Proposed Extension of Slipway for Outward Bound Singapore at Camp 2, Pulau Ubin

Environmental Impact Assessment Report (Final)

National Youth Council

Environmental Impact Assessment

September 2023

This report has been prepared under the DHI Business Management System certified by Bureau Veritas to comply with ISO 9001 (Quality Management), ISO 14001 (Environmental Management), ISO 45001 (Occupational Health and Safety Management) and bizSAFE STAR

Proposed Extension of Slipway for Outward Bound Singapore at Camp 2, Pulau Ubin

Environmental Impact Assessment Report (Final)

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1 Introduction

The National Youth Council (NYC or Client) is planning to reconstruct an existing slipway at Outward Bound Singapore (OBS) Camp 2 (Project), which is located on Pulau Ubin, an offshore island northeast of the Singapore mainland (Figure 1.1). The development comes in tandem with the need for accommodating larger new cutters which have been ordered for future needs by OBS.

Based on Letter of Acceptance (Ref. CCYNYCECI22000304 / 1) received from NYC dated 26 April 2022, DHI Water & Environment (S) Pte Ltd (DHI) has been engaged by the NYC to carry out an Environmental Impact Assessment (EIA) for the said Project. This EIA study is hereafter referred to as ‘Study’.

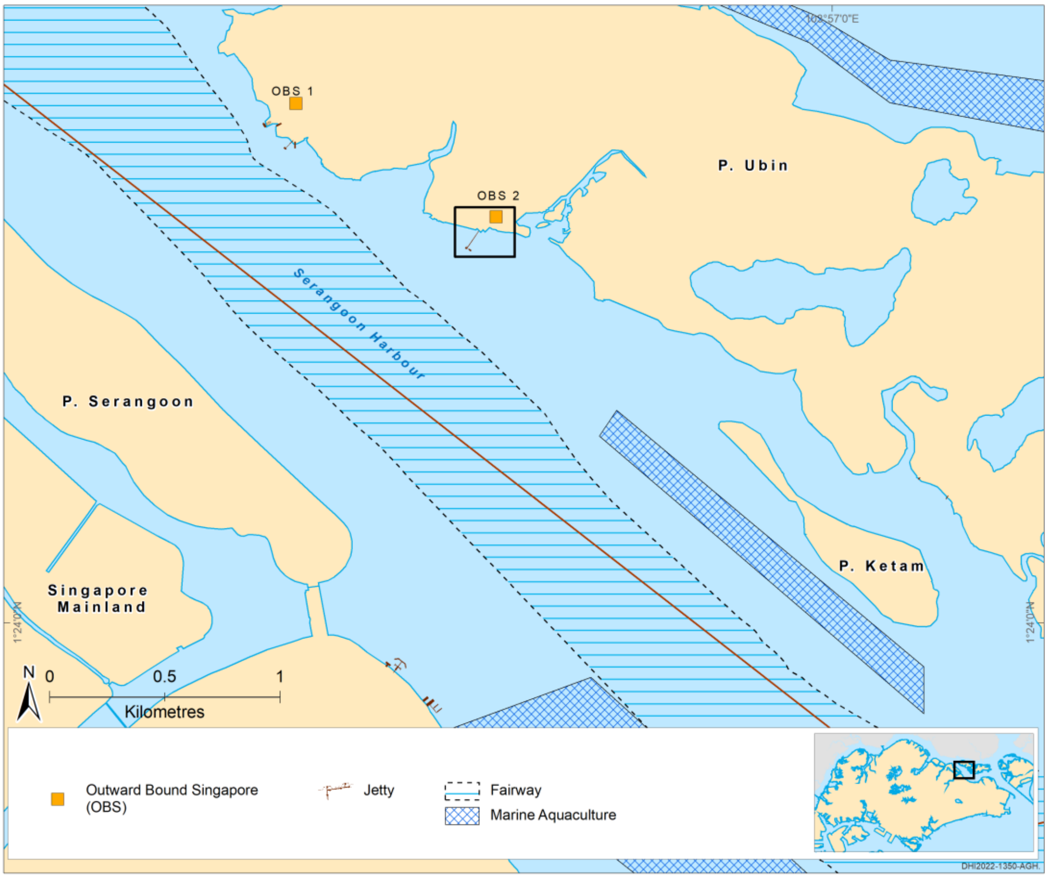


Figure 1.1 Location of the proposed development

1.1 Background

There are two (2) OBS campuses on Pulau Ubin, namely Camp 1 and Camp 2 located approximately 1 km apart on the western part of the island. With no access bridges or roads to the island from Singapore mainland, transport of material to the campuses have primarily been carried out through the marine waters by means of barge and seacrafts. However, the steep slope of the existing slipway at Camp 2 is unsafe for seacraft towing and docking is hindered by the presence of a curb at the ramp. With this difficulty at Camp 2, seacraft traffic has shifted to neighbouring Camp 1 and as a result Camp 1 parking bay is now fully utilized. To accommodate incoming larger cutter boats and to address present towing and docking challenges at Camp 2, NYC has proposed to reconstruct and extend the existing slipway with a gentler slope from existing gradient of 1:5 to a design of 1:10.

1.2 EIA Objectives

The initial consultation with relevant authorities that took place around December 2021 concluded that an environmental study is required as part of planning permission for the proposed reconstruction and extension of the concrete slipway at OBS Camp 2. This environmental study, i.e., the Study, reviews the existing environmental conditions in and around the project area, analyses potential changes to the physical, chemical, and biological environment and assesses the significance of the potential impacts on environmental and socio-economic receptors within the study area. The Study comprises of two (2) main components, purposes of which are listed as follows:

- **Environmental Impact Assessment (EIA):** to assess and document the environmental impacts of the proposed development.
- **Formulation of Environmental Monitoring and Management Plan (EMMP):** to provide input to development of EMMP during construction.

Adequacy and relevance of the recommended EMMP framework and implementation are hinged on the EIA study. Objectives of this EIA are therefore to provide detailed project understanding and thorough assessment on the nature and extent of environmental impacts that could arise from the construction of the proposed development to (1) obtain environmental approval for the Project and (2) form basis for a robust EMMP framework to ensure that the impacts from the construction phase are properly managed and mitigated.

2 Project Description

OBS premises occupy an approximate nine (9) hectares of land on Pulau Ubin, one of the remaining few rugged terrains in Singapore. With natural rugged terrain and the coastal surroundings, the OBS campuses provide excellent platforms for outdoor nature-based education. OBS intends to increase participation of their activities by elevating existing programs and providing new seacrafts to cater for anticipated increased volume of participants. Fulfilling this agenda requires that mobility to Camp 2 is unhindered thus triggering the need to modify the existing slipway.

This section further describes the proposed development, including location, schedule and preliminary construction methodology. These details serve as input to the analysis of environmental changes arising from the proposed construction works.

2.1 Project Location

The proposed development is located at the southwestern part of Pulau Ubin (Figure 2.1). The proposed length of the new slipway is approximately 48 m and with a width of 11 m. The operation of the existing OBS jetty adjacent to the slipway site will not be affected and can be used for delivery activities during the construction phase.

