compromise coral function and survival. According to Erftemeijer et al. (2012), sensitive coral species may be affected in less than 24 hours, while more resilient species may withstand burial for up to 14 days or longer.

The thresholds for sedimentation impacts are summarised in Table 8-10.

**Table 8-10: Magnitude of change criteria for sedimentation impact for corals**

| Severity | Definitions |
|---|---|
| No Impact | Sedimentation < 1.7 mm/ 14day |
| Slight impact | Sedimentation < 3.5 mm/ 14day |

| Severity | Definitions |
|---|---|
| Minor impact | Sedimentation < 7.0 mm/14 day |
| Moderate impact | Sedimentation < 17.5 mm/14 day |
| Major impact | Sedimentation > 17.5 mm/ 14 day |

Note: The terms "Slight", "Minor", etc. in this table refer to the magnitude of change in sedimentation, which are then cross-referenced with the general magnitude of change criteria in Table 8-5.

Based on the baseline intertidal surveys conducted, no hard or soft corals were recorded within the established transects. While coral colonies were absent along the transect lines, occasional sightings of *Oulastrea crispata* (zebra coral) were noted opportunistically within the broader intertidal survey area. These occurrences were limited to isolated individuals in nearshore environments. Although established coral reef habitats were located approximately 8 km east of the Project site and outside the predicted thermal plume dispersion zone, this species was recognised for its resilience and adaptability to suboptimal conditions, including elevated turbidity, high sedimentation rates, and variable salinity. These traits enable it to survive and persist in harsher, modified environments (Reimer et al., 2013; Todd et al., 2010). The occurrences of *Oulastrea crispata* in the vicinity of the Project site were sparse and typically confined to artificial substrates, rather than forming part of a structured reef system. Due to their limited spatial extent, patchy distribution, and location within an industrialised coastal setting, these colonies were assessed to have low ecological sensitivity (Tun et al., 2004; Todd et al., 2010, Guest et al., 2005). This assessment is consistent with regional coral studies, which note that coral assemblages in Singapore's nearshore waters are often fragmented and dominated by stress-tolerant, opportunistic species such as *O. crispata*, particularly in areas experiencing high anthropogenic influence (Guest et al., 2005).

Nevertheless, to ensure that incidental effects on hard-substrate fauna were managed appropriately, the EIA incorporated coral-specific environmental thresholds, particularly for suspended sediment concentration and sedimentation, into the impact evaluation framework in accordance with established best practices and precautionary principles.

#### 8.2.3.1.4 Aquaculture

Fish tolerance to suspended sediment concentration (SSC) and sedimentation varies by species and environmental setting. In open-water environments, most fish tend to avoid areas with elevated SSC by relocating to clearer waters. However, in aquaculture settings, where fish are confined and unable to exhibit avoidance behaviour, elevated SSC and sedimentation can pose more direct physiological and operational risks.

Research has shown that fish begin to show behavioural changes and physiological stress at SSC levels exceeding 10 mg/L to 25 mg/L. For example, Au et al. (2004) observed that behavioural avoidance and gill irritation occurred in fish exposed to SSC greater than 10 mg/L, while Newcombe and Jensen (1996) developed a severity-of-ill-effect model indicating that SSC above 25 mg/L could result in chronic stress, and concentrations exceeding 100 mg/L could lead to sub-lethal or lethal effects, depending on exposure duration. Tetra Tech (1992) also recommended maintaining SSC below 25 mg/L for aquaculture zones, especially given the limited mobility of cultured fish.

In terms of sedimentation, the accumulation of fine sediments can smother aquaculture infrastructure and reduce water exchange, potentially leading to reduced oxygen levels and health deterioration in fish. Sedimentation exceeding 10 mm over a two-week period has been reported to impair benthic oxygen levels and disrupt farm operations (Phillips et al., 2001). The Canadian Environmental Quality Guidelines (CCME, 2002) also suggest that sediment deposition in the range of 2 mm to 6 mm over 14 days is considered conservative to avoid habitat degradation, while the UK Environment Agency (2008) has identified 7 mm to 15 mm over a similar timeframe as a threshold for potential impact to aquaculture, particularly for benthic and shellfish species.

The thresholds and severity levels used in this EIA for assessing potential impact to aquaculture receptors, specifically, SSC above 25 mg/L and sedimentation exceeding 17.5 mm over 14 days as indicators of moderate to major impact were developed based on these references. These thresholds have also been informed by regional experience in aquaculture impact assessment.

Given that the nearest aquaculture facility was located at Serangoon Harbour, approximately 2 km west of the Project site, and that modelled sediment dispersion was not expected to extend to this location, the risk of direct impact to aquaculture activities was assessed to be low.

**Table 8-11: Magnitude of change criteria based on SSC and sedimentation impacts to aquaculture facilities**

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

Note: The terms *"Slight," "Minor,"* etc., used in this table refer to the relative magnitude of change in SSC and sedimentation. A project-specific definition of "magnitude of change" was not established, instead, a generalised classification approach was adopted (Table 4-4). These magnitude categories were cross-referenced with typical thresholds used in environmental impact evaluations to guide the assessment of potential effects.

#### 8.2.3.1.5 Marine Facilities and Navigation

Incremental sedimentation within navigation channels and berthing areas was considered a key concern, as it may compromise vessel manoeuvrability and hinder marine infrastructure operations. In addition to sedimentation from dredging and infilling activities, propeller wash from vessels and other construction-related disturbances could further elevate background sedimentation levels.

To evaluate the potential severity of impact, sedimentation thresholds were established based on recognised international and regional guidelines (Doorn-Groen & Foster, 2007; PIANC, 2010). These thresholds are presented in Table 8-12.

**Table 8-12: Magnitude of change criteria for sedimentation impact for marine infrastructure**

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

| Severity | Definitions |
|---|---|
| Moderate impact | Sedimentation 300 to < 500 mm/ year |
| Major impact | Sedimentation ≥ 500 mm/ year |

Note: The terms *"Slight," "Minor,"* etc., used in this table refer to the relative magnitude of change in sedimentation. A project-specific definition of "magnitude of change" was not established, instead, a generalised classification approach was adopted (Table 4-4). These magnitude categories were cross-referenced with typical thresholds used in environmental impact evaluations to guide the assessment of potential effects.

#### 8.2.3.1.6 Recreational and Cross Border

In Singapore waters, low concentrations of suspended sediments are generally not detectable at the surface when the SSC remains below 5 mg/L (Doorn-Groen & Foster, 2007). For the purposes of this assessment, visibility thresholds were adopted for different receptor types and were assessed over a typical 12-hour daylight period to reflect realistic viewing conditions.

For recreational areas such as Pasir Ris Park, a tolerance limit of 5 mg/L for suspended sediments has been adopted, with an exceedance threshold of less than 2.5% per day during a 12-hour daylight period. Additionally, while Malaysia is located at a considerable distance, the dispersion of suspended sediments into international waters may still result in visual impacts, which are considered undesirable. To minimize potential cross-border effects, a threshold of SSC > 5 mg/L for less than 5% of a 12-hour daylight period has been adopted as a precautionary measure.

### 8.2.3.2 Current

This section examines the potential changes in current characteristics resulting from the development of the floating module and the associated intake and outfall systems. Receptors that may be affected by these changes in current dynamics include navigational and neighbouring jetties. It was also important to note that the anchorage and fairway lie outside the projected zone of impact, and therefore, no impact to these areas were anticipated.

This section assessed the potential changes in current velocity and flow dynamics resulting from the installation of the floating data centre module and its associated intake and outfall infrastructure. The evaluation focused on receptors that could be affected by altered current patterns, particularly marine facilities such as jetties, berths, and navigation channels within the vicinity of the Project site.

**Table 8-13: Adopted thresholds for current impact assessment**

| Change | Definitions |
|---|---|
| Change in current field | This metric represents the instantaneous current speed and direction at the peak ebb and flood of each tidal stage. Assessing changes in the current field was essential for identifying the formation of shear zones and eddies, which serve as key indicators of potential risks to navigation. |
| Change in mean current speeds | The mean current speed was defined as the average of current speeds (10-minute model output interval) at any given location over the 14-day peak spring-neap tidal cycle. Variations in mean current speed below 0.05 m/s were generally classified as 'No Change.' The change in mean current speed was calculated as the difference between post-construction and pre-construction speeds, providing a measure of the Project's impact on long-term current conditions. |
| Change in 95th percentile current speed | The 95th percentile current speed was the value below which 95% of the recorded current speeds fall over the 14-day peak spring-neap tidal cycle. This parameter was to assess the worst-case changes to current conditions resulting from the development. Changes in the 95th percentile current speed of less than 0.1 m/s were generally regarded as 'No Change'. |

### 8.2.3.3 Thermal Plume

The assessment of thermal plume impacts was undertaken to evaluate the potential ecological risks associated with the discharge of heated cooling water from the Project. The evaluation criteria, which were developed in consultation with the Technical Agencies are presented in Table 8-14.

Severity thresholds were derived from a combination of international scientific literature, site-specific ecological considerations, and input from regulatory authorities. These thresholds reflected the known thermal tolerances of key marine receptors in Singapore, including coral reefs, seagrass, mangrove habitats, and intertidal ecosystems, many of which were recognised to be sensitive to prolonged or elevated thermal exposure.

A temperature increase of +2°C above ambient conditions was widely recognised as the upper permissible limit in regulatory standards for thermal discharges, particularly near the point of release. This value was consistent with the ASEAN Marine Water Quality Criteria, which aimed to protect aquatic life from acute thermal stress. While this +2°C threshold was considered the compliance limit, the EIA adopted a more precautionary approach by evaluating impacts at lower thresholds (+0.5°C and +1.0°C), particularly in relation to sensitive or thermally marginal species.

**Table 8-14: Magnitude of change criteria for temperature impact to ecological receptors**

| Severity | Definitions |
|---|---|
| No Impact | • Excess temperature > 0.5°C for less than 5% of the time<br>• Excess temperature < 1.0°C at any time |
| Slight Impact | • Excess temperature ≥ 0.5°C for ≥ 5% but ≤ 10% of time<br>• Excess temperature ≥ 1.0°C for ≤ 5% of time |
| Minor impact | • Excess temperature ≥ 0.5°C for > 10% of time<br>• Excess temperature ≥ 1.0°C for > 5% but ≤ 10% of time |
| Moderate impact | • Excess temperature ≥ 1.0°C for > 10% of time<br>• Excess temperature ≥ 1.5°C at any time |
| Major impact | • Excess temperature ≥ 2°C at any time |

Note: The terms "Slight", "Minor", etc. in this table refer to the magnitude of change in excess temperature, which are then cross-referenced with the general magnitude of change criteria in Table 8-5.

#### 8.2.3.3.1 Intertidal Habitat and Seagrass

Seagrasses exhibit varying levels of thermal tolerance, influenced by location, season, and species-specific adaptations to local temperature regimes. For instance, temperate species generally have lower optimal photosynthetic temperatures compared to tropical species (Lee et al. 2007). As water temperatures approach 38°C, the efficiency of photosynthesis begins to decline due to increased photorespiration. At temperatures between 38°C and 42°C, thermal stress can inactivate oxygen-producing enzymes in Photosystem II, disrupting electron transport processes and ultimately leading to plant mortality (SeagrassWatch, 2009).

Critical thermal stress thresholds for temperate seagrasses have been reported at temperatures exceeding 35°C (Bulthuis, 1983; Ralph, 1998). Similarly, temperatures above 35°C affect mangrove root systems, seed dispersal and growth, photosynthesis, and $CO_2$ fixation (Jacotot et al., 2018). These disruptions can alter vegetation dispersion patterns and, in extreme cases, lead to heat-stress phenomena such as shifts in organism phenology and coral bleaching (Sucharit Basu et al., 2017).

Apart from seagrass, studies have shown that tropical sea sponges are also affected by temperature rise, with recent research highlighting their susceptibility to microbial shifts under thermal stress. When exposed to warmer temperatures, sea sponges lose an essential microbe, which may explain why sponge tissue dies under prolonged heat exposure. A study published in ISME Communications found that a 3°C temperature increase caused a critical microbial partner to abandon the sponge, potentially leading to tissue poisoning and mortality (UNSW, 2023). These findings suggest that sponges could serve as valuable indicators of climate-induced microbial changes, particularly in tropical marine environments.

However, seagrass provides a more established and measurable bioindicator for assessing temperature-related impacts in intertidal and coastal ecosystems. Numerous studies have demonstrated that elevated temperatures lead to reduced photosynthetic efficiency, metabolic stress, biomass decline, and seagrass die-offs, with well-documented species-specific thermal tolerance thresholds beyond which degradation occurs (Short & Neckles, 1999; Campbell et al., 2006; Waycott et al., 2007). While sponges exhibit clear responses to thermal stress, their reactions tend to be species-dependent and influenced by microbial associations, making their responses more variable compared to seagrass (Bell et al., 2018). Given this, seagrass remains as a good bioindicator for long-term ecosystem health.

For seagrass and mangroves, the EQOs define a "no impact" condition if excess temperatures exceed 0.5°C for less than 5% of the time, reflecting their sensitivity to prolonged temperature increases. This threshold was designed to ensure that the thermal plume does not exceed levels known to disrupt photosynthetic efficiency or induce stress in seagrasses and mangroves, based on established scientific evidence of their thermal tolerance limits.

#### 8.2.3.3.2 Mangroves Habitat

Mangroves also exhibited thermal sensitivity, with impacts observed at temperatures above 35°C. Elevated temperatures could impair root respiration, seed dispersal, photosynthesis, and carbon fixation (Jacotot et al., 2018). These physiological disruptions could reduce growth and reproductive success, increasing vulnerability to external stressors. A conservative temperature threshold of 0.5°C above ambient was therefore applied in the impact evaluation to safeguard mangrove resilience.

#### 8.2.3.3.3 Coral

Detailed information on coral tolerance to thermal variations remained relatively limited and indicated that thermal sensitivity was highly species-specific and context dependent. Tolerance thresholds varied considerably based on coral morphology, local acclimatisation, historical exposure to environmental stressors, and site-specific factors such as turbidity, water flow, and baseline temperature regimes (Hoegh-Guldberg, 1999; Coles & Jokiel, 1977). Coral reef ecosystems were widely recognised to be sensitive to thermal stress, with sustained increases in sea surface temperature often resulting in coral bleaching or mortality.

Based on the baseline intertidal surveys conducted, no hard or soft corals were recorded within the established transects. While coral colonies were absent along the transect lines, occasional sightings of *Oulastrea crispata* (zebra coral) were noted opportunistically within the broader intertidal survey area. These occurrences were limited to isolated individuals in nearshore environments. Although established coral reef habitats were located approximately 8 km east of the Project site and outside the predicted thermal plume dispersion zone, the presence of *O. crispata* closer to the Project footprint highlighted the species' known resilience and ecological plasticity.

*O. crispata* was known for its ecological plasticity and resilience, exhibiting tolerance to elevated turbidity, high sedimentation, and variable salinity (Lam & Morton, 2006; Zhou et al., 2017; Reimer et al., 2013). This species had also demonstrated the ability to persist in warmer waters and withstand sub-lethal thermal stress without significant bleaching, making it a reliable indicator of survivability in marginal and urbanised environments. Notably, *O. crispata* was commonly observed in intertidal zones, where it was periodically exposed to direct sunlight and aerial exposure during low tides, conditions known to result in temperature fluctuations exceeding 0.5°C above ambient.

The thermal impact thresholds adopted in this assessment aligned with both international scientific literature and regional observations. NOAA Coral Reef Watch defines coral bleaching thresholds based on Degree Heating Weeks (DHW), with significant bleaching risk occurring when temperatures exceed the Maximum Monthly Mean (MMM) by approximately +1°C for sustained periods (NOAA, 2021). Additionally, sub-lethal hyperthermal limits for corals were typically reported between +3°C and +4°C above ambient summer levels (Goldberg, 1973; Coles & Jokiel, 1977; Marcus & Thorhaug, 1981; Hoegh-Guldberg, 1999). However, given Singapore's relatively stable seasonal temperatures and already elevated ambient conditions, the assessment adopted a more conservative "low-risk" threshold of +0.5°C to +1.0°C to reflect the cumulative stress from both anthropogenic pressures and ongoing climate-related warming.

#### 8.2.3.3.4 Marine Fauna

Cooling water discharge from industrial activities can lead to localized and immediate temperature increases in aquatic environments, causing thermal pollution that impacts fish populations. While many fish species exhibit thermal avoidance behaviour, relocating to cooler waters when exposed to elevated temperatures, this can lead to habitat fragmentation and biodiversity loss near discharge points (Peterson et al., 2013).

The tolerance limits for fish in response to elevated water temperatures vary depending on species, life stage, and exposure duration. Studies indicate that most tropical and temperate marine fish species have a Critical Thermal Maximum (CTMax) ranging from 30°C to 40°C, beyond which they experience severe stress, metabolic inefficiency, or mortality (McCullough et al., 2009). Warm-water species, including reef fish and coastal species, can tolerate temperatures up to 35°C to 40°C, but prolonged exposure has been shown to reduce growth rates and reproductive success (Nguyen & Tran, 2017).

However, in this case, the proposed cooling water discharge temperature increase of only 0.5°C is well within the Singapore's NEA guideline, which allows a maximum increase of 2°C from the discharge point. In addition, the nearest fish farm is located at approximately 2 km west of the Project site. Given this considerable distance, the likelihood of direct thermal impact on the fish farm is minimal.

#### 8.2.3.3.5 Plankton

Plankton, including phytoplankton and zooplankton, are highly sensitive to temperature changes, as they lack mobility to avoid thermal stress. Studies on tropical marine ecosystems indicate that phytoplankton species in Singaporean waters typically thrive between 25°C and 32°C, with reduced photosynthetic efficiency occurring above 34°C (Boyd et al., 2013).

Similarly, most tropical zooplankton tolerate temperatures between 26°C and 34°C, but prolonged exposure beyond 35°C may lead to population declines and food web disruptions (Richardson, 2008; Chew et al., 2018).

Similarly, most tropical zooplankton were known to tolerate temperatures between 26°C and 34°C, with prolonged exposure above 35°C associated with declines in abundance, reproductive impairment, and disruptions to the pelagic food web (Richardson, 2008; Chew et al., 2018). Since plankton communities are naturally regulated by tidal mixing and water circulation, any localized temperature increase from cooling water discharge is expected to dissipate rapidly, reducing prolonged exposure.

To ensure a precautionary assessment, receptor-specific severity thresholds were applied as outlined in Table 8-14. For instance, a "no impact" classification was defined as an excess temperature greater than 0.5°C for less than 5% of the time, or where temperatures remained below 1.0°C at all times. These conditions were consistent with the natural thermal variability observed in Singapore's coastal waters and were not anticipated to impair planktonic function, productivity, or survival.

### 8.2.3.4 Chlorine Plume

The assessment of chlorine plume impacts was undertaken to evaluate the potential ecological risks associated with the discharge of chlorinated cooling water from the Project. The evaluation criteria, which were developed in consultation with the Technical Agencies, are presented in Table 8-15. Severity thresholds were derived from a combination of international scientific literature, site-specific ecological considerations, and input from regulatory authorities.

Chlorine, as a strong oxidant, can have toxic effects on aquatic organisms, particularly at elevated concentrations. When discharged into seawater, chlorine rapidly dissociates into hypochlorous acid and hypochlorite ions, both of which are harmful to marine life.

Seagrass and mangroves in the project area may be affected by chlorine exposure. However, no specific tolerance thresholds for chlorine exposure have been established for these ecosystems. Studies suggest that oxidative stress from chlorine can damage plant tissues, reduce photosynthetic efficiency, and potentially affect overall growth and ecosystem functions (Larkum et al., 2006).

On the other hand, plankton, including phytoplankton and zooplankton, are also sensitive to chlorine exposure. Their response to chlorine varies by species and concentration levels.  Studies indicate that concentrations as low as 0.02 mg/L may cause growth inhibition in some phytoplankton species (Vinitha, Veeramani, & Venugopalan, 2010). Similarly, chlorine exposure above 0.25 mg/L has been associated with reduced survival and reproductive impairment in zooplankton species Similarly, chlorine exposure above 0.25 mg/L has been associated with reduced survival and reproductive impairment in zooplankton species (Rodriguez et al., 2012). While fish sensitive to chlorine exposure, particularly due to its effects on gill function, respiration, and overall metabolism.

In the absence of site-specific chlorine toxicity thresholds for Singapore's marine ecosystems, this assessment referred to internationally recognised water quality guidelines to evaluate the potential ecological risks associated with residual chlorine discharge. Several global and regional benchmarks were reviewed as part of the evaluation.

The World Health Organization (WHO) guideline for residual chlorine in drinking water, which ranged from 0.2 to 0.5 mg/L, was considered but ultimately not adopted, as it was designed to protect human health and was not ecologically relevant for marine environments. The United States Environmental Protection Agency (USEPA) provided both chronic and acute exposure limits for the protection of aquatic life in marine waters. Specifically, the USEPA defined a chronic exposure limit of 0.0075 mg/L and an acute exposure limit of 0.013 mg/L. Similarly, the United Kingdom's marine water standard set a 95th percentile concentration of 0.01 mg/L as a general ecological protection threshold.

Of particular relevance to this study was the updated guidance provided by the Australian Marine Water Quality Guidelines, which were based on recent toxicity testing and species sensitivity distribution models. These guidelines recommended a threshold of 0.012 mg/L to protect 99% of marine species and 0.018 mg/L to protect 95% of species (Wallis and Chidgey, 2022). These values were derived specifically for marine biodiversity protection and were widely accepted in tropical and equatorial marine environmental assessments.

For this study, the threshold of 0.012 mg/L was adopted as the evaluation criterion. This value was chosen because it offered a conservative and ecologically protective benchmark suitable for the diverse and sensitive marine organisms present in Singapore's waters.

Although Singapore's National Environment Agency (NEA) allowed a maximum free chlorine concentration of 1 mg/L at the point of discharge, this regulatory limit applied to the effluent itself and did not reflect conditions in the receiving environment after dilution and dispersion. Therefore, the lower 0.012 mg/L threshold was applied in this EIA to assess potential ecological effects at the exposure site rather than the discharge outlet.

**Table 8-15: Magnitude of change criteria for chlorine impact to biological and ecological**

| Severity | Definition |
|---|---|
| No Impact | • Excess chlorine < 0.012 mg/L at any time |
| Slight Impact | • Excess chlorine ≥ 0.012 mg/L but < 0.018 mg/L for ≤ 20% of the time |
| Minor impact | • Excess chlorine ≥ 0.012 mg/L but < 0.018 for > 20% of the time<br>• Excess chlorine ≥ 0.018 mg/L but <0.03 mg/L for ≤ 20% of the time |
| Moderate impact | • Excess chlorine ≥ 0.018 mg/L but < 0.03 mg/L for > 20% of time<br>• Excess chlorine ≥ 0.030 mg/L but <0.05 mg/L for ≤ 20% of the time |
| Major impact | • Excess chlorine ≥ 0.030 mg/L for > 20% of the time<br>• Excess chlorine ≥ 0.05 mg/L at any time |

Note: The terms "Slight", "Minor", etc. in this table refer to the magnitude of change in excess chlorine concentration, which are then cross-referenced with the general magnitude of change criteria in Table 8-5..

### 8.2.3.5 Air Quality

For air quality, magnitude of change was assessed by comparing the Predicted Contribution (PC) of each pollutant to the Ambient Air Quality Targets (AAQTs) published by the National Environment Agency (NEA). The thresholds used to classify the magnitude of change are presented below:

**Table 8-16: Thresholds for assessing magnitude of change for air quality**

| Magnitude of Change | Definition | Description |
|---|---|---|
| No Impact | PC < 5% of AAQT | Negligible contribution; below model uncertainty |
| Slight Impact | PC = 5 to 25% of AAQT | Minor contribution; unlikely to cause perceptible change |
| Minor impact | PC = 26 to 50% of AAQT | Moderate contribution; potential for cumulative interaction |
| Moderate impact | PC = 51 to 100% of AAQT | High contribution; approaching regulatory thresholds |
| Major impact | PC > 100% of AAQT | Exceedance; may trigger compliance or mitigation requirements |

### 8.2.3.6 Noise Quality

For noise, magnitude of change was evaluated by comparing predicted Project-contributed boundary noise levels with the maximum permissible noise limits outlined in the Environmental Protection and Management (Boundary Noise Limits for Factory Premises) Regulations.

**Table 8-17: Thresholds for assessing magnitude of change for noise quality**

| Magnitude of Change | Definition | Description |
|---|---|---|
| No Impact | Predicted level is <90% of the permissible limit | Noise levels well within compliance; no adverse effect |
| Slight Impact | 90 to 100% of permissible limit | Approaching limit; potential concern under worst-case scenario |
| Minor impact | 101 to 110% of permissible limit | Slight exceedance; may cause perceptible impact at receptors |
| Moderate impact | 111 to 125% of permissible limit | Clear exceedance; likely to be noticed and require mitigation |
| Major impact | >125% of permissible limit | Significant exceedance; high likelihood of adverse impact |

# 9

# Modelling and Impact Assessment

# 9 Modelling and Impact Assessment

The section assesses the potential environmental effects of the proposed Project on the surrounding environment. To understand the potential impacts, numerical simulations and modelling tools were utilized to predict and quantify the environmental changes resulting from the Project. This includes evaluating both short-term effects, such as sediment plumes from dredging, and long-term impacts, such as thermal and chlorine plumes from the cooling system during operation, as well as air and noise-related impacts.

***Coastal and Water Quality Dynamic***

The coastal environment is influenced by natural processes occurring over various temporal and spatial scales. Any alterations to the existing marine environment can potentially disrupt these coastal dynamics. Therefore, numerical simulations were required to predict, quantify, and assess these impacts. By modelling changes over relevant temporal and spatial scales, these simulations were essential for evaluating both potential long-term and short-term effects.

The proposed Project involves dredging to a depth of -7 mCD around the FDCM. The potential impacts of dredging activity were mainly related to sediment plumes and the incremental increase in suspended sediment concentrations in the marine environment. The impacts associated with these activities were anticipated to be short-term and temporary, confined to the duration of the dredging works.

Additionally, the installation of spud piles will permanently secure the prefabricated FDCM, with the structure's hull partially submerged. As the module is permanently moored, it is expected to influence the local current conditions, potentially causing localized changes to the current flow in the surrounding area.

During operation, a cooling water system, comprising an intake and outfall, is required to support the facility's cooling processes. The system circulates water to manage thermal loads, with anti-fouling agent added to control marine growth. Water will be drawn from the surrounding environment through an intake positioned at a depth of 2.5m below the water surface and subsequently discharged back into the marine environment via an outfall located at a depth of 1m below the water surface. These heated and chlorinated water discharge impacts are expected to be long-term or permanent throughout the operational life of the facility. No additional industrial discharges are expected apart from those associated with the cooling water system. The evaluation of impacts during the operational phase focuses on analyzing the dispersion patterns of temperature and chlorine in the surrounding waters to assess their potential environmental implications.

In summary, the impacts associated with the Project development include:

- Currents (Hydrodynamics)
- Sediment Plume
- Thermal Plume
- Chlorine Plume

The following simulation tools were applied to determine the impacts to the receptors and the details of the model setup can be found in Appendix G. The evaluation of the impacts was based on adopted criteria, with model results post-processed and compared against these thresholds. The extraction of values at specific receptor locations was carried out as required, based on discussions with the agencies.

**Table 9-1: Numerical model simulation tools**

| Item | Model Used |
|---|---|
| Current (hydrodynamics including thermal dispersion) | MIKE3 Flow Model FM – Hydrodynamic module |
| Sediment plume & sedimentation | MIKE3 Flow Model FM – Mud Transport module |
| Water Quality (chlorine) | MIKE3 Flow Model FM – Transport module |

***Air Modelling***

Air dispersion modelling is carried out to assess the dispersion of air emissions from potential sources using American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD).

The only potential source of air emission during operation of the FDCM is identified as the emergency gensets that will release air pollutants. Air emissions from the generators will consist primarily of $NO_X$, and, to a lesser extent, HC, CO and PM as combustion products from the facility's diesel-fired emergency generators.

Section 9.8 presents the summary impact assessment of air dispersion model and mitigation measures required. Detailed assessment methodology, model setup and results are attached in Appendix J.

***Noise Modelling***

Noise modelling is carried out to predict the noise propagation from the Project to the surrounding environment using CadnaA (Computer Aided Noise Abatement).

The potential source of air emission during operational phase of the FDCM are identified and modelled, including emergency standby gensets, exhaust flues, load bank, transformers, pumps and chillers.

Section 9.9presents the summary impact assessment of noise model and mitigation measures required. Detailed assessment methodology, model setup and results are attached in Appendix J.

## 9.1 Current

The construction of the FDCM, along with the associated intake and outfall systems, may potentially lead to long-term changes in local current conditions. To assess these potential impacts, a current impact assessment was conducted using a calibrated and validated MIKE 3 Hydrodynamic (HD) model.

### 9.1.1 Simulation Scenarios

The project site is situated in a sheltered environment where nearshore currents are predominantly influenced by local wind conditions. To capture potential current scenarios, simulations were carried out over a 14-day peak spring-neap cycle, reflecting the typical conditions of each monsoon period:

- Southwest Monsoon: 1 Jul 2023 to 15 Jul 2023
- Northeast Monsoon: 9 Dec 2023 to 23 Dec 2023
- Inter-monsoon: 1 Apr 2023 to 15 Apr 2023

The pre-construction and post-construction simulations account for the influence of the proposed intake/outfall and piles. The hydrodynamic assessment includes three (3) model scenarios for each monsoon period to evaluate potential changes associated with varying intake and outfall operations. The cooling system (Figure 2-2) will consist of one outfall and two intake points. The cooling system is designed to include one outfall and two intake points. Under normal operating conditions, both intake points will function simultaneously, with each operating at 50% capacity. However, during maintenance activities, one intake point will operate at 100% capacity while the other is offline. The following scenarios are considered for the current modelling:

- Scenario 1: Outfall operates at 4,800 $m^3/hr$ with two intakes, each drawing 2,400 $m^3/hr$ from the left and right intake points
- Scenario 2: Outfall operates at 4,800 $m^3/hr$ with a single intake on the left side drawing 4,800 $m^3/hr$.
- Scenario 3: Outfall operates at 4,800 $m^3/hr$ with a single intake on the right-side drawing 4,800 $m^3/hr$.

These scenarios aim to assess the environmental effects under different discharge conditions to determine potential changes in current patterns.

### 9.1.2 Receptors of Concern

This section examines the potential changes in current characteristics resulting from the development of the floating module and the associated intake and outfall systems. Receptors that may be affected by these changes in current dynamics include navigational and neighbouring jetties. It was also important to note that the anchorage and fairway lie outside the projected zone of impact, and therefore, no impact to these areas were anticipated.

### 9.1.3 Adopted Evaluation Criteria

The quantification of current impacts resulting from the development of the floating module and its associated intake and outfall systems is presented in the following sections. The assessment criteria adopted for evaluating the current field, including the mean current speed and the 95th percentile values, are detailed in Section 8.2.3.2, Table 8-13.

### 9.1.4 Result and Discussion

The quantification of the current impacts is presented as:

- Current field
- Mean current speed
- 95th percentile current speed
- Time series current speed, current direction, and water level

#### 9.1.4.1 Current Field

The overview of current field at peak ebb tide and flood tide during Southwest Monsoon, Northeast Monsoon, and Inter-monsoon for the pre-construction and post-construction phase for the three (3) scenarios are presented in Figure 9-1, Figure 9-2, and Figure 9-3 respectively.

During the Southwest Monsoon, the current patterns indicated by the current vectors within the Project area for both pre-construction and post-construction conditions across Scenario 1, 2, and 3, were similar for both peak and ebb tides. Similarly, during the Northeast Monsoon and Inter-monsoon, the current patterns for pre-construction and post-construction cases remain consistent across all scenarios for both peak and ebb tides.

There were no observed changes in currents along Serangoon Harbour, and no eddies form around the proposed data centre intake, outfall, or pile. It is predicted that the relatively small flow rate of intake and outfall compared to large tidal flow does not cause significant changes across the different scenarios. As the anchorage and fairway lie outside the projected zone of impact, no adverse changes are anticipated in the anchorage and fairway.

In summary, no changes in current field were observed between the pre-construction and post-construction phases, and no impact on navigation in the area was expected.

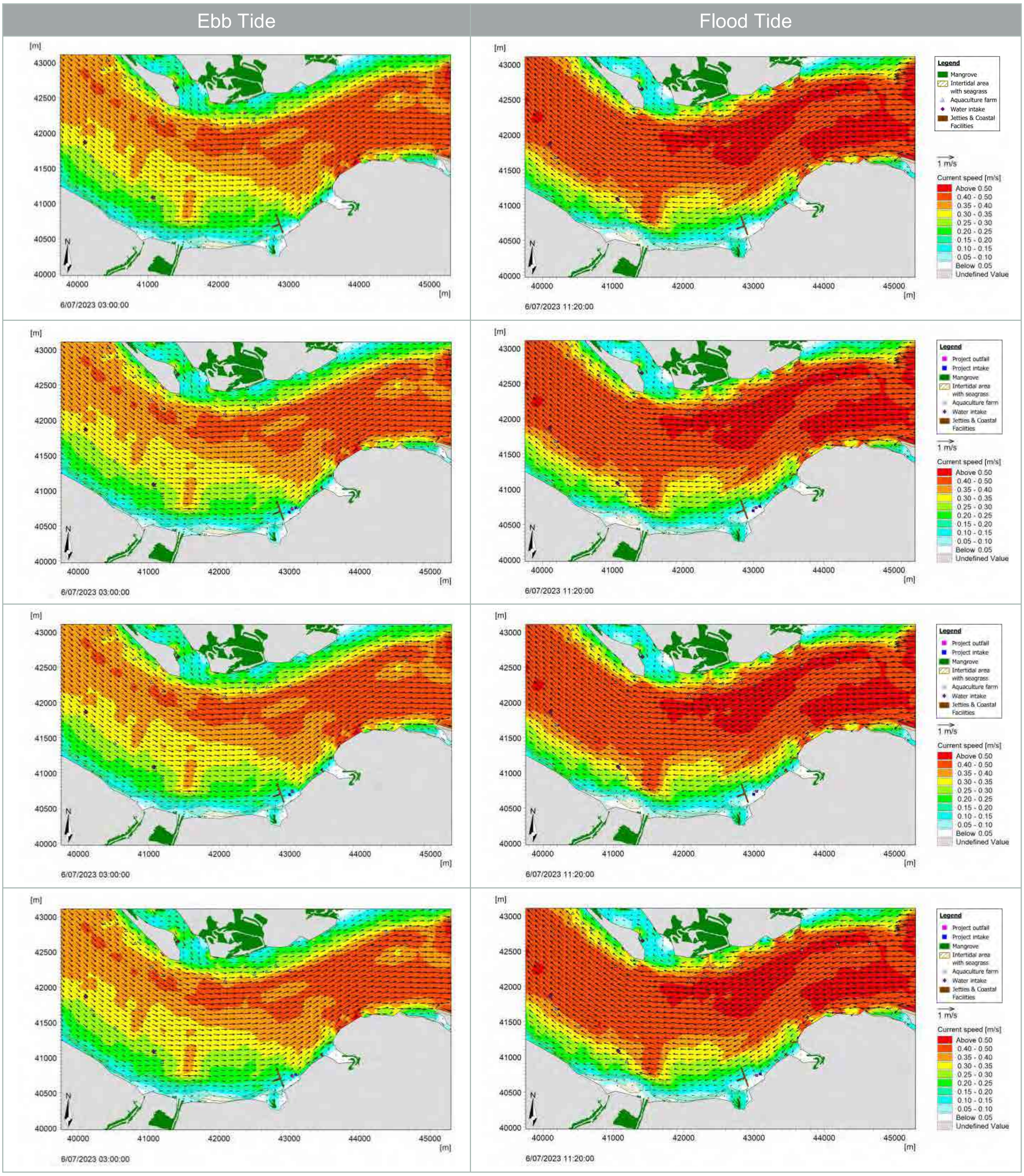



**Figure 9-1: Overview of current at peak ebb and flood tide during Southwest Monsoon for the pre-construction (top), post-construction stage – scenario 1 (second row), post-construction stage – scenario 2 (third row), post-construction stage – scenario 3 (bottom)**

| Ebb Tide | Flood Tide |
|---|---|

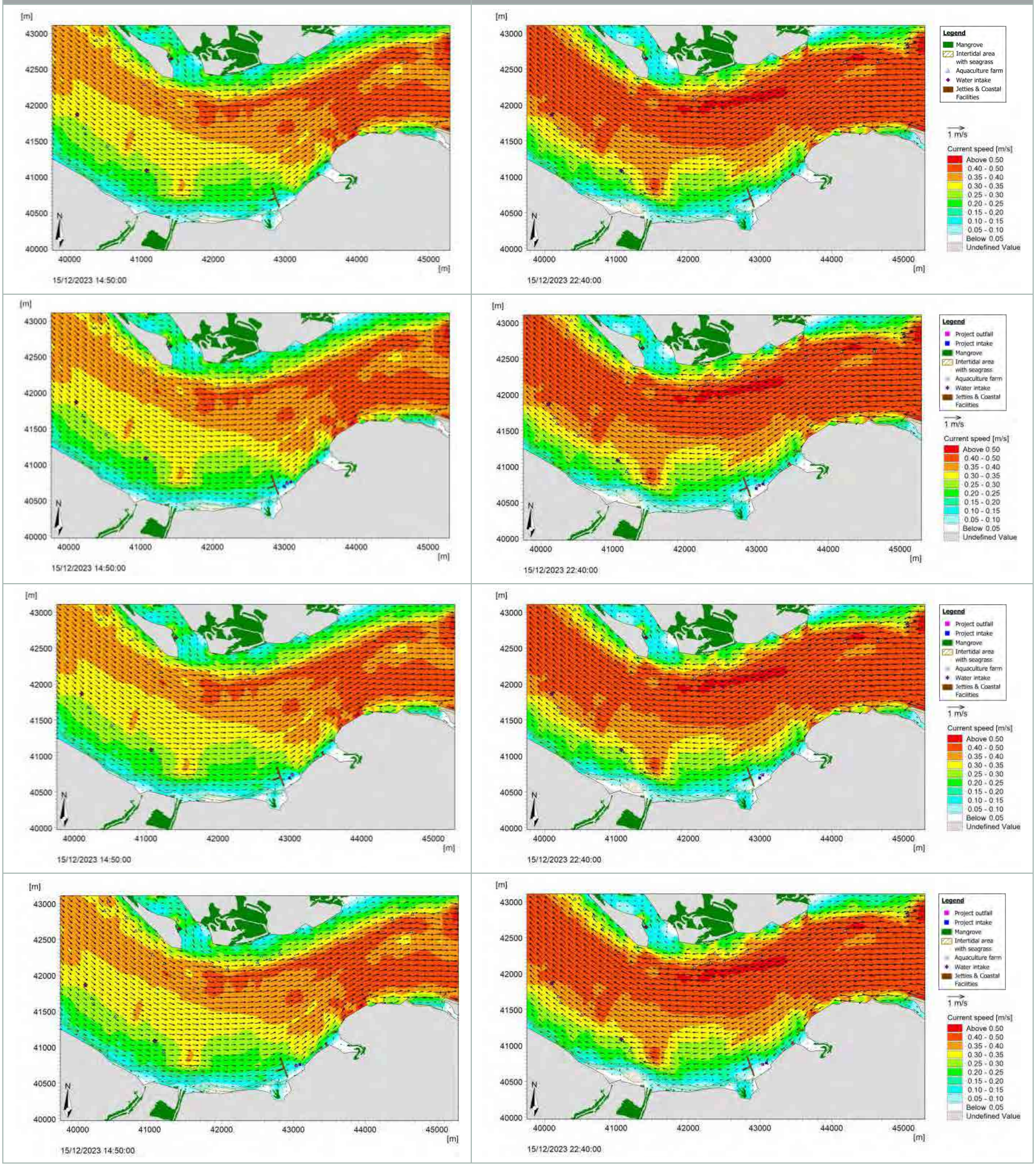



**Figure 9-2: Overview of current at peak ebb and flood tide during Northeast Monsoon for the pre-construction (top), post-construction stage – scenario 1 (second row), post-construction stage – scenario 2 (third row), post-construction stage – scenario 3 (bottom)**

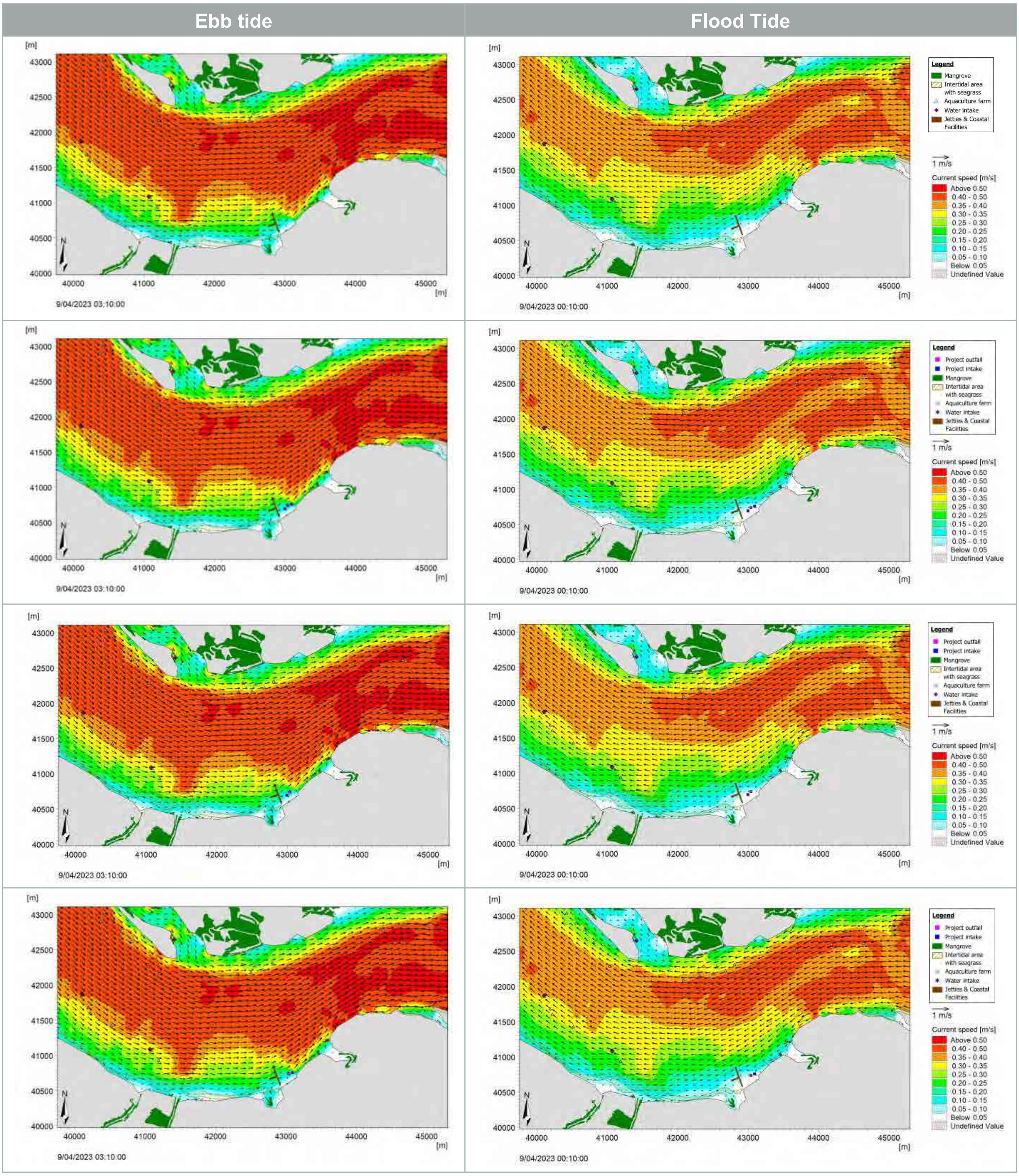



**Figure 9-3: Overview of current at peak ebb and flood tide during Inter-monsoon for the pre-construction (top), post-construction stage – scenario 1 (second row), post-construction stage – scenario 2 (third row), post-construction stage – scenario 3 (bottom)**

#### 9.1.4.2 Mean Current Speed

Figure 9-4, Figure 9-5, and Figure 9-6 provide an overview of the mean current speeds observed during the Southwest Monsoon, Northeast Monsoon, and Inter-monsoon periods, respectively. The figures compared pre-construction, post-construction phases, and the changes in mean current speed across the three modelled scenarios. In this analysis, the 'change in mean' refers to the difference in mean current speeds between the pre- and post-construction phases.

During the pre-construction phase, mean current speeds around the Project footprint typically ranged from 0.02 m/s to 0.07 m/s, regardless of monsoon conditions. Given the sheltered nature of the Project site, the current speeds remained relatively low throughout the different monsoon period. The highest mean current speeds were recorded along Serangoon Harbour, with speeds up to 0.26 m/s, irrespective of monsoon conditions.

Following the completion of the development (post-construction), an increase in mean current speed was observed in the immediate vicinity of the floating structure, with the highest mean current speed increase recorded at 0.01 m/s. This increase in current speed was attributed by partially submerged hull of the structure within the Project footprint, which facilitates increased flow velocities under the floating structure. These changes in current speed may potentially lead to local scour at the FDCM’s base. To mitigate this risk, engineering measures such as scour protection, reinforced foundations, or sediment management strategies may be recommended to ensure stability and minimize long-term maintenance needs.

However, these changes were considered localized impacts, and the post-construction current speeds exhibit similar values to those observed prior to construction (pre-construction). This indicates "no change" in mean current speed to marine facilities or marine navigation structures as a result of the installation of the floating data centre. Similar findings were observed across all monsoon periods.

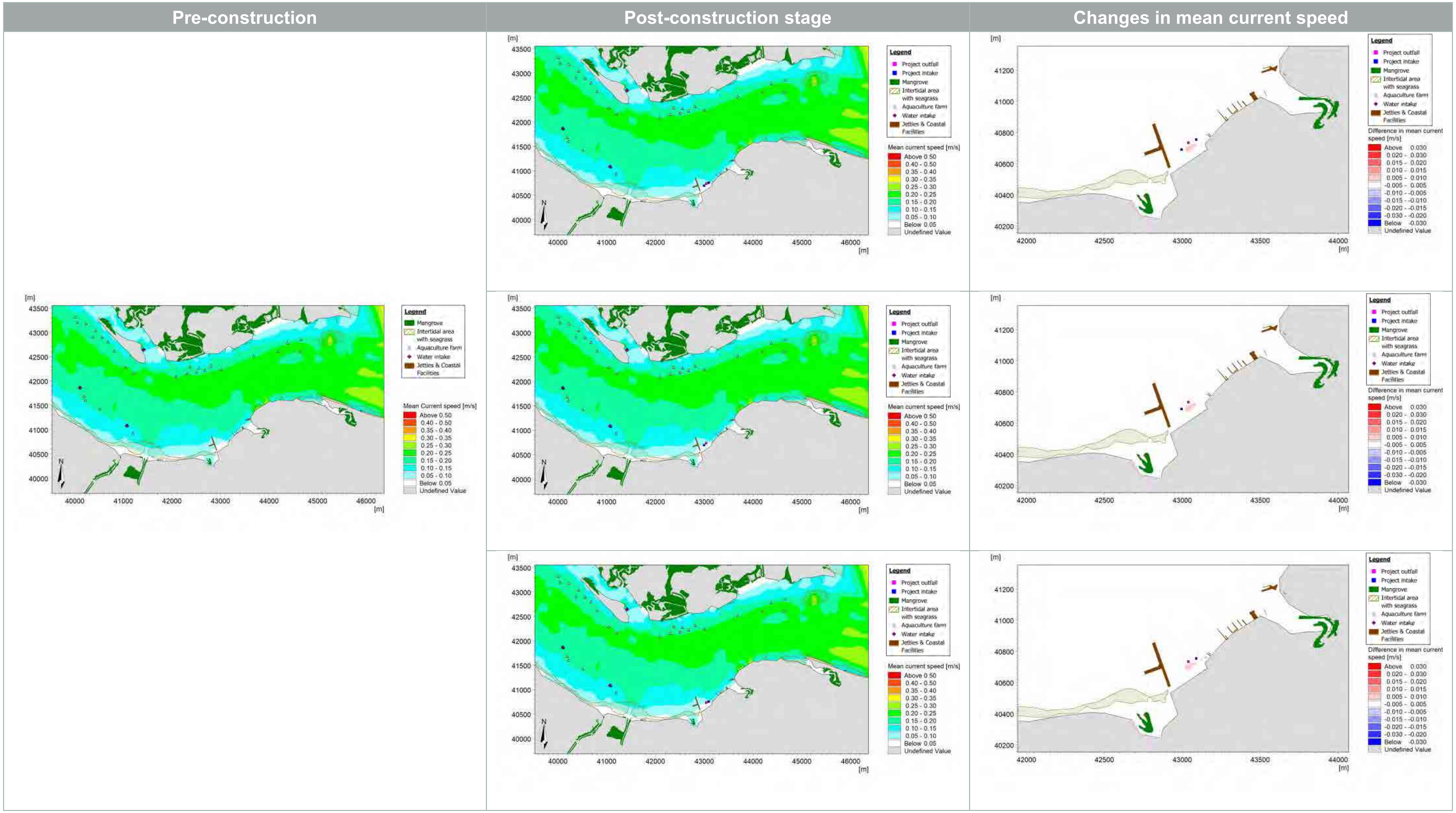



**Figure 9-4: Overview of mean current speed during Southwest Monsoon for the pre-construction, post-construction stage, and changes in mean current speed for scenario 1 (top), scenario 2 (middle), and scenario 3 (bottom)**

| Pre-construction | Post-construction stage | Changes in mean current speed |
|---|---|---|

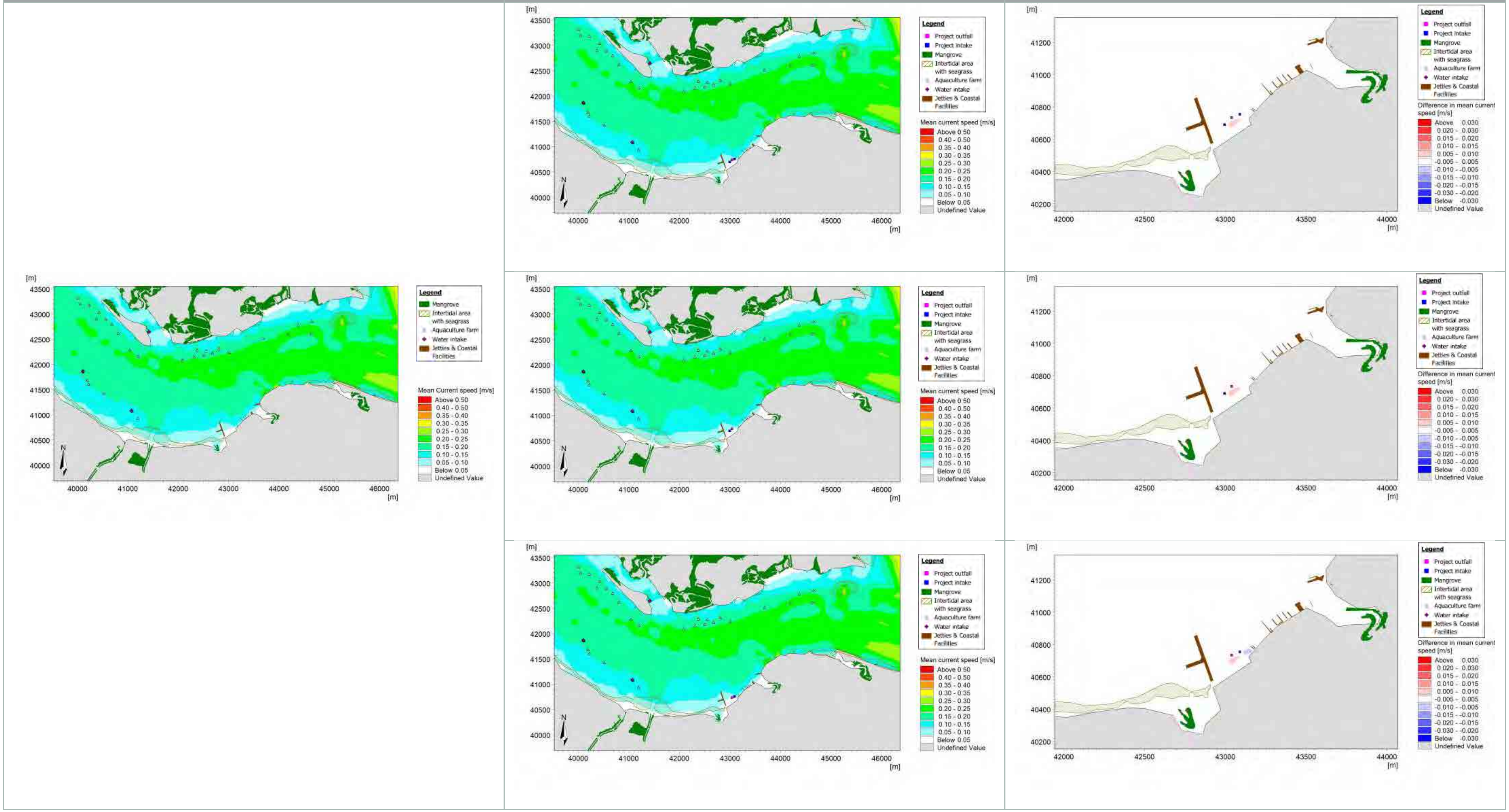



**Figure 9-5: Overview of mean current speed during Northeast Monsoon for the pre-construction, post-construction stage, and changes in mean current speed for Scenario 1 (top), Scenario 2 (middle), and Scenario 3 (bottom)**

| Pre-construction | Post-construction stage | Changes in mean current speed |
|---|---|---|

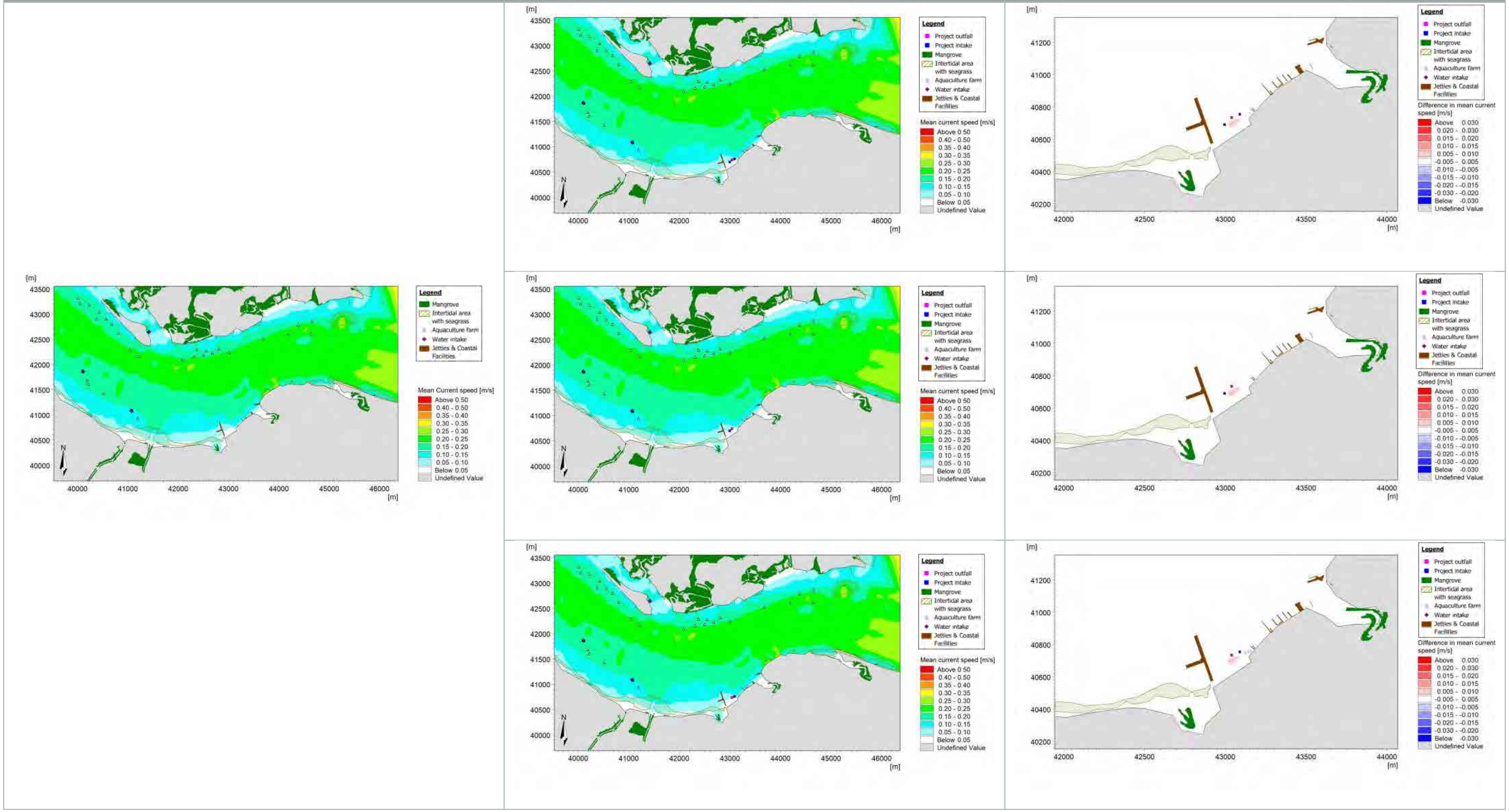



**Figure 9-6: Overview of mean current speed during Inter-monsoon for the pre-construction, post-construction stage, and changes in mean current speed for Scenario 1 (top), Scenario 2 (middle), and Scenario 3 (bottom)**

#### 9.1.4.3 95th Percentile Current Speed

Figure 9-7, Figure 9-8 and Figure 9-9 provide an overview of the 95th percentile current speeds observed during the Southwest Monsoon, Northeast Monsoon, and Inter-monsoon periods, respectively. The figures compared pre-construction, post-construction phases, and the changes in 95th percentile current speed across the three modelled scenarios. In this analysis, the 'change in 95th percentile' refers to the difference in 95th percentile current speeds between the pre- and post-construction phases.

During the pre-construction phase, 95th percentile current speeds around the Project footprint typically ranged from 0.04 to 0.13 m/s, regardless of monsoon conditions. Given the sheltered nature of the Project site, the current speeds remained relatively low throughout the different monsoon period. The highest 95th percentile current speeds were recorded along Serangoon Harbour, with speeds up to 0.47 m/s, irrespective of monsoon conditions.

Following the completion of the development (post-construction), an increase in 95th percentile current speed was observed in the immediate vicinity of the floating structure, with the highest 95th percentile current speed increase recorded at 0.03 m/s. This increase in current speed was attributed by partially submerged hull of the structure within the project footprint, which facilitates increased flow velocities under the floating structure. These changes in current speed may potentially lead to local scour at the FDCM's base. To mitigate this risk, engineering measures such as scour protection, reinforced foundations, or sediment management strategies may be recommended to ensure stability and minimize long-term maintenance needs.

However, these changes are considered localized impacts, and the post-construction current speeds exhibit similar values to those observed prior to construction (pre-construction). This indicates "no change" in 95th percentile current speed to marine facilities or marine navigation structures as a result of the installation of the floating data centre. Similar findings were observed across all monsoon periods.

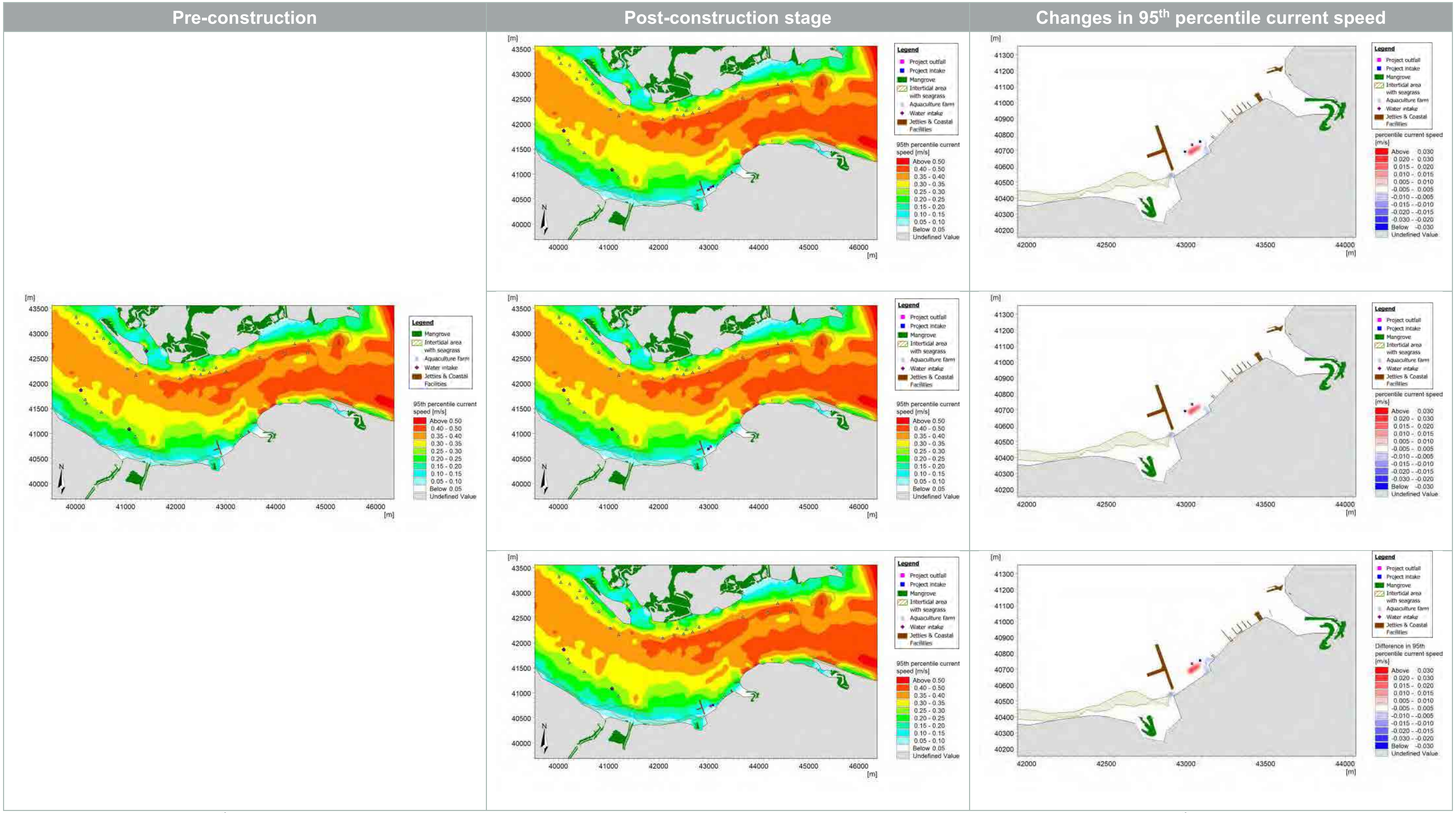



**Figure 9-7: Overview of 95th percentile current speed during Southwest Monsoon for the pre-construction, post-construction stage, and changes in 95th percentile current speed for Scenario 1 (top), Scenario 2 (middle), and Scenario 3 (bottom)**

| Pre-construction | Post-construction stage | Changes in 95th percentile current speed |
| --- | --- | --- |

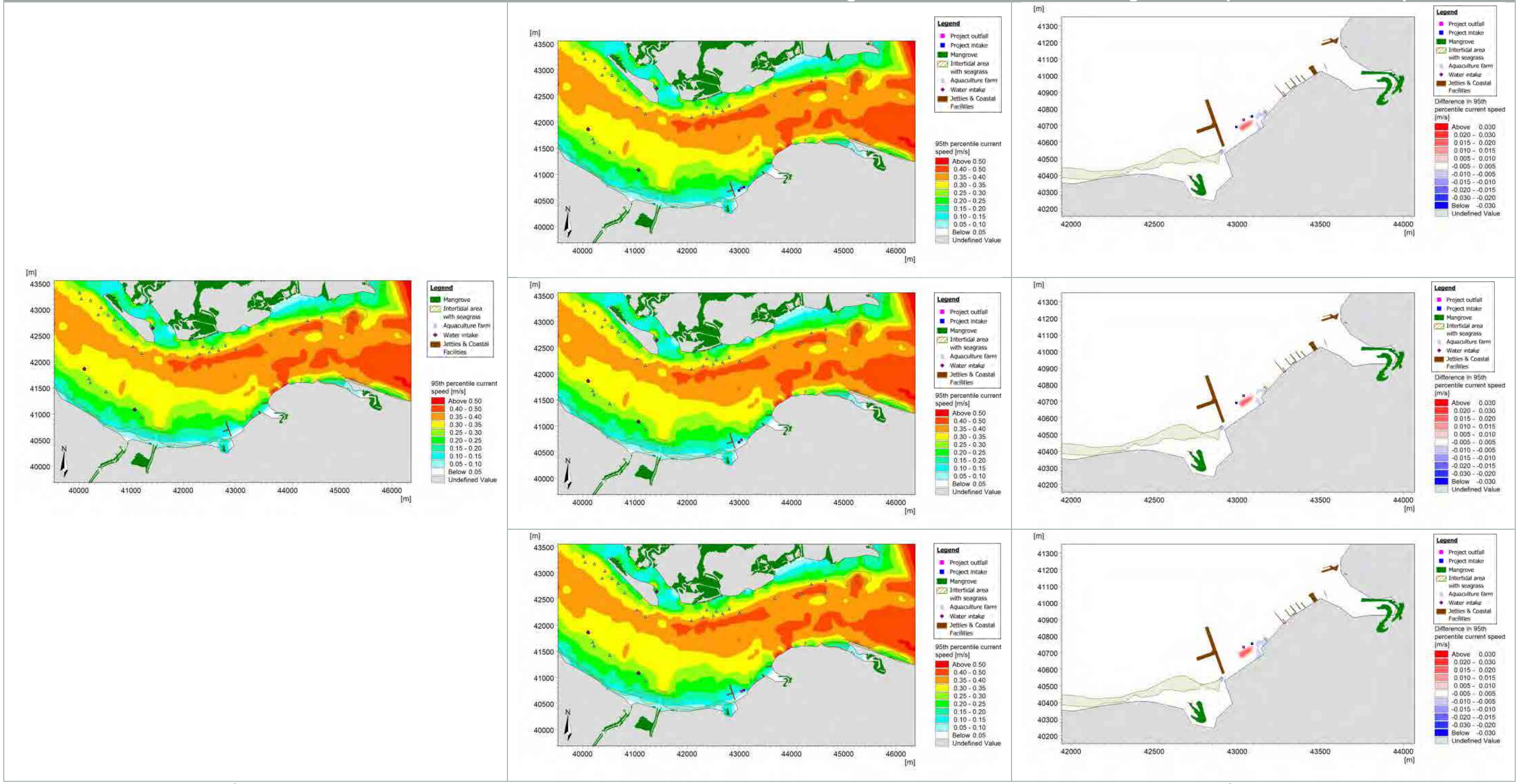



**Figure 9-8: Overview of 95th percentile current speed during Northeast Monsoon for the pre-construction, post-construction stage, and changes in 95th percentile current speed for Scenario 1 (top), Scenario 2 (middle), and Scenario 3 (bottom)**

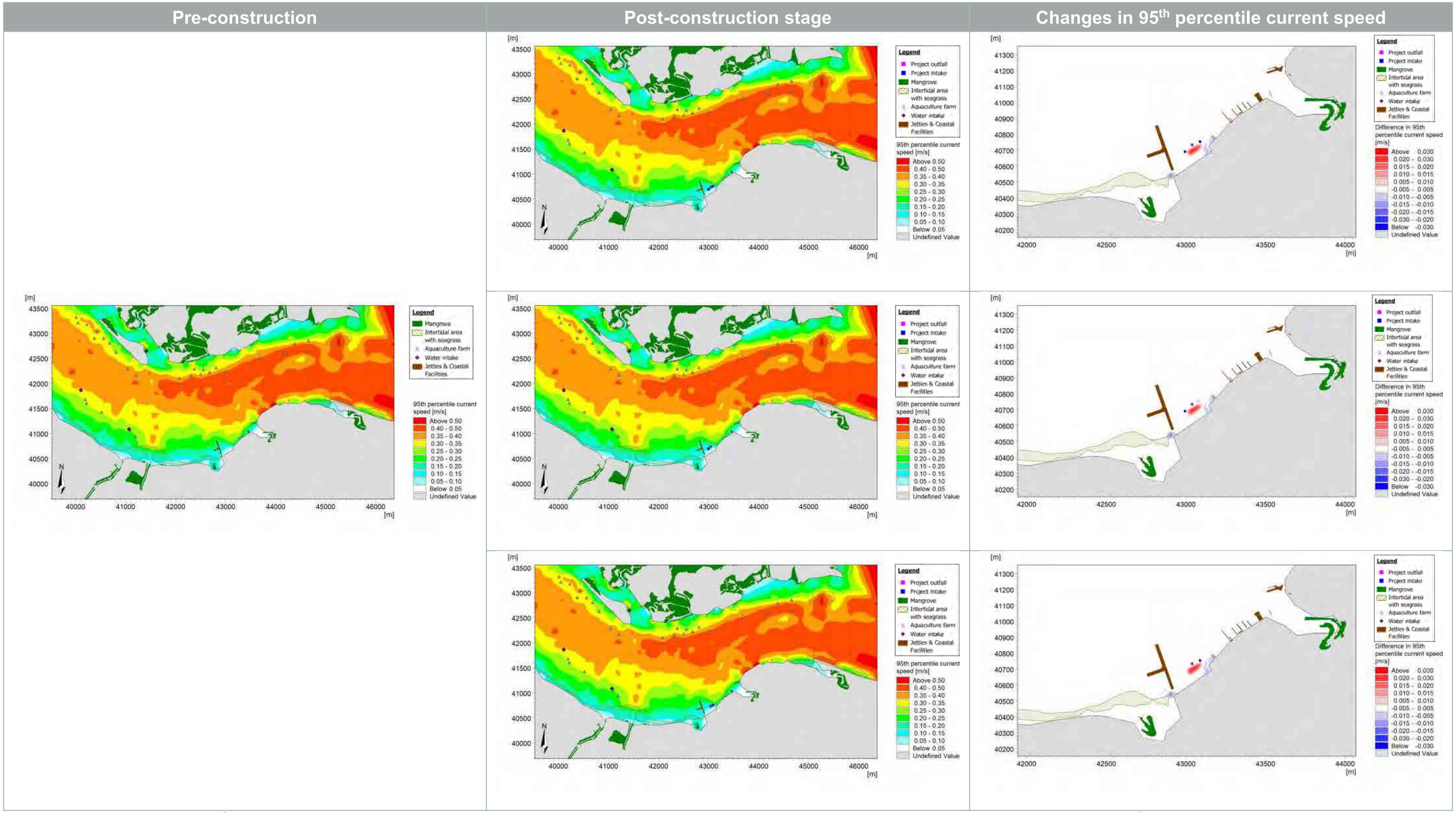



**Figure 9-9: Overview of 95th percentile current speed during Inter-monsoon for the pre-construction, post-construction stage, and changes in 95th percentile current speed for Scenario 1 (top), Scenario 2 (middle), and Scenario 3 (bottom)**

### 9.1.4.4 Time Series Current Speed, Current Direction, and Water Level

The current speed, direction, and water level have been assessed for the pre-construction and post-construction phase at selected location as illustrated in Figure 9-10 and Table 9-2. These locations were selected considering the sensitivity of these receptors to current behaviour within the proximity to the Project footprint.

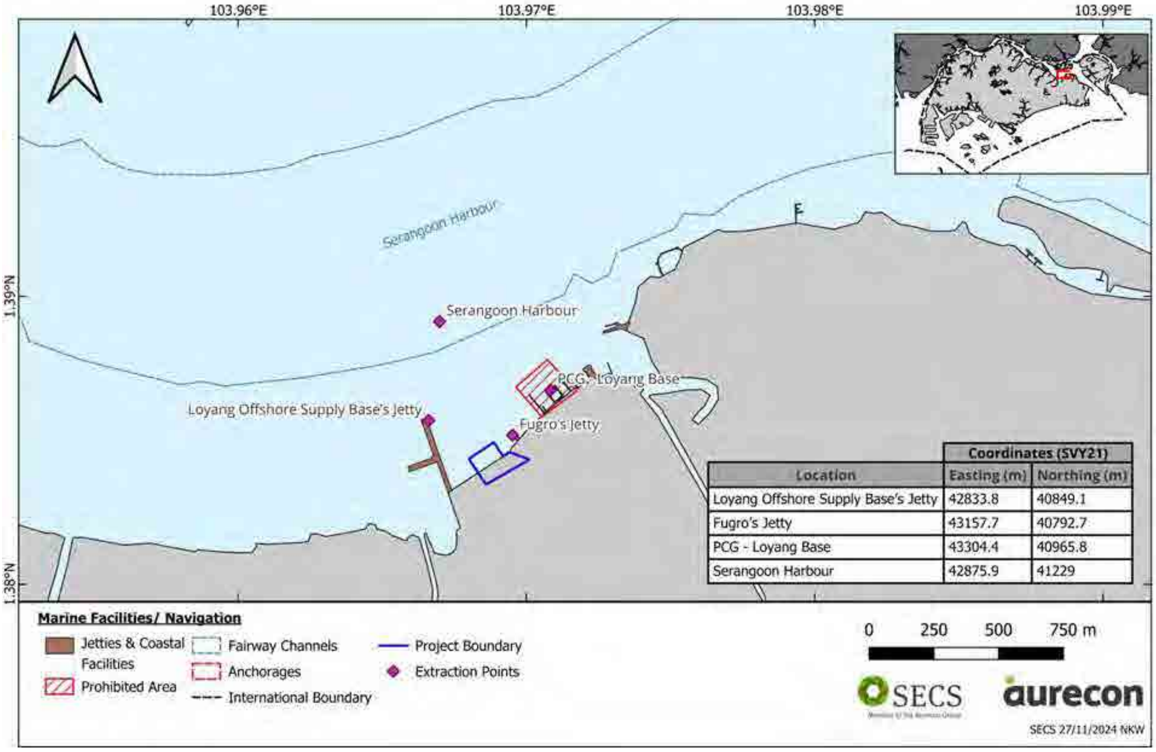



**Figure 9-10: Location map of the model extraction point**

**Table 9-2: Environmental receptors at the extraction point**

| Location | Remarks |
|---|---|
| 1 | Loyang Offshore Supply Base's Jetty |
| 2 | Fugro's Jetty |
| 3 | Police Coast Guard Loyang Regional Base |
| 4 | Serangoon Harbour |

The comparison of surface elevation, current speed and current direction between pre-construction and post construction scenario 1 are shown in Figure 9-11 to Figure 9-13. Only scenario 1 was selected for analysis, as it represents the normal operating condition. Additionally, the mean and 95$^{th}$ percentile current speeds exhibited minimal variation across all three scenarios. The blue lines showed the current speed, direction, and water level for pre-construction phase, while the red line represents the same parameter during post-construction phases.

At the locations of interest, there were negligible changes to the current speed, current direction, and water level observed during the post-construction phase. Therefore, the development of the Floating Module Data Centre was considered to have no impacts to Loyang Offshore Supply Base's jetty, Fugro's jetty, Police Coast Guard Loyang Regional Base, and Serangoon Harbour.

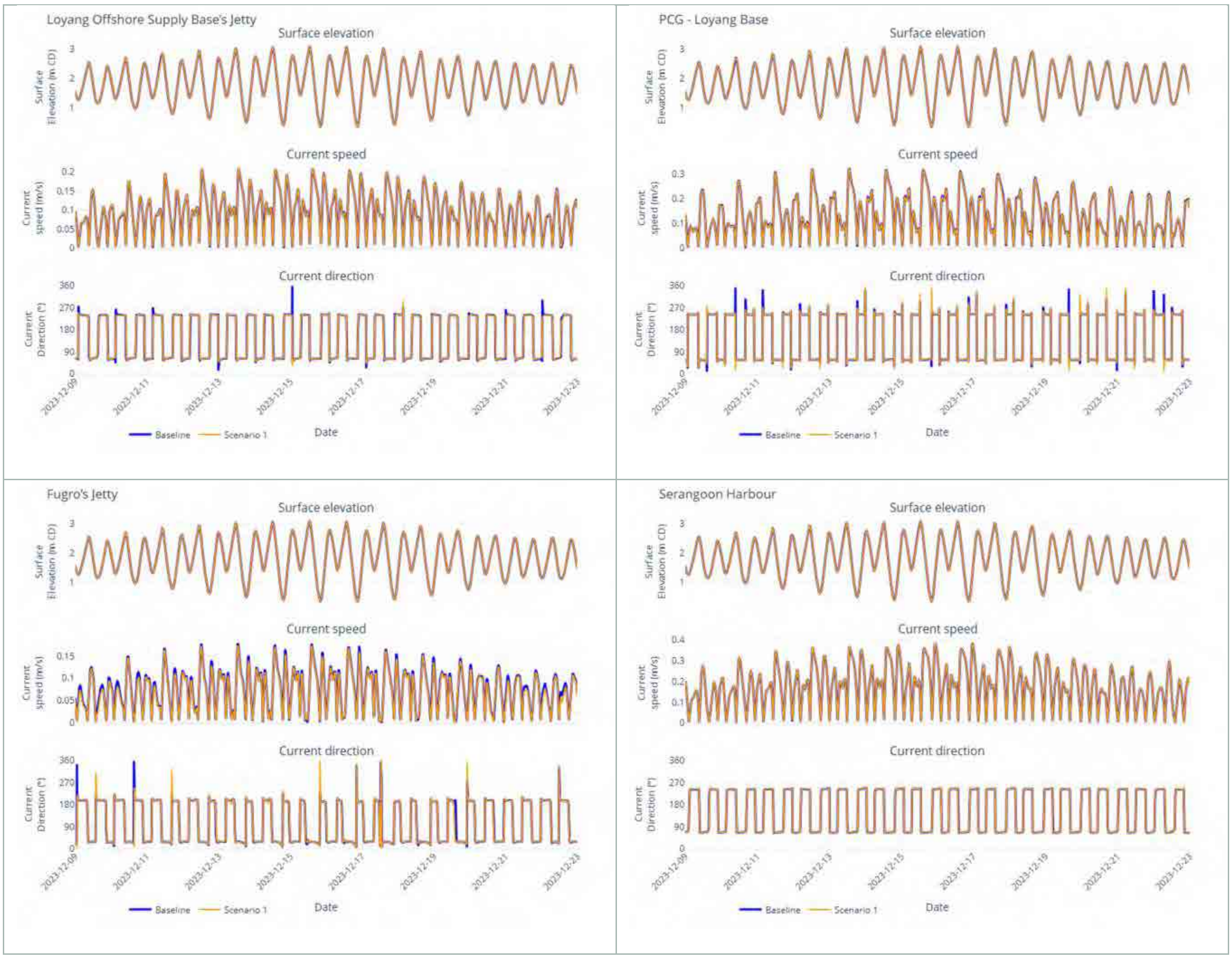



**Figure 9-11: Hydrodynamic conditions time series comparison between pre-construction and post-construction scenario 1 at various receptors during Northeast monsoon**

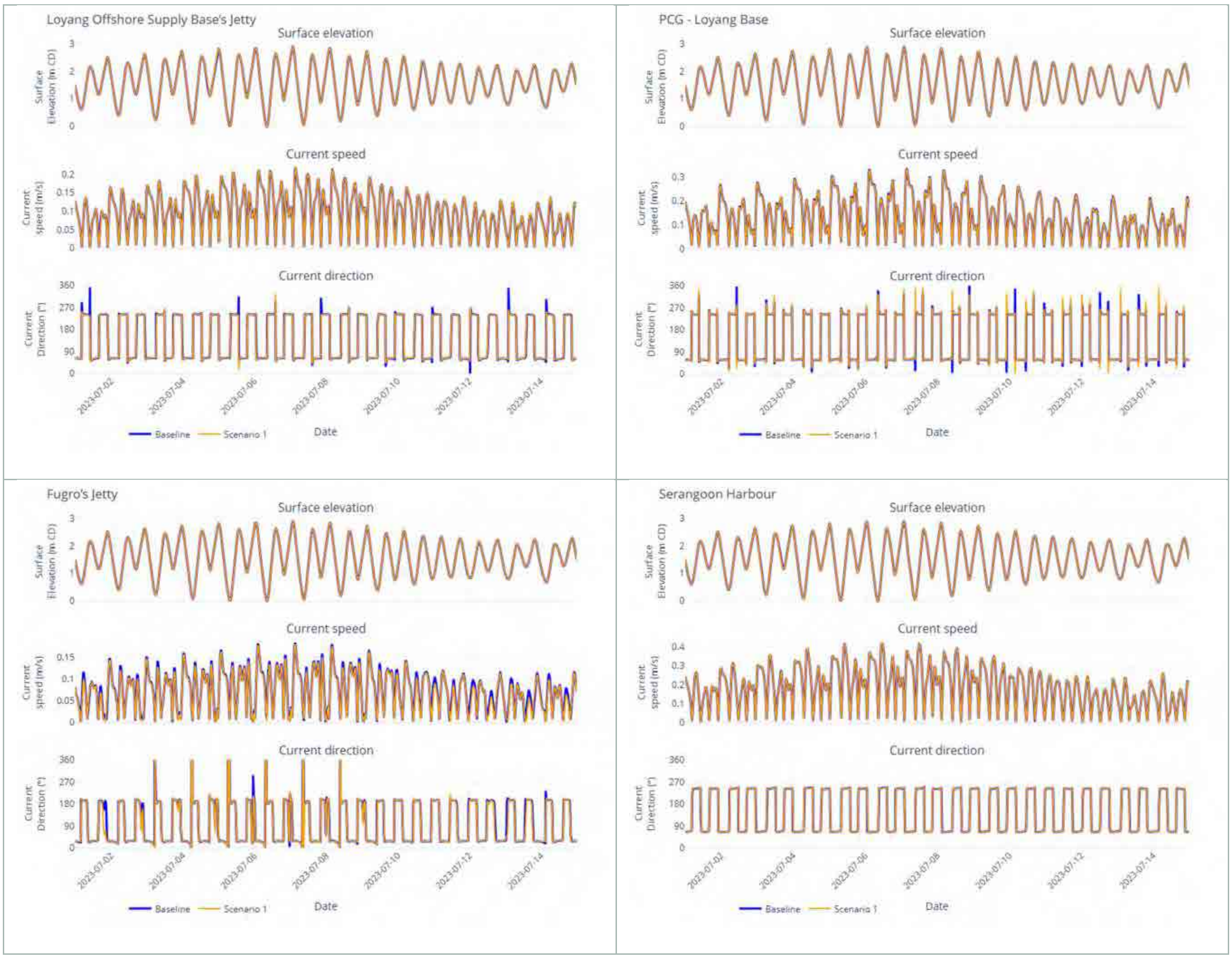



**Figure 9-12: Hydrodynamic conditions time series comparison between pre-construction and post-construction scenario 1 at various receptors during Southwest Monsoon**

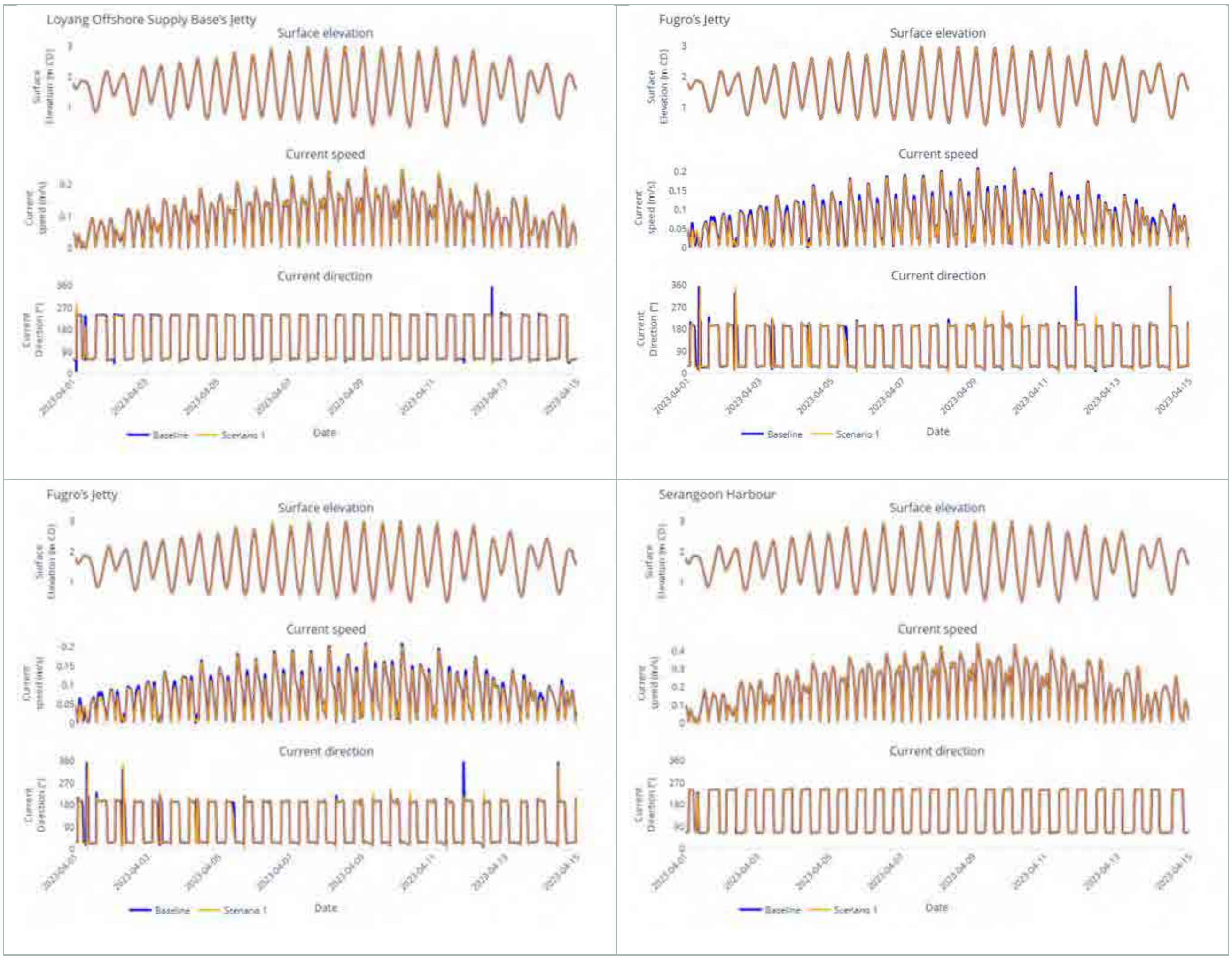



**Figure 9-13: Hydrodynamic conditions time series comparison between pre-construction and post-construction scenario 1 at various receptors during Inter-monsoon**

#### 9.1.4.5 Impact Summary

Based on hydrodynamic modelling and assessment, no significant impacts to the navigation channel and marine facilities surrounding the project footprint were identified. Within the floating structure, a slight increase in current speed was observed due to the partially submerged hull, which facilitates increased flow velocities beneath the floating structure. While this increase in current could potentially generate localized scour near the structures, engineering design measures will be incorporated to mitigate these effects.

As the changes are generally localised and unlikely to affect vessels berthing in these areas, it was predicted that no negative impacts will arise during the construction and post-construction phases. Therefore, no adverse impacts were anticipated on marine navigation or the marine facilities surrounding the project site.

**Table 9-3: Hydrodynamic model impact summary**

| Impacts | Predicted Impacts | | | | | | | Mitigation measures |
|---|---|---|---|---|---|---|---|---|
| | Potential impact | ES | I | M | P | R | C | |
| **Operational** | | | | | | | | |
| Current | No change/ no impact | -5 | 1 | -1 | 2 | 2 | 1 | Mitigation at engineering design phase |

## 9.2 Sediment Plume

Dredging activities will disturb sediments, generating suspended sediment plumes that may impact sensitive receptors near the Project site through the transport, dispersion, and settling of fine particles. This section examines the short-term impacts during the construction phase, focusing on suspended sediment concentrations and sedimentation effects on receptors.

### 9.2.1 Simulation Scenarios

The sediment plume assessment evaluates the dispersion and transport of sediments generated by dredging activities for the project, which involves dredging to a depth of -7 mCD around the FDCM.

The simulation was conducted over a 14-day period, capturing a full spring-neap tidal cycle during the Northeast Monsoon, Southwest Monsoon, and Inter-monsoon seasons. Key inputs for the model, detailed in Table 9-4, were incorporated to ensure accurate assessment.

The proposed dredging volume is based on information available at the time of writing. Should any changes to dredging operations or production volumes arise before construction, a detailed review will be necessary to ensure compliance with project-specific EQOs and ETLs.

**Table 9-4: Dredging Work Information**

<table>
<tr><th>Parameter</th><th>Remarks</th></tr>
<tr><td>Simulation Period</td><td><table>
<tr><th>Case</th><th>Monsoon</th><th>Simulation Period</th></tr>
<tr><td rowspan="3">During construction</td><td>Southwest</td><td>1 Jul 2023 to 15 July 2023</td></tr>
<tr><td>Northeast</td><td>9 Dec 2023 to 23 Dec 2023</td></tr>
<tr><td>Inter-monsoon</td><td>1 Apr 2023 to 15 Apr 2023</td></tr>
</table></td></tr>
<tr><td>Dredging hours</td><td>24 hours</td></tr>
<tr><td>Dredging depth</td><td>Dredged up to -7 mCD</td></tr>
<tr><td>Total Volume</td><td>9,000 $m^3$</td></tr>
<tr><td>Production Rate</td><td>• Scenario 1: The daily average production rate over a 14-day period is approximately 643 $m^3$ per day<br>• Scenario 2: The maximum daily production rate over a 9-day period is 1,000 $m^3$ per day.[1]</td></tr>
<tr><td>Bucket Size</td><td>The operation assumes the use of a grab bucket with a capacity of 8 to 10 $m^3$, operated by a single grab dredger. The dredged material will be collected by the grab bucket and transferred to a hopper barge. The hopper barge will then transport the material to an approved disposal site or dumping ground.</td></tr>
</table>

[1] The maximum daily production rate is based on grab bucket size assumption of 8 to 10$m^3$. Keppel has agreed that the proposed volume will be adhered to and hence, no scenarios with higher production rate are simulated.

### 9.2.2 Receptors of Concern

The dredging activity may create sediment plumes and sedimentation impacts on environmental receptors during the construction phase. These short-term changes may affect the following sensitive receptors:

- Suspended sediment impact and sedimentation impact to seagrass and mangroves
- Suspended sediment impact to marine intake
- Suspended sediment impact and sedimentation impact to aquaculture facilities
- Sedimentation impact to marine infrastructure
- Suspended sediment impact to recreational features
- Suspended sediment impact to cross-border

### 9.2.3 Adopted Evaluation Criteria

To assess the potential environmental impacts associated with sediment plume dispersion and sedimentation, the EQOs and ETLs presented in Table 9-5 were adopted.

The receptor importance evaluation framework used in this assessment follows the definitions outlined in Table 8-2 and Table 8-3, Section 8.2.1.3, and Section 8.2.1.4. For marine facilities and marine navigation, receptor importance is defined according to the RIAM framework criteria, as presented in Table 4-4.

To evaluate the magnitude of change, this assessment references the quantitative thresholds and criteria established for SSC and sedimentation. These criteria are detailed in Table 8-7, Table 8-8, Table 8-11, and Table 8-12. Together, these tables provide a standardised approach to assigning magnitude scores based on exposure conditions, which are then combined with receptor importance to determine overall impact significance.

Further details of the adopted impact assessment criteria, including thresholds and the rationale for receptor classification, are provided in Section 8.

**Table 9-5: Sediment plume and sedimentation impact criteria**

| Receptor | EQOs | ETLs |
|---|---|---|
| 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 < 1.7 mm/14 days |
| Cross-border | No impact | • SSC > 5 mg/L for less than 5% during 12-hour daylight period |
| Recreational Facilities | No impact | • SSC > 5 mg/L for less than 2.5% during 12-hour daylight period |
| Marine Facilities | No impact | • Sedimentation < 50 mm/year |

### 9.2.4 Result and Discussion

This section presents the sediment plume modelling and the interpretation of the results. The impacts of the sediment plume are quantified as excess SSC, with the findings assessed and presented in terms of

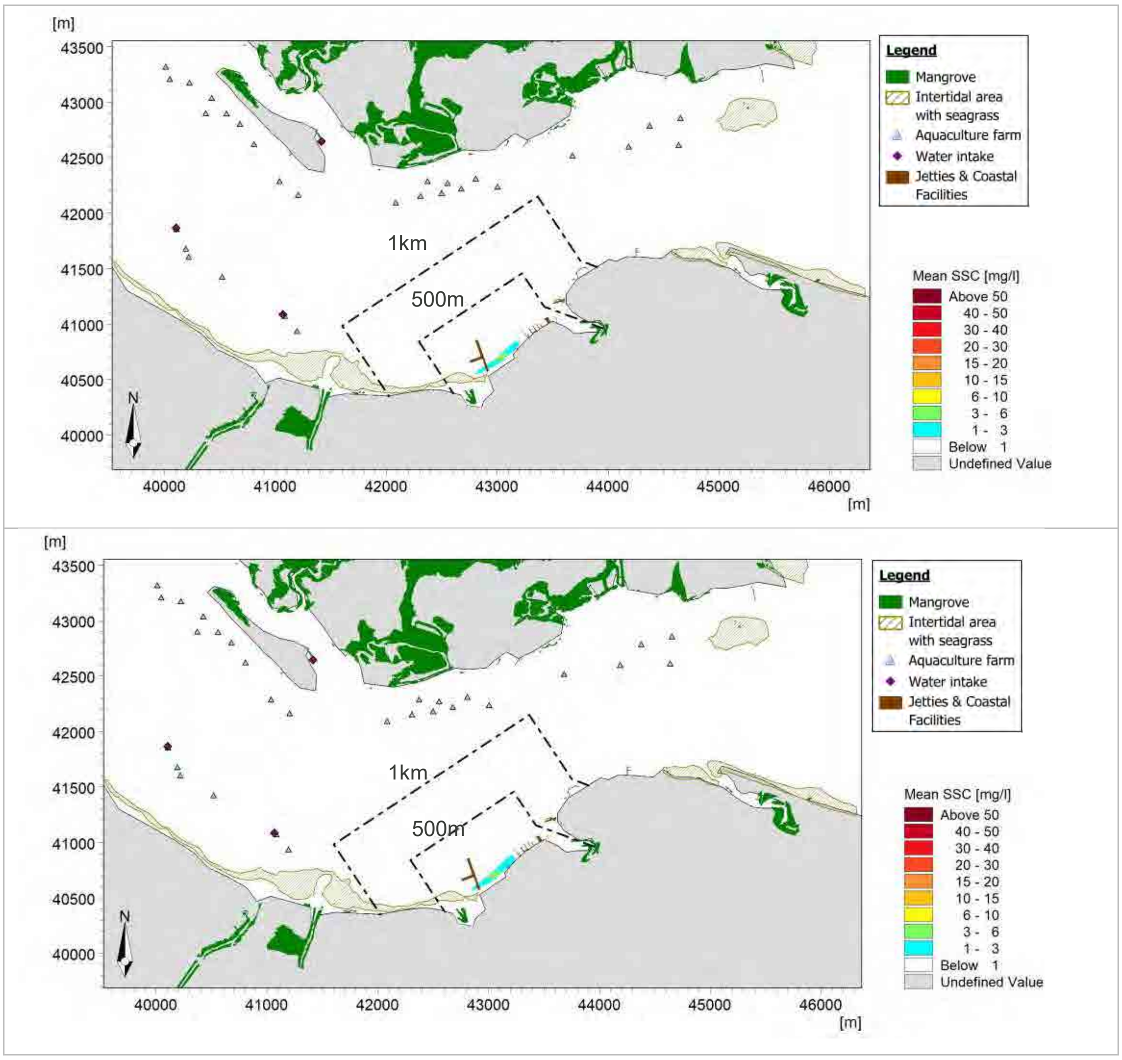
- Mean SSC
- $95^{th}$ Percentile SSC
- Percentage exceedance of SSC at 5 mg/L, 10 mg/L and 25 mg/L

- SSC time series extraction at selected locations
- Sedimentation

The following section presents the result plots for Scenario 1 and Scenario 2 based on the respective dredging durations. For Scenario 2, model results are derived from only 9 days of dredging, as the dredging works are projected to be completed within this timeframe based on a production rate of 1,000 m³/day. For Scenario 1, dredging works are projected to continue for the full simulation period of 14 days. Therefore, model results from 14 days of dredging operations have been used to generate the result plots and findings.

#### 9.2.4.1 Mean Suspended Solid Concentration (SSC)

Figure 9-14 and Figure 9-15 show the mean SSC across three (3) monsoon period based on daily average production rate and daily maximum production rate, respectively. Result plots indicate higher mean SSC of up to 20 mg/L near the spill location but decreases quickly away from the spill location across the three (3) monsoon periods for both daily average and daily maximum production rates. The closest marine intake to the Project is located in Serangoon harbour as shown in Figure 5-6, and the results are presented in Figure 9-14 and Figure 9-15 for daily average and daily maximum production rate respectively. The model results show no changes to the marine intake.



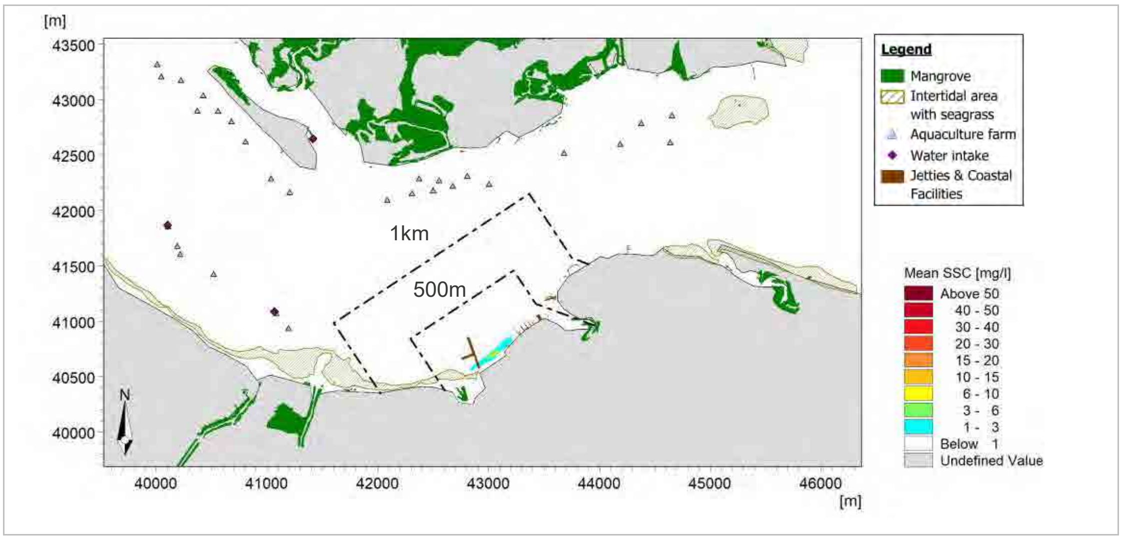
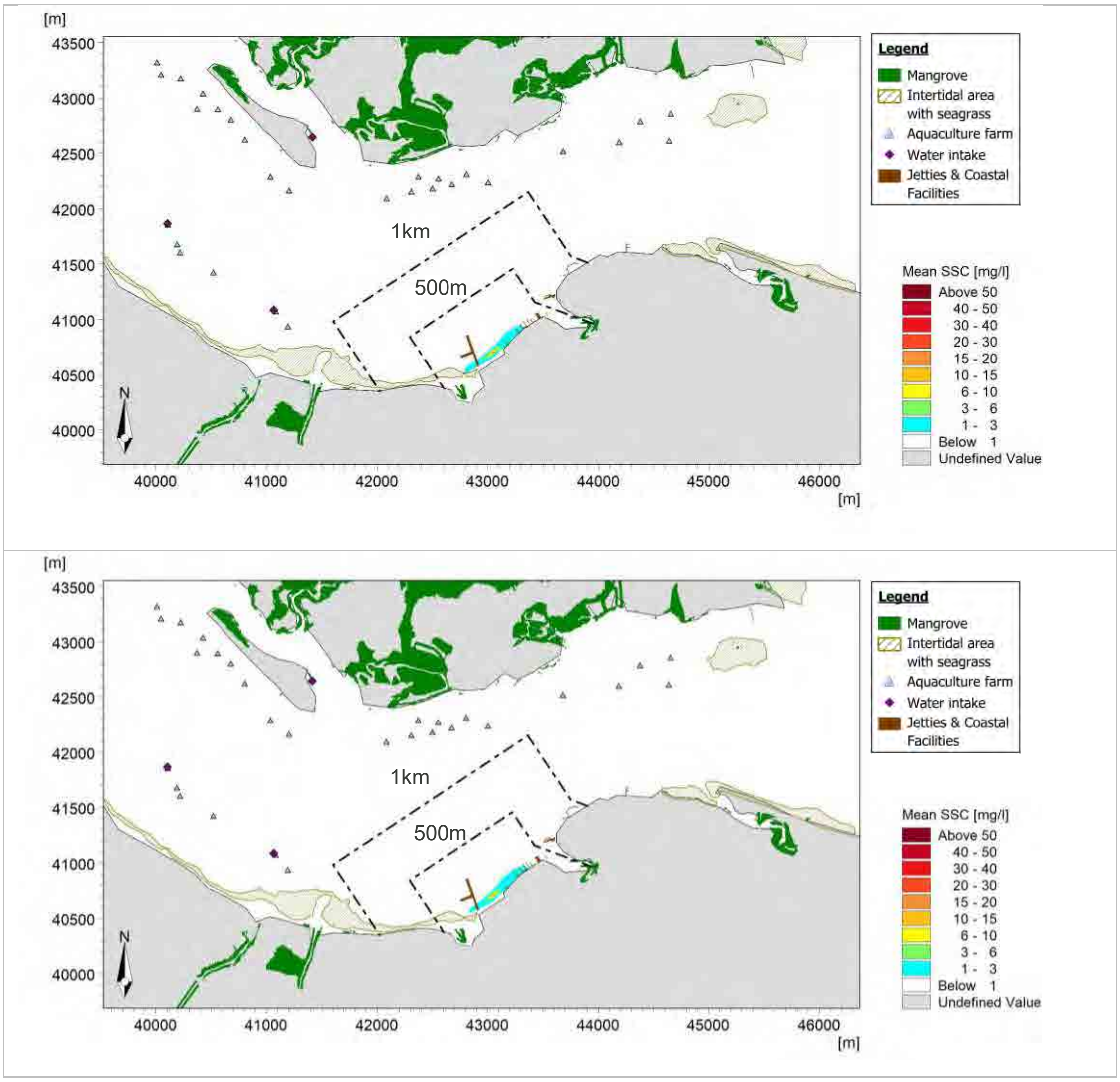



**Figure 9-14: Mean SSC plot during Northeast Monsoon (top), Southwest Monson (middle) and Inter-monsoon (bottom) based on daily average production rate**



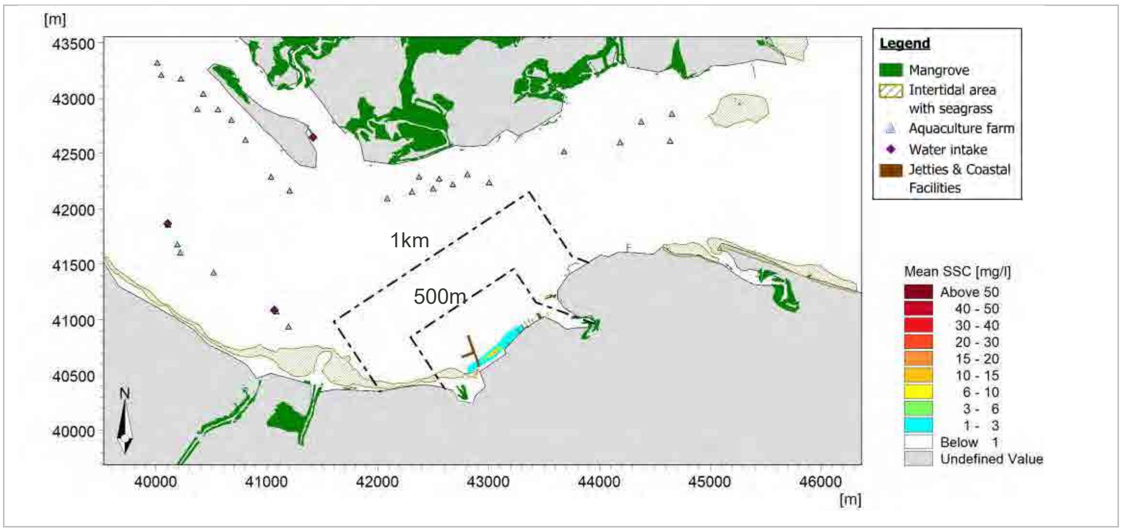



**Figure 9-15: Mean SSC plot during Northeast Monsoon (top), Southwest Monson (middle) and Inter-monsoon (bottom) based on daily maximum production rate**

### 9.2.4.2 95th Percentile Suspended Solid Concentration (SSC)

Figure 9-16 and Figure 9-17show the 95th percentile SSC across three (3) monsoon period based on daily average production rate and daily maximum production rate, respectively. Result plots indicate higher 95th percentile SSC of up to 49 mg/L near the spill location but decreases quickly away from the spill location across the three (3) monsoon periods for both daily average and daily maximum production rates.