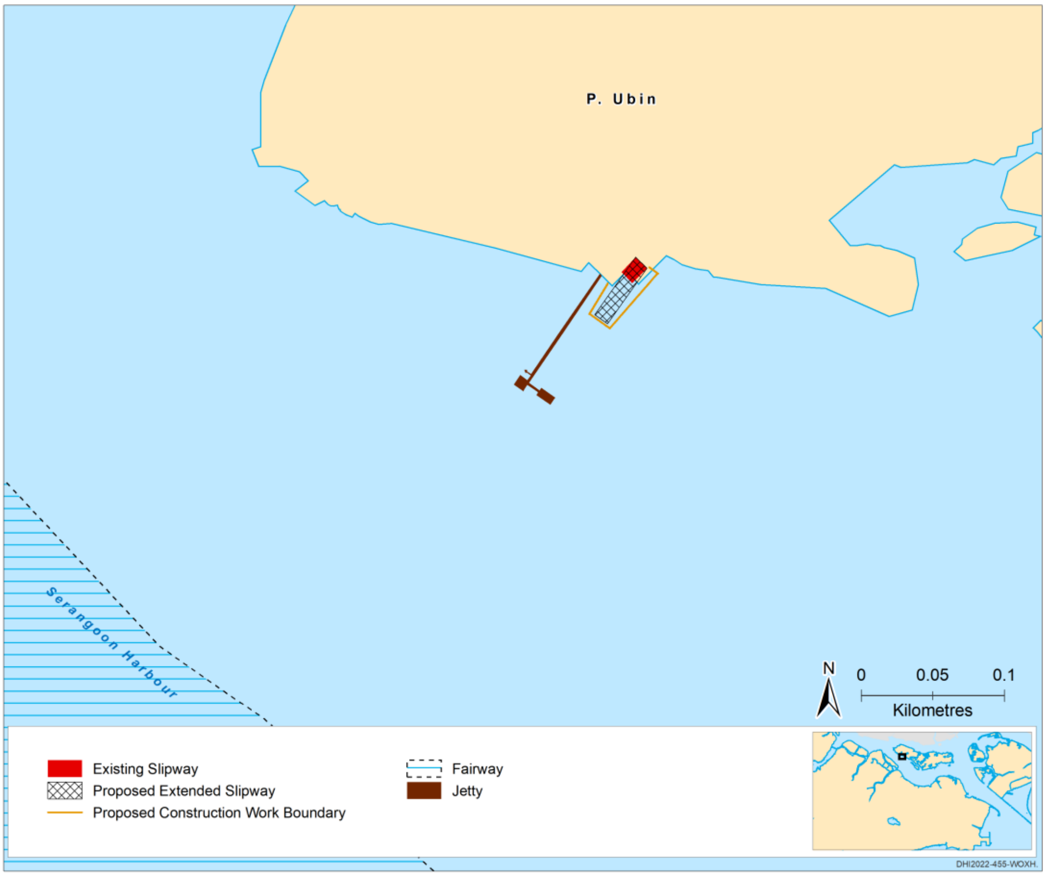


Figure 2.1 Location of project development

2.2 Project Design

The proposed development involves demolition of portion of the existing concrete slipway and recasting with a gentler gradient of 1:10 (Figure 2.2). The new slipway will be realigned such that it is nearly parallel to the adjacent OBS jetty.

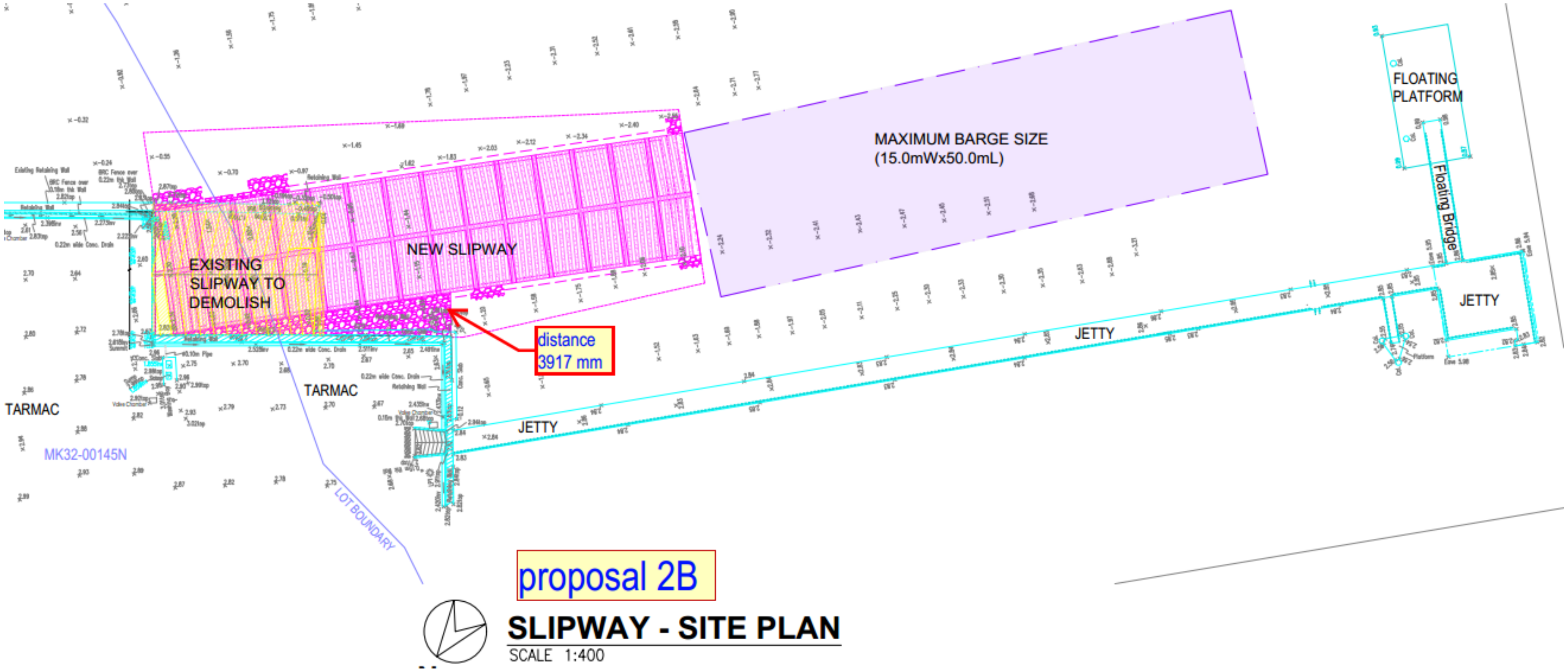


Figure 2.2 Plan view of the proposed extended slipway (Ref: 221129.HL-TKB-OBS-C1&2.PU-SLIPWAY-01-03)

2.3 Construction Phase

Construction of the new slipway is planned to commence in the first quarter of 2023 and to be completed in approximately three (3) months. The construction phase will largely comprise of construction and operation of Earth Retaining Stabilising Structure (ERSS), demolition of the existing reinforced concrete slipway, seabed excavation and concrete casting for the new slipway.

2.3.1 Construction Methodology

Before the commencement of the slipway construction, the site will be hoarded up by ERSS using sheet piles at the seaside to confine all related construction activities as shown by the red boundary in Figure 2.3. Upon completion of the sheet pile installation and strutting works, seawater will be pumped out to provide dry working condition within the work boundary for the slipway construction. Manual excavation of approximately 300 mm depth on the existing seabed will be first carried out before backfilling with graded stone. The excavated material will be used as backfill on the new slipway. A portion of the existing slipway will be demolished, and the remaining slipway's surface will be roughened before backfilling with graded stone. The new slipway will be constructed using precast slab; no concrete batching will be done on site.