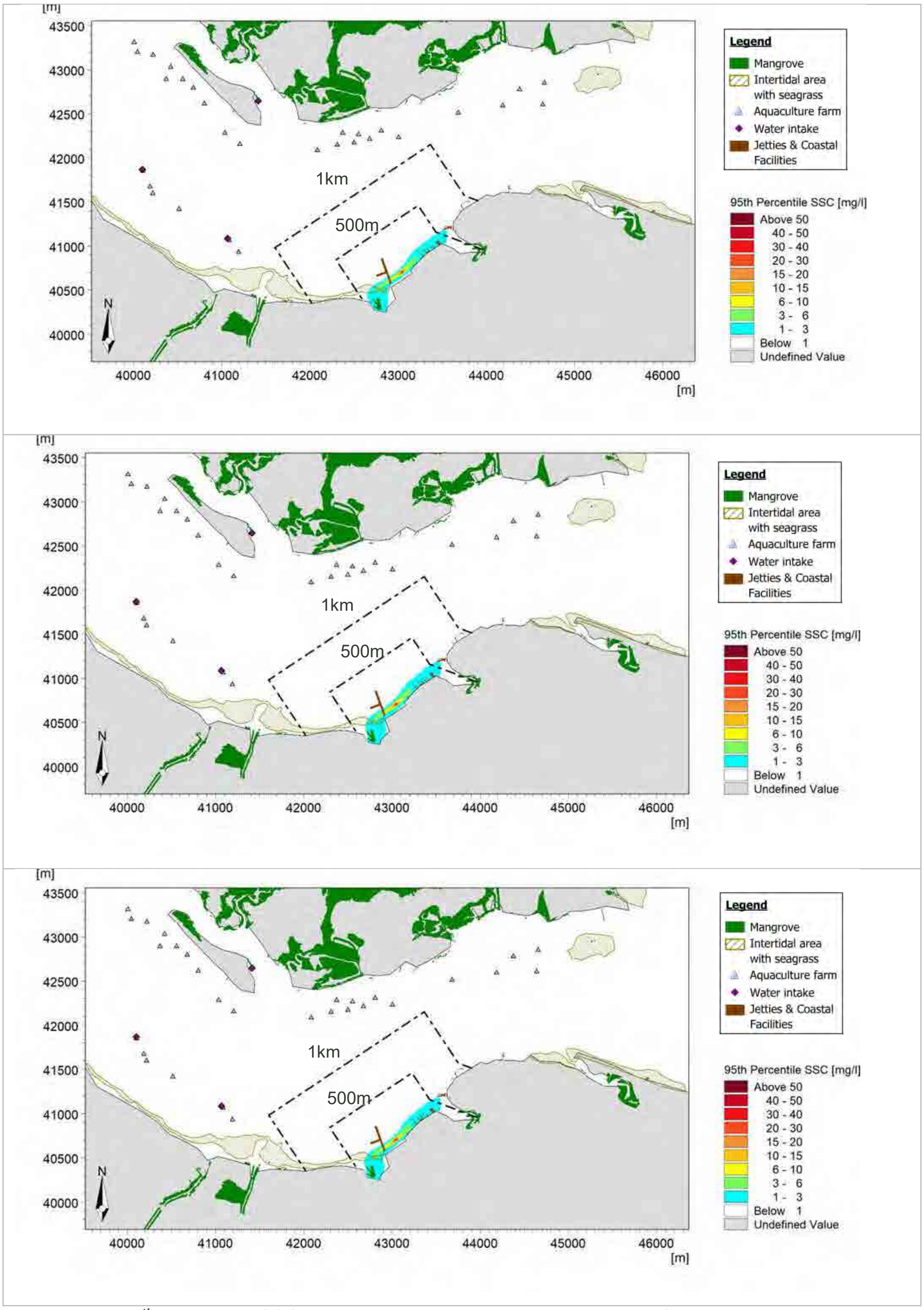



**Figure 9-16: 95th percentile SSC plot during Northeast Monsoon (top), Southwest Monson (middle) and Inter-monsoon (bottom) based on daily average production rate**

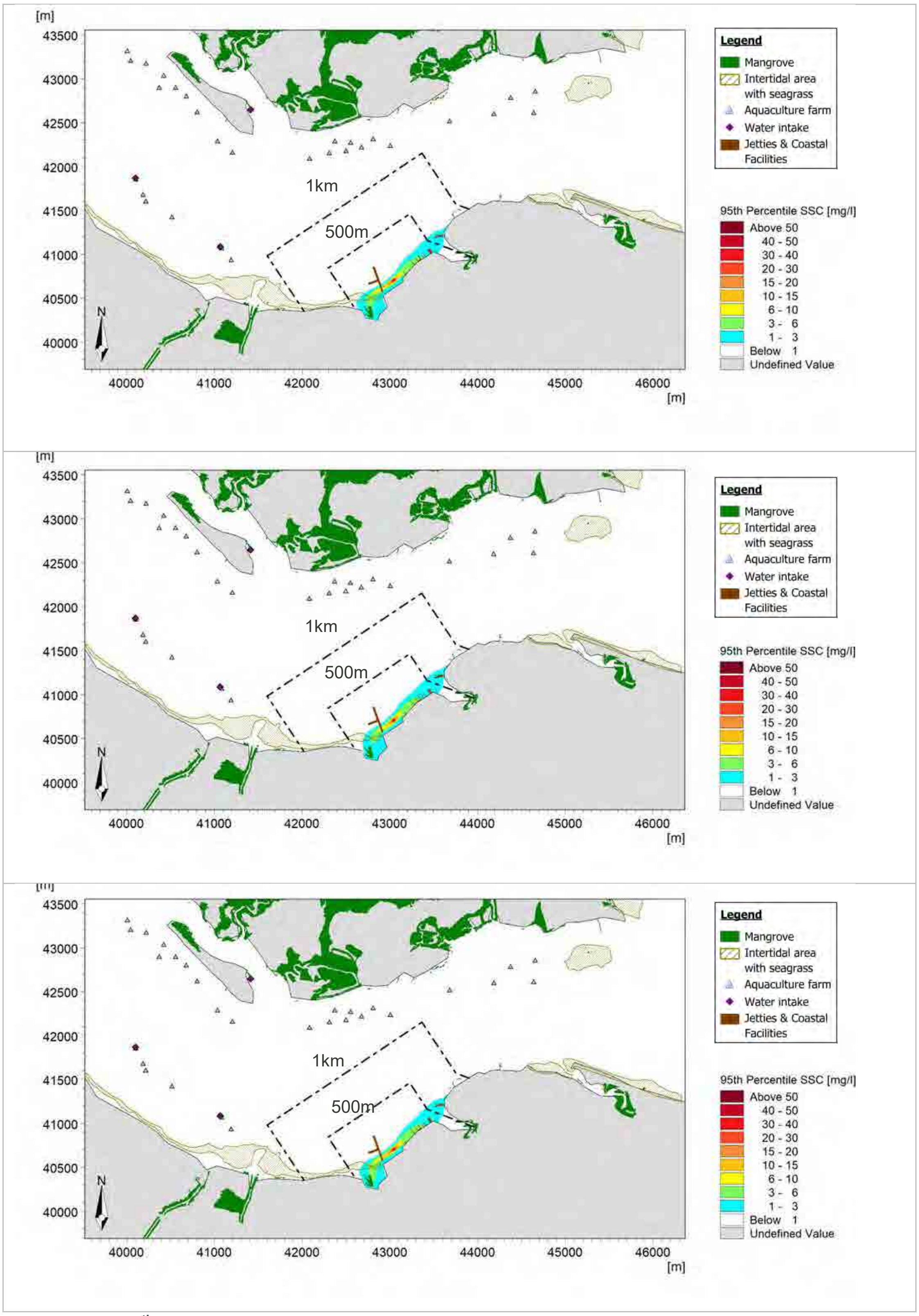



**Figure 9-17: 95th percentile SSC plot during Northeast Monsoon (top), Southwest Monson (middle) and Inter-monsoon (bottom) based on daily maximum production rate**

#### 9.2.4.3 Exceedance of Suspended Solid Concentration (SSC)

The percentage exceedance plots at 5 mg/L (24 hours), 10 mg/L (24 hours), and 25 mg/L (24 hours) over the 14 days model simulation period, for both the daily average production rate of 643 $m^3$/day and the maximum daily production rate of 1,000 $m^3$/day, are presented in Figure 9-18 to Figure 9-23. Exceedance was defined as the percentage of time over the 14-day simulation period that the suspended sediment concentrations are higher than the defined threshold value.

For both production rates, exceedances of more than 20% of the time at 5 mg/L indicate that the plume extends less than 250 meters from the source. Exceedances at 10 mg/L and 25 mg/L, exceeding 5% of the time, remain localized. The spatial extent of the sediment plume at the 14-day depth-averaged 5 mg/L threshold was limited to within the Project footprint, with no exceedances observed at seagrass or aquaculture facilities.

Percentage exceedance plots of 5 mg/L during daylight hours (12 hours) for both production rates are presented in Figure 9-24 and Figure 9-25. At exceedance of 5% and 2.5% of daylight hours, no exceedances were observed at cross-border or recreational facilities. Hence, no changes to cross-border or recreational facilities are anticipated as a result of the dredging works.

Minimal differences in plume extent were observed across the Northeast, Southwest, and Inter-monsoon seasons, with the overall spatial impact remaining consistent and localized within the Project area.

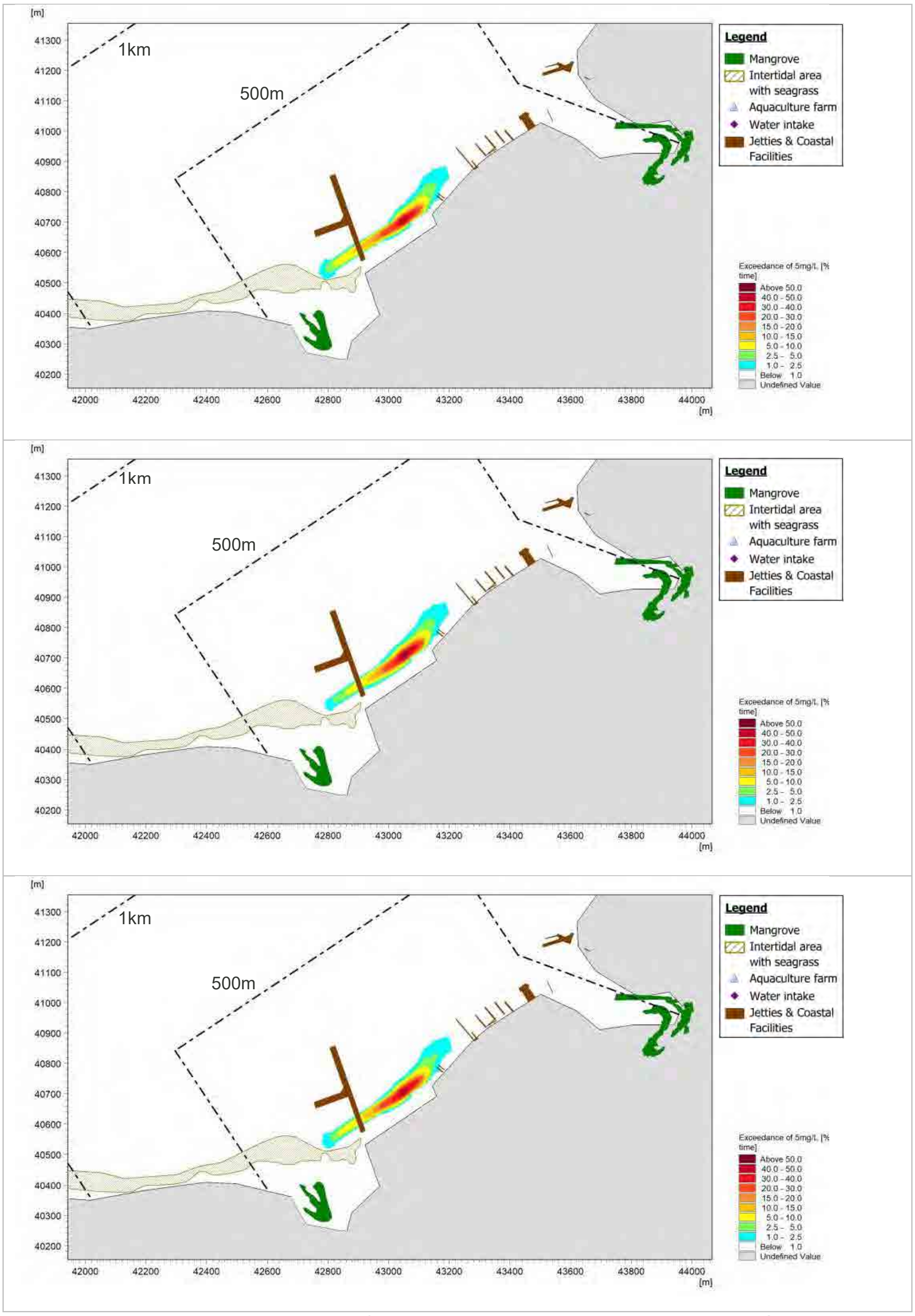



**Figure 9-18: Percentage exceedance of 5 mg/L during Northeast monsoon (top), Southwest Monsoon (middle) and Inter-monsoon (bottom) based on Daily Average Production Rate**

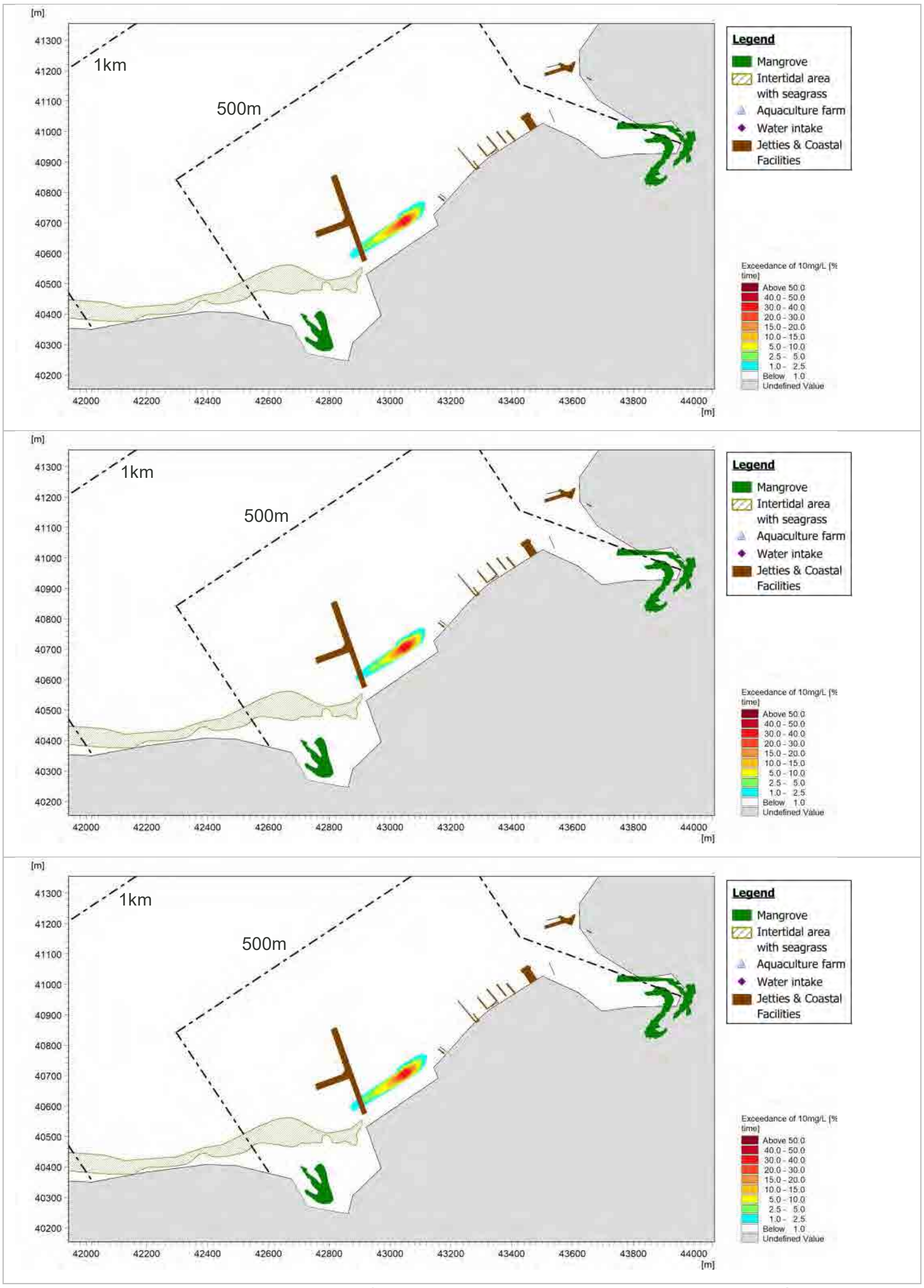



**Figure 9-19: Percentage exceedance of 10 mg/L during Northeast monsoon (top), Southwest Monsoon (middle) and Inter-monsoon (bottom) based on daily average production rate**

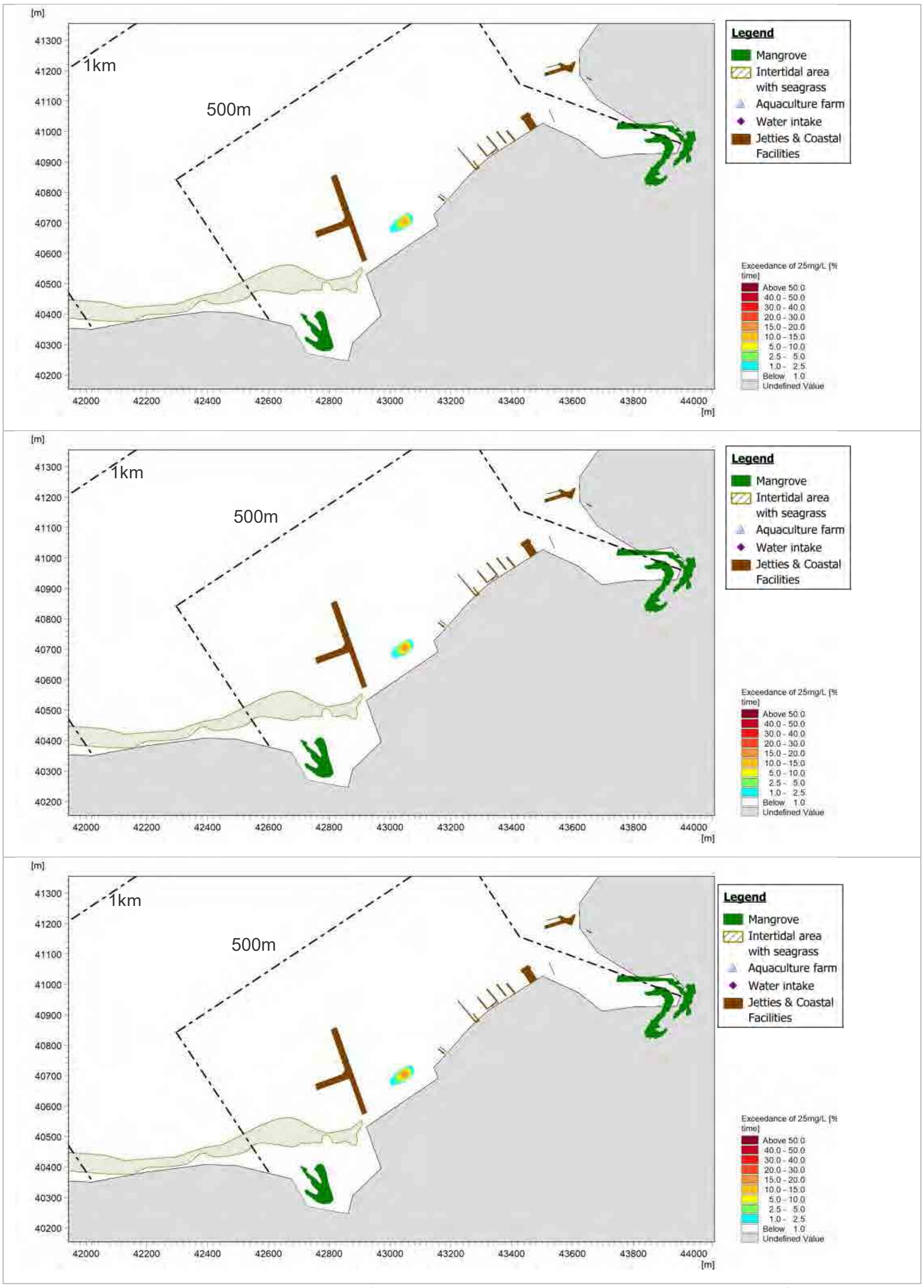



Figure 9-20: Percentage exceedance of 25 mg/L during Northeast monsoon (top), Southwest Monsoon (middle) and Inter-monsoon (bottom) based on daily average production rate

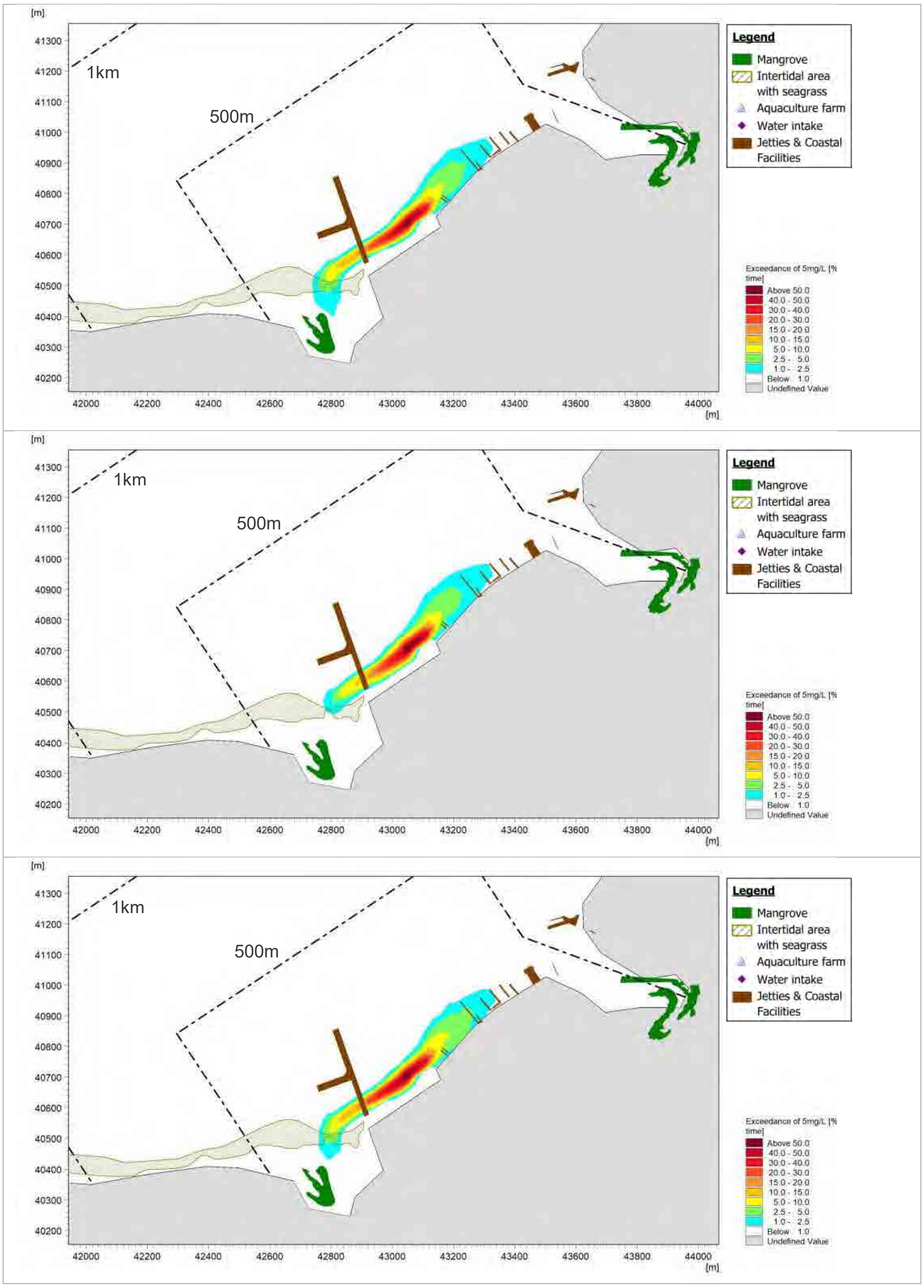



**Figure 9-21: Percentage exceedance of 5 mg/L during Northeast monsoon (top), Southwest Monsoon (middle) and Inter-monsoon (bottom) based on daily maximum production rate**

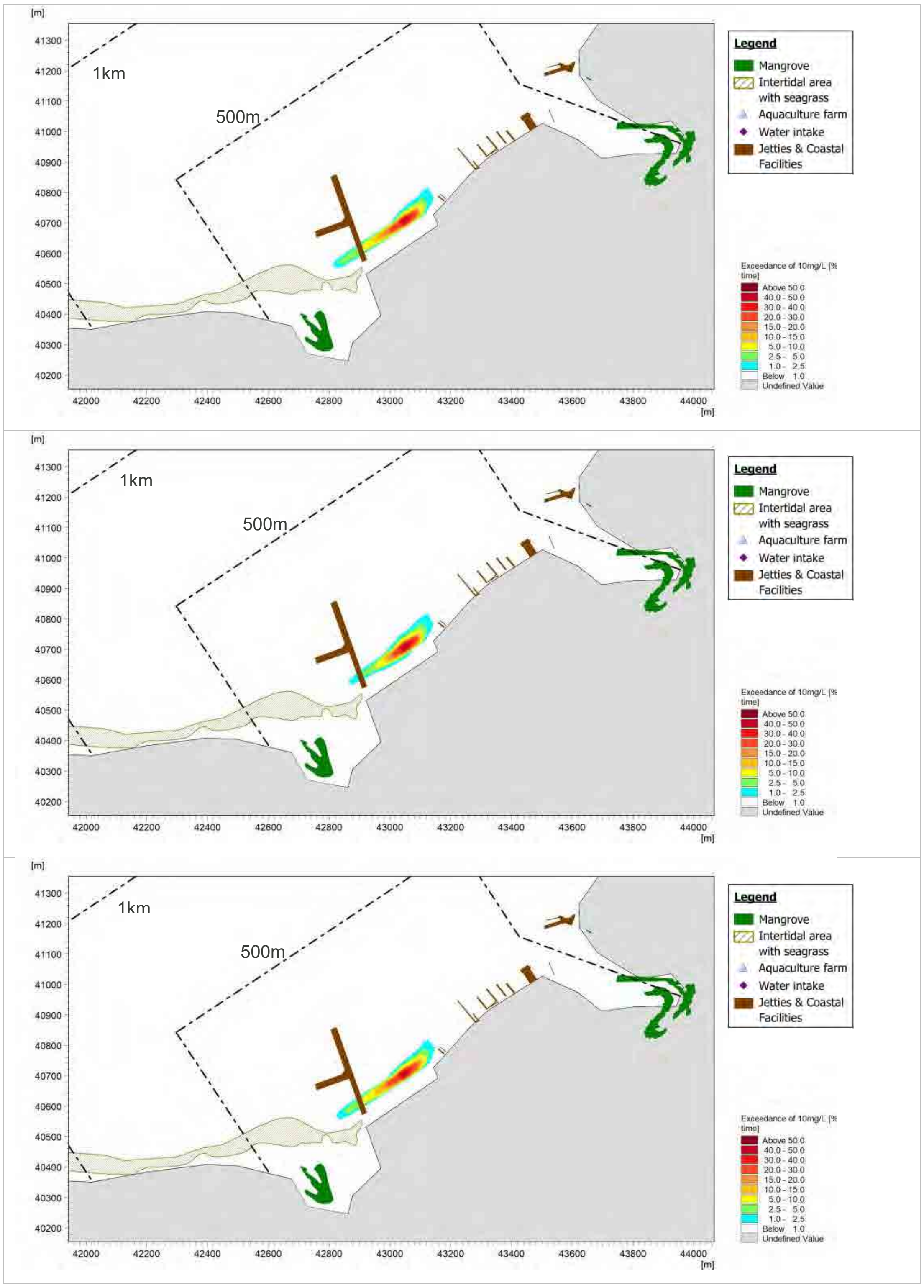



**Figure 9-22: Percentage exceedance of 10 mg/L during Northeast monsoon (top), Southwest Monsoon (middle) and Inter-monsoon (bottom) based on daily maximum production rate**

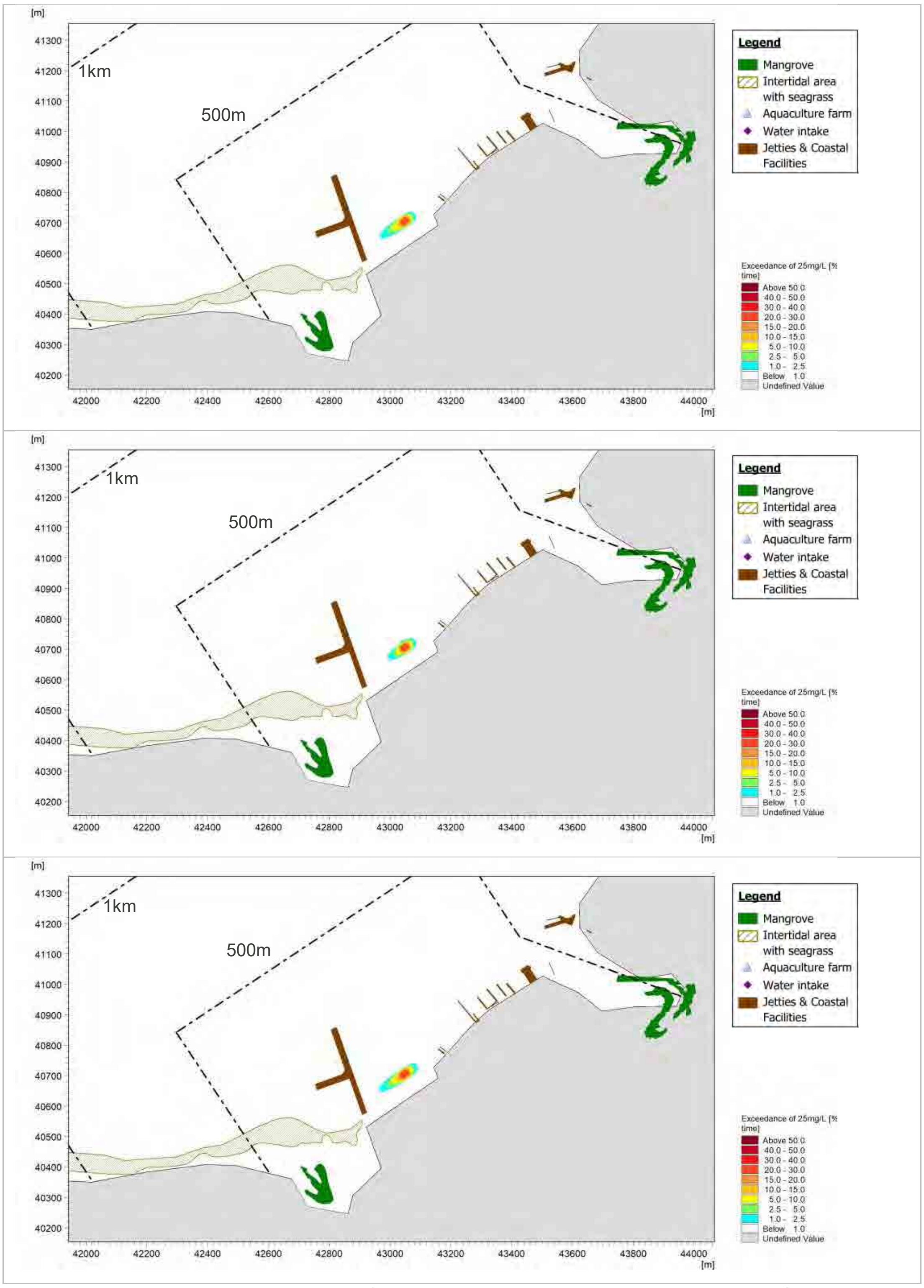



**Figure 9-23: Percentage exceedance of 25 mg/L during Northeast monsoon (top), Southwest Monsoon (middle) and Inter-monsoon (bottom) based on daily maximum production rate**

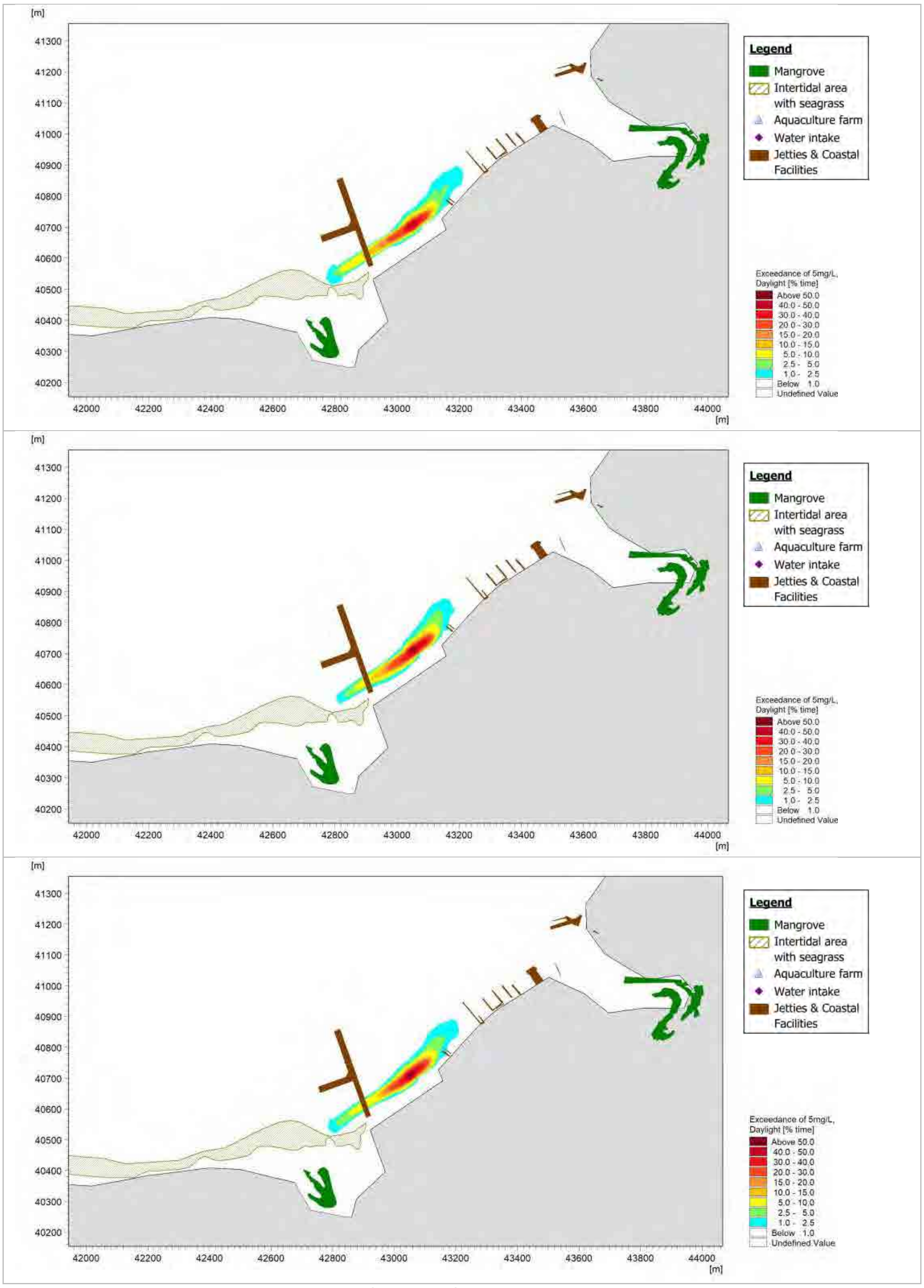



**Figure 9-24: Percentage exceedance of 5 mg/L for daylight hours during Northeast monsoon (top), Southwest Monsoon (middle) and Inter-monsoon (bottom) based on daily average production rate**

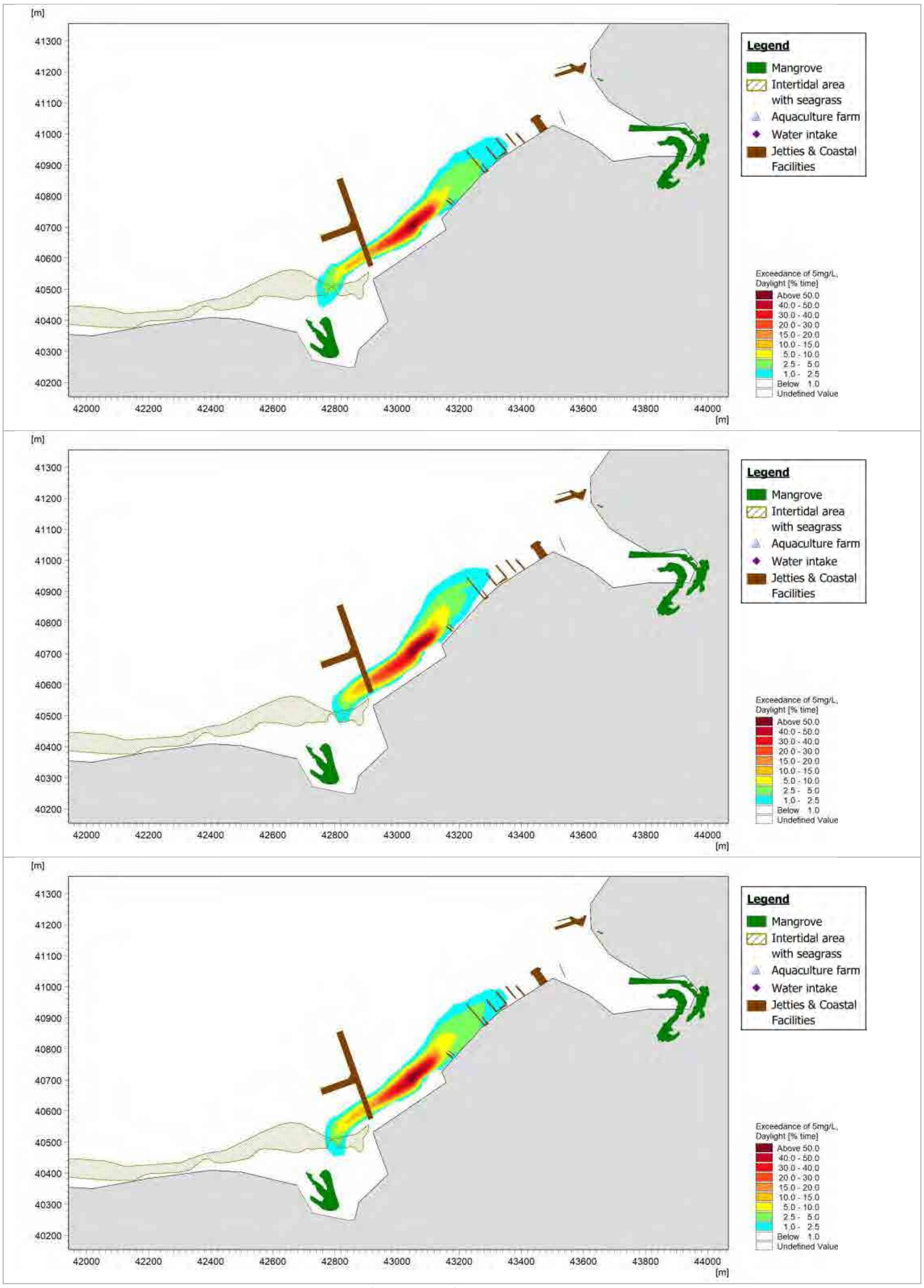



Figure 9-25: Percentage exceedance of 5 mg/L for daylight hours during Northeast monsoon (top), Southwest Monsoon (middle) and Inter-monsoon (bottom) based on daily maximum production rate

### 9.2.4.4 Time Series Suspended Solid Concentration

The time-series plots of depth-averaged SSC at different extraction points near the vicinal environmental receptors are presented in Figure 9-26 and Table 9-6. These extraction points were selected based on the sensitivity of the receptors of concern within the proximity to the Project footprint.

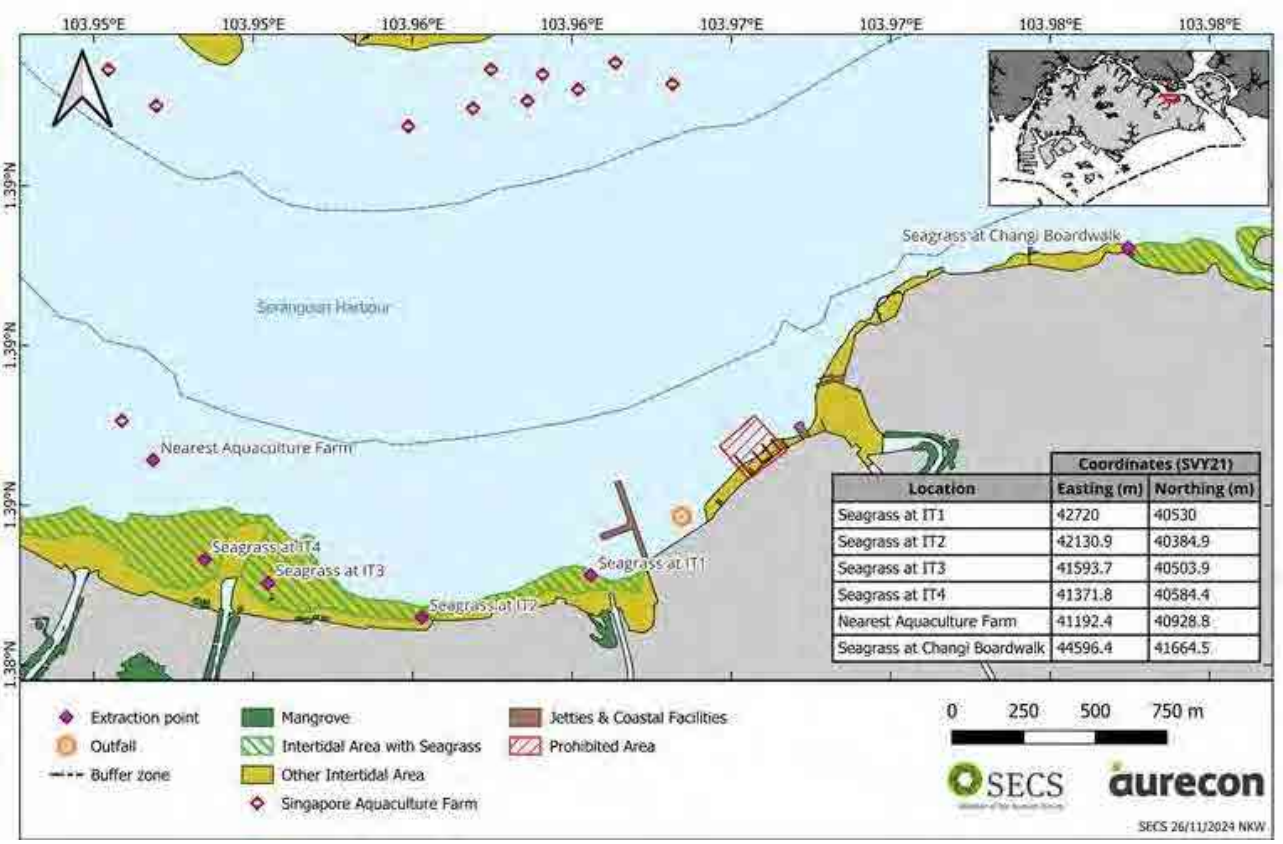



**Figure 9-26: Location map of the sediment plume model extraction points**

**Table 9-6: Environmental receptors at the extraction point**

| Location | Remarks |
|---|---|
| 1 | Seagrass at IT1 |
| 2 | Seagrass at IT2 |
| 3 | Seagrass at IT3 |
| 4 | Seagrass at IT4 |
| 5 | Aquaculture farm |
| 6 | Seagrass at Changi Boardwalk |

Figure 9-27, Figure 9-28, and Figure 9-29 show the extracted SSC time series at various receptors within the impacted area during the Northeast Monsoon, Southwest Monsoon, and Inter-monsoon, respectively. Only scenario 1 was selected for analysis, as it represents the normal operating condition. Additionally, the mean SSC exhibited minimal variation across all three scenarios.

The results indicate that sediment dispersion to the seagrass at IT1 recorded a maximum depth-averaged SSC of up to 4.3 mg/L. Further dispersion was predicted at receptors located farther from the Project site, with maximum depth-averaged SSC values ranging from 0.2 mg/L to 0.4 mg/L at the seagrass areas near IT2, IT3, and IT4, and up to 0.5 mg/L at the seagrass near Changi Boardwalk. These values were assessed across the various monsoon seasons and account for both daily average and maximum production rates.

SSC levels at distant receptors, including the marine intake and cross-border were anticipated to be negligible and were unlikely to pose significant environmental impacts.


**Figure 9-27: Extracted SSC time series for dredging works based on daily average (left) and daily maximum production rate (right) during Northeast Monsoon**

| Daily Average Production Rates | Daily Maximum Production Rates |
| --- | --- |

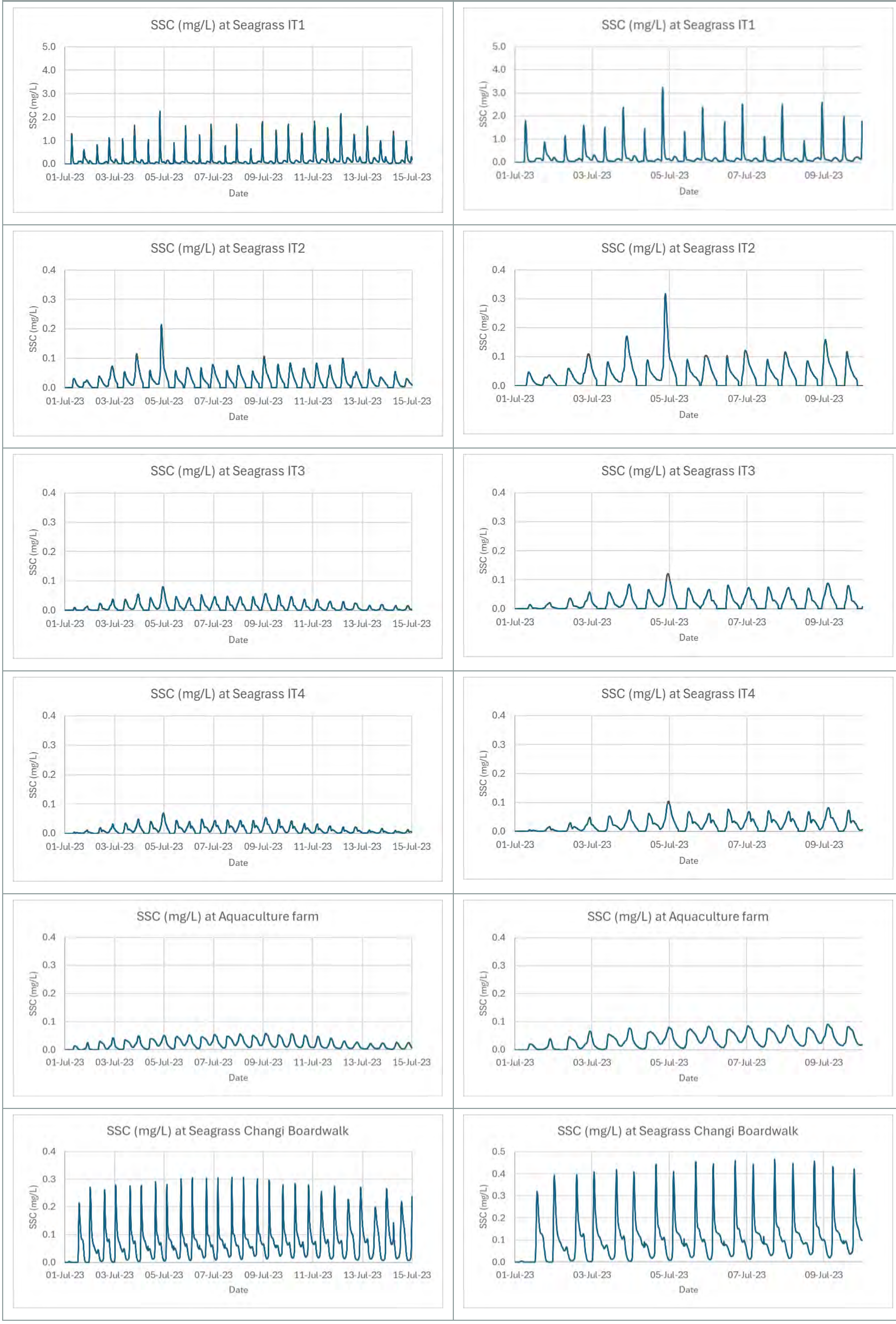



**Figure 9-28: Extracted SSC time series for dredging works based on daily average (left) and daily maximum production rate (right) during Southwest Monsoon**

| Daily Average Production Rates | Daily Maximum Production Rates |
|---|---|


**Figure 9-29: Extracted SSC time series for dredging works based on daily average (left) and daily maximum production rate (right) during Inter-monsoon**

#### 9.2.4.5 Sedimentation

Sediment spill generated by dredging work, when deposited can bring adverse effect to the marine facilities, aquaculture facilities and marine habitat. Increased sedimentation at marine facilities like jetty will affect the berthing window and maintenance requirement, while increased sedimentation at environmental receptors like seagrass can lead to burial or sedimentation which hinder seagrass growth.

Outputs of the model were plotted as sedimentation (mm/14 days and mm/ 9 days) in Figure 9-30 and Figure 9-31 for model scenarios based on daily average and daily maximum production rate, respectively. The net sedimentation at daily average production rate was forecasted to be highest at the immediate dredging area, exceeding 35 mm over 14 days (equivalent to 2.5 mm/day). Similarly, net sedimentation under the daily maximum production rate was forecasted to exceed 2.55 mm over 9 days (equivalent to 0.28 mm/day) during the construction phase.

In general, sedimentation associated with dredging activities was considered short-term and not a significant concern. The sedimentation effects were confined to the immediate construction area, with no predicted impacts to marine facilities, aquaculture operations, or seagrass habitats in proximity to the dredging works.

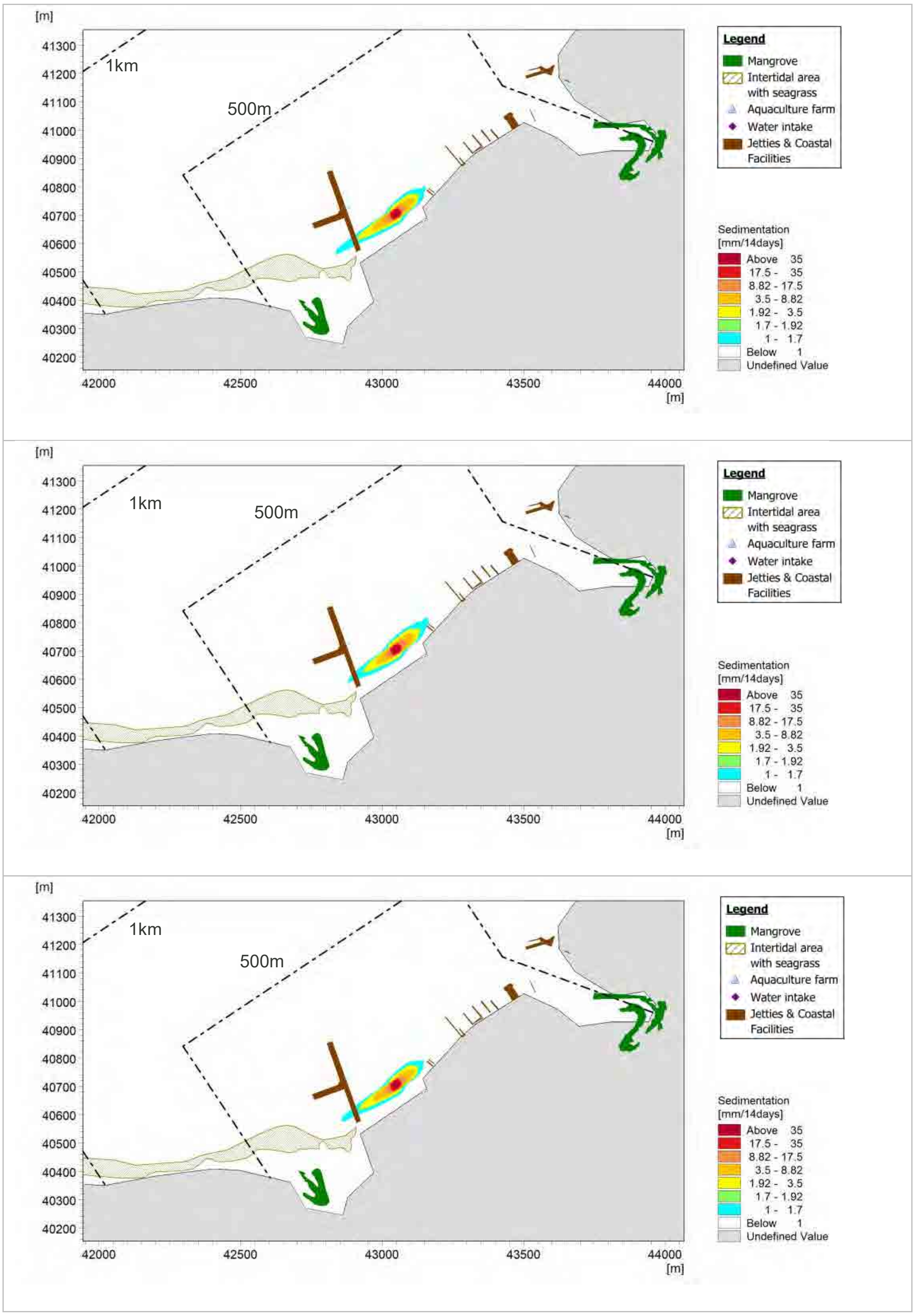



**Figure 9-30: Sedimentation plot during Northeast monsoon (top), Southwest Monsoon (middle) and Inter-monsoon (bottom) based on daily average production rate**

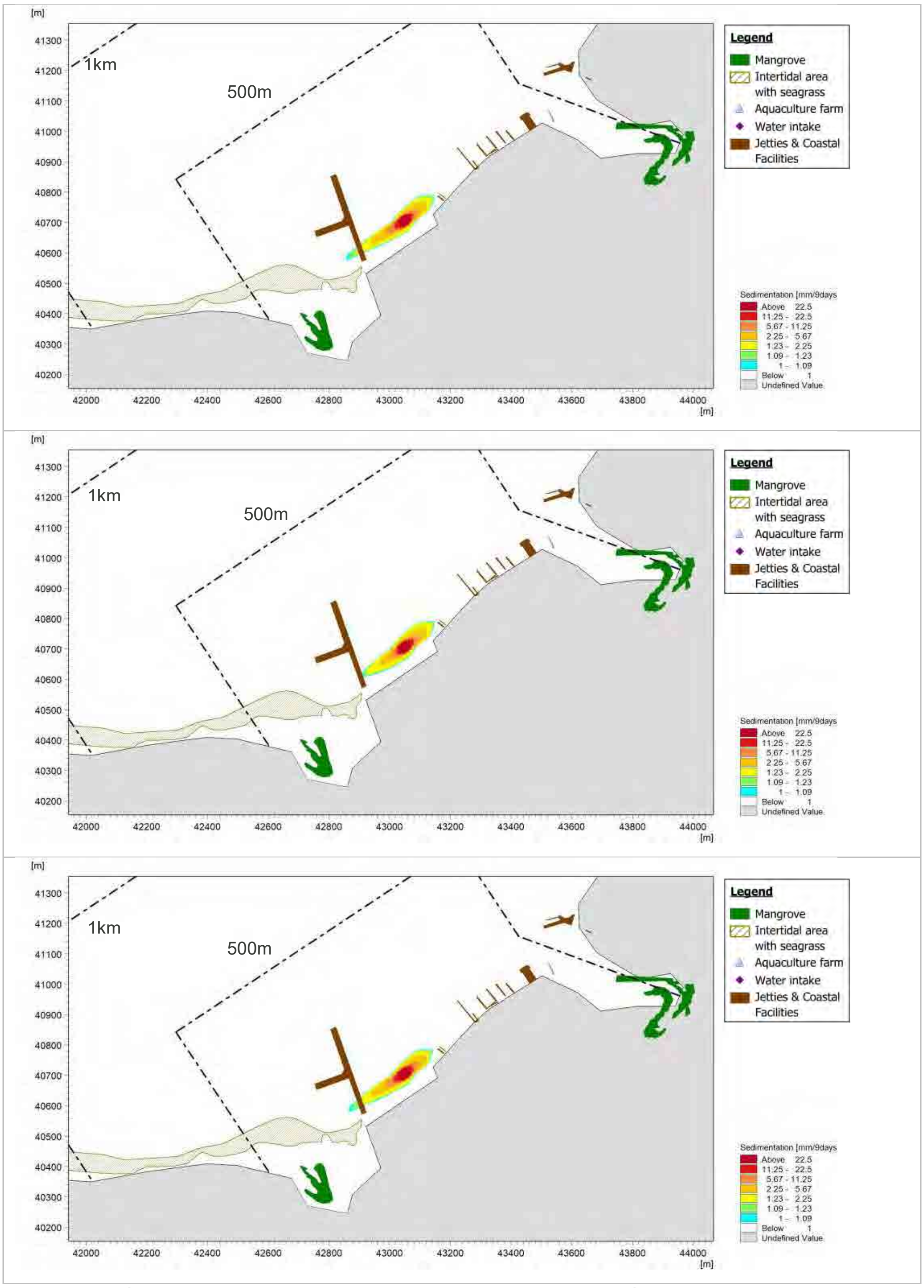



**Figure 9-31: Sedimentation plot during Northeast monsoon (top), Southwest Monsoon (middle) and Inter-monsoon (bottom) based on daily maximum production rate**

### 9.2.4.6 Impact Summary

#### 9.2.4.6.1 Suspended Solid Concentration

The results were analysed in against the SSC tolerance limits (Table 9-5) for seagrass, aquaculture facilities, recreational facilities, and cross-border.

***<u>Seagrass</u>***

- Sediment spills from dredging activities during the construction phase could elevate SSC, increasing turbidity and reducing light penetration essential for seagrass photosynthesis. Prolonged sedimentation may further smother seagrass beds, posing a threat to their survival and growth. Based on the model results, the plume is generally confined and deposited within the Project.
- According to the model result, there was no exceedance of 5 mg/L for more than 20% of the time. No impact to the seagrass habitat was forecasted due to the dredging activity. Therefore, the EQO and ETL were met.

***<u>Aquaculture facilities</u>***

- According to the model result, there was no exceedance of 5 mg/L for more than 5% of the time. No impact to the aquaculture facilities were forecasted due to the dredging activity. Therefore, the EQO and ETL were met.

***<u>Cross-border</u>***

- According to the model result, there was no exceedance of 5 mg/L for more than 5% of the time during 12-hr daylight period. No impact to the international boundary were forecasted due to the dredging activity. Therefore, the EQO and ETL were met.

***<u>Recreational facilities</u>***

- According to the model result, there was no exceedance of 5 mg/L for more than 2.5% of the time during 12-hr daylight period. No impact to the recreational facilities were forecasted due to the dredging activity. Therefore, the EQO and ETL were met.

**Table 9-7: Summary of SSC EQOs and ETLs compliance at receptors during Northeast Monsoon, Southwest Monsoon, and Inter-monsoon**

| Receptor | Environmental Quality Objectives (EQOs) | Environmental Tolerance Limits (ETLs) | Compliance | | |
|---|---|---|---|---|---|
| | | | NE | SW | IM |
| Seagrass | No impact | SSC > 5mg/L for less than 20% of the time | √ | √ | √ |
| Aquaculture facilities | No impact | SSC > 5mg/L for less than 5% of the time | √ | √ | √ |
| Cross-border | No impact | SSC > 5 mg/L for less than 5% during 12-hour daylight period | √ | √ | √ |
| Recreational Facilities | No impact | SSC > 5 mg/L for less than 2.5% during 12-hour daylight period | √ | √ | √ |

**Note**:
√ = Compliance; X = Non-compliance; NE = Northeast Monsoon; SW = Southwest Monsoon; IM = Inter-monsoon

**Table 9-8: Sediment plume impact summary**

| Impacts | Predicted Impacts | | | | | | | Mitigation measures |
|---|---|---|---|---|---|---|---|---|
| | Potential impact | ES | I | M | P | R | C | |
| **Construction** | | | | | | | | |
| Seagrass | No change/ no impact | 0 | 3 | 0 | 2 | 2 | 2 | Full Feedback EMMP with spill budget, compliance monitoring, habitat monitoring, and deployment of silt screen if required |
| Mangroves | No change/ no impact | 0 | 4 | 0 | 2 | 2 | 2 | Full Feedback EMMP with spill budget, compliance monitoring, habitat monitoring, and deployment of silt screen if required |
| Aquaculture facilities | No change/ no impact | 0 | 4 | 0 | 2 | 2 | 1 | None required |
| Marine intake | No change/ no impact | 0 | 2 | 0 | 2 | 2 | 1 | None required |
| Cross-border | No change/ no impact | 0 | 5 | 0 | 2 | 2 | 1 | None required |
| Recreational facilities | No change/ no impact | 0 | 1 | 0 | 2 | 2 | 1 | None required |

#### 9.2.4.6.2 Sedimentation

The results were analysed in against the sedimentation tolerance limits (Table 9-5) for seagrass, aquaculture facilities, and marine facilities.

***Seagrass***

- According to the sedimentation plot, the sedimentation thickness for seagrass was expected to be maximum of 0.5mm/ 14 days and 0.4mm/ 9 days. No sedimentation impact to seagrass along the shoreline of Pasir Ris Park shoreline, Changi Beach, and Chek Jawa were forecasted due to the dredging activity. Therefore, the EQO and ETL were met.

***Aquaculture facilities***

- According to the sedimentation plot, the sedimentation thickness at the closest aquaculture facilities was expected to be 0mm/ 14 days and 0mm/ 9 days. No sedimentation impact to aquaculture facilities were forecasted due to the dredging activity. Therefore, the EQO and ETL were met.

***Marine Facilities***

- According to the sedimentation plot, the sedimentation thickness at marine facilities were expected to be maximum of 1.7mm/ 14 days and 1.6mm/ 9 days at Loyang Offshore Supply Base's jetty. and 1.0mm/ 14 days and 0.8mm/ 9 days at Fugro's jetty. No sedimentation impact to marine facilities were forecasted due to the dredging works. Therefore, the EQO and ETL were met.

**Table 9-9: Summary of Sedimentation EQOs and ETLs Compliance at receptors during Northeast Monsoon, Southwest Monsoon, and Inter-monsoon**

| Receptor | Environmental Quality Objectives (EQOs) | Environmental Tolerance Limits (ETLs) | NE | SW | IM |
|---|---|---|---|---|---|
| Seagrass | No impact | Sedimentation < 0.25mm/ day | √ | √ | √ |
| Aquaculture facilities | No impact | Sedimentation < 1.7 mm/ 14 days | √ | √ | √ |
| Marine Facilities | No impact | Sedimentation < 50 mm/ year | √ | √ | √ |

**Note**:
√ = Compliance; X = Non-compliance; NE = Northeast Monsoon; SW = Southwest Monsoon; IM = Inter-monsoon

**Table 9-10: Sedimentation impact summary**

| Impacts | Predicted Impacts | | | | | | | Mitigation measures |
|---|---|---|---|---|---|---|---|---|
| | Potential impact | ES | I | M | P | R | C | |
| **Construction** | | | | | | | | |
| Seagrass | No change/ no impact | 0 | 3 | 0 | 2 | 2 | 2 | Full Feedback EMMP with spill budget, compliance monitoring, habitat monitoring, and deployment of silt screen if required |
| Mangroves | No change/ no impact | 0 | 4 | 0 | 2 | 2 | 2 | Full Feedback EMMP with spill budget, compliance monitoring, habitat monitoring, and deployment of silt screen if required |
| Aquaculture facilities | No change/ no impact | 0 | 4 | 0 | 2 | 2 | 1 | None required |
| Marine facilities | No change/ no impact | 0 | 1 | 0 | 2 | 2 | 1 | None required |

### 9.2.4.6.3 Total Suspended Solids (TSS) and ASEAN MWQC Compliance

This assessment was conducted to evaluate the potential short-term increase in TSS associated with the Project's dredging activities. The ASEAN MWQC recommended that TSS levels should not exceed a 10% increase over the seasonal average. However, applying this threshold required long-term baseline datasets collected across multiple seasons, which were not available during the EIA stage. As the baseline data were limited to a single sampling event, the direct application of the ASEAN MWQC thresholds was not appropriate in this context.

To address this, SECS developed an alternative comparative method as a proxy indicator. This approach involved measuring TSS at each water quality station during both flood and ebb tides, across surface and mid-depth layers. The measured values were averaged to establish a representative baseline for each depth and station and then compared against modelled TSS concentrations under two dredging scenarios: Scenario 1 (average daily production) and Scenario 2 (maximum daily production). The percentage increase of modelled TSS relative to the measured baseline was then calculated to identify locations where elevated TSS could occur due to dredging.

This methodology enabled the identification of localised areas with potentially higher TSS impacts and provided a transparent, reproducible framework for assessing relative changes in TSS levels. It was important to note that this assessment did not constitute formal compliance with the ASEAN MWQC and should not be interpreted as a regulatory pass/ fail threshold. Rather, it served as a precautionary estimate of potential short-term impacts, indicating that any TSS-related effects were likely to be localised, temporary, and not expected to affect receptors of concerns.

Based on TSS criteria outlined in ASEAN MWQC, the permissible total suspended solid shall be less than 10% increase over seasonal average concentration. SECS notes that the ASEAN MWQC for TSS applies to data collected over an extended period. As there is no long-term TSS data covering all seasons during the EIA stage, the application of ASEAN MWQC is not applicable in this context. Additionally, the baseline water quality sampling was conducted as a single event, resulting in insufficient data to draw statistically significant conclusions.

An alternative calculation is performed using measurement TSS at 4 water quality station during both flood and ebb tide and across surface and mid depth. For example, the average TSS measured at WQ01 surface layer is averaged as $\frac{TSS_{flood,surface}+TSS_{ebb,surface}}{2} = \frac{9.50+12.1 mg/L}{2} = 10.80\,mg/L$. Subsequently, the percentage increase of modelled scenario 1 TSS over measured TSS at WQ01 surface layer is calculated as $\frac{Maximum\ modelled\ TSS_{surface,WQ01}}{Measure\ TSS_{surface,WQ01}} = \frac{8.34\ mg/L}{10.80\ mg/L} x100 = 77.2\%$

The measured data are then used to compared against extracted modelled TSS values as shown in Table 9-11. The assessed results indicate that TSS increases remain below 10% of baseline values for all scenarios, except for exceedances at WQ01 surface layer, for both scenario 1 and 2. There are also exceedances at WQ02 surface layer for scenario 2. At mid depth, TSS increases exceeds 10% of baseline values for all scenarios at WQ01. This outcome is not unexpected, as WQ01 and WQ02 are in close proximity to the dredging footprint.

It should be noted that the presented assessment 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 seasonal average concentration, which needs to be derived from long term monitoring data.

Overall, the alternative calculation indicated that spatial impact of TSS increase due to dredging activity is localized within the Project area. Seagrass area and aquaculture farms located away dredging footprint (i.e. near WQ02, WQ03 and WQ04) experience low percentage of TSS increase compared to background TSS measurement. It is expected that the TSS increase will drop to background level after the short construction period of 14 or 9 days has ended.

**Table 9-11: Comparison of modelled TSS with measured TSS at different water quality station for Scenario 1 and Scenario 2. Green shading cells indicates values at surface layer, while blue shading cells indicate values at mid depth. Values in square bracket indicates percentage increase of modelled TSS over measured TSS, with values in bold indicating >10% increase over measured TSS values.**

| Station / Scenario | | Surface Layer | | | | | Mid Depth TSS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | WQ01 | WQ02 | WQ03 | WQ04 | Average | WQ01 | WQ02 | WQ03 | WQ04 | Average |
| Measured TSS (mg/L) | | 10.80 | 3.85 | 7.63 | 14.65 | 9.23 | 11.65 | 7.45 | 6.80 | 20.55 | 11.61 |
| NE monsoon Modelled TSS (mg/L) | Scenario 1 | 8.34 **[77.2%]** | 0.32 [8.3%] | 0.26 [3.4%] | 0.06 [0.4%] | 2.25 [24.3%] | 4.65 **[39.9%]** | 0.35 [4.7%] | 0.31 [4.6%] | 0.07 [0.3%] | 1.35 [11.6%] |
| | Scenario 2 | 10.87 **[100.6%]** | 0.40 **[10.4%]** | 0.33 [4.3%] | 0.08 [0.5%] | 2.92 [31.6%] | 6.46 **[55.5%]** | 0.67 [9.0%] | 0.40 [5.9%] | 0.09 [0.4%] | 1.91 [16.4%] |
| SW monsoon Modelled TSS (mg/L) | Scenario 1 | 7.05 **[65.3%]** | 0.32 [8.3%] | 0.17 [2.2%] | 0.06 [0.4%] | 1.90 [20.6%] | 5.38 **[46.2%]** | 0.26 [3.5%] | 0.20 [2.9%] | 0.06 [0.3%] | 1.48 [12.7%] |
| | Scenario 2 | 9.10 **[84.3%]** | 0.43 **[11.2%]** | 0.26 [3.4%] | 0.08 [0.5%] | 2.47 [26.7%] | 7.60 **[65.2%]** | 0.38 [5.1%] | 0.29 [4.3%] | 0.09 [0.4%] | 2.09 [18.0%] |
| Inter- monsoon Modelled TSS (mg/L) | Scenario 1 | 7.22 **[66.9%]** | 0.29 [7.5%] | 0.12 [1.6%] | 0.05 [0.3%] | 1.92 [20.8%] | 1.86 **[16.0%]** | 0.33 [4.4%] | 0.16 [2.4%] | 0.06 [0.3%] | 0.60 [5.2%] |
| | Scenario 2 | 9.15 **[84.7%]** | 0.40 **[10.4%]** | 0.18 [2.4%] | 0.08 [0.5%] | 2.45 [26.6%] | 5.15 **[44.2%]** | 0.40 [5.4%] | 0.22 [3.2%] | 0.08 [0.4%] | 1.46 [12.6%] |

Note:

1. Scenario 1 refers to dredging with daily average production rate while Scenario 2 refers to dredging with daily maximum production rate.
2. The modelled TSS are solely due to spill from the Project dredging work and does not take into account the background concentration TSS

# 9.3 Thermal Plume

The discharge of warm water from the cooling water system has the potential to impact sensitive receptors near the Project site. As part of the operational phase, the release of heated water into the surrounding environment can create a thermal plume that alters the local water temperature, potentially affecting the biodiversity of the area. This section of the report focuses on the long-term impacts of thermal plume dispersion, specifically the potential effects on sensitive environmental receptors.

## 9.3.1 Simulation Scenarios

The development of the cooling water system is expected to cause thermal release impacts on the surrounding environment due to the discharge of heated water via the outfall. The cooling system (Figure 2-2) includes one outfall and two intake points. The cooling system is designed to include one outfall and two intake points. Under normal operating conditions, both intake points will function simultaneously, with each operating at 50% capacity. However, during maintenance activities, one intake point will operate at 100% capacity while the other is offline.

Thermal plume modelling scenarios were summarised in Table 9-12, based on the proposed cooling water system information available at the time of the assessment. Any subsequent changes will require a detailed review to ensure compliance with project-specific EQOs and ETLs.

The designed outfall discharge flow rate is 4,800 $m^3$/hr, with the maximum temperature rise in the cooling water system not exceeding 5°C above the ambient seawater temperature. Thermal impacts were quantified as the increase in excess temperature (i.e., the temperature above ambient seawater levels) associated with project-related releases.

The simulations were conducted over 14 days peak spring-neap tidal cycle during each monsoon period:

- Southwest Monsoon: 1 Jul 2023 to 15 Jul 2023
- Northeast Monsoon: 9 Dec 2023 to 23 Dec 2023
- Inter-monsoon: 1 Apr 2023 to 15 Apr 2023

**Table 9-12: Intake and outfall information**

| Parameter | Intake | Outfall |
|---|---|---|
| Flow rate | • With one intake operating: 4,800 m³/hr<br>• With two intakes operating: 2,400 m³/hr per intake | 4,800 m³/hr |
| Water depth | Sea water intake from the side of the hull, positioned 2.5 m below the surface water | Positioned 1m below the surface water |
| Design discharge excess temperature increase (° C) | Ambient | + 5 ˚C |

The impacts of the dispersal of the warm water discharge from the outfall has been analysed for the design release flow rates of the proposed development. The following scenarios indicated in Table 9-13 were simulated.

**Table 9-13: Thermal plume model scenarios**

| Parameter | Intake |
|---|---|
| Scenario 1 | Outfall operates at 4,800 m³/hr with two intakes, each drawing 2,400 m³/hr from the left and right intake points |
| Scenario 2 | Outfall operates at 4,800 m³/hr with a single intake on the left side drawing 4,800 m³/hr |
| Scenario 3 | Outfall operates at 4,800 m³/hr with a single intake on the right side drawing 4,800 m³/hr |

### 9.3.2 Receptors of Concern

The thermal plume model will assess the dispersion characteristics of the thermal plume and its potential long-term impacts on the following sensitive receptors:

- Seagrass
- Mangroves
- Aquaculture facilities

### 9.3.3 Adopted Evaluation Criteria

To assess the potential environmental impacts associated with thermal plume dispersion, the EQOs and ETLs presented in Table 9-14 were adopted.

The receptor importance evaluation framework used in this assessment follows the definitions outlined in Table 8-2 and Section 8.2.1.2. To evaluate the magnitude of change, this assessment references the quantitative thresholds and criteria established for thermal plume and these criteria are stipulated in Table 8-14. Together, these tables provide a standardised approach to assigning magnitude scores based on exposure conditions, which are then combined with receptor importance to determine overall impact significance.

Further details of the adopted impact assessment criteria, including thresholds and the rationale for receptor classification, are provided in Section 8.

**Table 9-14: Thermal plume impact criteria**

| Receptor | Environmental Quality Objectives (EQOs) | Environmental Tolerance Limits (ETLs) |
|---|---|---|
| Seagrass and mangroves | No impact | • Excess temperature > 0.5°C for less than 5% of the time<br>• Excess temperature > 1.0°C at any time |
| Aquaculture facilities | No impact | • Excess temperature > 0.5°C for less than 5% of the time<br>• Excess temperature > 1.0°C at any time |

### 9.3.4 Results and Discussion

Thermal impacts were quantified as the increase in excess temperature (i.e., the temperature above ambient seawater levels) associated with project-related releases. The analysis was presented in terms of:

- Mean excess temperature
- 95$^{th}$ percentile excess temperature
- Percentage exceedance of excess temperature at 0.5°C and 1.0°C
- Time series temperature

#### 9.3.4.1 Mean Excess Temperature

Figure 9-34 to Figure 9-37 show the mean excess temperature across 14 days at Northeast Monsoon, Southwest Monsoon, and Inter-monsoon periods at different intake scenarios (Table 9-13). Result plots showed that higher value and wider extent of excess temperature plume on the surface layer compared to the bottom layer due to tendency of positively buoyant discharge to disperse upwards.

The mean excess temperature values extracted from Scenario 1 are tabulated in Table 9-15. Scenario 1 was selected for analysis as it represents the normal operating condition. Additionally, the spatial extent results of mean excess temperature show minimal variation across the three (3) scenarios, as represented in Figure 9-34 to Figure 9-37. The extracted excess temperature data includes the surface layer, bottom layer, and depth-averaged temperatures for the three (3) selected monsoon periods. However, to assess the potential impacts, a conservative approach was employed by using the depth-averaged temperature values, as sensitive receptors such as seagrass and mangroves are primarily located near the seabed. The predicted mean excess temperatures were extracted at various locations, including the seagrass, mangroves, and aquaculture facilities.

The results showed that at the seagrass area within 500 m from the outfall, the mean excess temperatures were predicted to be up to 0.46°C (surface layer), 0.17°C (bottom layer), and 0.26°C (depth-averaged). At the seagrass area between 500 m and 1 km away from the outfall, the highest values were 0.28°C (surface layer), 0.17°C (bottom layer), and 0.21°C (depth average).

For the mangroves at Sungei Loyang, the predicted mean excess temperatures were up to 0.36°C (surface layer), 0.24°C (bottom layer), and 0.27°C (depth average).

At receptors further away from the outfall, such as the seagrass at Changi Boardwalk, mangroves at Sungei Tampines, and the nearest aquaculture farm, negligible mean excess temperature impacts were predicted.

**Table 9-15: Mean excess temperature extraction at various locations/ receptors across different monsoon period for scenario 1**

| Receptor | Mean Excess Temperature (°C) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | NE monsoon | | | Southwest monsoon | | | Inter-monsoon | | |
| | Surface | Bottom | Depth average | Surface | Bottom | Depth average | Surface | Bottom | Depth average |
| Seagrass outside mixing zone (1) but within 500m (2) away from outfall | 0.41 | 0.17 | 0.25 | 0.46 | 0.15 | 0.21 | 0.45 | 0.17 | 0.26 |
| Mangroves at Sungei Long | 0.33 | 0.24 | 0.27 | 0.29 | 0.22 | 0.26 | 0.36 | 0.24 | 0.27 |
| Seagrass outside 500m(2) away from outfall but within 1km(2) away from outfall | 0.28 | 0.17 | 0.21 | 0.20 | 0.13 | 0.15 | 0.26 | 0.17 | 0.19 |
| Seagrass at Changi Boardwalk | 0.05 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | 0.04 | 0.04 | 0.03 |
| Nearest Aquaculture Farm | 0.04 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.04 | 0.03 |

**Note:**

(1) The mixing zone is defined as a 100m radius from the point of discharge. According to the IFC Guidelines, when a mixing zone is not specifically determined, a default distance of 100m is used, provided that no sensitive aquatic ecosystems are present within this range.

(2) The 500m and 1km distances are indicative references used to assess spatial concentration patterns and should not be interpreted as strict impact boundaries. Actual thermal dispersion may vary depending on hydrodynamic conditions and site-specific factors.

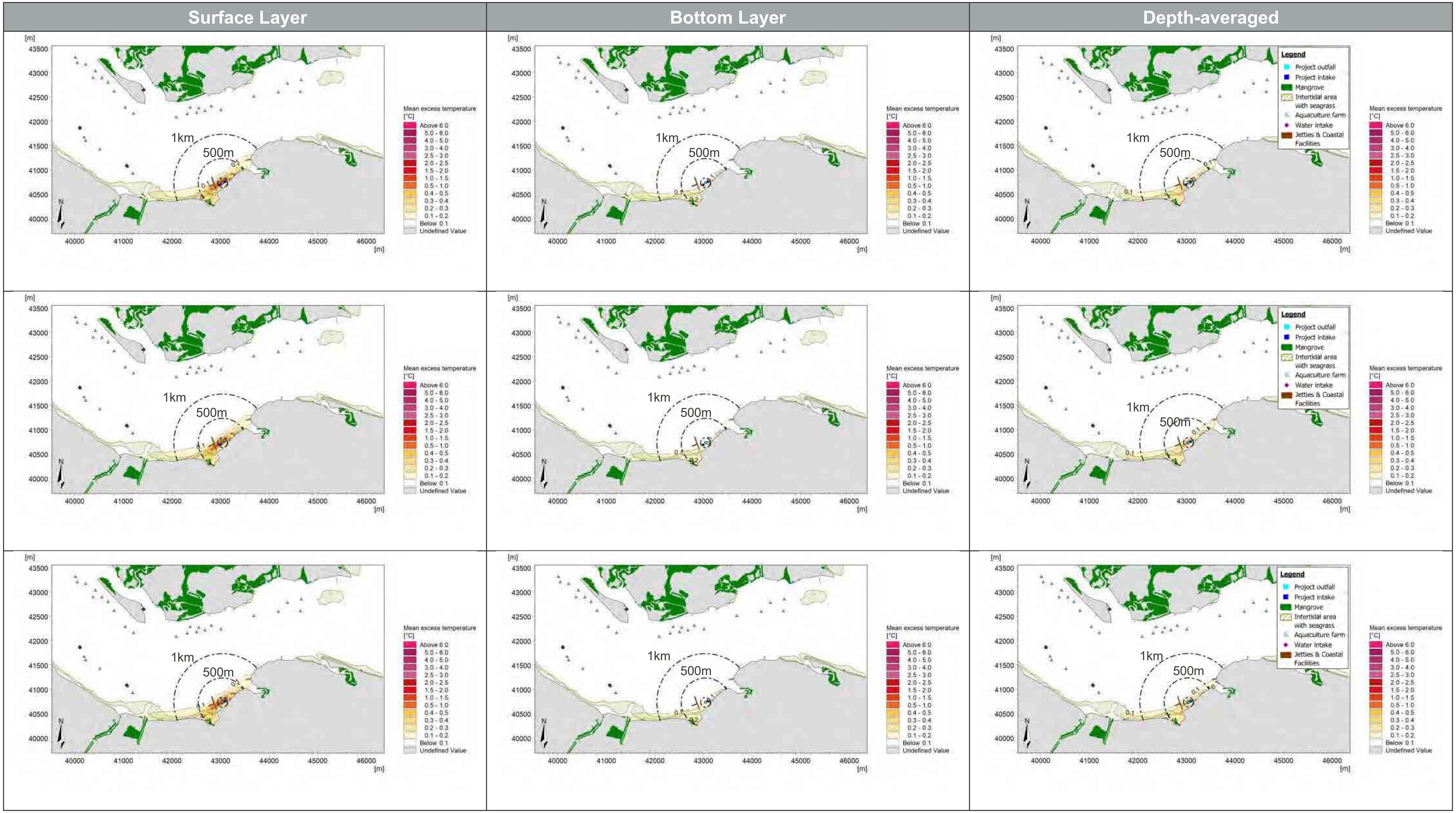



**Figure 9-32: Overview mean excess temperature plot during Northeast Monsoon for post-construction stage – Scenario 1 (top row), post-construction stage – Scenario 2 (middle row) and post-construction stage – Scenario 3 (bottom row)**

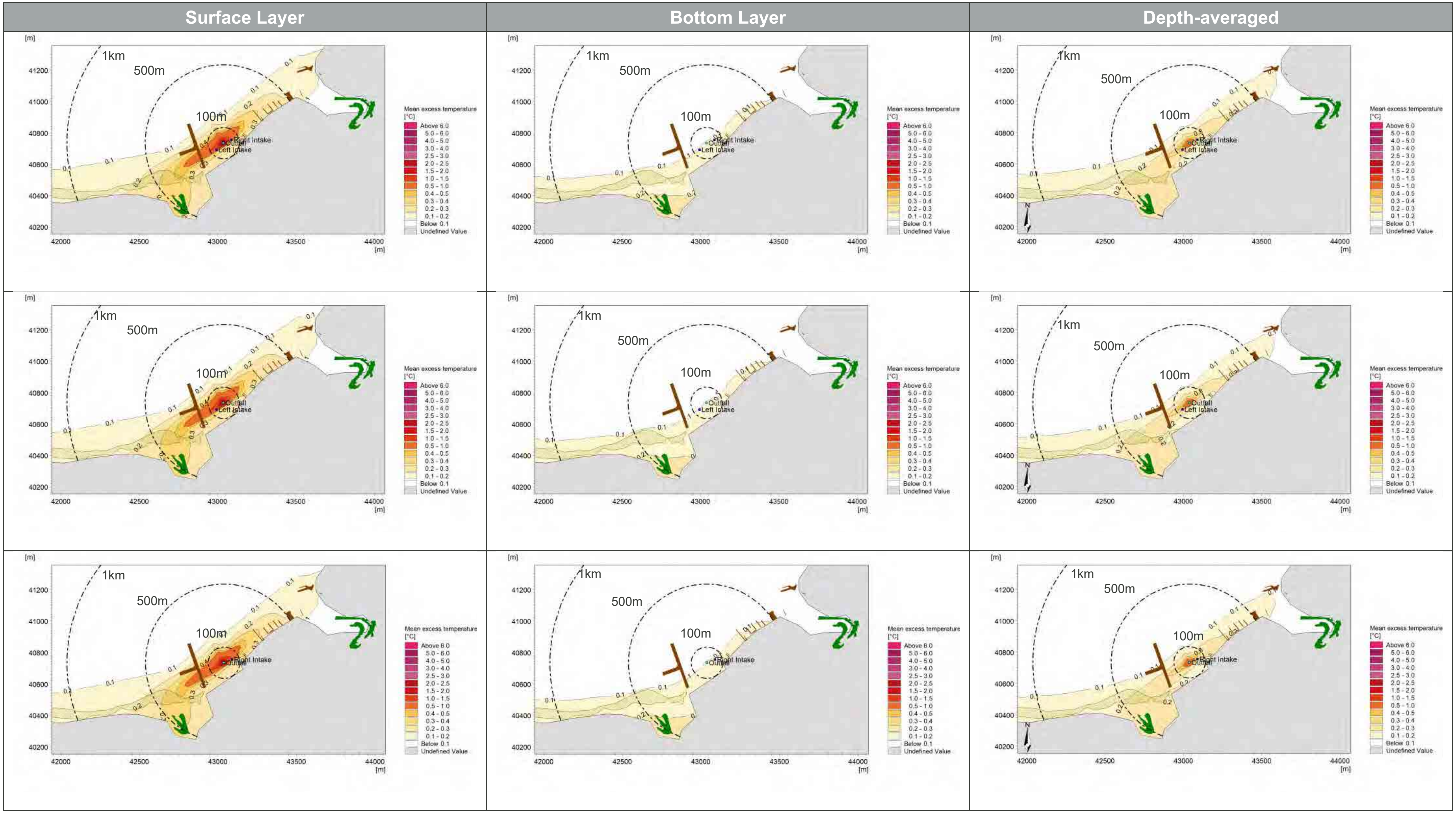



**Figure 9-33: Detailed mean excess temperature enlarged plot during Northeast Monsoon for post-construction stage – Scenario 1 (top row), post-construction stage – Scenario 2 (middle row) and post-construction stage – Scenario 3 (bottom row)**

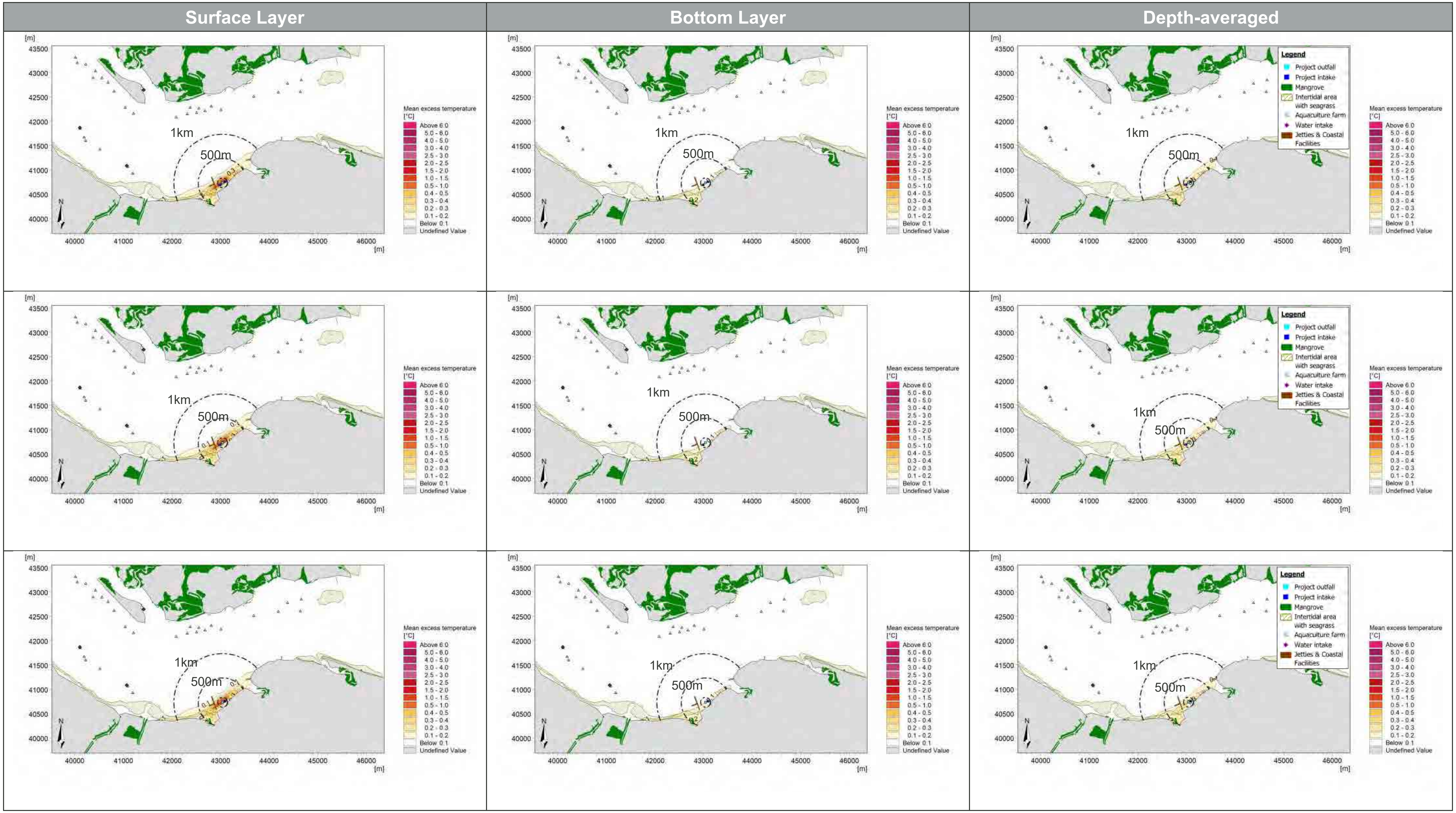



**Figure 9-34: Overview mean excess temperature plot during Southwest Monsoon for post-construction stage – Scenario 1 (top row), post-construction stage – Scenario 2 (middle row) and post-construction stage – Scenario 3 (bottom row)**

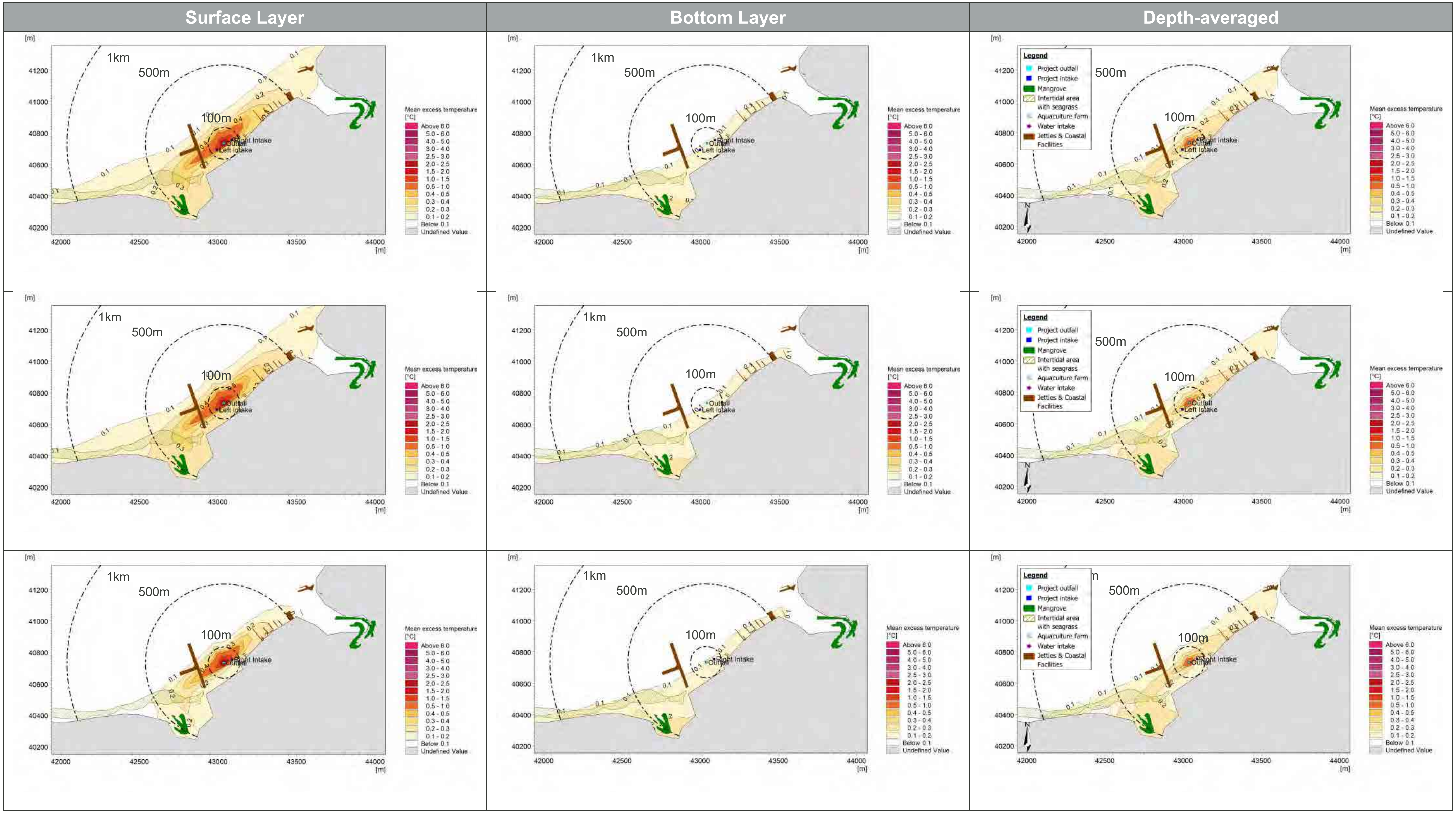



**Figure 9-35: Detailed mean excess temperature enlarged plot during Southwest Monsoon for post-construction stage – Scenario 1 (top row), post-construction stage – Scenario 2 (middle row) and post-construction stage – Scenario 3 (bottom row)**

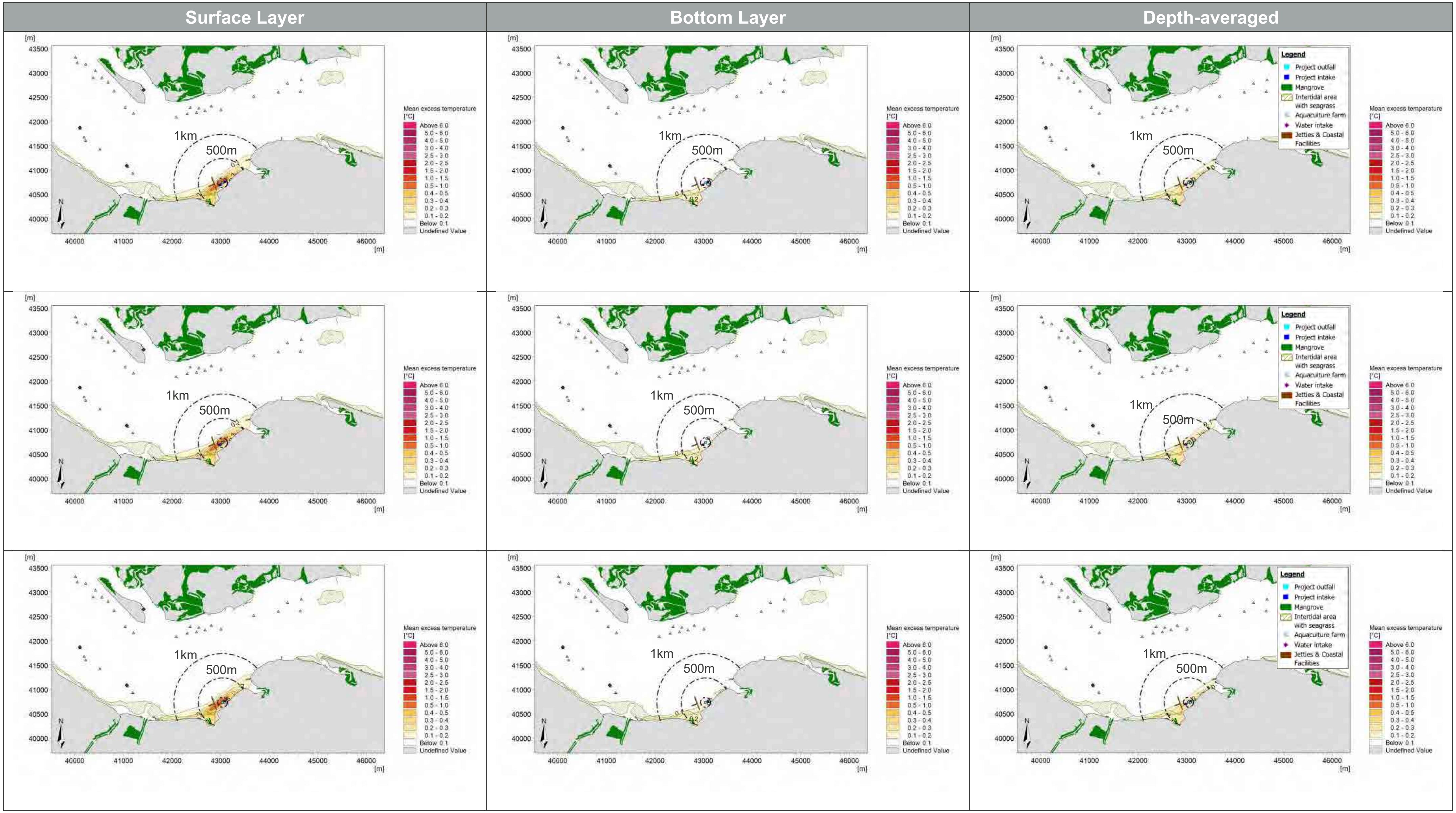



**Figure 9-36: Overview mean excess temperature plot during Inter-monsoon for post-construction stage – Scenario 1 (top row), post-construction stage – Scenario 2 (middle row) and post-construction stage – Scenario 3 (bottom row)**

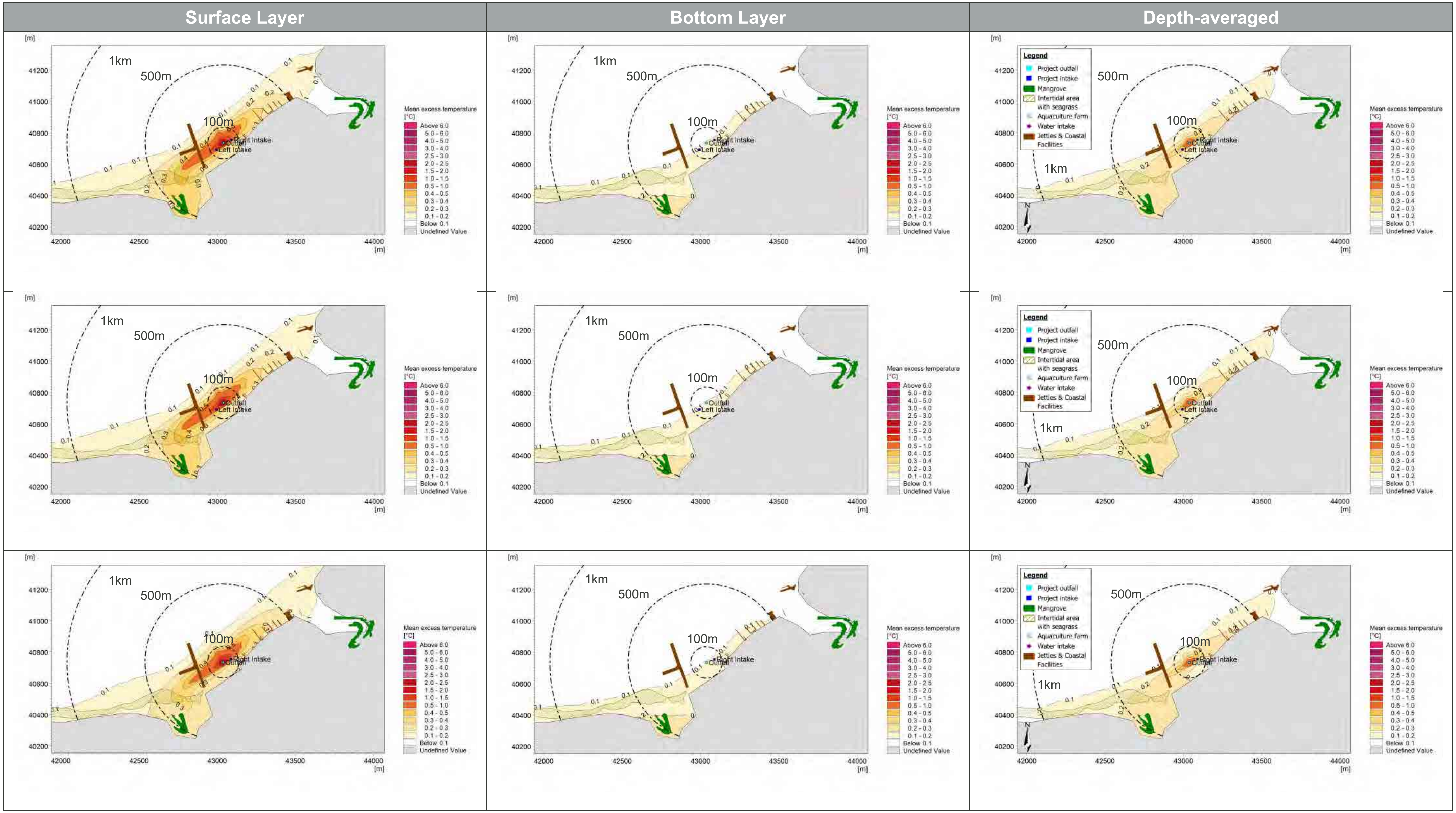



**Figure 9-37: Detailed mean excess temperature enlarged plot during Inter-monsoon for post-construction stage – Scenario 1 (top row), post-construction stage – Scenario 2 (middle row) and post-construction stage – Scenario 3 (bottom row)**

### 9.3.4.2 95th Percentile Excess Temperature

Figure 9-38 to Figure 9-43 show the 95th percentile excess temperature across 14 days at Northeast Monsoon, Southwest Monsoon, and Inter-monsoon periods at different intake scenarios (Table 9-13). Result plots show that higher value and wider extent of excess temperature plume on the surface layer due to tendency of positively buoyant discharge to disperse upwards.

Similarly, the 95th percentile excess temperature values extracted from Scenario 1 are tabulated in Table 9-16. Scenario 1 was selected for analysis as it represents the normal operating condition. Additionally, the spatial extent results of 95th percentile excess temperature show minimal variation across the three (3) scenarios, as represented in Figure 9-40 to Figure 9-43. The extracted excess temperature data includes the surface layer, bottom layer, and depth-averaged temperatures for the three (3) selected monsoon periods. However, to assess the potential impacts, a conservative approach was employed by using the depth-averaged temperature values, as sensitive receptors such as seagrass and mangroves are primarily located near the seabed. The predicted mean excess temperatures were extracted at various locations, including the seagrass, mangroves, and aquaculture facilities.

The results show that at the seagrass area outside the mixing zone but within 500 m of the outfall, the 95th percentile excess temperature was predicted to reach up to 1.13°C (surface layer), 0.34°C (bottom layer), and 0.50°C (depth-averaged). At the seagrass area located 500 m to 1 km away from the outfall, the 95th percentile excess temperature was predicted to reach up to 0.74°C (surface layer), 0.37°C (bottom layer), and 0.41°C (depth-averaged).

For the Sungei Loyang mangroves within 500 m of the outfall, the 95th percentile excess temperature was predicted to reach up to 0.76°C (surface layer), 0.41°C (bottom layer), and 0.47°C (depth-averaged).

At receptors further from the outfall, such as the seagrass at Changi Boardwalk, mangroves at Sungei Tampines, and the nearest aquaculture farm, negligible 95th percentile excess temperature impacts of approximately 0.1°C across the surface, bottom layers, and depth-averaged results were predicted.

**Table 9-16: 95th percentile excess temperature extraction at various locations/receptors across different monsoon period for scenario 1**

| Receptor | 95th Percentile Excess Temperature (°C) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | NE monsoon | | | SW monsoon | | | Inter-monsoon | | |
| | Surface | Bottom | Depth average | Surface | Bottom | Depth average | Surface | Bottom | Depth average |
| Seagrass outside mixing zone (1) but within 500m (2) away from outfall | 1.01 | 0.34 | 0.46 | 1.09 | 0.34 | 0.48 | 1.13 | 0.34 | 0.50 |
| Mangroves at Sungei Loyang | 0.66 | 0.38 | 0.42 | 0.74 | 0.41 | 0.47 | 0.76 | 0.38 | 0.47 |
| Seagrass outside 500m (2) away from outfall but within 1km away from outfall | 0.73 | 0.37 | 0.41 | 0.64 | 0.32 | 0.38 | 0.74 | 0.34 | 0.40 |
| Seagrass at Changi Boardwalk | 0.11 | 0.06 | 0.09 | 0.13 | 0.09 | 0.10 | 0.11 | 0.08 | 0.09 |
| Nearest Aquaculture Farm | 0.09 | 0.08 | 0.08 | 0.09 | 0.07 | 0.08 | 0.07 | 0.05 | 0.05 |

**Note:**

(1) The mixing zone is defined as a 100m radius from the point of discharge. According to the IFC Guidelines, when a mixing zone is not specifically determined, a default distance of 100m is used, provided that no sensitive aquatic ecosystems are present within this range.

(2) The 500m and 1km distances are indicative references used to assess spatial concentration patterns and should not be interpreted as strict impact boundaries. Actual thermal dispersion may vary depending on hydrodynamic conditions and site-specific factors.

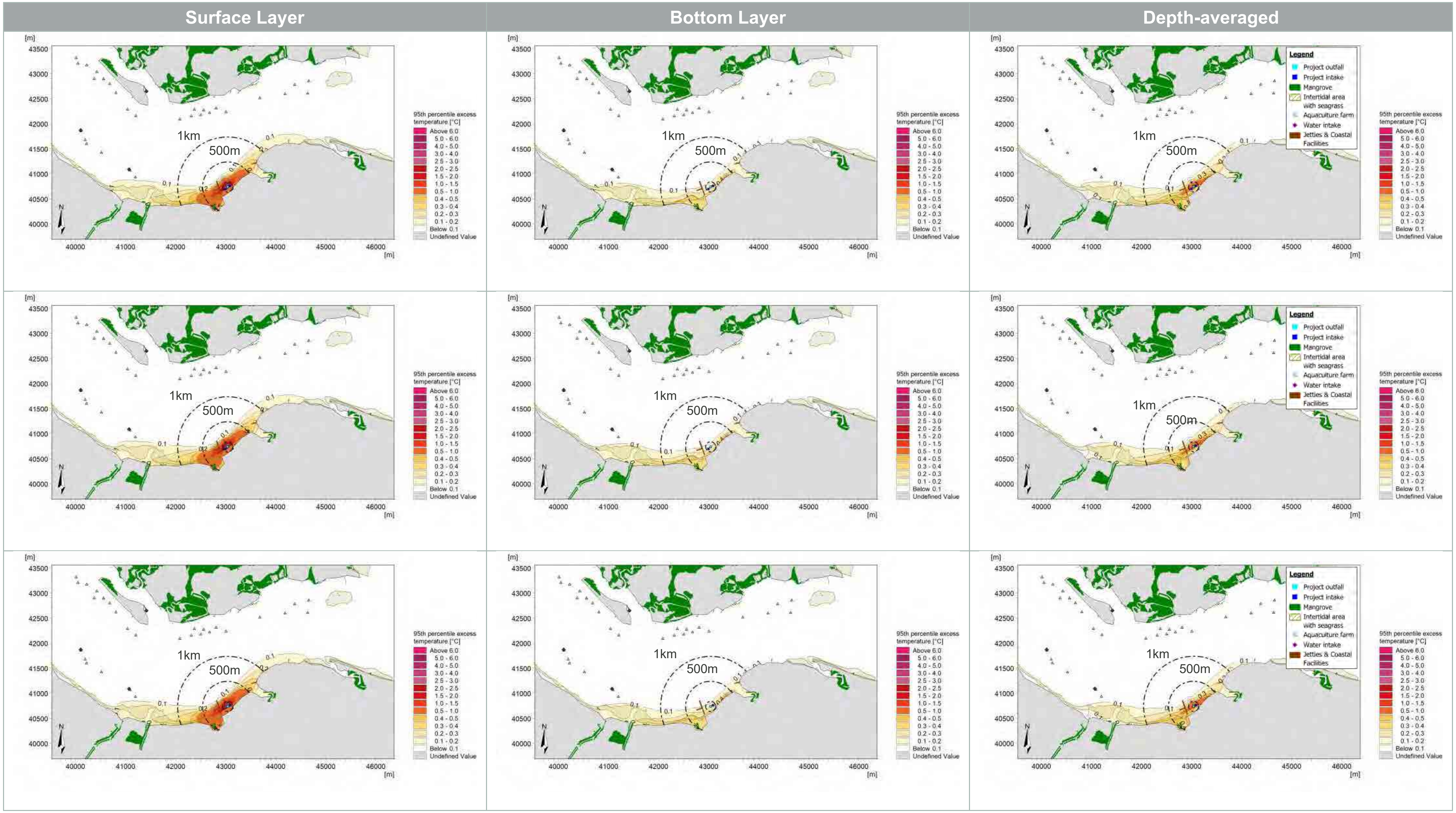



**Figure 9-38: Overview 95th percentile excess temperature plot during Northeast Monsoon for post-construction stage – Scenario 1 (top row), post-construction stage – Scenario 2 (middle row) and post-construction stage – Scenario 3 (bottom row)**

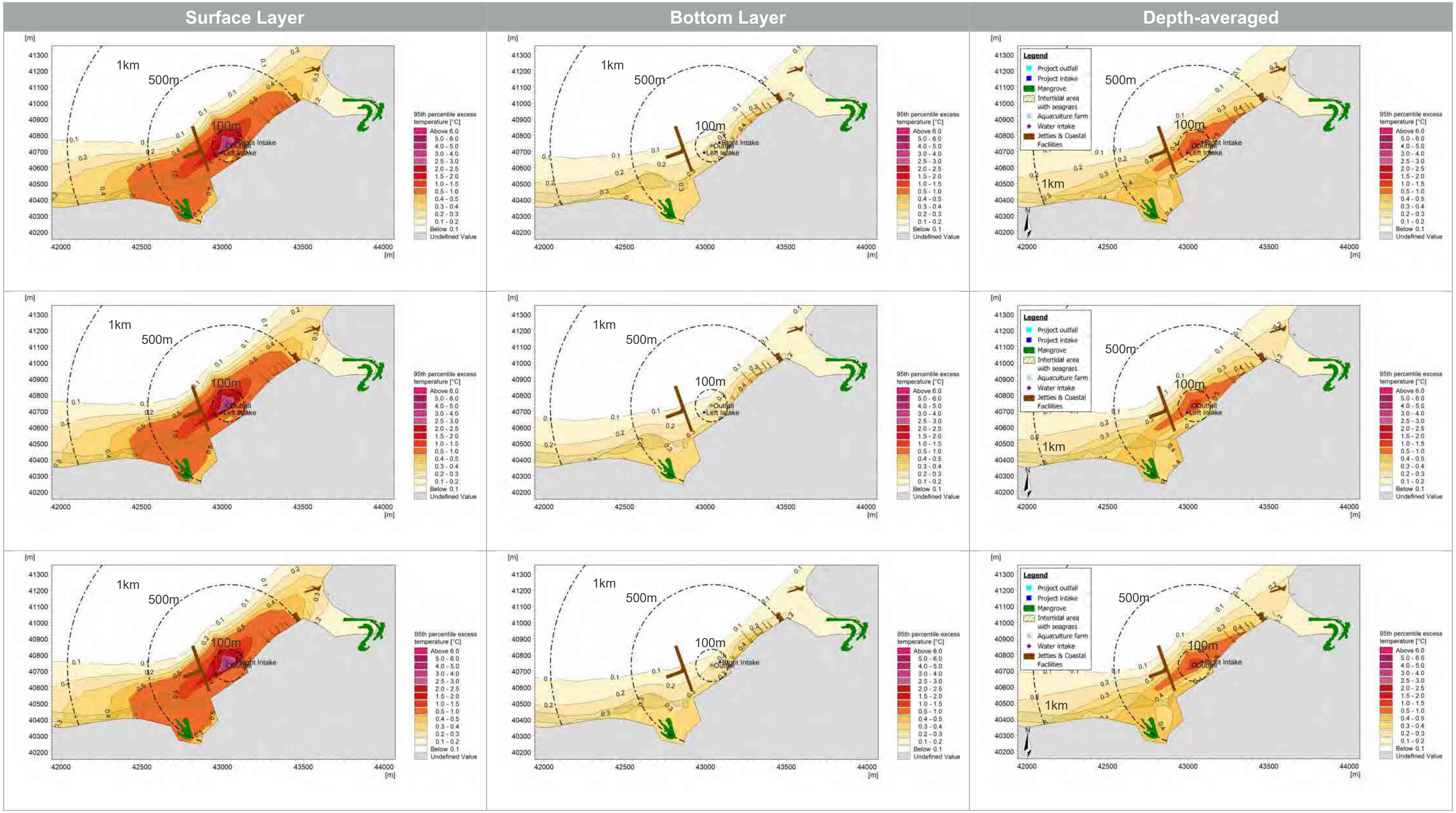



**Figure 9-39: Detailed 95th percentile excess temperature enlarged plot during Northeast Monsoon for post-construction stage – Scenario 1 (top row), post-construction stage – Scenario 2 (middle row) and post-construction stage – Scenario 3 (bottom row)**

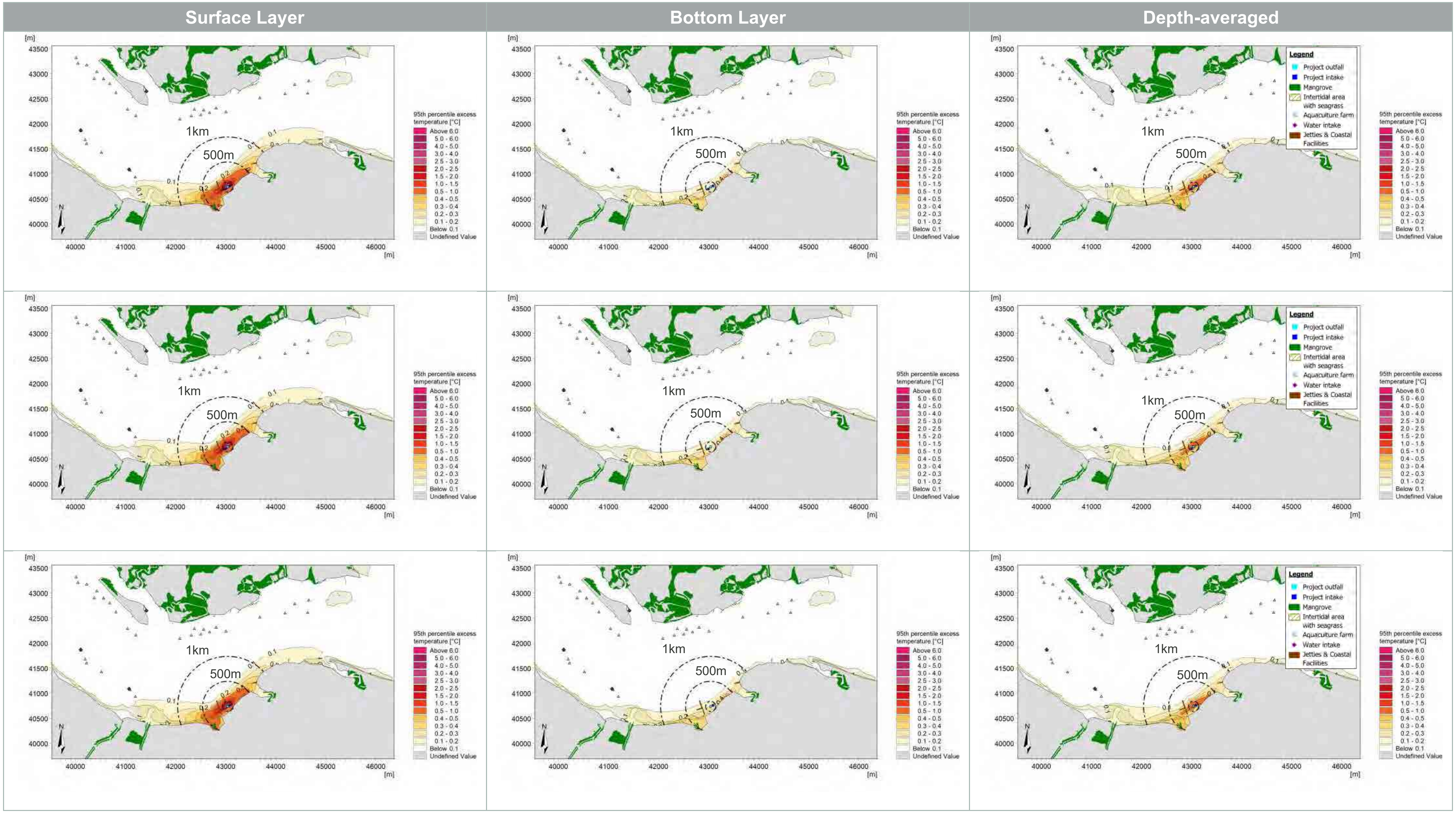



**Figure 9-40: Overview 95th percentile excess temperature plot during Southwest Monsoon for post-construction stage – Scenario 1 (top row), post-construction stage – Scenario 2 (middle row) and post-construction stage – Scenario 3 (bottom row)**

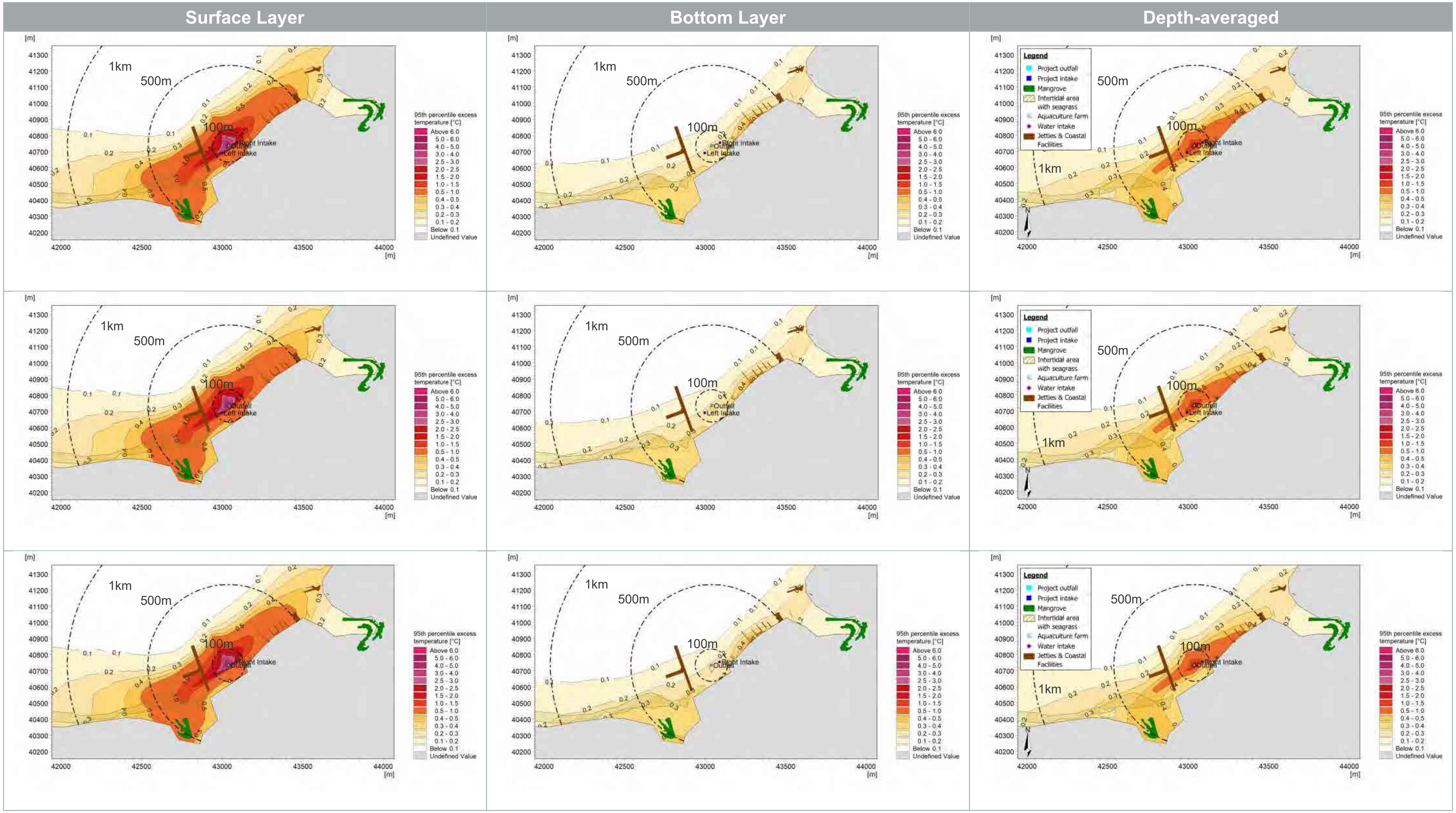



**Figure 9-41: Detailed 95th percentile excess temperature enlarged plot during Southwest Monsoon for post-construction stage – Scenario 1 (top row), post-construction stage – Scenario 2 (middle row) and post-construction stage – Scenario 3 (bottom row)**

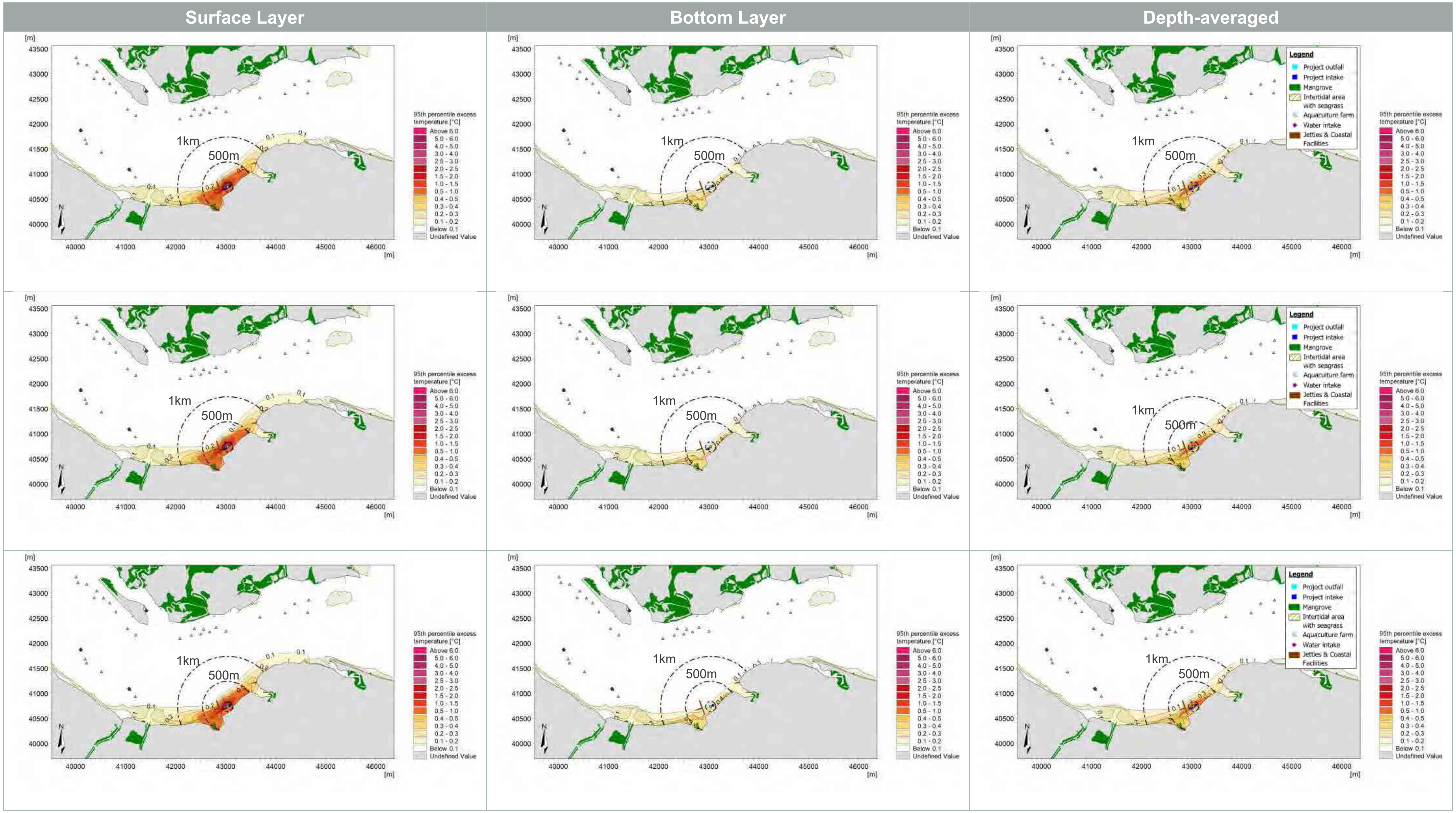



**Figure 9-42: Overview 95th percentile excess temperature plot during Inter-monsoon for post-construction stage – Scenario 1 (top row), post-construction stage – Scenario 2 (middle row) and post-construction stage – Scenario 3 (bottom row)**

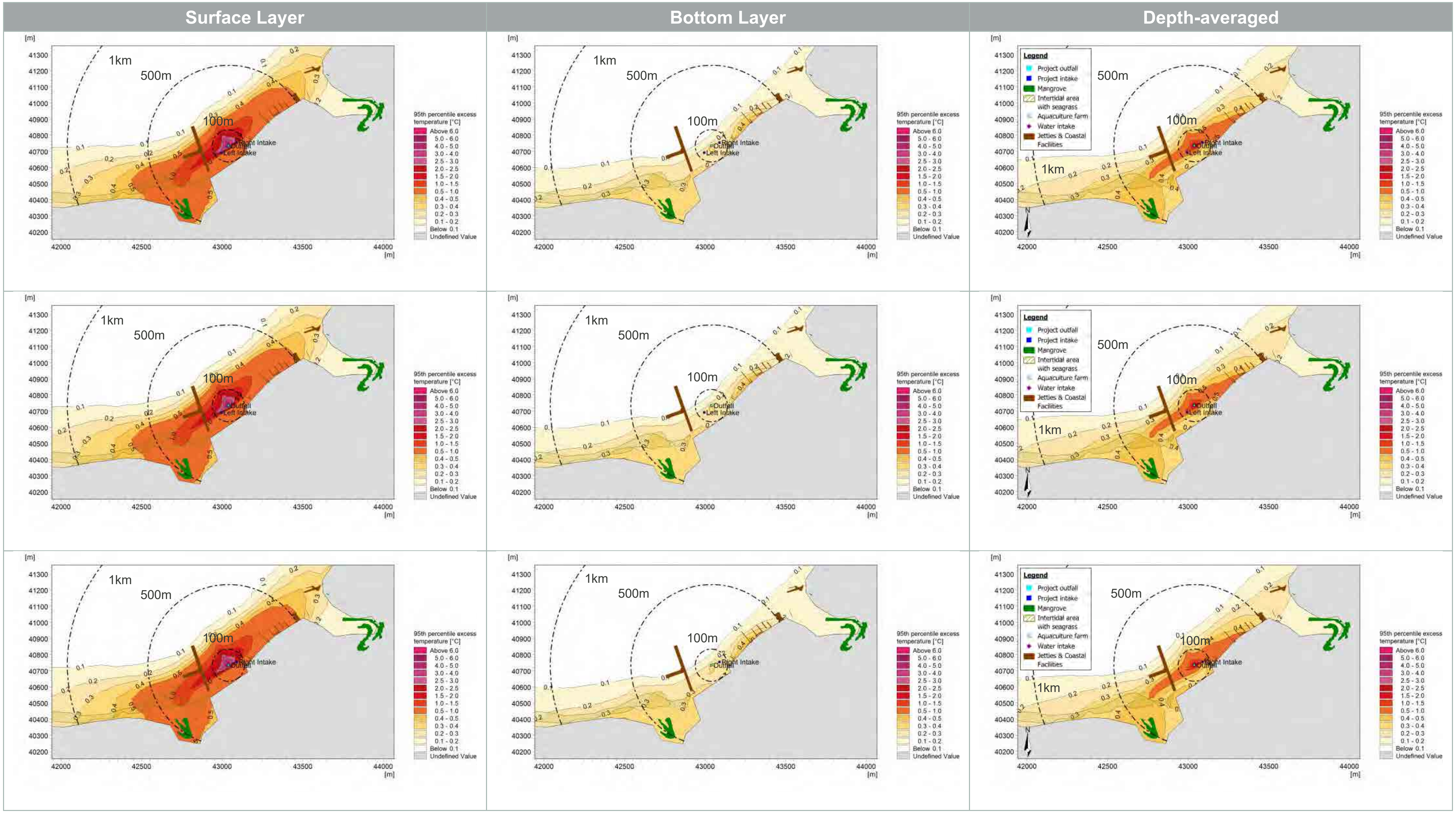



**Figure 9-43: Detailed 95th percentile excess temperature enlarged plot during Inter-monsoon for post-construction stage – Scenario 1 (top row), post-construction stage – Scenario 2 (middle row) and post-construction stage – Scenario 3 (bottom row)**

#### 9.3.4.3 Exceedance of Temperature

The percentage exceedance of excess temperature of 0.5°C plots are shown in Figure 9-44, Figure 9-45, and Figure 9-46, respectively. These exceedances represent the percentage of time, over 14 days simulation period, during which the excess temperature exceeds the defined thresholds (0.5°C and 1.0°C). To calculate these values, the 14 days 3D seawater temperature model results were depth-averaged prior to determining the percentage exceedances. According to Figure 9-44, Figure 9-45, and Figure 9-46, the highest exceedances are expected near the outfall. However, the temperature increase diminishes progressively with distance from the outfall.

The percentage exceedance at various nearby receptors is tabulated in Table 9-17, and compared against the adopted EQOs and ETLs, as shown in Table 9-14. Scenario 1 was selected for analysis as it represents normal operating conditions. The spatial extent results for the mean and 95$^{th}$ percentile excess temperatures indicate minimal variation across the three scenarios. The extracted excess temperature corresponds to the highest percentage exceedance observed. At the seagrass area located outside the mixing zone and within 500 m of the outfall, the exceedance of 0.5°C was predicted to reach a maximum of 4.8%. In the mangrove area at Sungei Loyang, the exceedance of 0.5°C was predicted to reach up to 3.4%. For all other receptors located 500 m to 1 km away from the outfall, including seagrass, mangroves, and aquaculture farms, 0% exceedance was predicted for thresholds of 0.5°C.

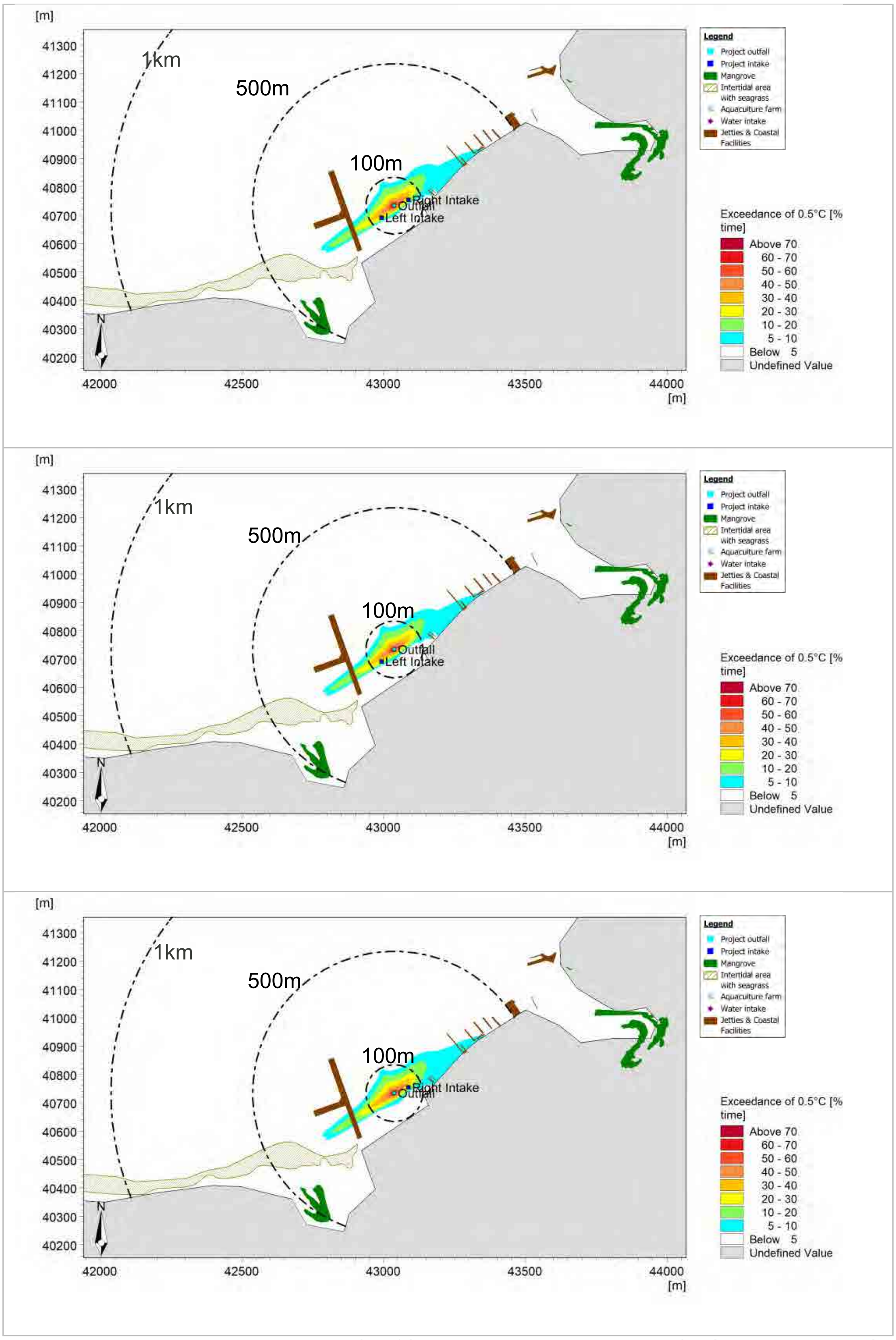



**Figure 9-44: Percentage exceedance of 0.5°C during Northeast Monsoon for Scenario 1 (top), Scenario 2 (middle) and Scenario 3 (bottom)**

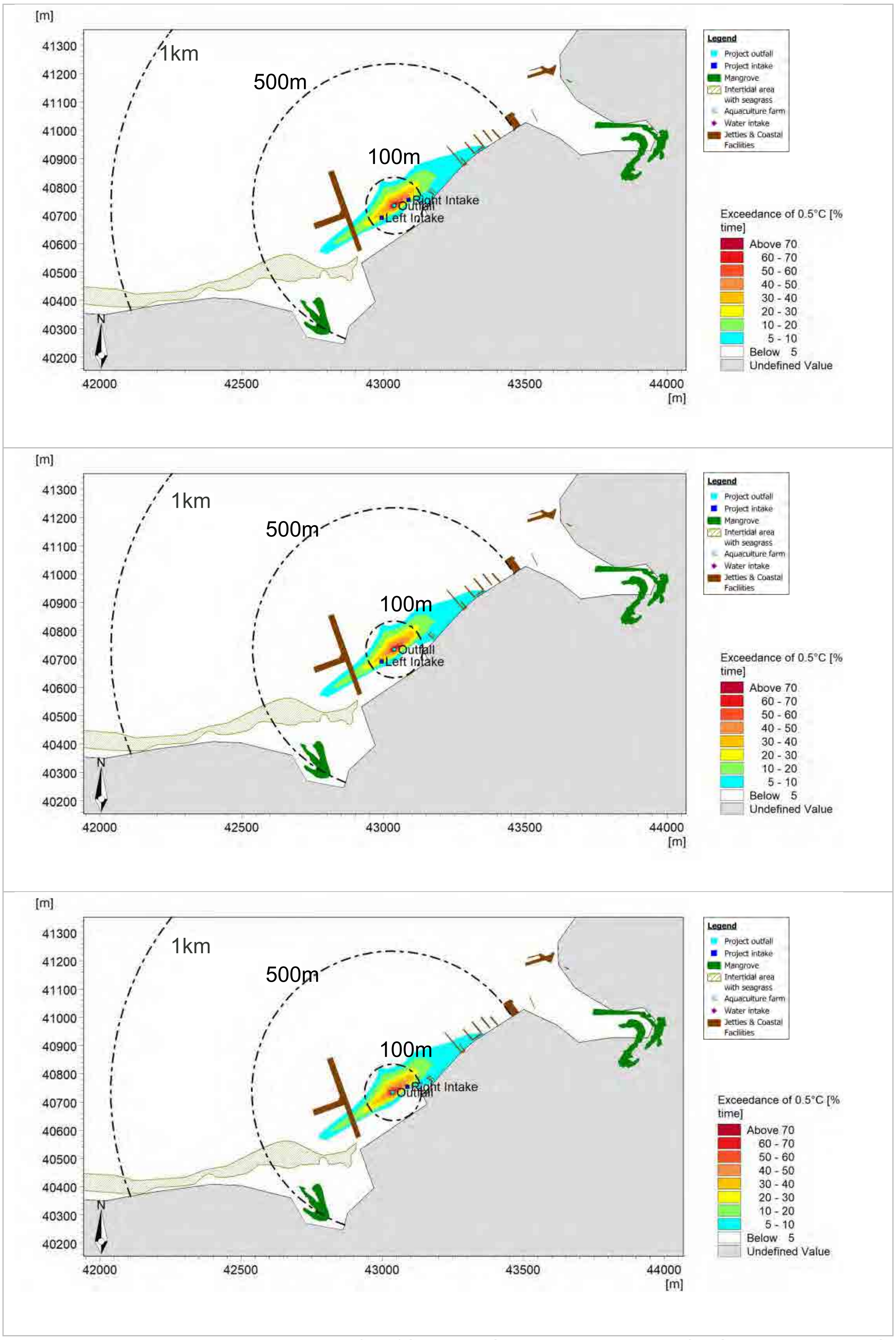



**Figure 9-45: Percentage exceedance of 0.5°C during Southwest Monsoon for Scenario 1 (top), Scenario 2 (middle) and Scenario 3 (bottom)**

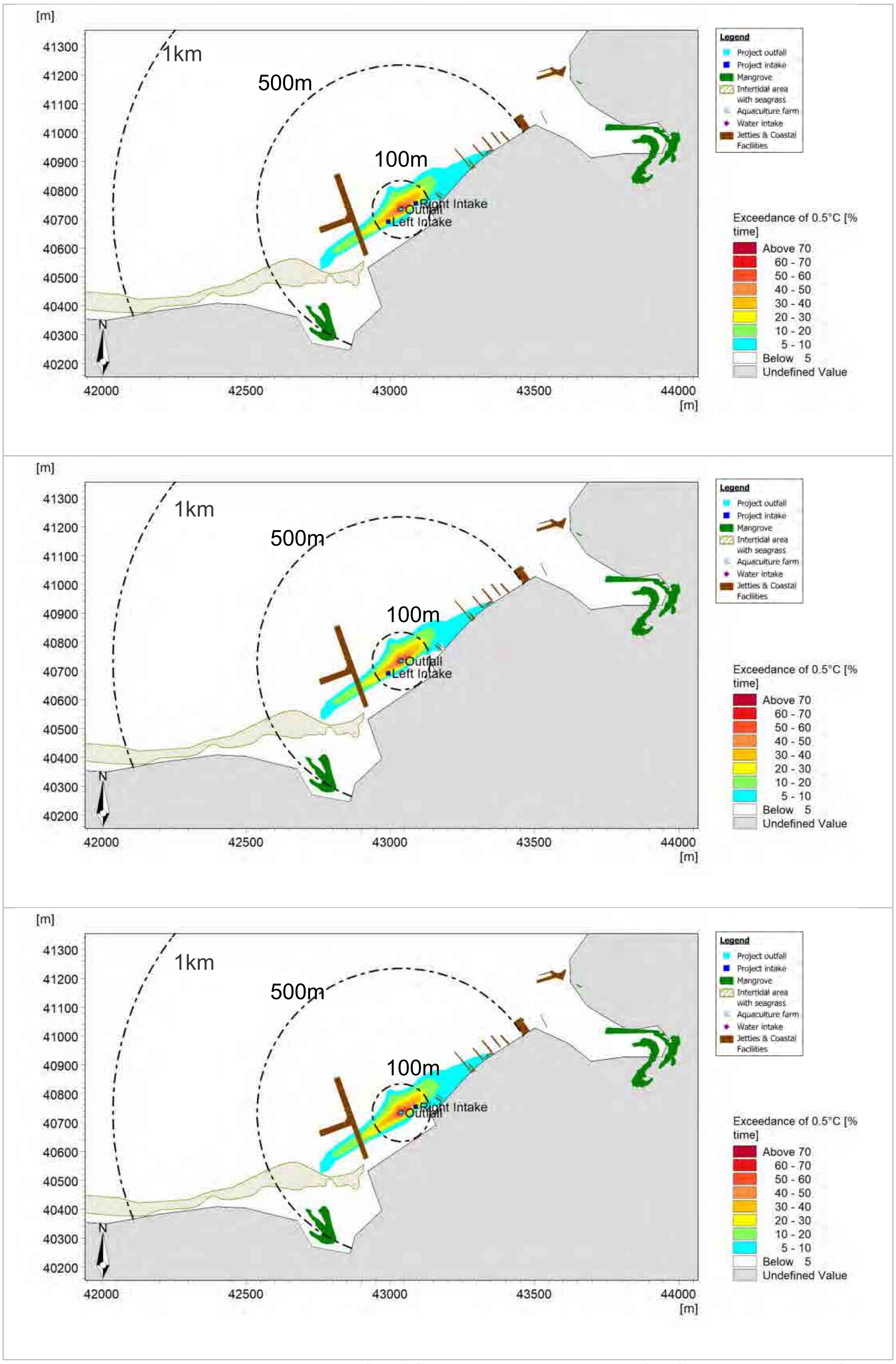



**Figure 9-46: Percentage exceedance of 0.5°C during Inter-monsoon for Scenario 1 (top), Scenario 2 (middle) and Scenario 3 (bottom)**

**Table 9-17: Percentage of time exceeding excess temperature threshold of 0.5°C at different locations**

| Receptor | Percentage of Time Exceeding Excess Temperature of 0.5°C (%) | | |
|---|---|---|---|
| | Northeast Monsoon | Southwest Monsoon | Inter-monsoon |
| Seagrass outside mixing zone (1) but within 500m away from outfall | 3.1 | 4.2 | 4.8 |
| Seagrass outside 500m (2) away from outfall but within 1km (2) away from outfall | 0.0 | 0.0 | 0.0 |
| Mangroves at Sungei Loyang | 2.6 | 3.3 | 3.4 |
| Nearest Aquaculture Farm | 0.0 | 0.0 | 0.0 |
| Seagrass at Changi Boardwalk | 0.0 | 0.0 | 0.0 |

**Note:**

(1) The mixing zone is defined as a 100m radius from the point of discharge. According to the IFC Guidelines, when a mixing zone is not specifically determined, a default distance of 100m is used, provided that no sensitive aquatic ecosystems are present within this range.

(2) The 500m and 1km distances are indicative references used to assess spatial concentration patterns and should not be interpreted as strict impact boundaries. Actual thermal dispersion may vary depending on hydrodynamic conditions and site-specific factors.

The percentage exceedance of excess temperature of 1.0°C plots are shown in Figure 9-47, Figure 9-48 and Figure 9-49, respectively. According to Figure 9-47, Figure 9-48 and Figure 9-49, the highest exceedances are expected near the outfall. However, the temperature increase diminishes progressively with distance from the outfall.

The percentage exceedance at various nearby receptors is tabulated in Table 9-18, and compared against the adopted EQOs and ETLs, as shown in Table 9-14. The extracted excess temperature corresponds to the highest percentage exceedance observed. At aquaculture farms, seagrass and mangroves area outside the mixing zone, the exceedance of 1.0°C was predicted to be 0% of the time.

As the excess temperatures of 0.5°C occur for less than 5% of the time and excess temperatures of 1.0°C occur for 0% of the time, no impacts were anticipated on these receptors from the warm water discharge of the data centre.

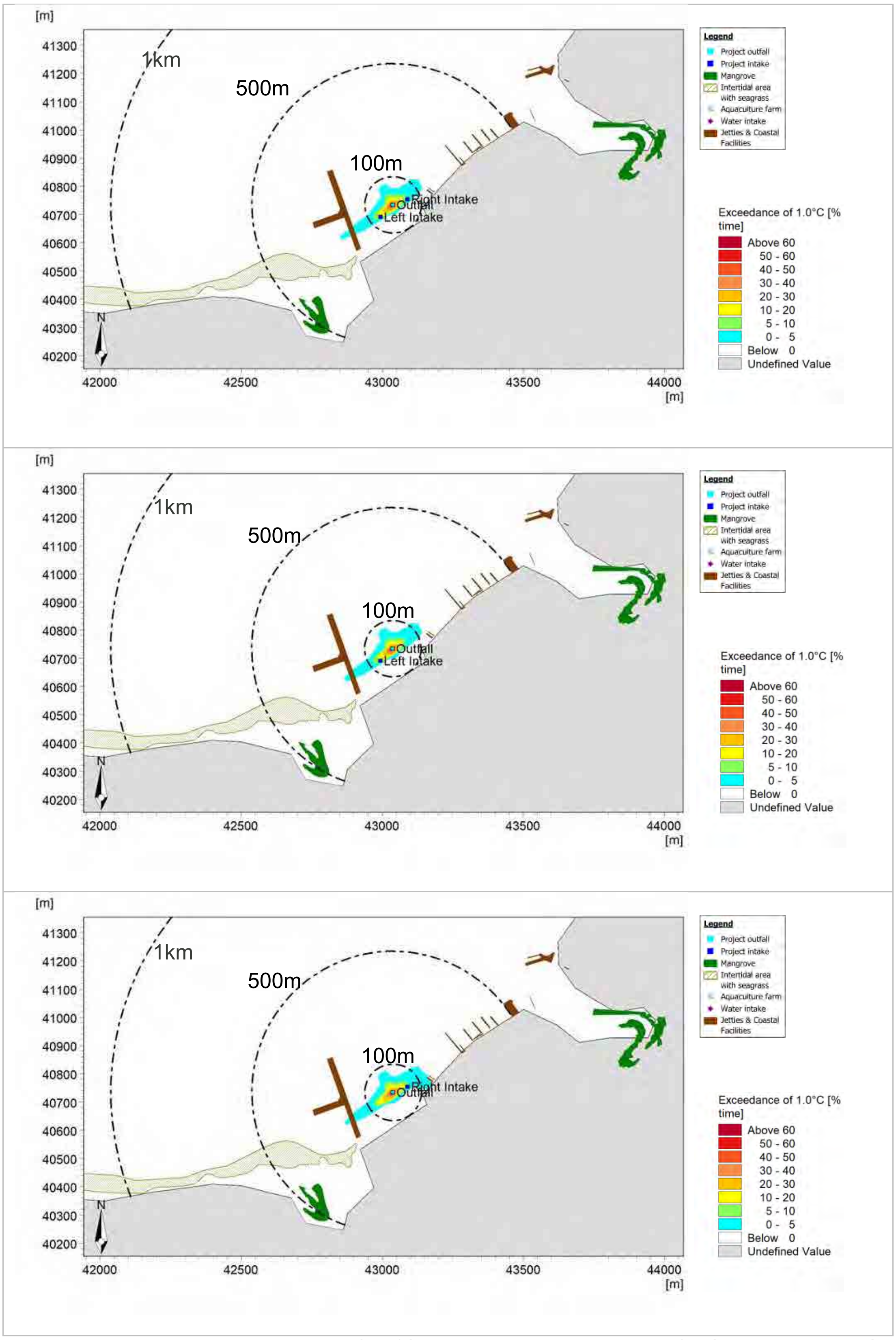



**Figure 9-47: Percentage exceedance of 1.0°C during Northeast Monsoon for Scenario 1 (top), Scenario 2 (middle) and Scenario 3 (bottom)**

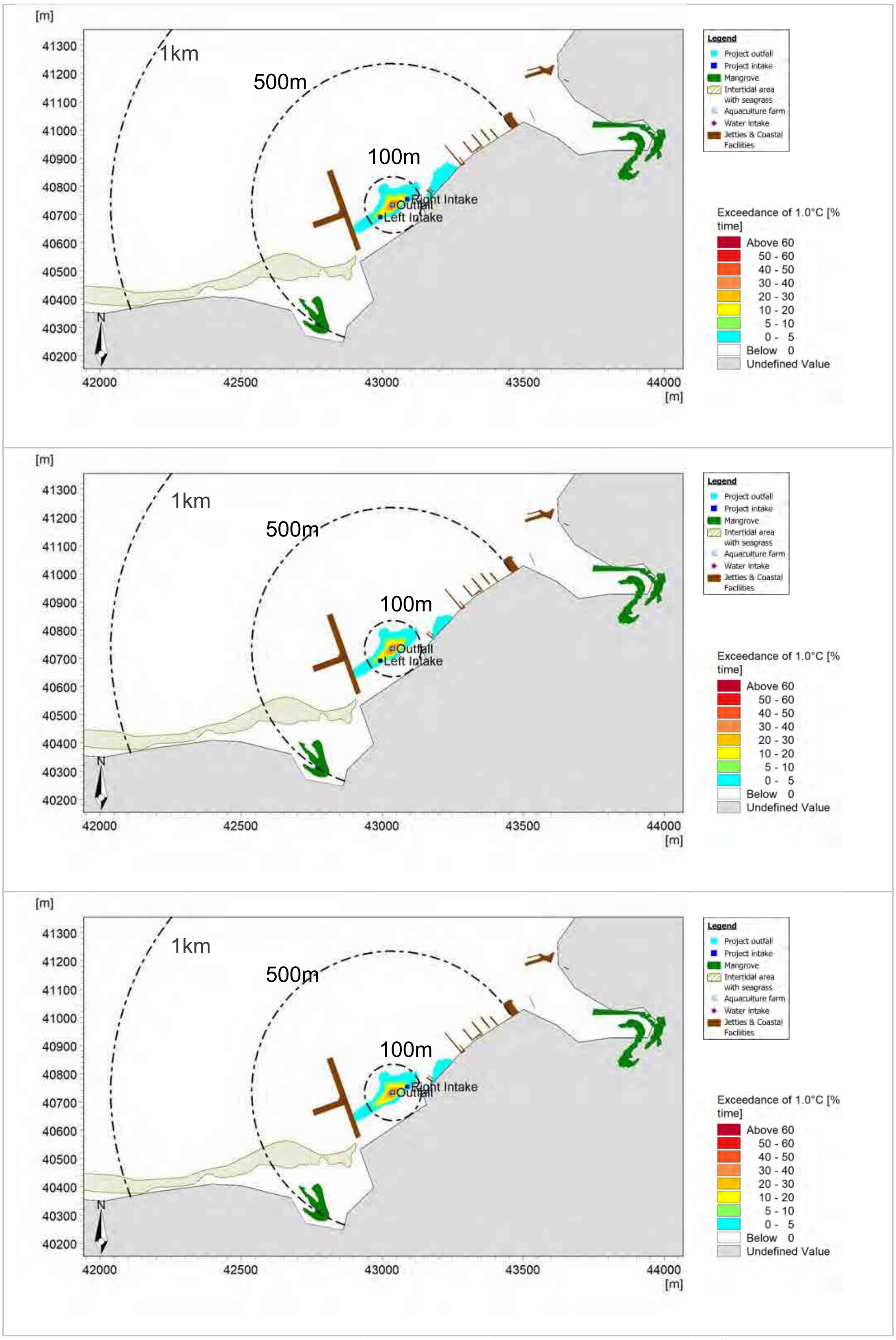



**Figure 9-48: Percentage exceedance of 1.0°C during Southwest Monsoon for Scenario 1 (top), Scenario 2 (middle) and Scenario 3 (bottom)**

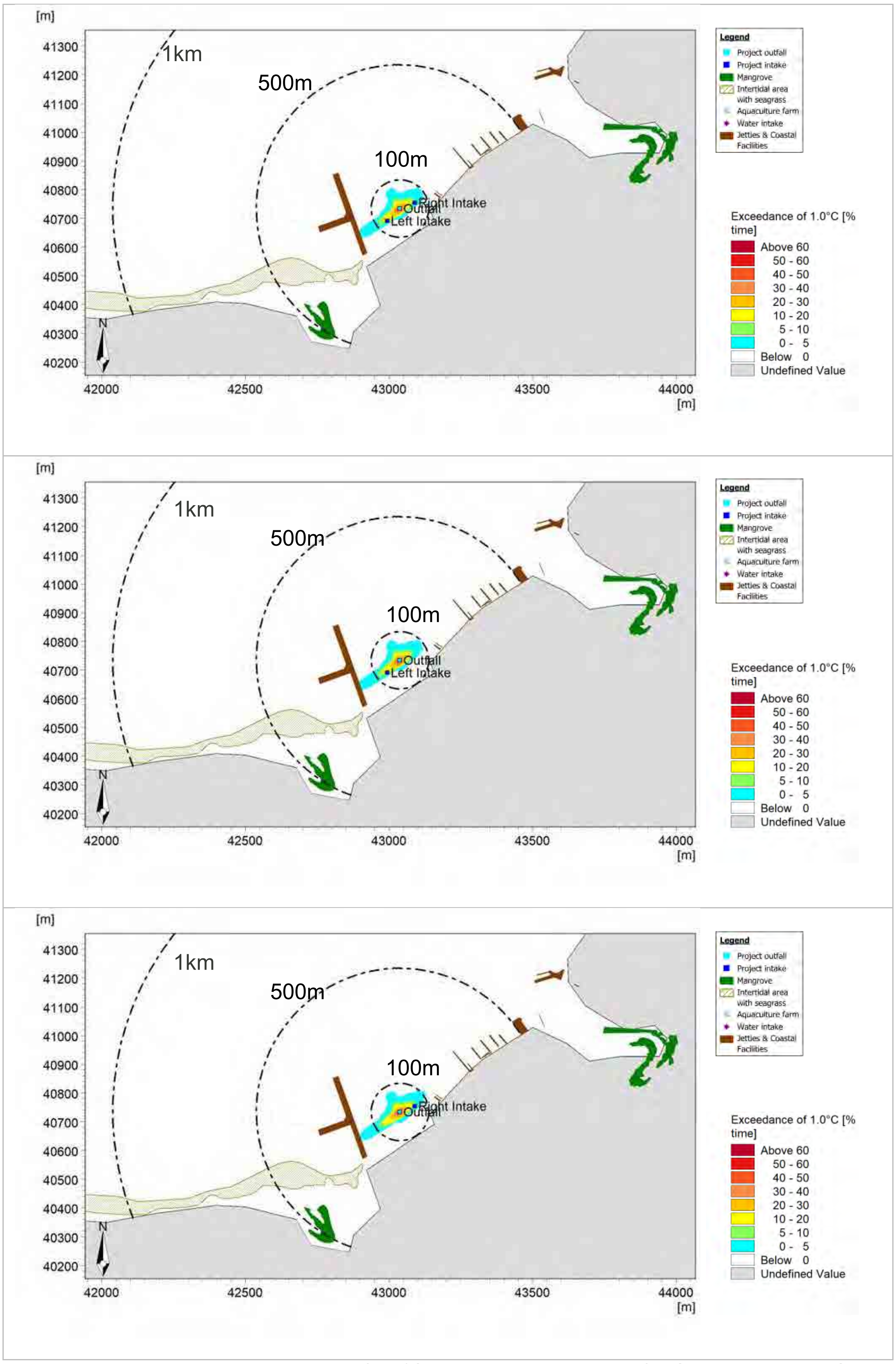



**Figure 9-49: Percentage exceedance of 1.0°C during Inter-monsoon for Scenario 1 (top), Scenario 2 (middle) and Scenario 3 (bottom)**

**Table 9-18: Percentage of time exceeding excess temperature threshold of 1.0°C at different locations**

| Receptor | Percentage of Time Exceeding Excess Temperature of 1.0°C (%) | | |
|---|---|---|---|
| | Northeast Monsoon | Southwest Monsoon | Inter-monsoon |
| Seagrass outside mixing zone (1) but within 500m away from outfall | 0.0 | 0.0 | 0.0 |
| Seagrass outside 500m (2) away from outfall but within 1km (2) away from outfall | 0.0 | 0.0 | 0.0 |
| Mangroves at Sungei Loyang | 0.0 | 0.0 | 0.0 |
| Nearest Aquaculture Farm | 0.0 | 0.0 | 0.0 |
| Seagrass at Changi Boardwalk | 0.0 | 0.0 | 0.0 |

**Note:**

(1) The mixing zone is defined as a 100m radius from the point of discharge. According to the IFC Guidelines, when a mixing zone is not specifically determined, a default distance of 100m is used, provided that no sensitive aquatic ecosystems are present within this range.

(2) The 500m and 1km distances are indicative references used to assess spatial concentration patterns and should not be interpreted as strict impact boundaries. Actual thermal dispersion may vary depending on hydrodynamic conditions and site-specific factors.

### 9.3.4.4 Time Series Temperature

The time-series plots of depth-averaged temperature at different extraction points near the vicinal environmental receptors are presented in Figure 9-50 and Table 9-6. These extraction points were selected based on the sensitivity of the receptors of concern within the proximity to the Project footprint.

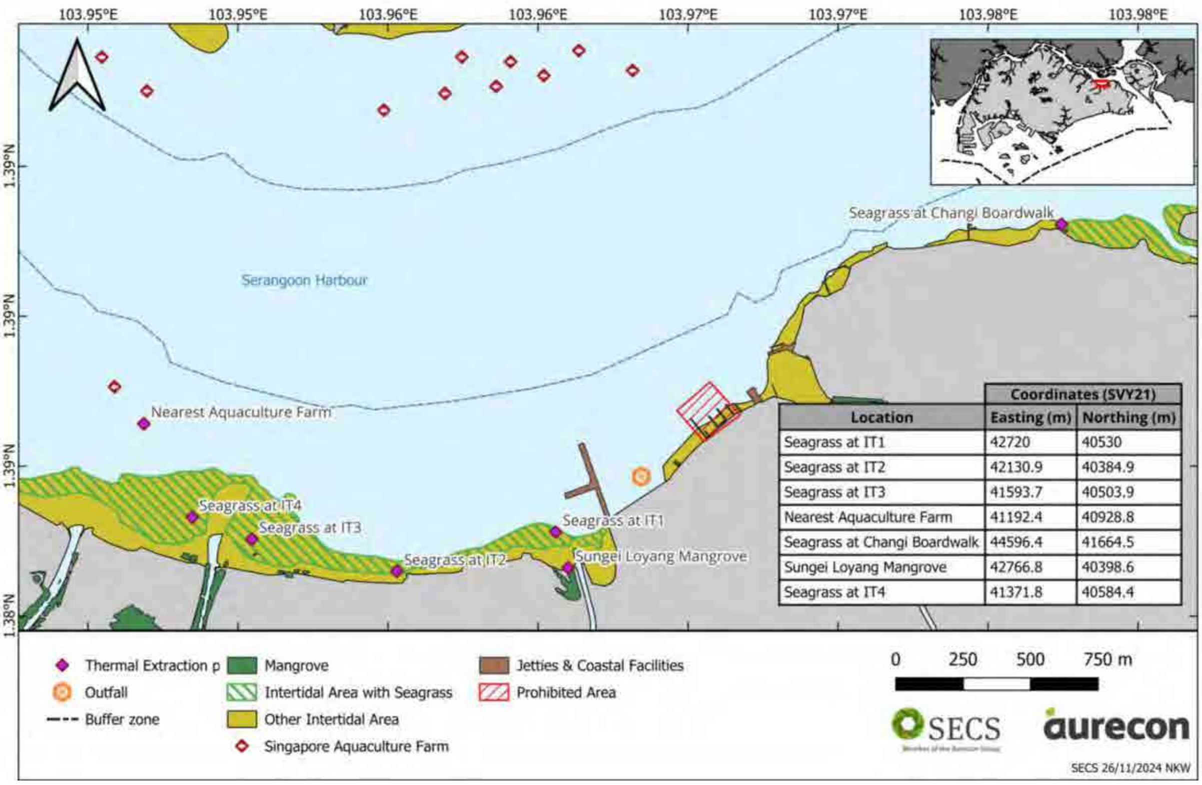



**Figure 9-50: Location map of the thermal plume model extraction points.**

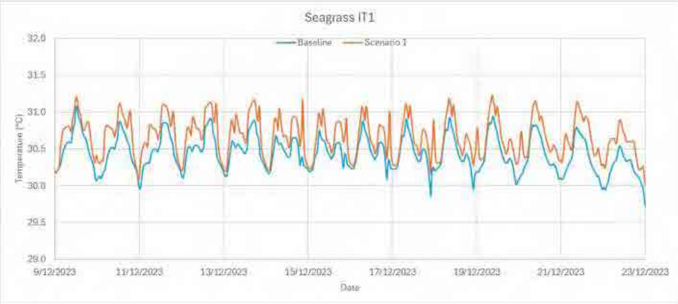
**Table 9-19: Environmental receptors at the extraction point**

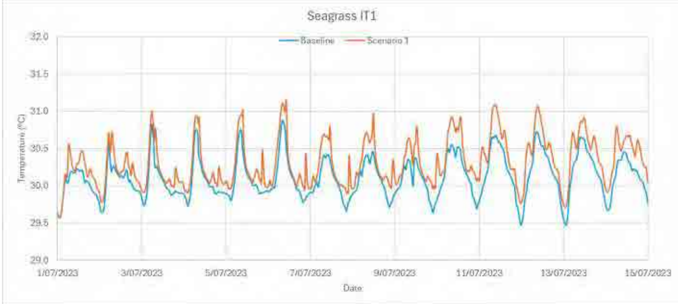
| Location | Remarks |
|---|---|
| 1 | Seagrass at IT1 |
| 2 | Seagrass at IT2 |
| 3 | Seagrass at IT3 |
| 4 | Aquaculture farm |
| 5 | Seagrass at Changi Boardwalk |
| 6 | Sungei Loyang Mangrove |

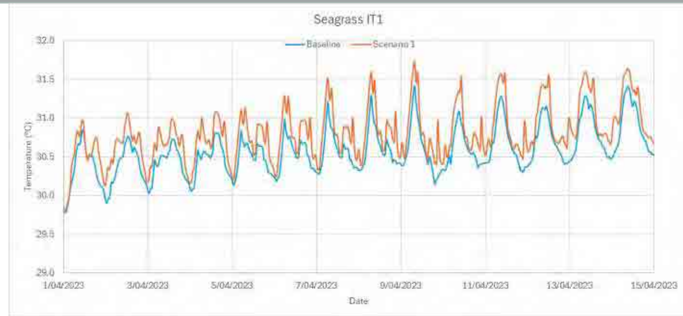
Figure 9-51 presents the extracted temperature time series at various receptors within the impacted area during the Northeast Monsoon, Southwest Monsoon, and Inter-monsoon periods. Only Scenario 1 was selected for analysis, as it represents normal operating conditions. Additionally, the mean and 95$^{th}$ percentile excess temperatures exhibited minimal variation across all three scenarios.

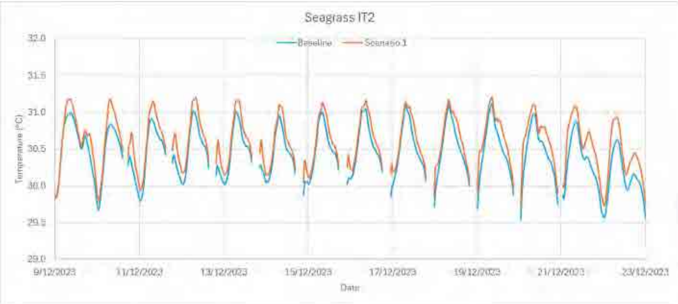
The results indicate that thermal plume dispersion at the seagrass at IT1 and the mangroves at Sungei Loyang recorded a maximum depth-averaged excess temperature of up to 0.82°C and 0.81°C, respectively. At receptors located farther from the project site, the highest depth-averaged temperature values ranged from 0.15°C to 0.44°C at the seagrass areas near IT2, IT3, and IT4, up to 0.15°C at the seagrass near Changi Boardwalk, and up to 0.12°C at the nearest aquaculture facilities. The temperature increased decreases with distance from the outfall, with only slight temperature rises observed at the seagrass near IT3, Changi Boardwalk, and the nearest aquaculture farm.

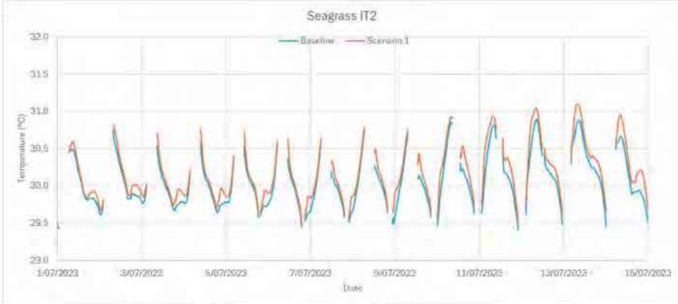
| Northeast Monsoon | Southwest Monsoon | Inter-monsoon |
|---|---|---|

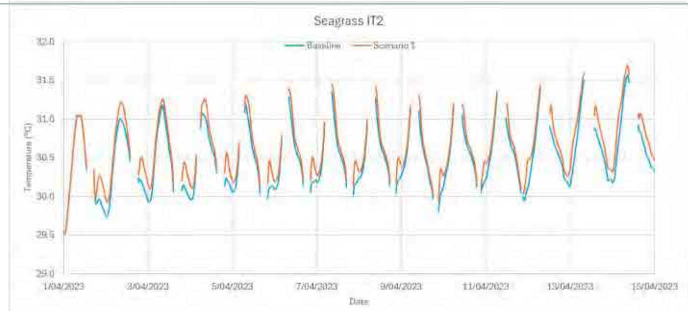


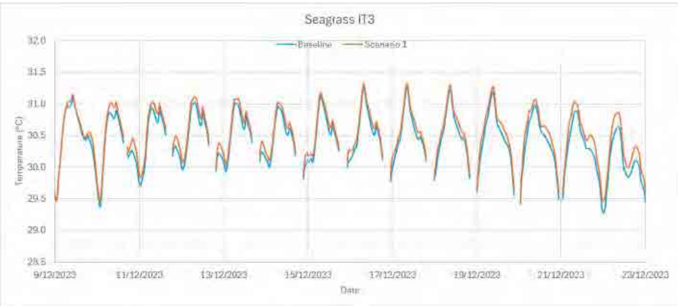



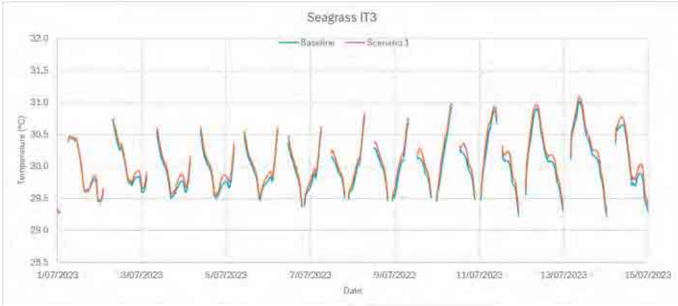



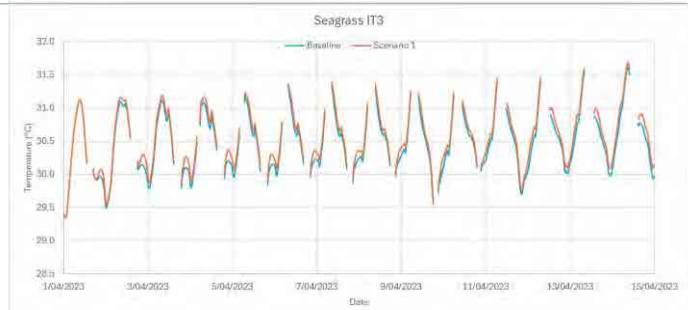



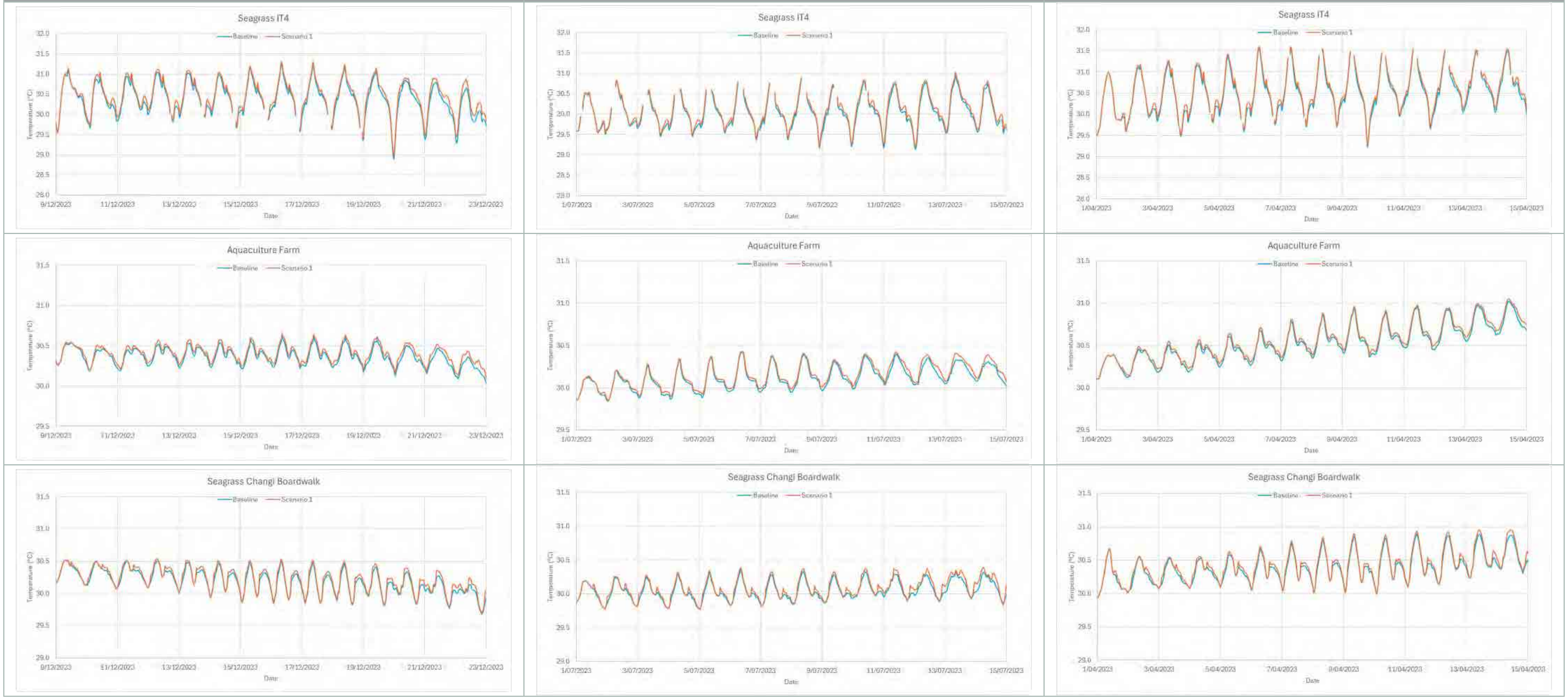



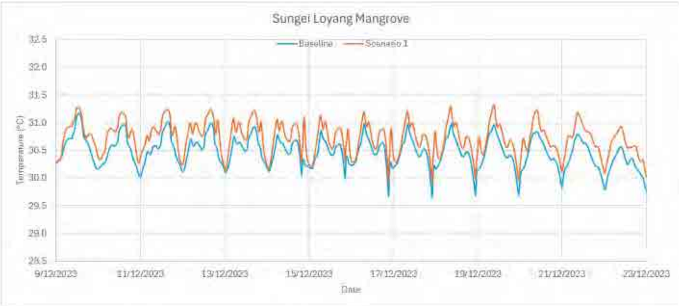



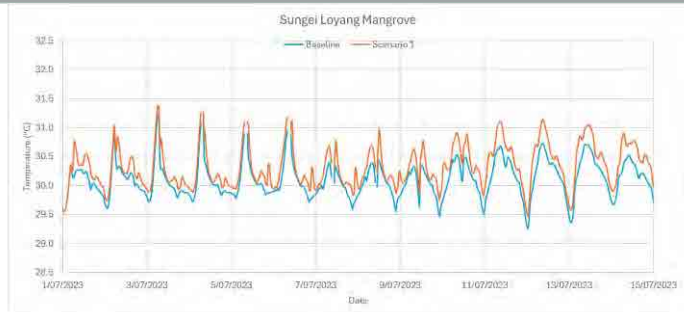



| Northeast Monsoon | Southwest Monsoon | Inter-monsoon |
| --- | --- | --- |



| Northeast Monsoon | Southwest Monsoon | Inter-monsoon |
|---|---|---|



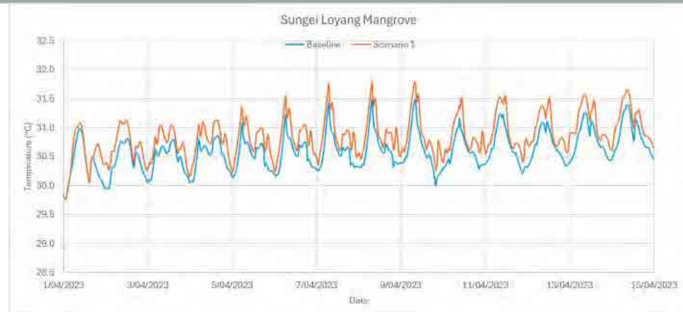




**Figure 9-51: Extracted temperature time series for various receptors during Northeast Monsoon, Southwest Monsoon and Inter-monsoon.**

### 9.3.5 Impact Summary

The results were analysed in against the excess temperature tolerance limits (Table 9-14) for seagrass, mangroves, and aquaculture facilities.

***Seagrass***

- According to the model results, no exceedance of 0.5°C occurred for more than 5% of the time and no exceedance of 1.0°C occurred at any time at the seagrass area. No impact to the seagrass habitat was forecasted due to the warm water discharge. Therefore, the EQO and ETL were met.

***Aquaculture facilities***

- According to the model result, there was no exceedance of 0.5°C occurred for more than 5% of the time and no exceedance of 1.0°C occurred at any time at the aquaculture facilities. No impact to the aquaculture facilities were forecasted due to the warm water discharge. Therefore, the EQO and ETL were met.

***Mangrove***

- According to the model result, there was no exceedance of 0.5°C occurred for more than 5% of the time and no exceedance of 1.0°C occurred at any time at the mangroves area. No impact to the mangrove habitat was forecasted due to the warm water discharge. Therefore, the EQO and ETL were met.

**Table 9-20: Summary of thermal plume EQOs and ETLs compliance at receptors during Northeast Monsoon, Southwest Monsoon, and Inter-monsoon**

| Receptor | Environmental Quality Objectives (EQOs) | Environmental Tolerance Limits (ETLs) | NE | SW | IM |
|---|---|---|---|---|---|
| Seagrass and mangroves | No impact | • Excess temperature > 0.5°C for less than 5% of the time<br>• Excess temperature < 1.0°C at any time | √ | √ | √ |
| Aquaculture facilities | No impact | • Excess temperature > 0.5°C for less than 5% of the time<br>• Excess temperature < 1.0°C at any time | √ | √ | √ |

**Note**:
√ = Compliance; X = Non-compliance; NE = Northeast Monsoon; SW = Southwest Monsoon; IM = Inter-monsoon

**Table 9-21: Thermal plume impact summary**

| Impacts | Predicted Impacts | | | | | | | Mitigation measures |
|---|---|---|---|---|---|---|---|---|
| | Potential impact | ES | I | M | P | R | C | |
| **Post-Construction** | | | | | | | | |
| Seagrass | No change/ no impact | 0 | 3 | 0 | 3 | 2 | 1 | • Continuous online monitoring system throughout project duration<br>• Regular biodiversity monitoring |
| Mangroves | No change/ no impact | 0 | 4 | 0 | 3 | 2 | 1 | |
| Aquaculture facilities | No change/ no impact | 0 | 4 | 0 | 3 | 3 | 1 | None required |

## 9.4 Chlorine Plume

The chlorinated water discharge from the cooling water system has the potential to impact sensitive receptors near the Project site. During the operational phase, the release of chlorinated water into the surrounding environment could create a chlorine plume, which may alter the local water quality and potentially affect the biodiversity of the area. This section of the report focuses on the long-term impacts of chlorine plume dispersion, specifically assessing the potential effects on sensitive environmental receptors.

### 9.4.1 Simulation Scenarios

The cooling water system is expected to cause chlorine release impacts on the surrounding environment due to the use of anti-fouling agent for controlling marine growth, which will lead to the discharge of chlorinated water via the outfall.

The simulation of chlorinated water discharge is done using the Transport model coupled with hydrodynamic and thermal model as described in section 9.1.1 and 9.3.1. Chlorine plume modelling scenarios were summarised in Table 9-22 based on the proposed cooling water system information available at the time of the assessment. Any subsequent changes will require a detailed review to ensure compliance with project-specific EQOs and ETLs.

Seawater is drawn from the intake and discharged back into the sea through the outfall structure. The outfall is designed to discharge at a flow rate of 4,800 $m^3$/hr, with the chlorine concentration not exceeding a maximum of 0.16 mg/L. This concentration complies with Singapore's Environmental Protection and Management (Trade Effluent) Regulations 2008, which stipulate that the concentration of free chlorine shall not exceed 1 mg/L at the point of entry to the watercourse. Chlorine impacts were quantified as the increase in excess chlorine (i.e., the chlorine above ambient seawater levels) associated with project-related releases.

The simulations were conducted over 14 days peak spring-neap tidal cycle during each monsoon period:

- Southwest Monsoon: 1 Jul 2023 to 15 Jul 2023
- Northeast Monsoon: 9 Dec 2023 to 23 Dec 2023
- Inter-monsoon: 1 Apr 2023 to 15 Apr 2023

**Table 9-22: Intake and outfall information**

| Parameter | Outfall |
|---|---|
| Flow rate | 4,800 $m^3$/hr |
| Residual chlorine release at discharge | 0.16 mg/L |

The impacts of the dispersal of chlorinated water from the outfall have been assessed based on the proposed residual chlorine concentration, with simulations conducted for the three (3) scenarios presented in Table 9-13. These scenarios include Scenario 1, with both intake points and the outfall in operation; and Scenarios 2 and 3, with one intake point and either of the two intake points functioning.

### 9.4.2 Receptor of Concern

The chlorine plume model will assess the dispersion characteristics of the chlorine plume and its potential long-term impacts on the following sensitive receptors:

- Seagrass
- Mangroves
- Aquaculture facilities

### 9.4.3 Adopted Evaluation Criteria

To assess the potential environmental impacts associated with chlorine plume dispersion, the EQOs and ETLs presented in Table 9-23 were adopted.

The receptor importance evaluation framework used in this assessment follows the definitions outlined in Table 8-2 and Section 8.2.1.2. To evaluate the magnitude of change, this assessment references the quantitative thresholds and criteria established for chlorine plume and these criteria are stipulated in Table 8-15. Together, these tables provide a standardised approach to assigning magnitude scores based on exposure conditions, which are then combined with receptor importance to determine overall impact significance.

Further details of the adopted impact assessment criteria, including thresholds and the rationale for receptor classification, are provided in Section 8.

**Table 9-23: Chlorine plume impact criteria**

| Receptor | Environmental Quality Objectives (EQOs) | Environmental Tolerance Limits (ETLs) |
|---|---|---|
| Seagrass and mangroves | No impact | • Excess chlorine < 0.012 mg/L at any time |
| Aquaculture facilities | No impact | • Excess chlorine < 0.012 mg/L at any time |

### 9.4.4 Result and Discussion

The quantification of water quality impacts due to the chlorine discharge with the associated warm water discharge is presented in the following section. This assessment includes the following components:

- Mean chlorine concentration
- 95$^{th}$ percentile chlorine concentration
- Exceedance of chlorine concentration at 0.012 mg/L

### 9.4.4.1 Mean Chlorine Concentration

Figure 9-52 shows the mean excess chlorine concentration over 14 days simulation at Northeast Monsoon, Southwest Monsoon, and Inter-monsoon periods at different intake scenarios (Table 9-13), with an outfall discharge chlorine concentration of 0.16 mg/L.

The mean excess chlorine values extracted from Scenario 1 are tabulated in Table 9-24. Scenario 1 was selected for analysis as it represents the normal operating condition. Additionally, the spatial extent results of mean excess chlorine concentration show minimal variation across the three (3) scenarios, as presented in Figure 9-52. To assess the potential impacts, the 3D excess chlorine concentrations were depth-averaged, and the predicted mean excess temperatures were extracted at various locations, including seagrass areas, mangroves, and aquaculture facilities, based on the identified zone of impact.

The results showed that at the seagrass area within 500 m from the outfall, the mean excess chlorine concentration was predicted to be up to 0.005 mg/L. At the seagrass area between 500 m and 1 km away from the outfall, the highest values were 0.004 mg/L.

For the mangroves at Sungei Loyang, the predicted mean excess chlorine concentration was up to 0.005 mg/L.

At receptors further away from the outfall, such as the seagrass at Changi Boardwalk, mangroves at Sungei Tampines, and the nearest aquaculture farm, there was no pronounced plume were observed.

**Table 9-24: Mean excess chlorine extraction at locations/ receptors across different monsoon period for scenario 1**

| Receptor | Mean Excess Chlorine Concentration (mg/L) | | |
|---|---|---|---|
| | Northeast Monsoon | Southwest Monsoon | Inter-monsoon |
| Seagrass outside mixing zone (1) but within 500 m(2) away from outfall | 0.004 | 0.004 | 0.005 |
| Seagrass outside 500 m(2) away from outfall but within 1 km (2) away from outfall | 0.004 | 0.003 | 0.003 |
| Mangroves at Sungei Loyang | 0.005 | 0.004 | 0.005 |
| Seagrass at Changi Boardwalk | <0.001 | <0.001 | <0.001 |
| Nearest Aquaculture Farm | <0.001 | <0.001 | <0.001 |

**Note:**

(1) The mixing zone is defined as a 100m radius from the point of discharge. According to the IFC Guidelines, when a mixing zone is not specifically determined, a default distance of 100m is used, provided that no sensitive aquatic ecosystems are present within this range.

(2) The 500m and 1km distances are indicative references used to assess spatial concentration patterns and should not be interpreted as strict impact boundaries. Actual thermal dispersion may vary depending on hydrodynamic conditions and site-specific factors.

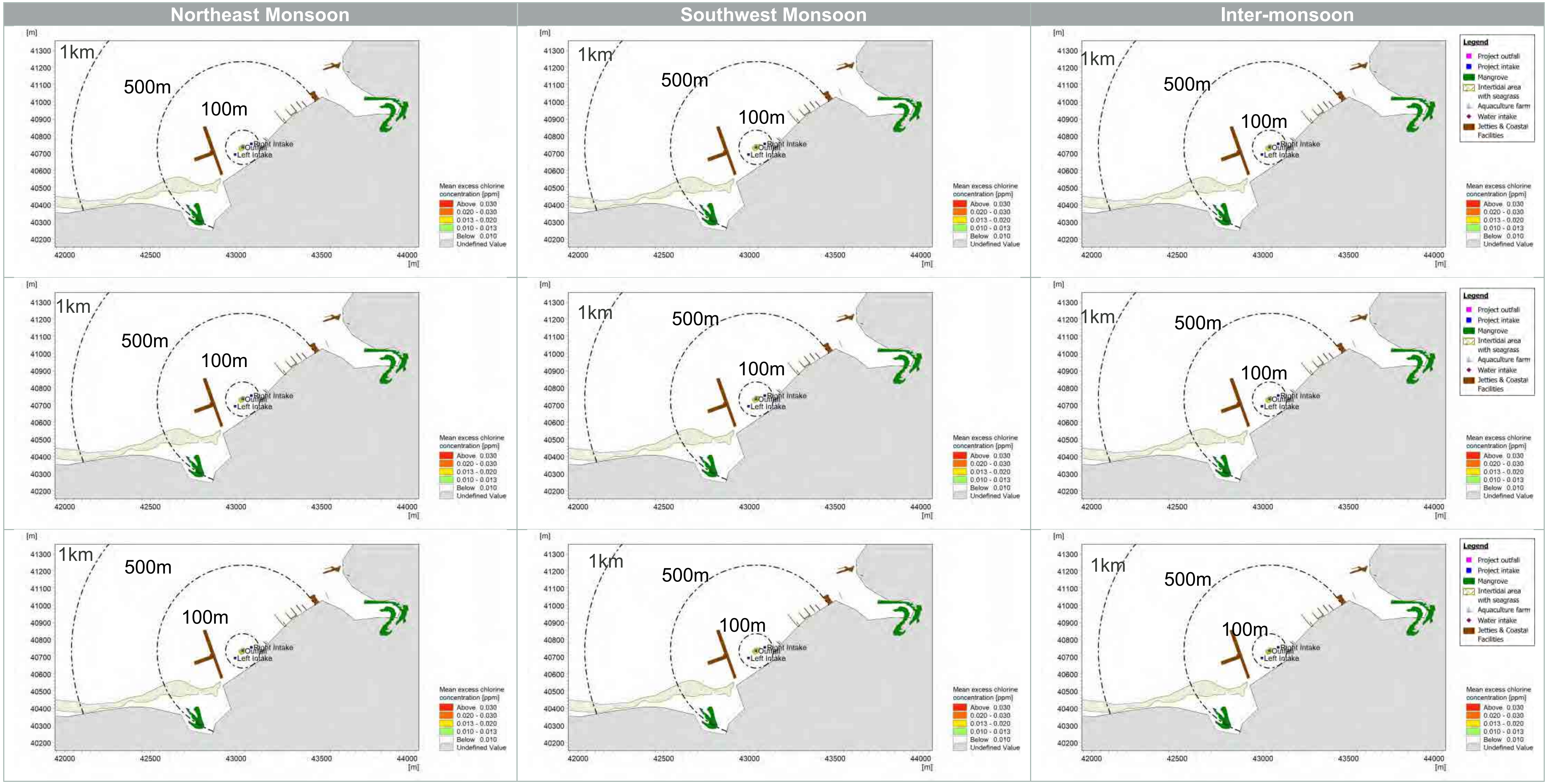



**Figure 9-52: Mean chlorine concentrations across scenario 1 (top row), 2 (middle row) and 3 (bottom row) during Northeast Monsoon (left column), Southwest Monsoon (middle column) and Inter-monsoon (right column)**

### 9.4.4.2 95th Percentile Chlorine Concentration

Figure 9-53 shows the 95th percentile chlorine concentration over 14 days simulation at Northeast Monsoon, Southwest Monsoon, and Inter-monsoon periods at different intake scenarios (Table 9-13), with an outfall discharge chlorine concentration of 0.16 mg/L.

Similarly, the 95th percentile excess temperature values extracted from Scenario 1 are tabulated in Table 9-25. Scenario 1 was selected for analysis as it represents the normal operating condition. Additionally, the spatial extent results of 95th percentile excess temperature show minimal variation across the three (3) scenarios, as represented in Figure 9-53.

To assess the potential impacts, the 95th percentile chlorine concentrations were extracted at various locations, including seagrass areas, mangroves, and aquaculture facilities, based on the identified zone of impact.

Results indicate that 95th percentile chlorine concentrations of up to 0.030 mg/L were observed near the outfall within the mixing zone. Beyond the mixing zone, chlorine plume concentrations showed a decreasing trend with distance. At seagrass areas within 1 km of the outfall, the 95th percentile excess chlorine concentration was predicted to reach up to 0.008 mg/L, while for mangroves at Sungei Loyang, the 95th percentile excess chlorine concentration was predicted to be up to 0.008 mg/L.

At receptors farther from the outfall, such as the seagrass at Changi Boardwalk, mangroves at Sungei Tampines, and the nearest aquaculture farm, no pronounced chlorine plume was observed.

**Table 9-25: 95th percentile excess chlorine extraction at locations/ receptors across different monsoon period for scenario 1**

| Receptor | 95th Percentile Excess Chlorine Concentration (mg/L) | | |
|---|---|---|---|
| | Northeast Monsoon | Southwest Monsoon | Inter-monsoon |
| Seagrass outside mixing zone (1) but within 500m (2) away from outfall | 0.008 | 0.008 | 0.008 |
| Seagrass outside 500m (2) away from outfall but within 1km(2) away from outfall | 0.007 | 0.008 | 0.007 |
| Mangroves at Sungei Loyang | 0.008 | 0.008 | 0.008 |
| Seagrass at Changi Boardwalk | 0.002 | 0.002 | 0.002 |
| Nearest Aquaculture Farm | 0.002 | 0.003 | 0.001 |

**Note:**

(1) The mixing zone is defined as a 100m radius from the point of discharge. According to the IFC Guidelines, when a mixing zone is not specifically determined, a default distance of 100m is used, provided that no sensitive aquatic ecosystems are present within this range.

(2) The 500m and 1km distances are indicative references used to assess spatial concentration patterns and should not be interpreted as strict impact boundaries. Actual thermal dispersion may vary depending on hydrodynamic conditions and site-specific factors.

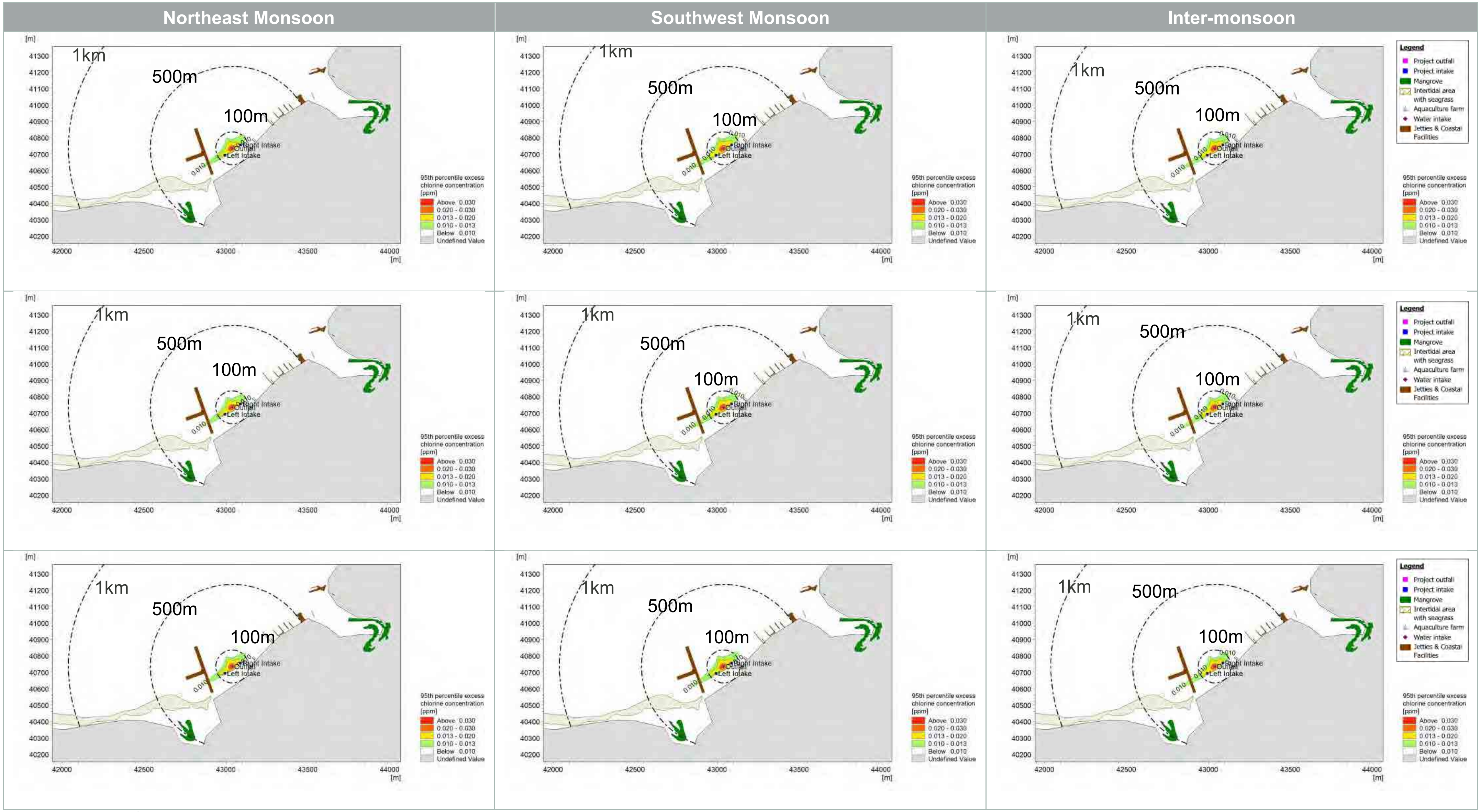



**Figure 9-53: 95th percentile chlorine concentrations across scenario 1 (top row), 2 (middle row) and 3 (bottom row) during Northeast Monsoon (left column), Southwest Monsoon (middle column) and Inter-monsoon (right column)**

### 9.4.4.3 Percentage Exceedance of Chlorine Concentration

The percentage exceedance of excess chlorine concentration at 0.012 mg/L are shown in Figure 9-54. These exceedances represent the percentage of time, over 14 days simulation period, during which the excess chlorine concentrations exceed the defined thresholds. To calculate these values, the 14 days chlorine plume model results were depth-averaged prior to determining the percentage exceedances.

The percentage exceedance at various nearby receptors is tabulated in Table 9-26, and compared against the adopted EQOs and ETLs, as shown in Table 9-26. Scenario 1 was selected for analysis as it represents normal operating conditions. The spatial extent results for the mean and 95th percentile excess chlorine concentrations indicate minimal variation across the three (3) scenarios

The extracted excess chlorine concentrations correspond to the highest percentage exceedance observed at different locations. At the seagrass area located outside the mixing zone and within 500 m of the outfall, the exceedance of the 0.012 mg/L threshold was predicted to be 0%. Similarly, at the mangrove area at Sungei Loyang, the exceedance of the 0.012 mg/L threshold was also predicted to be 0%.

For all other receptors located 500 m to 1 km away from the outfall, including seagrass, mangroves, and aquaculture farms, no exceedance (0%) was predicted for the threshold of 0.012 mg/L. This indicates compliance with established thresholds and suggests minimal impact on these sensitive receptors.

**Table 9-26: Percentage of time exceeding excess chlorine threshold of 0.012mg/L at different locations**

| Receptor | Percentage of Time Exceeding Excess Chlorine Threshold (%) | | |
|---|---|---|---|
| | Northeast Monsoon | Southwest Monsoon | Inter-monsoon |
| Seagrass outside mixing zone (1) but within 500m (2) away from outfall | 0.0 | 0.0 | 0.0 |
| Seagrass outside 500m (2) away from outfall but within 1km (2) away from outfall | 0.0 | 0.0 | 0.0 |
| Mangroves at Sungei Loyang | 0.0 | 0.0 | 0.0 |
| Seagrass at Changi Boardwalk | 0.0 | 0.0 | 0.0 |
| Nearest aquaculture farm | 0.0 | 0.0 | 0.0 |

**Note:**

(1) The mixing zone is defined as a 100m radius from the point of discharge. According to the IFC Guidelines, when a mixing zone is not specifically determined, a default distance of 100m is used, provided that no sensitive aquatic ecosystems are present within this range.

(2) The 500m and 1km distances are indicative references used to assess spatial concentration patterns and should not be interpreted as strict impact boundaries. Actual thermal dispersion may vary depending on hydrodynamic conditions and site-specific factors.

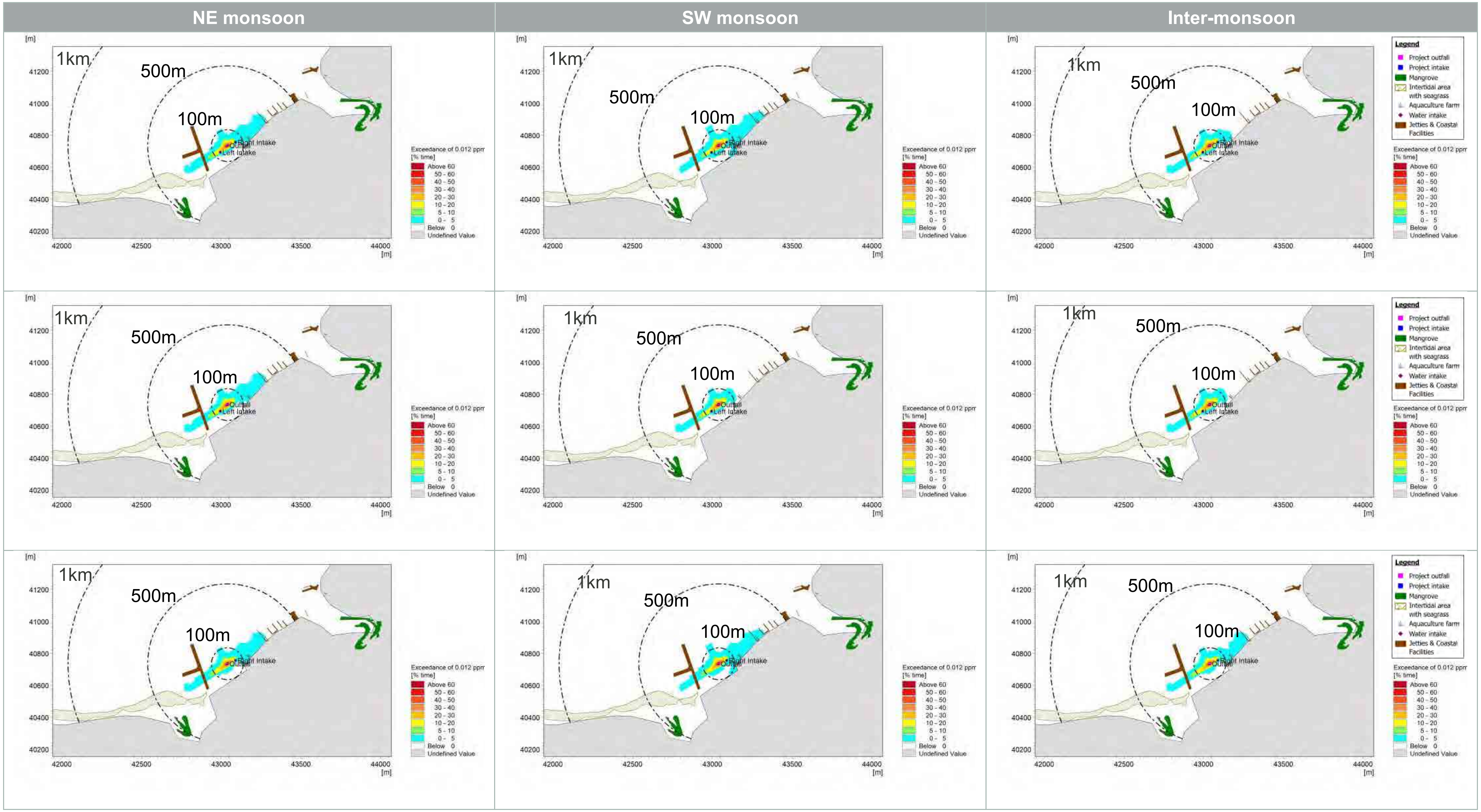



**Figure 9-54: Percentage exceedance of 0.012mg/L across scenario 1 (top row), 2 (middle row) and 3 (bottom row) during NE (left column), SW (middle column) and Inter-monsoon (right column)**

### 9.4.5 Impact Summary

The results were analysed in against the excess chlorine tolerance limits (Table 9-27) for seagrass, mangrove, and aquaculture facilities.

***Seagrass***

- According to the model results, no exceedance of more than 0.012 mg/L occurred at any time at the seagrass area. No impact to the seagrass habitat was forecasted due to the chlorinated water discharge. Therefore, the EQO and ETL were met.

***Aquaculture facilities***

- According to the model results, no exceedance of more than 0.012 mg/L occurred at any time at the aquaculture facilities. No impact to the aquaculture facilities were forecasted due to the chlorinated water discharge. Therefore, the EQO and ETL were met.

***Mangrove***

- According to the model result, there was no exceedance of more than 0.012 mg/L occurred at any time at the mangroves area. No impact to the mangrove habitat was forecasted due to the chlorinated water discharge. Therefore, the EQO and ETL were met.

**Table 9-27: Summary of chlorine plume EQOs and ETLs compliance at receptors during Northeast Monsoon, Southwest Monsoon, and Inter-monsoon**

| Receptor | Environmental Quality Objectives (EQOs) | Environmental Tolerance Limits (ETLs) | NE | SW | IM |
|---|---|---|---|---|---|
| Seagrass and mangroves | No impact | Excess chlorine < 0.012 mg/L at any time | √ | √ | √ |
| Aquaculture facilities | No impact | Excess chlorine < 0.012 mg/L at any time | √ | √ | √ |

**Note**:
√ = Compliance; X = Non-compliance; NE = Northeast Monsoon; SW = Southwest Monsoon; IM = Inter-monsoon

**Table 9-28: Chlorine plume impact summary**

| Impacts | Predicted Impacts | | | | | | | Mitigation measures |
|---|---|---|---|---|---|---|---|---|
| | Potential impact | ES | I | M | P | R | C | |
| **Post-construction** | | | | | | | | |
| Seagrass | No change/ no impact | 0 | 3 | 0 | 3 | 2 | 1 | • Continuous online monitoring system throughout project duration<br>• Regular biodiversity monitoring |
| Mangroves | No change/ no impact | 0 | 4 | 0 | 3 | 2 | 1 | |
| Aquaculture facilities | No change/ no impact | 0 | 4 | 0 | 3 | 3 | 1 | None required |

## 9.5 Underwater Noise Impact

Underwater noise generated during both construction and operational phases can produce low-frequency vibrations and acoustic emissions that may affect marine fauna, particularly those sensitive to sound such as fish and marine mammals.

During construction, piling activities were identified as a potential source of underwater noise and vibration that could affect sensitive marine receptors, including fish and marine mammals. Piling is known to produce impulsive sounds, with peak sound pressure levels typically ranging from 180 to 220 dB re 1 µPa at 1 metre, and dominant frequencies between 100 Hz and 1 kHz (Southall et al., 2007; Popper & Hastings, 2009). These frequencies overlap with the auditory ranges of many marine species, particularly cetaceans, and have the potential to cause behavioural responses, temporary threshold shifts (TTS), and, under extreme exposure conditions, permanent auditory damage. International guidelines, such as those issued by the National Oceanic and Atmospheric Administration (NOAA, 2018) and the Joint Nature Conservation Committee (JNCC, 2017), recommend the implementation of mitigation measures, including soft-start or ramp-up procedures, marine fauna exclusion zones, and acoustic monitoring, when undertaking impulsive activities such as piling. However, the Project site is located within a heavily industrialised coastal area, surrounded by jetties, vessel berths, and ongoing maritime operations. These existing activities contribute to an already elevated ambient underwater noise environment, reducing the relative contrast introduced by construction-related sounds. Furthermore, the short duration and localised footprint of the proposed piling works limited the spatial and temporal extent of potential impacts. To reduce potential risks to marine fauna, the use of low-noise piling methods and a soft-start procedure was considered during construction planning.