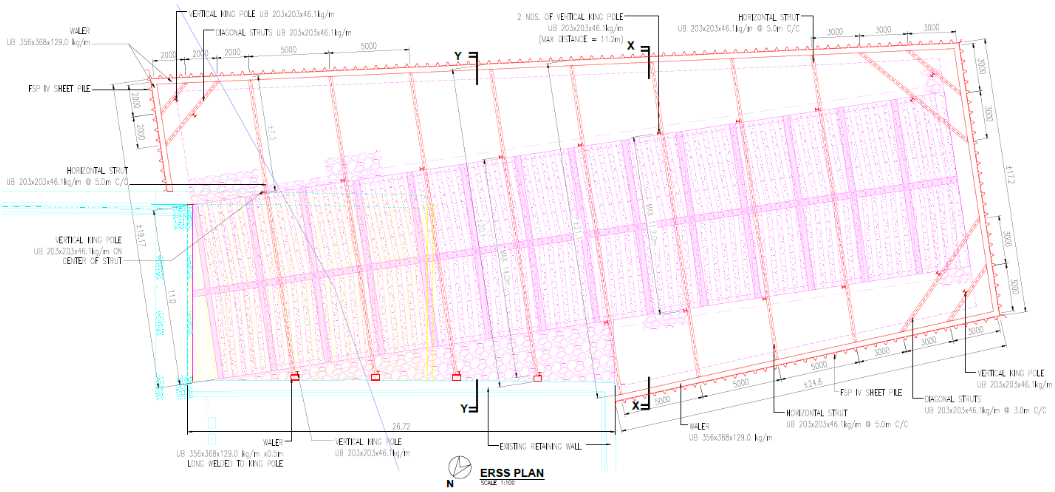


Figure 2.3 Layout of Earth Retaining Stabilising Structure (ERSS) using sheet piles

The key construction equipment that will be used during construction phase include those listed in Table 2.1 below.

Table 2.1 Anticipated construction equipment used during construction phase

Equipment	Estimated Quantity
Barge	2
Piling Rigs	2
Breaker	1
Excavator	1
Water Pump	2

Equipment	Estimated Quantity
Dump Truck	1
Concrete Mixer Truck + Pump	1
Poker Vibrator	1

2.3.2 Construction Site Layout Plan

There will be no site office built on site. Designated location for workers resting and dining will be within OBS Camp 2 premise. No temporary sanitary facilities will be installed as the workers will make use of OBS facilities. Washing bay and Earth Control Measures (ECM) treatment plan will not be in place as the construction vehicles will not access to the slipway construction area. As shown in Figure 2.4, there will be a designated material and equipment holding area located between the work area and OBS Camp 2 facilities. Construction waste will be collected and stored at temporary location before transported via land to OBS Camp 1 for disposal. No storage of flammable chemicals will be on site as all fuel will be brought in by jerry cans as and when required. On the marine side, a buffer zone of 70 m from the ERSS boundary is dedicated to barge berthing for the installation of sheet pile and strutting works.

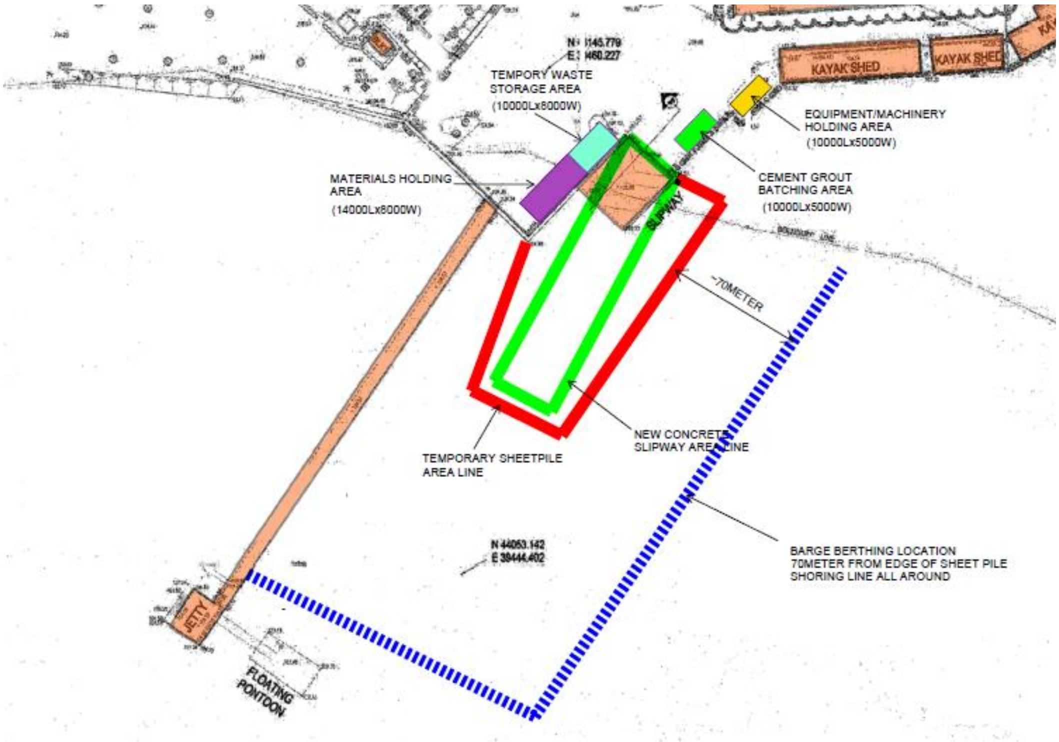
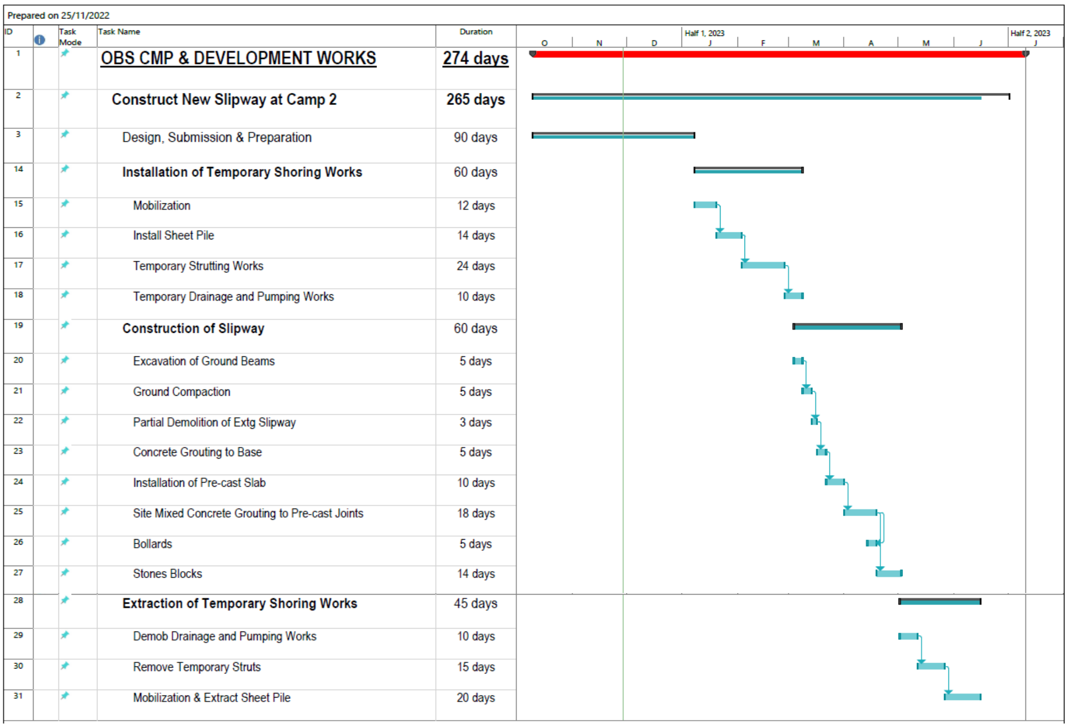


Figure 2.4 Construction site layout plan

2.3.3 Construction Schedule

The tentative schedule and the sequence of the proposed works at OBS Camp 2 are presented in Figure 2.5. All construction works are planned to be conducted during daylight hours (i.e. from 8 am to 6pm, known as “Daylight Hours”).



Prepared on 25/11/2022

ID	Task Name	Duration
1	OBS CMP & DEVELOPMENT WORKS	274 days
2	Construct New Slipway at Camp 2	265 days
3	Design, Submission & Preparation	90 days
14	Installation of Temporary Shoring Works	60 days
15	Mobilization	12 days
16	Install Sheet Pile	14 days
17	Temporary Strutting Works	24 days
18	Temporary Drainage and Pumping Works	10 days
19	Construction of Slipway	60 days
20	Excavation of Ground Beams	5 days
21	Ground Compaction	5 days
22	Partial Demolition of Extg Slipway	3 days
23	Concrete Grouting to Base	5 days
24	Installation of Pre-cast Slab	10 days
25	Site Mixed Concrete Grouting to Pre-cast Joints	18 days
26	Bollards	5 days
27	Stones Blocks	14 days
28	Extraction of Temporary Shoring Works	45 days
29	Demob Drainage and Pumping Works	10 days
30	Remove Temporary Struts	15 days
31	Mobilization & Extract Sheet Pile	20 days

Figure 2.5 Project schedule

2.4 Post-Construction Phase

Post-construction phase of the Project considers the long-term presence of the slipway and therefore anticipated impacts in this regard are related to those affected directly by the footprint (e.g., macrobenthos) as well as changes to hydrodynamics which could affect marine navigation and infrastructure. Post-construction phase activities also entail the use of the renovated slipway and therefore activities during this phase will include:

- Passenger movements in relation to seacraft embarkation and disembarkation
- Light traffic from vessel movement, including towing and docking
- Minor maintenance of slipway, where necessary

It is assumed that OBS will be in-charge of the above activities and would have proper protocols and procedures in place during operation including passenger safety consideration, operation and maintenance schedule, etc. It is thus anticipated that the impacts generated from the post-construction phase, if any, are minimal and localised.

3 Environmental Laws, Standards and Guidelines

Singapore adopts a systematic framework to determine and mitigate the potential impact of any new development on the environment. In general, development projects are required to undergo a thorough evaluation process that addresses the development's potential impact on traffic, public health, heritage, and the environment. In addition, proposed development projects near sensitive areas, such as Nature Reserves, Nature Areas, marine and coastal areas, other areas of significant biodiversity or with potential trans-boundary impact, are subject to greater scrutiny and may be required to carry out more detailed environmental studies.

For such projects, relevant Technical Agencies (e.g., the National Parks Board (NParks), National Environment Agency (NEA), Maritime and Port Authority of Singapore (MPA), and Singapore Food Agency (SFA)) are consulted more extensively, in which the developer sets out the relevant locational and environmental factors, make a considered statement on the potential impacts of the project based on these factors, and also indicate the measures that will be taken to minimize negative impact on the surrounding environment. Relevant guidelines and standards from various agencies including NEA, PUB, Urban Redevelopment Authority (URA), and NParks, are referenced.

The Environmental Protection and Management Act (EPMA), revised 2002, provides the overarching legislative framework for the control of environmental pollution, and covers air pollution, water pollution, land pollution, noise pollution and hazardous substances control. The EPMA is administered and enforced by the NEA. Two sections of the EPMA are relevant to EIA studies: Section 35 on the prevention of pollution from construction sites and Section 36 on pollution control.

Under the Planning Act, statutory permissions and conditions can be imposed for the conduct of environmental studies and investigations into biodiversity. The Wildlife Act also gives the NParks regulatory and enforcement powers to look into and to impose the relevant studies and measures. There is also a new Biodiversity Impact Assessment (BIA) Guideline released recently by NParks which directs the types of studies needed to conserve local biodiversity and ecosystems.

If no relevant guidelines from Singapore agencies are available, then relevant international guidelines such as from the World Health Organization (WHO), United States Environmental Protection Agency (USEPA) and Hong Kong Environmental Protection Department (HKEPD) are used as reference and adapted to the Singapore context. Relevant legislation, standards and guidelines on environmental protection and management are described in this section.

3.1 Local Legislative and Administrative Requirements

National environmental management requirements and biodiversity protection legislation that are applicable to the Project are found in several Acts, Regulations and Guidelines as listed in Table 3.1. In addition, Codes of Practices have been developed to address some specific environmental aspects and are generally endorsed by the relevant agency.

Table 3.1 List of applicable laws, standards and guidelines relevant to the Project

Environmental Aspect	Applicable Acts, Regulations & Guidelines
General	• Planning Act, 1998

Environmental Aspect	Applicable Acts, Regulations & Guidelines
	• Code of Practice for Pollution Control, 2013 • Code of Practice on Environmental Health, 2017 • Code of Practice for Environmental Control Officers for Construction Sites, 2020 • Environmental Public Health (Registration of Environmental Control Officers) Regulations, 2002 • NEA's Guidelines for Pollution Control Study (PCS), 2014 • Environmental Protection and Management Act, 2002
Water Protection	• Sewerage and Drainage Act (Trade Effluent) Regulations, 2001 • Sewerage and Drainage Act (Surface Water Drainage) Regulations, 2008 • Environmental Protection and Management (Trade Effluent) Regulations, 2008 • Guidebook on Erosion and Sediment Control at Construction Sites (PUB, 2014) • Code of Practice on Surface Water Drainage, 7th Edition (PUB, 2018, with amendments under Addendum 1 in 2021) • Managing Urban Runoff - Drainage Handbook 1st Edition (PUB, 2013)
Air Quality Protection	• Environmental Protection and Management Act, 2002 • Environmental Protection and Management (Vehicular Emissions) Regulations, 2008 • Environmental Protection and Management (Air Impurities) Regulations, 2008 • Environmental Protection and Management (Off-Road Diesel Engine Emissions) Regulations, 2012 • Environmental Protection & Management (Prohibition on the Use of Open Fires) Order 2008 • Singapore Air Quality Targets (NEA)
Noise Control	• Environmental Protection and Management Act, 2002 • Environmental Protection and Management (Control of Noise at Construction Sites) Regulations, 2008 • Code of Practice for Noise Control on Construction and Demolition Sites, 2014 • Technical Guidelines for Noise Impact Assessment (NEA), 2016 • LTA's Noise Guidance: Developing a Noise Management Plan in LTA Projects,2019
Wildlife Protection and Welfare	• Wildlife Act, Cap. 351, 2000 • Endangered Species (Import and Export) Act 2008 • Singapore Red Data Book, Second Edition, 2008

Environmental Aspect	Applicable Acts, Regulations & Guidelines
Habitat Protection/ Conservation of Protected Areas	• Parks and Trees Act, 2006 • Parks and Trees Regulations, 2006 • Parks and Trees (Preservation of Trees) Order, revised 1998 • Guidelines on Greenery Provision and Tree Conservation for Developments (NParks, 2020) • Biodiversity Impact Assessment Guidelines (NParks, 2020)
Waste and Hazardous Substances Management; General Waste Management	• Environmental Public Health Act, 2002 • Environmental Protection and Management (Hazardous Substances) Regulations, 2008 • Code of Practice for Licensed General Waste Collectors, 2019 • Code of Practice for Hazardous Waste Management, 2014 • Environmental Public Health (General Waste Collection) Regulations, 2000 • Environmental Public Health (Public Cleansing) Regulations, 2000 • Environmental Public Health (Toxic Industrial Waste) Regulations, 2000 • Sewerage and Drainage Act, 2001, Chapter 294 • Sewerage and Drainage (Trade Effluent) Regulations, 2008 • LTA's Guidebook for Best Environmental Practices – Construction Waste Management at LTA Sites, 2009
Vectors and Pesticides Management	• Control of Vectors and Pesticides Act, 2002 • NEA's Handbook of Scope of Works for Mosquito Control, 1995 • Code of Practice for Vector Control Operator, Technician and Worker, 2020 • Guidebook on Vector Control at LTA Sites, 2010

Nature Reserves, Nature Areas, and National Parks

Biodiversity protection areas in Singapore include Nature Reserves, Nature Areas, and National Parks. This Study Area is located within a designated Nature Area – Pulau Ubin. Nature Areas are recognised in the local context as areas that are rich in biodiversity, such that the Technical Agencies are consulted more extensively, and more thorough studies may be required for development proposals that are within or near the Nature Areas (URA, 2021). Nature Areas are protected by administrative safeguards under the Parks and Waterbodies Plan (Special and Detailed Controls Plan).