The operational phase of the project will involve the continuous operation of cooling water pumps, which are housed within the hull of the floating data centre. These pumps generate low-frequency, non-impulsive underwater noise, primarily associated with motor rotation, impeller turbulence, and mechanical vibration. When enclosed within a steel hull, the acoustic emissions are transmitted into the marine environment predominantly as structure-borne vibrations, which propagate through the hull plating and radiate into the surrounding water.

Based on typical operational data for cooling water systems and established literature (Erbe et al., 2019; DNV, 2021), the dominant frequencies associated with cooling pump noise are expected to fall within the 50 to 300 Hz range. When accounting for the transmission through the vessel hull, the primary underwater acoustic energy is expected to concentrate in the 50 to 150 Hz range. This frequency range overlaps with the auditory sensitivity of some marine fauna, particularly low- and mid-frequency cetaceans (e.g., *Sousa chinensis, Tursiops aduncus, Neophocaena phocaenoides*) and dugongs (*Dugong dugon*), as well as certain soniferous fish species. Although dugong populations in Singapore are rare and transient, available data indicate that sightings have been reported near Pasir Ris Park, with the last confirmed observation recorded in 2017. Given the absence of recent confirmed sightings and the existing urbanised and industrial setting of the project site, the likelihood of dugongs being exposed to operational noise from the data centre is considered to be low.

To minimise underwater noise emissions and reduce the risk of acoustic disturbance to marine fauna, the floating data centre incorporates several noise attenuation features as part of its engineering design. Although the final specifications of the pumps had not been confirmed at the time of reporting, the system will be developed to include the following targeted mitigation measures:

- Selection of low-noise, low-vibration pump models.
- Installation of vibration isolation systems, such as resilient mounts or dampers, at each pump unit.
- Use of a minimum 10 mm thick steel hull, providing inherent damping of low-frequency vibrations.

- Implementation of a double-hull configuration, incorporating a water tank compartment between the inner and outer hull layers, which enhances both acoustic and vibrational insulation.

These measures are expected to significantly reduce the transmission of structure-borne noise into the marine environment. Final design specifications and associated mitigation measures will be further defined and incorporated into the Operational Environmental Management Plan (OEMP).

With these mitigation measures in place, the expected sound pressure levels from pump operations are estimated to range between 110 and 125 dB re 1 μPa at 1 metre, depending on pump specifications, installation methods, and operating conditions. At these levels, the continuous underwater noise generated by the pumps is considered unlikely to cause behavioural disturbance or physiological impacts to marine mammals. This assessment aligns with international regulatory guidance, including NOAA (2018) and Southall et al., (2019), which indicate that non-impulsive continuous noise below 120 dB re 1 μPa at 1 metre is unlikely to elicit significant responses in most marine mammal species.

Additionally, underwater noise attenuation in open water conditions is rapid, with modelled estimates and literature indicating that pump-generated noise will typically fall below 100 dB re 1 μPa within 10 to 20 metres of the source (Popper et al., 2014). Given the industrialised setting of the project site, where ambient underwater noise is already elevated due to regular vessel traffic and berthing operations, the incremental contribution of pump noise is expected to be minimal and not discernible above background levels.

## 9.6 Light Pollution

The Project considered the presence of known bird roosting and nesting habitats at Loyang Rock, located approximately 800 m from the Project site. However, the site lies outside the Project's direct zone of influence. Based on the plume dispersion modelling results (Section 9), thermal, chlorine, and sediment plumes were expected to remain localised and confined to the immediate vicinity of the Project footprint. As such, no impacts to avifauna at Loyang Rock were anticipated.

Although lighting spillover is often a concern for developments near ecologically sensitive sites, the Project area is not classified as such and is already subject to artificial lighting from nearby infrastructure and ongoing maritime operations. Given this baseline lighting conditions and the separation distance to key ecological features, the risk of additional light-related disturbance to avifauna was assessed to be low.

While there is no universally fixed standard for light buffer distances, international guidelines and ecological studies generally recommend maintaining a separation of 50 to 100 m between artificial light sources and sensitive habitats (Longcore & Rich, 2004; Rodríguez et al., 2017). These recommendations are typically adapted based on local ecological context, receptor sensitivity, and lighting characteristics. In this case, the 800 m distance to Loyang Rock, the absence of direct lighting, and the lack of highly light-sensitive habitats provided sufficient assurance that no additional buffer-specific measures were required.

Nevertheless, lighting management strategies were incorporated into the Project's design and construction planning to minimise potential ecological disturbance. During the construction phase, low colour temperature lighting and reduced blue light output were adopted where practicable. For the operational phase, the lighting design was aligned with the NParks Biophilic Design Guidelines (NParks, 2021), including the Bird-Safe Building Guidelines (2024), to support a bird-friendly and ecologically sensitive lighting approach.

## 9.7 Direct Impact

The direct impact assessment involves the identification of the total area lost within the Project footprint and an evaluation of the significance of impacts based on identified receptors. For this Project, direct impacts arise from both construction and operational activities.

During the construction phase, direct impacts are associated with dredging and marine piling works, which result in the removal and permanent loss of benthic habitat.

During the operational phase, potential direct stressors include elevated temperatures and residual chlorine from the cooling water discharge, which may affect macrobenthic organisms in the outfall area.

**Construction – Dredging**

Dredging and piling activities will cause direct and permanent loss of existing soft-bottom macrobenthos habitat within the Project footprint. As noted in the baseline surveys (Section 7.8.3), brittle stars (*Ophiuroidea*) were the most abundant macrobenthic organisms recorded in the study area. Although many species present are motile, they are unlikely to relocate in time to avoid the disturbance. These species will be directly impacted, but the broader regional population, especially of brittle stars, is not expected to be significantly affected. Recovery is anticipated in areas outside of the direct impact zone.

**Operation – Thermal Discharge**

Macrobenthic assemblages in tropical estuarine environments, such as those found in Singapore, are known to tolerate a range of environmental variability, including gradual changes in temperature (Chou et al., 2004; Yap & Chou, 1998). Common taxa such as polychaetes, amphipods, and bivalves have demonstrated moderate to high tolerance to thermal fluctuations, particularly in nearshore and sediment-rich environments where temperature and oxygen levels are naturally variable. Unlike reef-building corals or planktonic organisms, macrobenthic species tend to be more resilient to low-intensity thermal shifts, especially when those shifts do not exceed critical thresholds or persist over extended periods (Kinne, 1963; Grassle & Sanders, 1973).

The potential impact of the thermal plume from the cooling water discharge on macrobenthic communities was assessed with reference to vertical mixing patterns, local hydrodynamic conditions, and known ecological tolerances of benthic fauna. As thermally elevated effluents are typically less dense than ambient seawater, they tend to remain buoyant and concentrated near the surface (USEPA, 2001). Based on modelled plume dispersion result, the predicted excess temperature at the seabed remained ≤ 0.5°C above ambient. As macrobenthic organisms reside at or within the sediment layer, their direct exposure to surface-heated water was expected to be limited. Additionally, the highest temperature increases were localised near the discharge point and remained well below biological thresholds known to induce stress in benthic fauna.

In summary, based on predicted thermal plume dispersion, ecological tolerance data, and conservative assumptions regarding thermal sensitivity, no adverse impact on macrobenthic community structure or function was anticipated.

**Operation – Chlorinated Discharge**

While for macrobenthic organisms, this include a wide range of sediment-dwelling species such as polychaete worms, amphipods, and bivalves, are integral components of coastal and estuarine ecosystems. These organisms play essential roles in nutrient cycling, sediment stability, and food web dynamics. As bottom-dwelling fauna, they are generally considered more vulnerable to contaminants that accumulate in sediments or persist in the near-bottom water column.

Residual chlorine from the cooling water discharge is reactive in seawater. Upon discharge into marine environments, it undergoes rapid chemical transformation and breakdown due to reactions with organic matter. These reactions typically result in the formation of less reactive by-products and the loss of free chlorine within minutes to hours (Howarth & Sposito, 1979; Hall et al., 1982; USEPA, 1989). As a result, concentrations of free chlorine decline rapidly with distance from the discharge point.

Due to its short-lived nature in the marine water column, free chlorine generally does not persist long enough to reach the seabed in appreciable concentrations, particularly under dynamic conditions. Studies have shown that in open coastal environments, such as those surrounding the Project area, chlorine is likely to degrade or dissipate before it can accumulate at the sediment-water interface (Thompson & Capuzzo, 1985; Pruett et al., 1980).

Furthermore, direct sorption of free chlorine onto sediments is considered negligible. While some chlorinated by-products may theoretically partition into sediments over time, their concentrations in well-flushed coastal waters are typically too low to cause acute or chronic toxicity to benthic fauna. Several ecotoxicological assessments have indicated that observed effects on macrobenthic communities due to chlorinated effluents are typically associated with long-term, high-concentration exposures in poorly flushed environments such as enclosed bays or industrial lagoons (Capuzzo, 1977; Rodriguez et al., 2012).

In this case, the Project's discharge was expected to occur in a coastal zone with regular tidal movement and active water mixing. Such conditions would promote rapid dilution and dissipation of chlorine, reducing the likelihood of sustained exposure at the seabed. Based on the expected behaviour of chlorine in marine waters and the environmental conditions at the site, no significant adverse impacts on macrobenthic communities were anticipated.

## 9.8 Air Quality

During the construction phase, the assessment focused on identifying and evaluating air pollutant emissions arising from temporary activities such as land-based construction, vessel movements, material handling, and earthworks. These emissions are primarily particulate matter ($PM_{10}$ and $PM_{2.5}$), $NO_2$, $SO_2$, and CO and were assessed using a qualitative approach, given their short-term and intermittent nature.

For the operational phase, the focus shifted to evaluating emissions from stationary sources associated with the facility. A quantitative air dispersion modelling assessment was undertaken to determine whether the predicted contribution (PC) from these sources would comply with the applicable Ambient Air Quality Targets (AAQTs) and statutory emission limits under Singapore's Environmental Protection and Management (Air Impurities) Regulations.

The modelling outcomes were used to determine potential exceedances at Air Sensitive Receptors (ASRs) located beyond the Project boundary and to assess the ground-level concentration of pollutants after atmospheric dispersion.

### 9.8.1 Receptors of Concern

The Project site is located within a Business 2 (B2) industrial zone, predominantly surrounded by port-related and industrial land uses. However, several potentially sensitive land use and natural receptors were identified within a 2 km radius of the site, as illustrated in Figure 7-31 and summarised in Table 7-29. Figure 9-55 specifically presents the sensitive receptors located within a 1 km radius from the Project boundary.

The closest land use receptors included the eastern end of Pasir Ris Park and the eastern most Seaview Bungalows at the Civil Service Club at Loyang. Both were situated within 500 m of the Project boundary and were zoned as "Park" and "Sports and Recreation" respectively, based on the URA Master Plan.

In addition, a construction site at 72 Loyang Way, approximately 335 m from the Project, was observed. This site was under development for a factory and worker dormitories. An undeveloped plot of land located approximately 600 metres to the southwest and identified as R5 in the 1 km sensitive receptor map, was designated for future residential use under the URA Master Plan.

There were no nature reserves, scenic areas, schools, healthcare institutions, or other designated sensitive land uses located within 500 m of the Project site. There were no existing residential developments or institutional premises identified within 500 m that are likely to be significantly affected by air emissions from the Project. The surrounding developments are primarily industrial in character, with limited permanent population exposure.


**Figure 9-55: Sensitive receptor map (1 km radius from site boundary)**

## 9.8.2 Construction Phase

Given the relatively small scale and limited duration of the land-based construction activities, a qualitative evaluation was undertaken to assess the potential impacts of construction-related air emissions. These impacts are expected to be localised, intermittent, and temporary, provided that appropriate mitigation measures are implemented.

The main sources of air pollutant emissions during the construction phase include:

- Fugitive dust arising from activities such as site clearance, excavation, material loading and unloading, and movement of vehicles on unpaved surfaces
- Combustion emissions from diesel-powered machinery and equipment (e.g., excavators, cranes, generators)
- Windblown dust from on-site stockpiles of soil and construction materials
- Exhaust emissions from construction-related traffic, including delivery vehicles, concrete mixers, and transport trucks.

These activities may release a range of common air pollutants, including particulate matter ($PM_{10}$ and $PM_{2.5}$), $NO_2$, $SO_2$, and CO. In the absence of mitigation, such emissions could potentially cause short-term localised degradation of air quality, particularly in the vicinity of air sensitive receptors (ASRs) such as residential areas, community facilities, or schools.

With the implementation of the proposed mitigation measures (refer to the Construction Environmental Monitoring and Management Plan (EMMP) in Section 12), the residual air quality impact during the construction phase is expected to be slight and temporary. The risk of significant or long-term air quality deterioration is low. Air quality conditions will be monitored throughout the construction period in accordance with the EMMP, and corrective actions will be undertaken promptly if any exceedances or adverse conditions are observed.

### 9.8.3 Operational Phase

The air quality impact assessment for the operational phase was conducted to evaluate potential emissions associated with the Project and to identify appropriate mitigation measures to be incorporated into the design and operation of the facility. To determine the potential impacts on air quality, a dispersion modelling exercise using AERMOD was undertaken to estimate ground-level pollutant concentrations resulting from emissions during the operational phase.

The detailed air dispersion assessment results are presented in Appendix J.

#### 9.8.3.1 Simulation Scenarios

Two operational scenarios were developed to evaluate the dispersion of pollutants under different exhaust configurations as indicated in Table 9-29. It should be noted that, as the detailed design of the data centre has not yet been finalised, this assessment was conducted based on the conceptual design parameters currently available. The results are therefore intended to guide mitigation planning and inform future design finalisation and regulatory submissions.

**Table 9-29: Model Scenario**

| Model Scenario | Operation hours/year/generator | Description |
|---|---|---|
| Unmitigated Scenario | • Once per month manufacturer-required testing<br>• Each test lasts for 15 minutes.<br>• One (1) genset is operated at 100% load during each test without concurrent operation. | • Exhaust gases will be released via the built-in flue of 5.165 m above the ground level. |
| Mitigated Scenario | • Once per month manufacturer-required testing<br>• Each test lasts for 15 minutes.<br>• One (1) genset is operated at 100% load during each test without concurrent operation. | • The genset's exhaust flues were simulated to be 3 m above the data centre module, the height building within 100 m radius. |

The only source of air emissions during the operational phase of the data centre is the diesel-fired emergency generators (gensets). These gensets are equipped with dedicated exhaust flues and are intended for use only during manufacturer-required testing and routine maintenance. As such, emissions from these units are expected to occur for short durations at low frequencies. Air emissions from the generators will consist primarily of $NO_X$, and, to a lesser extent, HC, CO and PM as combustion products from the facility's diesel-fired emergency generators.

It is noted that under NEA regulations effective July 2013, Near Sulphur-Free Diesel (NSFD) with a sulphur content of 0.001% has been mandated for use in Singapore. As a result, $SO_2$ emissions are negligible and are not considered a key pollutant of concern for this assessment.

#### 9.8.3.2 Result and Discussion

Air dispersion modelling was conducted to assess emissions from the standby diesel generators during periodic maintenance. Two scenarios were evaluated: the unmitigated design, with exhaust flues at 5.165 m above ground, and the mitigated design, which incorporated flue extensions to approximately 35.8 m SHD to improve pollutant dispersion.

Under the unmitigated scenario, exhaust gases will be discharged from the built-in flues which is 5.165 m above the ground level. The air dispersion modelling revealed that the short flue cannot ensure an adequate dispersion of the air emissions from the gensets.

According to the Singapore Standard SS 593: 2013 Code of practice on pollution control (COPPC), a chimney of an approved height should be provided for safe dispersion of flue gases from fuel burning equipment. A standard requirement based on the intent of the COPPC is that the chimney height should not be lower than 3 m above the roof level of all factory buildings in the vicinity, with no impediment to safe dispersion by mechanical and electrical equipment at roof level.

To address the identified dispersion limitations, the mitigation measure proposed was to extend the exhaust flues to 35.8 m SHD, which meets the requirement of at least 3 m above the highest building within 100 m radius. The proposed mitigation measure was assessed with an ADMS which verify the effectiveness of the mitigation measure. The air dispersion impact assessment found that:

The project contribution of the proposed development is classified with an ES of minor negative impact under the RIAM methodology, which is less significant than the impacts in the unmitigated scenario. It shows that implementing the proposed mitigation measure will effectively reduce the potential air quality impacts of the development; and

The cumulative ground-level concentration (GLCs) is well below Ambient Air Quality Target (AAQT) from the proposed development. This suggests that the maintenance of the standby genset under the planned schedule is unlikely to deteriorate the ambient air quality and result in a compliance risk for the proposed development.

The site will likely be required to conduct a Pollution Control Study (PCS) including air quality dispersion modelling to obtain environmental clearance from the NEA at Building Plan stage. Mitigation measures as proposed by the air quality modelling assessment would be adopted by the environmental clearance and thereby become enforceable emissions limits, operating restrictions, and/or control measures to be implemented and adhered to in order to achieve and maintain compliance with respect to air emissions. Installation of Tier 3 or Tier 4 generators, or technologies such as Selective Catalytic Reduction (SCR) filters on the facility's generators could be considered as alternative pollution control measures to be assessed under the PCS. Air quality monitoring (ambient baseline and commissioning phase monitoring to demonstrate compliance) is also typically required by the NEA prior to issue of the Temporary Occupation Permit (TOP).

The detailed air dispersion assessment results are presented in Appendix J.

## 9.9 Noise Level

During the construction phase, the assessment focused on identifying and evaluating airborne noise emissions arising from temporary activities. These noise emissions are expected to be intermittent and short-term, varying with the type and intensity of construction activity. A qualitative assessment was undertaken to evaluate potential exceedances of permissible noise levels, particularly in relation to nearby Noise Sensitive Receptors (NSRs) such as residential and institutional buildings.

For the operational phase, the focus shifted to evaluating continuous or periodic noise emissions from stationary sources. A quantitative noise modelling assessment was conducted to determine whether the Predicted Noise Levels (PNLs) from the Project would comply with the Permissible Noise Limits specified under Singapore's Environmental Protection and Management (Boundary Noise Limits for Factory Premises) Regulations.

The modelling outcomes were used to assess potential exceedances of noise thresholds at nearby NSRs located beyond the Project boundary and to evaluate the spatial extent of potential nuisance or disturbance associated with operational equipment.

### 9.9.1 Receptors of Concern

The Project site is located within a Business 2 (B2) industrial zone, predominantly surrounded by port-related and industrial land uses. However, several potentially sensitive land use and natural receptors were identified within a 2 km radius of the site, as illustrated in Figure 7-31 and summarised in Table 7-29. Figure 9-55 specifically presents the sensitive receptors located within a 1 km radius from the Project boundary.

### 9.9.2 Construction Phase

This section assesses the potential airborne noise impacts associated with the construction phase of the Project, with a focus on land-based activities supporting the installation and operational readiness of the floating data centre. Noise emissions during construction are typically short-term and intermittent but may cause disturbance if not properly managed, particularly when activities are located near sensitive human receptors.

Airborne noise generated during construction is primarily attributed to transportation and mobile sources, as well as operational machinery and equipment used in various construction tasks. Key sources of noise during the construction phase are expected to include:

- Site preparation and clearance, including vegetation removal and earthworks
- Foundation works, such as piling (if applicable), compaction, or concrete slab works
- Structural works, including concrete mixing, reinforcement assembly, and framework installation
- Operation of heavy machinery and equipment, such as excavators, cranes, dump trucks, generators, and compressors
- Material handling and logistics, such as unloading and movement of construction materials, prefabricated components, and utility equipment
- Vehicle movements, particularly from construction traffic entering and exiting the site

Construction-related noise emissions are expected to be intermittent, localised, and temporary, with higher levels associated with peak activity periods such as excavation or piling. Noise levels may also fluctuate depending on proximity to receptors, equipment maintenance, and mitigation measures implemented on site.

With the implementation of appropriate control measures, as outlined in the CEMMP (refer to Section 12), and strict adherence to NEA's Noise Guidelines for Construction Sites, construction noise impacts are expected to remain within permissible limits and be effectively minimised.

### 9.9.3 Operational Phase

The airborne noise impact assessment for the operational phase was conducted to evaluate potential noise emissions associated with the Project and to identify appropriate mitigation measures to be incorporated into the design and operational framework of the facility. To assess potential impacts on nearby receptors, a noise modelling exercise using CadnaA was undertaken to predict operational noise levels generated by key stationary sources. The modelling results were used to assess compliance with the applicable permissible noise limits under the Environmental Protection and Management (Boundary Noise Limits for Factory Premises) Regulations.

The detailed operational noise modelling results are presented in Appendix J.

#### 9.9.3.1 Simulation Scenarios

A noise simulation was conducted to assess the noise levels for the following operational scenarios:

- Unmitigated Scenario – Normal Operation and Scheduled Maintenance

  Two operational conditions were assessed:

  - Normal Operation: In this scenario, the facility operates under standard conditions without the activation of standby generators. Noise emissions are limited to mechanical sources, such as ventilation systems, pumps, and chillers. These sources are continuous but relatively low in intensity.
  - Scheduled Maintenance Operation: This involves routine testing of standby diesel generators. Testing is conducted sequentially, with no concurrent operation of multiple units. Noise from generator testing is expected to be more pronounced, albeit limited to short durations and scheduled intervals.

- Mitigated Scenario

  In the mitigated scenario, additional noise control measures were assumed and incorporated into the modelling for both normal operation and scheduled maintenance conditions

The simulation included key noise-emitting equipment anticipated during operations, including chiller, pump, transformer, load bank, and standby genset.

#### 9.9.3.2 Result and Discussion

The findings of noise impact assessment are as follow:

- The project-contributed noise will not cause any deterioration in ambient noise level with impacts categorised as “no impact”.
- The scheduled genset maintenance is predicted to exceed the Leq 5-min limit if conducted in the evening or night-time with impact categorised as “slight negative impacts”.

Mitigation measure is proposed to carry out the manufacturer-required maintenance and readiness testing of the emergency standby gensets during the day (between 9am and 6pm) to avoid noise impacts to the surrounding environment during the evening of night.

The site will likely be required to conduct a PCS including noise modelling to obtain environmental clearance from the NEA at the Building Plan stage. Ambient baseline noise monitoring is recommended to be conducted to inform the PCS. Commissioning phase monitoring to demonstrate compliance as is also typically required by the NEA prior to the operational phase.

Pursuant to the COPPC, all practical noise abatement measures should be adopted to comply with the applicable allowable boundary noise levels. Mechanical equipment of low sound power should be used wherever possible, and noise abatement measures should be factored into the building design in order to mitigate noise nuisance impact.

The detailed noise assessment results are presented in Appendix J.

# 10

## Climate Change Assessment

# 10 Climate Change Assessment

## 10.1 Introduction

This section evaluates the potential impacts of climate change on key environmental receptors, specifically seagrass habitats, mangrove ecosystems, and aquaculture facilities. The assessment considers the projected effects of climate stressors, such as rising sea levels, increasing sea surface temperatures, and extreme weather events, and their potential to interact with the thermal effects of cooling water discharge from the FDCM.

To assess these impacts, this study will integrate projections from Singapore's Third National Climate Change Study (V3) and the Intergovernmental Panel on Climate Change's (IPCC) 6th Assessment Report (AR6). These sources provide scientific insights into anticipated environmental changes, offering a basis for evaluating potential risks to marine biodiversity under future climate scenarios.

## 10.2 Climate Change Projection and Potential Impacts

The 6th Assessment Report (AR6) by the Intergovernmental Panel on Climate Change (IPCC, 2023) confirms that climate change induced by human activities, primarily through greenhouse gas emissions, will lead to rising global temperatures, increased extreme weather events, and sea level rise.

To better understand these potential impacts at a national level, Singapore has undertaken a series of National Climate Change Studies, commissioned by the National Environment Agency (NEA) under the Resilience Working Group. The latest of these, Singapore's Third National Climate Change Study (V3), conducted by the Centre for Climate Research Singapore (CCRS), provides projections for the country's climate from 2080–2099 under three Shared Socioeconomic Pathway (SSP) scenarios.

Table 10-1 presents a summary of key climate projections for Singapore under different Shared Socioeconomic Pathway (SSP) scenarios, which range from low emissions (SSP1-2.6) to high emissions (SSP5-8.5).

**Table 10-1: Summary of V3 projections at the end of the century (2080 – 2099) (Meteorological Service Singapore, 2024))**

| Variable | V3 Key Findings | | |
|---|---|---|---|
| | SSP1-2.6 | SSP2-4.5 | SSP5-8.5 |
| Increase in mean sea level (m) | 0.23 to 0.74 | 0.34 to 0.88 | 0.54 to 1.15 |
| Mean daily temperature (°C) | 28.5 to 29.5 | 29.3 to 30.7 | 30.7 to 32.9 |
| Mean daily West Bulb Globe Temperature (WBGT) (°C) | 27.1 to 28.0 | 27.8 to 29.0 | 29.1 to 30.9 |
| Mean maximum daily temperature (°C) | 31.9 to 33.1 | 32.8 to 34.4 | 34.3 to 36.7 |
| Mean maximum daily WBGT(°C) | 30.9 to 31.7 | 31.6 to 32.6 | 32.7 to 34.4 |
| No. of very hot days per year | 41 to 125 | 103 to 261 | 252 to 351 |
| No. of warm nights per year | 312 to 361 | 360 to 365 | 365 |
| No. of heat stress days per year | 54 to 135 | 107 to 205 | 207 to 326 |
| Annual average rainfall (mm) | 2608 to 3234 | 2452 to 2921 | 2295 to 3052 |
| 10-m wind | 10-m wind speed to increase by up to 20%, by end-century | | |

Based on the V3 Report and SSP5-8.5 projections, key climate change parameters relevant to Singapore's marine environment include:

- Air and seawater temperature increase: Historical records from 1972 to 2014 indicate an increase in the annual mean temperature from 26.6°C to 27.7°C. Projections suggest a further increase to 29.5°C by mid-century, with surface seawater temperatures expected to rise by 1 to 1.5°C under high-emission scenarios (RCP8.5) (Kay et al., 2023)
- Sea Level Rise (SLR): An average sea level rise of 0.79 ± 0.04m is projected by the end of the century, with an estimated 0.26m increase by mid-century, potentially leading to habitat loss and coastal erosion.
- Change in wind speed: A gradual upward trend in daily maximum wind gusts is expected, with mid-century increases of up to 3%, potentially affecting wave dynamics and thermal exchange processes.
- Change in relative humidity: Future projections indicate a decreasing trend in relative humidity, with estimated reductions in the range of -5.3% to 0.7% by end-century during February and March.
- Rainfall intensity: Extreme rainfall events are anticipated to increase in intensity and frequency, which may result in sudden salinity fluctuations in coastal waters, impacting marine life.

These climatic changes may influence hydrodynamic conditions and marine biodiversity. Table 10-2 summarizes the potential impact of climate change on EIA model results and marine biodiversity.

**Table 10-2: Potential impact on the model results due to climate change**

| Condition changes due to climate change | Potential Impact of present EIA model results | Potential impact on marine biodiversity |
|---|---|---|
| Sea level rise | Hydrodynamic model: increases water level, reduces current speed due to deeper water depth | Potentially negative impacts on marine biodiversity. |
| Wind speed increasing | Hydrodynamic model: increases surface water layer currents; Thermal model: affects heat exchange process | Potentially positive impact, as higher wind speeds promote heat exchange between cooling water discharge and the atmosphere, reducing local thermal stress. |
| Air Temperature rising | Thermal model: affects heat exchange process | Potentially negative impact as higher ambient air temperatures may reduce the effectiveness of heat dissipation, leading to a stronger thermal plume. |
| Seawater temperature increasing | Thermal model: affects heat exchange process | Potentially negative impact as warmer seawater reduces the cooling efficiency of discharged water, increasing thermal stress on the marine environment. |
| Relative humidity decreasing | Thermal model: affects heat exchange process | Potentially positive impact as lower humidity enhances evaporative cooling efficiency, increasing heat dissipation and potentially reducing cooling water discharge temperatures. |

| Condition changes due to climate change | Potential Impact of present EIA model results | Potential impact on marine biodiversity |
|---|---|---|
| Rainfall intensity increasing | No anticipated impact on all modelling results | Mixed impact. Potentially negative impacts, as extreme rainfall events can cause large drop in seawater salinity and affecting mortality of intertidal organisms. However, potential positive effects may include improved dilution of cooling water discharge, which can reduce localized thermal impacts on the marine environment. |

The impact of climate change on cooling water discharge is complex and influenced by multiple environmental factors, including air temperature, relative humidity, seawater temperature, wind speed, and rainfall intensity. While certain climate variables may positively impact cooling water discharge, others may cause negative impacts, such as increased thermal stress. Additionally, the overall impact is highly dependent on site-specific conditions, cooling system design, regulatory constraints, and the adaptive capacity of marine ecosystems to changing thermal conditions.

## 10.3 Assessment of Climate Change

A qualitative assessment of climate change impacts has been conducted by superimposing SSP5-8.5 climate projections onto existing model results. This approach allows for an estimation of potential changes in environmental conditions and their influence on marine biodiversity in the context of the FDCM project. The assessment assumes that the FDCM will remain operational until mid-century (year 2050), making it necessary to evaluate how projected climate variations within this timeframe could alter hydrodynamic and thermal conditions in the surrounding marine environment.

This qualitative assessment serves as an important step in understanding the potential cumulative impacts of both anthropogenic and climate-driven environmental changes. While exact quantitative projections remain uncertain, the incorporation of worst-case climate scenarios (SSP5-8.5) provides a conservative estimation of potential risks.

While the FDCM's operations do not contribute to climate change-induced effects such as sea level rise, seawater temperature increase, or extreme rainfall events, its long-term impact cannot be directly attributed to the FDCM alone. The broader environmental changes observed are driven by global climate trends rather than localized project activities.

### 10.3.1 Thermal Conditions Impacts

Based on V3 projections, Singapore mean air temperature is expected to increase to 29.5°C mid-century from 27.9°C during baseline period. While the report does not explicitly correlate seawater temperature increase with air temperature rise, Kay et al. (2023) predicted sea surface temperature rise by 1 to 1.5°C by mid-century under RCP8.5. The 95$^{th}$ percentile temperature (depth-averaged temperature from model results) post development at seagrass/intertidal and mangrove area is presented in Table 10-3. Adopting 1.5°C seawater temperature increases due to climate change, the 95$^{th}$ percentile temperature at seagrass/intertidal and mangrove area calculated assuming the addition of post development temperature and seawater temperature increase.

**Table 10-3: 95th percentile post development temperature with and without climate change effects**

| Monsoon period | Existing EIA model results – 95th Percentile Post Development Temperature (Depth-Averaged) | | 95th Percentile Post Development Temperature (Depth-Averaged) with seawater temperature increase due to climate change | |
|---|---|---|---|---|
| | Seagrass/Intertidal area | Mangrove area | Seagrass/Intertidal area | Mangrove area |
| NE monsoon | 31.5°C | 31.5°C | 33.0°C | 33.0°C |
| SW monsoon | 31.0°C | 31.0°C | 32.5°C | 32.5°C |
| Inter-monsoon | 31.5°C | 31.5°C | 33.0°C | 33.0°C |

Seagrass thermal tolerance varies by location, season, and species-specific adaptations to local temperature regimes. As noted in Section 9.3.3, photosynthetic efficiency declines as water temperatures approach 38°C due to increased photorespiration. Between 38°C and 42°C, thermal stress can inactivate oxygen-producing enzymes in Photosystem II, disrupting electron transport and ultimately causing plant mortality (SeagrassWatch, 2009). Temperate seagrass species experience critical thermal stress at temperatures exceeding 35°C (Bulthuis, 1983; Ralph, 1998). Similarly, mangrove root systems, seed dispersal, growth, photosynthesis, and $CO_2$ fixation are negatively affected at temperatures above 35°C (Jacotot et al., 2018).

Although the recorded 33°C remains below the critical stress threshold for temperate seagrasses and mangroves (35°C), climate-induced warming is projected to gradually increase seawater temperatures by 1.5°C over the assessment period (mid-century). This progressive rise may allow for some degree of species adaptation. However, as temperatures continue to rise, shifts in seagrass distribution are expected, with cool-adapted species experiencing range contractions while heat-tolerant species expand. Climate-induced thermal stress may also alter community composition, leading to reduced biodiversity and affecting the structure and function of seagrass meadows (Waycott et al., 2009; Short et al., 2016).

In the context of this project, the recorded 33°C remains within the thermal tolerance limits of temperate seagrasses and mangroves, and the immediate impacts are expected to remain within acceptable thresholds. However, when considering long-term climate change projections, prolonged exposure to rising temperatures could introduce multiple stressors to marine habitats.

For seagrasses, elevated temperatures may disrupt photosynthesis, metabolism, and reproductive success. Increased respiration rates could lead to an energy imbalance, weakening plant health and making them more susceptible to diseases such as seagrass wasting disease (Waycott et al., 2009). Prolonged thermal stress has been linked to large-scale seagrass die-offs, reducing their carbon sequestration capacity and impacting marine food webs (Short et al., 2016). Similarly, mangroves may experience growth limitations, altered leaf transpiration, and reproductive disruptions under prolonged heat stress. Persistent exposure to high temperatures can result in leaf chlorosis, stunted growth, and increased water loss (Ellison, 2000). Some mangrove species may also be forced to shift their distribution, potentially leading to localized biodiversity loss (Duke et al., 2007). On a broader scale, heat-induced stress on marine organisms, including fish and invertebrates, may reduce reproductive success, lower survival rates, and shift species dominance (Portner & Peck, 2010). These disruptions could weaken overall ecosystem resilience, making marine habitats more vulnerable to additional stressors such as pollution, habitat degradation, and extreme weather events (IPCC, 2019).

The immediate project-induced temperature increase remains within the thermal tolerance limits of seagrasses and mangroves, and no significant stressors are expected as a direct result of the project. However, independent of the project, long-term climate-driven warming may exacerbate these stressors over time.

Therefore, broader climate change considerations, rather than project-specific impacts, should be accounted for in long-term ecosystem management.

### 10.3.2 Hydrodynamic Conditions Impacts

Based on V3 projections, an average relative sea level rise of 0.79 ± 0.04m by 2100 is predicted. By mid-century, an assumed increment of 0.26m (0.79m/3) will likely impact marine habitats. However, these changes are independent of the FDCM and are part of broader climate change trends.

Rising sea levels are expected to reduce light penetration, which could decrease photosynthetic productivity and potentially lead to seagrass habitat loss. Seagrasses may attempt landward migration to maintain suitable growing conditions, but this adaptation may be constrained by coastal squeeze due to Singapore's extensive infrastructure and limited natural shoreline expansion (Brodie and De Ramon N'Yeurt, 2018; Short et al., 2016). Similarly, mangrove ecosystems may experience prolonged flooding if sediment accretion rates are insufficient to keep pace with rising sea levels. Some mangrove areas may be lost if they are unable to migrate inland, a process restricted by urban development and coastal defences. However, mangroves have a natural ability to adapt, and certain species may persist if sufficient sediment accretion occurs (Duke et al., 2007; Ellison, 2000).

V3 climate projections also indicate that extreme rainfall events will intensify across all seasons under Shared Socioeconomic Pathway (SSP) scenarios. Historically, prolonged heavy rainfall in Singapore and Southern Peninsular Malaysia has resulted in significant salinity drops, leading to mass mortality of intertidal organisms. For instance, in 2007, Chek Jawa experienced widespread biodiversity loss following extreme rainfall-induced freshwater influx (Toh et.al, 2012). While biodiversity typically recovers once conditions stabilize, such extreme events can cause lasting changes in community structure. A notable example is the establishment of the invasive Asian mussel at Chek Jawa after the 2007 event, highlighting ecosystem alterations driven by environmental stressors (Toh et al., 2012).

The FDCM is not expected to influence sea level rise, hydrodynamic conditions, or land use, as these are long-term, climate-driven changes. Additionally, the FDCM does not impact the hydrological cycle, meaning it has no effect on the frequency or intensity of extreme rainfall events.

## 10.4 Conclusion

The assessment of climate change impacts on Singapore's marine environment highlights the potential risks posed by rising sea levels, increasing sea surface temperatures, and extreme weather events. Projections from Singapore's Third National Climate Change Study (V3) and the IPCC's 6th Assessment Report (AR6) indicate that these climate stressors may significantly alter marine biodiversity and hydrodynamic conditions in the coming decades.

The thermal effects of cooling water discharge from the FDCM remain within tolerable thresholds for seagrasses and mangroves, as the recorded 31.5°C does not exceed critical stress limits (35°C) for these ecosystems. However, long-term climate change-driven warming, independent of the FDCM, may gradually increase seawater temperatures by 1.5°C by mid-century, potentially altering species distributions, reducing biodiversity, and increasing thermal stress on marine habitats (Waycott et al., 2009; Short et al., 2016).

Hydrodynamic conditions may also be affected by projected increases in wind speeds, humidity shifts, and changes in rainfall intensity. While stronger winds could enhance heat exchange and mitigate localized thermal stress, higher ambient temperatures and reduced humidity may weaken cooling efficiency, compounding climate-induced thermal impacts. Additionally, extreme rainfall events may cause sudden drops in seawater salinity, leading to localized biodiversity loss and potential disruptions in marine food webs.

Although the FDCM does not influence sea level rise, hydrodynamics, or extreme weather patterns, it is important to acknowledge the potential cumulative effects of climate change on marine biodiversity, habitat stability, and ecosystem resilience.

# 11

# Risk Assessment for Refrigerant

# 11 Risk Assessment for Refrigerant

Refrigerants are essential to the operation of the Floating Data Centre (FDC), supporting thermal regulation for both critical IT infrastructure and auxiliary systems such as air-conditioning and ventilation. While the use of refrigerants is standard in data centre design, the handling, containment, and disposal of these substances must be carefully managed due to their potential impacts on the atmosphere, occupational safety, and overall environmental quality.

This section presents a preliminary assessment of refrigerant-related risks, including potential hazards under routine operation and accidental release scenarios. The assessment is based on current design information and international best practices and will be further refined as part of the site-specific OEMMP.

## 11.1 System Description and Refrigerant Use

The proposed Floating Data Centre will utilise refrigerants as part of its cooling infrastructure to maintain optimal operating temperatures for data processing equipment. These refrigerants will be employed within sealed, closed-loop circuits across various subsystems, including the central chiller plant, HVAC systems, precision air-conditioning units, mechanical and electrical rooms, chilled water distribution lines, and, where applicable, battery cooling and fire suppression systems.

The refrigerants function as the primary thermal transfer medium, absorbing heat generated within the data centre and transferring it to a chilled water loop. This chilled water is subsequently cooled via heat exchangers connected to a seawater cooling circuit. Throughout the system, refrigerants remain fully isolated from seawater. Heat exchange occurs indirectly through intermediary chilled water loops housed within the hull or shore-side infrastructure.

Refrigerants will be contained within individual chiller units located on the hull level of the data centre. These units operate as part of the closed-loop system and are not designed to interface directly with the marine environment. No bulk storage of refrigerants will occur on-site.

The selected refrigerant is expected to be Hydrofluoroolefin (HFO) R-1233zd, or a suitable low-global-warming-potential (GWP) alternative, selected for its favourable environmental performance. This refrigerant has an Ozone Depletion Potential (ODP) of zero and a GWP of less than 15, in full compliance with the NEA's requirements. The system will be designed with appropriate leak detection, containment safeguards, and recovery protocols to ensure safe operation and compliance with health, safety, and environmental standards. The selected refrigerant also offers advantages in terms of low toxicity and non-flammability, reducing the potential for adverse impacts in the event of accidental release.

To ensure safe operation and environmental protection, all rooms housing refrigerant-based equipment, including chiller plant rooms and mechanical compartments, will be equipped with leak detection sensors, mechanical ventilation systems, and secondary containment infrastructure. These measures are intended to prevent accidental release, protect personnel, and safeguard the surrounding marine environment.

## 11.2 Risk Identification and Assessment

Although refrigerant systems within the Floating Data Centre are designed to operate within sealed and robust configurations, the potential for leakage or accidental release cannot be completely ruled out due to the complexity, scale, and continuous nature of operations. In the context of a marine-based facility, such incidents may present not only environmental risks but also occupational health and safety concerns. These preliminary risks can be broadly categorised into environmental risks and human health and operational safety risks.

### 11.2.1 Environmental Risk

The table below presents a consolidated qualitative assessment of key refrigerant-related risks based on likelihood, potential impact, and mitigation potential.

**Table 11-1: Environmental risk categories associated with refrigerant use**

| Risk | Description |
|---|---|
| Atmospheric emissions | The primary environmental concern is the release of refrigerants into the atmosphere, particularly in the event of a slow leak or sudden system failure. While R-1233zd has a significantly lower global warming potential than legacy hydrofluorocarbons, its release still contributes to greenhouse gas emissions. Large-scale leaks could undermine efforts to reduce the carbon footprint of the facility and negatively impact climate change mitigation goals. |
| Marine contamination | In scenarios where refrigerants leak and are captured by the bilge or drainage systems, there is a risk of accidental discharge into the sea. Although these substances are generally chemically stable, some degrade into persistent halogenated compounds when exposed to light or microbial activity. These by-products may bioaccumulate in the marine food web or interfere with critical physiological processes in marine invertebrates and microorganisms. |
| Aquatic toxicity | Studies have demonstrated that refrigerants, even in low concentrations, may cause sub-lethal toxicity in aquatic species. Marine invertebrates such as crustaceans and mollusks are particularly sensitive to changes in chemical composition in their environment. Chronic exposure can impair reproduction, disrupt enzyme function, and alter microbial diversity in sediment ecosystems. |
| Soil and sediment impact | Should refrigerant leaks occur near utility rooms or during waste handling, spilled fluids may seep into soil or accumulate in hull-associated sediments. These contaminants may persist in anaerobic sediment layers and alter nutrient cycling by affecting the microbial community structure |
| Waste generation | Spent refrigerants, used filter materials, and system oils must be handled as controlled waste. Inadequate disposal may introduce toxicants into waste streams or water catchments. These materials are also subject to international shipping regulations if transported off-site. |
| Climate change | Although R-1233zd is a low-GWP substance, its mass use still contributes to cumulative emissions. If refrigerant management is not strictly enforced, leakage over time can increase the facility's indirect contribution to climate change. |

### 11.2.2 Human Health and Occupational Safety Risks

In addition to environmental concerns, refrigerant systems also pose potential risks to personnel during normal operation and maintenance activities. These include exposure to gas leaks, handling hazards, and secondary risks such as fire or pressurised release. Proper design, training, and emergency procedures are critical in minimising these risks.

**Table 11-2: Human health and occupational safety risks**

| Risk | Description |
|---|---|
| Acute Exposure | In the event of a significant leak in confined spaces such as chiller plant rooms or mechanical enclosures, refrigerant gases may displace oxygen. This could create asphyxiation hazards for personnel without adequate ventilation. Although R-1233zd has low toxicity, inhalation at high concentrations may result in dizziness, respiratory irritation, or loss of consciousness. |

| Risk | Description |
|---|---|
| Chronic Exposure | Repeated exposure to low concentrations of refrigerants may cause mild respiratory symptoms or central nervous system effects in sensitive individuals. This is especially relevant for maintenance workers who may be in proximity to refrigerant piping and fittings during servicing. |
| Fire and Explosion Risk | Some low-GWP refrigerants are mildly flammable under specific conditions. While R-1233zd is classified as non-flammable in standard use, improper handling during system servicing or accidental contact with ignition sources could pose a localised fire hazard. |
| Chemical Handling Risk | Improper refrigerant recovery or disposal procedures may lead to exposure incidents or environmental contamination. If systems are not properly depressurised, pressurised gas release during maintenance could result in injury. |

#### 11.2.2.1 Risk Summary

This section presents an indicative qualitative risk assessment of potential hazards associated with the use of refrigerants at the proposed Floating Data Centre. Refrigerants are essential to the facility's thermal regulation systems but may pose environmental and occupational risks if not properly managed during storage, operation, or servicing.

The risk assessment has been conducted based on the preliminary system design and available operational data. While this assessment provides an early stage understanding of potential risks, a more detailed and site-specific risk evaluation shall be conducted during implementation and formally documented within the Operational Environmental Management and Monitoring Plan (OEMMP). The OEMMP will be submitted to relevant agencies for review and approval prior to commencement of operations.

To support transparent risk prioritisation and mitigation planning, the assessment adopts the Impact–Likelihood Assessment Matrix (IAM) structure. This approach is particularly suited for evaluating environmental risks to biodiversity and sensitive marine ecosystems and is also applicable to related occupational and operational risks.

In this framework, each risk is evaluated based on:

- Likelihood: The probability that the hazard could occur, based on operational experience, system robustness, and mitigation controls.
- Impact: The potential consequence or severity of the hazard, particularly its effect on ecological integrity, environmental quality, or human safety.

The resulting risk score (Likelihood × Impact) is then classified into one of five categories ranging from Very Low to Very High, which in turn guides the degree of mitigation and regulatory oversight required.

**Table 11-3: Impact–Likelihood Assessment Matrix**

| Impact \ Likelihood | Rare (1) | Unlikely (2) | Possible (3) | Likely (4) | Almost Certain (5) |
|---|---|---|---|---|---|
| Major (5) | Moderate | High | High | Very High | Very High |
| Significant (4) | Moderate | Moderate | High | High | Very High |
| Moderate (3) | Low | Moderate | Moderate | High | High |
| Minor (2) | Low | Low | Moderate | Moderate | High |
| Negligible (1) | Very Low | Low | Low | Moderate | Moderate |

**Table 11-4: Definition of Likelihood Ratings**

| Score | Descriptor | Description |
|---|---|---|
| 1 | Rare | Occurs only in exceptional circumstances; highly unlikely based on precedent |
| 2 | Unlikely | Not expected under normal operations, but possible if safeguards fail |
| 3 | Possible | Could occur under some conditions despite controls |
| 4 | Likely | Will probably occur in many circumstances |
| 5 | Almost Certain | Expected to occur frequently or repeatedly without controls |

**Table 11-5: Definition of Impact Ratings**

| Score | Descriptor | Description |
|---|---|---|
| 5 | Major | Irreversible or long-term impact on species, habitats, or ecosystem function; potential local extinction |
| 4 | Significant | Prolonged or extensive impact; affects rare or sensitive species or protected habitats |
| 3 | Moderate | Noticeable but recoverable impact; affects common species or habitats with good resilience |
| 2 | Minor | Localised short-term impact; no long-term changes to biodiversity or function |
| 1 | Negligible | No measurable impact or change to ecological condition |

**Table 11-6: Risk Level Interpretation**

| Risk level | Score range | Description |
|---|---|---|
| Very High | ≥ 20 | Unacceptable — strong mitigation and redesign required; project may not proceed without modification |
| High | 16–19 | Significant concern — impact must be reduced; strong mitigation and monitoring plan essential |
| Moderate | 10–15 | Manageable — mitigation measures required and subject to agencies review |
| Low | 5–9 | Acceptable — ensure mitigation is integrated in design and standard practice |
| Very Low | ≤ 4 | Negligible — no significant residual impact expected |

**Table 11-7: Preliminary risk of refrigerant use**

| Risk Category | Description | Likelihood | Impact | Risk Score | Risk Classification | Remarks |
|---|---|---|---|---|---|---|
| Leak during routine operations | Minor leakages from valves, fittings, or compressor seals during normal operations | Possible (3) | Moderate (3) | 9 | Low | Results in greenhouse gas emissions; generally confined to enclosed compartments; minimal marine impact if detected and contained promptly |
| Sudden refrigerant release | Unexpected release due to mechanical failure or accidental damage during operations or maintenance | Unlikely (2) | Major (5) | 10 | Moderate | Potential for occupational exposure and significant GHG release; requires emergency response and recovery protocols |

| Risk Category | Description | Likelihood | Impact | Risk Score | Risk Classification | Remarks |
|---|---|---|---|---|---|---|
| Discharge into marine systems | Contamination of bilge or condensate drainage resulting in refrigerant discharge into the sea | Rare (1) | Moderate (3) | 3 | Very Low | Unlikely with proper drainage design; environmental impact can be mitigated by containment and treatment infrastructure |
| Improper storage or refilling | Unsafe handling during refrigerant replacement or maintenance procedures | Possible (3) | Moderate (3) | 9 | Low | Risk of spillage or human exposure; can be mitigated through training, safety protocols, and equipment containment |
| Use of high-GWP refrigerants | Indirect climate impact from leakage or end-of-life disposal | Possible (3) | Moderate (3) | 9 | Low | Regulatory and reputational concern; use of low-GWP or natural refrigerants recommended to meet sustainability and reporting requirements |

Overall, the risk profile associated with refrigerant use is considered manageable, provided that proposed mitigation measures are implemented. These findings will be further validated and refined through a detailed site-specific risk assessment to be included in the Operational Environmental Management and Monitoring Plan (OEMMP).

### 11.2.3 Mitigation Measures

The following mitigation measures represent the preliminary framework that will guide refrigerant management and environmental protection. These general measures will be further detailed and refined in the site-specific Operational Environmental Management and Monitoring Plan (OEMMP), which will be submitted for regulatory review and approval prior to commencement of operations.

The typical mitigation measures that will be implemented as part of the refrigerant management strategy are summarised below:

- Proper Recovery and Disposal
  - All refrigerant recovery, charging, and disposal will follow NEA-approved procedures using certified recovery equipment. Decommissioning plans will include refrigerant disposal protocols.
- Compliance Monitoring and Reporting
  - Leak rates, servicing events, and gas volumes will be recorded and tracked. .
  - To mitigate the above risks, a comprehensive refrigerant management and safety plan will be implemented as part of the data centre’s operational environmental management system.
- Selection of Environmentally Responsible Refrigerants
  - The use of low-GWP refrigerants such as R-1233zd is central to the mitigation strategy. Alternative natural refrigerants may also be considered for auxiliary systems where feasible.
- System Integrity and Containment Design
  - All refrigerant-containing units will be located above deck drainage lines and fitted with secondary containment. Pipework will be pressure-rated and supported by structural brackets to minimise mechanical damage during vessel movement.
- Leak Detection and Monitoring

    - Real-time refrigerant leak detection sensors will be installed in chiller rooms, mechanical spaces, and HVAC ducts. These will be connected to the building management system to trigger alarms and initiate emergency responses.
- Automated Isolation and Recovery Systems
    - In the event of detected leakage, automated shutoff valves will isolate the affected system while recovery units will safely extract refrigerant to prevent further loss.
- Operational Controls and Training
    - Only certified personnel will be permitted to conduct refrigerant handling. All staff will receive training on emergency response protocols, including evacuation, purging, and ventilation management.
- Documentation and Compliance
    - All refrigerant use, including purchases, leakage incidents, recovery operations, and disposal, will be logged and audited under a refrigerant register in compliance with international best practices and greenhouse gas reporting obligations.
- Emergency Preparedness
    - Ventilation purging, safe evacuation routes, and localised spill containment procedures will be prepared and rehearsed.

## 11.3 Conclusion

When managed appropriately, refrigerant-related risks at the Floating Data Centre can be effectively contained. With the adoption of best practices in refrigerant selection, containment, detection, and response, the residual environmental risk is assessed to be Low to Moderate, while the human health risk is Low, assuming strict adherence to safety protocols and routine monitoring. Ongoing review of refrigerant technologies, staff competencies, and emissions reporting will ensure the facility continues to meet environmental performance benchmarks and regulatory expectations.

# 12

# Risk Assessment for Diesel, Fuel, and Chemical

# 12 Risk Assessment for Diesel, Fuel, and Chemical

The use and handling of diesel fuel and hazardous chemicals are necessary to support both the construction and operational phases of the Floating Data Centre. During construction, diesel is primarily used for heavy equipment, marine vessels, and site support machinery. In the operational phase, diesel is used for emergency power generation, while other chemicals such as cleaning agents, lubricants, and water treatment compounds may also be stored and used on-site. This section evaluates the potential environmental risks associated with these substances and outlines the mitigation measures that will be implemented to prevent adverse impacts to the environment.

## 12.1 Construction Phase Risk Assessment

During the construction phase, hazardous materials such as diesel, lubricants, cleaning agents, and solvents will be used to support site works and marine logistics. These substances are essential for the operation of machinery, vessel refuelling, equipment cleaning, and general maintenance activities. However, if they are not properly handled, stored, or transferred, there is a risk of accidental spills or leaks that could lead to contamination of soil, drainage pathways, and nearby marine waters.

Such spills may result in acute toxicity to marine organisms, particularly if the chemicals enter sensitive habitats. They can also reduce overall water quality by increasing concentrations of oil and grease, elevating chemical oxygen demand, and altering pH levels. In addition, the presence of hydrocarbons and other pollutants may cause localised oxygen depletion in the water column. The flammable nature of many of these substances also introduces fire and safety hazards on-site. Furthermore, these incidents may adversely affect sensitive ecological receptors and nearby socioeconomic stakeholders, such as aquaculture operators or coastal users who rely on clean marine resources.

Although the exact quantities and sources of these materials have yet to be finalised, the substances listed in Table 12-1. are indicative based on current construction planning. A project-specific risk assessment will be conducted closer to the implementation stage to confirm the actual materials to be used and define appropriate handling and storage measures.

**Table 12-1: Anticipated hazardous materials and associated activities during construction**

| Hazardous material | Activities |
|---|---|
| Diesel fuel | Powering of construction equipment, generators, and marine vessels; refuelling onshore and at sea |
| Lubricants and hydraulic fluids | Maintenance of cranes, winches, vessels, and construction machinery |
| Cleaning agents and degreasers | Equipment washing, general cleaning, and surface preparation |
| Solvents, adhesives, sealants | Temporary works, joint sealing, surface bonding, and equipment maintenance |

### 12.1.1 Risk Identification and Assessment

This section presents an indicative qualitative risk assessment of potential hazards associated with the use and storage of hazardous materials during the construction phase. The risk assessment has been conducted based on the preliminary system design and available data. While this assessment provides an early stage understanding of potential risks, a more detailed and site-specific risk evaluation shall be conducted during implementation and formally documented within the Construction Environmental Management and Monitoring

Plan (CEMMP). The CEMMP will be submitted to relevant agencies, for review and approval prior to commencement of operations.

To support transparent risk prioritisation and mitigation planning, the assessment adopts the Impact–Likelihood Assessment Matrix (IAM) structure (see Table 11-3, Table 11-4, Table 11-5, and Table 11-6).

In this framework, each risk is evaluated based on:

- Likelihood: The probability that the hazard could occur, based on operational experience, system robustness, and mitigation controls.
- Impact: The potential consequence or severity of the hazard, particularly its effect on ecological integrity, environmental quality, or human safety.

The resulting risk score (Likelihood × Impact) is then classified into one of five categories ranging from Very Low to Very High, which in turn guides the degree of mitigation and regulatory oversight required.

**Table 12-2: Summary of key construction-phase risks and assessment**

| Risk Category | Description | Likelihood | Impact | Risk score | Risk classification | Remarks |
|---|---|---|---|---|---|---|
| Diesel spill during refuelling | Accidental release during equipment or vessel refuelling due to hose failure or overfilling | Possible (3) | Moderate (3) | 9 | Low | May contaminate soil or coastal waters; requires containment and supervision |
| Bulk fuel storage leak | Leak from temporary tanks due to mechanical failure, corrosion, or poor containment | Unlikely (2) | Major (5) | 10 | Moderate | Potential for soil or groundwater contamination |
| Chemical handling spill | Improper handling or disposal of lubricants, oils, or cleaning agents | Possible (3) | Moderate (3) | 9 | Low | Risk of localised pollution, especially near drainage points |
| Fire hazard | Fire risk from flammable substances or poor fuel storage practices | Rare (1) | Major (5) | 5 | Very Low | Safety and environmental risk; mitigated through SCDF-compliant storage |
| Marine vessel collision | Accidental collision of construction vessels with submerged objects or other vessels, leading to hull breach or equipment damage | Unlikely (2) | Significant (4) | 8 | Low | May result in diesel or oil leaks into the marine environment; requires marine traffic control, navigation aids, and emergency spill response readiness |

The preliminary risk assessment identified five key environmental and safety hazards associated with the use of fuels and chemicals during the construction phase of the Floating Data Centre. Overall, the risks are considered manageable with proper design, planning, and site supervision, and will be further detailed in the site-specific Construction Environmental Management and Monitoring Plan (CEMMP).

### 12.1.2 Mitigation measures

To minimise environmental and safety risks, the following mitigation measures will be implemented during the construction phase:

- Diesel and chemical substances will be stored in secure, bunded areas located away from the shoreline and stormwater drains. All containers will be properly labelled in accordance with local hazardous material regulations.
- Refuelling will be conducted at designated zones using drip trays and supervised by trained personnel to reduce the risk of spillage.
- Spill response kits will be readily available at storage and refuelling areas, and personnel will be trained in the proper use of these kits.
- A Spill Management Plan will be included as part of the Construction Environmental Management and Monitoring Plan (CEMMP), detailing procedures for containment, clean-up, and reporting of any spill incidents.
- The appointed Environmental Control Officer (ECO) will carry out routine site inspections and audits to ensure compliance with all control measures and applicable legislation.
- \With the above measures in place, the risks associated with diesel and chemical use during the construction phase are expected to be adequately controlled.

All hazardous material handling during construction will be managed under the site-specific Construction Environmental Management and Monitoring Plan (CEMMP) and a Chemical Management Plan developed by the contractor and reviewed by relevant authorities prior to commencement of works. These documents will outline containment measures, emergency procedures, and compliance requirements.

## 12.2 Operational Phase Risk Assessment

During the operational phase, diesel will be used primarily to support emergency generator systems, which are not expected to run under normal conditions. According to the project proponent, the total diesel storage volume is anticipated to be below 400 $m^3$, housed in underground double-walled tanks within a reinforced concrete (RC) containment structure. Given the emergency-only application, fuel deliveries will be infrequent and conducted via road tankers. In addition to diesel, the facility will utilise operational chemicals such as lubricants, hydraulic fluids, cleaning agents, and water treatment chemicals (e.g., anti-fouling agent) throughout its lifecycle.

Environmental risks during operations primarily stem from potential fuel leaks or spills during storage and refuelling, as well as the improper handling or disposal of smaller quantities of cleaning agents, lubricants, and water treatment chemicals. Although the exact volumes and sources of these substances have not been finalised, their use, even in limited quantities, necessitates strict containment, safe handling protocols, and emergency response measures to prevent contamination of soil, drainage systems, or adjacent marine waters.

Based on typical operational needs of a Floating Data Centre, the hazardous materials anticipated are summarised in Table 12-3. This list is indicative and subject to refinement during the commissioning phases. A site-specific Operational Risk Assessment and Chemical Management Plan will be developed and implemented to manage associated risks in accordance with regulatory requirements.

**Table 12-3: Anticipated hazardous materials and associated activities during operation**

| Hazardous material | Activities |
|---|---|
| Diesel fuel | Backup power generation using emergency generators; |
| Lubricants and hydraulic fluids | Routine maintenance of mechanical equipment (e.g., pumps, winches, generators) |
| Cleaning agents and degreasers | General facility cleaning, surface preparation, and equipment maintenance |
| Water treatment chemicals / anti-fouling agent | Dosing into seawater cooling systems to prevent biofouling |
| Coolants | Circulated in closed-loop HVAC/chiller systems for heat removal |

| Hazardous material | Activities |
|---|---|
| Refrigerants | Used in data centre cooling systems (chillers, HVAC) |
| Battery chemicals | Contained within UPS or backup battery systems |
| Fire suppression chemicals | Used in automated fire suppression systems in server and generator rooms |
| Transformer oil | Used in electrical transformers within the FDCM hull |

### 12.2.1 Risk Identification and Assessment

This section presents an indicative qualitative risk assessment of potential hazards associated with the use and storage of hazardous materials during the operation phase. The risk assessment has been conducted based on the preliminary system design and available data. While this assessment provides an early stage understanding of potential risks, a more detailed and site-specific risk evaluation shall be conducted during implementation and formally documented within the Operation Environmental Management and Monitoring Plan (OEMMP). The OEMMP will be submitted to relevant agencies, for review and approval prior to commencement of operations.

To support transparent risk prioritisation and mitigation planning, the assessment adopts the Impact–Likelihood Assessment Matrix (IAM) structure (see Table 11-3, Table 11-4, Table 11-5, and Table 11-6).

In this framework, each risk is evaluated based on:

- Likelihood: The probability that the hazard could occur, based on operational experience, system robustness, and mitigation controls.
- Impact: The potential consequence or severity of the hazard, particularly its effect on ecological integrity, environmental quality, or human safety.

The resulting risk score (Likelihood × Impact) is then classified into one of five categories ranging from Very Low to Very High, which in turn guides the degree of mitigation and regulatory oversight required.

**Table 12-4: Summary of key operation-phase risks and assessment**

| Risk Category | Description | Likelihood | Impact | Risk score | Risk classification | Remarks |
|---|---|---|---|---|---|---|
| Diesel spill during refuelling | Accidental spill from transfer line or overfill | Possible (3) | Moderate (3) | 9 | Low | Can result in marine contamination and poses reputational and regulatory risk |
| Bulk fuel storage leak | Tank or bund failure due to corrosion or mechanical damage | Unlikely (2) | Major (5) | 10 | Moderate | Could cause land or marine contamination if not properly contained |
| Small-scale chemical spill | Improper handling or accidental discharge of lubricants or cleaners | Possible (3) | Moderate (3) | 9 | Low | Minor localised impact and higher risk if near drainage or bilge systems |
| Anti-fouling agent overdose or misdoing | Improper dosing of anti-fouling agent | Unlikely (2) | Significant (4) | 8 | Low | Can affect marine life at outfall and requires automated controls and alarms |

| Risk Category | Description | Likelihood | Impact | Risk score | Risk classification | Remarks |
|---|---|---|---|---|---|---|
| Fire hazard | Improper fuel storage or lack of ventilation in fuel compartments | Rare (1) | Major (5) | 5 | Very Low | Safety and occupational risk managed through marine and fire safety systems |
| Transformer oil leak | Accidental leakage from transformer unit due to seal failure or mechanical damage | Rare (1) | Significant (4) | 4 | Very Low | Managed through bunded containment, periodic inspection, and transformer maintenance protocols |

Overall, the risk profile associated with refrigerant use is considered manageable, provided that proposed mitigation measures are implemented. These findings will be further validated and refined through a detailed site-specific risk assessment to be included in the Operational Environmental Management and Monitoring Plan (OEMMP).

### 12.2.2 Mitigation Measures

To minimise environmental and safety risks, the following mitigation measures will be implemented during the operation phase:

- All underground diesel tanks will be constructed with double-walled designs and equipped with leak detection systems. Above-ground components such as day tanks will also be provided with secondary containment.
- Refuelling will follow strict standard operating procedures, including visual inspections, use of containment trays, and supervision by trained personnel to minimise the risk of spills.
- A site-specific Spill Management Plan will be maintained and regularly reviewed by the facility operator.
- On-site spill kits will be readily available, and personnel will be trained in emergency response procedures and reporting protocols in the event of a release.
- Operational chemicals such as cleaning agents and lubricants will be stored in clearly labelled, bunded areas with impermeable flooring, in compliance with relevant Workplace Safety and Health (WSH) regulations.
- Fuel and generator areas will be equipped with intrinsically safe equipment and fire suppression systems to mitigate fire hazards.
- Cooling water systems will utilise controlled, automated dosing of anti-fouling agent. Real-time monitoring will be implemented to ensure chlorine levels at the outfall remain within acceptable environmental thresholds.

All hazardous material handling during operation will be managed under the site-specific Operational Environmental Management and Monitoring Plan (CEMMP) and a Chemical Management Plan developed by the Developer and reviewed by relevant authorities prior to commencement of works. These documents will outline containment measures, emergency procedures, and compliance requirements.

## 12.3 Assessment of Potential Impact to Marine Ecological Receptors

Accidental spills and leaks of hazardous substances such as diesel fuel, lubricants, cleaning agents, anti-fouling agent, and coolants may occur during both the construction and operational phases of the Floating Data Centre project. These substances, if inadvertently released, may enter the marine environment through direct discharge, stormwater runoff, or leaks from refuelling operations and storage systems on land or at sea.

General environmental impacts from such incidents may include increased concentrations of oil and grease, elevated chemical oxygen demand, changes in water pH, localized depletion of dissolved oxygen, and toxic effects on aquatic life. For the anti-fouling agent impacts, please refer to Section 8. In the event of a large and uncontrolled spill, the environmental consequences could be significantly more severe and would require a separate risk assessment and emergency response plan.

These changes may negatively affect marine water quality and disrupt important ecological functions such as nutrient cycling, primary productivity, and food chain stability. Sensitive ecological receptors including intertidal seagrass beds, mangrove habitats, plankton communities, mobile marine species, and nearby fish farms or water intakes may be exposed depending on their location, the nature of the pollutant, and local tidal movement.

The extent and likelihood of these impacts depend on factors such as the volume and type of chemical released, proximity to sensitive habitats, and whether mitigation measures are effectively implemented. Without proper controls, accidental releases may lead to short-term ecological stress or temporary disturbance of habitats.

The following sections provide an assessment of potential impacts to individual receptors during the construction and operational phases, based on a qualitative review aligned with the RIAM framework.

### 12.3.1 Intertidal Habitats/ Seagrass

During the construction phase, accidental diesel spills may occur during refuelling of marine vessels or machinery near the coastline. If released, diesel can form surface slicks that reduce light penetration and disrupt photosynthesis in intertidal seagrass beds. Even thin oil films have the potential to cause physiological stress and tissue damage to seagrass blades. Without mitigation measures during construction, the likelihood of such impacts is higher. Under a conservative worst-case scenario in which no mitigation is implemented, the magnitude of change/ impact was assessed as a moderate negative change, corresponding to a score of -2 under the RIAM. This results in an overall impact significance classified as a **Minor Negative Change or Minor Negative Impact**. However, these impacts are expected to be short-term, reversible, and localised, particularly given the site's natural tidal flushing and dispersion characteristics. With mitigation measures in place, the risk is substantially reduced. Preventive actions such as bunded fuel storage, supervised refuelling procedures, and the availability of spill kits help prevent and control potential spills. When such controls are effectively implemented, the overall impact significance is reduced to a **Slight Negative Change or Slight Negative Impact**.

In addition, the operation of construction vessels around the on-site berthing jetty introduces additional risk of marine collisions. Manoeuvring errors or equipment failure could lead to vessel collisions with the jetty, or other vessels, resulting in fuel spills. Given the proximity of ecologically sensitive receptors and the increased frequency of marine activity, the unmitigated magnitude of impact is assessed as a **Minor Negative Change or Minor Negative Impact**. Impacts may include acute stress or contamination of seagrass and intertidal habitats if spills occur during high tide or under wind-driven dispersion. However, with mitigation measures such as marine traffic management plans, controlled approach procedures, designated berthing protocols, and emergency spill response kits stationed at the jetty, the impact significance can be reduced to a **Slight Negative Change or Slight Negative Impact**.

During the operational phase, the likelihood of exposure to intertidal seagrass areas is significantly lower. Diesel fuel will be stored in underground, double-walled tanks, and refuelling activities are expected to occur infrequently and under controlled conditions. In addition, the Floating Data Centre will operate with a closed-loop cooling water system, with no chemical or thermal discharges anticipated near intertidal zones. Without mitigation, there remains a potential environmental impact in the event of leaks or operational failure. However, with engineered containment systems, routine operational controls, and strict adherence to environmental compliance procedures, the likelihood of adverse impacts becomes negligible. Therefore, with mitigation measures in place, the overall impact significance during the operational phase is assessed as **Slight Negative Change or Slight Negative Impact**.

### 12.3.2 Mangrove Habitats

During the construction phase, accidental leaks from onshore storage of diesel, lubricants, or other construction-related chemicals could potentially enter nearby mangrove habitats via surface runoff, particularly during heavy rainfall events. While mangrove soils have a natural capacity to retain and degrade hydrocarbons, prolonged or repeated exposure may impair root function, alter soil microbial activity, and hinder seedling establishment. However, the mangrove stands in the vicinity of the project, including those at Pasir Ris Park, are located at a safe distance from active construction zones.

Without mitigation measures, the magnitude of impact is assessed as a minor negative change, corresponding to a RIAM score of -2. However, due to the presence of *Bruguiera hainesii*, a mangrove species listed as Critically Endangered on the IUCN Red List, even minor disturbances may carry elevated ecological importance. As such, the overall impact significance without mitigation is conservatively classified as a **Minor Negative Change or Minor Negative Impact**. However, with proper controls measures are, the overall impact significance is reduced to a **Slight Negative Change or Slight Negative Impact**.

During the operational phase, activities associated with the Floating Data Centre are not expected to pose significant risks to mangrove habitats. All hazardous materials, including diesel for emergency generators and chemical agents used for maintenance, will be stored in sealed, bunded, or underground containment systems. Additionally, marine discharges from the seawater cooling system will occur offshore and are not expected to interact with the mangrove root zone. With these engineered controls in place, and with operational procedures aligned with environmental compliance requirements, the potential for pollutant migration to mangrove areas is considered negligible. Therefore, the overall impact significance during the operational phase is assessed as **Slight Negative Change or Slight Negative Impact** after implementation is in place.

### 12.3.3 Plankton Communities

During the construction phase, accidental spills of diesel or lubricants from marine vessels may temporarily affect phytoplankton and zooplankton communities through toxicity, surface film formation, or localised oxygen depletion. These planktonic organisms form the base of the marine food web and are highly sensitive to chemical disturbances. However, due to the open-water nature of the site and prevailing tidal currents, small-scale spills are expected to disperse rapidly, which reduces both the duration of exposure and the severity of ecological impacts. With mitigation, the impact significance is assessed as a **Slight Negative Change or Slight Negative**. The effects are expected to be short-term and localised, with natural recovery likely once the disturbance subsides.

During the operational phase, accidental fuel leaks from backup generator systems or maintenance-related activities may pose minimal risk to plankton if containment measures fail. However, the likelihood of such incidents is very low due to the use of underground, double-walled fuel tanks, bunded chemical storage areas, and standard operating procedures for hazardous material handling. In the event of a spill, engineered containment systems and emergency response protocols will help prevent any pollutant migration to nearshore plankton habitats. As a result, the impact significance during the operational phase is also assessed as **Slight Negative Change or Slight Negative**.

### 12.3.4 Marine Fauna (Mobile Fish and Invertebrates)

During the construction phase, accidental spills of diesel or other hydrocarbons may pose acute or sub-lethal risks to mobile marine fauna, including fish, prawns, and invertebrates. Potential effects may include gill damage, behavioural avoidance responses, and impaired reproductive success. However, these organisms are highly mobile and are likely to temporarily avoid affected areas, reducing their exposure. With mitigation, the impact. With proper site management practices and timely implementation of spill response measures, the impacts are expected to be short-term, reversible, and localised. Thus, the impact significance to mobile marine fauna during the construction phase was reduced to **Slight Negative Change or Slight Negative Impact**.

During the operational phase, the likelihood of hydrocarbon or chemical leakage is considered very low due to the use of underground, double-walled diesel storage tanks and bunded containment systems. Other potential pollutants, such as lubricants and cleaning agents, will be stored in compliance with applicable hazardous materials regulations. With these preventive measures in place, the impact significance during the operational phase is assessed as **Slight Negative Change or Slight Negative Impact**, with risk effectively controlled through engineering design and standard operating procedures.

### 12.3.5 Caged Fish Farms and Water Intakes

In the event of an accidental spill of oil or chemicals from work barges or activities at the jetty during construction, surface currents may carry contaminants towards nearby fish farms or coastal water intakes. These receptors are highly sensitive to water quality changes and may be affected through reduced dissolved oxygen levels, fish stress, or mortality. While the potential consequence is high, the number of project vessels is limited, and similar risks already exist under normal marine traffic conditions. With the implementation of standard mitigation measures such as fuel handling protocols, and availability of spill response kits, the likelihood of widespread impact is considered low. Therefore, the overall impact significance during the construction phase is assessed as **Slight Negative Change or Slight Negative Impact.**

During the operational phase, fuel-related activities will be minimal, with diesel used only for emergency generators and stored in enclosed, double-walled tanks. The use of chemicals will be confined to cooling, HVAC, and maintenance systems, all of which are contained and monitored. In the unlikely event of a leak, engineered containment systems and emergency response procedures will be activated to prevent pollutant migration toward sensitive receptors such as aquaculture facilities or intake infrastructure. Under this conservative scenario, the magnitude of impact is assessed as a **Slight Negative Change or Slight Negative Impact.**

### 12.3.6 Conclusion

This risk assessment has identified key sources of potential impact during both construction and operational phases and evaluated them in terms of likelihood and severity. Mitigation measures will be developed in alignment with regulatory requirements and industry best practices. These will be implemented through site-specific plans such as the Construction and Operational Environmental Management and Monitoring Plans and the Chemical Management Plan. With these management systems and controls in place, the risks associated with the use of fuel and hazardous chemicals are considered low and manageable.

# 13

## Impacts to Biodiversity

# 13 Impacts to Biodiversity

This Biodiversity Impact Assessment evaluates the potential ecological impacts associated with the proposed development of a Floating Data Centre. It presents an assessment of the potential impacts on marine biodiversity within the study area. The assessment has been conducted in accordance with the NParks Biodiversity Impact Assessment Guidelines (2024) and references the Singapore Red Data Book (2023) and the IUCN Red List of Threatened Species (version 2022-2).

This study integrates findings from ecological baseline surveys and numerical modelling simulations, including assessments of suspended sediment concentration (SSC), sedimentation, thermal and chlorine plume dispersion. A receptor-based evaluation was carried out using the RIAM framework.

The primary objectives of this assessment are to identify ecologically significant receptors, evaluate the nature and magnitude of potential project-induced changes during both construction and operational phases, and recommend appropriate mitigation and monitoring strategies under the EMMP. The assessment adopts a precautionary approach to ensure alignment with applicable EQOs, ETLs, and relevant local regulatory frameworks and international standards.

## 13.1 Baseline Marine Ecological Conditions

Ecological baseline surveys were conducted starting in Oct 2024, following established methodologies consistent with the BIA Guidelines issued by NParks. The surveys covered intertidal habitats, mangroves, soft-bottom macrobenthos, and planktonic assemblages to establish existing ecological conditions and assess environmental sensitivity within the study area.

Intertidal surveys conducted along four transects (IT1 to IT4) recorded the presence of the pioneer seagrass species Halophila ovalis. Seagrass cover was sparse at IT1 and IT2 (<3%), but relatively high at IT3 (39.7%) and IT4 (30.9%). Transect IT1, which exhibited the lowest cover, was located closest to the proposed project footprint. Although the surveyed area supports only a single seagrass species and no rare or nationally threatened taxa were identified, the habitat contributes to local ecological heterogeneity and may function as a foraging ground for juvenile fish and benthic invertebrates. No critically endangered or nationally threatened seagrass species were recorded.

Fringe mangrove stands were surveyed approximately 1.5 to 2.0 km from the project site, near Sungei Loyang and Pasir Ris Park. Within the established transects, the mangrove community was dominated by *Avicennia alba, Rhizophora apiculata, Rhizophora mucronata,* and *Bruguiera cylindrica*, all of which are classified as Least Concern under the Singapore Red Data Book (2023). These mangrove species play important ecological roles in shoreline stabilisation, nutrient cycling, and providing nursery habitat for juvenile fish and invertebrates. No significant signs of habitat degradation were observed during the field survey

Soft-bottom macrobenthic surveys conducted at three stations revealed communities dominated by brittle stars (*Ophiuroidea*), with lower densities of bivalves, hermit crabs, and polychaete. Sediment analysis indicated a predominantly silty clay composition with low total organic carbon (TOC) concentrations, ranging from 1.33 to 1.48 mg/L.

Phytoplankton and zooplankton assessments indicated ecologically stable, non-eutrophic conditions across all surveyed stations. The phytoplankton community was dominated by marine diatoms, particularly *Chaetoceros* and *Skeletonema* species, with overall cell densities remaining low. The zooplankton assemblage was primarily composed of copepods, including *Euterpina*, and *Oithona* species, reflecting a typical trophic structure for coastal waters in the region.

## 13.2 Impacts Pathway and Modelling Results

Multiple potential impact pathways were evaluated through site-specific numerical simulations. These included hydrodynamic modelling, sediment plumes, sedimentation accumulation, and the dispersion of thermal and chlorinated from the proposed seawater cooling outfall. All simulations were conducted under Northeast, Southwest, and Inter-monsoon conditions to account for seasonal variability.

- **Suspended Sediment Concentration**: The key concern for this pathway was increased suspended sediment arising from dredging and activities. SSC plume modelling showed that concentrations were restricted to the immediate vicinity of the dredging footprint. Beyond this localised zone, sediment concentrations declined rapidly and remained below ecologically relevant thresholds at all sensitive receptors.
- **Sedimentation**: Sedimentation from marine activities was assessed for its potential to cause smothering of benthic fauna and intertidal seagrass. Modelled sedimentation rates at all ecological receptors were very low, with maximum accumulation predicted to be no more than 0.5 mm over a 14-day period (equivalent to ~0.036 mm/day). These levels fall significantly below recognised burial thresholds and are considered negligible. No sedimentation-related impacts are anticipated.
- **Thermal Discharge**: Thermal discharge from the seawater cooling system has the potential to elevate ambient seawater temperatures near the outfall and pose stress to thermally sensitive marine biota. Modelling results indicated that excess temperatures at ecological receptors, remained within established thermal tolerance ranges. No thermally induced impacts are anticipated at these locations under any of the simulated monsoonal conditions.
- **Chlorine Discharge**: Chlorine used for biofouling control in the cooling system was evaluated for its potential toxicological effects on marine organisms. Chlorine plume modelling indicated that concentrations beyond the designated 100 m mixing zone were effectively diluted and remained below the adopted assessment threshold of 0.012 mg/L at ecological sensitive locations.

Collectively, the modelling results suggest a low potential for widespread or long-term ecological impacts arising from project-related changes in water quality during both the construction and operational phases. All predicted changes remained within the range of environmental thresholds considered protective of marine ecological receptors.

## 13.3 Assessment of Impacts

This section presents an assessment of the potential ecological impacts of the proposed Floating Data Centre on key marine biodiversity receptors during both construction and operational phases. The assessment draws upon results from site-specific numerical modelling, ecological surveys, and application of the RIAM methodology.

Overall, the project is not expected to result in significant or irreversible ecological effects. Modelling indicates that key environmental parameters such as suspended sediment concentration (SSC), sedimentation, thermal discharge, and residual chlorine remain within conservative ecological thresholds at all identified receptor locations.

### 13.3.1 Intertidal Habitat/ Seagrass

During construction, intertidal and seagrass-associated fauna may be exposed to short-term increases in SSC and sedimentation. These changes have the potential to result in smothering, reduced photosynthesis, or respiratory stress for sensitive benthic organisms such as sponges, crustaceans, gastropods, and juvenile fish.

Model results showed that SSC did not exceed 5 mg/L for more than 20% of the time, and the sediment plume remained spatially confined within the project footprint. Sedimentation at sensitive receptors such as seagrass habitats was predicted to be no more than 0.5 mm over 14 days. These levels are below the adopted ETLs for seagrass and do not pose a risk of significant adverse effects. Therefore, no impact is predicted from suspended solids and sedimentation. As such, the impact significance, based on the RIAM assessment, is classified as **No Impact or No Change** for construction

In addition to sediment-related stressors, diesel spills from vessel refuelling or collisions near the berthing jetty pose a potential risk during construction. Diesel slicks may reduce light penetration and affect photosynthesis. Without mitigation, such incidents could result in moderate negative impacts. However, with bunded storage, controlled refuelling procedures, and emergency spill response measures in place, the residual impact significance is assessed as **Slight Negative Impact or Slight Negative Change**, provided the mitigation and preventive measures are followed.

During operation, intertidal and seagrass-associated fauna may be exposed to changes in seawater quality due to the discharge of heated and chlorinated seawater from the cooling system. Based on model results, the thermal plume was largely confined within the project area. No exceedance of 0.5°C occurred for more than 5% of the time, and no exceedance of 1.0°C occurred at any time within intertidal zones. These results indicate that temperature elevations remain well within the ecological tolerance range for seagrass and associated fauna. For residual chlorine, no Singapore-specific ecotoxicity limits currently exist. As such, a conservative threshold of 0.012 mg/L was adopted based on Australia's marine water protection guidelines. Modelling showed that chlorine concentrations at intertidal and seagrass habitats remained below this threshold at all times. Furthermore, chlorine introduced into seawater is known to degrade rapidly due to natural reactions with organic matter and other seawater constituents. This breakdown process is further accelerated by the elevated temperature of the discharge, reducing the persistence and spatial extent of the chlorine plume. Based on these findings, no adverse impacts are predicted for intertidal habitats or seagrass arising from thermal or chlorine discharges during the operational phase. As such, the impact significance, based on the RIAM assessment, is classified as **No Impact or No Change** for construction.

During the operational phase, all fuel and chemicals will be stored in sealed, bunded, or underground systems, and marine discharges are not expected to affect intertidal zones. Therefore, the overall impact significance during the operational phase is assessed as **Slight Negative Impact or Slight Negative Change**, assuming proper mitigation measures are in place.

### 13.3.2 Mangrove Communities

Mangrove areas located along the adjacent shoreline were spatially separated from the proposed works, and no encroachment or vegetation clearance was planned. Sediment deposition and changes in water quality were predicted to be **No Impact or No Change** based on modelling results. Thermal and chlorine discharges from the seawater cooling system were not expected to reach the mangrove zones at concentrations of ecological concern. As such, the impact significance, based on the RIAM assessment, is classified as **No Impact or No Change** for both the construction and operational phases.

However, during construction, accidental leaks may impair root and microbial function. With mitigation measures in place, such as bunded storage and chemical handling zones, the overall impact is assessed as slight negative. During the operational phase, all fuel and chemicals will be stored in sealed, bunded, or underground systems, and marine discharges are not expected to affect mangrove zones. RIAM assessment, is classified as **Slight Negative Impact or Slight Negative Change.**

### 13.3.3 Soft-bottom Macrobenthic Communities

During construction, soft-bottom macrobenthic communities are expected to be directly impacted by seabed disturbance from dredging and piling works. These activities will result in the removal of benthic habitat and the loss of organisms within the project footprint. The affected communities comprise polychaetes, brittle stars (Ophiuroidea), amphipods, and bivalves. While some species are motile, they are unlikely to avoid disturbance. However, the broader benthic population is not expected to be significantly affected, and recolonisation is anticipated in adjacent undisturbed areas. No rare or conservation-listed taxa were recorded during baseline surveys. As such, the impact significance, based on the RIAM assessment, is classified as **Slight Negative Impact or Slight Negative Change** for the construction phases.

Spills of diesel or lubricants during construction could lead to localised seabed contamination. However, the mobility of these contaminants is limited in sediment, and tidal dispersion is expected to prevent significant accumulation. With proper mitigation measures in place, such as spill control kits and rapid response protocols, the residual impact is expected to be short-term, localised, and reversible. Therefore, the overall impact significance is classified as **Slight Negative Impact or Slight Negative Change**.

During the operational phase, macrobenthic communities are generally tolerant of natural temperature fluctuations in coastal sediments. Thermal plume modelling showed that excess temperatures at the seabed remained at or below 0.5°C, with the heated water confined near the surface. As benthic organisms reside within or close to the seabed, direct thermal exposure is expected to be limited. While significant biological stress is not anticipated, minor localised effects cannot be fully ruled out. With regard to residual chlorine, concentrations are expected to degrade rapidly in seawater through natural reactions with organic matter, particularly under dynamic tidal conditions. Modelling results indicate that chlorine is unlikely to persist or accumulate at the seabed at levels of concern, although minor exposure to low concentrations within the mixing zone may occur.

In addition, the risk of hydrocarbon or chemical leaks during the operational phase is considered minimal, as all fuels and hazardous materials will be stored in underground, double-walled diesel tanks or within bunded chemical storage areas. Operational activities will be governed by standard operating procedures and emergency response protocols designed to prevent and contain any accidental releases. With these engineered containment and prevention measures effectively implemented, the likelihood of pollutant exposure to macrobenthic habitats is very low. Therefore, the overall impact significance during the operational phase is assessed as **Slight Negative Impact or Slight Negative Change**, assuming proper mitigation measures are in place.

### 13.3.4 Plankton Assemblages

During construction, plankton may have been exposed to short-term increases in turbidity due to dredging and piling activities. Elevated suspended sediment concentrations could have reduced light penetration, potentially affecting phytoplankton photosynthesis and zooplankton foraging success. However, model results indicated that suspended sediment levels remained spatially confined within the project footprint and stayed below ecologically significant thresholds. Given the short duration of works and the natural resilience of the receptors, no persistent impacts were expected. As such, the impact significance, based on the RIAM assessment, is classified as **No Change or No Impact** for the construction phases.

In addition, accidental diesel spills could temporarily affect plankton through the formation of surface films, light attenuation, and localised oxygen depletion. These effects are expected to be short-lived and reversible due to the natural flushing capacity of the area. With the implementation of appropriate mitigation measures such as containment kits, supervised refuelling procedures, and emergency spill response protocols, the likelihood of significant ecological disruption is substantially reduced. As such, although planktonic communities are highly sensitive to water quality changes, the effectiveness of these mitigation measures is expected to prevent adverse impacts. Therefore, the overall impact significance to plankton during the construction phase is **Slight Negative Impact or Slight Negative Change**, provided the mitigation and preventive measures are followed.

During the operational phase, plankton and fish may have been continuously exposed to residual heat and chlorine from the seawater cooling system. Modelling results showed that temperature elevations in the receiving waters remained below 0.5°C above ambient and were largely confined to surface waters near the outfall. Similarly, although chlorine concentrations were highest at the point of discharge, they were predicted to degrade rapidly through natural reactions with organic matter and to dissipate effectively under the influence of local tidal mixing. The ecological thresholds adopted for this assessment were a temperature increase of 0.5°C and a chlorine concentration of 0.012 mg/L. These thresholds were selected based on internationally recognised literature and regulatory guidance, in consultation with the relevant technical agencies. They were intended to be protective of sensitive marine organisms. As modelled concentrations at ecological receptor locations consistently remained below these thresholds, the predicted exposure levels were considered to fall within an ecologically acceptable range. No significant physiological or behavioural effects were anticipated in plankton or fish populations under the expected discharge conditions. As such, the impact significance, based on the RIAM assessment, is classified as **No Change or No Impact** for the operational phases.

The risk of accidental fuel or chemical leaks during operations is considered minimal due to the presence of underground, double-walled storage tanks, bunded containment systems, and strict operational procedures. The risk of spills and leaks impacts to planktonic assemblages are assessed as having a **Slight Negative Impact or Slight Negative Change**, provided the mitigation and preventive measures are followed.

### 13.3.5 Marine Fauna (Fish, Turtles, Dugongs)

During the construction phase, pile driving activities may have generated impulsive underwater noise with peak sound pressure levels typically ranging from 180 to 220 dB re 1 μPa at 1 m. These sound levels overlapped with the auditory sensitivity ranges of various marine fauna, including cetaceans and soniferous fish, and had the potential to induce behavioural responses or temporary hearing threshold shifts. However, the project was located in a highly industrialised coastal area where ambient underwater noise was already elevated due to ongoing maritime operations. The piling works were short in duration and spatially confined, which further limited their impact. Mitigation measures such as the use of soft-start procedures and low-noise piling methods were incorporated to reduce potential acoustic risks. Nonetheless, the residual impact significance is assessed as **No Change or No Impact** during construction.

Hydrocarbon spills may also pose short-term risks to mobile marine fauna, including fish and invertebrates, through mechanisms such as gill damage, physiological stress, or behavioural avoidance. However, most mobile species are likely to avoid impacted areas. With spill prevention measures in place including bunded storage, supervised fuelling, and emergency response protocols, the likelihood of exposure is reduced, and any residual impact is expected to be localised and reversible. As such, the impact significance from potential hydrocarbon exposure is assessed as **Slight Negative Impact or Slight Negative Change**, provided the mitigation and preventive measures are followed.

During the operational phase, underwater noise was generated by cooling water pumps enclosed within the floating structure. These systems emitted continuous, low-frequency, non-impulsive noise primarily between 50 and 150 hertz. The design included vibration isolation systems and a double-hull configuration to attenuate acoustic emissions. Modelled sound pressure levels were predicted to remain below 125 dB re 1 μPa at 1 metre and fell below 100 dB re 1 μPa within 10 to 20 metres of the source. These levels were unlikely to induce behavioural disturbances or physiological effects in marine mammals or fish, particularly in the context of an already elevated ambient noise environment. Thus, tthe residual impact significance is assessed as **No Change or No Impact**.

In addition, the ecological thresholds adopted for this assessment were a temperature increase of 0.5°C and a chlorine concentration of 0.012 mg/L. These thresholds were selected based on internationally recognised literature and regulatory guidance, in consultation with the relevant technical agencies. They were intended to be protective of sensitive marine organisms. Based on the model results, the impacts are classified as **No Change or No Impact**. For accidental leaks and spills, the risk of significant chemical impacts to sensitive marine species was considered low due to the implementation of engineered containment systems and operational controls. Based on the RIAM assessment, and assuming effective mitigation, the overall impact significance is assessed as **Slight Negative Impact or Slight Negative Change**.

## 13.4 Mitigation Measures

To safeguard marine biodiversity, a suite of mitigation measures will be implemented during both the construction and operational phases of the project. These include the deployment of silt curtains during dredging works to contain sediment plumes, as well as the enforcement of spill budget controls to minimise the risk of accidental releases. Regular water quality monitoring will be carried out to ensure compliance with established EQOs and regulatory thresholds.

For operational discharges, the seawater cooling system will incorporate flow regulation and temperature control mechanisms. Chlorine dosing will be optimised to minimise residual concentrations at the point of discharge. In addition, periodic ecological surveys will be conducted during the operational phase to support long-term biodiversity protection.

EMMP will be developed to guide the implementation of mitigation and monitoring measures. The EMMP framework presented in this EIA is recommended at the assessment stage. A project-specific Construction and Operational EMMP will be further refined and submitted for review in consultation with the relevant Technical Agencies prior to implementation.

# 14

## RIAM Impact Significance Summary

# 14 RIAM Impact Significance Summary

Table 14-1 outlines the significant impacts identified during both the construction and post-construction phases, along with their respective mitigation measures. Details of the RIAM assessment criteria used for evaluating these impacts are provided in Section 4.4.

**Table 14-1: Impact Summary**

| Impacts on receptor | Predicted Impacts | | | | | | | Impacts | Mitigation measures | Residual impacts after mitigation measures |
|---|---|---|---|---|---|---|---|---|---|---|
| | Potential impact | ES | I | M | P | R | C | | | |
| **Construction Phase** | | | | | | | | | | |
| ***Ecological*** | | | | | | | | | | |
| Seagrass and intertidal habitats | SSC | 0 | 3 | 0 | 2 | 2 | 2 | No change/ no impact | Full Feedback EMMP with spill budget, compliance monitoring, habitat monitoring, and deployment of silt screen if required | - |
| | Sedimentation | 0 | 3 | 0 | 2 | 2 | 2 | No change/ no impact | | - |
| | Accidental spills and leaks | -42 | 3 | -2 | 2 | 2 | 3 | Minor negative change/ minor negative impact | Implement safe practices and bunded fuel storage to minimise oil spill risks. Ensure emergency response kits are on standby at strategic locations and enforce marine traffic controls with designated vessel approach protocols. Spill kits should be readily available at all high-risk areas, including the berthing jetty. | Slight negative change/ slight negative impact |
| Mangroves habitats | SSC | 0 | 4 | 0 | 2 | 2 | 2 | No change/ no impact | Full Feedback EMMP with spill budget, compliance monitoring, habitat monitoring, and deployment of silt screen if required | - |
| | Sedimentation | 0 | 4 | 0 | 2 | 2 | 2 | No change/ no impact | | - |

| Impacts on receptor | Predicted Impacts | | | | | | | Impacts | Mitigation measures | Residual impacts after mitigation measures |
|---|---|---|---|---|---|---|---|---|---|---|
| | Potential impact | ES | I | M | P | R | C | | | |
| | Accidental spills and leaks | -56 | 4 | -2 | 2 | 2 | 3 | Minor negative change/ minor negative impact | Implement safe practices and bunded fuel storage to minimise oil spill risks. Ensure emergency response kits are on standby at strategic locations and enforce marine traffic controls with designated vessel approach protocols. Spill kits should be readily available at all high-risk areas, including the berthing jetty. | Slight negative change/ slight negative impact |
| Soft bottom macrobenthos | Direct impact | -14 | 1 | -2 | 3 | 3 | 1 | Slight negative change/ slight negative impact | Assessment at pre-construction | None required. No species of concern were found, and the macroinvertebrate is likely to repopulate after construction. |
| | Accidental spills and leaks | -7 | 1 | -1 | 2 | 2 | 3 | Slight negative change/ slight negative impact | Implement safe practices and bunded fuel storage to minimise oil spill risks. Ensure emergency response kits are on standby at strategic locations and enforce marine traffic controls with designated vessel approach protocols. Spill kits should be readily available at all high-risk areas, including the berthing jetty. | Slight negative change/ slight negative impact |
| Fish | SSC | 0 | 1 | 0 | 2 | 2 | 1 | No change/ no impact | Full Feedback EMMP with spill budget, compliance monitoring, and deployment of silt screen if required. | - |

| Impacts on receptor | Predicted Impacts | | | | | | | Impacts | Mitigation measures | Residual impacts after mitigation measures |
|---|---|---|---|---|---|---|---|---|---|---|
| | Potential impact | ES | I | M | P | R | C | | | |
| | Accidental spills and leaks | -7 | 1 | -1 | 2 | 2 | 3 | Slight negative change/ slight negative impact | Implement safe practices and bunded fuel storage to minimise oil spill risks. Ensure emergency response kits are on standby at strategic locations and enforce marine traffic controls with designated vessel approach protocols. Spill kits should be readily available at all high-risk areas, including the berthing jetty. | Slight negative change/ slight negative impact |
| | Underwater noise | 0 | 1 | 0 | 2 | 2 | 2 | No change/ no impact | Use soft-start piling procedures and low-noise piling equipment, as well as implement marine fauna observation es prior to piling. | - |
| Plankton | SSC | 0 | 1 | 0 | 2 | 2 | 1 | No change/ no impact | Full Feedback EMMP with spill budget, compliance monitoring, and deployment of silt screen if required. | - |
| | Accidental spills and leaks | -7 | 1 | -1 | 2 | 2 | 3 | Slight negative change/ slight negative impact | Implement safe practices and bunded fuel storage to minimise oil spill risks. Ensure emergency response kits are on standby at strategic locations and enforce marine traffic controls with designated vessel approach protocols. Spill kits should be readily available at all high-risk areas, including the berthing jetty. | Slight negative change/ slight negative impact |
| ***Recreational*** | | | | | | | | | | |
| Recreational activities | SSC impact | 0 | 1 | 0 | 2 | 2 | 1 | No change/ no impact | Full Feedback EMMP with spill budget, compliance monitoring, and deployment of silt screen if required | - |
| ***Socio-economic*** | | | | | | | | | | |

| Impacts on receptor | Predicted Impacts | | | | | | | Impacts | Mitigation measures | Residual impacts after mitigation measures |
|---|---|---|---|---|---|---|---|---|---|---|
| | Potential impact | ES | I | M | P | R | C | | | |
| Marine intake | SSC impact | 0 | 2 | 0 | 2 | 2 | 1 | No change/ no impact | Full Feedback EMMP with spill budget, compliance monitoring, and deployment of silt screen if required | - |
| | Accidental spills and leaks | -12 | 2 | -1 | 2 | 2 | 2 | Slight negative change/ slight negative impact | Implement safe practices and bunded fuel storage to minimise oil spill risks. Ensure emergency response kits are on standby at strategic locations and enforce marine traffic controls with designated vessel approach protocols. Spill kits should be readily available at all high-risk areas, including the berthing jetty. | Slight negative change/ slight negative impact |
| Cross-border | SSC impact | 0 | 5 | 0 | 2 | 2 | 1 | No change/ no impact | Full Feedback EMMP with spill budget, compliance monitoring, and deployment of silt screen if required. | - |
| | Accidental spills and leaks | 0 | 5 | 0 | 2 | 2 | 3 | No change/ no impact | Implement safe practices and bunded fuel storage to minimise oil spill risks. Ensure emergency response kits are on standby at strategic locations and enforce marine traffic controls with designated vessel approach protocols. Spill kits should be readily available at all high-risk areas, including the berthing jetty. | - |
| Aquaculture facilities | SSC impact | 0 | 4 | 0 | 2 | 2 | 1 | No change/ no impact | Full Feedback EMMP with spill budget, compliance monitoring, habitat monitoring, and deployment of silt screen if required | - |
| | Sedimentation | 0 | 4 | 0 | 2 | 2 | 1 | No change/ no impact | | - |

| Impacts on receptor | Predicted Impacts | | | | | | | Impacts | Mitigation measures | Residual impacts after mitigation measures |
|---|---|---|---|---|---|---|---|---|---|---|
| | Potential impact | ES | I | M | P | R | C | | | |
| | Accidental spills and leaks | -24 | 4 | -1 | 2 | 2 | 2 | Slight negative change/ slight negative impact | Implement safe practices and bunded fuel storage to minimise oil spill risks. Ensure emergency response kits are on standby at strategic locations and enforce marine traffic controls with designated vessel approach protocols. Spill kits should be readily available at all high-risk areas, including the berthing jetty. | Slight negative change/ slight negative impact |
| | Underwater noise | 0 | 4 | 0 | 2 | 2 | 2 | No change/ no impact | Use soft-start piling procedures and low-noise piling equipment, as well as implement marine fauna observation es prior to piling. | - |
| **Operation** | | | | | | | | | | |
| ***Ecological*** | | | | | | | | | | |
| Seagrass and intertidal habitats | Thermal stress | 0 | 3 | 0 | 3 | 2 | 1 | No change/ no impact | • Continuous online monitoring system throughout project duration<br>• Regular biodiversity monitoring | - |
| | Chlorine stress | 0 | 3 | 0 | 3 | 2 | 1 | No change/ no impact | | - |
| | Accidental spills and leaks | -18 | 3 | -1 | 2 | 2 | 2 | Slight negative change/ slight negative impact | Store diesel in underground or double-walled tanks with bunded containment. Maintain emergency spill response kits at high-risk areas. Implement spill response SOPs and ensure staff are trained in emergency procedures. | Slight negative change/ slight negative impact |
| Mangroves habitats | Thermal stress | 0 | 4 | 0 | 3 | 2 | 1 | No change/ no impact | • Continuous online monitoring system throughout project duration<br>• Regular biodiversity monitoring | - |
| | Chlorine stress | 0 | 4 | 0 | 3 | 2 | 1 | No change/ no impact | | - |

| Impacts on receptor | Predicted Impacts | | | | | | | Impacts | Mitigation measures | Residual impacts after mitigation measures |
|---|---|---|---|---|---|---|---|---|---|---|
| | Potential impact | ES | I | M | P | R | C | | | |
| | Accidental Spills and Leaks | -24 | 4 | -1 | 2 | 2 | 2 | Slight negative change/ slight negative impact | Store diesel in underground or double-walled tanks with bunded containment. Maintain emergency spill response kits at high-risk areas. Implement spill response SOPs and ensure staff are trained in emergency procedures. | Slight negative change/ slight negative impact |
| Soft bottom macrobenthos | Direct impact (thermal stress) | 0 | 1 | 0 | 3 | 3 | 1 | No change/ no impact | • Assessment at initial operation<br>• Continuous online monitoring system throughout project duration | - |
| | Direct impact (chlorine stress) | 0 | 1 | 0 | 3 | 3 | 1 | No change/ no impact | | - |
| | Accidental Spills and Leaks | -7 | 1 | -1 | 2 | 2 | 3 | Slight negative change/ slight negative impact | Store diesel in underground or double-walled tanks with bunded containment. Maintain emergency spill response kits at high-risk areas. Implement spill response SOPs and ensure staff are trained in emergency procedures. | Slight negative change/ slight negative impact |
| Fish | Accidental spills and leaks | -7 | 1 | -1 | 2 | 2 | 3 | Slight negative change/ slight negative impact | Store diesel in underground or double-walled tanks with bunded containment. Maintain emergency spill response kits at high-risk areas. Implement spill response SOPs and ensure staff are trained in emergency procedures. | Slight negative change/ slight negative impact |
| | Underwater noise | 0 | 1 | 0 | 2 | 2 | 2 | No change/ no impact | Enclose noise-generating equipment (e.g. pumps) within the floating structure. Use vibration isolation mounts and double-hull design to reduce sound transmission. Ensure regular maintenance to minimise mechanical noise | - |

| Impacts on receptor | Predicted Impacts | | | | | | | Impacts | Mitigation measures | Residual impacts after mitigation measures |
|---|---|---|---|---|---|---|---|---|---|---|
| | Potential impact | ES | I | M | P | R | C | | | |
| Plankton | Accidental Spills and Leaks | -7 | 1 | -1 | 2 | 2 | 3 | Slight negative change/ slight negative impact | Store diesel in underground or double-walled tanks with bunded containment. Maintain emergency spill response kits at high-risk areas. Implement spill response SOPs and ensure staff are trained in emergency procedures. | Slight negative change/ slight negative impact |
| ***Socio-economic*** | | | | | | | | | | |
| Aquaculture facilities | Thermal stress | 0 | 4 | 0 | 3 | 3 | 1 | No change/ no impact | Continuous online monitoring system throughout project duration | - |
| | Chlorine stress | 0 | 4 | 0 | 3 | 3 | 1 | No change/ no impact | | - |
| | Accidental Spills and Leaks | -24 | 4 | -1 | 2 | 2 | 2 | Slight negative change/ slight negative impact | Store diesel in underground or double-walled tanks with bunded containment. Maintain emergency spill response kits at high-risk areas. Implement spill response SOPs and ensure staff are trained in emergency procedures. | Slight negative change/ slight negative impact |
| | Underwater noise | 0 | 4 | 0 | 2 | 2 | 2 | No change/ no impact | Enclose noise-generating equipment (e.g. pumps) within the floating structure. Use vibration isolation mounts and double-hull design to reduce sound transmission. Ensure regular maintenance to minimise mechanical noise | - |
| Marine infrastructure and navigation | Sedimentation | 0 | 1 | 0 | 2 | 2 | 1 | No change/ no impact | Mitigation at engineering design phase due to local scouring at the FDCM base. | - |
| | Current | -5 | 1 | -1 | 2 | 2 | 1 | No change/ no impact | | Mitigation at engineering design phase |

| Impacts on receptor | Predicted Impacts | | | | | | | Impacts | Mitigation measures | Residual impacts after mitigation measures |
|---|---|---|---|---|---|---|---|---|---|---|
| | Potential impact | ES | I | M | P | R | C | | | |
| Human receptor | Air quality | -112 | 4 | -4 | 2 | 2 | 3 | Moderate negative change/ moderate negative impact | Recommended to extend the exhaust flues to 35.8 m SHD, which meets the requirement of at least 3 m above the highest building within 100 m radius | Slight negative change/ slight negative impact |
| Human receptor | Noise Quality | 0 | 4 | 0 | 1 | 1 | 3 | No change/ no impact | Recommended to carry out the manufacturer-required maintenance and readiness testing of the emergency standby gensets during the day (between 9am and 6pm) to avoid noise impacts to the surrounding environment during the evening or night-time. | - |
| Cross-border | Accidental spills and leaks | 0 | 5 | 0 | 2 | 2 | 3 | No change/ no impact | Store diesel in underground or double-walled tanks with bunded containment. Maintain emergency spill response kits at high-risk areas. Implement spill response SOPs and ensure staff are trained in emergency procedures. | - |

# 15

# Environmental Management Framework

# 15 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.
- 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.

## 15.1 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 have been tailored to the nature and sensitivity of the proposed development. The monitoring components and mitigation actions outlined are provided as recommendations to guide the environmental management framework. It should be noted that the developer will be required to prepare a separate, project-specific EMMP incorporating detailed construction methodologies, operational considerations, and implementation timelines. This standalone EMMP should be developed in consultation with the relevant Technical Agencies and submitted for their review and concurrence prior to the commencement of works. The proposed mitigation measures in this EIA may be further refined or expanded during that process in accordance with agency feedback and finalised design and construction plans.