3.2 International Guidance

Other internationally accepted policies and guidelines may be referenced and applied as a basis for assessing impacts. The following, amongst others, have been identified for this project:

- Association of Southeast Asian Nations Marine Water Quality Criteria (ASEAN 2008) for assessing water quality

- Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972, also known as the "London Convention" (1975), as updated by the “London Protocol” (2006)
- European Commission Integrated Pollution, Prevention and Control (IPPC) General Principles of Monitoring (2003)
- European Commission, Environmental Impact Assessment of Projects. Guidance on Scoping and Guidance on the preparation of the Environmental Impact Assessment Report (2017)
- European Commission, Guidelines on the Assessment of Indirect and Cumulative Impacts as well as Impact interactions (1999)
- Hong Kong Sediment Quality Criteria for Management of Dredged/Excavated Sediment (ETWB 2002)
- International Finance Corporation Performance Standards and Guidelines
- IUCN Red List of Threatened Species for assessing the vulnerability of species. Under this classification scheme, globally threatened species have been categorised as Extinct, Extinct in the Wild, Critically Endangered, Endangered, Vulnerable, Near Threatened or Least Concern
- The Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora
- World Health Organisation Guidelines

It should be noted that this list is not exhaustive, and specific standards, guidelines and tolerance limits may be referenced throughout the relevant EIA report sections.

4 EIA Scope and Approach

This section outlines the process, methodologies and tools employed in this EIA Study.

4.1 Overall Assessment Process

DHI has carried out this EIA in accordance with the standard EIA framework stipulated by Urban Redevelopment Authority (URA) and Ministry of National Development (MND) as part of the planning approval process (Figure 4.1).

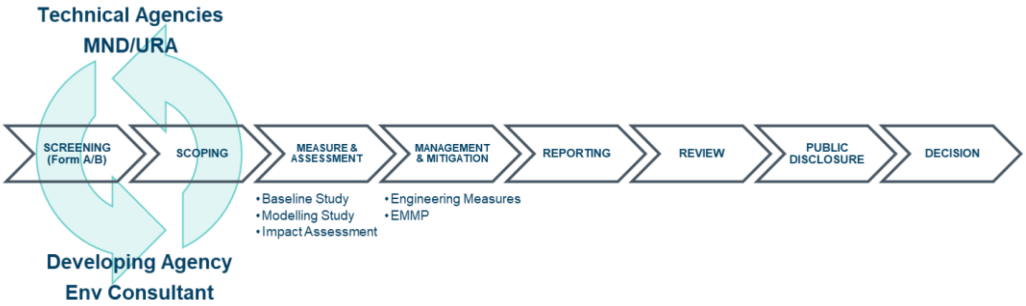


Figure 4.1 An illustration of EIA procedures in Singapore

- **Screening** - The screening stage has taken place around December 2021 and concluded an environmental study is required. Key feedback from Technical Agencies has been considered and incorporated in the Study.

- **Scoping** – Study objectives, spatial and temporal scales and parameters of the EIA as well as all the assessment criteria and methodologies have been described and proposed in the Inception Note (ref. 61803270-OBS Slipway EIA – Inception Report Rev.03). This report has been submitted to NYC on 07 July 2022. Core summary from this phase of the report is also provided in the sub-sections below.

- **Measurement** – this phase of the EIA includes the study of applicable environmental baseline conditions, either through field surveys or desktop literature searches. Findings of this phase of the EIA are described in brief under Section 5 of this report.

- **Assessment** – Prediction of potential changes in environmental parameters as a result of the Project is performed, either qualitatively or quantitatively. Assessment of impacts are classified based upon the significance of the environmental pressures and their influence on sensitive environmental receptors, through the Rapid Impact Assessment Matrix (RIAM) methodology. Assessment for the construction phase is detailed under Section 6 and in Section 7 for post-construction phase.

- **Management & Mitigation** – the EIA also identified appropriate measures to manage the predicted impacts to a reasonably practicable level. An outline of applicable monitoring program is also provided in the form of Environmental Management and Monitoring Plan (EMMP) to ensure that impacts are managed accordingly. Please refer to Section 8 for EMMP Framework.

4.2 Study Scope

The following sub-sections provide a general overview of key analysis scope as it relates to applied analysis parameters, analysis methodologies for each environmental category and the technique used for assigning impact significance.

4.2.1 Spatial and Temporal Scope

The spatial scope for analysis is typically defined based on the spatial scale of change that could result from the proposed Project activities. It has been ascertained through expert scoping that the Project will induce changes in currents and water quality (e.g., due to increased suspended sediment) but the anticipated impacts to the environment are minimal. These impacts are also expected to be highly localised due to the low current speeds in the project area. The analysis and assessment herein cover environmental conditions and receptors no more than 1 km from the work area.

The temporal scale of the Study is determined based upon the period at which the Project is expected to take place as well as the nature of the post-construction / operational phase. This Study considers that construction works will commence in 2023 and will take only 3 months and the slipway is assumed to have design life of 30 years.

4.2.2 Assessment Scope

Expert scoping for the Project was carried out between May and June 2022 that included consultation with URA and Technical Agencies. The exercise has identified relevant environmental pressures as listed in Table 4.1, sensitive receptors in Table 4.2 and the Scoping Matrix as presented in Table 4.3.

Table 4.1 Identified environmental pressures arising from construction and operation of Project

Construction Phase	Post-construction Phase
• Direct loss of habitats and biodiversity within Project Footprint • Hydrodynamic changes (due to intermediate stages of development) • Water quality changes due to increased turbidity generated from sediment plume released during sheet piling works • Inaesthetic appearance of the water may cause nuisance to recreational goers in Pulau Ubin • Physical disturbances in marine environment • Noise emission from various stages of construction, both airborne and underwater	• Hydrodynamic changes • Physical presence of the extended slipway • No long-term morphological changes due to the presence of the slipway is expected to result from such small-scale modifications of the existing shoreline.

Table 4.2 Key sensitive environmental receptors within and near to the proposed development

Receptor groups	Sensitive Environmental Receptors
Ecology and diversity	• Soft-bottom seafloor macrobenthos within the project footprint and surrounding seabed • Mangroves at Sungai Teris • Marine megafauna (e.g. dolphins, otters) of the general study area • Avifauna (resident and migratory birds) of the general study area • Coastal vegetation and terrestrial flora and fauna near to the project footprint and surrounding
Socio-economic receptors (human health and visual impacts)	• OBS staff at Camp 2, Pulau Ubin • Participants and OBS staff of the outdoor educational activities • Recreational users (e.g., kayakers)
Marine navigation and infrastructure	• Serangoon Harbour navigation channel is ~400m south of the Project area • Fish farmers' vessels plying the nearby area • OBS Camp 2 jetty is right outside the proposed construction work area
Aquaculture facilties	• Aquaculture facilities ~850 m offshore (off Pulau Ketam) from the Project area

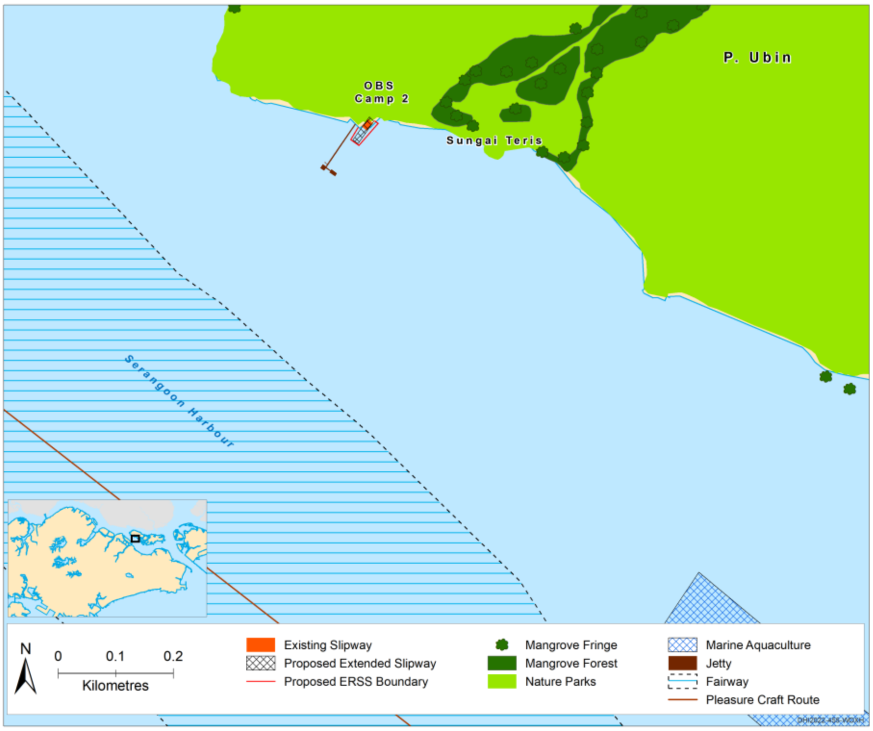


Figure 4.2 Overview of environmental features in the study area

Table 4.3 Scoping Matrix for the Project. Pressures = changes in environmental parameters as a result of the project. Receptors = social, economic or ecological features that may be affected by the pressure. S = Short-term impacts, construction phase impacts. L = Long-term impacts, post-construction phase impacts.

S/N	Pressures	Link to other pressures	Receptors							
			Marine transport	Aquaculture	Macrobenthos	Marine fauna	Mangroves/ Coastal vegetation	Terrestrial fauna	Avifauna	Recreational/ Public health
1	Physical disturbances				SL	SL		S	S	
2	Project footprint/ presence		SL		L	L				
3	Hydrodynamic changes	2	SL							
4	Suspended sediments	1		S		S				S
5	Sedimentation/Erosion	4	S		S		S			
6	Underwater noise and vibration	1		S		S				
7	Airborne noise and vibration	1						S	S	S
8	Air emissions	1						S	S	S
9	Spills/leaks			S	S	S	S		S	

4.3 Study Approach

DHI's overall workflow to environmental impact assessment is illustrated in Figure 4.3. This section offers to elaborate on the approach for Measure, Assess and Manage stages.

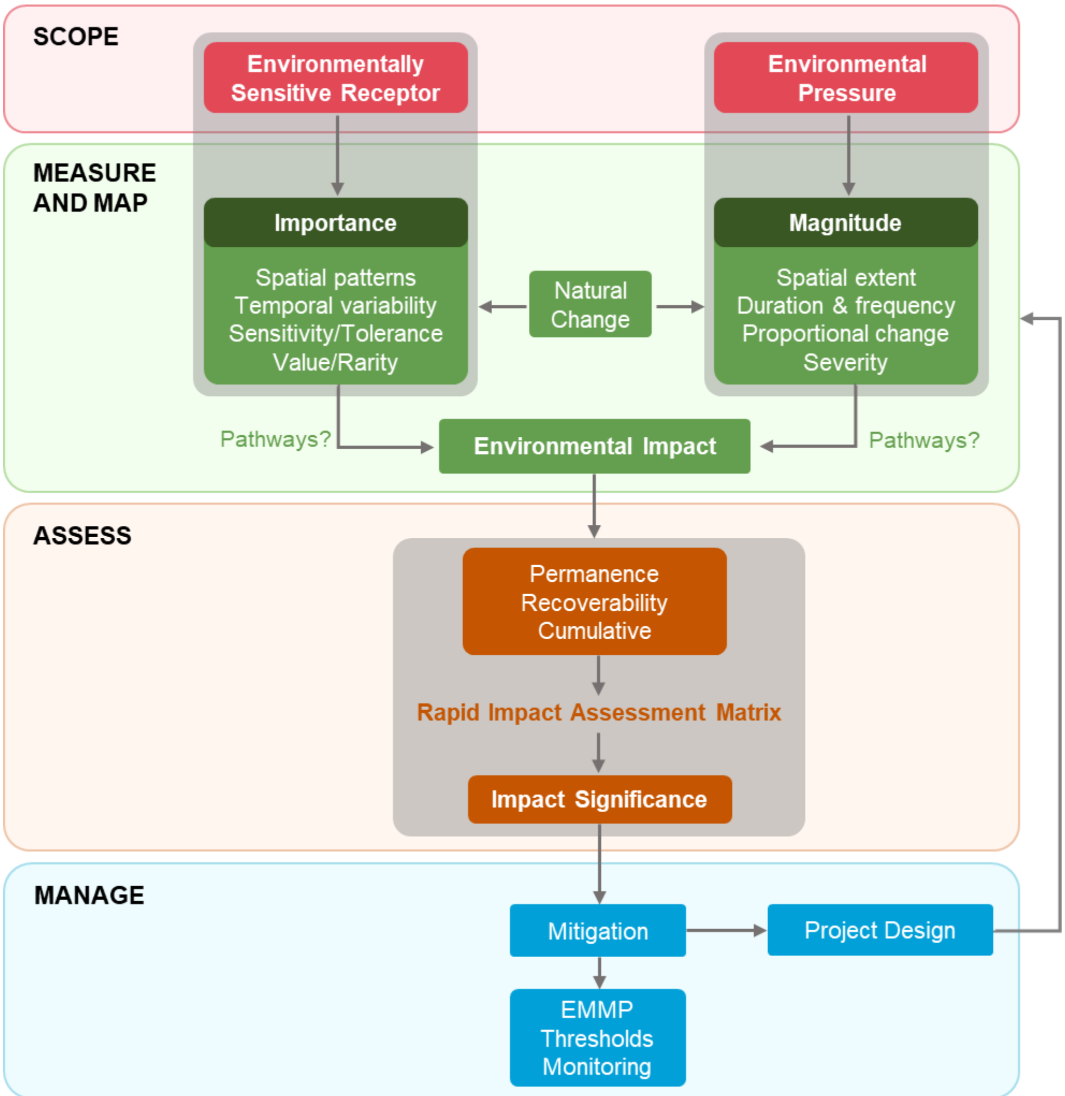


Figure 4.3 DHI's overall workflow for the impact assessment process.

4.3.1 Measurement

4.3.1.1 Baseline Conditions

The primary objective of the Environmental Baseline Study is to gather sufficient understanding of the existing environmental features and conditions at and around the proposed Project. This includes identification of the relevant sensitive receptors in the study area and establishing pertinent environmental baseline conditions. This is achieved through:

- Desktop analysis and secondary literature review, e.g., identification of sensitive receptors as presented in Section 4.2

- Primary data collection through field surveys and investigation to describe the pre-construction conditions of valued environmental components, e.g., water quality, sediment quality, and ecology

Table 4.4 Field surveys conducted in this Study

Environmental Aspect	No. of Stations/ Transects	Survey Dates
Marine Water Quality	1	22 July 2022 (neap-tide) 27 July 2022 (spring-tide)
Seabed Sediment Quality	1	22 July 2022
Mangrove/ Coastal Vegetation Flora	2	02 August 2022
Macrobenthos	1	22 July 2022

Findings from the above dedicated surveys and secondary data research are discussed in Section 5 of this report.