**Table 15-1: EMMP application**

| Impacts | Applied during | |
|---|---|---|
| | Construction Phase | Operational Phase |
| Water Quality (ECM) | ✓ | X |
| Water Quality (Spill budget) | ✓ | X |
| Water Quality (Marine water) | ✓ | ✓ |
| Air Quality | ✓ | ✓ |
| Noise Quality | ✓ | ✓ |
| Waste | ✓ | ✓ |
| Biodiversity | ✓ | ✓ |

| Impacts | Applied during | |
|---|---|---|
| | Construction Phase | Operational Phase |
| Vector control | ✓ | ✓ |

## 15.2 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 15-2: 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<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<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 |
| EMMP Consultant | • The EMMP Consultant is responsible for implementing the necessary monitoring and mitigation measures pertaining to the environment and biodiversity; as per the recommendations from the EIA | Relevant track records |

## 15.3 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. 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 15-3 provides recommendations on the types of monitoring that should be implemented, but this is not necessarily an exhaustive list.

**Table 15-3: 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 walks 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 | • Two (2) 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>• 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.<br>• Carry out ECM audit check | • 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 |
|---|---|---|---|---|---|---|---|---|
| | • 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 minimise 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 minimise 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 |
| Deterioration of marine water quality due to dredging works | • Turbidity measurement across the water profile to obtain a depth averaged value, along with daily plume photography.<br>• 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. | • Turbidity probe<br>• Measurement to be undertaken when the dredging operations occur during daylight (0700h to 1900h). | • Physical monitoring | • Three (3) locations. | Compliance to the turbidity limits not exceeding 20 NTU | • Daily throughout the dredging operation | • 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 |
|---|---|---|---|---|---|---|---|---|
| | • Secchi disc depth monitoring during daylight operations for dredging operation.<br>• If exceeding the compliance limit, the Contractor is to notify the Developer and correlate with the daily turbidity measurement and plume photography. | • Secchi disc depth monitoring to be carried when the dredging operations occur during daylight (0700h to 1900h) | • Physical monitoring | • Three (3) locations. | • The secchi disc measurement not below 0.5 m for non-recreational areas and not below 1.2 m for recreational areas. | • Daily throughout the dredging operation | • Secchi depth records | • Contractor<br>• ECO |
| | • Spill budget monitoring.<br>*Note: The EMMP Consultant shall validate the model assumptions used in the sediment plume dispersion model as presented in Appendix G, specifically the spill rate of equipment. Verification of the spill rate is a one-time process.*<br>• Modelling assumes a 14-day dredging period covering spring–neap tidal cycles. If works extend beyond 14 days with the same daily production rate, plume intensity and footprint remain valid. Remodelling is only required if daily volume increases or method changes. However, If the Contractor exceeds the proposed daily volume, they must notify the Developer and take corrective action. Should the Contractor's method fail to comply with the spill budget, it shall be refined until compliance is achieved. | • Compliance check between the actual daily dredged volume and forecasted production volume. | • Compliance monitoring | • During dredging operation | • The production volume not exceeding daily average production rate 643 m³ per day or maximum daily production rate of 1,000 m³ per day.<br>• The dredging works are assumed to be carried out using one (1) grab dredger (dredger bucket size between 8 m³ and 10 m³). A re-assessment is required in the event there is a significant change to the production rate, grab bucket size, or dredging hours. | • Daily throughout the dredging operation | • Dredging production volume records. | • Contractor<br>• ECO |
| | • Deployment of silt curtain. | • Visual inspection and compliance check. | • On-site visual and compliance monitoring | • Perimeter of the dredging operation | • Visual inspection to monitor the integrity of silt curtain. | • Daily throughout the dredging operation | • Inspection records | • Contractor |
| **Air quality** | | | | | | | | |

| Impact | Monitoring Measures/ Plan | Monitoring Method/ verification method | Technique | Location | Standards/ criteria | Time/ Duration/ Frequency | Reporting | Implementation |
|---|---|---|---|---|---|---|---|---|
| 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.<br>• Ambient air quality monitoring. If exceeding the compliance limit, a review of suppression techniques and construction plan are required, and additional measures shall be put in place to alleviate elevated dust levels.<br>• Stabilisation of stockpiles and exposed surfaces using tarpaulins, hydroseeding, or dust suppressants | • Visual inspection and compliance check | • On-site visual and compliance monitoring<br>• One (1) monitoring station | • Project site | • No visible exhaust plume, and dark smoke<br>• Vehicular/ machinery smoke emissions<br>• Compliance to the Singapore Ambient Air Quality Targets for $SO_2$, $PM_{10}$, $PM_{2.5}$, $NO_2$, $O_3$, and CO. | • During construction phase | • Inspection record | • Contractor<br>• ECO |
| **Biodiversity** | | | | | | | | |
| General | • Biodiversity Awareness Trainings and Toolbox Briefings | • On-site training | • On-site visual and compliance monitoring | • Project site | - | • Every 6 months | • Attendance sheet | • EMMP Consultant |
| | • Enactment of Fauna Response and Rescue Plan<br>• Recordkeeping of wildlife incidents (i.e., Wildlife Incident Form and Register) | | | | - | • When necessitated | • Wildlife Incident Form / Report | • Contractor<br>• ECO<br>• EMMP Consultant |
| Seagrass | • Pre and post intertidal seagrass habitat surveys | • Visual surveys, transect-based sampling, and habitat mapping | • Quadrat sampling method in accordance with NParks' Biodiversity Impact Assessment (BIA) guidelines | • Seagrass areas, particularly in areas identified during the baseline survey. | • Comparison pre and post seagrass habitat results | • Before construction and after completion construction works | • Survey report | • Contractor<br>• EMMP Consultant |
| Mangroves | • Pre and post mangrove habitat surveys | • Visual surveys, transect-based sampling, and habitat mapping | • Transect line plot method | • Mangrove area, particularly in areas identified during the baseline survey. | • Comparison pre and post mangrove results | • Before construction and after completion construction works | • Survey report | • Contractor<br>• EMMP Consultant |
| | • Pre and post mangrove fauna surveys (i.e., birds, herpetofauna & mammals) | • Visual surveys | • Ad-hoc | | | | | |

| Impact | Monitoring Measures/ Plan | Monitoring Method/ verification method | Technique | Location | Standards/ criteria | Time/ Duration/ Frequency | Reporting | Implementation |
|---|---|---|---|---|---|---|---|---|
| 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 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 |
| Marine fauna | Soft start (ramp-up procedure) to gradually increase sound pressure levels to allow marine fauna to vacate the area. | • Visual observation by trained Marine Mammal Observers (MMOs) before and during activity | • On-site visual and compliance monitoring | • Construction work zone (within safety radius) | • No disturbance to marine fauna | • Prior to and during piling or other impulsive noise-generating works | • Inspection records | • Contractor<br>• ECO |
| Avifauna | Low colour temperature lighting and reduced blue light output were adopted where practicable. | • Periodic inspection of light shielding and orientation | • Adjusted lighting | • Project site | • NParks' bird-safe building guidelines (2024), where applicable | • Throughout construction operation | • Inspection 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 |
| 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 |

| Impact | Monitoring Measures/ Plan | Monitoring Method/ verification method | Technique | Location | Standards/ criteria | Time/ Duration/ Frequency | Reporting | Implementation |
|---|---|---|---|---|---|---|---|---|
| Accidental spills and leaks | • Maintain spill kits on site; implement spill response plan<br>• Conduct staff training and toolbox briefings | • Weekly inspection and post-incident verification<br>• Attendance log and drill reports | • Spill containment and clean-up<br>• Awareness and response drills | • Construction site | • No visible sheen or contamination; immediate containment<br>• All staff trained and briefed | • Weekly checks and after any spill event<br>• Prior to works and every 6 months | • EMMP compliance report<br>• Training records | • Contractor<br>• ECO |

## 15.4 Operation EMMP

Table 15-4 provides recommendations on the types of monitoring that should be implemented during operation phase, but this is not necessarily an exhaustive list.

**Table 15-4: 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 | • 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 | • Utilisation 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 exceeds the system design threshold of ambient +5 °C. Operations will resume once ambient conditions fall within the design-operating range and compliance with discharge limits can be ensured.<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 thermal and chlorine limits | • Continuous measurement throughout the plant lifecycle.<br>• Stop work temporarily when the ambient seawater temperature exceeds the system design threshold of ambient +5 °C. Operations will resume once ambient conditions fall within the design-operating range and compliance with discharge limits can be ensured. | • Automated measurement of the temperature and chlorin concentration at discharge. | • Operation team |
| **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 |

| Impact | Monitoring Measures/ Plan | Monitoring Method/ verification method | Techniques | Location | Standards/ criteria | Time/ Duration/ Frequency | Reporting | Implementation |
|---|---|---|---|---|---|---|---|---|
| Accidental spill and leaks | • Maintain on-site containment system and spill kits; include in OEMP<br>• Emergency preparedness and incident reporting protocol | • Quarterly inspection and compliance audits<br>• Incident report review and mock drills | • Operational spill prevention system<br>• Emergency response and notification | • Entire plant | • NEA / port guidelines for hazardous materials handling<br>• Immediate reporting and annual drill | • Quarterly post-maintenance or incident<br>• Annually and after real incidents | • OEMP audit and reporting<br>• Internal safety reporting system | • 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 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 |
| Seagrass | • Pre and post intertidal seagrass habitat surveys | • Visual surveys, transect-based sampling, and habitat mapping | • Quadrat sampling method in accordance with NParks' Biodiversity Impact Assessment (BIA) guidelines | • Seagrass areas, particularly in areas identified during the baseline survey. | • Comparison seagrass habitat results | • Monitoring shall be conducted every six months for the first two years, followed by annual monitoring until Year 4. The continuation and necessity of regular monitoring beyond Year 4 shall be subject to further discussion with NParks, based on the monitoring results. All findings shall be submitted to NParks for review. | • Survey report | • Operation team |
| Mangroves | • Pre and post mangrove habitat surveys<br>• Pre and post mangrove fauna surveys (i.e., birds, herpetofauna & mammals) | • Visual surveys, transect-based sampling, and habitat mapping | • Transect line plot method | • Mangrove area, particularly in areas identified | • Comparison mangroves habitat results | • Monitoring shall be conducted every six months for the first two years, followed by annual | • Survey report | • Operation team |

| Impact | Monitoring Measures/ Plan | Monitoring Method/ verification method | Techniques | Location | Standards/ criteria | Time/ Duration/ Frequency | Reporting | Implementation |
|---|---|---|---|---|---|---|---|---|
| | | • Visual surveys | • Ad-hoc | during the baseline survey. | | monitoring until Year 4. The continuation and necessity of regular monitoring beyond Year 4 shall be subject to further discussion with NParks, based on the monitoring results. All findings shall be submitted to NParks for review. | | |
| Marine fauna | • Selection of low-noise, low-vibration pump models<br>• Installation of vibration isolation systems, such as resilient mounts or dampers, at each pump unit<br>• Implementation of a double-hull configuration, incorporating a water tank compartment between the inner and outer hull layers, | • Equipment inspection and vibration monitoring (if required) | • Engineering control | • Hull structure | • Periodic maintenance schedule of equipment | • Periodic maintenance schedule of equipment | • OEMP report | • Operation team |
| Avifauna | • No to designed with glass surfaces. Instead, the façade is proposed to avoid bird collision<br>• Low colour temperature lighting and reduced blue light output were adopted where practicable. | • Review of final architectural drawings and site inspection<br>• Periodic inspection of light shielding and orientation | • Use of non-reflective / patterned materials; avoidance of mirror/glass cladding<br>• Adjusted lighting | • Facility perimeter and façade<br>• Project site | • NParks' bird-safe building guidelines (2024), where applicable | • At design finalisation<br>• Throughout construction operation | • OEMP submission and as-built design review<br>• Inspection 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 |

## 15.5 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.

## 15.6 Specific Management Plan

### 15.6.1 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 dredging 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 15-5.

Table 15-5: Monitoring schedule

| Parameter | Frequency | Remarks |
|---|---|---|
| Turbidity measured in Nephelometric Turbidity Units (NTU) | Daily measurement using turbidity probe | During dredging 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 |

#### 15.6.1.1 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 does not exceed 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.

### 15.6.2 Spill Management Plan

A Spill Management Plan shall be developed and implemented to address potential spill risks during both the construction and operation phases of the Floating Data Centre. This plan shall be aligned with applicable local regulations (e.g., NEA, SCDF, WSH Act) and international best practices, and shall be integrated into the overall Major Accident Prevention Plan (MAPP) and Emergency Response Plan (ERP). The plan shall form part of the Environmental Management and Monitoring Plan (EMMP) and be made available for inspection by relevant authorities.

**<u>During construction phase</u>**

The Contractor shall prepare and implement a Spill Management Plan to address potential accidental releases of pollutants such as fuel, lubricants, and hydraulic fluids associated with marine vessels, equipment, and machinery. The plan shall include:

- Identification of spill sources (e.g., refuelling areas, equipment storage)
- Preventive measures to minimise spill risks

- Spill response procedures and escalation protocols
- Inventory of on-site spill response equipment
- Emergency contact list and notification steps
- Personnel training and periodic spill response drills

Spill containment and initial response measures shall be initiated within one (1) hour of any reported incident. Spill kits must be strategically positioned at all high-risk areas and regularly maintained to ensure readiness. In addition, contractors are required to carry out visual monitoring during works conducted near water bodies and must immediately report any observed hydrocarbon sheen or pollutant discharge to the site Environmental Control Officer (ECO) and relevant regulatory authorities.

**During operational phase**

During operation, the Facility Operator shall maintain a site-specific Spill Management Plan addressing potential leakages or spills from the fuel storage, power generation units (e.g., diesel gensets), and other onboard systems. The plan shall cover:

- Inventory and inspection schedule for storage tanks, pipework, and critical equipment
- Leak detection systems (e.g., sensors, alarms) and early warning protocols
- Secondary containment and bunded storage for fuels and chemicals
- Emergency shutdown, isolation, and containment procedures
- Coordination with marine authorities for offshore containment and spill recovery, where required
- Post-spill monitoring and environmental assessment (if spills enter marine waters)

The operator shall conduct regular drills, ensure all operational personnel are trained in spill prevention and containment procedures, and ensure training is refreshed at least once every 12 months. Spill response performance and learning from incidents shall be reviewed and used to update the plan accordingly.

**Monitoring, Review and Reporting**

The Spill Management Plan shall be reviewed and updated periodically, especially following system modifications or after any spill incidents. The operator shall also ensure all staff are trained in spill prevention and emergency response procedures.

Both plans shall be submitted to the ECO or competent personnel for review and kept available for audit by relevant regulatory agencies.

# 16

# Conclusion

# 16 Conclusion

SECS carried out the EIA for the development of a Floating Data Centre at Loyang Offshore Supply Base (LOSB) to assess the baseline conditons and to forecast any pontential impacts to the environment. The construction impact (SSC impact and sedimentation) and operational impact (thermal plume, chlorine plume, hydrodynamic, air quality and noise) has been summarised in Table 16-1.

**Table 16-1: Impact assessment summary**

| Impacts on receptor | | Potential impact |
|---|---|---|
| Seagrass | SSC impact | No change/ no impact |
| | Sedimentation impact | No change/ no impact |
| | Thermal plume impact | No change/ no impact |
| | Chlorine plume impact | No change/ no impact |
| | Accidental spills and leaks | Slight negative change/ slight negative impact |
| Mangroves | SSC impact | No change/ no impact |
| | Sedimentation impact | No change/ no impact |
| | Thermal plume impact | No change/ no impact |
| | Chlorine plume impact | No change/ no impact |
| | Accidental spills and leaks | Slight negative change/ slight negative impact |
| Soft bottom macrobenthos | Direct impact to benthic ecology | Slight negative change/ slight negative impact |
| | Thermal plume impact | Slight negative change/ slight negative impact |
| | Chlorine plume impact | Slight negative change/ slight negative impact |
| | Accidental spills and leaks | Slight negative change/ slight negative impact |
| Fish | SSC impact | No change/ no impact |
| | Thermal plume impact | No change/ no impact |
| | Chlorine plume impact | No change/ no impact |
| | Accidental spills and leaks | Slight negative change/ slight negative impact |
| | Underwater noise | No change/ no impact |
| Plankton | SSC impact | No change/ no impact |
| | Thermal plume impact | No change/ no impact |
| | Chlorine plume impact | No change/ no impact |
| | Accidental spills and leaks | Slight negative change/ slight negative impact |

| Impacts on receptor | | Potential impact |
|---|---|---|
| Recreational activities at Pasir Ris Park | SSC to recreational aesthetic value | No change/ no impact |
| Marine infrastructure and navigation: LOSB's and Fugro's jetties | Sedimentation impact | No change/ no impact |
| | Current impact | No change/ no impact |
| Water intake | SSC impact | No change/ no impact |
| | Accidental spills and leaks | Slight negative change/ slight negative impact |
| Cross-border | SSC impact at international boundary | No change/ no impact |
| | Accidental spills and leaks | No change/ no impact |
| Aquaculture facilities | SSC impact | No change/ no impact |
| | Thermal plume impact | No change/ no impact |
| | Chlorine plume impact | No change/ no impact |
| | Accidental spills and leaks | Slight negative change/ slight negative impact |
| | Underwater noise | No change/ no impact |
| Residentials, parks, sport and recreation facilities, hotels, place of worships, health and medical care facilities, civic & community institutions and educational institutions | Air Quality impact | Moderate negative change/ moderate impact (without mitigation measure)<br>Minor negative change/ minor impact (with mitigation measure) |
| | Noise impact | Slight negative change/ slight impact (without mitigation measure)<br>No change/ no impact (with mitigation measure) |

The impact assessment indicates that the proposed Project is not expected to have significant environmental effects on the identified marine receptors. Key ecosystems, including seagrass, mangroves, and aquaculture facilities, along with recreational activities at Pasir Ris Park, water intake systems, and cross-border areas, are anticipated to remain unaffected.

Marine infrastructure and navigation facilities, including LOSB's and Fugro's jetties, are also expected to experience no major impacts. However, localised scouring near the design structures may occur. No significant changes in sedimentation patterns within the Project area are predicted.

Overall, the Project is considered feasible, with no significant impacts identified in this study. However, further analysis should be conducted based on the updated concept design and sequencing to confirm these conclusions. The implementation of an EMMP is essential to meet EQOs and ETLs.

SECS has proposed an EMMP for both the construction phase (Section 15.3) and the operational phase (Section 15.4) to mitigate potential environmental impacts. This plan will monitor the implementation of mitigation measures to ensure the development does not cause significant adverse environmental impacts during both construction and operation phases.

# 17

# Reference

# 17 Reference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# Appendix A

## Ambient Air Quality Results

# TEST REPORT

| | | | | | |
|---|---|---|---|---|---|
| Our Reference No. | : | **R240 8508** | Date of Monitoring | : | 25/09/24 to 01/10/24 |
| Project Code / Ref. | : | - | Date Reported | : | 08/10/24 |

Customer Ref. No. : P527466
Customer Name : Singapore Environmental Consultancy and Solutions Pte Ltd
Customer Address : 1 Sunview Road #08-19,
Eco-Tech @ Sunview,
Singapore 627615

Attention To : Mr Chua Kiam Poh

**Subject** : **Air Quality Monitoring at Loyang Offshore Supply Base**

Description : Air Quality Monitoring at 1 location from 25/09/24 to 01/10/24

**Toh Teck Yeow**
**Snr Manager, Env Services**

**Terms & Conditions:**

1) This report shall not be reproduced except in full, unless approval in writing has been given by MLS.
2) The results in this report only apply to the sample received/analysed.
3) MLS agrees to use reasonable diligence in the performance of the service.

## SCOPE OF WORK

Baseline Ambient Air Monitoring was carried out at 1 location from 25/09/24 to 01/10/24.

Table 1: Scope of work carried out

| Parameters | Limit of Reporting / Detection Limit | Data Logging Interval |
|---|---|---|
| $PM_{10}$ | 0 - 10000 μg/m$^3$ | 10-min Avg |
| $PM_{2.5}$ | 0 - 2000 μg/m$^3$ | |
| $SO_2$ | 0 - 10000 ppb | 5-min Avg |
| CO | 0 - 12000 ppb | |
| $NO_2$ | 0 - 5000 ppb | |
| $O_3$ | 0 - 1800 ppb | |

## MONITORING LOCATION

Table 2: Location description and assigned air monitor

| Location Description | Air Monitor | GPS Coordinates | Date |
|---|---|---|---|
| AQ1 | Kunak 4 | 1°23'01.4"N 103°58'08.5"E | 25/09/24 to 01/10/24 |

## SAMPLING METHODOLOGY AND EQUIPMENT

Kunak AIR Pro

PM10 and PM2.5 were monitored using an onboard Optical Particle Counter (OPC) capable of measuring particles from 0.3 µm up to 40 µm. PM1, PM2.5, PM4, PM10, Total Suspended Particles (TSP) and Total Particle Counter (TPC) are calculated assuming a particle density profile. $SO_2$, CO, $O_3$ and $NO_2$ are measured by individual electrochemical sensors installed. The instrument is powered by solar. This instrument model is UKAS M-CERTS certified (certificate number: CSA MC230418/00).

## SINGAPORE AMBIENT AIR QUALITY TARGETS

Table 3: The following table summarises the Singapore Ambient Air Quality Guidelines

| Pollutant | Singapore Long Term Targets |
|---|---|
| Particulate Matter ($PM_{2.5}$) | **24-hour mean: 25 μg/m³** |
| Particulate Matter ($PM_{10}$) | **24-hour mean: 50 μg/m³** |
| Sulphur Dioxide ($SO_2$) | **24-hour mean: 20 μg/m³** |
| Carbon Monoxide (CO) | **8-hour mean: 10 mg/m³** |
| | **1-hour mean: 30 mg/m³** |
| Nitrogen Dioxide ($NO_2$) | **1-hour mean: 200 μg/m³** |
| Ozone ($O_3$) | **8-hour mean: 100 μg/m³** |

## MONITORING RESULTS

The results for the particulate matter were summarised in the following table. Raw air quality data and weather data are submitted electronically.

Table 4: Summary of 24-hour mean for $PM_{10}$ and $PM_{2.5}$ for Kunak 4

| Pollutants | | $PM_{10}$ | $PM_{2.5}$ |
|---|---|---|---|
| Averaging Period | | 24 hours | |
| Unit | | μg/m³ | |
| AQ1 | 25-Sep-24 | 16.7 | 6.7 |
| | 26-Sep-24 | 8.7 | 2.9 |
| | 27-Sep-24 | 14.1 | 5.0 |
| | 28-Sep-24 | 11.0 | 4.5 |
| | 29-Sep-24 | 10.9 | 4.6 |
| | 30-Sep-24 | 9.3 | 3.6 |
| | 01-Oct-24 | 7.5 | 2.7 |
| Singapore's Ambient Air Quality Long Term Targets | | **50** | **25** |

Table 5: Summary of 24-hour mean for $SO_2$, Max 1hr $NO_2$ and Max 8hr $O_3$ for Kunak 4

| Pollutants | | $SO_2$ | $NO_2$ | $O_3$ |
|---|---|---|---|---|
| Averaging Period | | 24 hours | Max 1 hour | Max 8 hours |
| Unit | | µg/m³ | | |
| AQ1 | 25-Sep-24 | 8.61 | 36.51 | 20.00 |
| | 26-Sep-24 | 10.37 | 24.86 | 2.99 |
| | 27-Sep-24 | 9.58 | 20.52 | 30.81 |
| | 28-Sep-24 | 2.56 | 22.77 | 27.00 |
| | 29-Sep-24 | 1.31 | 22.45 | 13.76 |
| | 30-Sep-24 | 2.58 | 32.31 | 16.27 |
| | 01-Oct-24 | 9.18 | 20.94 | 3.69 |
| Singapore's Ambient Air Quality Long Term Targets | | 20 | 200 | 100 |

Table 6: Summary of Max 8hr and 1hr CO for Kunak 4

| Pollutants | | CO | |
|---|---|---|---|
| Averaging Period | | Max 8 hours | Max 1 hour |
| Unit | | mg/m³ | |
| AQ1 | 25-Sep-24 | 0.23 | 0.28 |
| | 26-Sep-24 | 0.11 | 0.20 |
| | 27-Sep-24 | 0.27 | 0.32 |
| | 28-Sep-24 | 0.16 | 0.23 |
| | 29-Sep-24 | 0.14 | 0.23 |
| | 30-Sep-24 | 0.17 | 0.30 |
| | 01-Oct-24 | 0.16 | 0.36 |
| Singapore's Ambient Air Quality Long Term Targets | | 10 | 30 |

Note:

1) All the monitoring dates represent data collected from 0000hrs to 2359hrs.
2) Results are adjusted based on resulting slope and intercept derived from collocation with USEPA approved air monitors done from 26/02/24 to 06/03/24.

# Appendix B

## Noise Meter Calibration Certificate

# Calibration Certificate

Calibration Number: 240801021685

**Customer Name** : Absolute Instrument Systems (Pte.) Ltd.
**Customer Address** : 11 Kallang Place,
#06-02/03
Singapore 339155
**Manufacturer** : Svantek
**Item Description** : Sound Level Meter Class I
**Model Number** : SVAN 971
**Serial Number** : 60665
**Sub-Assemblies S/N** : SV18 47278/ 7052E 65590

**Job Reference No**: 24080102
**Certificate Issue Date**: 07/08/2024

**Calibration Date**: 07/08/2024
**Test Conditions**:
Ambient Temperature: 23 °C
Relative Humidity: 50 %R.H.
Pressure: 99.4 kPa

This certificate provides traceability of measurement to the International System of Units (SI).
Absolute Laboratories Pte. Ltd. certifies that the above product listed was calibrated in compliance with a quality management system using the applicable and approved Absolute Laboratories Pte. Ltd. calibration procedures as specified.
The reported expanded uncertainty is based on the standard uncertainty multiplied by a factor k = 2 (effective degrees of freedom = ∞) or as specified in the calibration report, which corresponds to a level of confidence of approximately 95%.

**Calibration Method:**
The instrument was calibrated following AL calibration procedure WI- 63-Rev-0

| Calibration Equipment(s) Used | | | |
|---|---|---|---|
| **Apparatus** | **Serial Number** | **Cal Due Date** | **Certificate Number** |
| Sound Source | KZF070009 | 07/05/2025 | 240500490742 |
| Calibrator | 148027 | 08/04/2025 | 240400840387 |
| Digital Multimeter | MY57230283 | 03/11/2024 | WO-00631175 |
| Arbitrary Function Generator | C015037 | 13/09/2024 | SST/SA/R/2023I/1004 |

Ambient Condition Range:
Temperature: (20-26)°C , Humidity: (25-70)%RH, Pressure: (80-105)kPa

**Calibration By :**
Han Chun Keong
Calibration Officer

**Reviewed/Approved By :**
Ang Siong Cheaw
Approving Officer





Absolute Laboratories Pte. Ltd.
11 Kallang Place #06-01 Singapore 339155
Tel: 65 6296 8012 Fax: 65 6296 3242

Absolute Laboratories

# Calibration Certificate

Calibration Number: 240600141032

| | | | | |
|---|---|---|---|---|
| **Customer Name** | : | Absolute Instrument Systems (Pte.) Ltd. | **Job Reference No**: | 24060014 |
| **Customer Address** | : | 11 Kallang Place,<br>#06-02/03<br>Singapore 339155 | **Certificate Issue Date**: | 05/06/2024 |
| **Manufacturer** | : | Svantek | **Calibration Date**: | 05/06/2024 |
| **Item Description** | : | Sound Level Meter Class I | **Test Conditions**: | |
| **Model Number** | : | SVAN 971 | Ambient Temperature: | 24 °C |
| **Serial Number** | : | 80334 | Relative Humidity: | 50 %R.H. |
| **Sub-Assemblies S/N** | : | SV18 38485/ 7052E 66831 | Pressure: | 99.5 kPa |

This certificate provides traceability of measurement to the International System of Units (SI).
Absolute Laboratories Pte. Ltd. certifies that the above product listed was calibrated in compliance with a quality management system using the applicable and approved Absolute Laboratories Pte. Ltd. calibration procedures as specified.
The reported expanded uncertainty is based on the standard uncertainty multiplied by a factor k = 2 (effective degrees of freedom = ∞) or as specified in the calibration report, which corresponds to a level of confidence of approximately 95%.

**Calibration Method:**
The instrument was calibrated following AL calibration procedure WI- 63-Rev-0

| Calibration Equipment(s) Used | | | |
|---|---|---|---|
| **Apparatus** | **Serial Number** | **Cal Due Date** | **Certificate Number** |
| Multifunction Acoustic Calibrator | 3094457 | 26/10/2024 | CDK2308082 |
| Arbitrary Function Generator | C015037 | 13/09/2024 | SST/SA/R/2023I/1004 |

Ambient Condition Range:
Temperature: (20-26)°C , Humidity: (25-70)%RH, Pressure: (80-105)kPa

**Calibration By :** Ang Siong Cheaw, Calibration Officer

**Reviewed/Approved By :** Rodrigo Manansala, Approving Officer



Absolute Laboratories Pte. Ltd. is an affiliated company of Absolute Instrument Systems (Pte.) Ltd.



Absolute Laboratories Pte. Ltd.
11 Kallang Place #06-01 Singapore 339155
Tel: 65 6296 8012 Fax: 65 6296 3242

# Appendix C

## Noise Quality Results

**Account:** Singapore Environmental Consultancy and Solutions Pte Ltd **Main Contractor:**
**Location:** NM1

**ReDac Serial Number:** G8-64 (Rental)
**Meter Serial Number:** 60665/ SV18 47278/ 7052E 65590
**Voltage:** 13.05

| Day | Time | LEQ 5 MINS (dBA) | | | | | | | | | | | | LEQ 1HR (dBA) | LEQ 12HR (dBA) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | | |
| | 7:00 | | | | | | | | | | | | | | |
| | 8:00 | | | | | | | | | | | | | | |
| | 9:00 | | | | | | | | | | | | | | |
| | 10:00 | | | | | | | | | | | | | | |
| | 11:00 | | | | | | | | | | | | | | |
| | 12:00 | | | | | | | | | | | | | | |
| | 13:00 | | | | | | | | | | | | | | |
| | 14:00 | | | | | | | | | | | | | | |
| 24-Sep-24 | 15:00 | | | | | | | | | | | | | | |
| | 16:00 | | | | | | | | | | | | | | |
| | 17:00 | | | | | | | | | | | | | | |
| | 18:00 | | | | | | | | | | | | | | |
| | 19:00 | 50.5 | 54 | 55 | 52.3 | 57.9 | 61.1 | 61.2 | 53.2 | 51.2 | 49.9 | 57.5 | 52.1 | 56.4 | 51.7 |
| | 20:00 | 52.9 | 56.2 | 54.5 | 55.1 | 57.7 | 57 | 54.8 | 55.1 | 57.1 | 55.1 | 52.3 | 58.4 | 55.8 | |
| | 21:00 | 51 | 51.5 | 51.5 | 53.4 | 49.6 | 50.2 | 51.6 | 50.4 | 50.3 | 50.7 | 50.4 | 50.4 | 51 | |
| | 22:00 | 50 | 50.3 | 49.8 | 49.6 | 50.4 | 49.7 | 49.8 | 50.2 | 49.8 | 51.2 | 49.2 | 48.2 | 49.9 | |
| | 23:00 | 48.4 | 48.5 | 48.5 | 48.9 | 49.1 | 47.8 | 47.9 | 47.7 | 47.8 | 47.9 | 48.1 | 48.2 | 48.2 | |
| | 0:00 | 48.1 | 48.3 | 48.9 | 48.9 | 50 | 50.4 | 51.3 | 51.2 | 50.6 | 50.7 | 50.1 | 50 | 50 | |
| | 1:00 | 50.1 | 52 | 51.3 | 51.2 | 52.1 | 50.5 | 50.1 | 50.1 | 49.8 | 50.1 | 49.8 | 49.5 | 50.6 | |
| | 2:00 | 49.6 | 49.9 | 49.8 | 49.8 | 49.3 | 49.3 | 49.9 | 51 | 49.7 | 50 | 49.4 | 49.7 | 49.8 | |
| | 3:00 | 50.5 | 49.4 | 49.2 | 50.1 | 50.2 | 50 | 49.7 | 49.4 | 49.2 | 49.2 | 49.6 | 48.9 | 49.6 | |
| | 4:00 | 49.2 | 50.4 | 49.7 | 49.1 | 50.5 | 49.5 | 49.8 | 49.6 | 49.2 | 49.4 | 49.6 | 49.8 | 49.7 | |
| | 5:00 | 49 | 49.2 | 50.5 | 50.7 | 51.1 | 50.4 | 49.8 | 50.4 | 49.6 | 49 | 49.1 | 49.1 | 49.9 | |
| | 6:00 | 49.2 | 48.7 | 48.3 | 47.9 | 48.3 | 50.7 | 48.9 | 48.4 | 50.4 | 50.8 | 48.9 | 49.5 | 49.3 | |
| | 7:00 | 49.7 | 49.7 | 49.5 | 48.9 | 49.6 | 50.3 | 50.4 | 49.6 | 50.2 | 53.7 | 58.1 | 53.1 | 52.1 | 55.8 |
| | 8:00 | 50.2 | 50 | 51.4 | 54.3 | 54.7 | 50.6 | 52.2 | 52.4 | 54.3 | 53.8 | 58.5 | 52.4 | 53.6 | |
| | 9:00 | 53.4 | 51.9 | 51.7 | 52.4 | 53.2 | 53.5 | 51.4 | 52.6 | 53.6 | 53.1 | 53 | 53.6 | 52.8 | |
| | 10:00 | 55.5 | 61 | 57.2 | 56.9 | 58.3 | 57.4 | 54.8 | 51.4 | 55 | 61.7 | 61.1 | 56.6 | 58.1 | |
| 25-Sep-24 | 11:00 | 57 | 55.6 | 54.4 | 58.2 | 57.7 | 54.5 | 55.4 | 53.7 | 55.1 | 61 | 55.5 | 54.3 | 56.6 | |
| | 12:00 | 52.5 | 53.4 | 53.1 | 52.2 | 53.9 | 51 | 50.8 | 55.8 | 55.2 | 55 | 50.5 | 52.1 | 53.3 | |
| | 13:00 | 52.9 | 52.4 | 54.2 | 58 | 54.9 | 51.5 | 51.8 | 53 | 56.8 | 54.4 | 54.2 | 57.5 | 54.8 | |
| | 14:00 | 60 | 63.4 | 61.8 | 59.5 | 56.2 | 54.4 | 58 | 57.4 | 56.8 | 56.1 | 54.4 | 56.1 | 58.7 | |
| | 15:00 | 54.6 | 58.5 | 58.3 | 55.2 | 54.2 | 59.7 | 56.1 | 56 | 57.1 | 61.6 | 57.3 | 54.1 | 57.5 | |
| | 16:00 | 59.1 | 56.8 | 56 | 59.1 | 55.1 | 54.4 | 61.2 | 55.5 | 55.8 | 55.8 | 55.9 | 52.4 | 57 | |
| | 17:00 | 55.9 | 54.3 | 55.6 | 56.6 | 54.3 | 52.9 | 52.3 | 52 | 53.9 | 52.4 | 53.6 | 53.3 | 54.2 | |
| | 18:00 | 53.1 | 51.3 | 50.6 | 51.1 | 50.9 | 51.9 | 52.3 | 51.6 | 53.7 | 53.4 | 58.8 | 56.2 | 53.7 | |
| | 19:00 | 52.6 | 53.4 | 50 | 49.2 | 50.8 | 51.5 | 51.3 | 52.4 | 52.6 | 53.3 | 52.2 | 52.2 | 51.9 | 50.1 |
| | 20:00 | 52.4 | 51 | 51.3 | 51.7 | 50.2 | 50.8 | 50.8 | 51.2 | 50.7 | 51 | 50.9 | 51.7 | 51.2 | |
| | 21:00 | 51.5 | 52.2 | 50.5 | 50.9 | 50.4 | 53.9 | 50.4 | 49.6 | 50.7 | 50.2 | 49.5 | 49.4 | 51 | |
| | 22:00 | 49.6 | 48.8 | 49.5 | 49.5 | 49.4 | 49.4 | 49.1 | 48.7 | 48.5 | 49 | 48.8 | 48.1 | 49 | |
| | 23:00 | 47.7 | 48 | 48.4 | 47.7 | 52.9 | 48.1 | 47.5 | 47.5 | 47.6 | 47.6 | 47.8 | 47.9 | 48.6 | |
| | 0:00 | 48.2 | 48.3 | 48.7 | 48.4 | 48.7 | 49.2 | 49.7 | 49.3 | 49.2 | 49 | 49.1 | 49.3 | 48.9 | |
| | 1:00 | 49.1 | 50.2 | 49.3 | 49.7 | 49.3 | 49.9 | 50.3 | 50.8 | 49.5 | 50 | 49.6 | 49.5 | 49.8 | |
| | 2:00 | 50.3 | 49.4 | 50 | 49.8 | 50.9 | 50.3 | 50.7 | 50.1 | 49.8 | 49.9 | 50.4 | 50.4 | 50.2 | |
| | 3:00 | 50.2 | 50.2 | 50 | 49.9 | 50.4 | 48.9 | 49.3 | 49.3 | 49.2 | 49.5 | 49.7 | 49.2 | 49.7 | |
| | 4:00 | 49.9 | 49 | 48.8 | 48.8 | 48.9 | 48.9 | 49.1 | 48.9 | 49.4 | 49.2 | 48.6 | 48.8 | 49 | |
| | 5:00 | 49.2 | 49.3 | 48.8 | 48.8 | 48.5 | 48.9 | 48.9 | 48.8 | 49.7 | 53.7 | 49 | 48.7 | 49.6 | |
| | 6:00 | 48.8 | 50.2 | 50 | 49.3 | 49.2 | 52.5 | 52.2 | 52.2 | 50.4 | 51.1 | 51.3 | 51.3 | 50.9 | |
| | 7:00 | 50.5 | 51 | 51.5 | 51.3 | 52.7 | 51.8 | 52.4 | 52.5 | 52.4 | 52.7 | 51.9 | 52 | 51.9 | 56.5 |
| | 8:00 | 52.6 | 54.2 | 53.4 | 55.2 | 53.1 | 52.7 | 56.6 | 56.9 | 60.3 | 61.7 | 57.4 | 60.3 | 57.3 | |
| | 9:00 | 60.1 | 55.2 | 56.8 | 57.9 | 60.3 | 60.4 | 59.2 | 61.4 | 61.2 | 61.5 | 59.2 | 57.7 | 59.6 | |
| | 10:00 | 56.6 | 58.5 | 56.6 | 58 | 57.4 | 55.2 | 56.2 | 58.9 | 56.9 | 58.9 | 59 | 57.4 | 57.6 | |
| 26-Sep-24 | 11:00 | 56.7 | 55.2 | 55.9 | 58.4 | 56.6 | 56.2 | 56.1 | 58 | 57.1 | 55.1 | 55.4 | 54.8 | 56.4 | |
| | 12:00 | 54.1 | 54.6 | 53.3 | 53.6 | 53.2 | 53 | 54.1 | 53.2 | 53.5 | 54.3 | 54.8 | 53.9 | 53.8 | |
| | 13:00 | 54.1 | 54.5 | 55.9 | 56.9 | 55.7 | 57.8 | 60 | 54.1 | 54.9 | 56.1 | 56.1 | 56.6 | 56.4 | |
| | 14:00 | 56.9 | 55.2 | 55.7 | 55.4 | 55.6 | 55.5 | 56.9 | 56 | 54.5 | 55.3 | 56.3 | 56 | 55.8 | |
| | 15:00 | 56 | 56.2 | 55.3 | 54.5 | 59.8 | 55.7 | 57.3 | 56.9 | 59.2 | 58.9 | 62.6 | 59.2 | 58.3 | |
| | 16:00 | 61.1 | 56.3 | 55.3 | 55.7 | 55.1 | 56.9 | 55.7 | 59 | 56.9 | 56.4 | 56.1 | 54.2 | 57 | |
| | 17:00 | 54.7 | 54.8 | 54.9 | 54.6 | 54.3 | 52.9 | 56 | 53.2 | 55.7 | 54.7 | 54 | 52.2 | 54.5 | |
| | 18:00 | 52.9 | 53 | 52.7 | 53.3 | 52.2 | 51.1 | 52.2 | 51 | 51.1 | 51.2 | 58.2 | 51.6 | 53.1 | |
| | 19:00 | 50.3 | 49.9 | 52.9 | 49.6 | 49.5 | 49.6 | 50.2 | 49.5 | 50.1 | 49.3 | 49.4 | 50.1 | 50.1 | 54.8 |
| | 20:00 | 49.2 | 49.3 | 49.2 | 50 | 49.9 | 50.7 | 50.7 | 50.4 | 49.1 | 49.4 | 49.3 | 49.1 | 49.7 | |
| | 21:00 | 49.4 | 50.5 | 49.5 | 49.6 | 51.8 | 50.8 | 49.3 | 49.4 | 49.3 | 48.9 | 49.4 | 49.1 | 49.8 | |
| | 22:00 | 48.9 | 49.2 | 49 | 48.7 | 48.7 | 49 | 49 | 48.7 | 49 | 49.3 | 50.4 | 53.8 | 49.7 | |
| | 23:00 | 48.3 | 48 | 47.6 | 48.7 | 47.9 | 48.2 | 48 | 48 | 47.8 | 48 | 48.1 | 47.9 | 48 | |
| | 0:00 | 48.3 | 49 | 49.1 | 49.6 | 50 | 50.4 | 50.1 | 50.3 | 50 | 50.2 | 49.7 | 49.5 | 49.7 | |
| | 1:00 | 49.6 | 49.5 | 49.4 | 49.6 | 49.6 | 50 | 51.1 | 50.3 | 49.4 | 49.3 | 49.6 | 49.4 | 49.8 | |
| | 2:00 | 49.5 | 49.6 | 49.3 | 49.4 | 49.2 | 49.3 | 49.2 | 49 | 49 | 49.4 | 49.6 | 49.3 | 49.3 | |
| | 3:00 | 49.4 | 49.6 | 49.2 | 49.2 | 49.3 | 49.2 | 49.9 | 50.3 | 49.5 | 49.5 | 49.5 | 49.9 | 49.5 | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4:00 | 50.3 | 49.7 | 50.4 | 50.4 | 49.7 | 49.9 | 49.5 | 74.8 | 56.9 | 49.2 | 49.9 | 50.8 | 64.2 | |
| | 5:00 | 49.5 | 49.4 | 49.4 | 49.1 | 49.3 | 49 | 48.9 | 48.8 | 48.8 | 48.9 | 48.8 | 51.5 | 49.4 | |
| | 6:00 | 50 | 49.9 | 49.8 | 49.9 | 51 | 49.7 | 50.1 | 51 | 52.8 | 52 | 50.7 | 51.5 | 50.8 | |
| | 7:00 | 51.8 | 50.4 | 50.3 | 51.9 | 51.3 | 50.2 | 52 | 51 | 50.6 | 51.3 | 50.5 | 50.3 | 51 | 55.2 |
| | 8:00 | 49.6 | 52.7 | 61.4 | 53 | 52.8 | 52.7 | 52.2 | 56 | 52 | 53 | 57.6 | 56.8 | 55.4 | |
| | 9:00 | 59 | 59.6 | 55.1 | 64.1 | 55 | 55.1 | 55.9 | 63.5 | 56.1 | 56.2 | 55.3 | 56 | 59 | |
| | 10:00 | 56.3 | 52.5 | 54.7 | 52.5 | 52.9 | 53.8 | 55.8 | 57 | 60.3 | 53.2 | 56.8 | 60.3 | 56.4 | |
| 27-Sep-24 | 11:00 | 61 | 54.4 | 57 | 60.8 | 54.2 | 53.6 | 52.5 | 52.6 | 51 | 53.3 | 54.9 | 51.3 | 56.1 | |
| | 12:00 | 53.9 | 50.5 | 52.9 | 53.5 | 53.5 | 51.1 | 50.3 | 49 | 50.3 | 51.2 | 51.5 | 53 | 52 | |
| | 13:00 | 52.7 | 53.4 | 52.9 | 54.2 | 54.1 | 52.9 | 53.3 | 54.5 | 55.7 | 58.2 | 56.1 | 57.7 | 55.1 | |
| | 14:00 | 52.4 | 51.7 | 51.8 | 55.8 | 52.6 | 55.4 | 63.7 | 57.2 | 58.6 | 54.7 | 63.6 | 53.3 | 58.1 | |
| | 15:00 | 53.3 | 52 | 53.1 | 54 | 54.2 | 51.9 | 52.5 | 51.9 | 52.8 | 57.5 | 55.3 | 51.7 | 53.7 | |
| | 16:00 | 56.2 | 53.2 | 53.4 | 52.4 | 56.1 | 55.9 | 50.3 | 52.3 | 51.2 | 56.1 | 50.7 | 54.4 | 54 | |
| | 17:00 | 52.3 | 49.9 | 50.9 | 50.2 | 51.6 | 50.4 | 52.6 | 53.7 | 53.1 | 55.2 | 52.2 | 50.5 | 52.2 | |
| | 18:00 | 52.3 | 52.5 | 53.2 | 51.9 | 52.7 | 51.3 | 50.6 | 50.1 | 49.7 | 49.3 | 49 | 50.6 | 51.3 | |
| | 19:00 | 52.3 | 50.9 | 52.9 | 52.8 | 50.1 | 49 | 47.6 | 50 | 49 | 50.8 | 48.9 | 49.9 | 50.6 | 48 |
| | 20:00 | 49.3 | 48.8 | 47.9 | 49.6 | 48.9 | 48.1 | 48.2 | 49.3 | 48.1 | 47.5 | 48.2 | 49.3 | 48.7 | |
| | 21:00 | 49.2 | 47.9 | 47.5 | 48.9 | 47.5 | 48.2 | 47.3 | 49.2 | 48.4 | 48.9 | 48.1 | 47.8 | 48.3 | |
| | 22:00 | 47.4 | 47.4 | 47.8 | 47.8 | 46.9 | 49.7 | 47 | 46.6 | 46.3 | 47.8 | 47.6 | 46.5 | 47.5 | |
| | 23:00 | 47.2 | 49.3 | 46.9 | 46.9 | 47.7 | 46.6 | 47.7 | 47.5 | 46.7 | 47 | 46.5 | 46.5 | 47.3 | |
| | 0:00 | 46.6 | 46.2 | 46.5 | 47.2 | 46.2 | 46.6 | 47 | 46.2 | 46.2 | 46.5 | 46.2 | 46.1 | 46.4 | |
| | 1:00 | 46.1 | 47.3 | 47.2 | 48.4 | 47 | 46.7 | 47 | 46.7 | 46.9 | 47 | 46.7 | 47.2 | 47 | |
| | 2:00 | 46.4 | 47.1 | 46.4 | 46.6 | 46.5 | 46.5 | 47.9 | 49.5 | 47.6 | 47.2 | 46.6 | 48 | 47.3 | |
| | 3:00 | 51.4 | 50.7 | 47.3 | 46.8 | 46.7 | 46.7 | 46.6 | 47.1 | 46.7 | 46.6 | 47.1 | 46.5 | 47.9 | |
| | 4:00 | 46.7 | 46.6 | 46.8 | 46.9 | 47 | 46.7 | 46.7 | 47.1 | 47.4 | 47.5 | 49.1 | 48.3 | 47.3 | |
| | 5:00 | 48.6 | 47.6 | 47.4 | 47.4 | 47.2 | 46.7 | 47.4 | 48.8 | 47.1 | 47 | 47.1 | 49.4 | 47.7 | |
| | 6:00 | 48 | 46.9 | 47.3 | 48.4 | 48.7 | 48 | 48 | 48 | 48.5 | 49 | 48.4 | 49.1 | 48.2 | |
| | 7:00 | 50.8 | 50.1 | 49.1 | 48.9 | 48.4 | 49 | 48.8 | 50.1 | 50.5 | 51.2 | 51.6 | 50.7 | 50 | 51.9 |
| | 8:00 | 49.3 | 49.7 | 51.1 | 49.6 | 51.8 | 53.3 | 52.5 | 54.5 | 52.2 | 52 | 50.3 | 51.1 | 51.7 | |
| | 9:00 | 50.5 | 49.9 | 50.8 | 51.7 | 50.9 | 50.9 | 52.8 | 55 | 52.4 | 56.1 | 53.2 | 56.4 | 53.1 | |
| | 10:00 | 52.2 | 57.3 | 54.9 | 55.7 | 53 | 61.1 | 58.7 | 53.7 | 52.7 | 53.1 | 50.9 | 50.5 | 55.7 | |
| 28-Sep-24 | 11:00 | 62.5 | 50.7 | 50.3 | 51.1 | 56.5 | 51.7 | 52.7 | 52.3 | 49.7 | 51.2 | 49 | 49.5 | 54.6 | |
| | 12:00 | 49 | 51 | 52.1 | 50.8 | 50.1 | 51.3 | 51 | 48.8 | 52.7 | 50 | 50.1 | 52.6 | 51 | |
| | 13:00 | 49.4 | 49.1 | 50.7 | 51.4 | 51.1 | 50.5 | 51.9 | 49.9 | 52.5 | 49.6 | 50.2 | 51.5 | 50.8 | |
| | 14:00 | 50.2 | 47.9 | 47.7 | 47.8 | 49.4 | 48.2 | 47.7 | 49.9 | 53.7 | 53.2 | 51.1 | 48.8 | 50.2 | |
| | 15:00 | 51.4 | 50.1 | 47.1 | 48.5 | 47.4 | 47.8 | 48.1 | 47.9 | 50.3 | 47.2 | 48.2 | 53.1 | 49.3 | |
| | 16:00 | 49.2 | 49.1 | 50.2 | 49.1 | 52.5 | 49.8 | 49.4 | 50.6 | 49.6 | 49.8 | 50.2 | 52 | 50.3 | |
| | 17:00 | 49.3 | 51.3 | 51 | 50.3 | 49.3 | 49.6 | 51.8 | 53.5 | 49.5 | 50.2 | 48.8 | 49.5 | 50.6 | |
| | 18:00 | 51.2 | 50.5 | 49.4 | 49 | 49.2 | 52.9 | 49.9 | 48.1 | 50.8 | 48.2 | 48.4 | 48 | 49.9 | |
| | 19:00 | 48.4 | 48.2 | 47.6 | 47.5 | 49.6 | 48.1 | 47.7 | 47.2 | 50.8 | 48.9 | 48.7 | 47.9 | 48.5 | 47.5 |
| | 20:00 | 48.8 | 47.3 | 47.9 | 47.3 | 47 | 47.3 | 47.5 | 47.9 | 49.1 | 47.1 | 47.4 | 47.5 | 47.7 | |
| | 21:00 | 47.4 | 47.3 | 46.9 | 47.1 | 47.1 | 47.1 | 47.2 | 47.3 | 47.1 | 47.2 | 47.6 | 47 | 47.2 | |
| | 22:00 | 46.6 | 47.4 | 47.3 | 46.9 | 47.1 | 47.1 | 47.1 | 48.3 | 48.2 | 47.6 | 48 | 48.1 | 47.5 | |
| | 23:00 | 47.9 | 47.2 | 47.3 | 46.7 | 47.3 | 46.6 | 46.5 | 46.6 | 47.1 | 46.5 | 48.9 | 48.8 | 47.4 | |
| | 0:00 | 46.6 | 47.8 | 46.9 | 48.8 | 47.9 | 47.4 | 47.1 | 47.4 | 47 | 46.7 | 47.1 | 47 | 47.3 | |
| | 1:00 | 47.3 | 47.1 | 46.9 | 46.7 | 46.6 | 46.8 | 46.6 | 47.2 | 46.8 | 47 | 47 | 47.4 | 47 | |
| | 2:00 | 47.9 | 47.2 | 47.3 | 47.2 | 47.4 | 47.2 | 47.1 | 46.9 | 47.2 | 46.9 | 47.1 | 47 | 47.2 | |
| | 3:00 | 47.3 | 47.2 | 47.3 | 47.2 | 47.1 | 47.1 | 48.9 | 47.4 | 48 | 47.7 | 47 | 47 | 47.5 | |
| | 4:00 | 47.3 | 47.5 | 47 | 47.6 | 47.7 | 47.2 | 47.4 | 47.4 | 47.4 | 47.1 | 47.4 | 47.5 | 47.4 | |
| | 5:00 | 47.4 | 47.5 | 47.4 | 47 | 47 | 47.2 | 47.5 | 47.5 | 47.1 | 47.1 | 47.4 | 47.2 | 47.3 | |
| | 6:00 | 47.3 | 48.4 | 47.4 | 47.8 | 47.4 | 47.3 | 48.5 | 48.7 | 50.8 | 48.4 | 49.3 | 48.2 | 48.4 | |
| | 7:00 | 50.3 | 50.2 | 51.6 | 51.2 | 51 | 51.9 | 53 | 51.6 | 49.8 | 50 | 50.2 | 49.3 | 51 | 48.7 |
| | 8:00 | 49.1 | 52.4 | 51.5 | 49.5 | 51.8 | 55.7 | 52.5 | 50.4 | 50.4 | 50.9 | 50.4 | 49.9 | 51.6 | |
| | 9:00 | 52.6 | 50.4 | 50.5 | 52.5 | 51.6 | 52.3 | 52.4 | 56 | 55.5 | 50.9 | 51.5 | 49.6 | 52.6 | |
| | 10:00 | 49.3 | 44.6 | 45.7 | 46.1 | 45 | 44.8 | 52.7 | 51.2 | 53 | 44.7 | 48.5 | 53 | 49.5 | |
| 29-Sep-24 | 11:00 | 45.2 | 47.1 | 48 | 44.6 | 47.1 | 45.4 | 46.2 | 49.1 | 51.4 | 48.5 | 50.2 | 45.9 | 47.9 | |
| | 12:00 | 43.2 | 44.2 | 43.7 | 42.5 | 42.7 | 45.8 | 43.6 | 44 | 44.5 | 45.3 | 44.3 | 47.9 | 44.6 | |
| | 13:00 | 45.9 | 48.1 | 46.2 | 48.3 | 47.6 | 50.1 | 45.3 | 46.6 | 43.8 | 45.5 | 45.5 | 46 | 46.9 | |
| | 14:00 | 45.8 | 45.7 | 47.2 | 48.3 | 48.8 | 47.8 | 43.5 | 45.1 | 43.2 | 42.7 | 43.2 | 46.2 | 46.1 | |
| | 15:00 | 48.2 | 44.8 | 48.2 | 46 | 46 | 44.8 | 46 | 50.9 | 44.4 | 44.2 | 46.1 | 46.6 | 46.8 | |
| | 16:00 | 43.3 | 43.3 | 43.6 | 45.6 | 48.4 | 46.3 | 47 | 49.7 | 49.7 | 47.6 | 47.9 | 44.8 | 47 | |
| | 17:00 | 45.4 | 46.6 | 49.1 | 51.9 | 49.9 | 44.2 | 47.6 | 43.9 | 43.8 | 47 | 45 | 42.5 | 47.3 | |
| | 18:00 | 41.9 | 44.1 | 46.2 | 42.6 | 44.3 | 44.1 | 42.7 | 44 | 45.7 | 42.5 | 43.3 | 43.5 | 43.9 | |
| | 19:00 | 43.3 | 42 | 42.4 | 42.6 | 43.1 | 44.1 | 44 | 42.2 | 42.1 | 45.6 | 44.2 | 45.5 | 43.6 | 43.1 |
| | 20:00 | 41.1 | 43.4 | 43.1 | 42.7 | 41.9 | 42.3 | 42.3 | 42.5 | 42.4 | 42.8 | 42.7 | 42.4 | 42.5 | |
| | 21:00 | 41.8 | 42 | 41.7 | 43.2 | 42.1 | 42.6 | 41.5 | 43 | 41.5 | 44.7 | 42.8 | 41.5 | 42.5 | |
| | 22:00 | 41.8 | 41.7 | 42.8 | 43.2 | 42.7 | 42 | 42.2 | 42.2 | 41.3 | 41.3 | 41.4 | 43 | 42.2 | |
| | 23:00 | 45.8 | 42.4 | 42.3 | 42 | 42 | 42.9 | 42.1 | 41.6 | 41.3 | 42 | 42.1 | 42.7 | 42.6 | |
| | 0:00 | 44.4 | 47.4 | 41.9 | 41.2 | 53 | 40.9 | 41.4 | 42 | 42.5 | 45.1 | 42.6 | 41.6 | 45.6 | |
| | 1:00 | 41.5 | 41.2 | 45.7 | 43.2 | 40.9 | 43.5 | 42.9 | 41.3 | 41.5 | 41 | 41.8 | 42.7 | 42.5 | |
| | 2:00 | 42.5 | 42.4 | 41 | 41.6 | 40.6 | 40.4 | 40.6 | 40.5 | 40.4 | 40.3 | 40.9 | 40.9 | 41.1 | |
| | 3:00 | 40.8 | 40.9 | 40.4 | 40.7 | 40.2 | 40.4 | 39.9 | 40.4 | 39.9 | 40 | 40.3 | 40 | 40.3 | |
| | 4:00 | 40.9 | 40.1 | 40.4 | 40 | 41 | 40.4 | 40.5 | 40.3 | 40.1 | 40 | 40.7 | 39.9 | 40.4 | |
| | 5:00 | 40.1 | 40 | 40.3 | 40.2 | 41.7 | 45.5 | 41.7 | 40.2 | 40.5 | 42.3 | 42.7 | 40.4 | 41.6 | |
| | 6:00 | 44.2 | 50.7 | 45.6 | 42.9 | 41.7 | 44.4 | 44.6 | 43.7 | 51.2 | 49 | 45.2 | 48 | 47 | |
| | 7:00 | 45.6 | 46.4 | 44.8 | 56.9 | 59.5 | 53.7 | 54.3 | 58.6 | 64.6 | 58.2 | 56.8 | 57.9 | 57.8 | 64.1 |
| | 8:00 | 64.8 | 66.2 | 66.2 | 65.8 | 65.2 | 65.3 | 65.1 | 65.2 | 65.3 | 65.4 | 65.8 | 65.7 | 65.5 | |
| | 9:00 | 65.6 | 66.4 | 65.3 | 65.2 | 65.1 | 65.3 | 66.2 | 65.5 | 65.7 | 65.7 | 65.7 | 67.2 | 65.8 | |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 30-Sep-24 | 10:00 | 65.9 | 64.8 | 64.6 | 64.4 | 64.8 | 64.5 | 64.5 | 64.8 | 65.2 | 65.6 | 65.2 | 65.4 | 65 | |
| | 11:00 | 65.2 | 65.1 | 64.4 | 65 | 65.3 | 65.4 | 65.5 | 65.6 | 66 | 65.1 | 65.4 | 65.1 | 65.3 | |
| | 12:00 | 65.2 | 65.4 | 63.7 | 64.1 | 58.2 | 60.5 | 54.9 | 53.6 | 55.9 | 54.1 | 54 | 54.2 | 61 | |
| | 13:00 | 54.5 | 54.3 | 58 | 62.8 | 64.4 | 63.7 | 64.6 | 65.5 | 65.5 | 66 | 66.9 | 65.1 | 64 | |
| | 14:00 | 64.7 | 64.5 | 64.2 | 64.6 | 64.4 | 65.1 | 66.6 | 65.3 | 64.6 | 64.1 | 67.3 | 65.8 | 65.2 | |
| | 15:00 | 63.8 | 64.8 | 64.7 | 64.6 | 64.7 | 64.1 | 64.1 | 63.6 | 64.6 | 63.8 | 63.8 | 64.9 | 64.3 | |
| | 16:00 | 65.3 | 66 | 66.9 | 67.3 | 65.6 | 60.3 | 60.8 | 58.5 | 60.4 | 62.2 | 65.7 | 61.1 | 64.3 | |
| | 17:00 | 61.4 | 59.3 | 60.3 | 58.8 | 57.7 | 61.4 | 56.9 | 55.8 | 57.6 | 58.4 | 64.6 | 62.5 | 60.3 | |
| | 18:00 | 74.6 | 60.6 | 60.7 | 52.1 | 53.6 | 48.6 | 48.3 | 48.9 | 49.9 | 48.2 | 54.6 | 57.3 | 64.4 | |
| | 19:00 | 52.9 | 48.3 | 53.2 | 51.8 | 61 | 60.5 | 56 | 57.4 | 58.9 | 61.1 | 59.1 | 57.8 | 57.9 | 55.1 |
| | 20:00 | 60.7 | 60.5 | 59.9 | 60.9 | 60.5 | 63.2 | 65.7 | 68.9 | 59.8 | 62.4 | 63.8 | 66.4 | 63.8 | |
| | 21:00 | 64.6 | 61.6 | 47.6 | 47.1 | 47.4 | 47.3 | 47.2 | 49.2 | 47.3 | 48.6 | 48.1 | 46.9 | 56.1 | |
| | 22:00 | 47.5 | 48 | 47.9 | 47.4 | 47.5 | 47.1 | 47.8 | 47.4 | 46.6 | 46.7 | 46.9 | 47 | 47.3 | |
| | 23:00 | 47 | 46.8 | 46.8 | 46.3 | 47 | 46.7 | 47.5 | 47.1 | 46.9 | 46.5 | 47.1 | 46.6 | 46.9 | |
| 1-Oct-24 | 0:00 | 47.4 | 46.7 | 47.1 | 46.7 | 46.4 | 47.4 | 47.3 | 46.5 | 46.6 | 46.7 | 46.4 | 47 | 46.9 | |
| | 1:00 | 49.1 | 48.6 | 46.6 | 47.1 | 46.3 | 46.4 | 47.8 | 49.2 | 49.4 | 47.1 | 47 | 46.7 | 47.7 | |
| | 2:00 | 46.6 | 46.3 | 46.8 | 46.4 | 46.2 | 46.2 | 46.3 | 46.2 | 46.1 | 46.1 | 46.1 | 45.9 | 46.3 | |
| | 3:00 | 45.8 | 45.9 | 45.9 | 45.8 | 47.1 | 47.6 | 46.4 | 45.9 | 45.9 | 46.3 | 46.2 | 46.1 | 46.3 | |
| | 4:00 | 46.4 | 46.1 | 46.1 | 46.1 | 46.3 | 46.5 | 46.5 | 45.5 | 45.5 | 45.5 | 45.7 | 45.5 | 46 | |
| | 5:00 | 45.6 | 45.6 | 46 | 45.6 | 45.8 | 45.9 | 46.2 | 45.8 | 45.8 | 45.6 | 45.7 | 45.6 | 45.8 | |
| | 6:00 | 45.9 | 46.3 | 48.7 | 50.7 | 48 | 49.7 | 47.1 | 46.2 | 49.6 | 50.2 | 46.6 | 48.4 | 48.4 | |
| | 7:00 | 47.5 | 48.3 | 47.8 | 47.4 | 47.7 | 47.4 | 47.4 | 47.1 | 49.2 | 50.9 | 50.2 | 51.9 | 48.9 | 58.9 |
| | 8:00 | 51.1 | 52.1 | 53.9 | 54 | 52.4 | 54.6 | 54.8 | 58.5 | 57.5 | 59.1 | 57.3 | 59.5 | 56.2 | |
| | 9:00 | 58.4 | 64.4 | 60.2 | 62.2 | 62.9 | 59.9 | 60.4 | 61.3 | 60.8 | 61.5 | 61.5 | 60.1 | 61.4 | |
| | 10:00 | 60.1 | 60.9 | 61.6 | 59.3 | 57.7 | 56.5 | 57.1 | 57.3 | 59.3 | 60.6 | 62.9 | 57.8 | 59.7 | |
| | 11:00 | 57.9 | 59.4 | 56.6 | 59.7 | 59.1 | 57.7 | 57.5 | 57.6 | 57.1 | 55.3 | 53.7 | 51.4 | 57.4 | |
| | 12:00 | 55.7 | 54.4 | 54 | 54.5 | 53.7 | 53 | 55.3 | 54.3 | 54.5 | 55.2 | 54.3 | 56.1 | 54.7 | |
| | 13:00 | 53.9 | 53.5 | 54 | 55.3 | 59.7 | 58.4 | 64 | 63.9 | 62.6 | 63 | 63.1 | 64 | 61.3 | |
| | 14:00 | 64.3 | 65 | 64.2 | 61.1 | 61.8 | 63.9 | 63.2 | 63.7 | 63 | 60.1 | 62.2 | 59.7 | 63 | |
| | 15:00 | 61.2 | 59 | 57.9 | 59.7 | 60.3 | 59.5 | 57 | 55.5 | 57.6 | 57.3 | 59.2 | 57.3 | 58.7 | |
| | 16:00 | 55.8 | 56.6 | 55.8 | 59.6 | 58.3 | 59.3 | 60.2 | 57.7 | 57.1 | 59.1 | 58.2 | 56.6 | 58.1 | |
| | 17:00 | 56.5 | 56.6 | 56 | 57.8 | 60.4 | 64.3 | 62.3 | 59 | 56.1 | 56.9 | 57 | 56.7 | 59.2 | |
| | 18:00 | 54.7 | 53.5 | 52.6 | 54.5 | 51.5 | 51.5 | 51.6 | 51.8 | 50.9 | 50.8 | 51.1 | 50.8 | 52.3 | |
| | 19:00 | 51.7 | 52 | 52.1 | 51.8 | 51 | 52 | 51.2 | 52.1 | 51.4 | 48.9 | 48.8 | 48.6 | 51.1 | 48 |
| | 20:00 | 49.6 | 51.5 | 48.1 | 47.8 | 47.8 | 47.9 | 48.4 | 48.9 | 49 | 48 | 48 | 48 | 48.7 | |
| | 21:00 | 48.4 | 47.7 | 49.9 | 47.8 | 48.4 | 50.2 | 49.5 | 47.6 | 49.3 | 47.4 | 48.3 | 48.4 | 48.7 | |
| | 22:00 | 49.5 | 47.7 | 48.2 | 47.4 | 47.5 | 47.5 | 47.2 | 46.9 | 47.1 | 47.1 | 46.9 | 47.7 | 47.6 | |
| | 23:00 | 47.2 | 47.3 | 47.3 | 47.9 | 47.2 | 47 | 47 | 48.2 | 47.1 | 46.9 | 47 | 47.1 | 47.3 | |
| 2-Oct-24 | 0:00 | 47.5 | 47 | 46.9 | 47 | 47 | 48.2 | 48.7 | 47.2 | 46.9 | 46.8 | 48.1 | 47.6 | 47.4 | |
| | 1:00 | 47.1 | 47.5 | 46.7 | 47.1 | 46.8 | 46.7 | 47.3 | 47.3 | 46.8 | 47.2 | 46.9 | 46.8 | 47 | |
| | 2:00 | 46.6 | 47.6 | 46.7 | 46.3 | 47.2 | 46.7 | 46.7 | 47.7 | 46.4 | 46.3 | 46.2 | 46.6 | 46.8 | |
| | 3:00 | 47.2 | 46.4 | 46.4 | 46.4 | 46.6 | 46.5 | 46.9 | 46.9 | 46.8 | 47 | 47 | 46.8 | 46.8 | |
| | 4:00 | 46.8 | 46.8 | 46.4 | 46.2 | 46.4 | 46.2 | 47.4 | 46.8 | 46.2 | 46.1 | 46.1 | 46 | 46.5 | |
| | 5:00 | 46 | 45.8 | 46.2 | 47 | 46.7 | 46.3 | 46.7 | 46.5 | 46.4 | 46.3 | 46.3 | 46.5 | 46.4 | |
| | 6:00 | 47 | 50.3 | 46.4 | 46.2 | 46.6 | 49.2 | 49.9 | 47.1 | 52.2 | 51.4 | 47 | 48.3 | 49 | |
| | 7:00 | | | | | | | | | | | | | | |
| | 8:00 | | | | | | | | | | | | | | |
| | 9:00 | | | | | | | | | | | | | | |
| | 10:00 | | | | | | | | | | | | | | |
| | 11:00 | | | | | | | | | | | | | | |
| | 12:00 | | | | | | | | | | | | | | |
| | 13:00 | | | | | | | | | | | | | | |
| | 14:00 | | | | | | | | | | | | | | |
| | 15:00 | | | | | | | | | | | | | | |
| | 16:00 | | | | | | | | | | | | | | |
| | 17:00 | | | | | | | | | | | | | | |
| | 18:00 | | | | | | | | | | | | | | |
| | 19:00 | | | | | | | | | | | | | | |
| | 20:00 | | | | | | | | | | | | | | |
| | 21:00 | | | | | | | | | | | | | | |
| | 22:00 | | | | | | | | | | | | | | |
| | 23:00 | | | | | | | | | | | | | | |

**Account:** Singapore Environmental Consultancy and Solutions Pte Ltd **Main Contractor:**
**Location:** NM2

**ReDac Serial Number:** N2-57 (rental) (5V)
**Meter Serial Number:** 80334/ SV18 38485/ 7052E 66831
**Voltage:** 12.98

| Day | Time | LEQ 5 MINS (dBA) | | | | | | | | | | | | LEQ 1HR (dBA) | LEQ 12HR (dBA) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | | |
| | 7:00 | | | | | | | | | | | | | | |
| | 8:00 | | | | | | | | | | | | | | |
| | 9:00 | | | | | | | | | | | | | | |
| | 10:00 | | | | | | | | | | | | | | |
| | 11:00 | | | | | | | | | | | | | | |
| | 12:00 | | | | | | | | | | | | | | |
| | 13:00 | | | | | | | | | | | | | | |
| | 14:00 | | | | | | | | | | | | | | |
| 24-Sep-24 | 15:00 | | | | | | | | | | | | | | |
| | 16:00 | | | | | | | | | | | | | | |
| | 17:00 | | | | | | | | | | | | | | |
| | 18:00 | | | | | | | | | | | | | | |
| | 19:00 | 49.9 | 51.8 | 53.7 | 49.8 | 54.9 | 60.4 | 60 | 49.2 | 48.4 | 47.6 | 54.2 | 49.1 | 54.7 | 51.1 |
| | 20:00 | 49.4 | 52.5 | 56.4 | 61.2 | 62 | 60 | 57.5 | 58.3 | 58.6 | 55.1 | 48.4 | 52.2 | 57.7 | |
| | 21:00 | 49.1 | 49.6 | 49.7 | 49.6 | 48 | 48.5 | 49.6 | 49.2 | 49.6 | 49.8 | 49.1 | 48.9 | 49.2 | |
| | 22:00 | 49.3 | 48.6 | 48.5 | 48.4 | 48.3 | 48.4 | 48.3 | 48.5 | 49 | 48.1 | 48.3 | 47.4 | 48.4 | |
| | 23:00 | 47.2 | 47 | 47.5 | 52.6 | 47.9 | 47.2 | 47.5 | 47.4 | 47.4 | 47.2 | 47.1 | 47.2 | 48.1 | |
| | 0:00 | 47.1 | 47.4 | 47.7 | 47.9 | 48 | 48.3 | 48.8 | 49 | 48.8 | 48.2 | 48.1 | 48.2 | 48.2 | |
| | 1:00 | 48.1 | 48.3 | 48.4 | 48.5 | 47.9 | 48.2 | 47.8 | 48.2 | 48.9 | 48.7 | 48.1 | 48 | 48.3 | |
| | 2:00 | 48 | 48.3 | 47.8 | 48.3 | 47.8 | 48.3 | 48.3 | 49.1 | 48.1 | 48.1 | 47.7 | 48.3 | 48.2 | |
| | 3:00 | 48.8 | 47.9 | 47.8 | 47.9 | 47.7 | 48.1 | 47.8 | 47.4 | 47.4 | 47.2 | 47.5 | 47.4 | 47.7 | |
| | 4:00 | 47.6 | 47.7 | 47.5 | 47.3 | 47.8 | 47.1 | 47.8 | 47.6 | 47.8 | 47.8 | 47.7 | 47.6 | 47.6 | |
| | 5:00 | 47.5 | 47.7 | 47.3 | 47.1 | 47.4 | 47.6 | 47.8 | 47.7 | 47 | 47.1 | 47.2 | 47.2 | 47.4 | |
| | 6:00 | 47.5 | 46.9 | 47.3 | 46.5 | 48.4 | 47.7 | 46.5 | 46.4 | 46.9 | 47.7 | 47.6 | 47.4 | 47.3 | |
| | 7:00 | 47.5 | 47.6 | 47.1 | 47.2 | 47.7 | 47.8 | 47.8 | 47.6 | 49 | 51.2 | 48.7 | 49.3 | 48.4 | 60 |
| | 8:00 | 48.8 | 49.6 | 50.4 | 54.8 | 52.7 | 51.9 | 56.3 | 57.9 | 57.3 | 58.6 | 59.8 | 57.2 | 55.9 | |
| | 9:00 | 56.8 | 59.7 | 53.5 | 57.7 | 55.6 | 51.9 | 53.1 | 55.6 | 56 | 58.2 | 68.1 | 60 | 59.9 | |
| | 10:00 | 56.5 | 62.8 | 57.2 | 60.6 | 61.1 | 57.6 | 58.6 | 55.6 | 60.3 | 61.2 | 61.7 | 60.8 | 60 | |
| 25-Sep-24 | 11:00 | 60.7 | 60.2 | 59.7 | 61.8 | 58.1 | 56.2 | 56.3 | 56.4 | 50.7 | 52.6 | 54.8 | 53.1 | 57.9 | |
| | 12:00 | 49.1 | 47.9 | 47 | 47.3 | 47.7 | 49.1 | 51.5 | 53.1 | 53.4 | 49.8 | 48.8 | 49.5 | 50 | |
| | 13:00 | 49.3 | 53.5 | 55.5 | 57.5 | 61.2 | 51.1 | 51.2 | 52 | 56.7 | 55.1 | 56.2 | 58.3 | 56 | |
| | 14:00 | 60.8 | 65.3 | 62.9 | 60.9 | 58.7 | 56.9 | 60.3 | 56.3 | 65.8 | 62.5 | 58.1 | 62 | 61.8 | |
| | 15:00 | 62.7 | 65.9 | 64.4 | 59.1 | 57.7 | 76.3 | 63.5 | 64.5 | 61.4 | 63.6 | 53.6 | 57.7 | 67.2 | |
| | 16:00 | 56.2 | 60.6 | 60.6 | 59.3 | 53.9 | 57.4 | 59.8 | 59.9 | 53.8 | 53.9 | 58.2 | 52.9 | 58 | |
| | 17:00 | 53.6 | 58.4 | 54.6 | 60 | 55.1 | 54.9 | 54.5 | 53.5 | 53 | 54.4 | 58.2 | 52.5 | 55.9 | |
| | 18:00 | 55.9 | 58.1 | 51.2 | 51.3 | 51.5 | 51.2 | 51.4 | 51.2 | 61.3 | 51.4 | 59.7 | 65.5 | 58.1 | |
| | 19:00 | 65.4 | 63.6 | 50.2 | 49.6 | 56.7 | 60.2 | 50.7 | 52.7 | 58.9 | 53.1 | 50.8 | 56.3 | 58.9 | 53.7 |
| | 20:00 | 51.1 | 50.3 | 50.7 | 60.5 | 50.2 | 51.6 | 51.6 | 59.5 | 53.7 | 52 | 52.2 | 52.1 | 54.6 | |
| | 21:00 | 61.3 | 56.9 | 51 | 51.8 | 57.3 | 67.4 | 55.4 | 50.9 | 51.5 | 51 | 50.9 | 50.7 | 58.8 | |
| | 22:00 | 51.2 | 50.3 | 51.2 | 50.6 | 50.3 | 50.4 | 50.2 | 50.4 | 50.5 | 50.7 | 50.7 | 49.8 | 50.5 | |
| | 23:00 | 49.9 | 49.8 | 49.7 | 49.5 | 53.7 | 49.5 | 49.7 | 49.3 | 49.4 | 48.9 | 50.3 | 49.5 | 50.1 | |
| | 0:00 | 49 | 49 | 49.9 | 49.9 | 49.1 | 49.8 | 49.8 | 50.5 | 50.2 | 50 | 50.2 | 49.7 | 49.8 | |
| | 1:00 | 49.6 | 50.7 | 50.2 | 50.7 | 49.7 | 50 | 51.1 | 50.8 | 50.3 | 50.8 | 50.1 | 49.9 | 50.4 | |
| | 2:00 | 51.2 | 50 | 50.5 | 50.4 | 50.8 | 50.5 | 50.9 | 50.1 | 50.6 | 50.8 | 50.7 | 50.7 | 50.6 | |
| | 3:00 | 50.6 | 50.7 | 50.7 | 50.4 | 51.5 | 50 | 50 | 49.8 | 49.8 | 50.2 | 49.9 | 50.1 | 50.3 | |
| | 4:00 | 50.1 | 50.1 | 50.1 | 49.8 | 49.9 | 49.7 | 49.8 | 50 | 50.1 | 50.3 | 49.3 | 49.6 | 49.9 | |
| | 5:00 | 49.9 | 50.1 | 50 | 49.8 | 49.7 | 50.3 | 50.2 | 50.2 | 50.2 | 52.1 | 50.4 | 50.1 | 50.3 | |
| | 6:00 | 50.2 | 50.2 | 54.6 | 50.1 | 50.1 | 50.6 | 50.4 | 50.7 | 50.6 | 50.6 | 50.7 | 51.1 | 51 | |
| | 7:00 | 50.8 | 50.8 | 51 | 51.3 | 51.6 | 52.3 | 53.1 | 52 | 52.4 | 52.1 | 52.2 | 52.7 | 51.9 | 57.8 |
| | 8:00 | 52 | 52.9 | 52.5 | 53.3 | 52.7 | 53.8 | 55.6 | 57.7 | 59.1 | 60.2 | 57.8 | 58.1 | 56.4 | |
| | 9:00 | 58.4 | 56.4 | 58 | 58.3 | 62.8 | 62.8 | 60.3 | 61.2 | 64.5 | 62.7 | 61.4 | 61 | 61.2 | |
| | 10:00 | 60.5 | 58.4 | 56.2 | 56.1 | 55.8 | 55.1 | 55.8 | 56.3 | 54.7 | 65.4 | 59 | 56.5 | 58.8 | |
| 26-Sep-24 | 11:00 | 56.4 | 55.5 | 56.6 | 56.1 | 55.7 | 55.5 | 55.8 | 56.9 | 56 | 57.4 | 58.7 | 56.1 | 56.5 | |
| | 12:00 | 55.5 | 54.7 | 54.9 | 55 | 54.3 | 53.6 | 55.3 | 55 | 54.2 | 54.5 | 55.6 | 54.9 | 54.8 | |
| | 13:00 | 54.8 | 53.9 | 57 | 58.8 | 58.2 | 59.4 | 55.7 | 60.1 | 56 | 56.6 | 58.8 | 57.7 | 57.6 | |
| | 14:00 | 58.3 | 58.5 | 62.4 | 59.4 | 59.1 | 57.3 | 60.3 | 55.2 | 54.3 | 58.6 | 58.1 | 57.8 | 58.8 | |
| | 15:00 | 53.9 | 53.8 | 54.2 | 53.2 | 54.5 | 54.4 | 60 | 54.8 | 56.9 | 60 | 65.4 | 63.7 | 59.2 | |
| | 16:00 | 62.8 | 60.4 | 58.4 | 56.1 | 53.1 | 64.3 | 62.8 | 58.9 | 52.9 | 54.6 | 55.3 | 56.1 | 59.6 | |
| | 17:00 | 53.7 | 52.5 | 56 | 53.1 | 56.5 | 52.6 | 52.7 | 51.1 | 51.6 | 57 | 53.1 | 52.1 | 53.9 | |
| | 18:00 | 51.6 | 60.6 | 51.8 | 52 | 51.4 | 51.5 | 58.7 | 51.6 | 51.8 | 52.1 | 64.7 | 50.6 | 57.1 | |
| | 19:00 | 50.5 | 50.4 | 65.7 | 58.6 | 50.7 | 51.9 | 58.1 | 50.8 | 54.6 | 50.5 | 50.5 | 61.6 | 58 | 53.7 |
| | 20:00 | 50.4 | 50.6 | 58.1 | 55.8 | 51.1 | 55.6 | 62.2 | 62.6 | 54.3 | 56.1 | 50 | 50.2 | 57.1 | |
| | 21:00 | 53.8 | 55.3 | 53.9 | 51.4 | 64.3 | 66.2 | 50.7 | 50.4 | 50.5 | 50.1 | 50.5 | 50.4 | 58.5 | |
| | 22:00 | 50.2 | 50 | 49.7 | 49.8 | 49.9 | 50.1 | 49.9 | 49.4 | 50.1 | 50.4 | 50.7 | 54 | 50.5 | |
| | 23:00 | 49.2 | 48.5 | 49.1 | 52.6 | 48.6 | 49 | 48.6 | 48.2 | 48.2 | 48.4 | 48.3 | 48.4 | 49.1 | |
| | 0:00 | 48.5 | 48.8 | 49.5 | 49.7 | 50.3 | 50.2 | 49.8 | 49.9 | 49.9 | 49.8 | 49.8 | 49.8 | 49.7 | |
| | 1:00 | 49.8 | 49.6 | 49.7 | 49.8 | 49.8 | 50.6 | 50.2 | 50.8 | 49.6 | 49.7 | 50.1 | 49.8 | 50 | |
| | 2:00 | 49.8 | 50 | 49.7 | 50 | 49.8 | 49.6 | 49.5 | 49.5 | 49.8 | 49.8 | 49.8 | 49.8 | 49.8 | |
| | 3:00 | 49.7 | 49.7 | 49.5 | 49.3 | 49.4 | 49.5 | 49.9 | 50.3 | 50 | 49.8 | 50 | 50.4 | 49.8 | |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4:00 | 49.9 | 50.3 | 54.6 | 51.6 | 50.3 | 53.5 | 50.2 | 54.5 | 50.4 | 50.1 | 50.1 | 50 | 51.7 | |
| | 5:00 | 49 | 49.6 | 49.7 | 49.9 | 49.3 | 49.2 | 49.3 | 49.5 | 49.7 | 49.8 | 49.7 | 50.4 | 49.6 | |
| | 6:00 | 50.6 | 50.5 | 50.5 | 50.9 | 51.8 | 54 | 51.1 | 51.4 | 51.5 | 51.7 | 51.8 | 51.9 | 51.6 | |
| | 7:00 | 52.1 | 51.2 | 51.3 | 53.8 | 51 | 50.4 | 51.9 | 50.6 | 51.4 | 50.4 | 50.9 | 51.3 | 51.4 | 58.3 |
| | 8:00 | 51.2 | 51.4 | 52 | 51.1 | 50.8 | 51.8 | 51.7 | 61.2 | 64.5 | 59.9 | 61.2 | 60.7 | 58.5 | |
| | 9:00 | 52 | 53.8 | 53.8 | 57.5 | 53 | 68.3 | 52.5 | 63.7 | 52.4 | 59.2 | 63.9 | 61.3 | 61.1 | |
| | 10:00 | 57.9 | 52.7 | 51.7 | 52.9 | 60.8 | 52 | 53.3 | 52.1 | 52.1 | 53.3 | 60 | 64.2 | 57.6 | |
| 27-Sep-24 | 11:00 | 66.5 | 53.6 | 59.2 | 60.6 | 51.3 | 51.1 | 57.1 | 50.9 | 51.4 | 50 | 61.8 | 49.9 | 58.9 | |
| | 12:00 | 50.3 | 50.9 | 54.3 | 51.2 | 51.4 | 48.7 | 49.4 | 48.8 | 49.3 | 49.9 | 49.5 | 49.8 | 50.6 | |
| | 13:00 | 50.9 | 50.5 | 62.4 | 62 | 52.2 | 53.1 | 61.6 | 52.1 | 51.4 | 59.2 | 50.1 | 52.6 | 57.5 | |
| | 14:00 | 53.2 | 53.5 | 53.7 | 54.4 | 59.6 | 54.7 | 57.6 | 57.5 | 66.1 | 59.8 | 68.9 | 64.4 | 61.9 | |
| | 15:00 | 53.2 | 53.1 | 53 | 53.1 | 53.6 | 53.4 | 64.1 | 52.9 | 53.4 | 53.7 | 55.9 | 60.6 | 57 | |
| | 16:00 | 58.2 | 63.7 | 62.6 | 66.3 | 51.5 | 51.5 | 52.2 | 58.3 | 52.5 | 51.1 | 51.4 | 54 | 59.6 | |
| | 17:00 | 55.8 | 53.1 | 53.1 | 56.9 | 60.2 | 56.8 | 56.1 | 56.9 | 60.5 | 53.5 | 53.3 | 57.9 | 56.9 | |
| | 18:00 | 58.4 | 59.5 | 52.9 | 57.2 | 56.7 | 60.5 | 62.3 | 49.8 | 55.6 | 48.6 | 48.4 | 49.1 | 57.2 | |
| | 19:00 | 48.5 | 64 | 52 | 48.8 | 61 | 50.5 | 48 | 49.6 | 53.1 | 50.6 | 48.5 | 49.7 | 56.1 | 50.9 |
| | 20:00 | 61.6 | 48.3 | 49.4 | 61.8 | 54.2 | 48.1 | 49.7 | 59 | 49.7 | 49.3 | 51.6 | 51.6 | 56 | |
| | 21:00 | 52.8 | 50.4 | 49 | 50 | 49.4 | 50.7 | 49.2 | 49.4 | 49.9 | 49.7 | 48.6 | 48.7 | 50 | |
| | 22:00 | 47.8 | 48 | 47.9 | 48.3 | 47.7 | 48.4 | 47.8 | 47.6 | 47.6 | 47.6 | 47.6 | 47.5 | 47.8 | |
| | 23:00 | 47.4 | 48 | 48.3 | 49.8 | 51.3 | 47.5 | 47.8 | 48.3 | 47.5 | 48.1 | 47.3 | 48 | 48.4 | |
| | 0:00 | 47.5 | 47.2 | 47.7 | 47.9 | 47.5 | 48 | 48.2 | 46.9 | 47.1 | 47.4 | 46.9 | 47.1 | 47.5 | |
| | 1:00 | 47.2 | 48.1 | 47.9 | 48.5 | 47.7 | 47.8 | 49.1 | 48.3 | 47.8 | 48 | 47.3 | 49.4 | 48.1 | |
| | 2:00 | 47.3 | 47.3 | 47.4 | 47.3 | 47.3 | 47.5 | 48.6 | 47.9 | 47.6 | 47.7 | 47 | 48.7 | 47.6 | |
| | 3:00 | 49.2 | 49 | 48.2 | 47.4 | 46.8 | 47.1 | 47.1 | 47.5 | 47.2 | 46.5 | 47.3 | 46.5 | 47.6 | |
| | 4:00 | 46.8 | 47.1 | 47 | 47 | 46.9 | 47.2 | 47.2 | 47.4 | 47.9 | 48.1 | 48.5 | 48 | 47.5 | |
| | 5:00 | 49.5 | 48 | 47.8 | 47.6 | 47.5 | 47.5 | 47.9 | 48.2 | 48.1 | 48 | 48.4 | 49 | 48.2 | |
| | 6:00 | 48.5 | 48.4 | 48.9 | 49 | 49.1 | 48.8 | 49.1 | 49.1 | 48.9 | 49.8 | 49.7 | 49.1 | 49 | |
| | 7:00 | 53.9 | 48.8 | 48.9 | 49.7 | 49.4 | 49.1 | 49.6 | 53.1 | 50.4 | 50.2 | 49.6 | 52.6 | 50.8 | 62.4 |
| | 8:00 | 63.3 | 55.1 | 77.4 | 70.2 | 55.7 | 49.5 | 69 | 71.5 | 50.6 | 53.1 | 53 | 51.9 | 68.8 | |
| | 9:00 | 50.7 | 52.3 | 53.5 | 50.5 | 50.8 | 50.5 | 51.5 | 50.2 | 54.3 | 60.1 | 49.3 | 50.3 | 53.3 | |
| | 10:00 | 51.1 | 50.5 | 52.8 | 57.6 | 59.3 | 58.3 | 55.4 | 55.1 | 76.5 | 74.6 | 63.5 | 60.5 | 68.3 | |
| | 11:00 | 57.1 | 54.8 | 55.2 | 58.9 | 57.7 | 58.1 | 58.3 | 55.4 | 55.1 | 54.9 | 54.8 | 54.9 | 56.5 | |
| 28-Sep-24 | 12:00 | 53.1 | 48 | 49.3 | 48.6 | 48.5 | 48.5 | 48.9 | 48.3 | 53.5 | 55.2 | 49.9 | 53.5 | 51.2 | |
| | 13:00 | 48.1 | 53.9 | 69.1 | 65.8 | 67.9 | 67.5 | 63.1 | 56.4 | 60.4 | 48.2 | 48.5 | 55 | 63.7 | |
| | 14:00 | 47.4 | 48 | 47.1 | 59.9 | 48.4 | 47.5 | 47.1 | 48 | 51.7 | 47.7 | 48.2 | 48.9 | 51.6 | |
| | 15:00 | 46.7 | 54.8 | 46.6 | 46.9 | 47.9 | 48.4 | 47.7 | 48.9 | 47.9 | 47.8 | 48.1 | 47.7 | 49 | |
| | 16:00 | 48.3 | 47.7 | 48.5 | 50.1 | 57.3 | 54.4 | 53 | 53 | 52.2 | 51.6 | 66.1 | 68.4 | 60.3 | |
| | 17:00 | 67.4 | 69.4 | 58.1 | 53.3 | 53.8 | 53.2 | 52.1 | 51.5 | 52.4 | 52.6 | 53.9 | 55 | 61.4 | |
| | 18:00 | 55.5 | 58.3 | 56.4 | 58.6 | 61.9 | 60.8 | 58.7 | 50.2 | 49.1 | 48.8 | 48.9 | 48.9 | 57 | |
| | 19:00 | 48.9 | 51.6 | 48.1 | 48.6 | 50.4 | 49.4 | 48.2 | 48.7 | 48.7 | 48.7 | 48.7 | 48.2 | 49.1 | 48.3 |
| | 20:00 | 48.8 | 48.4 | 48.9 | 48.9 | 48.4 | 48.2 | 48.3 | 48.1 | 48.6 | 48.2 | 48.9 | 48.6 | 48.5 | |
| | 21:00 | 48.1 | 47.9 | 47.2 | 47.7 | 47.9 | 47.9 | 48 | 48.1 | 47.6 | 48.1 | 48.4 | 47.7 | 47.9 | |
| | 22:00 | 47.4 | 48.3 | 48.5 | 47.6 | 47.7 | 48.2 | 48 | 47.9 | 47.6 | 47.7 | 48.5 | 48.7 | 48 | |
| | 23:00 | 48.6 | 49.2 | 48.8 | 48.4 | 48.1 | 47.4 | 47.4 | 47.5 | 48.2 | 47.2 | 49.8 | 49.5 | 48.4 | |
| | 0:00 | 48 | 48.8 | 47.9 | 49.8 | 48.4 | 47.9 | 47.7 | 48.3 | 47.6 | 48.2 | 48 | 47.6 | 48.2 | |
| | 1:00 | 47.9 | 48 | 47 | 47.1 | 47.9 | 47.7 | 48 | 49.2 | 47.1 | 47 | 46.8 | 47.8 | 47.7 | |
| | 2:00 | 48.1 | 47.2 | 47.6 | 47.6 | 47.5 | 47.6 | 47.5 | 47.9 | 48 | 47.2 | 47.7 | 47.5 | 47.6 | |
| | 3:00 | 47.9 | 47.7 | 48 | 48.6 | 48 | 48.2 | 48.7 | 48.9 | 48.6 | 49 | 48.2 | 48.6 | 48.4 | |
| | 4:00 | 49 | 48.5 | 49 | 49 | 48.5 | 48 | 47.5 | 47.6 | 47.9 | 47.7 | 48.1 | 47.8 | 48.3 | |
| | 5:00 | 47.6 | 48 | 48.2 | 47.6 | 48.3 | 48.6 | 48.9 | 49 | 48.6 | 48.9 | 49.3 | 49.4 | 48.6 | |
| | 6:00 | 49.8 | 49.5 | 49.5 | 49.7 | 49 | 48.9 | 49.5 | 48.9 | 49 | 48.1 | 49.1 | 48.6 | 49.2 | |
| | 7:00 | 51.4 | 49.7 | 52.3 | 50.7 | 50.1 | 50 | 52.2 | 49 | 48.9 | 50.5 | 51.5 | 48.4 | 50.6 | 58.3 |
| | 8:00 | 48.4 | 49.8 | 50.7 | 53.6 | 61.8 | 71.9 | 61.3 | 49 | 50.1 | 51.1 | 51.8 | 51.4 | 62.1 | |
| | 9:00 | 63.3 | 49.2 | 51 | 60 | 55.1 | 52.5 | 52.7 | 55.2 | 65 | 50.8 | 48.7 | 48.9 | 58.1 | |
| | 10:00 | 57 | 45.4 | 44.6 | 46.6 | 47 | 44.7 | 44.8 | 61.3 | 69.9 | 44.9 | 54.7 | 51.3 | 60.1 | |
| | 11:00 | 59.1 | 63.8 | 46.8 | 45.4 | 45.2 | 45.5 | 45.7 | 67.6 | 66.6 | 65.1 | 58.7 | 44.8 | 61.7 | |
| 29-Sep-24 | 12:00 | 44.1 | 44.1 | 43.6 | 43 | 42.6 | 46.7 | 44.6 | 44.7 | 45.9 | 44.9 | 44.6 | 44.5 | 44.6 | |
| | 13:00 | 44 | 46.1 | 45.3 | 58.6 | 63.7 | 65.9 | 53.1 | 61.1 | 52.2 | 61.5 | 58.8 | 59.9 | 60 | |
| | 14:00 | 58.1 | 57.8 | 62.1 | 70.7 | 65.9 | 56.6 | 45.1 | 42.8 | 44.1 | 46.4 | 47.6 | 44 | 62 | |
| | 15:00 | 51.5 | 51.4 | 56.9 | 44.4 | 43.9 | 45.9 | 49.2 | 54.7 | 49.7 | 44.6 | 42.3 | 53.8 | 51.3 | |
| | 16:00 | 52.9 | 52.5 | 53 | 53.8 | 58.1 | 57.2 | 53.9 | 54.7 | 56.5 | 54.4 | 53.3 | 53 | 54.8 | |
| | 17:00 | 53.2 | 53.8 | 53.9 | 54 | 53.3 | 53.3 | 53.3 | 53.2 | 53.2 | 53.8 | 48.8 | 41.7 | 52.9 | |
| | 18:00 | 44 | 44.3 | 47.2 | 42.4 | 44.7 | 44.7 | 42.1 | 40.9 | 41.6 | 41.2 | 49.5 | 42.8 | 44.6 | |
| | 19:00 | 43.2 | 41.5 | 41.7 | 42.2 | 41.6 | 43.8 | 42.9 | 41.6 | 40.9 | 44.7 | 44.7 | 45.1 | 43 | 42.8 |
| | 20:00 | 40.9 | 41.8 | 40.4 | 41.8 | 40.7 | 42.4 | 41.5 | 42 | 41.2 | 42.1 | 42.3 | 49.2 | 43 | |
| | 21:00 | 41.1 | 41.8 | 41.8 | 44.2 | 41.7 | 42.2 | 42.3 | 41.7 | 40.9 | 45.2 | 41.9 | 41.6 | 42.4 | |
| | 22:00 | 41.9 | 41.8 | 42.6 | 42.8 | 42.9 | 42.8 | 41.4 | 42.2 | 40.7 | 40.9 | 41.3 | 43.3 | 42.1 | |
| | 23:00 | 44.6 | 43.3 | 43.2 | 42.7 | 42 | 42.6 | 41.5 | 43.5 | 41.8 | 42.5 | 42.6 | 43.7 | 42.9 | |
| | 0:00 | 44.7 | 48.1 | 41.5 | 41.3 | 54.4 | 40.8 | 41.6 | 42.3 | 42.5 | 44.2 | 42.1 | 41.1 | 46.3 | |
| | 1:00 | 41 | 40.9 | 45.4 | 40.9 | 40.5 | 43.4 | 47.5 | 40.5 | 40.6 | 40.4 | 41.7 | 42.3 | 42.7 | |
| | 2:00 | 41 | 41.4 | 40.4 | 40.6 | 39.6 | 39.2 | 39.7 | 39.7 | 39.8 | 39.9 | 40.3 | 40.6 | 40.2 | |
| | 3:00 | 40.5 | 40.3 | 40 | 40 | 38.9 | 39.6 | 39.2 | 39.5 | 39 | 39.5 | 39.6 | 39.4 | 39.6 | |
| | 4:00 | 40.1 | 40 | 40 | 39.7 | 39.9 | 39.3 | 45.8 | 39.6 | 39.3 | 39.2 | 39.5 | 39.2 | 40.7 | |
| | 5:00 | 39.8 | 39.8 | 39.9 | 39.6 | 41.7 | 43.8 | 41.1 | 40 | 39.9 | 40.3 | 40.5 | 40 | 40.7 | |
| | 6:00 | 41.4 | 42.4 | 42.7 | 42.6 | 41.7 | 43.9 | 45.4 | 48 | 44.2 | 47.4 | 42.5 | 49.6 | 45.2 | |
| | 7:00 | 44.6 | 48.9 | 45.9 | 55.5 | 57 | 53.8 | 55.1 | 62.8 | 63.7 | 57.8 | 56.5 | 58.5 | 58 | 62.7 |
| | 8:00 | 62.9 | 62.6 | 63 | 62.9 | 62.4 | 62.3 | 62.1 | 62 | 62.5 | 61.7 | 70.1 | 69.6 | 64.9 | |
| | 9:00 | 62.2 | 63.4 | 61.2 | 63.6 | 61.4 | 60.8 | 61.9 | 61.7 | 62.1 | 61.2 | 61.6 | 64.3 | 62.3 | |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 30-Sep-24 | 10:00 | 63.4 | 63.2 | 62.5 | 64.2 | 63.6 | 62.7 | 63.1 | 63 | 62.3 | 64.2 | 63.2 | 62.5 | 63.2 | |
| | 11:00 | 62.3 | 63.5 | 62 | 63.4 | 62.1 | 62.3 | 62.1 | 63.3 | 63.9 | 63.2 | 63.5 | 62.3 | 62.9 | |
| | 12:00 | 61.3 | 61.3 | 61.3 | 62.5 | 61.7 | 61.5 | 60.1 | 59.1 | 60.8 | 58.7 | 58.4 | 58.8 | 60.7 | |
| | 13:00 | 59 | 58.5 | 61.7 | 64.7 | 63 | 62.3 | 62 | 63.7 | 63.2 | 61.5 | 62.3 | 61.3 | 62.2 | |
| | 14:00 | 60.8 | 60.7 | 60.2 | 61 | 60 | 59.8 | 70.1 | 73.7 | 75.1 | 59 | 65.2 | 62.7 | 68.1 | |
| | 15:00 | 62.2 | 63.6 | 62 | 62.1 | 61.8 | 62 | 61.4 | 60.1 | 62.7 | 62.5 | 60.7 | 60 | 61.9 | |
| | 16:00 | 60.3 | 59.6 | 61.7 | 61 | 59.9 | 56.1 | 58 | 56.6 | 57.8 | 60 | 59.5 | 63.1 | 59.9 | |
| | 17:00 | 61.4 | 59.6 | 62.5 | 60.7 | 59.3 | 59.9 | 59.7 | 57.8 | 56.8 | 53.4 | 54.3 | 55.6 | 59.2 | |
| | 18:00 | 55.2 | 56.1 | 55.1 | 57.1 | 57.5 | 46.6 | 45.5 | 52.6 | 52.6 | 45.4 | 56.8 | 58.8 | 55.1 | |
| | 19:00 | 55.3 | 47.1 | 56.5 | 48.3 | 56.8 | 59.3 | 53 | 54.4 | 57.5 | 56.2 | 56 | 56.2 | 55.7 | 50.2 |
| | 20:00 | 56.4 | 54.3 | 54 | 56.1 | 60.1 | 57.5 | 54.9 | 57.5 | 50.4 | 52.7 | 52.7 | 56.7 | 56 | |
| | 21:00 | 59.2 | 60.4 | 45.9 | 46 | 46.5 | 45.6 | 45.9 | 48.5 | 45.3 | 48.2 | 46.1 | 44.7 | 52.9 | |
| | 22:00 | 44.7 | 45 | 45.9 | 45.8 | 46.1 | 45.1 | 45.5 | 45.7 | 44.8 | 45 | 45.3 | 45.7 | 45.4 | |
| | 23:00 | 45.7 | 45.3 | 45.2 | 45 | 44.8 | 44.7 | 51.4 | 47.6 | 45 | 45 | 46 | 45.7 | 46.5 | |
| 1-Oct-24 | 0:00 | 46 | 46.4 | 46.6 | 46 | 45.7 | 45.7 | 45.5 | 45.2 | 45.2 | 45.4 | 45.3 | 45.8 | 45.8 | |
| | 1:00 | 48 | 45.2 | 46.1 | 44.5 | 44 | 43.9 | 45.7 | 47.1 | 46.8 | 44.2 | 48.4 | 44.7 | 46 | |
| | 2:00 | 44.3 | 44.1 | 44.6 | 44.2 | 44.4 | 44 | 43.9 | 44.2 | 44.1 | 44.2 | 44.3 | 44.2 | 44.2 | |
| | 3:00 | 43.9 | 44.1 | 44.2 | 44.1 | 45.4 | 45.8 | 45.4 | 43.7 | 44.4 | 45 | 45.3 | 45.4 | 44.8 | |
| | 4:00 | 45.5 | 45.1 | 44.8 | 45.1 | 45.1 | 45.5 | 45.6 | 43.8 | 43.7 | 43.6 | 43.7 | 43.4 | 44.7 | |
| | 5:00 | 43.4 | 43.7 | 44.2 | 43.8 | 44 | 44.8 | 44.6 | 44.5 | 44.2 | 43.9 | 43.8 | 43.9 | 44.1 | |
| | 6:00 | 44.2 | 44.8 | 45.1 | 45.4 | 44.7 | 46 | 44.4 | 44 | 45 | 46.3 | 45.7 | 46.2 | 45.2 | |
| | 7:00 | 45.4 | 45 | 44.9 | 45.6 | 46.3 | 46.5 | 45.8 | 46.4 | 47.7 | 49.2 | 47.6 | 48.3 | 46.8 | 58.1 |
| | 8:00 | 48.4 | 48.9 | 49.4 | 48.6 | 49.1 | 50.5 | 52 | 53.3 | 51.9 | 58 | 52.8 | 57.1 | 52.9 | |
| | 9:00 | 54.1 | 58.6 | 58.6 | 57.3 | 58.2 | 58 | 57.6 | 58.7 | 57.7 | 58.8 | 58.3 | 55.8 | 57.8 | |
| | 10:00 | 56.7 | 58.3 | 58.6 | 56.7 | 56.4 | 59 | 55.6 | 55.8 | 60.6 | 58.6 | 57.9 | 56.3 | 57.8 | |
| | 11:00 | 54.2 | 53.7 | 52.7 | 58.5 | 60.7 | 61.3 | 54.6 | 55.4 | 54 | 57 | 57.2 | 55.8 | 57.1 | |
| | 12:00 | 51.9 | 51.9 | 54.2 | 53.3 | 52.9 | 53.4 | 61.3 | 54.8 | 52.1 | 52.5 | 51.9 | 51.9 | 54.6 | |
| | 13:00 | 51.8 | 53.3 | 54.1 | 54.5 | 60.6 | 56.9 | 61.3 | 61.6 | 61 | 61.2 | 61.5 | 61.9 | 59.6 | |
| | 14:00 | 63.1 | 64.6 | 62.2 | 63 | 61.6 | 61.9 | 61.7 | 61.9 | 62.9 | 62.5 | 64 | 63.7 | 62.9 | |
| | 15:00 | 62 | 59.8 | 56.9 | 61 | 61.2 | 57 | 55.9 | 54.9 | 56.7 | 56.8 | 57.8 | 56.1 | 58.6 | |
| | 16:00 | 54.8 | 56.6 | 52.1 | 57.7 | 56.1 | 55.3 | 58.6 | 56.2 | 55.2 | 57 | 57.2 | 57.4 | 56.5 | |
| | 17:00 | 64.3 | 55.9 | 59.9 | 64.5 | 59.8 | 61 | 60.7 | 61.6 | 61.4 | 57.2 | 56.1 | 54.5 | 60.8 | |
| | 18:00 | 54.8 | 53.1 | 51.7 | 52.5 | 52.5 | 52.3 | 57.3 | 56.1 | 51.9 | 55.3 | 51.4 | 51 | 53.8 | |
| | 19:00 | 58 | 59.8 | 61.1 | 52.6 | 51.1 | 58.1 | 51.3 | 52.5 | 51 | 51.3 | 48.9 | 49.1 | 55.8 | 50.5 |
| | 20:00 | 50.5 | 50.2 | 49.4 | 49.3 | 50.5 | 49 | 49.3 | 49.6 | 49.5 | 47.8 | 48.1 | 48.1 | 49.4 | |
| | 21:00 | 52.9 | 48.9 | 53.8 | 50.9 | 49.1 | 56 | 53 | 50.3 | 50.8 | 49.1 | 49.1 | 52.5 | 52 | |
| | 22:00 | 52.5 | 51.6 | 52.4 | 52.2 | 52.3 | 52.4 | 50.2 | 50.9 | 51 | 51.3 | 51.2 | 51.3 | 51.6 | |
| | 23:00 | 50.1 | 47.6 | 48.5 | 50.6 | 48.9 | 50.8 | 52.1 | 54.3 | 51.7 | 51.7 | 51.5 | 51.5 | 51.1 | |
| 2-Oct-24 | 0:00 | 51.5 | 48.7 | 48.3 | 48.3 | 48.7 | 49 | 49.1 | 48.7 | 47.8 | 49.1 | 48.7 | 47.7 | 48.9 | |
| | 1:00 | 48.3 | 49.1 | 48.5 | 48.1 | 48.2 | 48.3 | 47.9 | 49.1 | 47.8 | 49.5 | 50 | 49.9 | 48.8 | |
| | 2:00 | 47.5 | 47.1 | 46.5 | 47.3 | 48.7 | 48 | 48.1 | 50.9 | 47.6 | 47 | 48.5 | 48.9 | 48.2 | |
| | 3:00 | 49.4 | 48.7 | 47.2 | 47.2 | 47.4 | 47.1 | 47.4 | 47.5 | 47.4 | 47.5 | 47.3 | 47.3 | 47.7 | |
| | 4:00 | 47.5 | 47.5 | 46.6 | 46.3 | 46.4 | 46.2 | 47.5 | 46.5 | 46.2 | 46.1 | 46 | 46 | 46.6 | |
| | 5:00 | 45.7 | 45.7 | 45.8 | 46.5 | 46.3 | 46.4 | 46.4 | 46.7 | 45.9 | 46.5 | 46.3 | 46.6 | 46.3 | |
| | 6:00 | 47.2 | 47.2 | 46.7 | 46.6 | 46.7 | 53.8 | 47.6 | 46.9 | 47.6 | 47.1 | 48.1 | 47.5 | 48.4 | |
| | 7:00 | | | | | | | | | | | | | | |
| | 8:00 | | | | | | | | | | | | | | |
| | 9:00 | | | | | | | | | | | | | | |
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| | 20:00 | | | | | | | | | | | | | | |
| | 21:00 | | | | | | | | | | | | | | |
| | 22:00 | | | | | | | | | | | | | | |
| | 23:00 | | | | | | | | | | | | | | |