4.3.1.2 Impact Prediction

Prioritisation of key impacts and applicable assessment methodologies have been agreed at the scoping stage and presented in the Inception Report (ref. 61803270-OBS Slipway EIA – Inception Report rev. 03). In this Study, DHI adopts a selection of qualitative (e.g., review of existing survey data/ consultation data), semi-quantitative and modelling analyses to predict changes arising from the Project, as presented in Table 4.5.

Table 4.5 Summary of potential impacts and corresponding assessment methods

Receptors	Potential Short-term Impacts	Potential Long-term Impacts
Navigation	Changes in hydrodynamic conditions (current speed and direction) due to construction of slipway affect navigation activities in the area **Tool:** DHI's MIKE 21 HD model	Changes in hydrodynamic conditions (current speed and direction) due to the extended slipway affect navigation activities in the area **Tool:** DHI's MIKE 21 HD model
	Construction vessel traffic causing congestion to navigation in the area. **Tool:** Qualitative assessment	N/A
	Sedimentation from construction works to areas outside project footprint, causing adverse impacts on navigation and berthing areas **Tool:** DHI's MIKE 21 MT model	N/A
Jetties	Changes in hydrodynamic conditions (current speed and direction) due to construction stage may affect berthing and mooring activities at nearby jetties, pontoons	Changes in hydrodynamic conditions (current speed and direction) may affect berthing and mooring activities at nearby jetties, pontoons. **Tool:** DHI's MIKE 21 HD model

Receptors	Potential Short-term Impacts	Potential Long-term Impacts
	Tool: DHI's MIKE 21 HD model	
	Construction vessel traffic causing congestion to navigation in the area. **Tool:** Qualitative assessment	N/A
	Sedimentation from construction works to areas outside project footprint, causing adverse impact on nearby jetties **Tool**: DHI's MIKE 21 MT model	N/A
Aquaculture	Physical disturbance, including underwater noise and vibration, during construction could potentially affect the caged fishes **Tool:** Qualitative assessment on physical disturbances on site	N/A
	Sediment plume resulting in increase in Suspended Sediment Concentrations (SSC) causing a wide range of physiological effects on the caged fishes **Tool:** DHI's MIKE 21 MT model	N/A
	Altered water quality (spills/leaks) **Tool:** Qualitative assessment	N/A
Macrobenthos	Short-term sedimentation may cause smothering of macrobenthos near the work area and altering sediment quality and reducing dissolved oxygen levels, potentially affecting macrobenthos community **Tool**: DHI's MIKE 21 MT model	Direct loss of macrobenthic community in the project footprint **Tool:** Qualitative assessment
	Spills or leaks during construction smother or intoxicate or reduce growth of subtidal benthic community **Tool:** Qualitative assessment	N/A
Marine fauna	Physical disturbance, including underwater noise and vibration within the project site causing avoidance behavior of fauna in the area **Tool:** Qualitative assessment on physical disturbances on site	Direct loss of habitat for fish in the waters that will be casted by the extended slipway **Tool:** Qualitative assessment
	Increased suspended sediment concentrations (SSC) and	N/A

Receptors	Potential Short-term Impacts	Potential Long-term Impacts
	resultant altered water quality block gills and/or adversely affect fish nearby the construction site **Tool:** DHI's MIKE 21 MT model	
	Altered water quality (spills/leaks) affecting the fish community **Tool:** Qualitative assessment on spills/leaks impacts	N/A
Mangroves/ coastal vegetation	Contamination of the intertidal area due to silty runoffs, sediment plume, spills and leaks from construction site **Tool:** Qualitative assessment & DHI's MIKE 21 MT model	N/A
Terrestrial ecology	Physical disturbance, including airborne noise and vibration, dust emission within the project site causing avoidance behavior of terrestrial fauna. **Tool:** Qualitative assessment on physical disturbances on site	N/A
Avifauna	Physical disturbance, including airborne noise and vibration, dust emission, loss of access, etc. within the project site causing avoidance behavior of fauna in the shoreline/intertidal habitats. **Tool:** Qualitative assessment on physical disturbances on site	N/A
	Potential contamination due to spills/leaks from construction site if wastes and inventories are not properly managed **Tool:** Qualitative assessment	N/A
Recreational/ Public health	Physical disturbance, including airborne noise and vibration, and dust emission during construction could potentially affect any residents, workers or worker dormitory nearby. **Tool:** Qualitative assessment on physical disturbances on site	N/A
	Sediment plume from construction works altered water quality (spills/leaks) affecting public health through interaction with waters (e.g., kayaking).	N/A

Receptors	Potential Short-term Impacts	Potential Long-term Impacts
	Tool: DHI's MIKE 21 MT model	
	Sediment plume from construction works causing increased turbidity/visual impact at recreational areas **Tool:** DHI's MIKE 21 MT model	N/A
	Altered water quality during construction affecting public health through interaction with waters (water sports, beach activities) **Tool:** Qualitative assessment on spills/leaks impacts	N/A

4.3.2 Assessment

Methodology

The well-recognised Rapid Impact Assessment Matrix (RIAM) developed by Pastakia & Jensen (1998) is applied in this EIA. RIAM allows for a holistic and rapid comparable presentation and summary of the overall project impacts. The method allows for a transparent presentation and summary of overall Project impacts within a common framework; and ultimately aids in pinpointing which impacts are most significant. RIAM also accounts for the presence of impacts that may be cumulative in nature. The use of the RIAM method is also consistent with the Biodiversity Impact Assessment (BIA) Guidelines of Singapore (National Parks Board, 2020) recommendation as being one of three approved methods for assessing and summarizing the overall significance of impacts. The definitions applied in the ranking of impacts are provided in Table 4.6 below.

Table 4.6 Broad definitions for each level of predicted impact significance. Impacts can be either negative or positive.

Impact Significance	Broad Definition
No Impact	Changes are significantly below physical detection level and below the reliability of numerical models, so that no change to the quality or functionality of the receptor will occur.
Slight Impact	Changes can be resolved by numerical models but are difficult to detect in the field as they are associated with changes that cause slight and localised nuisance or disruption of daily activities, not mortality, to ecosystems. Slight impacts may be recoverable once the stress factor has been removed.
Minor Impact	Changes can be resolved by numerical models and are likely to be detected in the field, which may cause stress to a portion of the population at endurable levels, but at a spatial scale that is unlikely to have any secondary consequences.
Moderate Impact	Changes can be resolved by numerical models and are obviously detectable in the field, which may cause significant stress to a large

Impact Significance	Broad Definition
	portion of population and would likely disrupt the quality and functionality of the receptor.
Major Impact	Changes are highly detectable in the field and are likely to be related to significant habitat loss. Major impacts are likely to have secondary influences beyond the area of assessment.

RIAM translates qualitative standard definitions of evaluation criteria into semi-quantitative ordinal scores which are then used to calculate Environmental Scores (ES), via the formula:

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

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

(I) Importance – This defines the 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 – Impact Magnitude or Magnitude of change is based on the relationship between the analysed physical-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 – This defines whether an impact is temporary or permanent, i.e., a measure of the temporal status of the loss/change. For example, slope stabilization with gabion walls will be a permanent impact, while slope stabilization with sheet piles will be a temporary impact, given their eventual removal.

(R) Recoverability – The score 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. It is not equated with permanence. For example, the loss of streetscape trees is recoverable with replacement plantings, while the loss of an endemic species is irrecoverable.

(C) Cumulative Impact – This 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. For example, the loss of flora and fauna species is cumulative, given that it is also associated with other impacts such as the loss of ecosystem functioning and ecological connectivity.

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

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

The standard (generic) definitions of each evaluation criteria, and the associated ordinal scores used to calculate ES, are shown in Table 4.7. To account for the wide variability and context-specificity of sensitive receptors and predicted environmental impacts (pressures), the generic definitions of Importance and Magnitude in Table 4.7 will be customized and made specific for sensitive receptors and predicted environmental impacts respectively, with justifications elaborated in each assessment in Section 6.