# Appendix D

## In-situ Water Quality Results

| Site | Tide | Date Time | Date | Time | pH | Temperature (°C) | DO (mg/L) | Turbidity (NTU) | Salinity (PSU) | Depth (m) |
|---|---|---|---|---|---|---|---|---|---|---|
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:29 | 7.80 | 30.67 | 6.23 | 4.34 | 26.43 | 1.16 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:30 | 7.81 | 30.68 | 6.23 | 4.27 | 26.43 | 1.18 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:31 | 7.81 | 30.68 | 6.23 | 4.20 | 26.43 | 1.20 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:32 | 7.86 | 30.70 | 6.19 | 4.28 | 26.43 | 1.07 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:33 | 7.86 | 30.70 | 6.18 | 4.29 | 26.43 | 1.07 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:34 | 7.87 | 30.71 | 6.18 | 4.29 | 26.43 | 1.07 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:35 | 7.89 | 30.74 | 6.09 | 4.20 | 26.49 | 1.47 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:36 | 7.89 | 30.74 | 6.09 | 4.20 | 26.49 | 1.48 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:37 | 7.89 | 30.74 | 6.08 | 4.19 | 26.50 | 1.50 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:38 | 7.90 | 30.69 | 6.01 | 5.05 | 26.67 | 2.11 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:39 | 7.90 | 30.69 | 6.01 | 5.09 | 26.68 | 2.15 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:40 | 7.90 | 30.69 | 6.00 | 5.14 | 26.69 | 2.19 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:41 | 7.90 | 30.66 | 5.87 | 5.87 | 26.80 | 2.61 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:42 | 7.90 | 30.65 | 5.86 | 5.92 | 26.81 | 2.64 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:43 | 7.90 | 30.65 | 5.85 | 5.98 | 26.82 | 2.68 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:44 | 7.90 | 30.65 | 5.85 | 6.04 | 26.83 | 2.71 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:45 | 7.91 | 30.65 | 5.73 | 5.70 | 26.84 | 2.95 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:46 | 7.91 | 30.65 | 5.73 | 5.70 | 26.85 | 2.97 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:47 | 7.91 | 30.65 | 5.72 | 5.70 | 26.85 | 2.99 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:48 | 7.91 | 30.65 | 5.67 | 5.96 | 26.89 | 3.30 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:49 | 7.91 | 30.65 | 5.66 | 5.96 | 26.89 | 3.33 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:50 | 7.91 | 30.65 | 5.66 | 5.97 | 26.90 | 3.35 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:51 | 7.91 | 30.64 | 5.57 | 6.46 | 26.98 | 3.72 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:52 | 7.91 | 30.64 | 5.56 | 6.49 | 26.99 | 3.74 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:53 | 7.91 | 30.64 | 5.56 | 6.52 | 26.99 | 3.77 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:54 | 7.91 | 30.63 | 5.51 | 6.85 | 27.05 | 4.43 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:55 | 7.91 | 30.63 | 5.51 | 6.88 | 27.05 | 4.47 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:56 | 7.91 | 30.63 | 5.50 | 6.91 | 27.06 | 4.51 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:57 | 7.92 | 30.61 | 5.44 | 7.11 | 27.20 | 4.95 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:58 | 7.92 | 30.61 | 5.43 | 7.13 | 27.21 | 4.99 |
| WQ01 | Flood | 3/10/2024 10:08 | 03-Oct-24 | 10:08:59 | 7.92 | 30.61 | 5.43 | 7.15 | 27.22 | 5.02 |
| WQ01 | Flood | 3/10/2024 10:09 | 03-Oct-24 | 10:09:00 | 7.92 | 30.59 | 5.41 | 6.41 | 27.28 | 5.85 |
| WQ01 | Flood | 3/10/2024 10:09 | 03-Oct-24 | 10:09:01 | 7.92 | 30.59 | 5.40 | 6.38 | 27.28 | 5.90 |
| WQ01 | Flood | 3/10/2024 10:09 | 03-Oct-24 | 10:09:02 | 7.92 | 30.59 | 5.40 | 6.34 | 27.29 | 5.95 |
| WQ01 | Flood | 3/10/2024 10:09 | 03-Oct-24 | 10:09:03 | 7.92 | 30.58 | 5.35 | 8.17 | 27.38 | 6.43 |
| WQ01 | Flood | 3/10/2024 10:09 | 03-Oct-24 | 10:09:04 | 7.92 | 30.58 | 5.35 | 8.25 | 27.38 | 6.48 |
| WQ01 | Flood | 3/10/2024 10:09 | 03-Oct-24 | 10:09:05 | 7.92 | 30.58 | 5.35 | 8.33 | 27.39 | 6.52 |
| WQ01 | Flood | 3/10/2024 10:09 | 03-Oct-24 | 10:09:06 | 7.92 | 30.58 | 5.28 | 8.07 | 27.42 | 7.02 |
| WQ01 | Flood | 3/10/2024 10:09 | 03-Oct-24 | 10:09:07 | 7.92 | 30.58 | 5.28 | 8.10 | 27.43 | 7.05 |
| WQ01 | Flood | 3/10/2024 10:09 | 03-Oct-24 | 10:09:08 | 7.92 | 30.58 | 5.27 | 8.12 | 27.43 | 7.09 |
| WQ01 | Flood | 3/10/2024 10:09 | 03-Oct-24 | 10:09:09 | 7.92 | 30.58 | 5.27 | 8.15 | 27.44 | 7.12 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:22 | 7.78 | 30.81 | 6.23 | 4.33 | 26.38 | 1.17 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:23 | 7.79 | 30.81 | 6.23 | 4.24 | 26.38 | 1.21 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:24 | 7.80 | 30.81 | 6.23 | 4.16 | 26.38 | 1.25 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:25 | 7.81 | 30.81 | 6.23 | 4.07 | 26.38 | 1.29 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:26 | 7.85 | 30.81 | 6.24 | 7.15 | 26.40 | 1.62 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:27 | 7.85 | 30.81 | 6.24 | 7.30 | 26.40 | 1.66 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:28 | 7.86 | 30.81 | 6.24 | 7.44 | 26.40 | 1.69 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:29 | 7.90 | 30.81 | 6.23 | 19.93 | 26.41 | 2.40 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:30 | 7.90 | 30.80 | 6.23 | 20.63 | 26.41 | 2.44 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:31 | 7.90 | 30.80 | 6.23 | 21.33 | 26.42 | 2.49 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:32 | 7.92 | 30.75 | 6.20 | 8.45 | 26.76 | 2.49 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:33 | 7.92 | 30.75 | 6.20 | 8.04 | 26.77 | 2.51 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:34 | 7.92 | 30.74 | 6.20 | 7.63 | 26.79 | 2.52 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:35 | 7.93 | 30.73 | 6.14 | 5.21 | 26.68 | 3.04 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:36 | 7.93 | 30.72 | 6.14 | 4.80 | 26.68 | 3.06 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:37 | 7.93 | 30.72 | 6.13 | 4.39 | 26.68 | 3.09 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:38 | 7.92 | 30.71 | 6.01 | 6.10 | 26.90 | 3.22 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:39 | 7.92 | 30.71 | 6.01 | 6.14 | 26.91 | 3.24 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:40 | 7.92 | 30.70 | 6.00 | 6.17 | 26.92 | 3.25 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:41 | 7.91 | 30.70 | 5.90 | 6.41 | 26.94 | 3.93 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:42 | 7.91 | 30.70 | 5.89 | 6.45 | 26.95 | 3.97 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:43 | 7.91 | 30.70 | 5.88 | 6.50 | 26.96 | 4.01 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:44 | 7.91 | 30.67 | 5.72 | 6.97 | 27.10 | 4.33 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:45 | 7.91 | 30.67 | 5.71 | 7.00 | 27.11 | 4.36 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:46 | 7.91 | 30.67 | 5.70 | 7.04 | 27.12 | 4.39 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:47 | 7.90 | 30.65 | 5.60 | 7.89 | 27.25 | 4.65 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:48 | 7.90 | 30.65 | 5.59 | 7.95 | 27.26 | 4.67 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:49 | 7.90 | 30.65 | 5.58 | 8.01 | 27.27 | 4.69 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:50 | 7.90 | 30.62 | 5.45 | 8.46 | 27.33 | 5.30 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:51 | 7.90 | 30.62 | 5.45 | 8.50 | 27.34 | 5.34 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:52 | 7.90 | 30.62 | 5.44 | 8.54 | 27.34 | 5.38 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:53 | 7.91 | 30.58 | 5.33 | 11.08 | 27.57 | 5.79 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:54 | 7.91 | 30.58 | 5.32 | 11.22 | 27.58 | 5.82 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:55 | 7.91 | 30.58 | 5.31 | 11.37 | 27.59 | 5.86 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:56 | 7.92 | 30.52 | 5.27 | 22.36 | 27.83 | 6.07 |

| Site | Tide | Date Time | Date | Time | pH | Temperature (°C) | DO (mg/L) | Turbidity (NTU) | Salinity (PSU) | Depth (m) |
|---|---|---|---|---|---|---|---|---|---|---|
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:57 | 7.92 | 30.52 | 5.27 | 23.00 | 27.84 | 6.09 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:58 | 7.92 | 30.52 | 5.27 | 23.64 | 27.86 | 6.11 |
| WQ02 | Flood | 3/10/2024 10:19 | 03-Oct-24 | 10:19:59 | 7.92 | 30.50 | 5.23 | 11.94 | 28.04 | 6.88 |
| WQ02 | Flood | 3/10/2024 10:20 | 03-Oct-24 | 10:20:00 | 7.92 | 30.50 | 5.23 | 11.54 | 28.05 | 6.92 |
| WQ02 | Flood | 3/10/2024 10:20 | 03-Oct-24 | 10:20:01 | 7.92 | 30.49 | 5.23 | 11.13 | 28.07 | 6.97 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:30 | 7.88 | 30.67 | 5.71 | 8.55 | 26.77 | 1.51 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:31 | 7.88 | 30.67 | 5.71 | 8.56 | 26.77 | 1.50 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:32 | 7.89 | 30.67 | 5.71 | 8.57 | 26.77 | 1.50 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:33 | 7.89 | 30.67 | 5.70 | 8.58 | 26.77 | 1.50 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:34 | 7.91 | 30.66 | 5.72 | 7.03 | 26.65 | 1.55 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:35 | 7.92 | 30.66 | 5.71 | 7.00 | 26.65 | 1.55 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:36 | 7.92 | 30.66 | 5.71 | 6.97 | 26.65 | 1.54 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:37 | 7.92 | 30.66 | 5.71 | 6.94 | 26.65 | 1.54 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:38 | 7.92 | 30.66 | 5.71 | 6.91 | 26.65 | 1.54 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:39 | 7.92 | 30.66 | 5.71 | 6.88 | 26.65 | 1.53 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:40 | 7.92 | 30.66 | 5.71 | 6.85 | 26.64 | 1.53 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:41 | 7.94 | 30.67 | 5.74 | 6.83 | 26.66 | 2.73 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:42 | 7.94 | 30.67 | 5.74 | 6.81 | 26.66 | 2.76 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:43 | 7.94 | 30.67 | 5.74 | 6.80 | 26.66 | 2.79 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:44 | 7.94 | 30.67 | 5.74 | 6.78 | 26.66 | 2.82 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:45 | 7.95 | 30.67 | 5.74 | 6.77 | 26.66 | 2.84 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:46 | 7.95 | 30.67 | 5.74 | 6.75 | 26.66 | 2.87 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:47 | 7.95 | 30.67 | 5.74 | 6.74 | 26.66 | 2.90 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:48 | 7.94 | 30.68 | 5.59 | 10.00 | 26.94 | 3.72 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:49 | 7.94 | 30.68 | 5.59 | 10.08 | 26.94 | 3.75 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:50 | 7.94 | 30.68 | 5.58 | 10.15 | 26.95 | 3.78 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:51 | 7.94 | 30.68 | 5.58 | 10.23 | 26.96 | 3.82 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:52 | 7.94 | 30.68 | 5.58 | 10.30 | 26.96 | 3.85 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:53 | 7.94 | 30.68 | 5.57 | 10.38 | 26.97 | 3.88 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:54 | 7.94 | 30.68 | 5.57 | 10.45 | 26.98 | 3.91 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:55 | 7.94 | 30.68 | 5.57 | 10.52 | 26.98 | 3.94 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:56 | 7.93 | 30.63 | 5.37 | 9.85 | 27.15 | 5.06 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:57 | 7.93 | 30.63 | 5.37 | 9.87 | 27.16 | 5.10 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:58 | 7.93 | 30.63 | 5.36 | 9.89 | 27.16 | 5.13 |
| WQ03 | Flood | 3/10/2024 10:29 | 03-Oct-24 | 10:29:59 | 7.93 | 30.63 | 5.36 | 9.90 | 27.17 | 5.17 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:00 | 7.93 | 30.63 | 5.35 | 9.92 | 27.18 | 5.20 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:01 | 7.93 | 30.63 | 5.34 | 9.94 | 27.18 | 5.24 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:02 | 7.93 | 30.63 | 5.34 | 9.96 | 27.19 | 5.27 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:03 | 7.92 | 30.62 | 5.19 | 14.40 | 27.53 | 3.98 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:04 | 7.92 | 30.62 | 5.18 | 14.49 | 27.54 | 3.97 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:05 | 7.91 | 30.62 | 5.18 | 14.59 | 27.55 | 3.95 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:06 | 7.91 | 30.62 | 5.17 | 14.68 | 27.56 | 3.93 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:07 | 7.91 | 30.62 | 5.17 | 14.78 | 27.57 | 3.92 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:08 | 7.91 | 30.62 | 5.16 | 14.87 | 27.57 | 3.90 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:09 | 7.91 | 30.62 | 5.16 | 14.96 | 27.58 | 3.88 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:10 | 7.91 | 30.55 | 5.01 | 11.69 | 27.31 | 4.64 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:11 | 7.91 | 30.55 | 5.01 | 11.66 | 27.31 | 4.64 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:12 | 7.91 | 30.54 | 5.00 | 11.63 | 27.30 | 4.65 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:13 | 7.91 | 30.54 | 5.00 | 11.59 | 27.30 | 4.65 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:14 | 7.91 | 30.54 | 4.99 | 11.56 | 27.30 | 4.66 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:15 | 7.91 | 30.54 | 4.99 | 11.53 | 27.29 | 4.67 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:16 | 7.91 | 30.54 | 4.98 | 11.50 | 27.29 | 4.67 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:17 | 7.91 | 30.54 | 4.98 | 11.46 | 27.29 | 4.68 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:18 | 7.91 | 30.60 | 4.89 | 14.34 | 27.55 | 5.11 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:19 | 7.91 | 30.60 | 4.88 | 14.38 | 27.56 | 5.13 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:20 | 7.91 | 30.60 | 4.88 | 14.41 | 27.56 | 5.15 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:21 | 7.91 | 30.60 | 4.88 | 14.44 | 27.56 | 5.16 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:22 | 7.91 | 30.61 | 4.87 | 14.48 | 27.57 | 5.18 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:23 | 7.91 | 30.61 | 4.87 | 14.51 | 27.57 | 5.20 |
| WQ03 | Flood | 3/10/2024 10:30 | 03-Oct-24 | 10:30:24 | 7.91 | 30.61 | 4.86 | 14.54 | 27.57 | 5.22 |
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:25 | 7.95 | 30.73 | 6.27 | 3.98 | 26.52 | 1.23 |
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:26 | 7.95 | 30.73 | 6.28 | 3.99 | 26.52 | 1.26 |
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:27 | 7.95 | 30.73 | 6.28 | 4.00 | 26.52 | 1.29 |
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:28 | 7.96 | 30.73 | 6.28 | 4.00 | 26.51 | 1.32 |
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:29 | 7.96 | 30.72 | 6.27 | 4.17 | 26.72 | 1.75 |
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:30 | 7.96 | 30.72 | 6.27 | 4.18 | 26.73 | 1.78 |
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:31 | 7.96 | 30.72 | 6.27 | 4.19 | 26.74 | 1.81 |
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:32 | 7.95 | 30.70 | 6.22 | 4.30 | 26.77 | 2.48 |
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:33 | 7.95 | 30.70 | 6.22 | 4.31 | 26.78 | 2.53 |
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:34 | 7.95 | 30.70 | 6.21 | 4.32 | 26.79 | 2.57 |
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:35 | 7.94 | 30.71 | 6.10 | 4.51 | 26.81 | 2.98 |
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:36 | 7.94 | 30.71 | 6.09 | 4.52 | 26.81 | 3.01 |
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:37 | 7.94 | 30.71 | 6.08 | 4.54 | 26.81 | 3.04 |
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:38 | 7.93 | 30.71 | 6.02 | 4.45 | 26.83 | 3.69 |
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:39 | 7.93 | 30.71 | 6.02 | 4.45 | 26.83 | 3.74 |
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:40 | 7.93 | 30.71 | 6.01 | 4.44 | 26.83 | 3.78 |

| Site | Tide | Date Time | Date | Time | pH | Temperature (°C) | DO (mg/L) | Turbidity (NTU) | Salinity (PSU) | Depth (m) |
|---|---|---|---|---|---|---|---|---|---|---|
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:41 | 7.93 | 30.71 | 5.87 | 5.20 | 26.87 | 4.18 |
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:42 | 7.93 | 30.71 | 5.86 | 5.24 | 26.87 | 4.21 |
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:43 | 7.92 | 30.71 | 5.85 | 5.27 | 26.87 | 4.25 |
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:44 | 7.92 | 30.71 | 5.74 | 5.83 | 26.91 | 4.75 |
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:45 | 7.92 | 30.71 | 5.73 | 5.88 | 26.91 | 4.78 |
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:46 | 7.92 | 30.71 | 5.72 | 5.92 | 26.91 | 4.81 |
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:47 | 7.92 | 30.70 | 5.66 | 5.94 | 27.00 | 5.33 |
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:48 | 7.92 | 30.70 | 5.65 | 5.95 | 27.00 | 5.37 |
| WQ04 | Flood | 3/10/2024 10:45 | 03-Oct-24 | 10:45:49 | 7.92 | 30.70 | 5.65 | 5.96 | 27.01 | 5.41 |
| WQ01 | Ebb | 3/10/2024 13:19 | 03-Oct-24 | 13:19:52 | 7.78 | 30.60 | 5.72 | 7.63 | 26.61 | 1.22 |
| WQ01 | Ebb | 3/10/2024 13:19 | 03-Oct-24 | 13:19:53 | 7.79 | 30.60 | 5.71 | 7.65 | 26.62 | 1.27 |
| WQ01 | Ebb | 3/10/2024 13:19 | 03-Oct-24 | 13:19:54 | 7.80 | 30.60 | 5.71 | 7.68 | 26.62 | 1.32 |
| WQ01 | Ebb | 3/10/2024 13:19 | 03-Oct-24 | 13:19:55 | 7.86 | 30.59 | 5.61 | 6.81 | 27.43 | 1.30 |
| WQ01 | Ebb | 3/10/2024 13:19 | 03-Oct-24 | 13:19:56 | 7.87 | 30.59 | 5.60 | 6.78 | 27.47 | 1.32 |
| WQ01 | Ebb | 3/10/2024 13:19 | 03-Oct-24 | 13:19:57 | 7.87 | 30.59 | 5.60 | 6.74 | 27.52 | 1.33 |
| WQ01 | Ebb | 3/10/2024 13:19 | 03-Oct-24 | 13:19:58 | 7.88 | 30.59 | 5.57 | 7.26 | 27.52 | 2.24 |
| WQ01 | Ebb | 3/10/2024 13:19 | 03-Oct-24 | 13:19:59 | 7.88 | 30.59 | 5.57 | 7.26 | 27.54 | 2.28 |
| WQ01 | Ebb | 3/10/2024 13:20 | 03-Oct-24 | 13:20:00 | 7.89 | 30.59 | 5.56 | 7.27 | 27.56 | 2.33 |
| WQ01 | Ebb | 3/10/2024 13:20 | 03-Oct-24 | 13:20:01 | 7.91 | 30.58 | 5.51 | 7.43 | 27.54 | 2.56 |
| WQ01 | Ebb | 3/10/2024 13:20 | 03-Oct-24 | 13:20:02 | 7.91 | 30.58 | 5.51 | 7.45 | 27.54 | 2.59 |
| WQ01 | Ebb | 3/10/2024 13:20 | 03-Oct-24 | 13:20:03 | 7.91 | 30.58 | 5.50 | 7.47 | 27.54 | 2.63 |
| WQ01 | Ebb | 3/10/2024 13:20 | 03-Oct-24 | 13:20:04 | 7.92 | 30.58 | 5.48 | 8.29 | 27.55 | 3.37 |
| WQ01 | Ebb | 3/10/2024 13:20 | 03-Oct-24 | 13:20:05 | 7.92 | 30.58 | 5.48 | 8.34 | 27.55 | 3.42 |
| WQ01 | Ebb | 3/10/2024 13:20 | 03-Oct-24 | 13:20:06 | 7.92 | 30.58 | 5.48 | 8.38 | 27.55 | 3.46 |
| WQ01 | Ebb | 3/10/2024 13:20 | 03-Oct-24 | 13:20:07 | 7.93 | 30.57 | 5.45 | 8.28 | 27.55 | 3.62 |
| WQ01 | Ebb | 3/10/2024 13:20 | 03-Oct-24 | 13:20:08 | 7.93 | 30.57 | 5.45 | 8.29 | 27.55 | 3.64 |
| WQ01 | Ebb | 3/10/2024 13:20 | 03-Oct-24 | 13:20:09 | 7.93 | 30.57 | 5.45 | 8.30 | 27.55 | 3.67 |
| WQ01 | Ebb | 3/10/2024 13:20 | 03-Oct-24 | 13:20:10 | 7.93 | 30.57 | 5.41 | 7.28 | 27.54 | 4.63 |
| WQ01 | Ebb | 3/10/2024 13:20 | 03-Oct-24 | 13:20:11 | 7.93 | 30.57 | 5.41 | 7.23 | 27.54 | 4.69 |
| WQ01 | Ebb | 3/10/2024 13:20 | 03-Oct-24 | 13:20:12 | 7.94 | 30.57 | 5.41 | 7.17 | 27.54 | 4.74 |
| WQ01 | Ebb | 3/10/2024 13:20 | 03-Oct-24 | 13:20:13 | 7.94 | 30.53 | 5.39 | 7.57 | 27.66 | 4.10 |
| WQ01 | Ebb | 3/10/2024 13:20 | 03-Oct-24 | 13:20:14 | 7.94 | 30.53 | 5.38 | 7.57 | 27.66 | 4.09 |
| WQ01 | Ebb | 3/10/2024 13:20 | 03-Oct-24 | 13:20:15 | 7.94 | 30.53 | 5.38 | 7.57 | 27.67 | 4.08 |
| WQ01 | Ebb | 3/10/2024 13:20 | 03-Oct-24 | 13:20:16 | 7.95 | 30.52 | 5.37 | 7.78 | 27.60 | 4.00 |
| WQ01 | Ebb | 3/10/2024 13:20 | 03-Oct-24 | 13:20:17 | 7.95 | 30.52 | 5.37 | 7.80 | 27.60 | 3.99 |
| WQ01 | Ebb | 3/10/2024 13:20 | 03-Oct-24 | 13:20:18 | 7.95 | 30.52 | 5.36 | 7.82 | 27.59 | 3.97 |
| WQ01 | Ebb | 3/10/2024 13:20 | 03-Oct-24 | 13:20:19 | 7.95 | 30.54 | 5.36 | 8.19 | 27.59 | 4.80 |
| WQ01 | Ebb | 3/10/2024 13:20 | 03-Oct-24 | 13:20:20 | 7.95 | 30.54 | 5.36 | 8.21 | 27.58 | 4.84 |
| WQ01 | Ebb | 3/10/2024 13:20 | 03-Oct-24 | 13:20:21 | 7.95 | 30.54 | 5.36 | 8.23 | 27.58 | 4.88 |
| WQ01 | Ebb | 3/10/2024 13:20 | 03-Oct-24 | 13:20:22 | 7.95 | 30.53 | 5.34 | 7.58 | 27.64 | 4.89 |
| WQ01 | Ebb | 3/10/2024 13:20 | 03-Oct-24 | 13:20:23 | 7.95 | 30.53 | 5.34 | 7.56 | 27.64 | 4.91 |
| WQ02 | Ebb | 3/10/2024 13:10 | 03-Oct-24 | 13:10:10 | 8.02 | 30.62 | 6.66 | 5.24 | 24.27 | 1.48 |
| WQ02 | Ebb | 3/10/2024 13:10 | 03-Oct-24 | 13:10:11 | 8.02 | 30.63 | 6.66 | 5.28 | 24.28 | 1.49 |
| WQ02 | Ebb | 3/10/2024 13:10 | 03-Oct-24 | 13:10:12 | 8.02 | 30.63 | 6.66 | 5.32 | 24.28 | 1.50 |
| WQ02 | Ebb | 3/10/2024 13:10 | 03-Oct-24 | 13:10:13 | 8.01 | 30.60 | 6.65 | 5.14 | 26.73 | 2.41 |
| WQ02 | Ebb | 3/10/2024 13:10 | 03-Oct-24 | 13:10:14 | 8.01 | 30.59 | 6.64 | 5.17 | 26.73 | 2.46 |
| WQ02 | Ebb | 3/10/2024 13:10 | 03-Oct-24 | 13:10:15 | 8.01 | 30.59 | 6.64 | 5.19 | 26.73 | 2.50 |
| WQ02 | Ebb | 3/10/2024 13:10 | 03-Oct-24 | 13:10:16 | 8.01 | 30.61 | 6.55 | 6.23 | 26.98 | 2.48 |
| WQ02 | Ebb | 3/10/2024 13:10 | 03-Oct-24 | 13:10:17 | 8.01 | 30.61 | 6.55 | 6.29 | 27.00 | 2.50 |
| WQ02 | Ebb | 3/10/2024 13:10 | 03-Oct-24 | 13:10:18 | 8.01 | 30.61 | 6.54 | 6.35 | 27.01 | 2.51 |
| WQ02 | Ebb | 3/10/2024 13:10 | 03-Oct-24 | 13:10:19 | 7.98 | 30.59 | 6.45 | 6.63 | 27.07 | 3.39 |
| WQ02 | Ebb | 3/10/2024 13:10 | 03-Oct-24 | 13:10:20 | 7.98 | 30.59 | 6.45 | 6.67 | 27.07 | 3.43 |
| WQ02 | Ebb | 3/10/2024 13:10 | 03-Oct-24 | 13:10:21 | 7.98 | 30.59 | 6.44 | 6.71 | 27.08 | 3.48 |
| WQ02 | Ebb | 3/10/2024 13:10 | 03-Oct-24 | 13:10:22 | 7.96 | 30.62 | 6.23 | 7.36 | 27.25 | 3.49 |
| WQ02 | Ebb | 3/10/2024 13:10 | 03-Oct-24 | 13:10:23 | 7.96 | 30.62 | 6.22 | 7.40 | 27.26 | 3.51 |
| WQ02 | Ebb | 3/10/2024 13:10 | 03-Oct-24 | 13:10:24 | 7.96 | 30.62 | 6.20 | 7.44 | 27.27 | 3.53 |
| WQ02 | Ebb | 3/10/2024 13:10 | 03-Oct-24 | 13:10:25 | 7.96 | 30.56 | 6.13 | 6.64 | 27.32 | 4.51 |
| WQ02 | Ebb | 3/10/2024 13:10 | 03-Oct-24 | 13:10:26 | 7.96 | 30.56 | 6.13 | 6.61 | 27.33 | 4.56 |
| WQ02 | Ebb | 3/10/2024 13:10 | 03-Oct-24 | 13:10:27 | 7.95 | 30.55 | 6.12 | 6.58 | 27.33 | 4.61 |
| WQ02 | Ebb | 3/10/2024 13:10 | 03-Oct-24 | 13:10:28 | 7.95 | 30.53 | 5.94 | 9.56 | 27.52 | 5.42 |
| WQ02 | Ebb | 3/10/2024 13:10 | 03-Oct-24 | 13:10:29 | 7.95 | 30.53 | 5.93 | 9.70 | 27.53 | 5.49 |
| WQ02 | Ebb | 3/10/2024 13:10 | 03-Oct-24 | 13:10:30 | 7.95 | 30.53 | 5.92 | 9.84 | 27.54 | 5.55 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:07 | 7.68 | 30.17 | 6.42 | 3.23 | 27.07 | 0.86 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:08 | 7.80 | 30.27 | 6.42 | 4.72 | 26.80 | 1.00 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:09 | 7.81 | 30.28 | 6.42 | 4.72 | 26.79 | 1.02 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:10 | 7.82 | 30.28 | 6.42 | 4.72 | 26.79 | 1.03 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:11 | 7.85 | 30.29 | 6.42 | 4.12 | 26.77 | 1.64 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:12 | 7.85 | 30.29 | 6.42 | 4.09 | 26.77 | 1.68 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:13 | 7.86 | 30.29 | 6.42 | 4.05 | 26.77 | 1.71 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:14 | 7.90 | 30.36 | 6.42 | 4.49 | 26.77 | 2.69 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:15 | 7.90 | 30.37 | 6.42 | 4.50 | 26.77 | 2.76 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:16 | 7.90 | 30.37 | 6.42 | 4.51 | 26.77 | 2.83 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:17 | 7.91 | 30.38 | 6.40 | 4.46 | 26.77 | 2.84 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:18 | 7.91 | 30.38 | 6.40 | 4.47 | 26.77 | 2.86 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:19 | 7.91 | 30.38 | 6.40 | 4.47 | 26.77 | 2.88 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:20 | 7.93 | 30.44 | 6.38 | 4.92 | 26.79 | 3.64 |

| Site | Tide | Date Time | Date | Time | pH | Temperature (°C) | DO (mg/L) | Turbidity (NTU) | Salinity (PSU) | Depth (m) |
|---|---|---|---|---|---|---|---|---|---|---|
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:21 | 7.93 | 30.44 | 6.38 | 4.95 | 26.79 | 3.68 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:22 | 7.93 | 30.44 | 6.38 | 4.97 | 26.79 | 3.72 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:23 | 7.92 | 30.48 | 6.23 | 5.90 | 27.13 | 3.99 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:24 | 7.92 | 30.48 | 6.22 | 5.96 | 27.15 | 4.02 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:25 | 7.92 | 30.49 | 6.21 | 6.02 | 27.17 | 4.05 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:26 | 7.90 | 30.49 | 6.06 | 7.39 | 27.49 | 4.53 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:27 | 7.90 | 30.49 | 6.05 | 7.49 | 27.52 | 4.56 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:28 | 7.89 | 30.49 | 6.04 | 7.58 | 27.54 | 4.60 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:29 | 7.90 | 30.44 | 5.88 | 7.78 | 27.72 | 5.45 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:30 | 7.90 | 30.43 | 5.87 | 7.82 | 27.74 | 5.51 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:31 | 7.90 | 30.43 | 5.86 | 7.86 | 27.75 | 5.57 |
| WQ03 | Ebb | 3/10/2024 13:00 | 03-Oct-24 | 13:00:32 | 7.90 | 30.43 | 5.84 | 7.89 | 27.77 | 5.62 |
| WQ04 | Ebb | 3/10/2024 12:46 | 03-Oct-24 | 12:46:54 | 7.77 | 30.17 | 6.44 | 3.60 | 26.72 | 0.96 |
| WQ04 | Ebb | 3/10/2024 12:46 | 03-Oct-24 | 12:46:55 | 7.84 | 30.26 | 6.47 | 3.55 | 26.73 | 1.78 |
| WQ04 | Ebb | 3/10/2024 12:46 | 03-Oct-24 | 12:46:56 | 7.85 | 30.26 | 6.48 | 3.55 | 26.73 | 1.83 |
| WQ04 | Ebb | 3/10/2024 12:46 | 03-Oct-24 | 12:46:57 | 7.85 | 30.27 | 6.48 | 3.56 | 26.73 | 1.88 |
| WQ04 | Ebb | 3/10/2024 12:46 | 03-Oct-24 | 12:46:58 | 7.88 | 30.30 | 6.43 | 3.83 | 27.03 | 2.07 |
| WQ04 | Ebb | 3/10/2024 12:46 | 03-Oct-24 | 12:46:59 | 7.88 | 30.31 | 6.43 | 3.84 | 27.05 | 2.10 |
| WQ04 | Ebb | 3/10/2024 12:47 | 03-Oct-24 | 12:47:00 | 7.88 | 30.31 | 6.43 | 3.85 | 27.06 | 2.12 |
| WQ04 | Ebb | 3/10/2024 12:47 | 03-Oct-24 | 12:47:01 | 7.89 | 30.32 | 6.43 | 3.87 | 27.08 | 2.15 |
| WQ04 | Ebb | 3/10/2024 12:47 | 03-Oct-24 | 12:47:02 | 7.85 | 30.41 | 6.28 | 4.79 | 27.13 | 1.06 |
| WQ04 | Ebb | 3/10/2024 12:47 | 03-Oct-24 | 12:47:03 | 7.85 | 30.41 | 6.27 | 4.84 | 27.14 | 1.01 |
| WQ04 | Ebb | 3/10/2024 12:47 | 03-Oct-24 | 12:47:04 | 7.85 | 30.42 | 6.27 | 4.90 | 27.15 | 0.95 |
| WQ04 | Ebb | 3/10/2024 12:47 | 03-Oct-24 | 12:47:05 | 7.87 | 30.42 | 6.18 | 3.72 | 26.74 | 0.84 |
| WQ04 | Ebb | 3/10/2024 12:47 | 03-Oct-24 | 12:47:06 | 7.87 | 30.43 | 6.17 | 3.68 | 26.72 | 0.81 |
| WQ04 | Ebb | 3/10/2024 12:47 | 03-Oct-24 | 12:47:07 | 7.87 | 30.43 | 6.16 | 3.64 | 26.70 | 0.78 |
| WQ04 | Ebb | 3/10/2024 12:47 | 03-Oct-24 | 12:47:08 | 7.91 | 30.43 | 6.19 | 3.62 | 26.67 | 1.22 |
| WQ04 | Ebb | 3/10/2024 12:47 | 03-Oct-24 | 12:47:09 | 7.92 | 30.44 | 6.19 | 3.60 | 26.66 | 1.24 |
| WQ04 | Ebb | 3/10/2024 12:47 | 03-Oct-24 | 12:47:10 | 7.92 | 30.44 | 6.19 | 3.57 | 26.65 | 1.26 |
| WQ04 | Ebb | 3/10/2024 12:47 | 03-Oct-24 | 12:47:11 | 7.94 | 30.45 | 6.29 | 3.44 | 26.66 | 1.46 |
| WQ04 | Ebb | 3/10/2024 12:47 | 03-Oct-24 | 12:47:12 | 7.94 | 30.45 | 6.30 | 3.44 | 26.66 | 1.48 |
| WQ04 | Ebb | 3/10/2024 12:47 | 03-Oct-24 | 12:47:13 | 7.94 | 30.46 | 6.31 | 3.43 | 26.66 | 1.50 |
| WQ04 | Ebb | 3/10/2024 12:47 | 03-Oct-24 | 12:47:14 | 7.94 | 30.49 | 6.34 | 3.62 | 26.66 | 2.33 |
| WQ04 | Ebb | 3/10/2024 12:47 | 03-Oct-24 | 12:47:15 | 7.94 | 30.49 | 6.35 | 3.62 | 26.66 | 2.37 |
| WQ04 | Ebb | 3/10/2024 12:47 | 03-Oct-24 | 12:47:16 | 7.94 | 30.49 | 6.35 | 3.63 | 26.66 | 2.42 |
| WQ04 | Ebb | 3/10/2024 12:47 | 03-Oct-24 | 12:47:17 | 7.91 | 30.61 | 6.27 | 4.82 | 27.06 | 2.46 |
| WQ04 | Ebb | 3/10/2024 12:47 | 03-Oct-24 | 12:47:18 | 7.91 | 30.61 | 6.27 | 4.88 | 27.08 | 2.48 |
| WQ04 | Ebb | 3/10/2024 12:47 | 03-Oct-24 | 12:47:19 | 7.91 | 30.62 | 6.26 | 4.95 | 27.11 | 2.50 |
| WQ04 | Ebb | 3/10/2024 12:47 | 03-Oct-24 | 12:47:20 | 7.89 | 30.62 | 6.04 | 4.91 | 27.23 | 3.24 |
| WQ04 | Ebb | 3/10/2024 12:47 | 03-Oct-24 | 12:47:21 | 7.89 | 30.62 | 6.03 | 4.93 | 27.24 | 3.28 |
| WQ04 | Ebb | 3/10/2024 12:47 | 03-Oct-24 | 12:47:22 | 7.89 | 30.62 | 6.01 | 4.95 | 27.26 | 3.32 |
| WQ04 | Ebb | 3/10/2024 12:47 | 03-Oct-24 | 12:47:23 | 7.88 | 30.59 | 5.91 | 7.70 | 27.55 | 3.95 |

# Appendix E

## Marine Water Quality Laboratory Results

# TEST REPORT

| | | | | | |
|---|---|---|---|---|---|
| Our Reference No. | : | **R240 8464/1** | Date Received | : | 03/10/2024 |
| Project Code / Ref. | : | Keppel Data Centres Holding Pte Ltd | Date Commenced | : | 03/10/2024 |
| | | | Date Reported | : | 14/10/2024 |

Customer Ref. No. : P527466
Customer Name : Singapore Environmental Consultancy and Solutions Pte Ltd
Customer Address : 1 Sunview Road
#08-19
Singapore 627615

Attention To : Ms Chin Wan Li

Sample Description : 16 Seawater samples as per received

**RESULTS** : Refer to Page 2 to Page 4

**Tan Thuan Piang**
**Senior Technical Manager**



**Marchwood Laboratory Services Pte Ltd:** Co. Reg No. : 201422686C
Main (Office and Laboratory): 116 Tuas South Ave 2, West Point Bizhub Singapore 637163 ☎ : +65 6790 0118 Fax : +65 6790 0091
Branch (Site and Laboratory): 216 Tuas South Ave 2, West Point Bizhub Singapore 637213 ☎ : +65 6262 3736 (Lab) ☎ : +65 6262 3726 / 3776 (Site)
Website: www.mls.sg

**RESULTS**

| Test Parameter | Unit | Test Method | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 5 | Sample 6 | LOR |
|---|---|---|---|---|---|---|---|---|---|
| | | | Sampling Date: 03/10/2024 | | | | | | |
| | | | WQ01_F_S | WQ01_F_MD | WQ01_E_S | WQ01_E_MD | WQ02_F_S | WQ02_F_MD | |
| Total Suspended Solids, TSS | mg/L | APHA 2540D | 9.50 | 13.5 | 12.1 | 9.80 | 5.90 | 9.10 | 1 |
| Total Nitrogen, TN | mg/L | APHA 4500-P (J) | 0.44 | 0.42 | 0.34 | 0.51 | 0.40 | 0.48 | 0.01 |
| Total Phosphorus, TP | mg/L | APHA 4500-P (J) | 0.068 | 0.071 | 0.060 | 0.048 | 0.070 | 0.056 | 0.01 |
| Ammonia as NH3-N | mg/L | APHA 4500-NH3 (H) | 0.019 | 0.045 | 0.036 | 0.042 | 0.011 | 0.032 | 0.01 |
| Nitrate as NO3-N | mg/L | APHA 4500-NO3 (I) | 0.073 | 0.064 | 0.060 | 0.058 | 0.050 | 0.053 | 0.01 |
| Phosphate as PO4-P | mg/L | APHA 4500-P (G) | ND | 0.016 | ND | 0.012 | 0.029 | 0.010 | 0.01 |
| Oil & Grease* | mg/L | Accredited In-house Method MLS-SOP-WQ-033 Rev 1 | ND | ND | 1.03 | ND | ND | ND | 1 |
| Chlorophyll-a | µg/L | APHA 10150B | 6.97 | 6.45 | 3.35 | 3.34 | 7.21 | 2.89 | 1 |
| Arsenic as As | µg/L | APHA 3125B | 19.2 | 16.1 | 49.2 | 36.5 | 12.3 | 65.2 | 0.1 |
| Aluminium as Al | µg/L | APHA 3125B | 2.77 | 3.04 | 2.82 | 2.76 | 2.75 | 2.98 | 0.1 |
| Cadmium as Cd | µg/L | APHA 3125B | ND | ND | ND | ND | ND | ND | 0.1 |
| Chromium as Cr | µg/L | APHA 3125B | 1.10 | 2.20 | 0.93 | 0.90 | 0.86 | 1.01 | 0.1 |
| Copper as Cu | µg/L | APHA 3125B | 3.42 | 2.26 | 3.14 | 3.34 | 2.86 | 3.39 | 0.5 |
| Mercury as Hg | µg/L | APHA 3125B | ND | ND | ND | ND | ND | ND | 0.05 |
| Nickel as Ni | µg/L | APHA 3125B | 1.28 | 2.10 | 0.94 | 1.13 | 1.19 | 1.51 | 0.5 |
| Lead as Pb | µg/L | APHA 3125B | 1.07 | 0.46 | 0.43 | 0.40 | 0.18 | 0.33 | 0.1 |
| Zinc as Zn | µg/L | APHA 3125B | 7.09 | 1.44 | 2.30 | 3.72 | 1.54 | 6.62 | 0.5 |
| Biochemical Oxygen Demand, BOD5 | mg/L | APHA 5210B | ND | ND | ND | ND | ND | ND | 1 |
| Faecal Coliform | MPN/100mL | APHA 9221E | 22 | 4.5 | 4 | 49 | 6.8 | 6.8 | 1.8 |
| Enterococcus | cfu/100mL | APHA 9230C | ND | ND | ND | 12 | ND | 2 | 1 |
| E.Coli | MPN/100mL | APHA 9221F | 2 | ND | ND | 2 | ND | ND | 1.8 |

***Note:***

1. APHA is a standard method for Determination of Water and Waste Water (APHA 24th Edition, 2023).
2. LOR = Limit of Reporting. This value may also represent Detection Limit required for the project.
3. ND = Not detected. The data reported is less than the LOR.
4. * = For Oil & Grease TPH by In-house method MLS-SOP-WQ-033 Rev 1 (adapted from APHA 5520C), the qualitative and quantitative tests are based on the Reference Oil recommended in APHA 5520C.

RESULTS

| Test Parameter | Unit | Test Method | Sample 7 | Sample 8 | Sample 9 | Sample 10 | Sample 11 | Sample 12 | LOR |
|---|---|---|---|---|---|---|---|---|---|
| | | | Sampling Date: 03/10/2024 | | | | | | |
| | | | WQ02_E_S | WQ02_E_MD | WQ03_F_S | WQ03_F_MD | WQ03_E_S | WQ03_E_MD | |
| Total Suspended Solids, TSS | mg/L | APHA 2540D | 1.80 | 5.80 | 8.15 | 7.20 | 7.10 | 6.40 | 1 |
| Total Nitrogen, TN | mg/L | APHA 4500-P (J) | 0.39 | 0.48 | 0.43 | 0.39 | 0.37 | 0.44 | 0.01 |
| Total Phosphorus, TP | mg/L | APHA 4500-P (J) | 0.056 | 0.054 | 0.083 | 0.059 | 0.051 | 0.072 | 0.01 |
| Ammonia as NH3-N | mg/L | APHA 4500-NH3 (H) | 0.038 | 0.043 | 0.023 | 0.045 | 0.020 | 0.054 | 0.01 |
| Nitrate as NO3-N | mg/L | APHA 4500-NO3 (I) | 0.051 | 0.057 | 0.064 | 0.066 | 0.048 | 0.060 | 0.01 |
| Phosphate as PO4-P | mg/L | APHA 4500-P (G) | 0.011 | 0.013 | 0.012 | 0.016 | ND | 0.017 | 0.01 |
| Oil & Grease* | mg/L | Accredited In-house Method MLS-SOP-WQ-033 Rev 1 | ND | ND | ND | ND | ND | ND | 1 |
| Chlorophyll-a | µg/L | APHA 10150B | 9.24 | 7.01 | 7.39 | 4.94 | 13.0 | 5.76 | 1 |
| Arsenic as As | µg/L | APHA 3125B | 39.5 | 29.4 | 32.2 | 35.6 | 13.5 | 40.2 | 0.1 |
| Aluminium as Al | µg/L | APHA 3125B | 2.82 | 2.67 | 2.83 | 3.21 | 3.14 | 2.97 | 0.1 |
| Cadmium as Cd | µg/L | APHA 3125B | ND | ND | ND | ND | 0.11 | ND | 0.1 |
| Chromium as Cr | µg/L | APHA 3125B | 0.90 | 0.89 | 0.92 | 1.14 | 0.92 | 1.54 | 0.1 |
| Copper as Cu | µg/L | APHA 3125B | 2.32 | 2.18 | 2.20 | 2.88 | 2.56 | 2.20 | 0.5 |
| Mercury as Hg | µg/L | APHA 3125B | ND | ND | ND | ND | ND | ND | 0.05 |
| Nickel as Ni | µg/L | APHA 3125B | 1.03 | 1.10 | 1.25 | 1.37 | 1.12 | 1.38 | 0.5 |
| Lead as Pb | µg/L | APHA 3125B | 0.21 | 0.12 | 0.16 | 0.15 | 0.29 | 0.20 | 0.1 |
| Zinc as Zn | µg/L | APHA 3125B | 3.25 | ND | 2.56 | 1.76 | 1.47 | 1.69 | 0.5 |
| Biochemical Oxygen Demand, BOD5 | mg/L | APHA 5210B | ND | ND | ND | ND | ND | ND | 1 |
| Faecal Coliform | MPN/100mL | APHA 9221E | 2 | 2 | 1.8 | ND | ND | 2 | 1.8 |
| Enterococcus | cfu/100mL | APHA 9230C | 2 | 4 | ND | 3 | 2 | 3 | 1 |
| E.Coli | MPN/100mL | APHA 9221F | ND | ND | ND | ND | ND | ND | 1.8 |

***Note:***

1. APHA is a standard method for Determination of Water and Waste Water (APHA 24th Edition, 2023).
2. LOR = Limit of Reporting. This value may also represent Detection Limit required for the project.
3. ND = Not detected. The data reported is less than the LOR.
4. * = For Oil & Grease TPH by In-house method MLS-SOP-WQ-033 Rev 1 (adapted from APHA 5520C), the qualitative and quantitative tests are based on the Reference Oil recommended in APHA 5520C.

**RESULTS**

| Test Parameter | Unit | Test Method | Sample 13 | Sample 14 | Sample 15 | Sample 16 | LOR |
|---|---|---|---|---|---|---|---|
| | | | Sampling Date: 03/10/2024 | | | | |
| | | | WQ04_F_S | WQ04_F_MD | WQ04_E_S | WQ04_E_MD | |
| Total Suspended Solids, TSS | mg/L | APHA 2540D | 5.00 | 4.30 | 24.3 | 36.8 | 1 |
| Total Nitrogen, TN | mg/L | APHA 4500-P (J) | 0.37 | 0.39 | 0.37 | 0.38 | 0.01 |
| Total Phosphorus, TP | mg/L | APHA 4500-P (J) | 0.061 | 0.066 | 0.063 | 0.069 | 0.01 |
| Ammonia as NH3-N | mg/L | APHA 4500-NH3 (H) | 0.039 | 0.048 | 0.045 | 0.035 | 0.01 |
| Nitrate as NO3-N | mg/L | APHA 4500-NO3 (I) | 0.065 | 0.064 | 0.077 | 0.055 | 0.01 |
| Phosphate as PO4-P | mg/L | APHA 4500-P (G) | 0.012 | 0.016 | 0.015 | 0.011 | 0.01 |
| Oil & Grease* | mg/L | Accredited In-house Method MLS-SOP-WQ-033 Rev 1 | ND | ND | ND | ND | 1 |
| Chlorophyll-a | µg/L | APHA 10150B | 5.97 | 7.33 | 7.83 | 4.94 | 1 |
| Arsenic as As | µg/L | APHA 3125B | 30.8 | 63.3 | 98.9 | 26.1 | 0.1 |
| Aluminium as Al | µg/L | APHA 3125B | 2.99 | 2.66 | 2.74 | 2.86 | 0.1 |
| Cadmium as Cd | µg/L | APHA 3125B | ND | ND | ND | ND | 0.1 |
| Chromium as Cr | µg/L | APHA 3125B | 0.90 | 0.88 | 1.13 | 1.54 | 0.1 |
| Copper as Cu | µg/L | APHA 3125B | 2.25 | 2.05 | 2.13 | 2.08 | 0.5 |
| Mercury as Hg | µg/L | APHA 3125B | ND | ND | ND | ND | 0.05 |
| Nickel as Ni | µg/L | APHA 3125B | 1.12 | 1.03 | 1.49 | 1.62 | 0.5 |
| Lead as Pb | µg/L | APHA 3125B | 0.11 | 0.14 | 0.12 | 0.12 | 0.1 |
| Zinc as Zn | µg/L | APHA 3125B | 1.13 | 2.46 | 1.86 | 2.16 | 0.5 |
| Biochemical Oxygen Demand, BOD5 | mg/L | APHA 5210B | ND | ND | ND | ND | 1 |
| Faecal Coliform | MPN/100mL | APHA 9221E | ND | 4.5 | ND | 2 | 1.8 |
| Enterococcus | cfu/100mL | APHA 9230C | ND | ND | ND | ND | 1 |
| E.Coli | MPN/100mL | APHA 9221F | ND | ND | ND | ND | 1.8 |

***Note:***

1. APHA is a standard method for Determination of Water and Waste Water (APHA 24th Edition, 2023).
2. LOR = Limit of Reporting. This value may also represent Detection Limit required for the project.
3. ND = Not detected. The data reported is less than the LOR.
4. * = For Oil & Grease TPH by In-house method MLS-SOP-WQ-033 Rev 1 (adapted from APHA 5520C), the qualitative and quantitative tests are based on the Reference Oil recommended in APHA 5520C.

SINGAPORE ENVIRONMENTAL CONSULTANCY AND SOLUTIONS PTE LTD

SECS

## CHAIN OF CUSTODY FORM

03 OCT 2024

Form No.: OPS-QR-01 Rev (B)
Page 1 of 2

| | |
|---|---|
| CLIENT | : Keppel Data Centres Holding Pte Ltd |
| CONTACT | : |
| ADDRESS | : |
| PROJECT No. | : P527466 |
| SITE | : |
| QUOTATION / JOB REQUEST / PO No. | : |
| SEND REPORT TO | : Wanli.Chin@aurecongroup.com |
| REPORT NEEDED BY (DATE) | : |
| COMMENT / SPECIAL INSTRUCTION | : |
| STORAGE / DISPOSAL | : |

FOR LAB USE
Reg. No.: R2408464

| S/N | SAMPLE ID / LOCATION | SAMPING DEPTH (m) | MATRIX* | DATE | TIME (HRS) | TOTAL NOs OF CONTAINERS# / SAMPLING MEDIA$ | STORAGE CONDITION** | Total Suspended Solids | BOD | TN, TP, Nitrate, Phosphate, Ammonium, | Al, As, Cd, Cr, Cu, Pb, Hg, Ni, Zn | Oil and Grease (mg/L) | Faecal Colifomrs (MPN/100ml) E. Coli (MPN/100ml) Enterococcus (cfu/100ml) | Chlorophyll-a | Phytoplankton | REMARKS / OBSERVATION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | WQ01_F_S | | SW | 3/10/24 (brace for rows 1–16) | | | | X | X | X | X | X | X | X | X | 250ml Sterile - PP. |
| 2 | WQ01_F_MD | | SW | | | | | X | X | X | X | X | X | X | | |
| 3 | WQ01_E_S | | SW | | | | | X | X | X | X | X | X | X | X | |
| 4 | WQ01_E_MD | | SW | | | | | X | X | X | X | X | X | X | | |
| 5 | WQ02_F_S | | SW | | | | | X | X | X | X | X | X | X | X | |
| 6 | WQ02_F_MD | | SW | | | | | X | X | X | X | X | X | X | | |
| 7 | WQ02_E_S | | SW | | | | | X | X | X | X | X | X | X | X | |
| 8 | WQ02_E_MD | | SW | | | | | X | X | X | X | X | X | X | | |
| 9 | WQ03_F_S | | SW | | | | | X | X | X | X | X | X | X | X | |
| 10 | WQ03_F_MD | | SW | | | | | X | X | X | X | X | X | X | | |
| 11 | WQ03_E_S | | SW | | | | | X | X | X | X | X | X | X | X | |
| 12 | WQ03_E_MD | | SW | | | | | X | X | X | X | X | X | X | | |
| 13 | WQ04_F_S | | SW | | | | | X | X | X | X | X | X | X | X | |
| 14 | WQ04_F_MD | | SW | | | | | X | X | X | X | X | X | X | | |
| 15 | WQ04_E_S | | SW | | | | | X | X | X | X | X | X | X | X | |
| 16 | WQ04_E_MD | | SW | | | | | X | X | X | X | X | X | X | | |
| 17 | | | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | |

| RELINQUISHED BY: | DATE / TIME | RECEIVED BY: | DATE / TIME | RELINQUISHED BY: | DATE / TIME | RECEIVED BY: | DATE / TIME | SHIPMENT BY COURIER: |
|---|---|---|---|---|---|---|---|---|
| Name: Chua Kiam Poh | 3/10/24 | Name: [signature] | 3/10/24 | Name: | | Name: | | Courier Co. / Carrier Name: |
| Sign: [signature] | | Sign: [signature] | | Sign: | | Sign: | | |
| Company: SECS | 15.25 hrs | Company: | 1525 hrs | Company: | hrs | Company: | hrs | Consignment Note / Airway Bill: |

* = For Water sample: Please Indicate FW (Fresh Water), SW (Seawater), BW (Ballast Water), DW (Drinking Water), GW (Ground water), WW (Wastewater)

\# Type of Sampling Bottles: G = Glass; P = Plastic; T = Tube; V = VOC vial; S = Steriled bottle; B = Bag

** Storage Condition: C = Refrigerate at 4 oC; R = Room Temperature; P = Preserved as per Lab's instruction

$ Type of Sampling Media: ST = Sorbent Tube; IM = Impinger solution; F = Filter; RT = Resin Trap; AP = Agar Plate; W = Wipe Sample; Others (PUF, etc. - please specify)

# Appendix F

## Sediment Quality Laboratory Results

# TEST REPORT

| | | | | | |
|---|---|---|---|---|---|
| Our Reference No. | : | **R240 8519** | Date Received | : | 04/10/2024 |
| Project Code / Ref. | : | P527466 | Date Commenced | : | 04/10/2024 |
| | | | Date Reported | : | 18/10/2024 |

Customer Ref. No. : Keppel Data Centres Holding Pte Ltd
Customer Name : Singapore Environmental Consultancy and Solution Pte Ltd
Customer Address : 1 Sunview Road
#08-66
Singapore 627615

Attention To : Ms. Chin Wanli

Sample Description : 3 Sediment samples as per received.

**RESULTS** : Refer to Page 2 of Page 5

**Tan Thuan Piang**
**Senior Technical Manager**

**Terms & Conditions:**

1) This report shall not be reproduced except in full, unless approval in writing has been given by MLS.
2) The results in this report only apply to the sample received/analysed.
3) MLS agrees to use reasonable diligence in the performance of the service.

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Branch (Site and Laboratory): 216 Tuas South Ave 2, West Point Bizhub Singapore 637213 ☎ : +65 6262 3736 (Lab) ☎ : +65 6262 3726 / 3776 (Site)
Website: www.mls.sg

MLS

**RESULTS**

| Test Parameter | Unit | Test Method | Sample 1 | Sample 2 | Sample 3 | Client's Detection Limit |
|---|---|---|---|---|---|---|
| | | | SQ01 | SQ02 | SQ03 | |
| | | | 04/10/2024 | 04/10/2024 | 04/10/2024 | |
| Arsenic as As | mg/kg | APHA 3120B | 8.76 | 10.3 | 11.2 | 0.5 |
| Cadmium as Cd | mg/kg | APHA 3120B | ND | 0.55 | 0.56 | 0.5 |
| Chromium as Cr | mg/kg | APHA 3120B | 23.1 | 20.3 | 26.0 | 0.02 |
| Copper as Cu | mg/kg | APHA 3120B | 27.5 | 55.5 | 32.9 | 0.1 |
| Lead as Pb | mg/kg | APHA 3120B | 24.3 | 118 | 31.3 | 0.5 |
| Mercury as Hg | mg/kg | APHA 3120B | 0.27 | 0.16 | 0.19 | 0.01 |
| Nickel as Ni | mg/kg | APHA 3120B | 15.0 | 11.8 | 15.1 | 0.1 |
| Zinc as Zn | mg/kg | APHA 3120B | 107 | 205 | 129 | 0.5 |
| Total Petroleum Hydrocarbons as TPH | mg/kg | USEPA 8440 (1996) | 134 | 108 | 120 | 5.0 |
| Total Organic Carbon, TOC | % | Accredited In-house Method MLS-SOP-SED-007 Rev 1 (by Suspension) | 1.48 | 1.33 | 1.39 | 0.3 |
| Percentage Fines | % | ASTM D1140-17 | 98.6 | 52.1 | 98.4 | 0.01 |

***Note:***

1. APHA is a standard method for Determination of Water and Waste Water (APHA 24th Edition, 2023).
2. LOR = Limit of Reporting. This value may also represent Detection Limit required for the project.

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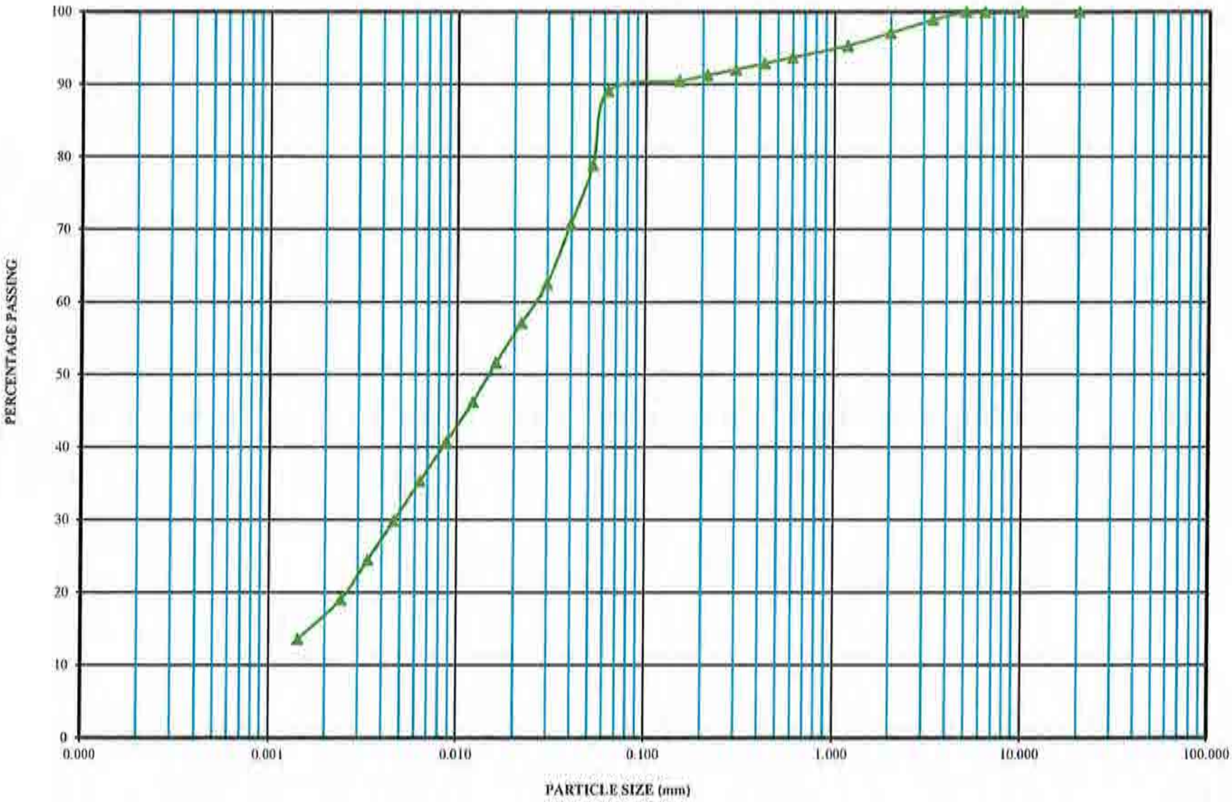
## RESULTS FOR PARTICLE SIZE DISTRIBUTION

| | | |
|---|---|---|
| Test Method | : | Test Method - BS 1377-2: 2022 |
| SN | : | Sample 1 |
| Sample ID | : | SQ01 |
| Sampling Date | : | 04/10/2024 |




| CLAY | SILT | SAND | GRAVEL |
|---|---|---|---|

| Percentage | CLAY | SILT | SAND | GRAVEL |
|---|---|---|---|---|
| | 19 | 70 | 8 | 3 |

| Diameter (mm) | 20.000 | 10.000 | 6.300 | 5.000 | 3.350 | 2.000 | 1.180 | 0.600 | 0.425 | 0.300 | 0.212 | 0.150 | 0.063 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % passing | 100 | 100 | 100 | 100 | 99 | 97 | 95 | 94 | 93 | 92 | 91 | 91 | 89 |

| Diameter (mm) | 0.0524 | 0.0397 | 0.0298 | 0.0219 | 0.0160 | 0.0121 | 0.0088 | 0.0064 | 0.0046 | 0.0034 | 0.0024 | 0.0014 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % passing | 79 | 71 | 63 | 57 | 52 | 46 | 41 | 35 | 30 | 24 | 19 | 14 |

**Note:**

1. The above test was sub-contracted to external lab.

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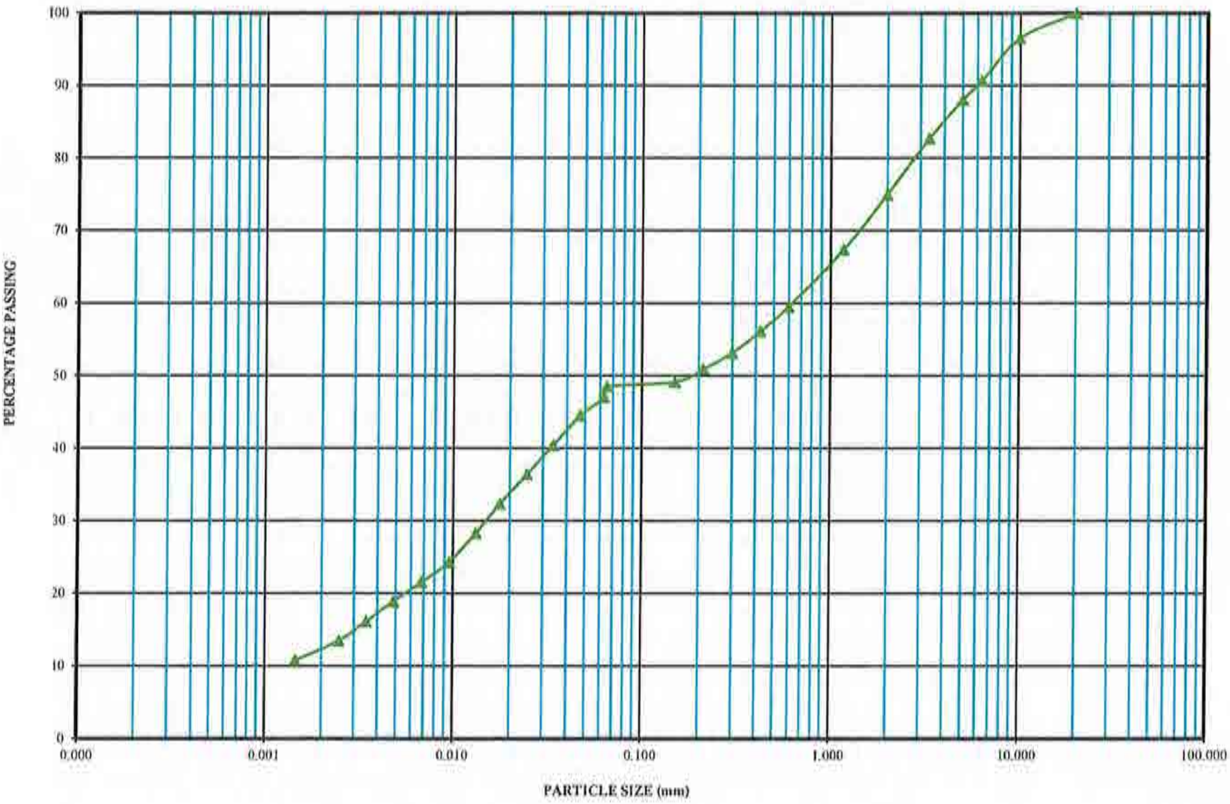
## RESULTS FOR PARTICLE SIZE DISTRIBUTION

| | | |
|---|---|---|
| **Test Method** | : | **Test Method - BS 1377-2: 2022** |
| **SN** | : | **Sample 2** |
| **Sample ID** | : | **SQ02** |
| **Sampling Date** | : | **04/10/2024** |




| | | | |
|---|---|---|---|
| CLAY | SILT | SAND | GRAVEL |

| Percentage | CLAY | SILT | SAND | GRAVEL |
|---|---|---|---|---|
| | 13 | 34 | 28 | 25 |

| Diameter (mm) | 20.000 | 10.000 | 6.300 | 5.000 | 3.350 | 2.000 | 1.180 | 0.600 | 0.425 | 0.300 | 0.212 | 0.150 | 0.065 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % passing | 100 | 97 | 91 | 88 | 83 | 75 | 67 | 60 | 56 | 53 | 51 | 49 | 49 |

| Diameter (mm) | 0.0630 | 0.0471 | 0.0341 | 0.0246 | 0.0178 | 0.0132 | 0.0095 | 0.0068 | 0.0049 | 0.0035 | 0.0025 | 0.0015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % passing | 47 | 45 | 40 | 36 | 32 | 28 | 24 | 22 | 19 | 16 | 13 | 11 |

**Note:**

1. The above test was sub-contracted to external lab.

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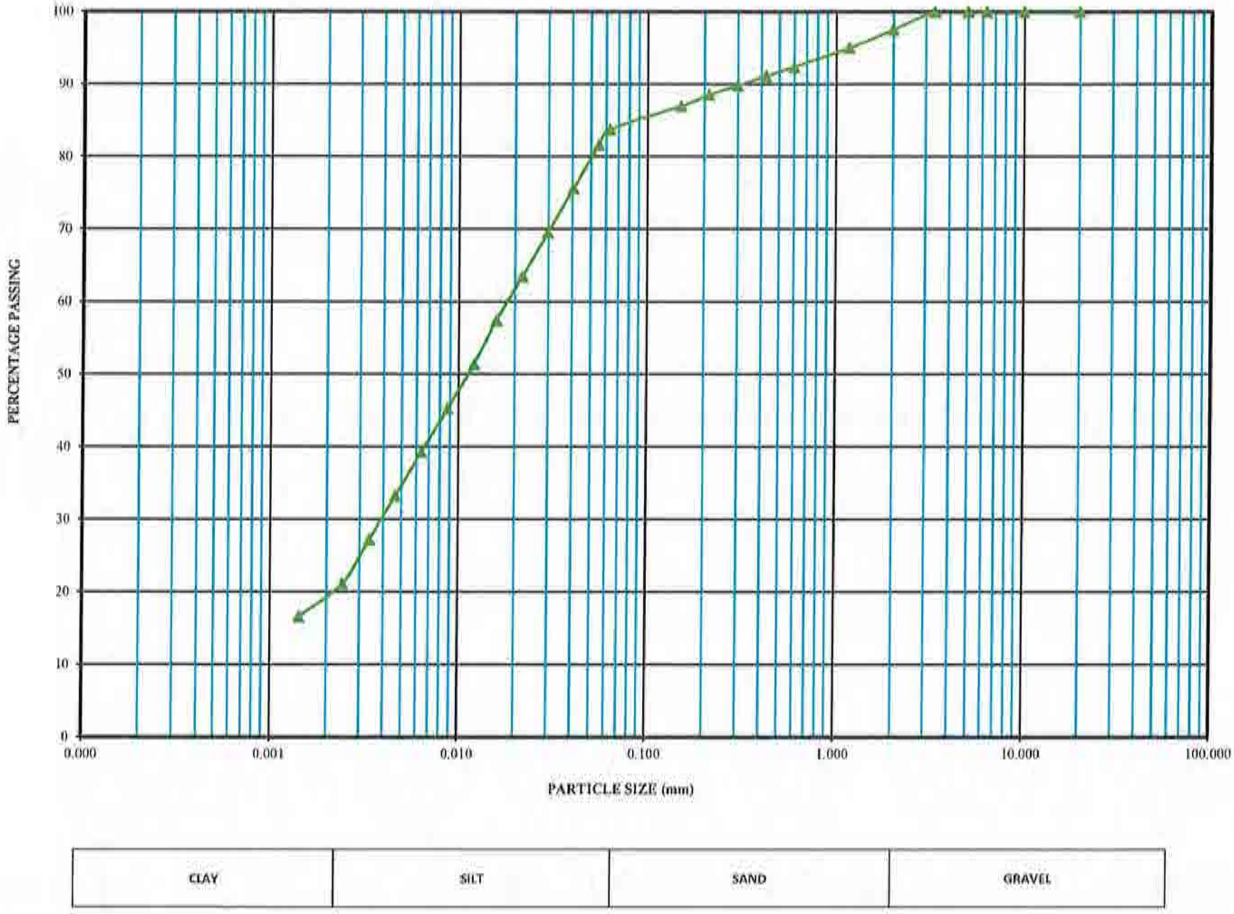
## RESULTS FOR PARTICLE SIZE DISTRIBUTION

| | | |
|---|---|---|
| **Test Method** | : | **Test Method - BS 1377-2: 2022** |
| **SN** | : | **Sample 3** |
| **Sample ID** | : | **SQ03** |
| **Sampling Date** | : | **04/10/2024** |




| Percentage | CLAY | SILT | SAND | GRAVEL |
|---|---|---|---|---|
| | 21 | 63 | 14 | 2 |

| Diameter (mm) | 20.000 | 10.000 | 6.300 | 5.000 | 3.350 | 2.000 | 1.180 | 0.600 | 0.425 | 0.300 | 0.212 | 0.150 | 0.063 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % passing | 100 | 100 | 100 | 100 | 100 | 98 | 95 | 92 | 91 | 90 | 89 | 87 | 84 |

| Diameter (mm) | 0.0549 | 0.0406 | 0.0298 | 0.0219 | 0.0160 | 0.0121 | 0.0088 | 0.0064 | 0.0046 | 0.0034 | 0.0024 | 0.0014 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % passing | 82 | 76 | 70 | 63 | 57 | 51 | 45 | 39 | 33 | 27 | 21 | 17 |

**Note:**

1. The above test was sub-contracted to external lab.

# Appendix G

## Model Set Up

# G. Model Set Up

## G.1 Introduction

This appendix details the model setup of the various numerical models carried out for the Environmental Impact Assessment (EIA) for the development of a Floating Data Centre at Loyang Offshore Supply Base (LOSB) (referred to as the "Project").

The following sections details the model setup of each numerical model as listed below.

- Hydrodynamic Model (section G.3)
- Sediment Plume Model (section G.4)
- Thermal Model (section G.5)
- Chlorine Plume Model (section G.6)

### G.1.1 Abbreviations

| | |
|---|---|
| CD | Chart Datum |
| EIA | Environmental Impact Assessment |
| FDCM | Floating Data Centre Module |
| IOA | Index of Agreement |
| MAE | Mean Average Error |
| MPA | Maritime & Port Authority of Singapore |
| RMSE | Root Mean Square Errors |
| UKFWR | UK Foundation for Water Research |

### G.1.2 Study datum

Water depths and levels presented in this report are referenced to Chart Datum (CD).

Geographical positions are provided in Singapore TM/SVY21, unless stated otherwise.

### G.1.3 Conventions

All units are in standard International System of Units unless otherwise stated, with all bearings and directions provided in degrees relative to True North.

All directions quoted are in degrees relative to True North. Wind direction quoted is the direction from which wind originates. Current directions quoted are the direction to which currents flow.

All time refers to Singapore local time (GMT+8), unless stated otherwise.

## G.2 Available Information

This section presents the available data and basis information incorporated into the model. The information include:

- Bathymetry
- Wind
- Proposed cooling water system: Outfall and intakes

### G.2.1 Bathymetry

A bathymetric survey has been undertaken in Year 2024 and provided to SECS for this study as shown in Figure 1.

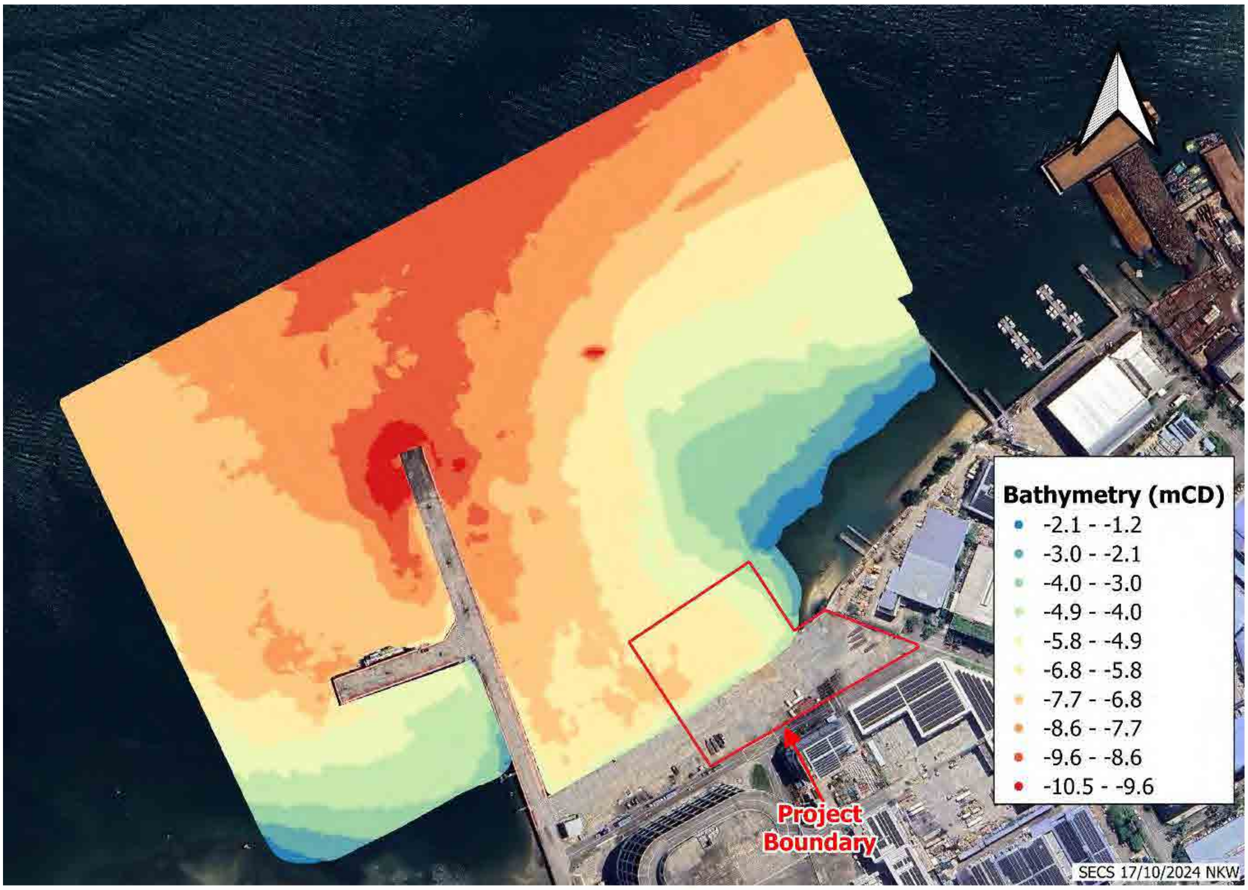



**Figure 1: Bathymetry data survey at Project site**

The bathymetry data used in the modelling study comprises of the following sources.

- Survey data at the Project site
- C-map bathymetry database
- Landline identified through Google Earth.

### G.2.2 Wind

Wind data are sourced from nearest local wind station (Changi Airport wind station). The data was analysed to provide local wind conditions, which are also used to input into the hydrodynamic model, sediment plume model, thermal and water quality modelling.

### G.2.3 Proposed Seawater Cooling System

The design intake and outfall discharge rates are provided as 4,800 $m^3$/hr. The excess temperature ($\Delta T$) induced by the proposed outfall is +5°C above the ambient temperature of marine water, while the proposed intake will draw the ambient water using a pump installed on FDCM.

## G.3 Hydrodynamic Model

A 3D hydrodynamic model was setup using MIKE 3 Hydrodynamic Model based on flexible mesh approach (MIKE 3 HDFM) to model the 3D free surface flow. MIKE 3 HDFM numerically solves the 3D incompressible Reynolds averaged Navier-Stokes equations subject to the assumptions of Boussinesq and of hydrostatic pressure. Thus, the model consists of continuity, momentum, temperature, heat exchange, salinity and density equations and it is closed by a turbulent closure scheme. The free surface is taken into account using a sigma-coordinate transformation. Wetting and drying effects in intertidal areas are also accounted for in the model, which is particularly important to this EIA given the large tidal range in the region.

The model was run with temperature module invoked from the specification of density. in addition to the tide forcing, as the main driving mechanisms. The currents due to wind and temperature variations are included from the model. This 3D hydrodynamic model will also provide hydrodynamic forcing for the subsequent sediment plume dispersion, thermal dispersion and water quality modelling.

### G.3.1 Model Domain

The model domain covers the Johor River confluence and part of Singapore Strait around Pulau Ubin and Pulau Tekong on the east. On the west, the Johor-Singapore Causeway represents a close boundary in the model domain (Figure 2). This relatively large model domain is selected to generate realistic current field in the project area.

A single open boundary was defined along the south of the model domain linking to Singapore Strait near to an existing Tide Station: Tanah Merah (shown in Figure 2 and Figure 3). The boundary conditions (tidal surface elevation variation) were generated using Singapore Tide Table (MPA, 2023).

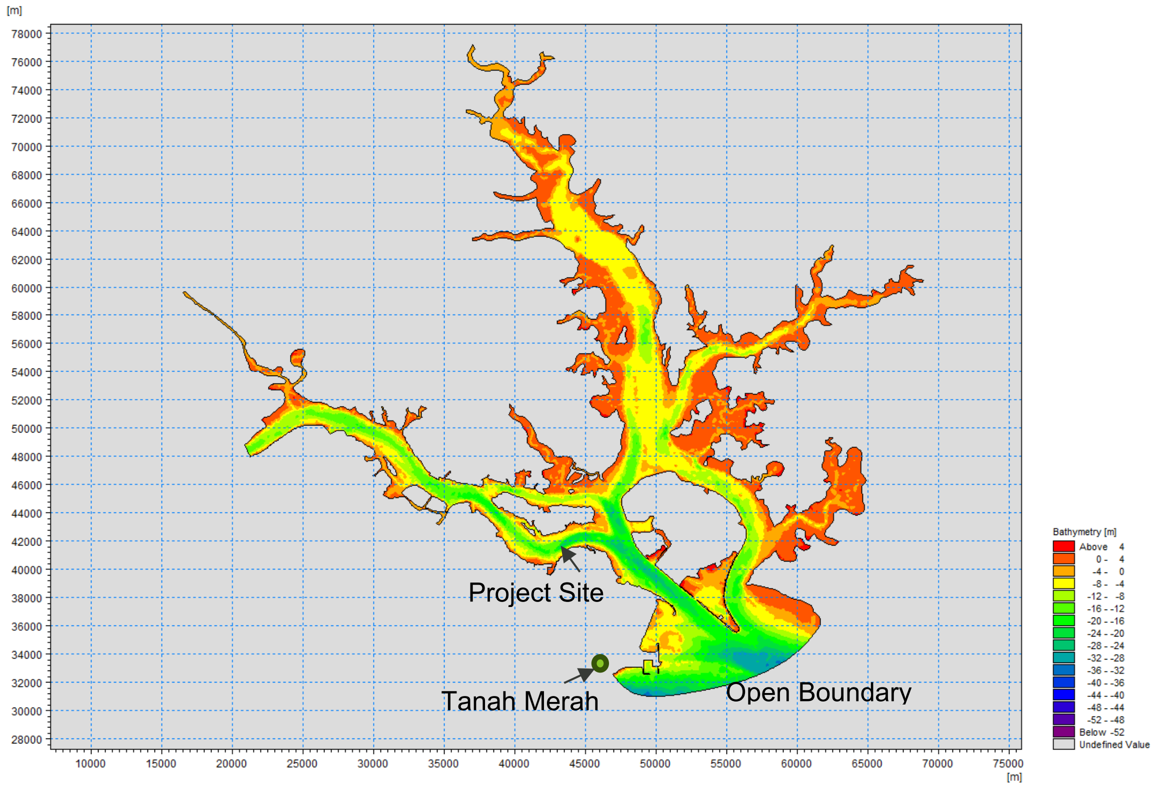



**Figure 2: Model Domain**

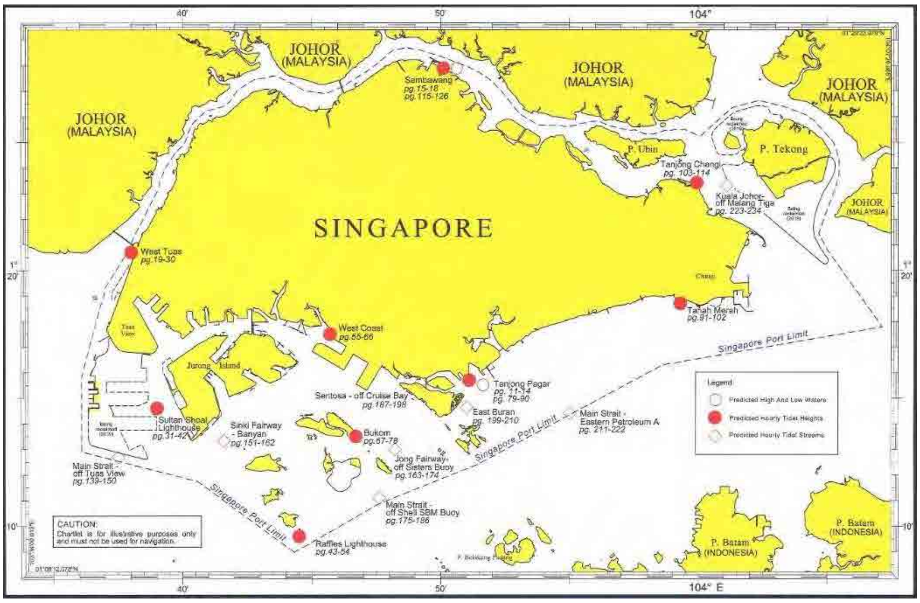



Figure 3: Singapore Tidal Stations (MPA, 2023)

Figure 4 presents the model mesh. The mesh resolution is approximately 150 m resolution at the open boundary, reduces to 60 m resolution near Pualu Ubin and further west to the Causeway. A finer 10m to 20m resolution is implemented for project area to assess the hydrodynamic conditions and thermal dispersion more accurately.

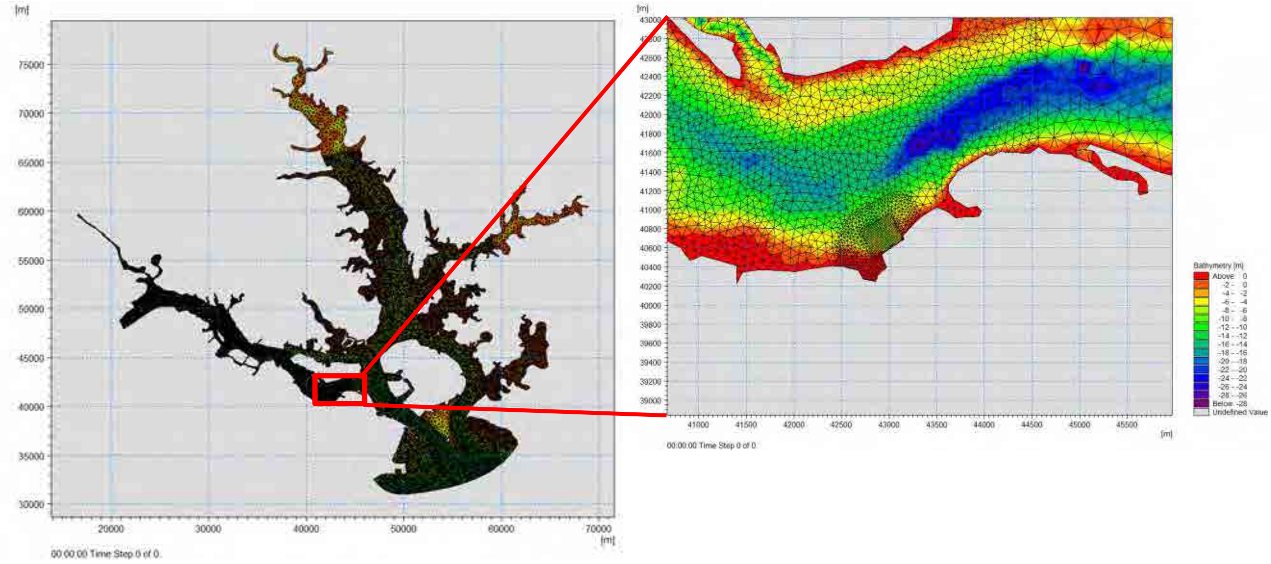



Figure 4: Model mesh varying from 10m to 150m resolution

## G.3.2 Model Calibration and Validation

Model calibration is the process whereby the model’s main governing conditions are adjusted, within accurate bounds, to produce the best reflection of measured data from the calibration control period. The model’s performance is then verified against an independent set of data (often a different survey period) while holding the previously determined calibration parameters constant.

The measured tidal level and currents are calibrated and validated using ADCP measurement close to the project site (SECS in house data). Figure 5 presents the comparison of measured surface elevation, current speed and directions against modelled results for September 2022. Visual comparison indicates a close match between the measured and modelled data during calibration period.

Model validation is the process by which the robustness of the model set-up and calibration is checked for an independent period, whilst maintaining all calibration parameters constant based on the results of the calibration process. Figure 6 presents the comparison of measured surface elevation, current speed and directions against modelled results for November 2022. Visual comparison indicates a close match between the measured and modelled data during validation period.

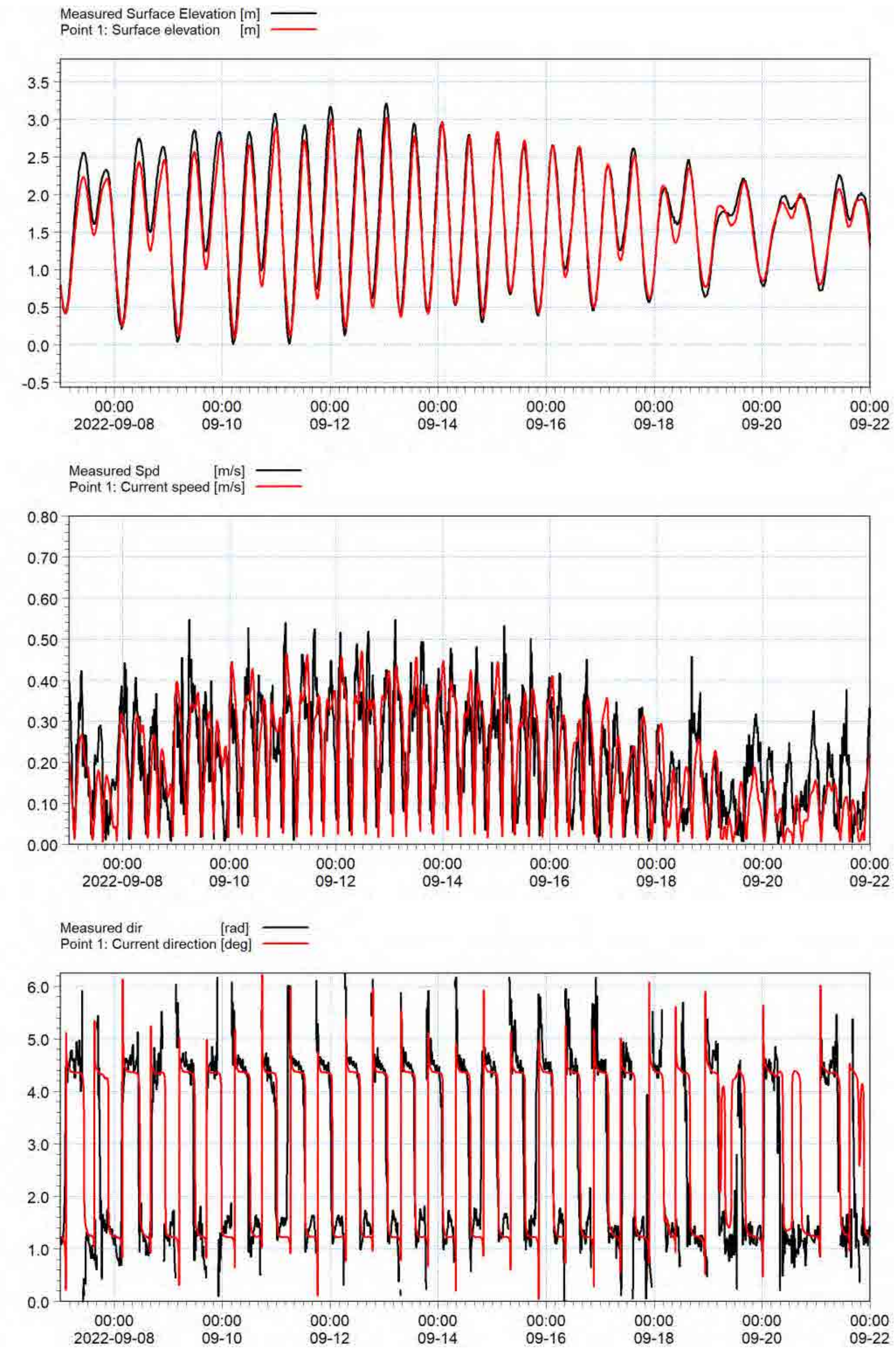



**Figure 5: Model calibration: Comparison of measured surface elevation, current speed and directions against modelled results for September 2022**

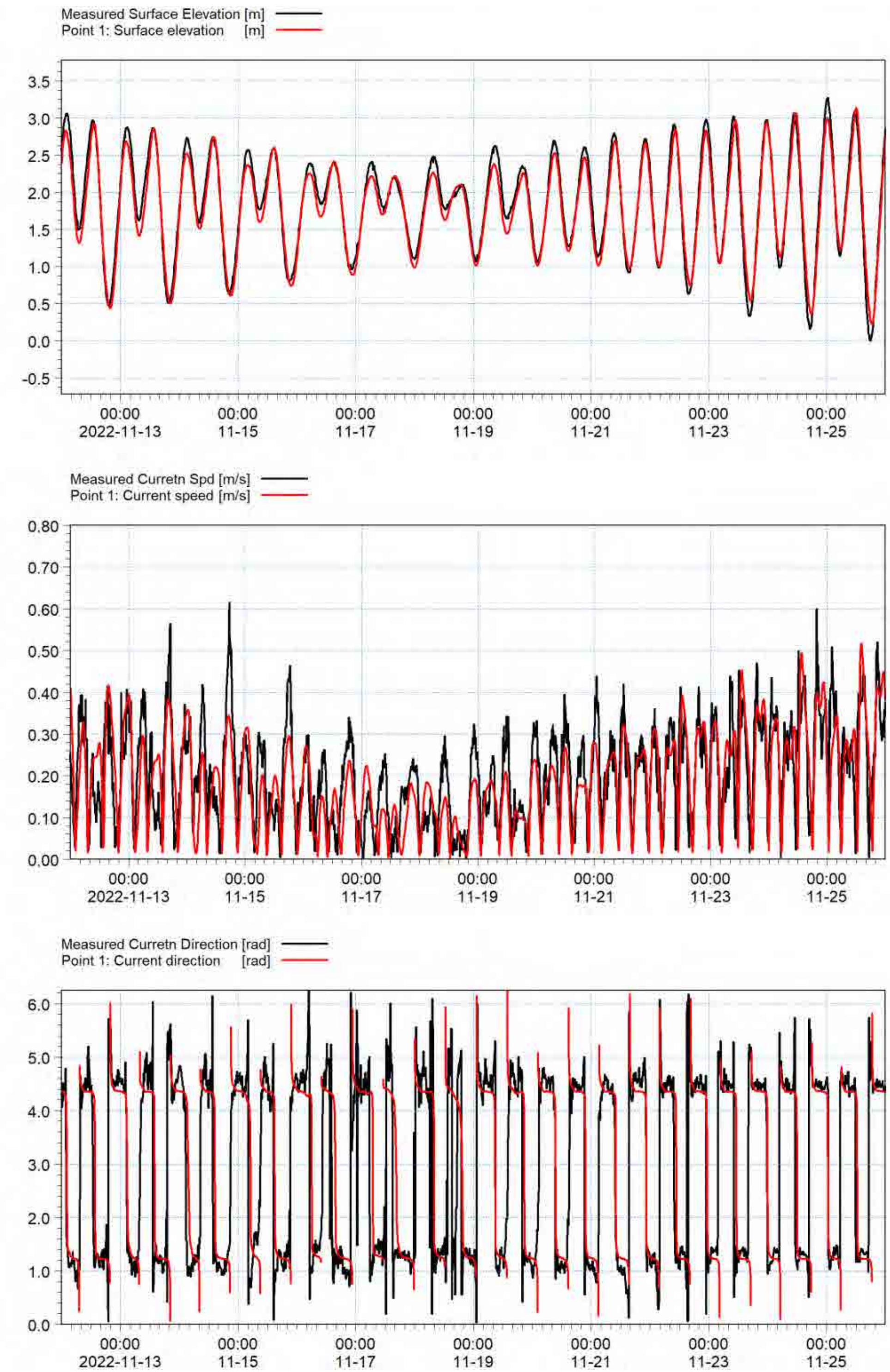



**Figure 6: Model validation: Comparison of measured surface elevation, current speed and directions against modelled results for November 2022**

To evaluate the model performance quantitatively, the UK Foundation for Water Research - FR0374 "*A framework for marine and estuarine model specification in the UK*" evaluation criteria is adopted with the following model performance limit.

- Tidal elevations: Root Mean Square Error (RMSE) < 10% on spring tide ranges
- Current speed: RMSE < 20% of observed peak current speed (maximum deviation 0.2 m/s)
- Current direction: RMSE < 15° where current speeds are more than 0.2 m/s.

Table 1 summarises the hydrodynamic model performance assessment, with all the calculated RMSE complying with the defined criteria, indicating the model is fit for purpose.

**Table 1: Environmental receptors at the extraction point**

| Measurement Period | Calibration/ Validation Parameter | UKFWR Criterion | RMSE |
|---|---|---|---|
| September 2022 (Inter-monsoon period for calibration) | Current speed (m/s) | 0.12 | 0.08 |
| | Current direction (degree) | 15 | 13 |
| | Surface elevation (m CD) | 0.32 | 0.14 |
| November 2022 (Northeast period for calibration) | Current speed (m/s) | 0.12 | 0.10 |
| | Current direction (degree) | 15 | 9 |
| | Surface elevation (m CD) | 0.32 | 0.22 |

A further model validation is carried out to confirm the model performance using more recent site measurement with current transect survey carried out near the development area on 5 October 2024. Figure 7 and Figure 8 present the comparison of transect measurements against modelled results during ebb and flood tide, respectively.

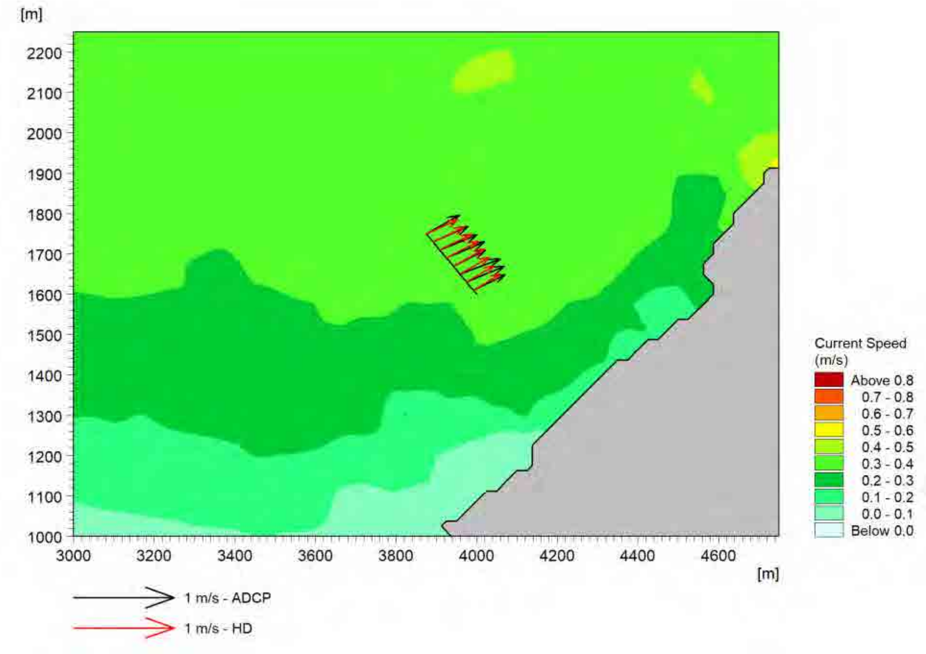



**Figure 7: Model validation: Comparison of transect measurement (ebb tide) against modelled results at 4.17pm on 5 Oct 2024**

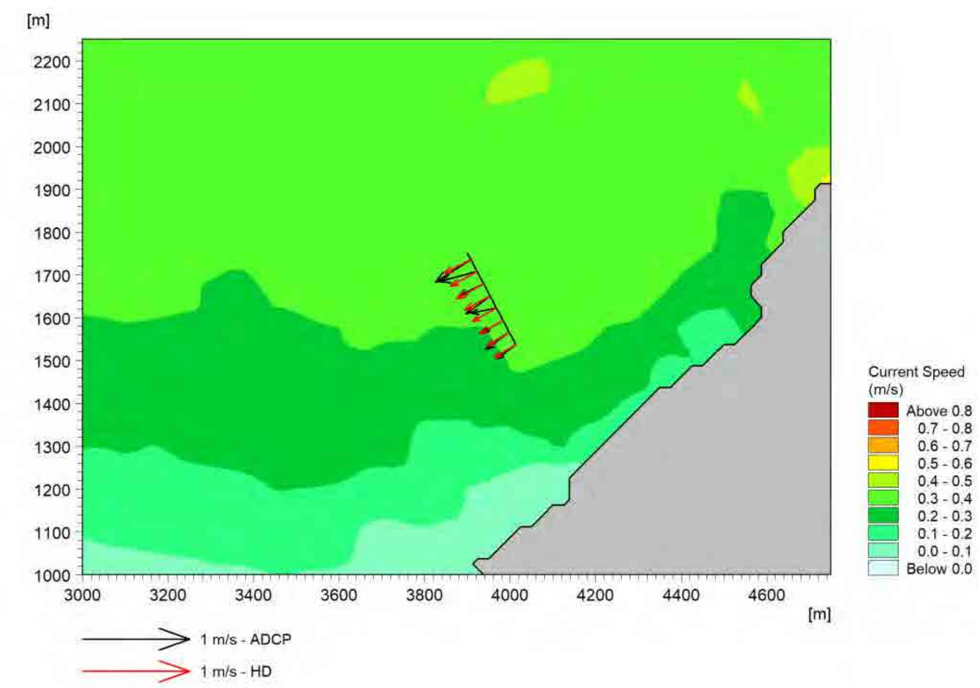



**Figure 8: Model validation: Comparison of transect measurement (flood tide) against modelled results at 11.20am on 5 Oct 2024**

A quantitative analysis of the results was performed by calculating the Index of Agreement (IOA) for current speed, presented in Willmott (1981) and Root Mean Square Errors (RMSE) for current direction.

The IOA, which is used to assess agreement between time-series datasets in a wide variety of literature, is calculated based on the following equation:

$$IOA = 1 - \frac{\sum(\lfloor X_{model} - X_{obs} \rfloor^2)}{\sum(\lfloor X_{model} - \overline{X_{obs}} \rfloor + \lfloor X_{obs} - \overline{X_{obs}} \rfloor)^2}$$

Where:

$X_{model}$ is the modelled current speed value

$X_{obs}$ is the measured current speed value

$\overline{X_{obs}}$ is the mean of measured current speed value

A perfect agreement can be said to exist between the two datasets if the index gives a measure of one, while complete disagreement will produce an index measure of zero. It is difficult to find guidelines on what IOA values might represent a good agreement, although Willmott & Matsuura 2005 suggests that values meaningfully are not less than 0.5 represent good agreement, with values higher than 0.9 indicating that a negligible difference exists between the two datasets in most instances.

Table 2 presents the IOA results for the modelled and measured current speed. Both comparison values are more than 0.5 which represent good agreement for both ebb and flood tidal transect speed.

For the comparison of current directions, Table 3 presents the RMSE for depth-averaged current direction based on UKFWR Criterion. Both errors are less than 15°, which represent good agreement for both ebb and flood current direction.

**Table 2: IOA for modelled and measured current speed**

| Survey Timing | Tide | IOA for Depth Averaged Current Speed |
|---|---|---|
| Morning | Flood | 0.55 |
| Afternoon | Ebb | 0.50 |

**Table 3: RMSE for modelled and measured current direction**

| Survey Timing | Tide | RMSE for Depth-averaged Current Direction (°) (Criterion: 15°) |
|---|---|---|
| Morning | Flood | 14 |
| Afternoon | Ebb | 12 |

## G.3.3 Model Set Up Parameters

### G.3.3.1 Model Vertical Layers

A sigma layer system was adopted, whereby the same number of vertical water layers is present at each point of the computational domain irrespective of water depth. The sigma layers were set with five (5) layers, each spanning 20% of the local water depth. Five layers were considered appropriate to resolve the 3D hydrodynamics both deeper water along the channel and water depth near the project site, especially important to simulate the further thermal exchange and sediment plume dispersion within the different water column throughout the water depth.

### G.3.3.2 Eddy Viscosity

The constant of the horizontal eddy viscosity used in the Smagorinsky formulation is set to be $C_S$=0.35. The vertical eddy viscosity adopts log law formulation under the default setting.

### G.3.3.3 Bed Resistance

For 3D hydrodynamic model input, either quadratic drag coefficients or roughness height ($K_s$), which are equivalent to Manning numbers, can be defined in the bed resistance parameter.

The friction parameter is expressed as:

$$k = \frac{g}{M^2 h^{\frac{1}{3}}}$$ **Equation 1**

where $M$ is the Manning Number ($m^{1/3}/s$) (the Manning number is also seen in the literature as n=1/M)

It is deemed necessary to develop a detailed resistance map of the study area with the basic depth relationship shown in Table 4 to accurately model the flow in the region.

**Table 4: Bottom friction parameters applied**

| Water Depth Range | Manning Number ($m^{1/3}/s$) | Roughness Height ($K_s$) (m) |
|---|---|---|
| Less than15 | 45 | 0.03 |
| 15 to 30 | 40 | 0.07 |
| 30 to 80 | 35 | 0.15 |
| Greater than 80 | 32 | 0.20 |
| Mangrove | 17.5 | 0.30 |
| Wetland | 20 | 0.30 |

Near the Project site, there are structures of the existing jetty, and the proposed Jetty consist of catwalks, berthing dolphins, mooring dolphins and platforms which are supported by pile structure. Higher flow energy loss is expected due to the piles group structures. Such loss depends on the prevailing water depth, current speed, pile dimension and pile spacing. Hence, higher bottom friction values are derived for model to capture the flow energy loss.

Bed shear stress ($\tau$) is generally can be express as:

$$\tau = f\frac{1}{2}\rho v^2 \qquad \textbf{Equation 2}$$

where $f$ is friction coefficient, $\rho v^2$ is the water density, $v$ relates to the depth averaged flow velocity and $\frac{1}{2}\rho v^2$ usually refers to the fluid motion energy.

In practical cases, friction coefficient can be determined using Manning number showed in Equation 1

In piles group, the resistance caused by piles group will dominate the friction in this area compared with friction caused by other factors (such as bed resistance). For one isolate pile, the drag force can be express using Morison equation as:

$$F = \frac{1}{2}C_D\rho(Dh)v^2 \qquad \textbf{Equation 3}$$

where
$F$ is drag force, $C_D$ the drag coefficient, $v^2$ the diameter of the pile and $h$ the water depth. In turbulence flow, $C_D$ is a constant value, i.e. 0.42. For piles groups, the drag coefficient will increase due to the interaction between piles. Duclos and Clement's (2004) study shows that there is about 40% energy lose after flow passes through unevenly spaced vertical piles. Thus, an increased drag coefficient of 0.7 should be applied in the present case.

On the piles group area, the resistance by piles group can be expressed as:

$$A\tau = nF \qquad \textbf{Equation 4}$$

where $A$ is the area covering the piles group and $n$ the piles numbers.

Thus, Manning number due to pile drag can be express as:

$$M = \left(\frac{A}{n}\frac{2g}{C_d D h^{\frac{4}{3}}}\right)^{\frac{1}{2}} \qquad \textbf{Equation 5}$$

The Manning Numbers for the various pile groups are presented in Table 5. Figure 9 presents the resulting Roughness Height ($K_s$) map for the model near the development area.

**Table 5: Bottom Friction Parameters Applied for Pile structures**

| Pile Structure | Manning Number ($m^{1/3}/s$) | Roughness Height ($K_s$) (m) |
|---|---|---|
| Existing Wharf and Jetty | 10 | 0.40 |
| Proposed pile supporting FDCM | 5 | 0.45 |

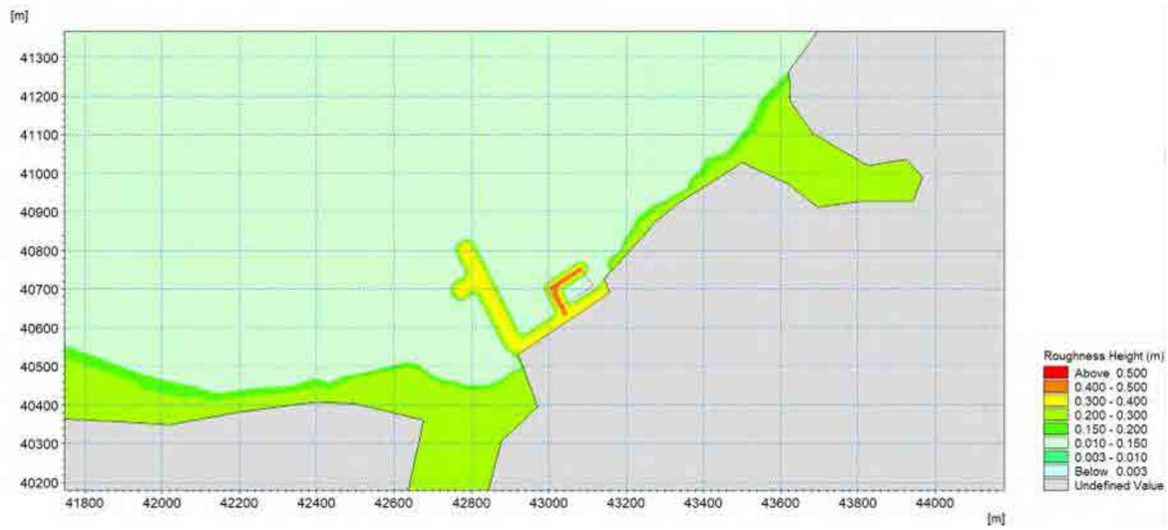



**Figure 9: Spatial bottom friction map for post development (FDCM hull area outlined)**

## G.3.3.4 Post Development Bathymetry

The post development bathymetry is amended to reflect

- Capital dredging to -7 mCD for the development area
- Reduced water depth to reflect the submerged part of the hull structure (Draft of 4m)

Figure 10 presents the bathymetry for pre-construction and post construction scenario, which the FDCM hull structure area highlighted in a hatched area.

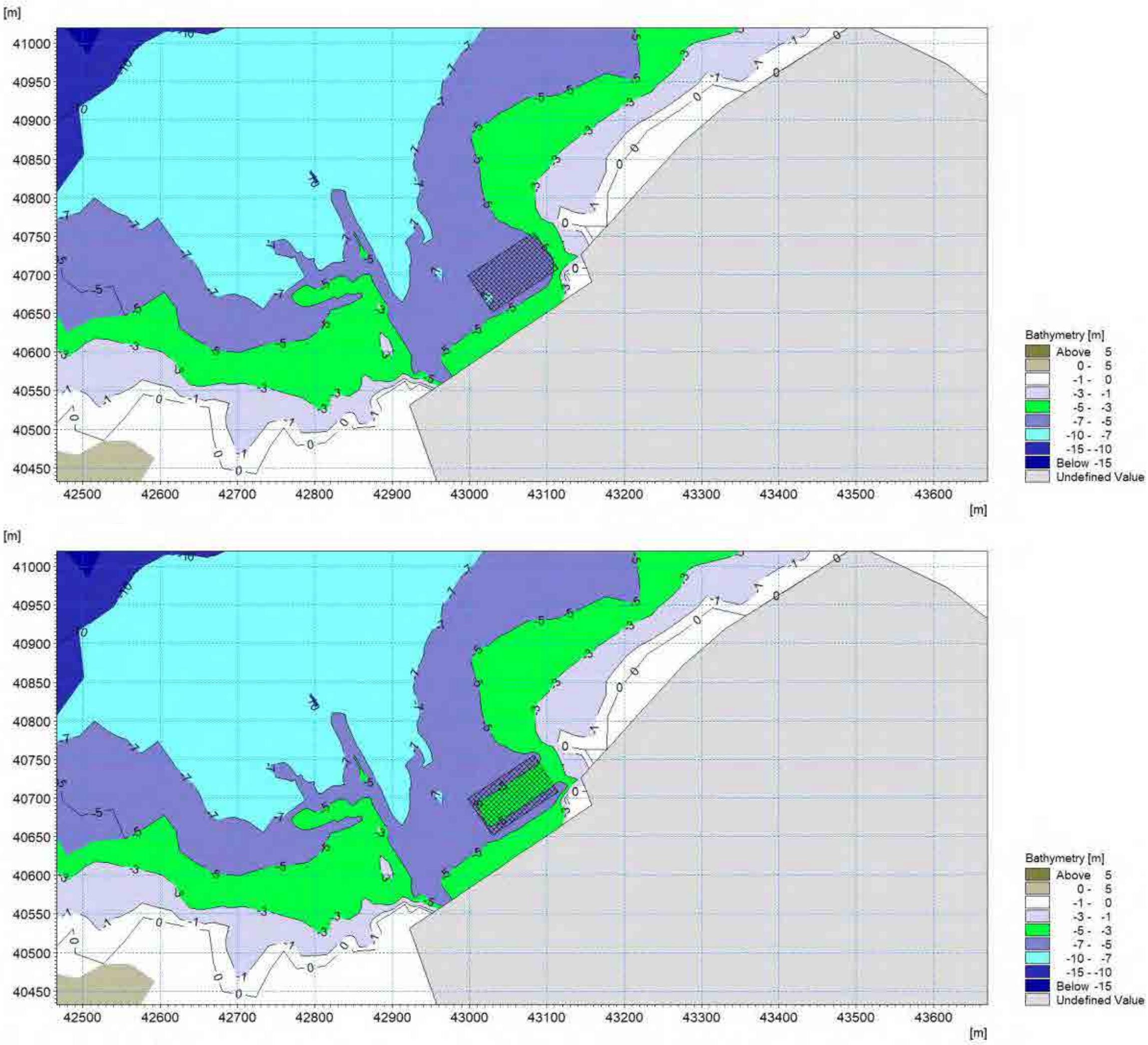



**Figure 10: Bathymetry for pre-construction case (top) and post construction case (bottom). Floating hull area highlighted in hatched area.**

### G.3.3.5 Density

The density function in the model is enabled to reflect the potential denser flow due to the density difference within the water column. This enabled function in modelling for this study is due to water temperature variation, which is important for the further thermal transport.

The heat exchange process has also been included in the model simulation to simulate the heat exchange between the atmospheric conditions, solar radiation and surface water layer.

The atmospheric conditions including air temperature and humidity at Changi station sourced from Meteorological Service Singapore.

### G.3.3.6 Project Outfall and Intake

The project FDCM will have one (1) one outfall proposed at location (43038E; 40734N) facing Serangoon Harbour. The outfall port is assumed at the depth of 2.5 m below the surface water. The exiting flow rate is calculated as 1.33 $m^3$/s (4,800 $m^3$/hour) with the speed at 0.59 m/s (two pipes with pipe diameter as 1.2 m).

Two intakes will be located at west and east of the hull structures. The locations are as follows.

- Location 1: 42994E; 40691N

- Location 2: 43089E; 40754N

For the modelling simulation of the present study, the following intake and outfall scenarios are defined

- Scenario 1: Outfall operates at 4,800 m³/hr with two intakes, each drawing 2,400 m³/hr from the left and right intake points
- Scenario 2: Outfall operates at 4,800 m³/hr with a single intake on the left side drawing 4,800 m³/hr.
- Scenario 3: Outfall operates at 4,800 m³/hr with a single intake on the right side drawing 4,800 m³/hr.

For the scenario of only one intake in operation (Scenario 2 or 3), the intake rate is calculated as 4,800 $m^3$/hour or equivalent speed of 0.95 m/s. The area of inlet strum holes is 1.4 $m^2$ (2 x 0.7 $m^2$ = 1.4 $m^2$). For the scenario of two intakes operation at the same time (Scenario 1), each intake flow rate is 2,400 $m^3$/hour with equivalent speed of 0.48 m/s.

## G.3.4 Simulation Scenarios

The hydrodynamic modelling scenarios are summarised in Table 6.

**Table 6: Hydrodynamic model scenarios**

| No | Bathymetry | Monsoon | Simulation Period | Intake and Outfall Scenario |
|---|---|---|---|---|
| 1 | Pre-construction | Northeast | 9 Dec 2023 to 23 Dec 2023 | NA |
| 2 | | Southwest | 1 Jul 2024 to 15 July 2023 | NA |
| 3 | | Inter-monsoon | 1 Apr 2023 to 15 Apr 2023 | NA |
| 4 | Post-construction | Northeast | 9 Dec 2023 to 23 Dec 2023 | Scenario 1 |
| 5 | | Southwest | 1 Jul 2024 to 15 July 2023 | Scenario 2 |
| 6 | | Inter-monsoon | 1 Apr 2023 to 15 Apr 2023 | Scenario 3 |
| 7 | | Northeast | 9 Dec 2023 to 23 Dec 2023 | Scenario 1 |
| 8 | | Southwest | 1 Jul 2024 to 15 July 2023 | Scenario 2 |
| 9 | | Inter-monsoon | 1 Apr 2023 to 15 Apr 2023 | Scenario 3 |
| 10 | | Northeast | 9 Dec 2023 to 23 Dec 2023 | Scenario 1 |
| 11 | | Southwest | 1 Jul 2024 to 15 July 2023 | Scenario 2 |
| 12 | | Inter-monsoon | 1 Apr 2023 to 15 Apr 2023 | Scenario 3 |

## G.4 Sediment Plume Model

MIKE3 Mud Transport (MT) model is used to simulate the multi fraction cohesive sediment transport module during construction stage. As the MIKE3 MT model is dynamically coupled with the MIKE3 hydrodynamic model, the sediment plume model adopts the same model domain as that used in the hydrodynamic model.

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 characterized 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.

The MIKE 3 MT module, which calculates the combined transport of cohesive sediments (silt/clay; with grain size diameter ≤63 μm) and non-cohesive sediments (sand; diameter >63 μm), is basically a solution of the advection dispersion equation. For a selected water layer, the equation can be represented as:

$$\frac{\partial c}{\partial t}+v_x\frac{\partial c}{\partial x}+v_y\frac{\partial c}{\partial y}=\frac{1}{h}\frac{\partial}{\partial x}\left(hD_x\frac{\partial c}{\partial x}\right)+\frac{1}{h}\frac{\partial}{\partial y}\left(hD_y\frac{\partial c}{\partial y}\right)+Q_LC_L\frac{1}{h}-S$$

Where,

$c$ = suspended sediment concentration;

$v_x, v_y$ = the current speed in the x and y directions;

$h$ = water layer thickness;

$D_x, D_y$ = dispersion coefficients in x and y directions;

$Q_L$ = source discharge rate;

$C_L$ = source discharge sediment concentration; and

$S$ = deposition / erosion rates.

### G.4.1 Model Input

#### G.4.1.1 Dredging

Based on the existing bathymetry and target depth after dredging seabed to -7 mCD at the Project site, an estimated 9,000 $m^3$ (including an approximate 20% buffer) of seabed material is to be dredged. We assume a grab bucket size of 8 to 10 $m^3$, utilizing one (1) grab dredger for the operation.

The dredged material will be transferred to a hopper barge, which will then transport the material to an approved dumping ground. No simulation of dumping material will be included in the sediment plume modelling study.

#### G.4.1.2 Geotechnical Parameters

3 recent seabed samples were collected during sediment quality surveys on 4 Oct 2024 as shown in Figure 11. The %fine value averaged over the three samples for only clay/silt part of material (grain size diameter ≤63 μm) is 73.67%, and %fine value to include fine sand material (assume grain size diameter between 63 μm and 150 μm) is 75.67%. The %fine of 75.67% will be used for calculation of spill mass input to the model, as the real sediment plume from site contains fine sand (S. E. Mousadik, et. al., 2024) which have been included the present model simulation.

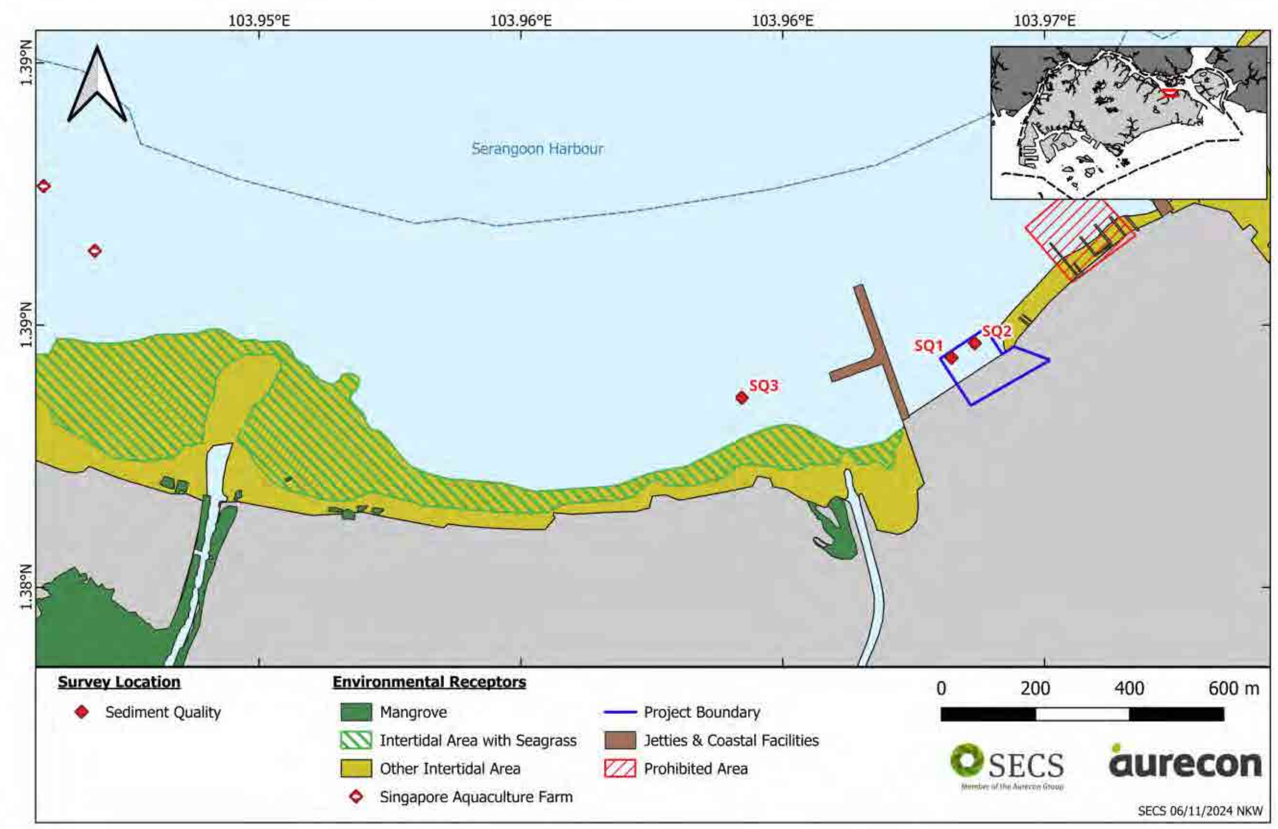



**Figure 11: Sediment quality survey stations**

**Table 7: Coordinates of sediment quality survey stations**

| Station ID | Coordinates | | Location | Survey Date |
|---|---|---|---|---|
| | Latitude (N) | Longitude (E) | | |
| SQ01 | 1.384379° | 103.968223° | Loyang Shore Front | 4 Oct 2024 |
| SQ02 | 1.384656° | 103.968666° | | |
| SQ03 | 1.383617° | 103.964217° | Pasir Ris Beach Front | |

Without a further Owen Tube analysis for these samples, the fine material's settling velocity within the water column cannot be directly derived from provided particle size distribution because of flocculation process. Flocculation is an important process, that influence the settling velocity of suspended matter by allowing the individual particles to stick together and form larger aggregates which in turn influence the settling velocity of the suspended matter.

The present 3D sediment plume model has considered the flocculation process, which has assumed corresponding settling velocities listed in Table 8. To refine the sediment under the different settling velocity groups, the model is defined with five fractions for more accurate sediment plume prediction. The percentage of fine material for each fraction of each sediment sample are based on the particle size distribution but has assumed relationship with the corresponding settling velocities. However, before real dredging work to start, the Owen Tube analysis is required to confirm the assumptions.

**Table 8: Settling velocity for 5 defined fractions of fine materials**

| Fraction | Corresponding to settling velocity range (mm/s) | PSD-SQ1 Percentage of fine material (%) | PSD-SQ2 Percentage of fine material (%) | PSD-SQ3 Percentage of fine material (%) | Average Percentage of Fine material (%) |
|---|---|---|---|---|---|
| F1 | < 0.08 | 19 | 6 | 4 | 10 |
| F2 | 0.08 to 0.4 | 11 | 16 | 14 | 14 |
| F3 | 0.4 to 1.0 | 12 | 14 | 17 | 14 |
| F4 | 1.0 to 4.0 | 37 | 37 | 41 | 38 |
| F5 | > 4.0 | 21 | 27 | 26 | 24 |

#### G.4.1.3 Spill Rates

The spill rate of grab dredger is assumed as 4.7% for the sediment plume modelling.

#### G.4.1.4 Spill Mass

The dredging operation is modelled as spill mass input taking into consideration of dredging time and location. A dredging source file was created for the spill event as determined in Section G.4.3.

The general formula for calculating a Spill Mass is:

$$Spill\ Mass\ [Kg] = V \times PF \times SR \times BD$$

Where,

$SR$ = spill rate (%);

$V$ = volume of dredged material ($m^3$);

$PF$ = percentage of fine sediment with grain size diameter ≤ 150μm in the dredged material (75.67%); and

$BD$ = bulk density of the dredged or infilled material, assumed as 2,000 kg/$m^3$

### G.4.2 Model Parameters

Some key parameters and formulations of the sediment plume model applies the same parameters used for hydrodynamic model described in Section G.3, with the pre-construction stage bathymetry used for sediment plume modelling.

In the sediment plume model, the deposition rate is formulated as a function of the settling velocity, the near-bed concentration and the actual critical bed shear stress for deposition. The settling velocity in this formula depends on two key parameters, namely the grain size and an estimation of the level of flocculation, with larger grain sizes (i.e. those associated with sands) exhibiting much higher settling velocities than finer materials. As such, sands are more readily deposited in the model than the fine silt and clay materials, which tend to remain suspended and transport greater distances in the model.

For the present study, a range of (0.1 to 0.3 N/$m^2$) critical bed shear stress for deposition was employed to reflect the five of sediment fraction, the shear stress adopted is consistent with recommendations for dredge dispersion studies in areas of similar seabed characteristics (Doorn-Groen & Foster, 2007).

The erosion rate depends on the seabed properties; that is, whether the seabed is dense and consolidated or soft and only partly consolidated. In the present model, the bed is assumed as a single layer, with material deposited and re-suspended solely from the Construction Works. This enabled the impact of the proposed dredging works to be isolated in the analysis. The layer contains the material which is re-suspended and subsequently settled during each tidal cycle. A critical shear stress parameter is usually set to determine whether the deposition material is re-suspended or not. The criterion for erosion occurs when driving forces exceed sediment stabilising forces. For the sediment plume model, the critical shear for bed erosion have been set as 0.3 N/m$^2$ for all area.

### G.4.3 Simulation Scenarios

Two (2) scenarios with different production rate were set as follows.

- Scenario 1: The daily average production rate over a 14-day period = approximately 643 m³ per day
  $Spill\ Mass = V \times PF \times SR \times BD = 643m^3 \text{ x } 75.67\% \text{ x } 4.7\% \text{ x } 2000\ \frac{Kg}{m^3} = 45.7\frac{\text{T}}{\text{day}}$
- Scenario 2: The maximum daily production rate over a 9-day period = 1,000 m³ per day.
  $Spill\ Mass = V \times PF \times SR \times BD = 1000 \text{ x } 75.67\% \text{ x } 4.7\% \text{ x } 2000\frac{Kg}{m^3} = 71.1\frac{\text{T}}{\text{day}}$

A single spill location (43057E, 40703N) is defined at the proposed project area.

The modelling scenarios are summarised in Table 9.

**Table 9: Sediment Plume Model Scenarios**

| No. | Dredging Scenario | Monsoon | Simulation Period (14-days) |
|---|---|---|---|
| 1 | Scenario 1 | Northeast | 9 Dec 2023 to 23 Dec 2023 |
| 2 | | Southwest | 1 Jul 2024 to 15 July 2023 |
| 3 | | Inter-monsoon | 1 Apr 2023 to 15 Apr 2023 |
| 4 | Scenario 2 | Northeast | 9 Dec 2023 to 23 Dec 2023 |
| 5 | | Southwest | 1 Jul 2024 to 15 July 2023 |
| 6 | | Inter-monsoon | 1 Apr 2023 to 15 Apr 2023 |

## G.5 Thermal Plume Model

Thermal plume model applied the same Hydrodynamic model with density function enabled as a function of temperature. The heat exchange process has been included also in the hydrodynamic model simulation described in Section G.3.3.5. For the thermal impact assessment to determine the thermal dispersion and area, the design discharge excess temperature increase (+5°C) above the ambient seawater temperature has been simulated and the results were compared to those temperature variation pre-development.

### G.5.1 Model Validation

Marine water quality surveys were conducted on 3 Oct 2024 at 4 locations (Figure 12), whereby seawater temperatures throughout the water profiles are measured.

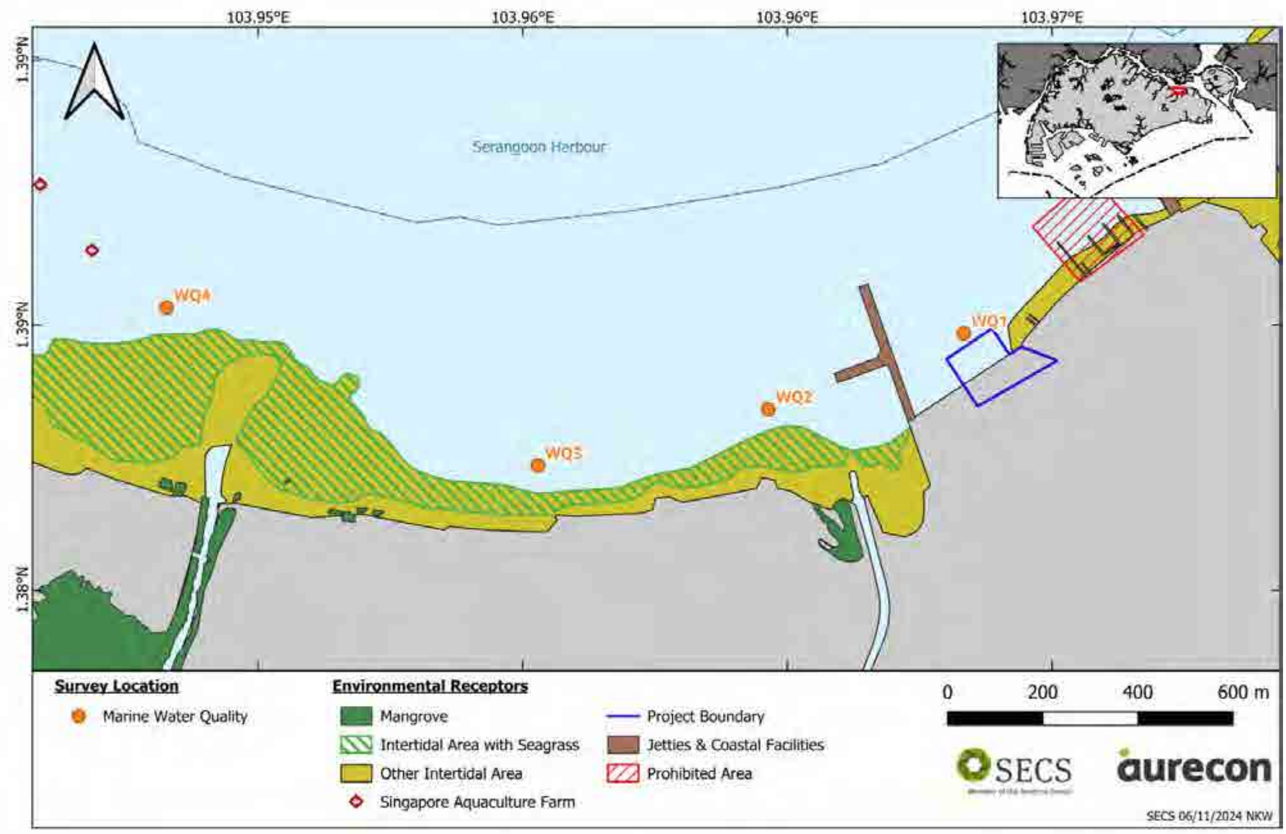



**Figure 12: Marine water quality survey stations**

**Table 10: Water quality survey stations coordinates**

| Station ID | Coordinates | | Location | Survey Date |
|---|---|---|---|---|
| | Latitude (N) | Longitude (E) | | |
| WQ01 | 1.384848° | 103.968333° | Loyang Shore Front | 3 Oct 2024 |
| WQ02 | 1.383413° | 103.964638° | Pasir Ris Beach Front | |
| WQ03 | 1.382353° | 103.960287° | | |
| WQ04 | 1.385331° | 103.953270° | | |

The comparison plots of measured and modelled seawater temperatures during flood and ebb tide are shown in Figure 13. Visual inspection indicate that the modelled temperatures match well with measurement, with negligible maximum deviation up to 0.3°C.

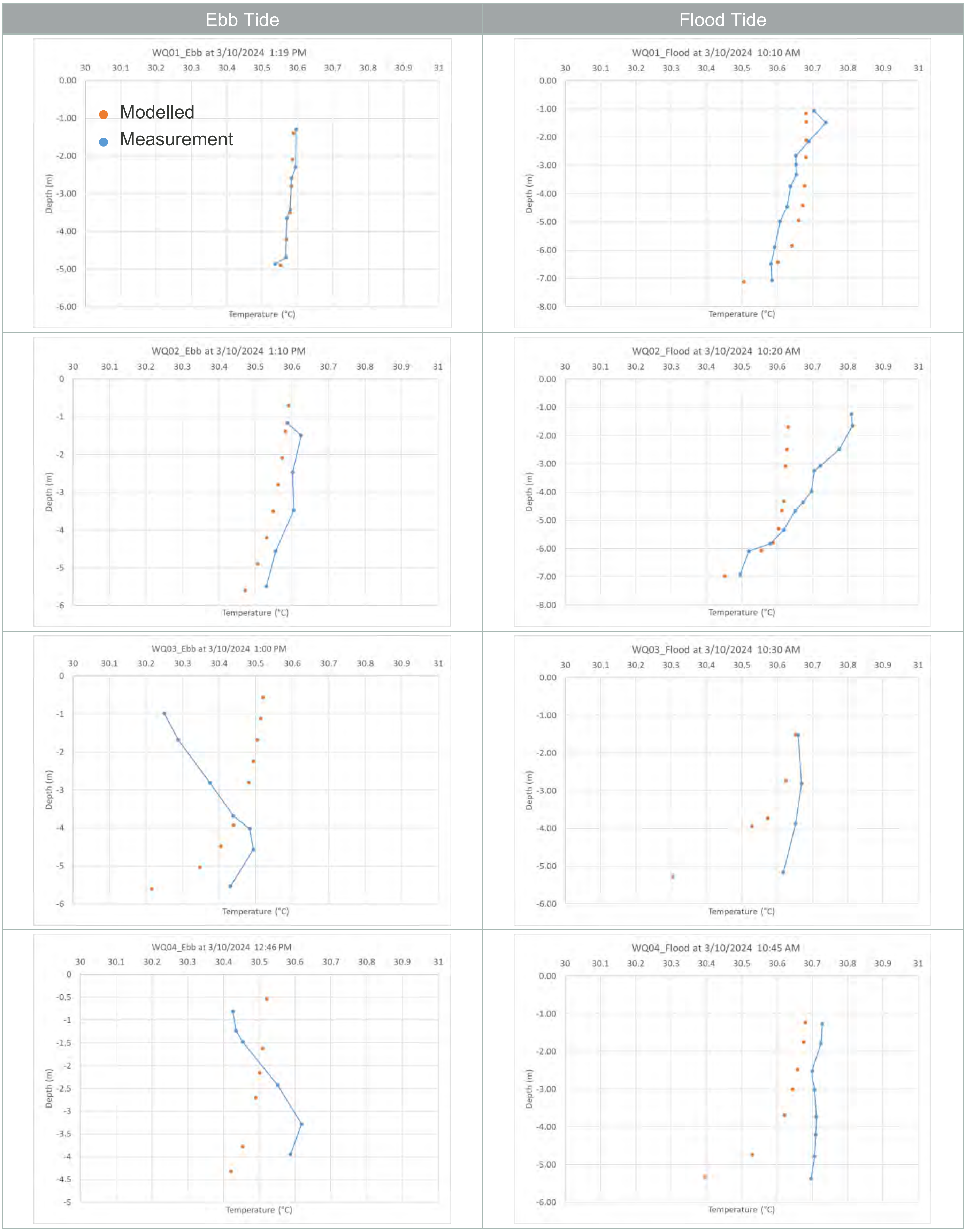



**Figure 13: Comparison of measured and modelled sea water temperature through water depth different water quality stations during ebb (left) and flood (right) tide**

## G.5.2 Simulation Scenarios

The intake and outfall information and scenarios are presented in Table 11. Table 12 summarises the 12 number of thermal plume model runs carried out.

**Table 11: Intake and outfall information and scenarios**

<table>
<tr><th>Parameter</th><th>Intake</th><th>Outfall</th></tr>
<tr><td>Flow rate</td><td>• With one intake operating: 4,800 m³/hr<br>• With two intakes operating: 2,400 m³/hr per intake</td><td>4,800 m³/hr</td></tr>
<tr><td>Water depth</td><td>Sea water intake from the side of the hull, positioned 2.5 m below the surface water</td><td>Positioned 1m below the surface water</td></tr>
<tr><td>Design discharge excess temperature increase (° C)</td><td>Ambient</td><td>+ 5 ° C</td></tr>
<tr><td>Scenarios</td><td colspan="2"><table>
<tr><th>Scenario</th><th>Intake and Outfall Flow Rate</th></tr>
<tr><td>Scenario 1</td><td>Outfall operates at 4,800 m³/hr with two intakes, each drawing 2,400 m³/hr from the left and right intake points</td></tr>
<tr><td>Scenario 2</td><td>Outfall operates at 4,800 m³/hr with a single intake on the left side drawing 4,800 m³/hr</td></tr>
<tr><td>Scenario 3</td><td>Outfall operates at 4,800 m³/hr with a single intake on the right side drawing 4,800 m³/hr</td></tr>
</table></td></tr>
</table>

**Table 12: Thermal plume model scenarios**

| No | Bathymetry | Monsoon | Simulation Period | Intake and Outfall Scenario |
|---|---|---|---|---|
| 1 | Pre-construction | Northeast | 9 Dec 2023 to 23 Dec 2023 | NA |
| 2 | | Southwest | 1 Jul 2024 to 15 July 2023 | NA |
| 3 | | Inter-monsoon | 1 Apr 2023 to 15 Apr 2023 | NA |
| 4 | Post-construction | Northeast | 9 Dec 2023 to 23 Dec 2023 | Scenario 1 |
| 5 | | Southwest | 1 Jul 2024 to 15 July 2023 | Scenario 2 |
| 6 | | Inter-monsoon | 1 Apr 2023 to 15 Apr 2023 | Scenario 3 |
| 7 | | Northeast | 9 Dec 2023 to 23 Dec 2023 | Scenario 1 |
| 8 | | Southwest | 1 Jul 2024 to 15 July 2023 | Scenario 2 |
| 9 | | Inter-monsoon | 1 Apr 2023 to 15 Apr 2023 | Scenario 3 |
| 10 | | Northeast | 9 Dec 2023 to 23 Dec 2023 | Scenario 1 |
| 11 | | Southwest | 1 Jul 2024 to 15 July 2023 | Scenario 2 |
| 12 | | Inter-monsoon | 1 Apr 2023 to 15 Apr 2023 | Scenario 3 |

## G.6 Chlorine Plume Model

Chlorine plume model applied the same hydrodynamic model couple with transport module in the MIEK3 model package.

The transport module allows chemical and water quality components discharge into the water using the transport (advection-dispersion) equations to predict the discharge components mixing, dilution and further movement associated with the flow. The module also allows for simulating the components with decay linearly in time. Many processes can be approximated by a linear decay, such as die-off of E. Coli due to exposure to light, decay of the activity of radioactive substances or estimating the age of water bodies.

For the present proposed chlorine discharge, the chlorine plume model applies the MIKE3 coupled flexible mesh hydrodynamic modelling system to simulate the chlorine plume dispersion process. All the model setups including domain and parameters are in line with the hydrodynamic model setup and application as presented in section G.3.

### G.6.1 Model Set Up Parameters

The transport module setups for chlorine plume model are as follows.

- Horizontal dispersion using a constant value of 1 for the Scaled eddy viscosity formulation;
- Vertical dispersion using a constant value of 0.1 for the Scaled eddy viscosity formulation to identify the dispersion process through the water column;
- No decay process with the assumption of discharged chlorine remaining within the water;
- Discharged chlorine concentration using 0.16 mg/L associated with the outfall discharge flow rate.

### G.6.2 Simulation Scenarios

Table 13summarises the nine (9) chlorine plume modelling runs. The intake and outfall scenarios are identical as presented in previous section G.3.3.6 and G.5.2.

**Table 13: Chlorine plume model scenarios**

| No | Bathymetry | Monsoon | Simulation Period | Intake and Outfall Scenario |
|---|---|---|---|---|
| 1 | Post-construction | Northeast | 9 Dec 2023 to 23 Dec 2023 | Scenario 1 |
| 2 | | Southwest | 1 Jul 2024 to 15 July 2023 | Scenario 2 |
| 3 | | Inter-monsoon | 1 Apr 2023 to 15 Apr 2023 | Scenario 3 |
| 4 | | Northeast | 9 Dec 2023 to 23 Dec 2023 | Scenario 1 |
| 5 | | Southwest | 1 Jul 2024 to 15 July 2023 | Scenario 2 |
| 6 | | Inter-monsoon | 1 Apr 2023 to 15 Apr 2023 | Scenario 3 |
| 7 | | Northeast | 9 Dec 2023 to 23 Dec 2023 | Scenario 1 |
| 8 | | Southwest | 1 Jul 2024 to 15 July 2023 | Scenario 2 |
| 9 | | Inter-monsoon | 1 Apr 2023 to 15 Apr 2023 | Scenario 3 |

# References

Duclos, G and Clement, A.H., 2004. Wave Propagation through Arrays of Unevenly Spaced Vertical Piles, Journal of Ocean Engineering.

MPA, 2023. Singapore Tide Table.

S. E. Mousadik, et. al., 2024. In situ optical measurement of particles in sediment plumes generated by a pre-prototype polymetallic nodule collector. Scientific reports www.nature.com/scientificreportrs

Willmott, C.1981, 'On the validation of models', J. Phys. Oceanogr., 2, 184-

# Appendix H

## In-situ Probes Certificate of Calibration

**Aurecon Singapore (Pte) Ltd**
152 Beach Road
#16-00 Gateway East
Singapore 189721

**T** +65 6256 6188
**F** +65 6251 7188
**E** singapore@aurecongroup.com
**W** aurecongroup.com

SECS
Member of the Aurecon Group

aurecon

# CERTIFICATE OF CALIBRATION

Date: 02 Oct 2024

Project Name : EIA for the development of Floating Data Centre at Loyang
Project Code : P527466

Client : Keppel Data Centre Fund II

Description : Calibration for In-Situ AquaTROLL 500 Multiparameter SN 607618.
All calibration was done in accordance to manufacturer's specification using calibration solution, which are NIST traceable.

| **Description of Calibration** | **Procedure (Buffer Solution / Standard Solution)** |
|---|---|
| pH | Calibration was performed using buffer solution 4.00, 7.00 and 10.00 @ 25°C |
| Conductivity | Calibration was performed using standard solution 1413 µS/cm @ 25°C |
| Turbidity | Calibration was performed using standard solution 100 NTU |
| Dissolved Oxygen | Calibration was performed at 100% water-saturated air calibration |

**Note:**
(1) Salinity: Derived from conductivity reading

Koh Lay Kuan
Director of Operations, Environment

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2) SECS agrees to use reasonable diligence in the performance of the service.
3) The results reported herein have been performed in accordance with the terms of accreditation under the Singapore Accreditation Council.

VWR® (BDH) CHEMICALS

# Certificate of Analysis

| | |
|---|---|
| Material | 32095.264 |
| Material description | Buffer solution pH 4.00 |
| Grade | |
| Lot | 23A274103 |
| Expires end of | 2025-Jan-25 |
| Last Quality Control | 2023-Feb-15 |
| Additional information | |

| Characteristics | Specifications | Measured values |
|---|---|---|
| pH (20°C) (tolerance ± 0.02) | 3.98 - 4.02 | 3.99 |
| pH laboratory uncertainty | ± 0.007 (k=1) | ± 0.007 (k=1) |
| pH homogeneity uncertainty | ± 0.000 (k=1) | ± 0.000 (k=1) |
| pH stability uncertainty | ± 0.001 (k=1) | ± 0.001 (k=1) |
| pH expanded, combined uncertainty | ± 0.02 (k=2; 95 %) | ± 0.02 (k=2; 95 %) |

## Signature

This document has been produced electronically and is valid without a signature.

Anja Vanhalle, Head of Laboratory - Haasrode
VWR International bv; Geldenaaksebaan 464; BE-3001 Leuven; Belgium

**Certified Reference Material**

**ISO 17034**

BELAC

Accreditation N°: 542-RM
VWR International bv
Geldenaaksebaan 464
BE-3001 Leuven, Belgium
Coverage available on: www.belac.be

## Additional information

pH-Method: pH value is analyzed with a glass electrode after 4-point calibration following the validated standard procedure. The expanded uncertainty relevant for the user contains contributions of bottle to bottle variation (inhomogeneity), stability over time and laboratory measurement uncertainties as shown above and using a coverage factor k=2 for a 95 % coverage probability.

Preparation and use: This reference material is prepared gravimetrically from potassium hydrogen phthalate and high purity water. It is intended to be used for calibrating pH measurement devices. The minimum sample size for use is 17.5 ml.

Accreditation: VWR International bv is accredited as reference material producer according to ISO 17034. The batch homogeneity has been proven by analyzing minimum 6 samples distibuted over the entire production process.

The pH of this buffer solution is traceable to and verified against primary Standard Reference Materials (SRM) from National Institute of Standards and Technology (NIST): SRM 188 and SRM 186 I + II.

Store at +2°C to +25°C tightly closed in the original container under nitrogen. Keep this reference material always under nitrogen. Consume within 4 weeks after first opening.

VWR® BDH CHEMICALS

# Certificate of Analysis

| | |
|---|---|
| Material | 32096.267 |
| Material description | Buffer solution (phosphate buffer) pH 7.00 ± 0.02 (20°C) |
| Grade | |
| Lot | 23A234130 |
| Expires end of | 2025-Jan-12 |
| Last Quality Control | 2023-Feb-02 |
| Additional information | |

| Characteristics | Specifications | Measured values |
|---|---|---|
| pH (20°C) (tolerance ± 0.02) | 6.98 - 7.02 | 7.00 |
| pH laboratory uncertainty | ± 0.005 (k=1) | ± 0.005 (k=1) |
| pH homogeneity uncertainty | ± 0.002 (k=1) | ± 0.002 (k=1) |
| pH stability uncertainty | ± 0.002 (k=1) | ± 0.002 (k=1) |
| pH expanded, combined uncertainty | ± 0.02 (k=2; 95 %) | ± 0.02 (k=2; 95 %) |

## Signature

This document has been produced electronically and is valid without a signature.

Anja Vanhalle, Head of Laboratory - Haasrode
VWR International bv; Geldenaaksebaan 464; BE-3001 Leuven; Belgium

**Certified Reference Material**
**ISO 17034**

BELAC
Accreditation N°: 542-RM
VWR International BVBA
Geldenaaksebaan 464
BE-3001 Leuven, Belgium
Coverage available on: www.belac.be

## Additional information

pH-Method: pH value is analyzed with a glass electrode after 4-point calibration following the validated standard procedure. The expanded uncertainty relevant for the user contains contributions of bottle to bottle variation (inhomogeneity), stability over time and laboratory measurement uncertainties as shown above and using a coverage factor k=2 for a 95 % coverage probability.

Preparation and use: This reference material is prepared gravimetrically from potassium di-hydrogen phosphate, di-sodium hydrogen phosphate and high purity water. It is intended to be used for calibrating pH measurement devices. The minimum sample size for use is 17.5 ml.

Accreditation: VWR International bv is accredited as reference material producer according to ISO 17034. The batch homogeneity has been proven by analyzing minimum 6 samples distibuted over the entire production process.

The pH of this buffer solution is traceable to and verified against primary Standard Reference Materials (SRM) from National Institute of Standards and Technology (NIST): SRM 186 I + II + SRM 187.

Store at +2°C to +25°C tightly closed in the original container under nitrogen. Keep this reference material always under nitrogen. Consume within 4 weeks after first opening.

VWR®
(BDH) CHEMICALS

# Certificate of Analysis

| | |
|---|---|
| Material | 32040.260 |
| Material description | Buffer solution pH 10 |
| Grade | |
| Lot | 23A184126 |
| Expires end of | 2025-Jan-16 |
| Last Quality Control | 2023-Feb-02 |

Additional information

| Characteristics | Specifications | Measured values |
|---|---|---|
| pH (20°C) (tolerance ± 0.02) | 9.98 - 10.02 | 9.99 |
| pH laboratory uncertainty | ± 0.007 (k=1) | ± 0.007 (k=1) |
| pH homogeneity uncertainty | ± 0.003 (k=1) | ± 0.003 (k=1) |
| pH stability uncertainty | ± 0.009 (k=1) | ± 0.009 (k=1) |
| pH expanded, combined uncertainty | ± 0.03 (k=2; 95 %) | ± 0.03 (k=2; 95 %) |

## Signature

This document has been produced electronically and is valid without a signature.

Anja Vanhalle, Head of Laboratory - Haasrode
VWR International bv; Geldenaaksebaan 464; BE-3001 Leuven; Belgium

**Certified Reference Material**
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BELAC
Accreditation N°: 542-RM
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BE-3001 Leuven, Belgium
Coverage available on: www.belac.be

## Additional information

pH-Method: pH value is analyzed with a glass electrode after 4-point calibration following the validated standard procedure. The expanded uncertainty relevant for the user contains contributions of bottle to bottle variation (inhomogeneity), stability over time and laboratory measurement uncertainties as shown above and using a coverage factor k=2 for a 95 % coverage probability.

Preparation and use: This reference material is prepared gravimetrically from sodium hydrogen carbonate, sodium carbonate and high purity water. It is intended to be used for calibrating pH measurement devices. The minimum sample size for use is 17.5 ml.

Accreditation: VWR International bv is accredited as reference material producer according to ISO 17034. The batch homogeneity has been proven by analyzing minimum 6 samples distibuted over the entire production process.

The pH of this buffer solution is traceable to and verified against primary Standard Reference Materials (SRM) from National Institute of Standards and Technology (NIST): SRM 187, SRM 191 I + II.

Store at +2°C to +25°C tightly closed in the original container under nitrogen. Keep this reference material always under nitrogen. Consume within 4 weeks after first opening.

Jw. 04/07/2023

avantor™ delivered by VWR™

# Certificate of Analysis

| | |
|---|---|
| Material Number: | 84135.290 |
| Material description: | Conductivity Standard 1,413 µS/cm @ 25°C |
| Lot Number: | 230130 |
| Use by*: | 2024-Nov-28 |
| Date of Quality Control: | 2023-May-10 |

| Characteristics | Specification: | Measured Values |
|---|---|---|
| **Conductance** | 1399 - 1427 µS/cm @ 25°C | 1414 µS/cm @ 25°C |
| **Method:** | The result reported above was determined by analysis of a sample of this lot taken at time of manufacture. This certificate relates solely to the lot number given above. The uncertainty of measurement has been calculated not to exceed ± 1% at 95% confidence level, k=2. | |
| **Metrological Traceability:** | Measurement taken by comparison with standard prepared from National Institute of Standards and Technology (USA), Standard Reference Material 999 (Potassium Chloride). Electrode used for measurement: Platinised Platinum Dip Cell. Reference: ASTM D-1125 Method A. | |

Signature

We certify that this batch conforms to the specifications listed above. This document has been produced electronically and is valid without a signature

Signed on behalf of VWR: 12 May 2023

HOSZOWSKA Anna
QC Technician

Other Information
* The use by date is the date to which VWR guarantees the above specification will be met for the product in an unopened container stored under our recommended conditions.

# Appendix I

## Air Meter Certificate of Calibration

# CHARACTERIZATION AND CALIBRATION CERTIFICATE

KUNAK TECHNOLOGIES S.L., as manufacturer of the product, certifies that the cartridge meets the internal manufacturing quality conditions, as well as the laboratory tests and the correct calibration of the cartridges according to the QA&QC proccedings.

Cartridges are tested according to the laboratory pre-test specified in CEN/TS 17660-1:2021 ”Air quality - Performance evaluation of air quality sensor systems - Part 1: Gaseous pollutants in ambient air”, regarding the Response Time (t90), Limit of Detection (LOD) and Repeatability (Rep).

## CERTIFIED CARTRIDGE

| | | | |
|---|---|---|---|
| **Cartridge type:** | Carbon monoxide (CO) | **Manufacture Date:** | 2023-10-02 |
| **P/N:** | K-CO-A-01 | **Expiry Date:** | 2025-12-04 |
| **S/N:** | 3023360159 | | |

## TEST 1: ENVIRONMENTAL CHARACTERIZATION TEST

Environmetal characterization test - not required for Carbon monoxide (CO) cartridges.

## TEST 2: LABORATORY TEST

The Response Time, the Limit of Detection and the Repeatability of the cartridge are calculated using certified gas bottles according to the CEN/TS 17660-1:2021.

- **Response Time:** The response time of the sensor systems is estimated using t90 (the time required for the sensor system to reach 90% of the final stable value).
- **Limit of Detection:**Value of the measured quantity that gives the probability of falsely asserting the absence or presence of a component.
- **Repeatability:** closeness of the agreement between the results of successive measurements of the same measure and carried out under the same conditions of measurement.

| Test | Cartridge S/N | Kunak requirement | TS 17660-1:2021 requirement | STATUS |
|---|---|---|---|---|
| Response Time | 3023360159 | < 30 s | < 360 s | PASS |
| Limit of Detection | 3023360159 | < 10 ppb | < 150 ppb | PASS |
| Repeatability | 3023360159 | < 20 ppb | < 50 ppb | PASS |

## REMARKS

The results indicated refer exclusively to the cartridge subjected to the characterization and laboratory tests and described in this certificate.

Signature:

KUNAK TECHNOLOGIES, S.L.
C.I.F. B71110837
Parque Empresarial La Muga, 9 Plt. 4 Ofi. 1
31160 ORKOIEN (Navarra)

# PRODUCT CONFORMITY CERTIFICATE

This is to certify that the

## *Kunak AIR Pro*

Manufactured by:

***Kunak Technologies SL***
*Parque Empresarial La Muga, 9*
*Floor 4, Office 1 – Orcoyen*
*Navarra*
*Spain*

has been assessed by CSA Group
and for the conditions stated on this certificate complies with:

**MCERTS Performance Standards for Indicative Ambient Particulate Monitors, Environment Agency, August 2017, version 4**

Certification ranges:

$PM_{2.5}$ 0-1,500 µg/$m^3$
$PM_{10}$ 0-2,000 µg/$m^3$

| | |
|---|---|
| Project No.: | 80150788 |
| Certificate No: | CSA MC230418/00 |
| Initial Certification: | 9 June 2023 |
| This Certificate issued: | 9 June 2023 |
| Renewal Date: | 8 June 2028 |

Andrew Young
Environmental Team Manager

MCERTS is operated on behalf of the Environment Agency by


CSA Group Testing UK Ltd
Unit 6, Hawarden Industrial Park
Hawarden, Deeside, CH5 3US
Tel: +44 (0)1244 670 900

**Certificate Contents**



## Approved Site Application

Any potential user should make sure, in consultation with the manufacturer, that the monitoring system is suitable for the intended application. For general guidance on monitoring techniques refer to the Environment Agency guidance available at www.mcerts.net

The indicative dust monitoring analyser(s) can be operated in one of two ways:

For qualitative measurements: Providing qualitative measurement data for the analysis of particulate pollution trends, and source identification studies based for example on pollution roses etc. Such application can rely on instrument factory calibration only.

For quantitative measurements: Providing measurement data with the uncertainty defined for indicative instruments (+/- 50%). This can be achieved on condition that each instrument used for measurement has been calibrated on the specific site where monitoring is taking place against a standard reference method for a period of two weeks and the resulting slope and intercept have been used for instrument calibration. Using non-standard filters and procedures for this purpose is not acceptable. To maintain the validity of data this calibration has to be repeated at least every twelve months or when the instrument is moved to a different site.

They **cannot** be used on national automatic monitoring networks for compliance reporting against the Ambient Air Quality Directives.

The field tests were carried out from the 1 April 2022 to the 7 February 2023 on two candidate 'Kunak AIR Pro' samplers, collocated with a Palas Fidas 200 (the reference method). The location of the field test was University of Manchester, Fallowfield, Manchester, UK. The serial numbers of the two 'Kunak AIR Pro' monitors were '0321 180036' and '0321 180037'.

## Basis of Certification

This certification is based on the following test report(s) and on CSA Group's assessment and ongoing surveillance of the product and the manufacturing process:

Bureau Veritas, test report ref. AIR17810339, dated June 2023, "Kunak, Test of the Air Pro for use as an Indicative Monitor for $PM_{10}$ and $PM_{2.5}$"

**Product Certified**

The ‘Kunak AIR Pro’ measuring system consists of the following parts:

- Base Station includes data storage with eSIM cellular communications.
- Power Pack embedded in the base station.
- Particulate sensor cartridge to measure $PM_{2.5}$ and $PM_{10}$.
- Solar protected shield.

*Sensor type and firmware version*
Alphasense OPC-N3 with firmware version 1.32.DT

*Algorithm Version (note 5.)*
KAIR_OPCN3_31

The particle firmware - Senor type OPC-N3 firmware version 1.17a.B with algorithm version KAIR_OPCN3_30.

This certificate applies to all instruments fitted with serial number 0321 180037 onwards.

## Certified Performance

| Test (***Laboratory***) | Results expressed as % of the certification range | | | | Other results | MCERTS specification |
|---|---|---|---|---|---|---|
| | <0.5 | <1 | <2 | <5 | | |
| Constancy of the sample volumetric flow | | | | | Not applicable<br>Note 1 | To remain constant within ± 3% |
| Tightness of the sampling system | | | 1.44% | | | Leakage not to exceed 2% of sampled volume |

| Test (**Field**) | Results expressed as % of the certification range | | | | Other results | MCERTS specification |
|---|---|---|---|---|---|---|
| | <0.5 | <1 | <2 | <5 | | |
| Intra-instrument uncertainty for the reference method | | | | | | |
| $PM_{10}$ | | | | | 0.33µg/m$^3$ | ≤2.5µg/m$^3$ |
| $PM_{2.5}$ | | | | | 0.25µg/m$^3$ | ≤2.5µg/m$^3$ |
| Intra-instrument uncertainty for the candidate method | | | | | | |
| $PM_{10}$ | | | | | | ≤5µg/m$^3$ for all data as well as for the subsets: < or ≥ 30 µg/m$^3$ |
| All data (n=306) | | | | | 1.74µg/m$^3$ | |
| ≥ 30 µg/m$^3$ (n=4) | | | | | 2.47µg/m$^3$ | |
| < 30 µg/m$^3$ (n=302) | | | | | 1.74µg/m$^3$ | |
| $PM_{2.5}$ | | | | | | ≤5µg/m$^3$ for all data as well as for the subsets: < or ≥ 30 µg/m$^3$ |
| All data (n=306) | | | | | 0.81µg/m$^3$ | |
| ≥ 18 µg/m$^3$ (n=14) | | | | | 1.64µg/m$^3$ | |
| < 18 µg/m$^3$ (n=292) | | | | | 0.75µg/m$^3$ | |
| Highest resulting uncertainty estimate comparison against data quality objective (Measurement Uncertainty) | | | | | | $W_{CM}$≤50% <br> $W_{CM} \leq W_{dpo}$ <br> ($W_{dpo}$ Measurement uncertainty defined as 50% for indicative instruments) |
| $PM_{10}$ | | | | | | |
| All data (n=306) | | | | | 81.1% | |
| All data (slope corrected) (n=306) | | | | | 12.2% (note 2) | |
| ≥ 30 µg/m$^3$ (slope corrected) (n=4) | | | | | 46.6% | |
| $PM_{2.5}$ | | | | | | |
| All data (n=306) | | | | | 67.0% | |
| All data (slope corrected) (n=306) | | | | | 10.6% (note 3) | |
| ≥ 18 µg/m$^3$ (slope corrected) (n=14) | | | | | 40.9% (note 3) | |
| Maintenance Interval | | | | | 44 weeks <br> Note 4 | ≥2 weeks |

Note 1 - The Kunak AIR Pro utilises a fan and not a pump, therefore it was agreed that this test was not applicable.
Note 2 - This data was slope corrected by dividing by 0.596. All users must slope correct $PM_{10}$ data by dividing by 0.596 - it is recommended that the manufacturer program this value into their algorithm in order to avoid confusion to end users. End users should check with the manufacturers that this has been carried out.
Note 3 - This data was slope corrected by dividing by 0.667. All users must slope correct $PM_{2.5}$ data by dividing by 0.667 - it is recommended that the manufacturer program this value into their algorithm in order to avoid confusion to end users. End users should check with the manufacturers that this has been carried out.
Note 4 - Maintenance - the manufacturer recommends that users clean the PM inlet if it becomes dirty. If a problem arises, such as sensor malfunction or obstruction, then the software will detect it automatically and will invalidate the measurements and advise the user to carry out specific maintenance. It is further recommended to change the PM sensor after 2 years operation.
Note 5 - The Kunak AIR Pro must be set up using the configuration, as follows; i) Alphasense OPC-N3 sensor with firmware version '1.32.DT', and ii) Algorithm version: KAIR_OPCN3_31. The firmware version incorporates slope correction – firmware version '31' is approved and no slope correction required.

## Description

The Kunak AIR Pro has a particulate matter sensor that consists of an optical particle counter (OPC) capable of measuring particles from 0.3µm up to 40µm. $PM_{2.5}$ and $PM_{10}$ are calculated assuming a particle density profile.
The effect of humidity is corrected using the embedded algorithm. The particle size distributions are available on Kunak Cloud.

The Kunak AIR Pro communicates using GPRS, 3G, 4G, ethernet and Modbus RTE Slave. Secure encryption and direct communication protocols, results in bi-directional communications and facilitates remote configuration, firmware update and sensor calibration of the devices through the Kunak Cloud web platform.

Kunak AIR Pro is equipped with an internal rechargeable battery. The battery can be powered either through a small solar panel to facilitate the installation of the device or by an outdoor charger to via the main network.

## General Notes

1. This certificate is based upon the equipment tested. The Manufacturer is responsible for ensuring that on-going production complies with the standard(s) and performance criteria defined in this certificate. The manufacturer is required to maintain an approved quality management system controlling the manufacture of the certified product. Both the product and the quality management system shall be subject to regular surveillance according to 'Regulations Applicable to the Holders of CSA Group Testing UK Ltd Certificates'.

2. The design of the product certified is defined in the CSA Group design schedule V00 for certificate no. CSA MC230418/00.

3. If a certified product is found not to comply, CSA Group should be notified immediately at the address shown on this certificate.

4. The certification marks that can be applied to the product or used in publicity material are defined in 'Regulations Applicable to the Holders of CSA Group Testing UK Ltd Certificates'.

5. This document remains the property of CSA Group and shall be returned when requested by CSA Group.

# CHARACTERIZATION AND CALIBRATION CERTIFICATE

KUNAK TECHNOLOGIES S.L., as manufacturer of the product, certifies that the cartridge meets the internal manufacturing quality conditions, as well as the laboratory tests and the correct calibration of the cartridges according to the QA&QC proccedings.

Cartridges are tested according to the laboratory pre-test specified in CEN/TS 17660-1:2021 "Air quality - Performance evaluation of air quality sensor systems - Part 1: Gaseous pollutants in ambient air", regarding the Response Time (t90), Limit of Detection (LOD) and Repeatability (Rep).

## CERTIFIED CARTRIDGE

| | | | |
|---|---|---|---|
| **Cartridge type:** | Nitrogen dioxide (NO2) | **Manufacture Date:** | 2023-10-05 |
| **P/N:** | K-NO2-A-01 | **Expiry Date:** | 2025-12-04 |
| **S/N:** | 3223320231 | | |

## TEST 1: ENVIRONMENTAL CHARACTERIZATION TEST

Typical baseline error in the whole temperature (<40ºC) and humidity range.

| Test | Cartridge S/N | Test results | Kunak requirement | STATUS |
|---|---|---|---|---|
| Environmetal characterization | 3223320231 | 19.06 ppb | < 16 ppb | PASS |

## TEST 2: LABORATORY TEST

The Response Time, the Limit of Detection and the Repeatability of the cartridge are calculated using certified gas bottles according to the CEN/TS 17660-1:2021.

- **Response Time:** The response time of the sensor systems is estimated using t90 (the time required for the sensor system to reach 90% of the final stable value).
- **Limit of Detection:**Value of the measured quantity that gives the probability of falsely asserting the absence or presence of a component.
- **Repeatability:** closeness of the agreement between the results of successive measurements of the same measure and carried out under the same conditions of measurement.

| Test | Cartridge S/N | Kunak requirement | TS 17660-1:2021 requirement | STATUS |
|---|---|---|---|---|
| Response Time | 3223320231 | < 120 s | < 360 s | PASS |
| Limit of Detection | 3223320231 | < 3 ppb | < 10 ppb | PASS |
| Repeatability | 3223320231 | < 4 ppb | < 4 ppb | PASS |

## REMARKS

The results indicated refer exclusively to the cartridge subjected to the characterization and laboratory tests and described in this certificate.

Signature:

KUNAK TECHNOLOGIES, S.L.
C.I.F. B71110837
Parque Empresarial La Muga, 9 Plt. 4 Ofi. 1
31160 ORKOIEN (Navarra)

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# CHARACTERIZATION AND CALIBRATION CERTIFICATE

KUNAK TECHNOLOGIES S.L., as manufacturer of the product, certifies that the cartridge meets the internal manufacturing quality conditions, as well as the laboratory tests and the correct calibration of the cartridges according to the QA&QC proccedings.

Cartridges are tested according to the laboratory pre-test specified in CEN/TS 17660-1:2021 ”Air quality - Performance evaluation of air quality sensor systems - Part 1: Gaseous pollutants in ambient air”, regarding the Response Time (t90), Limit of Detection (LOD) and Repeatability (Rep).

## CERTIFIED CARTRIDGE

| | | | |
|---|---|---|---|
| **Cartridge type:** | Ozone (O3) | **Manufacture Date:** | 2023-10-05 |
| **P/N:** | K-O3-A-01 | **Expiry Date:** | 2025-12-04 |
| **S/N:** | 3323160049 | | |

## TEST 1: ENVIRONMENTAL CHARACTERIZATION TEST

Typical baseline error in the whole temperature (<40ºC) and humidity range.

| Test | Cartridge S/N | Test results | Kunak requirement | STATUS |
|---|---|---|---|---|
| Environmetal characterization | 3323160049 | 8.30 ppb | < 7.5 ppb | PASS |

## TEST 2: LABORATORY TEST

The Response Time, the Limit of Detection and the Repeatability of the cartridge are calculated using certified gas bottles according to the CEN/TS 17660-1:2021.

- **Response Time:** The response time of the sensor systems is estimated using t90 (the time required for the sensor system to reach 90% of the final stable value).
- **Limit of Detection:**Value of the measured quantity that gives the probability of falsely asserting the absence or presence of a component.
- **Repeatability:** closeness of the agreement between the results of successive measurements of the same measure and carried out under the same conditions of measurement.

| Test | Cartridge S/N | Kunak requirement | TS 17660-1:2021 requirement | STATUS |
|---|---|---|---|---|
| Response Time | 3323160049 | < 120 s | < 360 s | PASS |
| Limit of Detection | 3323160049 | < 3 ppb | < 10 ppb | PASS |
| Repeatability | 3323160049 | < 4 ppb | < 4 ppb | PASS |

## REMARKS

The results indicated refer exclusively to the cartridge subjected to the characterization and laboratory tests and described in this certificate.

Signature:

KUNAK TECHNOLOGIES, S.L.
C.I.F. B71110837
Parque Empresarial La Muga, 9 Plt. 4 Ofi. 1
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# CHARACTERIZATION AND CALIBRATION CERTIFICATE

KUNAK TECHNOLOGIES S.L., as manufacturer of the product, certifies that the cartridge meets the internal manufacturing quality conditions, as well as the laboratory tests and the correct calibration of the cartridges according to the QA&QC proccedings.

Cartridges are tested according to the laboratory pre-test specified in CEN/TS 17660-1:2021 "Air quality - Performance evaluation of air quality sensor systems - Part 1: Gaseous pollutants in ambient air", regarding the Response Time (t90), Limit of Detection (LOD) and Repeatability (Rep).

## CERTIFIED CARTRIDGE

| | | | |
|---|---|---|---|
| **Cartridge type:** | Sulphur dioxide (SO2) | **Manufacture Date:** | 2023-10-05 |
| **P/N:** | K-SO2-A-01 | **Expiry Date:** | 2025-12-04 |
| **S/N:** | 3523320113 | | |

## TEST 1: ENVIRONMENTAL CHARACTERIZATION TEST

Typical baseline error in the whole temperature (<40ºC) and humidity range.

| Test | Cartridge S/N | Test results | Kunak requirement | STATUS |
|---|---|---|---|---|
| Environmetal characterization | 3523320113 | 18.88 ppb | < 15 ppb | PASS |

## TEST 2: LABORATORY TEST

The Response Time, the Limit of Detection and the Repeatability of the cartridge are calculated using certified gas bottles according to the CEN/TS 17660-1:2021.

- **Response Time:** The response time of the sensor systems is estimated using t90 (the time required for the sensor system to reach 90% of the final stable value).
- **Limit of Detection:** Value of the measured quantity that gives the probability of falsely asserting the absence or presence of a component.
- **Repeatability:** closeness of the agreement between the results of successive measurements of the same measure and carried out under the same conditions of measurement.

| Test | Cartridge S/N | Kunak requirement | TS 17660-1:2021 requirement | STATUS |
|---|---|---|---|---|
| Response Time | 3523320113 | < 120 s | < 360 s | PASS |
| Limit of Detection | 3523320113 | < 3 ppb | < 10 ppb | PASS |
| Repeatability | 3523320113 | < 4 ppb | < 4 ppb | PASS |

## REMARKS

The results indicated refer exclusively to the cartridge subjected to the characterization and laboratory tests and described in this certificate.

Signature:

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# Appendix J

## Air and Noise Environmental Impact Assessment Report

Intended for
Keppel Data Centres

Document type
Report

Date
December 2024

# Environmental Impact Assessment (Air and Noise)

## Data Centre at Loyang, Singapore

Bright ideas.
Sustainable change.

Confidential

# Environmental Impact Assessment (Air and Noise)

## Data Centre at Loyang, Singapore

| | |
|---|---|
| Project name | EIA for Floating DC at Loyang |
| Project no. | 384000481 |
| Recipient | Keppel Data Centres |
| Document type | Report |
| Version | 00 |
| Date | 05/12/2024 |
| Prepared by | Brenda Ma, Ruimin Li, Jessica Lee |
| Checked by | Cara Quinn |
| Approved by | Cara Quinn |

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Version Control Log

| Revision | Date | Prepared by | Checked by | Approved by | Description |
|---|---|---|---|---|---|
| 00 | 05/12/2024 | BM, RL, JL | CQ | CQ | 1st draft |
| | | | | | |
| | | | | | |

Ramboll Pte Ltd
Company No: 199605843G
GST Reg No: 199605843G
PEB Ref. No: PEB112/07-L

# Contents

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# Acronyms & Abbreviations

| | |
|---|---|
| AAQT | Ambient Air Quality Target |
| ADMS | Air Dispersion Modelling study |
| °C | Degrees Celsius |
| $CO_2$ | Carbon Dioxide |
| COPPC | Code of practice on pollution control |
| dB | decibel |
| EIA | Environmental Impact Assessment |
| EPMA | Environmental Protection and Management Act |
| ES | Environmental Score |
| GLC | ground-level concentration |
| ha | Hectare |
| HT | High Tension |
| JTC | JTC Corporation |
| km | kilometre |
| l/h | litres per hour |
| LORs | Limits of reporting |
| m | metre |
| $m^2$ | square metres |
| $m^3$ | cubic metres |
| $m^3/h$ | cubic metres per hour |
| $NO_2$ | Nitrogen Dioxide |
| $NO_x$ | Nitrogen Oxides |
| NEA | National Environment Agency |
| NSFD | Near Sulphur-Free Diesel |
| ORDE | off-road diesel engines |
| PCS | Pollution Control Study |
| $PM_{10}$ | particulate matters |
| $PM_{2.5}$ | fine particulate matter |
| Ramboll | Ramboll Pte Ltd |
| RIAM | Rapid Impact Assessment Matrix |
| SCR | Selective Catalytic Reduction |
| SHD | Singapore Height Datum |
| $SO_2$ | sulphur dioxide |
| URA | Urban Redevelopment Authority |
| µg/L | micrograms per litre |
| WHO | World Health Organization |

# 1. Introduction

## 1.1 Background

Ramboll Pte Ltd (Ramboll) was commissioned by Aurecon Singapore Pte Ltd (Aurecon) to conduct an Environmental Impact Assessment (EIA) focusing on air quality and noise for a proposed data centre to be located within the Tolls Offshore Supply Base in Loyang, Singapore (herein referred to as the "Project"). The Project is under development by Keppel Data Centres.

The EIA has been prepared to assess the potential environmental impacts associated with the proposed data centre. The assessment focuses on identifying, predicting, and assessing the implications of the Project's activities, particularly in terms of air and noise emissions, on the surrounding environment. The findings of this EIA aim to inform decision-making and guide the development of mitigation measures to minimise environmental risks.

## 1.2 Scope of Work

The EIA is conducted to evaluate the noise and air impacts from the proposed data centre and ensure that it is in line with local requirements. The scope of work comprises the following:

- Investigation, review, and consolidation publicly available weather and air quality data;
- Collection of air quality data from nearest meteorological monitoring station;
- Identification of air emission and noise sources;
- Identification of facilities and activities within a 2-kilometre (km) radius of the Project, as well as any seasonal effects, that could impact air quality levels;
- Conducting air and noise dispersion modelling;
- Assessing the impacts of identified project activities;
- Identification of sensitive receptors in the surrounding area, including local community (or wider, if applicable) and ecological species (habitat-based, foraging or migrating, if applicable); and
- Provide recommendations to manage potential air quality or noise impacts from the Project.

## 1.3 Assumptions & Limitations

For this desktop study, the following assumptions and limitations apply:

- No air or noise quality monitoring exercise was performed; and,
- Meteorological conditions onsite were reviewed based on publicly available data. This data serves as a regional representation and are not site-specific.

# 2. Methodology

## 2.1 Identification of Sources

### 2.1.1 Identification of Potential Air Emissions

The only source of air emissions during the operations of the data centre are the emergency gensets. The emergency gensets are fuel-burning equipment with dedicated exhaust flues that will release air pollutants. Routine operation of these standby gensets is only expected for relatively short durations during manufacturer-required routine maintenance operations.

The air pollutant parameters of interest to the study include nitrogen oxides ($NO_x$, stated as $NO_2$ for this assessment), carbon monoxide (CO), particulate matters ($PM_{10}$), fine particulate matter ($PM_{2.5}$), and sulphur dioxide ($SO_2$).

Air emissions from the generators will consist primarily of $NO_X$, and, to a lesser extent, HC, CO and PM as combustion products from the facility's diesel-fired emergency generators. Effective July 2013, NEA mandated the supply of Near Sulphur-Free Diesel (NSFD) with a sulphur content of 0.001%, thus $SO_2$ is no longer a key pollutant of concern for data centres in Singapore.

### 2.1.2 Identification of Potential Noise Sources

The noise assessment accounts for the relevant noise sources present during the operational phase of the data centre, as outlined below:

- Six (6) emergency standby gensets were modelled at generator high tension (HT) Panel; and two (2) emergency standby gensets were modelled at south of the site, near the fire hydrant pump room.
- A total of eight (8) exhaust flues were modelled on the east side of the generator HT panel, near the panel.
- One (1) load bank were modelled at west side of the generator HT panel, adjacent to the panel.
- Twenty-eight (28) transformers were modelled in total: twenty-four (24) transformers were placed at the hull level of data centre module with the remaining four (4) transformers located outdoor near the site's southern boundary.
- Ten (10) pumps were modelled at the hull level of data centre module; and,
- Nine (9) chillers were also modelled at hull level of data centre module.

## 2.2 Air Dispersion Modelling

To assess the dispersal of air emissions from the gensets' exhaust flues, air dispersion modelling was conducted using the most recently approved and promulgated version (24142) of the American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD). AERMOD has been used by Ramboll in previous air dispersion modelling studies of facilities located in Singapore for submission to the relevant government agency, the National Environmental Agency (NEA), and it is the United States Environmental Protection Agency's (USEPA) recommended air dispersion model that has been designed to support the USEPA's regulatory modelling programs. It is a current-generation air dispersion model that incorporates concepts such as planetary boundary layer theory and advanced methods for handling complex terrain.

AERMOD was developed to replace the Industrial Source Complex Model-Short Term (ISCST3) as USEPA's preferred model for most local scale regulatory applications. AERMOD incorporates the Plume Rise Model Enhancements (PRIME) building downwash algorithms, which provide a more realistic handling of downwash effects than previous approaches. AERMOD is further assisted by the Geographic Information System (GIS) software developed by ESRI; the ArcGIS software used by NEA for the current National Emission Inventory. The ArcGIS system for the air dispersion assessment was developed to analyze the modelling results and compare them to the ambient air quality targets (AAQTs). The layers used for analysis include raster and feature layers representing both the physical elements (modelling grid, buildings, flues, roads, etc.) and the results of the analysis (point source emissions, pollutant concentration contours, etc.). The geospatial analyzes were performed by the Spatial Analysis extension of ArcGIS.

To simulate the building downwash effect, AERMOD incorporates the PRIME/BPIP building downwash algorithms. Each building produces an area of wake effect influence that can extend out to approximately five times the building length directly downwind from the trailing edge of the structure. As the wind rotates full circle, each direction-specific area of influence changes and is integrated into one overall area of influence termed the Good Engineering Practice (GEP) 5L Area of Influence, where L is the lesser of the building height or projected building width. Any flue that is on or within the limit line is affected by GEP wake effects for some wind direction or range of wind direction. Buildings in site surroundings incorporated into the model. The building locations, heights, and other dimensions were primarily estimated from Google Maps.

## 2.3 Noise Modelling

The computer modelling programme CadnaA (Computer Aided Noise Abatement) by DataKustik GmbH has been used to predict the noise propagation from the Project to the surrounding environment. This computer software uses the International Standard *ISO 9613-2 industrial standard for sound propagation (Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation)*. CadnaA accounts for lateral diffraction around building edges and multiple reflections off parallel buildings and solid ground areas. Within the CadnaA model, the industrial noise prediction standard programme was selected, which requires the following inputs:

- Meteorological Information;
- Topographical Data;
- Ground Absorption and Attenuation;
- Building Transmission Loss; and,
- Source Sound Power Levels.

## 2.4 Impact Assessment

All the identified impacts will be assessed using the Rapid Impact Assessment Matrix (RIAM) which allows for a holistic, rapid, and easily comparable presentation of overall project impacts. This allows for clearer pinpointing of the most significant predicted impacts in accordance with the definitions presented in Table 2.1.

Table 2.1: Levels of Impact Significance and their Definitions

| Significance | 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. |

| Significance | Definition |
|---|---|
| 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. |

RIAM translates qualitative standard definitions of evaluation criteria into semi-quantitative ordinal scores which are then used to calculate the Environmental Scores (ES) via the following formula:

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

The five evaluation criteria are defined as:

- (I) Importance of the sensitive receptor identified which is assessed against spatial or political boundaries, socio-economic value, intrinsic quality, or the degree of rarity.
- (M) Magnitude is based on the relationship between the analysed physio-chemical, biological, or socio-economic deviation from baseline conditions and the relevant environmental standards, benchmarks, guidelines, or tolerance limits. Importantly, the Magnitude value should reflect the magnitude of change experienced at a particular sensitive receptor. In this way, the impact pathway is considered, i.e., whether there is a spatial and/or temporal overlap between the environmental change and receptor. Positive or negative impacts are represented though positive or negative ordinal scores for Magnitude respectively.
- (P) Permanence defines whether an impact is temporary or permanent, i.e. a measure of the temporal status of the loss/change.
- (R) Recoverability expresses whether the receptor can recover from the impact, either unassisted or via mitigation measures. Recoverability is also a measure of the control over the effect of the condition.
- (C) Cumulative Impact is a measure of whether the effect will have a single direct impact or whether there will be a cumulative effect over time, or a synergistic effect with other conditions.

The multiplication of Magnitude and Importance in the formula ensures that the weight of both these evaluation criteria is expressed and is individually able to significantly influence the ES. The summation of Permanence, Importance, and Cumulative Impact ensures that these criteria are represented collectively without having a large influence on ES individually.

The standard definitions of each evaluation criteria, and the associated ordinal scores used to calculate ES, are shown in Table 2.2. For each identified environmental impact affecting a sensitive receptor, an ES will be calculated. The ES are then banded together and ranked in range bands as presented in Table 2.3, which are then translated to Impact Significance – the reported output of the impact assessment process

Table 2.2: Evaluation Criteria and Associated Ordinal 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 |
| 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 | 2 |
| | Presence of obvious cumulative/cascading effect that will affect other Developments or activities or trigger secondary impacts | 3 |

Table 2.3: Environmental Significance Range Bands

| Range Bands for RIAM ES | Impact Indicators according to Range Band | | Description of Range Value |
|---|---|---|---|
| | Range Value (alphabetical) | Range Value (numeric) | |
| 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 |

# 3. Site Setting

## 3.1 Site Description

The site consists of a plot of vacant land along the existing wharf within Tolls Offshore Supply Base and extends into the adjacent sea, where a floating data centre will be built. The floating component will be a non-propelled and permanently moored steel structure. According to the current land lot plan, the site is part of Lots MK31-04684C and MK31-04865P. The development will take up a land area of approximately 9870 $m^2$ and sea area of approximately 7580 $m^2$, subject to further confirmation.

As per the URA classification, the site and immediate surroundings are located within the Pasir Ris Planning Area, Loyang West Planning Subzone and are designated for "Business 2" land use, which is for light industrial use such as "clean industry, light industry, general industry, warehouse, public utilities and telecommunication uses and other public installations." The site location and vicinity map is presented in Figure 3.1.

The site was formerly marshland with mangroves as its natural vegetation, until it was developed for industrial purposes as part of the Loyang Offshore Supply Base around 1970, which was used for providing support services to offshore drilling until 2013.

## 3.2 Sensitive Receptors

The eastern end of Pasir Ris Park and the easternmost Seaview Bungalows at Civil Service Club @ Loyang are within 500 m of the site. The land these sit on are designated as "Park" and "Sports & Recreation" respectively. There are no other designated sensitive land use areas (e.g., natural reserves, scenic resorts, residential areas, schools, etc.) within 500 m of the site. A construction site located at 72 Loyang Way, approximately 335 m away from the site, is being developed into a factory with worker dormitories. Additionally, there is a currently undeveloped land plot approximately 600 m southwest of the site, denoted as R5 on the 1-km sensitive receptor map (Figure 3.2), designated for residential use in the URA Master Plan.

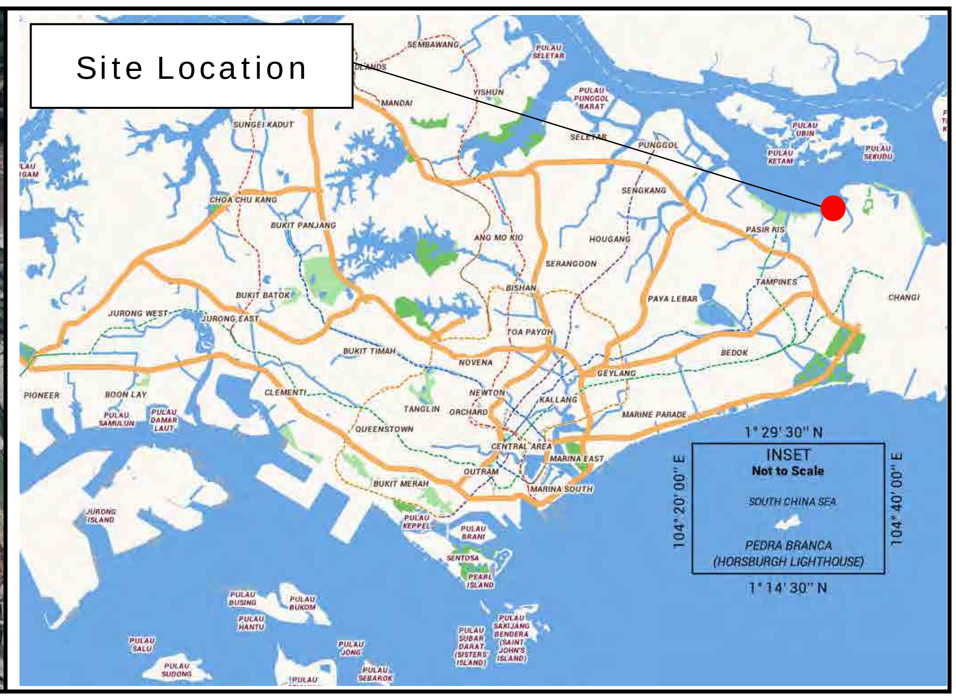
The nearest existing sensitive natural receptors to the site is the Johor Strait which is adjacent north of the site, as well as two other waterbodies, Loyang River and Selarang River. Loyang River is located approximately 325 m west and Selarang River is located approximately 500 m east of the site. These rivers discharge into the Johor Strait. There are no neighbouring premises which may be sensitive to air quality impacts, and future neighbouring premises are anticipated to be industrial in nature.

A summary of potential sensitive receptors within 2 km of the site, estimated to the nearest 0.1 km based on the shortest distance between the site boundary and each receptor, is presented in Table 3.1 below.

Table 3.1: Potentially Sensitive Receptors in Site Vicinity (2 km radius)

| Receptor Type | Receptor | Direction from Site | Distance from Site (km) |
|---|---|---|---|
| Residential | Aston Residence | WSW | 0.6 |
| | Casa Pasir Ris | WSW | 0.7 |
| | Ripple Bay Condominium | WSW | 1.0 |
| | The EdgeWater Condominium | WSW | 0.6 |
| | Vacant Land (Future Residential) | SW | 0.6 |

| Receptor Type | Receptor | Direction from Site | Distance from Site (km) |
|---|---|---|---|
| Park | Changi Beach Park | ENE | 2.0 |
| | Pasir Ris Park & Future Park Connector | WSW | 0.3 |
| Sport & Recreation | Civil Service Club @Loyang | WSW | 0.6 |
| | Changi Beach Club | ENE | 0.8 |
| | Changi Sailing Club | ENE | 1.2 |
| | Changi Ferry Point Chalet | ENE | 0.7 |
| | Changi Boardwalk | ENE | 0.8 |
| | Civil Service Club @ Changi I | ENE | 1.9 |
| | Civil Service Club @ Changi II | ENE | 1.6 |
| | Changi Point Coastal Walk | ENE | 2.2 |
| Hotel | Changi Cove | ENE | 0.9 |
| | Village Hotel Changi | ENE | 1.9 |
| Place of Worship | Sree Ramar Temple | ENE | 1.9 |
| | Carmel Presbyterian Church | WSW | 0.9 |
| | Masjid Al-Istighfar | SW | 1.3 |
| | Loyang Tua Pek Kong Temple | SW | 1.3 |
| Health & Medical Care | Orange Valley Nursing Home | ENE | 1.5 |
| | Apex Harmony Lodge Nursing Home | SW | 1.4 |
| Civic & Community Institution | Police Coast Guard - Loyang Base | ENE | 0.2 |
| Educational Institution | Odyssey the Global Preschool @ Loyang | WSW | 0.6 |
| | Pasir Ris Primary School | SW | 1.2 |



Legend

Site Boundary

A: Keppel Floating Data Centre
B: Toll's Offshore Supply Base
C: Pasir Ris Park; Civil Service Club @ Loyang
D: Police Coast Guard Loyang Base
E: AirTrunk SGP1 Data Centre
F: GE Aviation Service Operation Pte Ltd
G: Changi Logistics Centre
H: SKP Industrial Building I & II
I: Bell Flavors & Fragrances Singapore Pte Ltd
J: Apex Pharma Marketing Pte Ltd
K: Tech-Link Storage Engineering Pte Ltd
L: Primetop Building
M: Yappy Pets Pte Ltd
N: Aerogaz (S) Pte Ltd
O: Power Station
P: Loyang Industrial Estate
Q: Changi Air Base (West) (Airfield Military Airbase)
R: Substation (U/C)
S: Hendon Camp (Military Base)
T: 72 Loyang Way Workers Dormitories (U/C)
U: SIA Engine Test Facility
V: Pratt & Whitney Aircraft
W: Carmel Presbyterian Church
X: Odyssey The Global Preschool – Loyang
Y: Private Condominiums & Apartments
Z: Housing Development Board (HDB) Pasir Ris flats

| | | | |
|---|---|---|---|
| Title: Site Location and Vicinity Map | Scale: As Shown | Date: Dec 2024 | Job No.: 384000481 |
| Location: Toll's Offshore Supply Base, Loyang, Singapore | Dwg Size: A4 | Approved: Final | Drawing No.: Figure 3.1 |
| Client: Keppel Data Centres | Consultant: RAMBOLL | | |


## Legend

- Site Boundary
- 1 km Buffer

**Land Use as per URA Masterplan 2019**

- Business 2
- Civic & Community Institution
- Commercial
- Educational Institution
- Hotel
- Park
- Place of Worship
- Residential
- Special Use
- Sports and Recreation

| Land Use | ID | Name |
|---|---|---|
| Residential | R1 | Aston Residence |
| | R2 | Casa Pasir Ris |
| | R3 | Ripple Bay Condominium |
| | R4 | The EdgeWater Condominium |
| | R5 | Vacant Land (Future Residential) |
| Park | P | Pasir Ris Park & Future Park Connector |
| Sport & Recreation | S1 | Civil Service Club @ Loyang |
| | S2 | Changi Beach Club |
| | S3 | Changi Fairy Point Chalet |
| | S4 | Changi Boardwalk |
| Hotel | H | Changi Cove |
| Place of Worship | W | Carmel Presbyterian Church |
| Civic & Community Institution | C | Police Coast Guard – Loyang Base |
| Educational Institution | E | Odyssey the Global Preschool |

Data sources:
URA Master Plan 2019; NParks Parks and Nature Reserves Boundaries; OneMap; OpenStreetMap

| | | | | |
|---|---|---|---|---|
| Title: Sensitive Receptor Map (1 km Radius from Site Boundary) | Client: Keppel Data Centres | Scale: As Shown | Date: December 2024 | Job No.: 384000481 |
| Location: Tolls Offshore Supply Base, Loyang, Singapore | Consultant: RAMBOLL | Dwg Size: A3 | Approved: Final | Drawing No.: Figure 3.2 |

# 4. Air Quality Assessment

## 4.1 Regulatory Requirements and Criteria

In Singapore, regulatory and permitting requirements for air quality are governed primarily by the *Environmental Protection and Management Act (EPMA)* and its associated regulations which provides the legal basis for environmental protection in the country. The Act empowers the NEA to enforce the environmental protection and management requirements related to air. It also provides the legal basis for penalties and actions against those who violate these regulations. Specifically for data centre, NEA's jurisdiction will focus particularly on the fuel burning equipment, i.e., backup generators registrations and emissions.

### 4.1.1 Environmental Protection and Management Act

The EPMA provides a comprehensive legislative framework for the control and management of environmental pollution in Singapore. The provisions for air pollution control are established in Part IV of the Act. Specifically, these provisions stipulate the following:

- Any industrial premises in which fuel burning equipment is situated shall comply with the standards of concentration of air impurities listed in the Schedule;
- Every owner of any industrial premises shall carry out tests with respect to the emission of air impurities and keep a register of such tests and enable authorised officers to inspect and obtain representative samples of any discharge from the flue;
- It is an offence to cause, permit or allow the emission of air impurities in excess of the standard of concentration or rate of emission prescribed in respect of that industry, process, fuel burning equipment or industrial plant; and
- Where any such standard has not been so prescribed, it shall be the duty of the owner or occupier of any industrial or trade premises to conduct any trade or industrial process or operate any fuel burning equipment or industrial plant in or on the premises by the best practicable means available as may be necessary to prevent or minimise air pollution.

### 4.1.2 Off-Road Diesel Engines (Generators)

The *EPM (Off-Road Diesel Engine Emissions) Regulations* establish the requirements for the import, use, and examination of off-road diesel engines (ORDEs). Any internal combustion engine that operates by burning diesel fuel must be tested by an accredited examiner in accordance with ISO 8178. It is not permitted to import an off-road diesel engine for installation and operation in any industrial plant, except with the prior written approval of the Director-General (i.e., the responsible authority/agency, the NEA). If installed, the backup emergency generators are considered to be ORDEs.

ORDEs to be imported for use in Singapore must comply with the EU Stage II, US Tier II or Japan Tier I off-road diesel engine emission standards as prescribed in the regulations. An application must be made to register each ORDE with the NEA; an emission test report for each ORDE must be provided as part of the application to confirm conformance to the prescribed emission standards. Each ORDE must be registered. Installation of Tier 3 or Tier 4 generators, or technologies such as Selective Catalytic Reduction (SCR) on the facility's generators would be considered to be additional pollution control measures.

Exhaust emission standards for off-road engines are listed in the Schedule to the Regulations and are provided in Table 4.1.

Table 4.1: Emission Standards Prescribed under the EPM (Off-Road Diesel Engine Emissions) Regulations

(a) US Tier II

| Net Power (P) (kW) | CO (g/kWh) | NMHC + NOx (g/kWh) | PM (g/kWh) |
|---|---|---|---|
| P > 560 | 3.5 | 6.4 | 0.2 |
| 450 ≤ P < 560 | 3.5 | 6.4 | 0.2 |
| 225 ≤ P < 450 | 3.5 | 6.4 | 0.2 |
| 130 ≤ P < 225 | 3.5 | 6.6 | 0.2 |
| 75 ≤ P < 130 | 5.0 | 6.6 | 0.3 |
| 37 ≤ P < 75 | 5.0 | 7.5 | 0.4 |
| 19 ≤ P < 37 | 5.5 | 7.5 | 0.6 |
| 8 ≤ P < 19 | 6.6 | 7.5 | 0.8 |
| P < 8 | 8.0 | 7.5 | 0.8 |

(b) EU Stage II

| Net Power (P) (kW) | HC (g/kWh) | CO (g/kWh) | NOx (g/kWh) | PM (g/kWh) |
|---|---|---|---|---|
| 130 ≤ P < 560 | 1.0 | 3.5 | 6.0 | 0.2 |
| 75 ≤ P < 130 | 1.0 | 5.0 | 6.0 | 0.3 |
| 37 ≤ P < 75 | 1.3 | 5.0 | 7.0 | 0.4 |
| 18 ≤ P < 37 | 1.5 | 5.5 | 8.0 | 0.8 |

(c) Japan Tier I

| Net Power (P) (kW) | HC (g/kWh) | CO (g/kWh) | NOx (g/kWh) | PM (g/kWh) | Smoke opacity (%) |
|---|---|---|---|---|---|
| 130 ≤ P < 560 | 1.0 | 3.5 | 6.0 | 0.2 | 40 |
| 75 ≤ P < 130 | 1.0 | 5.0 | 6.0 | 0.3 | 40 |
| 37 ≤ P < 75 | 1.3 | 5.0 | 7.0 | 0.4 | 40 |
| 19 ≤ P < 37 | 1.5 | 5.0 | 8.0 | 0.8 | 40 |
| 8 ≤ P < 19 | 1.5 | 5.0 | 9.0 | 0.8 | — |

Source: Schedule to the *Environmental Protection and Management (Off-Road Diesel Engine Emissions) Regulations*

Notes per the Schedule:

"CO" means carbon monoxide;

"g/kWh" means gram per kilowatt hour;

"HC" means hydrocarbons;

"ISO" means International Standards Organisation;

"NMHC" means non-methane hydrocarbons;

"NOx" means oxides of nitrogen;

"PM" means particulate matter

### 4.1.3 Fuel Type

The NEA's *General Requirements to be Complied with at Development Control & Building Plan Stage* indicates that the type of fuel used should be specified at that stage. Section 12.3 of the COPPC has general guidance on the type of fuel to be used:

> *12.3. Fuel burning equipment should be efficiently operated and maintained. The fuel burning equipment should use fuel (e.g., natural gas, town gas, LPG (liquefied petroleum gas), and/or diesel with sulphur content) approved by the relevant authority*.

### 4.1.4 Flue Height

Section 12.4 of the COPPC specifies the design height for the flues (referred to as chimneys in the code):

> *12.4. A chimney of an approved height should be provided for safe dispersion of flue gases from fuel burning equipment. The design height of the chimney shall be computed based on the mass rate of fuel burnt to determine the sulphur dioxide ($SO_2$) emission from the fuel burning equipment, and take into account the height of buildings in the vicinity. The design chimney height computed from the $SO_2$ emission calculation shall not be lower than*

> *3 m above roof level of all factory buildings in the vicinity (refer to Figure 1 for distance criteria) or 15 m measured from ground level, whichever is higher*.

In addition, the NEA's *General Requirements to be Complied with at Development Control & Building Plan Stage* clarifies that for fuel burning equipment, a chimney of an approved height is to be provided *"to ensure that the flue gases are dispersed safely into the atmosphere. In general, the chimney height required shall be at least 3 m above the roof level of the proposed development and not lower than surrounding buildings (within 100 m of the proposed chimney location). The required chimney height will be specified at the Development Control ("DC") stage taking into consideration the fuel type and quantity, and the heights of surrounding buildings"*.

Air pollutant concentrations experienced at ground levels are highly influenced by the height of the exhaust emission point compared to the surrounding roof height. A higher exhaust flue height above roof level improves the effectiveness of dispersion of air emissions. As such, it is recommended that the genset exhaust flues be of adequate height to ensure that the flue gases are dispersed into the atmosphere. However, it is understood that the flue height is limited by the building height limit applicable to the site which is 45 m Singapore Height Datum (SHD) as enforced by URA.

#### 4.1.5 Codes of Practice

The *Singapore Standard SS 593: 2013 Code of practice on pollution control* (referred to as the "COPPC"), provides guidance on air pollution control and specific measures to control air pollution. The COPPC requires that factories which can generate air impurities install, operate, and maintain air pollution control equipment to minimise air pollution arising from their operations, in accordance with the EPMA.

In addition, the COPPC requires that:

- A chimney of approved height should be provided for safe dispersion of flue gases from fuel burning equipment; and

- Monitoring equipment is to be provided at discharge stacks and chimneys to monitor air impurities in order to ensure that the emissions comply with the air emission limits.

#### 4.1.6 Ambient Air Quality Targets (AAQT)

Singapore launched the *Sustainable Singapore Blueprint* (SSB) in 2009 to provide a strategic sustainability roadmap for the country. Although Singapore has not adopted ambient air quality standards, the air quality targets within the SSB make reference to international air quality benchmarks such as the World Health Organisation (WHO) Air Quality Guidelines (AQGs). NEA formed the Advisory Committee on Ambient Air Quality in 2010 to advise on a set of air quality targets for Singapore to safeguard public health. The Ministry of Sustainability and the Environment (MSE) (formerly the Ministry of Environment and Water Resources [MEWR]), together with NEA, reviewed the recommendations of the Advisory Committee and the SSB commitments, and has worked with relevant government agencies and various stakeholders to arrive at a set of revised national air quality targets pegged to the WHO AQGs[1].

The primary aim of the WHO guidelines (WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide - Global update 2005) is to provide a basis for protecting the public from adverse effects of air pollution and for eliminating or reducing to a minimum those air contaminants that are known or likely to be hazardous to human health and well-being. The WHO guidelines are intended to provide background information for use in making assessments of risk, rather than strict standards. They aim to provide a basis for setting standards or limiting values for

[1] http://www.nea.gov.sg/anti-pollution-radiation-protection/air-pollution-control

air pollutants by setting levels below which exposure for a given period of time does not constitute a significant health risk. Singapore's AAQTs were obtained from the latest version of the SSB and the NEA's website and are presented in Table 4.2.

Table 4.2: Singapore Ambient Air Quality Targets

<table>
<tr><th rowspan="2">Pollutant</th><th colspan="2">Singapore Ambient Air Quality Targets</th></tr>
<tr><th>2020 Targets</th><th>Long Term Targets</th></tr>
<tr><td>$SO_2$</td><td>24-hour mean: 50 µg/m$^3$<br>(WHO Interim Target)<br><br>Annual mean: 15 µg/m$^3$ (Sustainable Singapore Blueprint Target)</td><td>24-hour mean: 20 µg/m$^3$<br>(WHO Final)</td></tr>
<tr><td rowspan="2">Particulate Matter ($PM_{2.5}$)</td><td rowspan="2">Annual mean: 12 µg/m$^3$ (Sustainable Singapore Blueprint Target)<br><br>24-hour mean: 37.5 µg/m$^3$<br>(WHO Interim Target)</td><td>Annual mean: 10 µg/m$^3$</td></tr>
<tr><td>24-hour mean: 25 µg/m$^3$<br>(WHO Final)</td></tr>
<tr><td>Particulate Matter ($PM_{10}$)</td><td colspan="2">Annual mean: 20 µg/m$^3$<br>24-hour mean: 50 µg/m$^3$<br>(WHO Final)</td></tr>
<tr><td>Ozone</td><td colspan="2">8-hour mean: 100 µg/m$^3$<br>(WHO Final)</td></tr>
<tr><td>$NO_2$</td><td colspan="2">Annual mean: 40 µg/m$^3$<br>1-hour mean: 200 µg/m$^3$<br>(WHO Final)</td></tr>
<tr><td>CO</td><td colspan="2">8-hour mean: 10 mg/m$^3$<br>1-hour mean: 30 mg/m$^3$<br>(WHO Final)</td></tr>
<tr><td colspan="3">Reference:<br>NEA Website Air Quality and Targets<br>Ministry of the Environment and Water Resources and Ministry of National Development (2015) Sustainable Singapore Blueprint 2015.</td></tr>
</table>

## 4.2 Ambient Air Quality Baseline Conditions

### 4.2.1 Air Quality Secondary Data Review

The ambient air quality in Singapore is routinely monitored by the NEA through a network of air monitoring sensors across the island called the Telemetric Air Quality Monitoring and Management System (TAQMMS). The system comprises 23 fixed air monitoring stations strategically located to assess the air quality in different parts of Singapore.[2] The data from the air monitoring sensors are reported for five (5) regions (North, South, East, West and Central) and is accessible through NEA's resource portal for pollutant concentrations.[3]

The monitoring stations measure the concentrations of six (6) criteria air pollutants, namely particulate matter ($PM_{10}$), fine particulate matter ($PM_{2.5}$), sulphur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), ozone ($O_3$), and carbon monoxide (CO). The analysers are highly specialised equipment and certified by international bodies.

The main sources of air pollution in Singapore are emissions from the industries and motor vehicles. From time to time, transboundary smoke haze from land and forest fires in the region also affect Singapore's air quality, particularly during the Southwest monsoon period from August to October.[4]

The air quality data published by NEA in its annual report is the official air quality information for Singapore. The latest available annual data at the time of this report preparation is for 2023. Table 4.3 compares the annual statistics for 2021-2023. CO was within the WHO 2021 AQG, while $SO_2$, $PM_{10}$, $PM_{2.5}$, and ozone were within the WHO Interim Targets. Note that the average ambient hourly $NO_2$, a key parameter for data centre air quality assessments, was recorded at 61% to 64% of the AAQT.

[2] https://www.nea.gov.sg/docs/default-source/air-quality/aqmc---rfp-on-low-cost-sensors_finale9ac1a6e-c9f4-4ea5-b3f3-1fecf45df77c.pdf
[3] https://www.haze.gov.sg/resources/pollutant-concentrations
[4] https://www.nea.gov.sg/our-services/pollution-control/air-pollution/air-quality

Table 4.3: Ambient Air Quality Statistics 2021-2023 and the Singapore Air Quality Targets

| Pollutant (Unit) | Statistics | Averaging Time | 2021 | 2022 | 2023 | Singapore Air Quality Target[1] | 2005 WHO AQG[2] Level | WHO Interim Target[3] 1 | WHO Interim Target 2 | WHO Interim Target 3 | WHO Interim Target 4 | 2021 WHO AQG Level |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SO_2$ (µg/m$^3$) | Maximum | 24-hour | 89 | 37 | 20 | 20 | 20 | 125 | 50 | - | - | 40 |
| $NO_2$ (µg/m$^3$) | Maximum | 1-hour | 123 | 128 | 122 | 200 | 200 | - | - | - | - | 200 |
| | Mean | Annual | 25 | 25 | 23 | 40 | 40 | 40 | 30 | 20 | - | 10 |
| $O_3$ (µg/m$^3$) | Maximum | 8-hour | 176 | 124 | 154 | 100 | 100 | 160 | 120 | - | - | 100 |
| $PM_{10}$ (µg/m$^3$) | 99th Percentile | 24-hour | 51 | 51 | 62 | 50 | 50 | 150 | 100 | 75 | 50 | 45 |
| | Mean | Annual | 28 | 24 | 24 | 20 | 20 | 70 | 50 | 30 | 20 | 15 |
| $PM_{2.5}$ (µg/m$^3$) | 99th Percentile | 24-hour | 28 | 26 | 39 | 25 | 25 | 75 | 50 | 37.5 | 25 | 15 |
| | Mean | Annual | 12 | 11 | 11 | 10 | 10 | 35 | 25 | 15 | 10 | 5 |
| CO (mg/m$^3$) | Maximum | 1-hour | 1.3 | 2.1 | 1.8 | 30 | 35 | - | - | - | - | 35 |
| | Maximum | 8-hour | 1.2 | 1.7 | 1.5 | 10 | 10 | - | - | - | - | 10 |

Note:

[1] Singapore's air quality targets are benchmarked against the World Health Organisation's (WHO) Interim Targets and Air Quality Guidelines (Global update 2005), except for the $PM_{2.5}$ annual target. Singapore's $PM_{2.5}$ annual target is stringent than WHO's interim target from Global update 2005. The Singapore Ambient Air Quality Targets (AAQTs) were defined by 99$^{th}$ percentile of 24-hour averaging for $PM_{10}$ and $PM_{2.5}$;

[2] WHO Quality Guidelines were estimated and defined by 99$^{th}$ percentile of 24-hour averaging for $SO_2$, $PM_{10}$, $PM_{2.5}$, and of 8-hour for $O_3$;

[3] WHO interim targets were introduced in the 2005 Global Update as additional integral elements of guidance, designed to complement the WHO air quality guidelines. The interim targets were defined for levels of $SO_2$, $PM_{10}$, $PM_{2.5}$, and $O_3$ in the 2005 Global update and were retained in the updated WHO guidance (Global update 2021). The long-term air quality guideline from Global update 2005 of 40 µg/m$^3$ is used as interim target 1 for $NO_2$. The interim targets are intended for use in areas where pollution is high. There will be significant reductions in risks for acute and chronic human health effects from air pollution when these interim targets were to be achieved.

The Loyang area in which the Project is located falls under the "East" Region.[5] According to NEA, major town centres/areas within "East" region include Serangoon, Hougang, Tampines, Pasir Ris, Loyang, Simei, Kallang, Katong, East Coast, Macpherson, Bedok, Pulau Ubin, and Pulau Tekong.

A tabular summary of average and maximum concentrations of monitored pollutants ($NO_2$, CO, $PM_{10}$, $PM_{2.5}$, $SO_2$, and $O_3$) for the "East" region is presented in Table 4.4.

Table 4.4: NEA Monitored Pollutants for East Region (2023)

| Pollutant (unit) | Assessment Period | AAQT | Average NEA East Data | Maximum NEA East Data[4] |
|---|---|---|---|---|
| $NO_2$ (µg/m$^3$) | 1-hr[1] | 200 | 27 | 126 |
| CO (mg/m$^3$) | 1-hr[1] | 30 | - | - |
| | 8-hr[1] | 10 | 0.5 | 1.8 |
| $SO_2$ (µg/m$^3$) | 24-hr[1] | 20 | 4 | 19 |
| $PM_{10}$ (µg/m$^3$) | 24-hr[2] | 50 | 27 | 54 |
| $PM_{2.5}$ (µg/m$^3$) | 24-hr[2] | 25 | 15 | 39 |
| $O_3$ (µg/m$^3$) | 8-hr[2] | 100 | 23 | 110 |

Notes:

1. Maximum 24-hour, 8-hour or 1-hour
2. 99$^{th}$ percentile
3. Levels exceeding the standards are marked in bold font
4. NEA east data indicates the air quality status for the entire east region which generally covers the following areas: Serangoon, Hougang, Tampines, Pasir Ris, Loyang, Simei, Kallang, Katong, East Coast, Macpherson, Bedok, Pulau Ubin, Pulau Tekong. The data is accessible through https://www.haze.gov.sg/resources/pollutant-concentrations.

Based on a review of the data presented in the table above, the maximum concentrations of the criteria pollutants are below the corresponding AAQTs except $PM_{10}$ and $PM_{2.5}$. While the average concentrations of all pollutants fall far below the AAQTs. Figure 4.1 presents the distribution of the monitoring data. According to the figure, most of the monitored $PM_{10}$ and $PM_{2.5}$ throughout 2023 are below the 24-hour AAQTs, i.e., 50 µg/m$^3$ for 24-hour $PM_{10}$ and 25 µg/m$^3$ for 24-hour $PM_{2.5}$. Specifically, 75% of monitored $PM_{10}$ is well below 32 µg/m$^3$ and 75% of monitored $PM_{2.5}$ is well below 18 µg/m$^3$. Exceedances of AAQTs is likely a low probability event in this region and the regional air quality considered to be good compared to national averages.

[5] https://www.nea.gov.sg/our-services/pollution-control/air-pollution/faqs

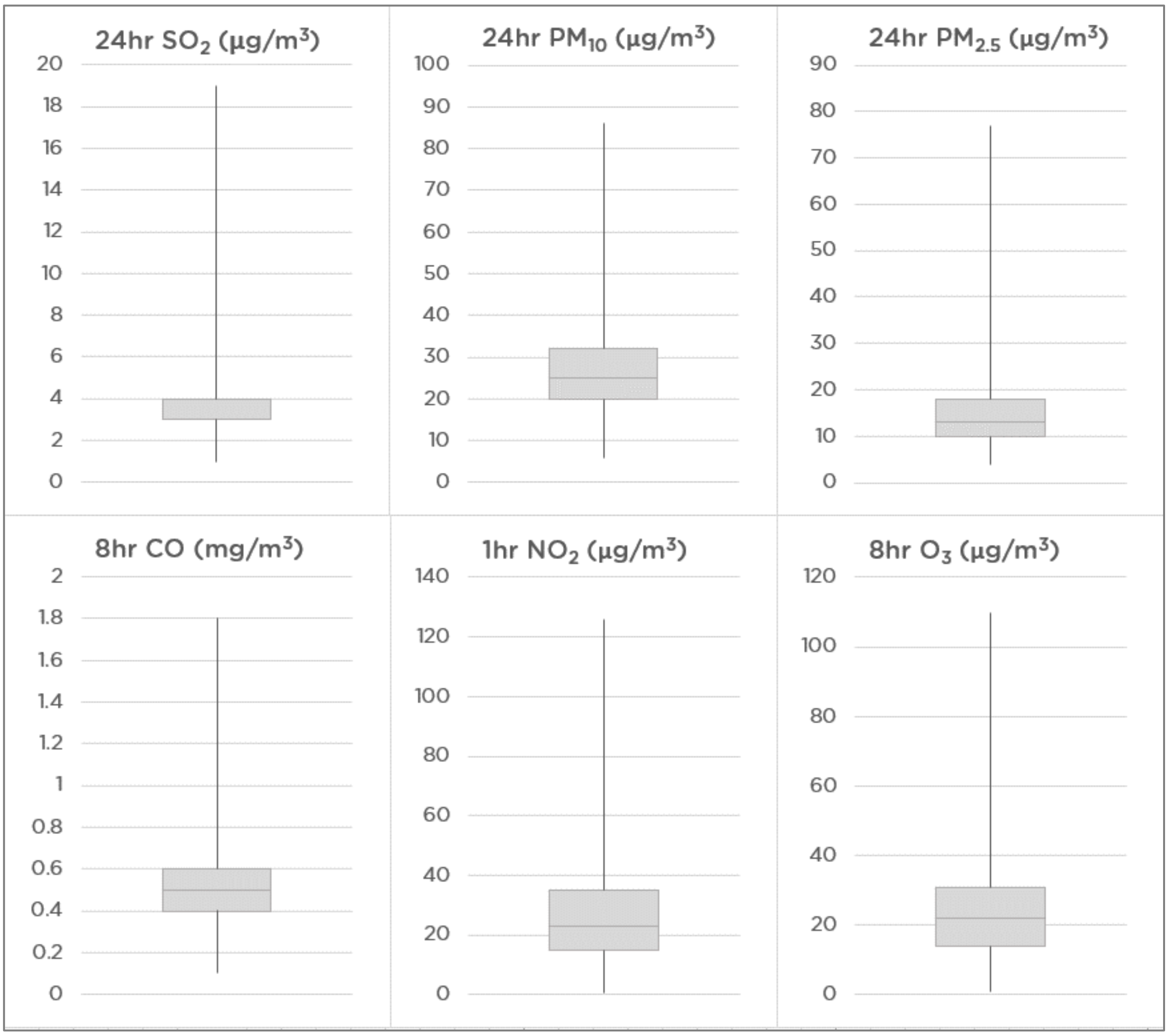



Figure 4.1: Distribution of NEA Monitored Pollutants for East Region

### 4.2.2 Site-Specific Ambient Air Quality Data

Site-specific baseline ambient air quality monitoring has been conducted at the site for consecutive 7 days from 25 Sep 2024 to 01 Oct 2024. The baseline status is demonstrated by comparing the measurement against the AAQT in Table 4.5. As demonstrated in Table 4.5, the 7-day measurements show a compliance with AAQT which suggest a good baseline air quality at the site.

Table 4.5: Baseline Status of Air Quality at the Site

| Parameter | Baseline Air Quality (µg/m$^3$) | AAQT (µg/m$^3$) |
|---|---|---|
| 1-hr $NO_2$ | 36.5 | 200 |
| 24-hr $PM_{10}$ | 16.7 | 50 |
| 24-hr $PM_{2.5}$ | 6.7 | 25 |
| 1-hr CO | 360 | 30,000 |
| 8-hr CO | 230 | 10,000 |
| 24-hr $SO_2$ | 10.4 | 20 |
| 8-hr $O_3$ | 30.8 | 100 |

### 4.2.3 Ambient Weather Considerations

The Meteorological Service Singapore (MSS) is Singapore's national authority on weather and climate. It is a pillar under the NEA. MSS currently operates a network of five manned observation stations, one upper air observatory and around 100 automatic weather stations. All the automatic weather stations measure rainfall and more than one-fifth of them measure other meteorological elements including temperature, relative humidity, pressure, and wind. This observation network serves as the main source of climate data for MSS, and data reported in this summary of weather data is based on MSS resources including the MSS Annual Climate Assessment Singapore, 2021[6].

Singapore is situated near the equator and has a typically tropical climate, with abundant rainfall, high and uniform temperatures, and high humidity all year round. Many of its climate variables, such as temperature and relative humidity, do not show large month-to-month variation. However, many variables exhibit prominent diurnal (or daily) variations from hour to hour, indicating the strong influence that solar heating has on the local climate.

The most prominent winds in Singapore are from the northeast and the south, reflecting the dominance of the monsoons in Singapore. On any given day, winds generally follow the prevailing monsoon flow except when light winds are being modified by terrain or weather systems (e.g., showers or thunderstorms and land or sea breezes). Wind directions are mainly from northerly to north-easterly during the Northeast Monsoon (December to March) and southerly to south-easterly during the Southwest Monsoon (June to September). Wind strength is greater during the Northeast Monsoon. The inter-monsoon months (April, May, October, and November) are transition periods between the monsoons and show lighter and more variable winds.

A tabular summary of average rainfall, temperature, relative humidity, wind speed and thunder and lightning is presented in Table 4.6 for the period 1991-2020[7] which is the latest publicly available climate data.

The Singapore wind rose is presented in Figure 4.2. The wind rose illustrates that this area is subject to the impacts of two prevailing winds, north-easterly winds and south-easterly winds. Usually, north-easterly prevailing winds occur from December to early March when is the northeast monsoon season while south-easterly winds dominant the southwest monsoon season from June to September.[8]

A site-specific pre-processed surface and upper air meteorological file generated by the Weather Research Forecast (WRF) has been used for further detailed assessment during the air dispersion modelling study. AERMOD requires a meteorological input file to characterise the transport and dispersion of pollutants in the atmosphere. Surface and upper air meteorological data inputs, as well as surface parameter data describing the land use and surface characteristics near the site, are processed using AERMET, the meteorological preprocessor to AERMOD. The output file generated by AERMET is the meteorological input file required by AERMOD.

[6] http://www.weather.gov.sg/wp-content/uploads/2022/03/ACAR_2021.pdf
[7] http://www.weather.gov.sg/climate-climate-of-singapore/
[8] http://www.weather.gov.sg/climate-climate-of-singapore/

Table 4.6: MSS Record of Climate Station Means for 1991-2020

| Parameter | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainfall | Mean Monthly/ Annual Total (mm) | 221.6 | 105.1 | 151.7 | 164.3 | 164.3 | 135.3 | 146.6 | 146.9 | 124.9 | 168.3 | 252.3 | 331.9 |
| | Mean Raindays | 13 | 9 | 12 | 15 | 15 | 13 | 14 | 14 | 13 | 15 | 19 | 19 |
| Temperature (°C) | Mean Daily Maximum | 30.6 | 31.5 | 32.2 | 32.4 | 32.3 | 31.9 | 31.4 | 31.4 | 31.6 | 31.8 | 31..2 | 30.5 |
| | Mean Daily Minimum | 24.3 | 24.6 | 24.9 | 25.3 | 25.7 | 25.7 | 25.4 | 25.3 | 25.2 | 25.0 | 24.6 | 24.3 |
| | 24-hr Mean | 26.8 | 27.3 | 27.8 | 28.2 | 28.6 | 28.5 | 28.2 | 28.1 | 28.0 | 27.9 | 27.2 | 26.8 |
| Relative Humidity (%) | Mean Daily Maximum | 94.7 | 93.7 | 94.5 | 95.6 | 95.2 | 93.7 | 93.3 | 93.0 | 93.8 | 95.2 | 96.5 | 96.0 |
| | Mean Daily Minimum | 66.0 | 62.1 | 61.4 | 62.3 | 63.7 | 63.4 | 64.1 | 63.6 | 62.2 | 61.4 | 65.5 | 68.0 |
| | 24-hr Mean | 83.5 | 81.2 | 81.7 | 82.6 | 82.3 | 80.9 | 80.9 | 80.9 | 80.7 | 81.5 | 84.9 | 85.5 |
| Wind Speed (m/s) | Mean Monthly/Annual | 2.6 | 2.8 | 2.2 | 1.6 | 1.7 | 2.0 | 2.4 | 2.5 | 2.1 | 1.6 | 1.4 | 1.9 |
| Thunderstorm and Lightning | Mean Thunderstorm Days | 6 | 5 | 12 | 20 | 19 | 15 | 13 | 13 | 14 | 17 | 19 | 14 |
| | Mean Lightning Days | 7 | 4 | 13 | 21 | 21 | 16 | 13 | 12 | 12 | 18 | 22 | 16 |

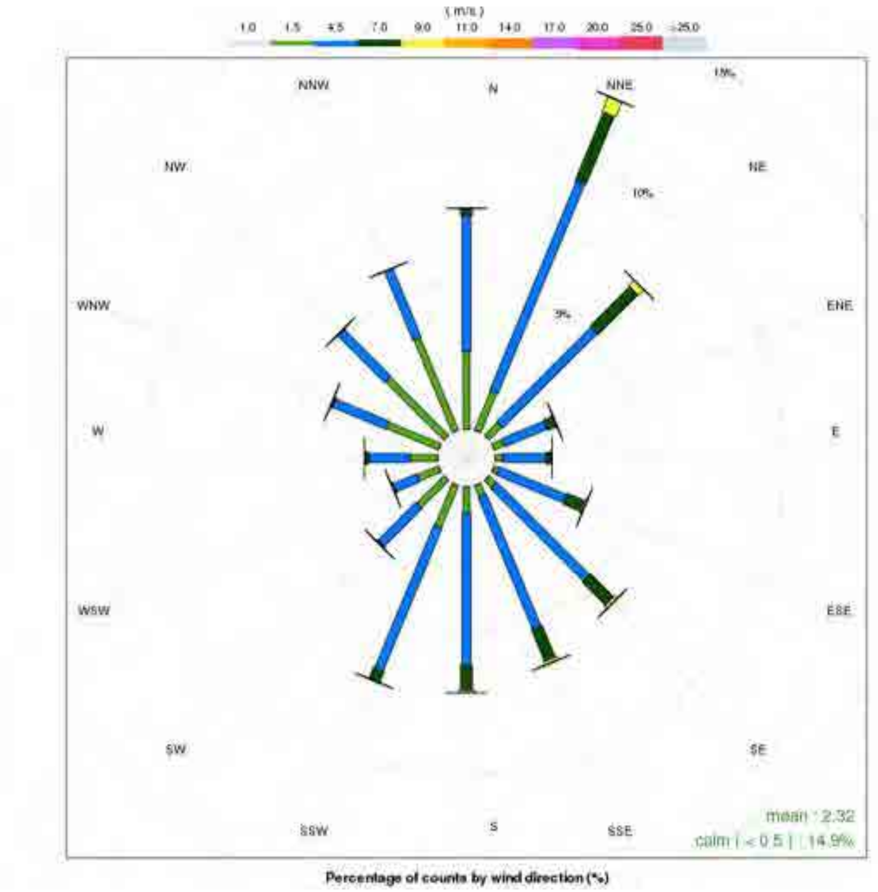



Figure 4.2: Wind Rose for 2019 - 2020

## 4.3 Modelling Assumptions and Parameters

### 4.3.1 Building Height and Flue Height

The building and flue heights used for the assessment were based on the concept design / test fit developed for the Project in October 2024, and are presented in Table 4.7.

Table 4.7: Building and Flue Height Parameters

| Parameter | Height – Before Mitigation (metres SHD) | Height – After Mitigation (metres SHD) |
|---|---|---|
| Developmental Height Constraint | 45[1] | 45[1] |
| Building Roof Level of Data Centre Module | 32.8[2] | 32.8[2] |
| Building Ground Floor of Data Centre Module | 4[3] | 4[3] |
| Genset Exhaust Flue Height | 9.165[2] | 35.8[3] |
| Notes:<br>[1] Indicative value provided by JTC<br>[2] Design value<br>[3] Modelled values | | |

### 4.3.2 Selection of Emergency Standby Generator Engines

The manufacturer-required maintenance and readiness testing of the emergency standby gensets presents a source of air emissions for assessment within the study. As the data centre is currently in the early stages of development, the make and model of the emergency standby gensets is still being evaluated with respect to environmental performance, technical performance, and cost. As such, representative generator details provided by the client were used for the modelling assessment presented herein. However, other genset models may also be considered as possible options. The characteristics of the selected gensets are summarised in Table 4.8, and the flue parameters used in the assessment are summarised in Table 4.9. The emergency standby gensets will be Tier 2 certified, as defined by the USEPA, and in compliance with the standards for off-road diesel engine according to the *EPMA (Off-Road Diesel Engine Emissions) Regulations*.

Table 4.8: Technical Characteristics of the Generators

| Parameter | Standby Genset |
|---|---|
| Genset Model | CNT-6000EN |
| Genset Power Rating | 4800 kW |
| Emission Standards | EU Stage II, US Tier II or Japan Tier |

Table 4.9: Parameters for Design Exhaust Flues

| Parameter | Unit | Standby Genset (Engine Load 100%) |
|---|---|---|
| Diameter | metre (m) | 1.9[2] |
| Temperature | degree Celsius (°C) | 580[1] |
| Actual Flow Rate | cubic metre per hour ($m^3$/min) | 3,845[1] |
| Exhaust Flue Velocity | metre per second (m/s) | 23[2] |

Notes:
1. [1] Data drawn from Niigata generator engine datasheet
2. [2] Calculated value

### 4.3.3 Modelling Grids

AERMOD was run using a 6,000 m x 6,000 m grid centred on the site. The southwest coordinates of the grid were 384620 mE and 152400 mN (WGS 1984 UTM Zone 48N). Four (4) nested grids were used to obtain a higher spatial resolution in the near field. The features of the nested grids are listed in Table 4.10, and the receptor distribution is illustrated in Figure 4.3.

Table 4.10: Nested Modelling Grids

| Grid ID | X and Y Extent (m) for Bounding Box | Receptor Spacing (m) |
|---|---|---|
| GRID-01 | 2,000 | 20 |
| Grid ID | Distance from Bounding Box (m) | Receptor Spacing (m) |
| GRID-02 | 1,000 | 50 |
| GRID-03 | 3,000 | 80 |
| GRID-04 | 5,000 | 120 |

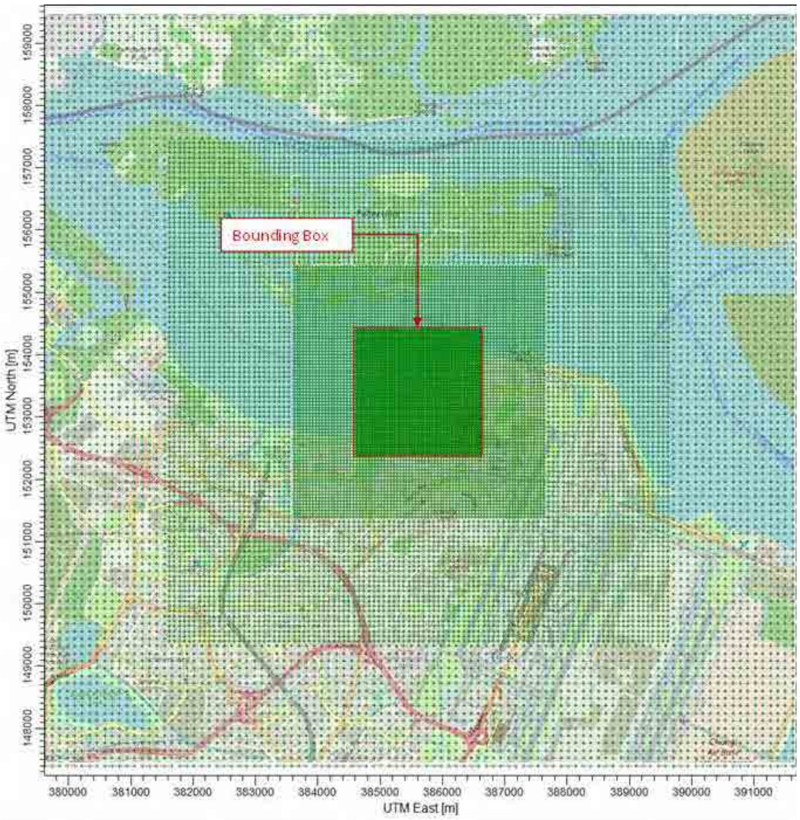



Figure 4.3: Modelling Grids

### 4.3.4 Dispersion Options

The following regulatory default options were selected in AERMOD:

- Flue tip downwash;
- Employing the effects of terrain; and,
- Employing the calms processing routine.

### 4.3.5 Terrain Data

Terrain data for the modelled domain was sourced from the US National Aeronautics and Space Administration's (NASA) Shuttle Radar Topography Mission (SRTM) and incorporated into AERMOD using the AERMAP terrain processor.

#### 4.3.6 Air Emission Scenarios for Consideration

The emission of flue gases from the emergency gensets (which are classified as fuel burning equipment) may cause adverse impact to surrounding developments. The detailed design is undergoing during the stage of the assessment. The genset's exhaust flues were simulated to be 35.8 m SHD, i.e., 3 m above the data centre module, as agreed with the Client, as presented in Section 4.4. This is the unmitigated scenario. Since it was predicted that the unmitigated scenario will result in moderate negative change in ambient air quality, a mitigated scenario was simulated with extended exhaust flues of 45 m SHD which will alleviate the negative change to be minor, as presented in Section 4.5. Table 4.11 below compares the two (2) model scenarios.

Table 4.11: Model Scenario

| Model Scenario | Operation hours/year/generator | Description |
|---|---|---|
| Unmitigated Scenario | • Once per month manufacturer-required testing<br>• Each test lasts for 15 minutes.<br>• One (1) genset is operated at 100% load during each test without concurrent operation. | Exhaust gases will be released via the built-in flue of 5.165 m above the ground level. |
| Mitigated Scenario | • Once per month manufacturer-required testing<br>• Each test lasts for 15 minutes.<br>• One (1) genset is operated at 100% load during each test without concurrent operation. | The genset's exhaust flues were simulated to be 3 m above the data centre module, the height building within 100 m radius. |

### 4.4 Potential Impact (Before Mitigation)

The assessment considers the pollutant emissions from the exhaust flues (i.e. the incremental load from the Project) in conjunction with the surrounding air quality, the AAQTs for the region, and the presence (or lack thereof) of sensitive receptors. Specifically, cumulative ground-level concentrations (GLCs; incremental plus background) were analysed for comparison versus the AAQTs for both Short Term Targets and Long-Term Targets.

Air dispersion modelling for this assessment focused on the periodic genset runs for maintenance and reliability testing. The modelling results are presented as maximum/high percentile project contributions. The major pollutants are $NO_2$, $PM_{10}$, $PM_{2.5}$, and CO based on the information provided by the Client.

The maximum project contribution for $NO_2$ is presented in Table 4.12 along with the impact classification for the initial design with flue height of 5.165 m above the ground level. As shown in Table 4.12, the exhaust gases from the standby genset will result in moderate negative impact to the ambient air quality before taking any mitigation measures. A significant exceedance of AAQT was predicted for 1-hour $NO_2$.

According to the initial design, exhaust gases are to be vented through a built-in exhaust flue with a height of 5.165 meters above ground level. Due to this relatively low release height, the gases may not disperse adequately before reaching ground level. To minimise adverse impacts, Ramboll proposed to extend the exhaust flue to meet the requirement of at least 3 m above the highest building within 100 m radius from the chimney to ensure adequate dispersal of air emissions from the data centre. The mitigation measure was evaluated through modelling exercises to simulate different combinations of design phase and operational phase mitigation measures. The model results are summarised in Section 4.5.

Table 4.12: Maximum Project Contribution for $NO_2$ and the Impact Classification

| Parameter | Project Contribution | AAQT (µg/m$^3$) | Percentage of AAQT | Environmental Scores | Impact Indicators | Impact Classification |
|---|---|---|---|---|---|---|
| 1-hr $NO_2$ | 345 | 200 | 173% | -112 | -C | Moderate negative impact |
| Annual $NO_2$ | 17.6 | 40 | 44% | -112 | -C | Moderate negative impact |

## 4.5 Residual Impact (After Mitigation)

The section provides an analysis of the proposed mitigation measure, specifically the extension of the exhaust flue to 35.8 m SHD. The maximum and high percentile contributions of the Project across the modelling domain, along with the impact classification for major pollutants from the proposed development, are presented in Table 4.13.

As demonstrated in Table 4.13, the project contribution of the proposed development is classified as a minor negative impact, which is less significant than the impacts in the unmitigated scenario. It shows that the implementing the proposed mitigation measure will effectively reduce the potential air quality impacts of the development.

Table 4.13: Maximum/High Percentile Project Contribution and the Impact Classification

| Parameter | Project Contribution | AAQT (µg/m$^3$) | Percentage of AAQT | Environmental Scores | Impact Indicators | Impact Classification |
|---|---|---|---|---|---|---|
| 1-hr $NO_2$ | 78.5 | 200 | 39% | -56 | -B | Minor negative impact |
| Annual $NO_2$ | 3.2 | 40 | 8% | -28 | -A | Slight negative impact |
| 24-hr $PM_{10}$ | 5.1 | 50 | 10% | -56 | -B | Minor negative impact |
| Annual $PM_{10}$ | 1.4 | 20 | 7% | -28 | -A | Slight negative impact |
| 24-hr $PM_{2.5}$ | 5.1 | 25 | 20% | -56 | -B | Minor negative impact |

| Parameter | Project Contribution | AAQT (µg/m3) | Percentage of AAQT | Environmental Scores | Impact Indicators | Impact Classification |
|---|---|---|---|---|---|---|
| Annual $PM_{2.5}$ | 1.4 | 10 | 14% | -56 | -A | Minor negative impact |
| 1-hr CO | 5.4 | 30,000 | 0.02% | -28 | -A | Slight negative impact |
| 8-hr CO | 3.5 | 10,000 | 0.04% | -28 | -A | Slight negative impact |

Cumulative ground level concentrations (GLCs) were calculated based on the baseline air quality shown in Table 4.5 and are presented in Table 4.14. As shown in Table 4.14, the cumulative GLCs are well below AAQT for the major emission from the proposed development. This suggests that the maintenance of the standby genset under the planned schedule is unlikely to deteriorate the ambient air quality and result in a compliance risk for the proposed development.

Table 4.14: Cumulative GLCs

| Parameter | Baseline Air Quality (µg/m3) | Cumulative GLCs (µg/m3) | AAQT (µg/m3) |
|---|---|---|---|
| 1-hr $NO_2$ | 36.5 | 115 | 200 |
| 24-hr $PM_{10}$ | 16.7 | 21.8 | 50 |
| 24-hr $PM_{2.5}$ | 6.7 | 11.8 | 25 |
| 1-hr CO | 360 | 365.4 | 30,000 |
| 8-hr CO | 230 | 233.5 | 10,000 |

## 4.6 Recommended Further Studies

Under Section 36 of the EPMA, anyone intending to carry out any activity, which could cause substantial pollution of the environment or increase the level of such pollution, may be required to conduct a Pollution Control Study (PCS). It is a standard practice for data centres in Singapore to be required to conduct a PCS as part of the planning process. This is because data centres are industrial facilities with fuel burning equipment (emergency backup generators with stack emissions during power failure events and scheduled maintenance).

In accordance with the NEA's Guidelines for Pollution Control Study (March 2024 Ed.),[10] a PCS shall:

a) Identify the sources of emission of air pollutants, discharge of trade effluent, generation of wastes and emission of noise.
b) Quantify and evaluate the impacts of such pollutive emissions.
c) Recommend the measures to be incorporated in the design and operation of the plant to reduce the pollutive emissions to acceptable levels that would not pose nuisance or harm to the people and the environment.

The Air Pollution Control section of the PCS should include the following sections:

i. Sources of air pollution and sources of odour (if applicable).
ii. Quality, rates and quantities of air and odour emissions.
iii. Assessment of the impacts of the air and odour emissions by using dispersion modelling. For odour emissions, the report shall include assessment of the impact from odorous gases or volatile organic compounds (VOCs) that may be emitted from the plant operations.
iv. Measures to control air pollution and ensure compliance with emission standards and requirements in the COPPC, the EPMA and its Regulations.
v. Measures, including the use of best available technologies referenced from similar projects in other countries, to be put in place at the plant to control and prevent air emissions and odour nuisance.
vi. Management plans to ensure effectiveness of control measures for air and odour emissions and to manage contingencies such as when plant facilities are not able to treat the air and odour emissions.
vii. Monitoring programme – Air / odour impurities monitored, type of monitoring equipment/test carried out (e.g., United States Environmental Protection Agency [USEPA] approved or designated reference and equivalent methods), and frequency of monitoring.

To assess the dispersal of air emissions from the gensets' exhaust flues (and any other identified air emissions sources), air dispersion modelling conducted using American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) is recommended as part of the PCS. AERMOD has been used by Ramboll in previous air dispersion modelling studies of facilities located in Singapore for submission to the NEA, and it is the USEPA's recommended air dispersion model that has been designed to support the USEPA's regulatory modelling programs.

Mitigation measures as proposed by the air quality modelling assessment would be adopted by the environmental clearance and thereby become enforceable emissions limits, operating restrictions, and/or control measures to be implemented and adhered to in order to achieve and maintain compliance with respect to air emissions. The backup emergency diesel generators would be considered to be off-road diesel engines (ORDEs), regulated under the *Environmental Protection and Management (Off-Road Diesel Engine Emissions) Regulations*. ORDEs to be imported for use in

[10] https://www.nea.gov.sg/docs/default-source/our-services/building-planning/pcs-guidelines-15-mar-24.pdf

Singapore must comply with the EU Stage II, US Tier II or Japan Tier I off-road diesel engine emission standards as prescribed in the regulations. An application must be made to register each ORDE with the NEA; an emission test report for each ORDE must be provided as part of the application to confirm conformance to the prescribed emission standards. Each ORDE must be registered. Installation of Tier 3 or Tier 4 generators, or technologies such as Selective Catalytic Reduction (SCR) filters on the facility's generators would be considered to be additional pollution control measures.

# 5. Noise Assessment

## 5.1 Ambient Noise Baseline Conditions

### 5.1.1 Secondary Data Review

There is no publicly available ambient noise quality data available in Singapore during the period of this desktop review.

### 5.1.2 Site-Specific Ambient Noise Level Data

Site-specific baseline ambient noise monitoring has been conducted at the site by Aurecon. The baseline background noise survey established the baseline noise levels to be approximate 68 dB(A).

Ramboll recommends that the baseline ambient noise monitoring is also carried out during the detailed design, to capture ambient noise conditions in the surrounding environment closer to the operational phase, yet prior to commencement of construction work. These future baseline noise level data can then be used to during the noise impact assessment and to establish the Correction Factor under the *EPM Boundary Noise Regulations*. Commissioning phase monitoring to demonstrate compliance as is also typically required by the NEA prior to issue of the Temporary Occupation Permit (TOP).

## 5.2 Regulatory Requirements and Criteria

In Singapore, regulatory and permitting requirements for environmental noise are governed primarily by the *Environmental Protection and Management Act* (EPMA) and its associated regulations which provides the legal basis for environmental protection in the country. The Act empowers the NEA to enforce the environmental protection and management requirements related to noise pollution. It also provides the legal basis for penalties and actions against those who violate these regulations. Specifically for data centre, NEA's jurisdiction will focus particularly on the potential for mechanical equipment to result in noise pollution.

### 5.2.1 Environmental Protection and Management Act

The EPMA provides a comprehensive legislative framework for the control and management of environmental pollution in Singapore. The provisions for noise pollution control are established in Part VIII of the Act. Specifically, these provisions stipulate the following:

- Construction sites shall control noise and may need to follow requirements such as the plant of machinery which is, or is not to be used, hours during which work may be carried out and level of noise and vibration which may be emitted from the premises;
- Construction sites may be required to install, operate and keep recordings of a surveillance system for the purpose of monitoring whether and when the works are being carried out on the subject premises;
- Every owner or occupier of a work place must not allow activities or operations that cause the emission of noise from the premises exceeding the allowable levels, and may be required to operate noise control equipment;
- It is an offence to fail to comply with a written notice issued requiring the operation of noise control equipment or contravening any regulations in relation to noise emitted from any work place.

### 5.2.2 Environmental Noise Regulations

Industrial Premises

The control of environmental noise pollution by industrial premises is regulated by the *Environmental Protection and Management (Boundary Noise Limits for Factory Premises) Regulations* (referred to as the "*EPM Boundary Noise Regulations*"). The maximum permitted boundary noise levels at each type of affected premises are established in the First Schedule in Part I and Part II of the *EPM Boundary Noise Regulations*, as presented below in Table 5.3 and Table 5.4, respectively.

Table 5.3: Maximum Permissible Noise Levels, Part I

| Type of Affected Premises | Maximum Permissible Noise Levels (reckoned as an equivalent continuous noise level over the specified period) in decibels (A) | | |
|---|---|---|---|
| | Day (7am – 7pm) | Evening (7pm – 11pm) | Night (11pm – 7am) |
| Noise Sensitive Premises | 60 | 55 | 50 |
| Residential Premises | 65 | 60 | 55 |
| Commercial Premises | 70 | 65 | 60 |

Table 5.4: Maximum Permissible Noise Levels, Part II

| Type of Affected Premises | Maximum Permissible Noise Levels (reckoned as an equivalent continuous noise level over 5 minutes) in decibels (A) | | |
|---|---|---|---|
| | Day (7am – 7pm) | Evening (7pm – 11pm) | Night (11pm – 7am) |
| Noise Sensitive Premises | 65 | 60 | 55 |
| Residential Premises | 70 | 65 | 60 |
| Commercial Premises | 75 | 70 | 65 |
| Factory Premises | 75 | 70 | 65 |

Per Section 2 of the *EPM Boundary Noise Regulations*, "Affected Premises" refer to:

1. Any building or part thereof, occupied by persons other than the owner or occupier of the premises being monitored, which is located within the same factory premises as the premises being monitored;
2. Premises adjoining the factory premises at or within which the premises being monitored is located; or,
3. Premises not adjoining the factory premises at or within which the premises being monitored is located, if there is no building on any intervening premises or if the intervening premises are not commercial, factory, noise sensitive or residential premises.

Section 2 of the *EPM Boundary Noise Regulations* discusses four (4) types of affected premises, as follows:

- Noise Sensitive Premises are used for purposes that require peace and quiet and includes any recreational area, nature park, hospital, home for the aged sick, educational institution, place of worship, library, and court of law.
- Residential Premises are used for human habitation.

- Commercial Premises are used for the purposes of trade, business or commerce and includes any shopping complex, financial institution and hotel but does not include any factory premises.
- Factory Premises are used for any industrial or manufacturing purposes and includes any repair or processing workshop, and warehouse, excluding construction sites.

During the operational phase and based on the current zoning of the site and surrounding land for industrial use, the applicable maximum permissible noise levels have been determined to be for future yet-to-be-developed industrial premises (termed 'factory premises') immediately at its site boundary. However, the NEA is empowered to take enforcement actions should they receive complaints from surrounding communities with regards to the site's activities.

### 5.2.3 Codes of Practice

The *Singapore Standard SS 593: 2013 Code of practice on pollution control* (COPPC) provides guidance on noise pollution control and specific measures to control noise pollution. The COPPC requires that factories install, operate, and maintain pollution control equipment to minimise noise pollution arising from their operations, in accordance with the EPMA.

The *Singapore Standard SS 602-2014 Code of practice on noise control on construction and demolition sites* contains various recommendations for consideration of noise mitigation throughout the project lifecycle, as follows (refer to the COP for further details):

- Design stage
  - Whilst consideration of design, equipment and phasing of operations may be challenging given the space and time constraints associated with the development, measures could be taken such as conducting a Noise Impact Assessment (NIA) of the demolition and construction phases;
  - Where permanent barriers (e.g., walls) are a feature of the final design, these could be constructed early to provide noise mitigation during the demolition and construction operations;
- Tender stage
  - Specify that the *EPM (Control of Noise at Construction Sites) Regulations* are to be complied with, as a minimum;
  - Include provision for noise control and monitoring in the tender documents, with reference to specific noise measurement points such as at the western boundary areas;
  - Stipulate that a Noise Management Plan is required to be prepared to identify and document all necessary noise management measures before commencement of work;
- Planning stage
  - Plan the work such that noise mitigation can be integrated into the schedule e.g., arrange the electrical power supply to the site as early as possible in order to reduce the use of on-site generators;
  - Plan for the most appropriate method of piling to ensure piling noise is kept to a minimum;
  - Scheduling the site's rest day with consideration of the activities at the nearby noise-sensitive receptors (e.g., busiest day at the places of worship); and
- Construction stage
  - The *EPM (Control of Construction Noise) Regulations* allow for correction of the permissible noise limits based on the difference between the permissible noise limits and the background noise levels at the site in question. In addition to noise mitigation as proposed by the NIA, monitor noise levels at the site vicinity and in the event of significant changes to background noise, carry out re-correction for background noise levels, as permitted by the regulations.

## 5.3 Modelling Assumptions and Parameters

### 5.3.1 Equipment Noise Levels

The major noise-generation equipment includes chiller, pump, transformer, load bank, and standby genset as demonstrated in Section 2.1.2. The sound pressure levels/sound power level of the sources used in the model are provided in Table 5.1.

Table 5.1: Equipment Sound Power Levels

| Equipment | Total dB(A) | Distance from Equipment (m) |
|---|---|---|
| Chiller | 85[1] | 1 |
| Chiller Water Pump | 65[1] | 1 |
| Seawater Pump | 65[1] | 1 |
| Transformer (2MVA 11kV/0.4kV) | 70.2[1] | 0.3 |
| Transformer (10MVA 22kV/11kV) | 70[1] | 3 |
| Standby Genset | 85[1] | 1 |
| Load Bank | 109[2] | - |
| Genset Exhaust Flue | 87[2] | - |

Note:
[1] Sound pressure level provided by the Client
[2] Sound power level estimated based on experience given the lack of the information

### 5.3.2 Meteorological Information

The meteorological information incorporated into the model was based on Singapore conditions and is conservative in terms of noise propagation. Specifically, the meteorological data used included an average humidity of 70% and all wind directions. As per Section 5 of ISO 9613-2, the model assumed the following downwind propagation conditions:

- Wind direction within an angle of ± $45^0$ of the direction connecting the centre of the dominant sound source and centre of the specified receiver region, with wind blowing from source to receiver; and,
- Wind speed between approximately 1 m/s and 5 m/s, measured at a height of 3 m to 11 m above the ground.

These conditions also apply for average propagation under a well-developed, moderate ground-based temperature inversion, such as those which commonly occur on clear, calm nights. Since ISO assumes general light downwind conditions (i.e., wind from source to receiver), the calculations result in conservative noise levels.

### 5.3.3 Topographical Data

A foundation height of 4 m for the site has been accounted for in the model. Only the data centre's main building has been included in the model.

#### 5.3.4 Ground Absorption, Reflection and Attenuation

Ground absorption varies from 0 to 1, with 0 being an acoustically reflective ground (e.g., water, concrete or bitumen) and 1 for acoustically absorbent ground (e.g., grass or porous ground). The model was set to a universal ground absorption of 0 for the site and surrounding industrial area (corresponding to concrete and no reflectivity. The data centre's main building is also assumed to have reflecting facades.

### 5.4 Potential Impact (Before Mitigation)

Two (2) operation scenarios were assessed in this study: one is the normal operation without running standby genset; and the other one is the scheduled maintenance operation with the genset being tested in sequence, i.e., no concurrent operation involved.

During the normal operation scenario, there will be only mechanical noise. The definitions of mechanical noise and generator maintenance are detailed below:

- Mechanical Noise. Constant noise at the site from the chillers, pumps, and transformers. The emergency standby gensets are not included in this scenario. Mechanical noise is subject to both day and night noise criteria.
- Generator Maintenance. Includes constant mechanical noise and the testing of one (1) genset at a time. Noise sources include the chillers, pumps, transformers, load bank, generator bodies, and generator exhausts.

The predicted maximum boundary noise levels under Normal Operation and Scheduled Maintenance Operation, along with the impact classification, are demonstrated in Table 5.2 and Table 5.3 respectively. The maximum project-contributed boundary noise is predicted to be 53 dB(A) for normal operation, which is well below the maximum permissible noise level of 65 dB(A). The overall environmental impact is classified as no impact.

During the scheduled maintenance operation, the maximum project-contributed boundary noise is predicted to be 71 dB(A) which is below the maximum permissible noise level for daytime. Slight exceedances were predicted during evening and nighttime. The overall environmental impact is classified as *slight negative impact*.

Table 5.2: Maximum Project-Contributed Boundary Noise and the Impact Classification – Normal Operation

| Duration | Predicted 5-min Leq dB(A) | Permissible Noise Level dB(A) | Exceedance dB(A) | Environmental Scores | Impact Indicators | Impact Classification |
|---|---|---|---|---|---|---|
| Day | 53 | 75 | No exceedance | 0 | N | No impact |
| Evening | 53 | 70 | No exceedance | 0 | N | No impact |
| Night | 53 | 65 | No exceedance | 0 | N | No impact |

Table 5.3: Maximum Project-Contributed Boundary Noise and the Impact Classification – Scheduled Maintenance Operation

| Duration | Predicted 5-min Leq dB(A) | Permissible Noise Level dB(A) | Exceedance dB(A) | Environmental Scores | Impact Indicators | Impact Classification |
|---|---|---|---|---|---|---|
| Day | 71 | 75 | No exceedance | 0 | N | No impact |
| Evening | 71 | 70 | 1 | -14 | -A | Slight negative impact |
| Night | 71 | 65 | 6 | -28 | -A | Slight negative impact |

Cumulative noise levels for these two operation scenarios are then calculated based on the baseline of 68 dB(A) and presented in Table 5.4 and Table 5.5.

## 5.5 Proposed Mitigation Measures

To minimise adverse impacts, it is recommended to carry out the manufacturer-required maintenance and readiness testing of the emergency standby gensets during the day (between 9am and 6pm) to avoid noise impacts to the surrounding environment during the evening or night-time.

The mitigated cumulative noise impact after mitigation is presented in Table 5.4 and Table 5.5. As shown in Table 5.4, the project-contributed noise will not cause any deterioration in ambient noise level, while the scheduled maintenance is predicted to contribute up to 6 dB(A) increment in the ambient noise over the maximum permissible noise level, if conducted at night-time.

Table 5.4: Maximum Cumulative Boundary Noise – Normal Operation

| Duration | Predicted 5-min Leq dB(A) | Permissible Noise Level dB(A) | Exceedance dB(A) | Environmental Scores | Impact Indicators | Impact Classification |
|---|---|---|---|---|---|---|
| Day | 68 | 75 | No exceedance | 0 | N | No impact |
| Evening | 68 | 70 | No exceedance | 0 | N | No impact |
| Night | 68 | 65 | No exceedance | 0 | N | No impact |

Table 5.5: Maximum Cumulative Boundary Noise – Scheduled Maintenance

| Duration | Predicted 5-min Leq dB(A) | Permissible Noise Level dB(A) | Exceedance dB(A) | Environmental Scores | Impact Indicators | Impact Classification |
|---|---|---|---|---|---|---|
| Day | 73 | 75 | No exceedance | 0 | N | No impact |
| Evening | 73 | 70 | 1 | -14 | -A | Slight negative impact |
| Night | 73 | 65 | 6 | -28 | -A | Slight negative impact |

## 5.6 Proposed Mitigation Measures

To minimise adverse impacts, it is recommended to carry out the manufacturer-required maintenance and readiness testing of the emergency standby gensets during the day (between 9am and 6pm) to avoid noise impacts to the surrounding environment during the evening or night-time.

The mitigated cumulative noise impact after mitigation is presented in Table 5.6.

Table 5.6: Maximum Cumulative Boundary Noise – Scheduled Maintenance (after Mitigation)

| Duration | Predicted 5-min Leq dB(A) | Permissible Noise Level dB(A) | Exceedance dB(A) | Environmental Scores | Impact Indicators | Impact Classification |
|---|---|---|---|---|---|---|
| Day | 73 | 75 | No exceedance | 0 | N | No impact |
| Evening | - | 70 | - | - | - | - |
| Night | - | 65 | - | - | - | - |

## 5.7 Recommended Further Studies

*Pollution Control Study*

Under Section 36 of the EPMA, anyone intending to carry out any activity, which could cause substantial pollution of the environment or increase the level of such pollution, may be required to conduct a Pollution Control Study (PCS). It is a standard practice for data centres in Singapore to be required to conduct a PCS as part of the planning process. This is because data centres are industrial facilities with fuel burning equipment (emergency backup generators with stack emissions during power failure events and scheduled maintenance). In accordance with the NEA's *Guidelines for Pollution Control Study* (March 2024 Ed.)[11], a PCS shall:

d) Identify the sources of emission of air pollutants, discharge of trade effluent, generation of wastes and emission of noise;

e) Quantify and evaluate the impacts of such pollutive emissions; and

f) Recommend the measures to be incorporated in the design and operation of the plant to reduce the pollutive emissions to acceptable levels that would not pose nuisance or harm to the people and the environment.

The Noise Pollution Control section of the PCS should include the following sections:

viii. Sources of air pollution and sources of odour (if applicable);

ix. Estimates of noise levels emitted;

x. Impacts of the noise emissions i.e. the noise levels at the receptors surrounding the plant especially residential housing;

xi. Measures to control noise pollution and ensure compliance with noise emission standards and requirements in the COPPC, the EPMA and its Regulations; and

xii. Monitoring programme - Type of monitoring equipment/test carried out, frequency of monitoring.

To assess the noise impact of mechanical equipment (and any other identified noise sources), noise modelling is recommended as part of the PCS. CadnaA has been used by Ramboll in previous noise modelling studies of facilities located in Singapore for submission to the NEA.

*Monitoring Programme*

A noise monitoring and verification programme is recommended to confirm that the surrounding premises will not be adversely affected by noise emissions from the Project. Measurement of noise levels for the purposes of the verification should be carried out at the premises boundary using a sound level meter which complies with the standards specified in the International Electrotechnical Commission Publications 651 (Type 1) and Publication 804 (Type 1), or any other comparable standards approved by the Director-General. Verification of compliance with the relevant regulatory requirements should also be conducted through periodic updating of the noise modelling assessment, using measured noise levels at noise sources and measured ambient background noise levels.

[11] https://www.nea.gov.sg/docs/default-source/our-services/building-planning/pcs-guidelines-15-mar-24.pdf

# 6. Conclusions

## 6.1 Air Quality Impact

Backup emergency diesel generators to be installed at the proposed data centre are fuel-burning equipment with dedicated exhaust flues that will release air pollutants. Routine operation of these standby gensets is only expected for relatively short durations during manufacturer-required routine maintenance operations. Air emissions from the generators will consist primarily of $NO_X$, and, to a lesser extent, HC, CO and PM as combustion products from the facility's diesel-fired emergency generators. Effective July 2013, NEA mandated the supply of Near Sulphur-Free Diesel (NSFD) with a sulphur content of 0.001%, thus $SO_2$ is no longer a key pollutant of concern for data centres in Singapore.

To assess the dispersal of air emissions from the gensets' exhaust flues, air dispersion modelling was conducted using AERMOD.

As the detail design has not yet been finalised for the data centre, the assessment was conducted based on the conceptual design of the data centre. According to the initial design, exhaust gases will be discharged from the built-in flues which is 5.165 m above the ground level. The air dispersion modelling revealed that the short flue cannot ensure an adequate dispersion of the air emissions from the gensets.

Pursuant to the COPPC, a chimney of an approved height should be provided for safe dispersion of flue gases from fuel burning equipment. A standard requirement based on the intent of the COPPC is that the chimney height should not be lower than 3 m above the roof level of all factory buildings in the vicinity, with no impediment to safe dispersion by mechanical and electrical equipment at roof level.

Given this, it is recommended to extend the exhaust flues to 35.8 m SHD, which meets the requirement of at least 3 m above the highest building within 100 m radius. The proposed mitigation measure was assessed with an ADMS which verify the effectiveness of the mitigation measure.

The air dispersion impact assessment found that:

- The project contribution of the proposed development is classified with an ES of *minor negative impact* under the RIAM methodology, which is less significant than the impacts in the unmitigated scenario. It shows that the implementing the proposed mitigation measure will effectively reduce the potential air quality impacts of the development; and
- The cumulative GLCs are well below AAQT from the proposed development. This suggests that the maintenance of the standby genset under the planned schedule is unlikely to deteriorate the ambient air quality and result in a compliance risk for the proposed development.

The site will likely be required to conduct a PCS including air quality dispersion modelling to obtain environmental clearance from the NEA at Building Plan stage.

Mitigation measures as proposed by the air quality modelling assessment would be adopted by the environmental clearance and thereby become enforceable emissions limits, operating restrictions, and/or control measures to be implemented and adhered to in order to achieve and maintain compliance with respect to air emissions. Installation of Tier 3 or Tier 4 generators, or technologies such as Selective Catalytic Reduction (SCR) filters on the facility's generators could be considered as alternative pollution control measures to be assessed under the PCS. Air quality monitoring (ambient baseline and commissioning phase monitoring to demonstrate compliance) is also typically required by the NEA prior to issue of the Temporary Occupation Permit (TOP).

### 6.2 Noise Impact

The noise impact was quantitatively assessed by an acoustic propagation modelling study, CadnaA.

The noise impact assessment found that:

- The project-contributed noise will not cause any deterioration in ambient noise level, with an ES of *no impact* under the RIAM methodology;
- However, the scheduled genset maintenance is predicted to exceed the Leq 5-min limit if conducted in the evening or night-time, with an ES of *slight negative impact* under the RIAM methodology.

To minimise adverse impacts, it is recommended to carry out the manufacturer-required maintenance and readiness testing of the emergency standby gensets during the day (between 9am and 6pm) to avoid noise impacts to the surrounding environment during the evening of night.

The site will likely be required to conduct a PCS including noise modelling to obtain environmental clearance from the NEA at the Building Plan stage. Ambient baseline noise monitoring is recommended to be conducted to inform the PCS. Commissioning phase monitoring to demonstrate compliance as is also typically required by the NEA prior to the operational phase.

Pursuant to the COPPC, all practical noise abatement measures should be adopted to comply with the applicable allowable boundary noise levels. Mechanical equipment of low sound power should be used wherever possible, and noise abatement measures should be factored into the building design in order to mitigate noise nuisance impact.

# 7. References


Meteorological Service Singapore's Annual Climate Assessment Report for 2021 http://www.weather.gov.sg/wp-content/uploads/2022/08/ACAR_2021.pdf

NEA's website on Air Pollution https://www.nea.gov.sg/our-services/pollution-control/air-pollution/air-quality

NEA's website on Noise Pollution https://www.nea.gov.sg/our-services/pollution-control/noise-pollution

Environmental Protection and Management Act https://sso.agc.gov.sg/act/epma1999

Environmental Protection and Management (Air Impurities) Regulations https://sso.agc.gov.sg/SL/EPMA1999-RG8

Environmental Protection and Management (Off-Road Diesel Engine Emissions) Regulations https://sso.agc.gov.sg/SL/EPMA1999-S299-2012

Environmental Protection and Management (Control of Noise at Construction Sites) Regulations https://sso.agc.gov.sg/SL/EPMA1999-RG2

Environmental Protection and Management (Boundary Noise Limits for Factory Premises) Regulations https://sso.agc.gov.sg/SL/EPMA1999-RG1

Singapore Standard SS 593: 2013 Code of practice on pollution control (COPPC) https://www.singaporestandardseshop.sg/

Singapore Standard SS 602-2014 Code of practice on noise control on construction and demolition sites https://www.singaporestandardseshop.sg/

# Appendix K

## Marine Biodiversity Results

Intertidal Benthic Cover Compiled

| Groups | | IT1 | | IT2 | | IT3 | | IT4 | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean (%) | SE | Mean (%) | SE | Mean (%) | SE | Mean (%) | SE |
| Seagrass | *Cymodocea rotundata* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | *Cymodocea serrulata* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | *Enhalus acoroides* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | *Halodule uninervis* | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 4.11 | 0.00 | 5.22 |
| | *Halophila ovalis* | 2.09 | 0.71 | 2.73 | 0.00 | 39.73 | 0.00 | 30.88 | 0.00 |
| | *Halophila spinulosa* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | *Syringodium isoetifolium* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | *Thalassia hemprichii* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Algae | Ochrophyta | 0.00 | 0.00 | 0.00 | 5.45 | 0.00 | 2.18 | 0.00 | 0.84 |
| | Chlorophyta | 5.52 | 1.04 | 46.97 | 0.61 | 14.58 | 0.14 | 6.64 | 0.00 |
| | Rhodophyta | 1.82 | 0.71 | 1.64 | 0.00 | 0.67 | 0.00 | 0.00 | 0.00 |
| | Algal Assemblage | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Calcareous Algae | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Other Fauna | Ascidian | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 |
| | Anemone | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 |
| | Hard Coral | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Soft Coral | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Sponge | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Zoanthid | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Other Fauna | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Abiotic | Dead Corals | 0.00 | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Rock | 0.00 | 0.00 | 0.18 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Rubble | 0.00 | 0.00 | 0.06 | 5.47 | 0.00 | 5.06 | 0.00 | 5.19 |
| | Sand | 32.70 | 7.68 | 21.55 | 5.70 | 45.03 | 0.00 | 62.45 | 0.00 |
| | Silt | 57.88 | 7.81 | 26.88 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Total** | | **100.00** | | **100.00** | | **100.00** | | **100.00** | |

Mangrove Transect Survey Data Compiled

| Transect T1 | | | | | | |
|---|---|---|---|---|---|---|
| Left Offset | Chainage | Right Offset | Species | GBH (cm) | Height (m) | Note |
| 0.5 | 0.5 | | *Terminalia catapa* | 29 | 5 | |
| | 1.4 | 0.5 | *Derris trifoliata* | | | |
| | 1.4 | 0.0 | *Hibiscus tiliaceus* | 26 | 4 | |
| 0.5 | 2.2 | | *Terminalia catappa* | 16 | 4 | |
| 0.5 | 3.0 | | *Hibiscus tiliaceus* | 28 | 5 | |
| 1.3 | 3.6 | | *Morinda citrifolia* | 9 | 1 | |
| | 8.5 | 0.0 | *Bruguiera cylindrica* | 10 | 5 | |
| 0.5 | 8.5 | | *Bruguiera cylindrica* | 9 | 4 | |
| | 9.0 | 0.7 | *Bruguiera cylindrica* | 10 | 4 | |
| | 10.0 | 0.0 | *Bruguiera cylindrica* | 9 | 2 | |
| | 12.4 | 2.0 | *Terminalia catapa* | 32 | 6 | |
| | 12.8 | | | | | bund |
| 0.5 | 13.5 | | *Hibiscus tiliaceus* | 17 | 5 | |
| 0.7 | 13.6 | | *Terminalia catapa* | 34 | 6 | |
| 0.5 | 16.0 | | *Bruguiera cylindrica* | 28 | 6 | |
| | 16.3 | 1.5 to 2 | *Bruguiera cylindrica* | 17 | 7 | |
| | 17.1 | 0.2 | *Bruguiera cylindrica* | 15 | 7 | |
| 1.0 | 17.8 | | *Bruguiera cylindrica* | 11 | 4 | |
| | 17.8 | 1.0 | *Rhizophora mucronata* | 39 | 9 | edge of stream |
| | 18.2 | 0.0 | *Bruguiera cylindrica* | 18 | 5 | |
| | 24.5 | 0.0 | *Bruguiera cylindrica* | 10 | 4 | |
| | 33.0 | | | | | end of mangroves |
| | 35.0 | 2.0 | *Ptychosperma macarthurii* | 15 | 7 | |
| | 37.0 | 0.5 | *Ptychosperma macarthurii* | 23 | 8 | |
| | 40.0 | 1.5 | *Ptychosperma macarthurii* | 23 | 2 | |
| 1.5 | 41.2 | | *Ptychosperma macarthurii* | 12 | 4 | |
| | 43.9 | 0.0 | *Ptychosperma macarthurii* | 17 | 6 | |
| | 45.8 | 1.5 | *Ptychosperma macarthurii* | 15 | 6 | |
| | 47.0 | 1.2 | *Ptychosperma macarthurii* | 13 | 4 | |
| | 48.7 | 0.5 | *Hibiscus tiliaceus* | 21 | 8 | |
| 1.0 | 49.0 | | *Ptychosperma macarthurii* | 17 | 4 | |
| | 51.2 | 0.0 | *Ptychosperma macarthurii* | 20 | 4 | |
| | 52.0 | 4.0 | *Falcataria falcata* | 140 | 30 | |
| | 53.0 | | *Andira inermis* | | | seedling |
| | 54.0 | 1.0 | *Ochna kirkii* | | | shrub |
| | 55.0 | 1.0 | *Ptychosperma macarthurii* | 12 | 3 | |
| | 59.0 | 1.0 | *Caryota mitis* | 30 | 7 | |
| 2.0 | 59.4 | | *Ptychosperma macarthurii* | 20 | 7 | |
| 1.6 | 62.8 | | *Artocarpus heterophyllus* | 9 | 4 | |
| | 65.0 | | | | | bund, pond beyond |

| Transect T2 | | | | | | |
|---|---|---|---|---|---|---|
| **Left Offset** | **Chainage** | **Right Offset** | **Species** | **GBH (cm)** | **Height (m)** | **Note** |
| | 0.0 | 3.0 | *Avicennia alba* | 80 | 12 | |
| | 0.0 | | *Rhizophora mucronata* | 27 | 8 | |
| 0.3 | 2.5 | | *Bruguiera cylindrica* | 30 | 3 | |
| 1.5 | 3.0 | | *Rhizophora mucronata* | 44 | 10 | |
| 3.0 | 4.0 | | *Rhizophora apiculata* | 30 | 10 | |
| | 4.3 | 3.5 | *Rhizophora apiculata* | 28 | 8 | |
| | 5.0 | | | | | back of stream |
| 3.0 | 6.0 | | *Avicennia alba* | 29 | 12 | |
| 8.0 | 8.0 | | *Nypa fruticans* | 120 | 3 | |
| | 9.2 | 4.0 | *Rhizophora apiculata* | 12 | 7 | |
| 4.0 | 9.4 | | Avicennia alba | 58 | 12 | |
| 1.0 | 9.5 | | *Avicennia alba* | 59 | 13 | |
| 1.5 | 10.0 | | *Rhizophora mucronata* | 25 | 8 | |
| 5.0 | 10.3 | | *Rhizophora apiculata* | 12 | 10 | |
| 2.0 | 11.0 | | *Avicennia alba* | 35 | 5 | |
| 4.0 | 11.0 | | *Rhizophora mucronata* | 13 | 15 | |
| 1.0 | 11.3 | | *Avicennia alba* | 20 | 10 | |
| 3.0 | 11.8 | | *Avicennia alba* | 51 | 11 | |
| 4.0 | 14.0 | | *Rhizophora apiculata* | 15 | 8 | |
| | 14.0 | | *Rhizophora mucronata* | 8 | 8 | |
| | 14.8 | 1.0 | Rhizophora mucronata | 6 | 2 | |
| | 15.0 | 2.0 | *Rhizophora mucronata* | 49 | 10 | |
| 0.3 | 16.0 | | *Sonneratia alba* | 3 | 1 | |
| 5.0 | 17.0 | | *Rhizophora apiculata* | 36-40 | 12 | |
| | 17.3 | 4.0 | | | | stream bank |
| 5.0 | 19.0 | | *Avicennia alba* | 101 | 15 | |
| 3.0 | 19.7 | | *Avicennia alba* | 40 | 12 | |
| | 20.0 | 4.0 | *Rhizophora mucronata* | 15 | 6 | |
| 3.5 | 20.3 | | *Avicennia alba* | 103 | 15 | |
| | 21.0 | 5.0 | *Avicennia alba* | 76 | 15 | |
| | 22.1 | 8.0 | *Avicennia alba* | 130 | 15 | |
| | 23.0 | 3.0 | | | | stream bank |
| 2.0 | 23.4 | | *Rhizophora mucronata* | 14 | 6 | |
| 6.0 | 23.6 | | *Rhizophora apiculata* | 13 | 4 | |
| 1.0 | 26.4 | | *Rhizophora mucronata* | 12 | 6 | |
| | 28.0 | 6.0 | *Avicennia alba* | 89 | 15 | |
| | 29.7 | 5.0 | *Rhizophora apiculata* | 12 | 7 | |
| 5.0 | 31.0 | | *Avicennia alba* | 136 | 18 | |
| | 32.8 | 6.0 | *Avicennia alba* | 65 | 15 | |
| | 33.0 | 1.5 | | | | bank of stream |
| 1.0 | 34.0 | | *Avicennia alba* | 36 | 12 | |
| | 34.0 | 2.0 | | | | stream bank |
| 1.5 | 35.6 | | *Rhizophora mucronata* | 8 | 5 | |
| 1.5 | 37.6 | | *Rhizophora mucronata* | 8 | 6 | |
| 2.0 | 37.9 | | *Avicennia alba* | 47 | 16 | |
| | 38.6 | 5.0 | *Rhizophora mucronata* | 87 | 12 | |
| 3.0 | 39.5 | | *Avicennia alba* | 22 | 11 | |

| Transect T2 | | | | | | |
|---|---|---|---|---|---|---|
| **Left Offset** | **Chainage** | **Right Offset** | **Species** | **GBH (cm)** | **Height (m)** | **Note** |
| 0.5 | 44.0 | | *Rhizophora mucronata* | 26 | 10 | |
| 1.5 | 44.5 | | *Rhizophora mucronata* | 29 | 12 | |
| 3.0 | 45.5 | | *Avicennia alba* | 81 | 13 | |
| | 46.4 | | *Rhizophora mucronata* | 28 | 0 | |
| 2.0 | 26-32 | | *Rhizophora apiculata* | | | numerous seedlings |

Intertidal Benthic Cover Compiled

| Groups | | IT1 | | IT2 | | IT3 | | IT4 | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean (%) | SE | Mean (%) | SE | Mean (%) | SE | Mean (%) | SE |
| Seagrass | *Cymodocea rotundata* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | *Cymodocea serrulata* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | *Enhalus acoroides* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | *Halodule uninervis* | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 4.11 | 0.00 | 5.22 |
| | *Halophila ovalis* | 2.09 | 0.71 | 2.73 | 0.00 | 39.73 | 0.00 | 30.88 | 0.00 |
| | *Halophila spinulosa* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | *Syringodium isoetifolium* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | *Thalassia hemprichii* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Algae | Ochrophyta | 0.00 | 0.00 | 0.00 | 5.45 | 0.00 | 2.18 | 0.00 | 0.84 |
| | Chlorophyta | 5.52 | 1.04 | 46.97 | 0.61 | 14.58 | 0.14 | 6.64 | 0.00 |
| | Rhodophyta | 1.82 | 0.71 | 1.64 | 0.00 | 0.67 | 0.00 | 0.00 | 0.00 |
| | Algal Assemblage | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Calcareous Algae | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Other Fauna | Ascidian | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 |
| | Anemone | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 |
| | Hard Coral | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Soft Coral | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Sponge | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Zoanthid | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Other Fauna | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Abiotic | Dead Corals | 0.00 | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Rock | 0.00 | 0.00 | 0.18 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Rubble | 0.00 | 0.00 | 0.06 | 5.47 | 0.00 | 5.06 | 0.00 | 5.19 |
| | Sand | 32.70 | 7.68 | 21.55 | 5.70 | 45.03 | 0.00 | 62.45 | 0.00 |
| | Silt | 57.88 | 7.81 | 26.88 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Total** | | **100.00** | | **100.00** | | **100.00** | | **100.00** | |

Mangrove Transect Survey Data Compiled

| Transect T1 | | | | | | |
|---|---|---|---|---|---|---|
| **Left Offset** | **Chainage** | **Right Offset** | **Species** | **GBH (cm)** | **Height (m)** | **Note** |
| 0.5 | 0.5 | | *Terminalia catapa* | 29 | 5 | |
| | 1.4 | 0.5 | *Derris trifoliata* | | | |
| | 1.4 | 0.0 | *Hibiscus tiliaceus* | 26 | 4 | |
| 0.5 | 2.2 | | *Terminalia catappa* | 16 | 4 | |
| 0.5 | 3.0 | | *Hibiscus tiliaceus* | 28 | 5 | |
| 1.3 | 3.6 | | *Morinda citrifolia* | 9 | 1 | |
| | 8.5 | 0.0 | *Bruguiera cylindrica* | 10 | 5 | |
| 0.5 | 8.5 | | *Bruguiera cylindrica* | 9 | 4 | |
| | 9.0 | 0.7 | *Bruguiera cylindrica* | 10 | 4 | |
| | 10.0 | 0.0 | *Bruguiera cylindrica* | 9 | 2 | |
| | 12.4 | 2.0 | *Terminalia catapa* | 32 | 6 | |
| | 12.8 | | | | | bund |
| 0.5 | 13.5 | | *Hibiscus tiliaceus* | 17 | 5 | |
| 0.7 | 13.6 | | *Terminalia catapa* | 34 | 6 | |
| 0.5 | 16.0 | | *Bruguiera cylindrica* | 28 | 6 | |
| | 16.3 | 1.5 to 2 | *Bruguiera cylindrica* | 17 | 7 | |
| | 17.1 | 0.2 | *Bruguiera cylindrica* | 15 | 7 | |
| 1.0 | 17.8 | | *Bruguiera cylindrica* | 11 | 4 | |
| | 17.8 | 1.0 | *Rhizophora mucronata* | 39 | 9 | edge of stream |
| | 18.2 | 0.0 | *Bruguiera cylindrica* | 18 | 5 | |
| | 24.5 | 0.0 | *Bruguiera cylindrica* | 10 | 4 | |
| | 33.0 | | | | | end of mangroves |
| | 35.0 | 2.0 | *Ptychosperma macarthurii* | 15 | 7 | |
| | 37.0 | 0.5 | *Ptychosperma macarthurii* | 23 | 8 | |
| | 40.0 | 1.5 | *Ptychosperma macarthurii* | 23 | 2 | |
| 1.5 | 41.2 | | *Ptychosperma macarthurii* | 12 | 4 | |
| | 43.9 | 0.0 | *Ptychosperma macarthurii* | 17 | 6 | |
| | 45.8 | 1.5 | *Ptychosperma macarthurii* | 15 | 6 | |
| | 47.0 | 1.2 | *Ptychosperma macarthurii* | 13 | 4 | |
| | 48.7 | 0.5 | *Hibiscus tiliaceus* | 21 | 8 | |
| 1.0 | 49.0 | | *Ptychosperma macarthurii* | 17 | 4 | |
| | 51.2 | 0.0 | *Ptychosperma macarthurii* | 20 | 4 | |
| | 52.0 | 4.0 | *Falcataria falcata* | 140 | 30 | |
| | 53.0 | | *Andira inermis* | | | seedling |
| | 54.0 | 1.0 | *Ochna kirkii* | | | shrub |
| | 55.0 | 1.0 | *Ptychosperma macarthurii* | 12 | 3 | |
| | 59.0 | 1.0 | *Caryota mitis* | 30 | 7 | |
| 2.0 | 59.4 | | *Ptychosperma macarthurii* | 20 | 7 | |
| 1.6 | 62.8 | | *Artocarpus heterophyllus* | 9 | 4 | |
| | 65.0 | | | | | bund, pond beyond |

| Transect T2 | | | | | | |
|---|---|---|---|---|---|---|
| **Left Offset** | **Chainage** | **Right Offset** | **Species** | **GBH (cm)** | **Height (m)** | **Note** |
| | 0.0 | 3.0 | *Avicennia alba* | 80 | 12 | |
| | 0.0 | | *Rhizophora mucronata* | 27 | 8 | |
| 0.3 | 2.5 | | *Bruguiera cylindrica* | 30 | 3 | |
| 1.5 | 3.0 | | *Rhizophora mucronata* | 44 | 10 | |
| 3.0 | 4.0 | | *Rhizophora apiculata* | 30 | 10 | |
| | 4.3 | 3.5 | *Rhizophora apiculata* | 28 | 8 | |
| | 5.0 | | | | | back of stream |
| 3.0 | 6.0 | | *Avicennia alba* | 29 | 12 | |
| 8.0 | 8.0 | | *Nypa fruticans* | 120 | 3 | |
| | 9.2 | 4.0 | *Rhizophora apiculata* | 12 | 7 | |
| 4.0 | 9.4 | | Avicennia alba | 58 | 12 | |
| 1.0 | 9.5 | | *Avicennia alba* | 59 | 13 | |
| 1.5 | 10.0 | | *Rhizophora mucronata* | 25 | 8 | |
| 5.0 | 10.3 | | *Rhizophora apiculata* | 12 | 10 | |
| 2.0 | 11.0 | | *Avicennia alba* | 35 | 5 | |
| 4.0 | 11.0 | | *Rhizophora mucronata* | 13 | 15 | |
| 1.0 | 11.3 | | *Avicennia alba* | 20 | 10 | |
| 3.0 | 11.8 | | *Avicennia alba* | 51 | 11 | |
| 4.0 | 14.0 | | *Rhizophora apiculata* | 15 | 8 | |
| | 14.0 | | *Rhizophora mucronata* | 8 | 8 | |
| | 14.8 | 1.0 | Rhizophora mucronata | 6 | 2 | |
| | 15.0 | 2.0 | *Rhizophora mucronata* | 49 | 10 | |
| 0.3 | 16.0 | | *Sonneratia alba* | 3 | 1 | |
| 5.0 | 17.0 | | *Rhizophora apiculata* | 36-40 | 12 | |
| | 17.3 | 4.0 | | | | stream bank |
| 5.0 | 19.0 | | *Avicennia alba* | 101 | 15 | |
| 3.0 | 19.7 | | *Avicennia alba* | 40 | 12 | |
| | 20.0 | 4.0 | *Rhizophora mucronata* | 15 | 6 | |
| 3.5 | 20.3 | | *Avicennia alba* | 103 | 15 | |
| | 21.0 | 5.0 | *Avicennia alba* | 76 | 15 | |
| | 22.1 | 8.0 | *Avicennia alba* | 130 | 15 | |
| | 23.0 | 3.0 | | | | stream bank |
| 2.0 | 23.4 | | *Rhizophora mucronata* | 14 | 6 | |
| 6.0 | 23.6 | | *Rhizophora apiculata* | 13 | 4 | |
| 1.0 | 26.4 | | *Rhizophora mucronata* | 12 | 6 | |
| | 28.0 | 6.0 | *Avicennia alba* | 89 | 15 | |
| | 29.7 | 5.0 | *Rhizophora apiculata* | 12 | 7 | |
| 5.0 | 31.0 | | *Avicennia alba* | 136 | 18 | |
| | 32.8 | 6.0 | *Avicennia alba* | 65 | 15 | |
| | 33.0 | 1.5 | | | | bank of stream |
| 1.0 | 34.0 | | *Avicennia alba* | 36 | 12 | |
| | 34.0 | 2.0 | | | | stream bank |
| 1.5 | 35.6 | | *Rhizophora mucronata* | 8 | 5 | |
| 1.5 | 37.6 | | *Rhizophora mucronata* | 8 | 6 | |
| 2.0 | 37.9 | | *Avicennia alba* | 47 | 16 | |
| | 38.6 | 5.0 | *Rhizophora mucronata* | 87 | 12 | |
| 3.0 | 39.5 | | *Avicennia alba* | 22 | 11 | |

| Transect T2 | | | | | | |
|---|---|---|---|---|---|---|
| **Left Offset** | **Chainage** | **Right Offset** | **Species** | **GBH (cm)** | **Height (m)** | **Note** |
| 0.5 | 44.0 | | *Rhizophora mucronata* | 26 | 10 | |
| 1.5 | 44.5 | | *Rhizophora mucronata* | 29 | 12 | |
| 3.0 | 45.5 | | *Avicennia alba* | 81 | 13 | |
| | 46.4 | | *Rhizophora mucronata* | 28 | 0 | |
| 2.0 | 26-32 | | *Rhizophora apiculata* | | | numerous seedlings |

Soft-bottom Macrobenthos Data Compiled

| No. | CLASS | Density (individuals/m²) | | | | | | | | | Sum | Mean | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MB01 | | | MB02 | | | MB03 | | | | | |
| | | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | | | |
| 1 | Polychaeta | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 47.62 | 0.00 | 47.62 | 5.29 | 15.873 |
| 2 | Malacostraca | 0.00 | 15.87 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 15.87 | 0.00 | 31.75 | 3.53 | 6.999 |
| 3 | Ophiuroidea | 95.24 | 95.24 | 0.00 | 0.00 | 0.00 | 79.37 | 79.37 | 47.62 | 79.37 | 476.19 | 52.91 | 41.996 |
| 4 | Bivalvia | 47.62 | 0.00 | 0.00 | 15.87 | 15.87 | 47.62 | 0.00 | 0.00 | 0.00 | 126.98 | 14.11 | 20.148 |
| 5 | Sipunculidea | 0.00 | 0.00 | 0.00 | 0.00 | 15.87 | 15.87 | 0.00 | 0.00 | 0.00 | 31.75 | 3.53 | 6.999 |
| 6 | Nemertea | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 15.87 | 15.87 | 1.76 | 5.291 |
| **Sum** | | **142.86** | **111.11** | **0.00** | **15.87** | **31.75** | **142.86** | **79.37** | **111.11** | **95.24** | **730.16** | **81.13** | **53.50** |
| **Sum per Site** | | **253.97** | | | **190.48** | | | **285.71** | | | | | |
| **Mean Per Site** | | **84.66** | | | **63.49** | | | **95.24** | | | | | |

MLS

# TEST REPORT

| | | | | | |
|---|---|---|---|---|---|
| Our Reference No. | : | **R240 8464/2** | Date Received | : | 03/10/2024 |
| Project Code / Ref. | : | Keppel Data Centres Holding Pte Ltd | Date Commenced | : | 03/10/2024 |
| | | | Date Reported | : | 14/10/2024 |

Customer Ref. No. : P527466
Customer Name : Singapore Environmental Consultancy and Solutions Pte Ltd
Customer Address : 1 Sunview Road
#08-19
Singapore 627615

Attention To : Ms Chin Wan Li

Sample Description : 16 Water Samples as per received

Test Parameter : Phytoplankton Total Count
Test Method : APHA 10200F

**RESULTS** : Refer to Page 2

**Renugopal**
**Principal Microbiologist**



**Marchwood Laboratory Services Pte Ltd:** Co. Reg No. : 201422686C
Main (Office and Laboratory): 116 Tuas South Ave 2, West Point Bizhub Singapore 637163 Tel: +65 6790 0118 Fax: +65 6790 0091
Branch (Site and Laboratory): 216 Tuas South Ave 2, West Point Bizhub Singapore 637213 Tel: +65 6262 3736 (Lab) Tel: +65 6262 3726 / 3776 (Site)
Website: www.mls.sg

**RESULTS**

| Phyla | Lower taxon | WQ01_F_S | | WQ01_E_S | | WQ02_F_S | | WQ02_E_S | |
|---|---|---|---|---|---|---|---|---|---|
| | | **S01** | **Percentage** | **S03** | **Percentage** | **S05** | **Percentage** | **S07** | **Percentage** |
| Dinophyta | *Protoperidinium* sp. | | 0.0% | 1 | 1.4% | | 0.0% | | 0.0% |
| Ochrophyta | *Coscinodiscus* sp. | 3 | 1.4% | | 0.0% | | 0.0% | | 0.0% |
| | *Chaetoceros sp.* | 200 | 94.8% | 70 | 98.6% | 217 | 100.0% | 201 | 93.5% |
| | *Rhizosolenia.sp* | | 0.0% | | 0.0% | | 0.0% | | 0.0% |
| | *Skeletonema.sp* | 8 | 3.8% | | 0.0% | | 0.0% | 14 | 6.5% |
| Total counted | | 211 | 100.0% | 71 | 100.0% | 217 | 100.0% | 215 | 100.0% |
| No. of squares counted / No. of ul counted | | 200 | | 200 | | 200 | | 116 | |
| Total count | No. of organism per 1 ml | 1,055 | | 355 | | 1,085 | | 1,853 | |

| Phyla | Lower taxon | WQ03_F_S | | WQ03_E_S | | WQ04_F_S | | WQ04_E_S | |
|---|---|---|---|---|---|---|---|---|---|
| | | **S09** | **Percentage** | **S11** | **Percentage** | **S13** | **Percentage** | **S15** | **Percentage** |
| Dinophyta | *Protoperidinium* sp. | | 0.0% | | 0.0% | | 0.0% | | 0.0% |
| Ochrophyta | *Coscinodiscus* sp. | | 0.0% | | 0.0% | | 0.0% | | 0.0% |
| | *Chaetoceros sp.* | 105 | 47.3% | 195 | 90.7% | 197 | 90.8% | 204 | 94.0% |
| | *Rhizosolenia.sp* | | 0.0% | | 0.0% | 1 | 0.5% | | 0.0% |
| | *Skeletonema.sp* | 117 | 52.7% | 20 | 9.3% | 19 | 8.8% | 5 | 2.4% |
| Total counted | | 222 | 100.0% | 215 | 100.0% | 217 | 100.0% | 209 | 96.4% |
| No. of squares counted / No. of ul counted | | 63 | | 87 | | 105 | | 103 | |
| Total count | No. of organism per 1 ml | 3,524 | | 2,471 | | 2,067 | | 2,029 | |

MLS

# TEST REPORT

| | | | | | |
|---|---|---|---|---|---|
| Our Reference No. | : | **R240 8465** | Date Received | : | 03/10/2024 |
| Project Code / Ref. | : | Keppel Data Centres Holding Pte Ltd | Date Commenced | : | 03/10/2024 |
| | | | Date Reported | : | 16/10/2024 |

Customer Ref. No. : P527466
Customer Name : Singapore Environmental Consultancy and Solutions Pte Ltd
Customer Address : 1 Sunview Road
#08-19
Singapore 627615

Attention To : Ms Chin Wan Li

Sample Description : 8 Water Samples as per received

Test Parameter : Zooplankton Total Count
Test Method : APHA 10200G

**RESULTS** : Refer to Page 2

**Renugopal**
**Principal Microbiologist**

**Terms & Conditions:**
1) This report shall not be reproduced except in full, unless approval in writing has been given by MLS.
2) The results in this report only apply to the sample received/analysed.
3) MLS agrees to use reasonable diligence in the performance of the service.

**Marchwood Laboratory Services Pte Ltd:** Co. Reg No. : 201422686C
Main (Office and Laboratory): 116 Tuas South Ave 2, West Point Bizhub Singapore 637163 ☎ : +65 6790 0118 Fax : +65 6790 0091
Branch (Site and Laboratory): 216 Tuas South Ave 2, West Point Bizhub Singapore 637213 ☎ : +65 6262 3736 (Lab) ☎ : +65 6262 3726 / 3776 (Site)
Website: www.mls.sg

RESULTS

| Phyla | Lower taxon | WQ01_F | | WQ01_E | | WQ02_F | | WQ02_E | |
|---|---|---|---|---|---|---|---|---|---|
| | | S01 | Percentage | S02 | Percentage | S03 | Percentage | S04 | Percentage |
| Arthropoda | F.Paracalanidae copepod | 9 | 17.3% | 6 | 10.2% | 3 | 4.3% | 4 | 6.3% |
| | *Acartia* sp. | | 0.0% | | 0.0% | 1 | 1.4% | | 0.0% |
| | *Euterpina.sp* | 10 | 19.2% | 17 | 28.8% | 17 | 24.3% | 6 | 9.4% |
| | Cirriped | | 0.0% | 2 | 3.4% | 2 | 2.9% | 3 | 4.7% |
| | Copepod nauplii | 18 | 34.6% | 23 | 39.0% | 21 | 30.0% | 22 | 34.4% |
| | *Oithona* sp. | 5 | 9.6% | 4 | 6.8% | 17 | 24.3% | 4 | 6.3% |
| Ciliophora | Tintinnid species | 6 | 11.5% | 5 | 8.5% | 7 | 10.0% | 24 | 37.5% |
| Mollusca | Bivalve | 4 | 7.7% | | 0.0% | 2 | 2.9% | 1 | 1.6% |
| | Gastropod | | 0.0% | 2 | 3.4% | | 0.0% | | 0.0% |
| Total counted | | 52 | 100.0% | 59 | 100.0% | 70 | 100.0% | 64 | 100.0% |
| Concentrated Volume (L) | | 3167 | | 2764 | | 3217 | | 2111 | |
| Lab volume (mL) | | 970 | | 990 | | 1000 | | 960 | |
| Volume counted (mL) | | 1 | | 1 | | 1 | | 1 | |
| Total count | No. of organism per $m^3$ | 15,927 | | 21,132 | | 21,759 | | 29,105 | |

| Phyla | Lower taxon | WQ03_F | | WQ03_E | | WQ04_F | | WQ04_E | |
|---|---|---|---|---|---|---|---|---|---|
| | | S05 | Percentage | S06 | Percentage | S07 | Percentage | S08 | Percentage |
| Arthropoda | F.Paracalanidae copepod | 6 | 5.3% | 7 | 6.1% | 6 | 4.1% | 3 | 6.4% |
| | *Acartia* sp. | | 0.0% | | 0.0% | | 0.0% | | 0.0% |
| | *Euterpina.sp* | 26 | 22.8% | 19 | 16.5% | 18 | 12.4% | 8 | 17.0% |
| | Cirriped | 4 | 3.5% | 3 | 2.6% | 2 | 1.4% | | 0.0% |
| | Copepod nauplii | 43 | 37.7% | 36 | 31.3% | 64 | 44.1% | 17 | 36.2% |
| | *Oithona* sp. | 12 | 10.5% | 23 | 20.0% | 21 | 14.5% | 7 | 14.9% |
| Ciliophora | Tintinnid species | 10 | 8.8% | 13 | 11.3% | 23 | 15.9% | 8 | 17.0% |
| Mollusca | Bivalve | 13 | 11.4% | 14 | 12.2% | 11 | 7.6% | 4 | 8.5% |
| | Gastropod | | 0.0% | | 0.0% | | 0.0% | | 0.0% |
| Total counted | | 114 | 100.0% | 115 | 100.0% | 145 | 100.0% | 47 | 100.0% |
| Concentrated Volume (L) | | 1608 | | 2211 | | 2111 | | 1206 | |
| Lab volume (mL) | | 990 | | 990 | | 990 | | 990 | |
| Volume counted (mL) | | 1 | | 1 | | 1 | | 1 | |
| Total count | No. of organism per $m^3$ | 70,187 | | 51,493 | | 68,001 | | 38,582 | |

**SINGAPORE ENVIRONMENTAL CONSULTANCY AND SOLUTIONS PTE LTD**

03 OCT 2024

SECS

## CHAIN OF CUSTODY FORM

Form No.: OPS-QR-01 Rev (B)
Page 2 of 2

| | |
|---|---|
| CLIENT | : Keppel Data Centres Holding Pte Ltd |
| CONTACT | : |
| ADDRESS | : |
| PROJECT No. | : P527466 |
| SITE | : |
| QUOTATION / JOB REQUEST / PO No. | : |
| SEND REPORT TO | : Wanli.Chin@aurecongroup.com |
| REPORT NEEDED BY (DATE) | : |
| COMMENT / SPECIAL INSTRUCTION | : |
| STORAGE / DISPOSAL | : |

**FOR LAB USE**
Reg. No.: R2408465

| S/N | SAMPLE ID / LOCATION | SAMPING DEPTH (m) | MATRIX* | DATE | TIME (HRS) | TOTAL NOs OF CONTAINERS# / SAMPLING MEDIA$ | STORAGE CONDITION** | ANALYSIS PARAMETER (Enter "x" below to indicate Request): Zooplankton | | | | | | | | REMARKS / OBSERVATION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | WQ01_F | | SW | | | | | X | | | | | | | | 1L Amber – ZP. |
| 2 | WQ01_E | | SW | | | | | X | | | | | | | | |
| 3 | WQ02_F | | SW | 3/10/24 (all samples 1–8) | | | | X | | | | | | | | |
| 4 | WQ02_E | | SW | | | | | X | | | | | | | | |
| 5 | WQ03_F | | SW | | | | | X | | | | | | | | |
| 6 | WQ03_E | | SW | | | | | X | | | | | | | | |
| 7 | WQ04_F | | SW | | | | | X | | | | | | | | |
| 8 | WQ04_E | | SW | | | | | X | | | | | | | | |
| 9 | | | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | |

| RELINQUISHED BY: | DATE / TIME | RECEIVED BY: | DATE / TIME | RELINQUISHED BY: | DATE / TIME | RECEIVED BY: | DATE / TIME | SHIPMENT BY COURIER: |
|---|---|---|---|---|---|---|---|---|
| Name: Chua Kiam Poh | 3/10/24 | Name: [signature] | 3/10/24 | Name: | | Name: | | Courier Co. / Carrier Name: |
| Sign: [signature] | | Sign: [signature] | | Sign: | | Sign: | | Consignment Note / Airway Bill: |
| Company: SECS | 15.25 hrs | Company: [signature] | 1325 hrs | Company: | hrs | Company: | hrs | |

* = For Water sample: Please Indicate FW (Fresh Water), SW (Seawater), BW (Ballast Water), DW (Drinking Water), GW (Ground water), WW (Wastewater)

\# Type of Sampling Bottles: G = Glass; P = Plastic; T = Tube; V = VOC vial; S = Steriled bottle; B = Bag

** Storage Condition: C = Refrigerate at 4 oC; R = Room Temperature; P = Preserved as per Lab's instruction

$ Type of Sampling Media: ST = Sorbent Tube; IM = Impinger solution; F = Filter; RT = Resin Trap; AP = Agar Plate; W = Wipe Sample; Others (PUF, etc. - please specify)

MLS

# TEST REPORT

| | | | | | |
|---|---|---|---|---|---|
| Our Reference No. | : | **R240 8464/2** | Date Received | : | 03/10/2024 |
| Project Code / Ref. | : | Keppel Data Centres Holding Pte Ltd | Date Commenced | : | 03/10/2024 |
| | | | Date Reported | : | 14/10/2024 |

Customer Ref. No. : P527466
Customer Name : Singapore Environmental Consultancy and Solutions Pte Ltd
Customer Address : 1 Sunview Road
#08-19
Singapore 627615

Attention To : Ms Chin Wan Li

Sample Description : 16 Water Samples as per received

Test Parameter : Phytoplankton Total Count
Test Method : APHA 10200F

**RESULTS** : Refer to Page 2

**Renugopal**
**Principal Microbiologist**



**Marchwood Laboratory Services Pte Ltd:** Co. Reg No. : 201422686C
Main (Office and Laboratory): 116 Tuas South Ave 2, West Point Bizhub Singapore 637163 Tel: +65 6790 0118 Fax: +65 6790 0091
Branch (Site and Laboratory): 216 Tuas South Ave 2, West Point Bizhub Singapore 637213 Tel: +65 6262 3736 (Lab) Tel: +65 6262 3726 / 3776 (Site)
Website: www.mls.sg

**RESULTS**

| Phyla | Lower taxon | WQ01_F_S | | WQ01_E_S | | WQ02_F_S | | WQ02_E_S | |
|---|---|---|---|---|---|---|---|---|---|
| | | **S01** | **Percentage** | **S03** | **Percentage** | **S05** | **Percentage** | **S07** | **Percentage** |
| Dinophyta | *Protoperidinium* sp. | | 0.0% | 1 | 1.4% | | 0.0% | | 0.0% |
| Ochrophyta | *Coscinodiscus* sp. | 3 | 1.4% | | 0.0% | | 0.0% | | 0.0% |
| | *Chaetoceros sp.* | 200 | 94.8% | 70 | 98.6% | 217 | 100.0% | 201 | 93.5% |
| | *Rhizosolenia.sp* | | 0.0% | | 0.0% | | 0.0% | | 0.0% |
| | *Skeletonema.sp* | 8 | 3.8% | | 0.0% | | 0.0% | 14 | 6.5% |
| Total counted | | 211 | 100.0% | 71 | 100.0% | 217 | 100.0% | 215 | 100.0% |
| No. of squares counted / No. of ul counted | | 200 | | 200 | | 200 | | 116 | |
| Total count | No. of organism per 1 ml | 1,055 | | 355 | | 1,085 | | 1,853 | |

| Phyla | Lower taxon | WQ03_F_S | | WQ03_E_S | | WQ04_F_S | | WQ04_E_S | |
|---|---|---|---|---|---|---|---|---|---|
| | | **S09** | **Percentage** | **S11** | **Percentage** | **S13** | **Percentage** | **S15** | **Percentage** |
| Dinophyta | *Protoperidinium* sp. | | 0.0% | | 0.0% | | 0.0% | | 0.0% |
| Ochrophyta | *Coscinodiscus* sp. | | 0.0% | | 0.0% | | 0.0% | | 0.0% |
| | *Chaetoceros sp.* | 105 | 47.3% | 195 | 90.7% | 197 | 90.8% | 204 | 94.0% |
| | *Rhizosolenia.sp* | | 0.0% | | 0.0% | 1 | 0.5% | | 0.0% |
| | *Skeletonema.sp* | 117 | 52.7% | 20 | 9.3% | 19 | 8.8% | 5 | 2.4% |
| Total counted | | 222 | 100.0% | 215 | 100.0% | 217 | 100.0% | 209 | 96.4% |
| No. of squares counted / No. of ul counted | | 63 | | 87 | | 105 | | 103 | |
| Total count | No. of organism per 1 ml | 3,524 | | 2,471 | | 2,067 | | 2,029 | |

Soft-bottom Macrobenthos Data Compiled

| No. | CLASS | Density (individuals/m²) | | | | | | | | | Sum | Mean | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MB01 | | | MB02 | | | MB03 | | | | | |
| | | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | | | |
| 1 | Polychaeta | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 47.62 | 0.00 | 47.62 | 5.29 | 15.873 |
| 2 | Malacostraca | 0.00 | 15.87 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 15.87 | 0.00 | 31.75 | 3.53 | 6.999 |
| 3 | Ophiuroidea | 95.24 | 95.24 | 0.00 | 0.00 | 0.00 | 79.37 | 79.37 | 47.62 | 79.37 | 476.19 | 52.91 | 41.996 |
| 4 | Bivalvia | 47.62 | 0.00 | 0.00 | 15.87 | 15.87 | 47.62 | 0.00 | 0.00 | 0.00 | 126.98 | 14.11 | 20.148 |
| 5 | Sipunculidea | 0.00 | 0.00 | 0.00 | 0.00 | 15.87 | 15.87 | 0.00 | 0.00 | 0.00 | 31.75 | 3.53 | 6.999 |
| 6 | Nemertea | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 15.87 | 15.87 | 1.76 | 5.291 |
| **Sum** | | **142.86** | **111.11** | **0.00** | **15.87** | **31.75** | **142.86** | **79.37** | **111.11** | **95.24** | **730.16** | **81.13** | **53.50** |
| **Sum per Site** | | **253.97** | | | **190.48** | | | **285.71** | | | | | |
| **Mean Per Site** | | **84.66** | | | **63.49** | | | **95.24** | | | | | |

# TEST REPORT

| | | | | | |
|---|---|---|---|---|---|
| Our Reference No. | : | **R240 8465** | Date Received | : | 03/10/2024 |
| Project Code / Ref. | : | Keppel Data Centres Holding Pte Ltd | Date Commenced | : | 03/10/2024 |
| | | | Date Reported | : | 16/10/2024 |

Customer Ref. No. : P527466
Customer Name : Singapore Environmental Consultancy and Solutions Pte Ltd
Customer Address : 1 Sunview Road
#08-19
Singapore 627615

Attention To : Ms Chin Wan Li

Sample Description : 8 Water Samples as per received

Test Parameter : Zooplankton Total Count
Test Method : APHA 10200G

**RESULTS** : Refer to Page 2

**Renugopal**
**Principal Microbiologist**



**Marchwood Laboratory Services Pte Ltd:** Co. Reg No. : 201422686C
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Branch (Site and Laboratory): 216 Tuas South Ave 2, West Point Bizhub Singapore 637213 Tel: +65 6262 3736 (Lab) Tel: +65 6262 3726 / 3776 (Site)
Website: www.mls.sg

MLS

R240 8465

RESULTS

| Phyla | Lower taxon | WQ01_F | | WQ01_E | | WQ02_F | | WQ02_E | |
|---|---|---|---|---|---|---|---|---|---|
| | | S01 | Percentage | S02 | Percentage | S03 | Percentage | S04 | Percentage |
| Arthropoda | F.Paracalanidae copepod | 9 | 17.3% | 6 | 10.2% | 3 | 4.3% | 4 | 6.3% |
| | *Acartia* sp. | | 0.0% | | 0.0% | 1 | 1.4% | | 0.0% |
| | *Euterpina.sp* | 10 | 19.2% | 17 | 28.8% | 17 | 24.3% | 6 | 9.4% |
| | Cirriped | | 0.0% | 2 | 3.4% | 2 | 2.9% | 3 | 4.7% |
| | Copepod nauplii | 18 | 34.6% | 23 | 39.0% | 21 | 30.0% | 22 | 34.4% |
| | *Oithona* sp. | 5 | 9.6% | 4 | 6.8% | 17 | 24.3% | 4 | 6.3% |
| Ciliophora | Tintinnid species | 6 | 11.5% | 5 | 8.5% | 7 | 10.0% | 24 | 37.5% |
| Mollusca | Bivalve | 4 | 7.7% | | 0.0% | 2 | 2.9% | 1 | 1.6% |
| | Gastropod | | 0.0% | 2 | 3.4% | | 0.0% | | 0.0% |
| Total counted | | 52 | 100.0% | 59 | 100.0% | 70 | 100.0% | 64 | 100.0% |
| Concentrated Volume (L) | | 3167 | | 2764 | | 3217 | | 2111 | |
| Lab volume (mL) | | 970 | | 990 | | 1000 | | 960 | |
| Volume counted (mL) | | 1 | | 1 | | 1 | | 1 | |
| Total count | No. of organism per $m^3$ | 15,927 | | 21,132 | | 21,759 | | 29,105 | |

| Phyla | Lower taxon | WQ03_F | | WQ03_E | | WQ04_F | | WQ04_E | |
|---|---|---|---|---|---|---|---|---|---|
| | | S05 | Percentage | S06 | Percentage | S07 | Percentage | S08 | Percentage |
| Arthropoda | F.Paracalanidae copepod | 6 | 5.3% | 7 | 6.1% | 6 | 4.1% | 3 | 6.4% |
| | *Acartia* sp. | | 0.0% | | 0.0% | | 0.0% | | 0.0% |
| | *Euterpina.sp* | 26 | 22.8% | 19 | 16.5% | 18 | 12.4% | 8 | 17.0% |
| | Cirriped | 4 | 3.5% | 3 | 2.6% | 2 | 1.4% | | 0.0% |
| | Copepod nauplii | 43 | 37.7% | 36 | 31.3% | 64 | 44.1% | 17 | 36.2% |
| | *Oithona* sp. | 12 | 10.5% | 23 | 20.0% | 21 | 14.5% | 7 | 14.9% |
| Ciliophora | Tintinnid species | 10 | 8.8% | 13 | 11.3% | 23 | 15.9% | 8 | 17.0% |
| Mollusca | Bivalve | 13 | 11.4% | 14 | 12.2% | 11 | 7.6% | 4 | 8.5% |
| | Gastropod | | 0.0% | | 0.0% | | 0.0% | | 0.0% |
| Total counted | | 114 | 100.0% | 115 | 100.0% | 145 | 100.0% | 47 | 100.0% |
| Concentrated Volume (L) | | 1608 | | 2211 | | 2111 | | 1206 | |
| Lab volume (mL) | | 990 | | 990 | | 990 | | 990 | |
| Volume counted (mL) | | 1 | | 1 | | 1 | | 1 | |
| Total count | No. of organism per $m^3$ | 70,187 | | 51,493 | | 68,001 | | 38,582 | |

**SINGAPORE ENVIRONMENTAL CONSULTANCY AND SOLUTIONS PTE LTD**

03 OCT 2024

SECS

Form No.: OPS-QR-01 Rev (B)
Page 2 of 2

## CHAIN OF CUSTODY FORM

| | |
|---|---|
| CLIENT | : Keppel Data Centres Holding Pte Ltd |
| CONTACT | : |
| ADDRESS | : |
| PROJECT No. | : P527466 |
| SITE | : |
| QUOTATION / JOB REQUEST / PO No. | : |
| SEND REPORT TO | : Wanli.Chin@aurecongroup.com |
| REPORT NEEDED BY (DATE) | : |
| COMMENT / SPECIAL INSTRUCTION | : |
| STORAGE / DISPOSAL | : |

FOR LAB USE
Reg. No.: R2408465

| S/N | SAMPLE ID / LOCATION | SAMPING DEPTH (m) | MATRIX* | DATE | TIME (HRS) | TOTAL NOs OF CONTAINERS# / SAMPLING MEDIA$ | STORAGE CONDITION** | ANALYSIS PARAMETER (Enter "x" below to indicate Request): Zooplankton | | | | | | | | REMARKS / OBSERVATION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | WQ01_F | | SW | | | | | X | | | | | | | | 1L Amber – ZP. |
| 2 | WQ01_E | | SW | | | | | X | | | | | | | | |
| 3 | WQ02_F | | SW | 3/10/24 | | | | X | | | | | | | | |
| 4 | WQ02_E | | SW | | | | | X | | | | | | | | |
| 5 | WQ03_F | | SW | | | | | X | | | | | | | | |
| 6 | WQ03_E | | SW | | | | | X | | | | | | | | |
| 7 | WQ04_F | | SW | | | | | X | | | | | | | | |
| 8 | WQ04_E | | SW | | | | | X | | | | | | | | |
| 9 | | | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | |

| RELINQUISHED BY: | DATE / TIME | RECEIVED BY: | DATE / TIME | RELINQUISHED BY: | DATE / TIME | RECEIVED BY: | DATE / TIME | SHIPMENT BY COURIER: |
|---|---|---|---|---|---|---|---|---|
| Name: Chua Kiam Poh | 3/10/24 | Name: [signature] | 3/10/24 | Name: | | Name: | | Courier Co. / Carrier Name: |
| Sign: [signature] | | Sign: [signature] | | Sign: | | Sign: | | |
| Company: SECS | 15:25 hrs | Company: [signature] | 1525 hrs | Company: | hrs | Company: | hrs | Consignment Note / Airway Bill: |

* = For Water sample: Please Indicate FW (Fresh Water), SW (Seawater), BW (Ballast Water), DW (Drinking Water), GW (Ground water), WW (Wastewater)

\# Type of Sampling Bottles: G = Glass; P = Plastic; T = Tube; V = VOC vial; S = Steriled bottle; B = Bag

** Storage Condition: C = Refrigerate at 4 oC; R = Room Temperature; P = Preserved as per Lab's instruction

$ Type of Sampling Media: ST = Sorbent Tube; IM = Impinger solution; F = Filter; RT = Resin Trap; AP = Agar Plate; W = Wipe Sample; Others (PUF, etc. - please specify)

**Document prepared by**

**Aurecon (Singapore) Pte. Ltd**

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