Table 4.7 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
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	Temporary or short-term change.	2
	Permanent change or long-term; value and/or function unlikely to return.	3
Recoverability	Recoverable or controllable through EMMP	2
	Irrecoverable	3
Cumulativity	Impact can be defined as non-cumulative/single (not interaction with other impacts).	2
	Presence of obvious cumulative/cascading effect that will affect other projects or activities or trigger secondary impacts.	3

* Definitions and scorings of Importance and Magnitude will be customised for all identified sensitive receptors and environmental impacts respectively in Section 6 and 7.

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 4.8, which are then translated to Impact Significance – the reported output of the impact assessment process.

Table 4.8 Range bands of ES and the associated Impact Significance used in RIAM

Environmental Scores (Range Bands)	Impact Significance Translated from Environmental Scores
116 to 180	Major positive change/impact
81 to 115	Moderate positive change/impact
37 to 80	Minor positive change/impact
7 to 36	Slight positive impact
-6 to +6	No impact/Status quote/Not applicable
-7 to -36	Slight negative change/impact
-37 to -80	Minor negative change/impact
-81 to -115	Moderate negative change/impact
-116 to -180	Major negative change/impact

Criteria

Ranking Magnitude of change requires knowledge of relevant environmental standards, benchmarks, guidelines, or tolerance limits of the sensitive receptors – the assessment criteria. This EIA adopts various assessment criteria from various regulations, standards and guidelines.

For other environmental aspects which do not have a regulatory limit of impact (e.g. ecological and biodiversity receptors), DHI will assess qualitatively based on knowledge from international literature, expert opinion and past project experiences. An example of such is the tolerance limits that were developed by DHI, adopted for previous EIA studies in Singapore and validated against long-term environmental monitoring and management projects undertaken for multiple Singapore government agencies. The identified tolerance limits allow for a level of detail that will enable the results of the short- and long-term impact assessments to be quantified in terms of magnitude and scale of impact on each individual receptor.

The criteria adopted in this Study are described in each impact assessment section of Chapter 6 and 7.

4.3.3 Management and Mitigation

A core aspect of the EIA is also to provide appropriate mitigation measures to address any significant predicted impacts, particularly those classified as ‘Moderate’ or ‘Major’ negative. Mitigation measures are recommended and designed to reduce the impact down to an as-low-as-practicable level. Slight or Minor impacts may also require mitigation actions, but these are often in the form of best environmental management procedures and operational controls.

Mitigation measures are often established through industry standards and may include:

- Changes to the design of the Project during the design process
- Engineering controls and other physical measures applied (e.g., noise barrier)
- Operational plans and procedures (e.g., noise pollution control management plan)
- Provision of like-for-like replacement, restoration, or compensation

The mitigation hierarchy concept is presented in Figure 4.4. In developing mitigation measures, the primary focus is to avoid or minimise impacts by means of design modification or optimisation and/or project management, e.g., through application of appropriate abatement measures. Where impacts cannot be avoided, offsets and /or compensation could be considered.

It is important to note that not all impacts are necessarily negative. There are actions that can be recommended to create net positive gains. Avoidance, minimisation and/or restoration alone are generally not enough to achieve a net gain and some form of offset is also necessary.

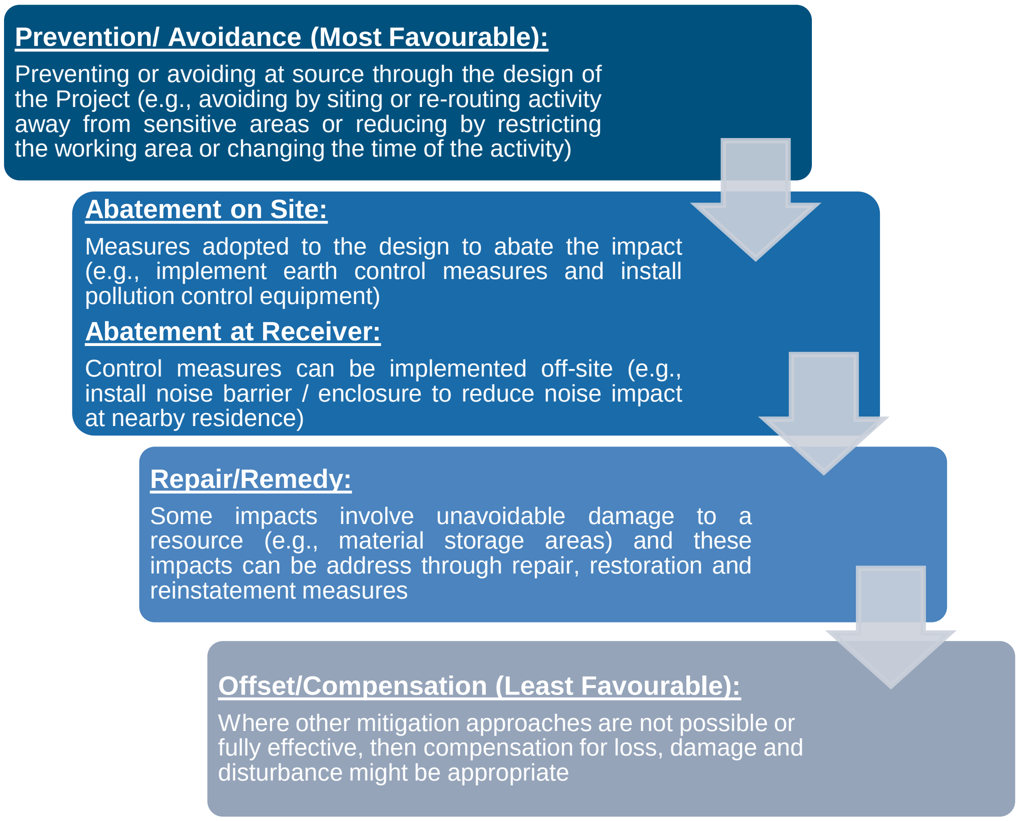


Figure 4.4 Hierarchy of mitigation strategy adopted in this EIA

4.4 General Structure of Impact Assessment Section

The impact assessment sections for Construction phase (Section 6) and Post-construction phase (Section 7) are carefully structured to describe the key components involved in analysing environmental impacts, namely:

- Relevant sensitive receptors and their importance scores
- Evaluation framework for defining and scoring magnitude of environmental change
- Prediction of impact significance
- Proposed mitigation measures
- Evaluation of residual impact significance

5 Environmental Baseline

The project site is located along the coastline on the south-western side of Pulau Ubin. The area is generally well-sheltered from waves and with weaker tidal flows as compared to main Johor Strait. The intertidal zone fronting the project site is gently sloped and the substrate at the shore is dominated by sand. Adjacent to the east of the project site is Sungai Teris and its associated riverine mangroves whereas the type of vegetation cover to the west of the project site is mainly coastal trees. There are no recreational shoreline or water uses within the immediate vicinity except for the OBS facilities themselves. The project site is also close to some cage aquaculture farms, with the nearest facility approximately 850 m distant. It is common to observe fish farmers' vessels plying the nearby area.

The following subsections present the findings from the environmental baseline study that comprises both desktop study of online literature and various field surveys conducted in this EIA.

5.1 Coastal Dynamics

5.1.1 Bathymetry

The project location is shallow, with water depth ranging from approximately -0.6 mCD at the outermost part of the slipway sloping up to above 1 mCD towards land. The water gets deeper towards Serangroon Harbour, -4 mCD to below -7 mCD.

This bathymetry data is produced from DHI's database that comprises data from various sources over the years. The data were combined to produce a consistent bathymetry dataset covering the entire study area. To obtain such a consistent dataset, common references were applied. The horizontal reference adopted for the study was longitude, latitude geographical coordinates (WGS-84 datum), while the vertical reference was in Chart Datum (CD).

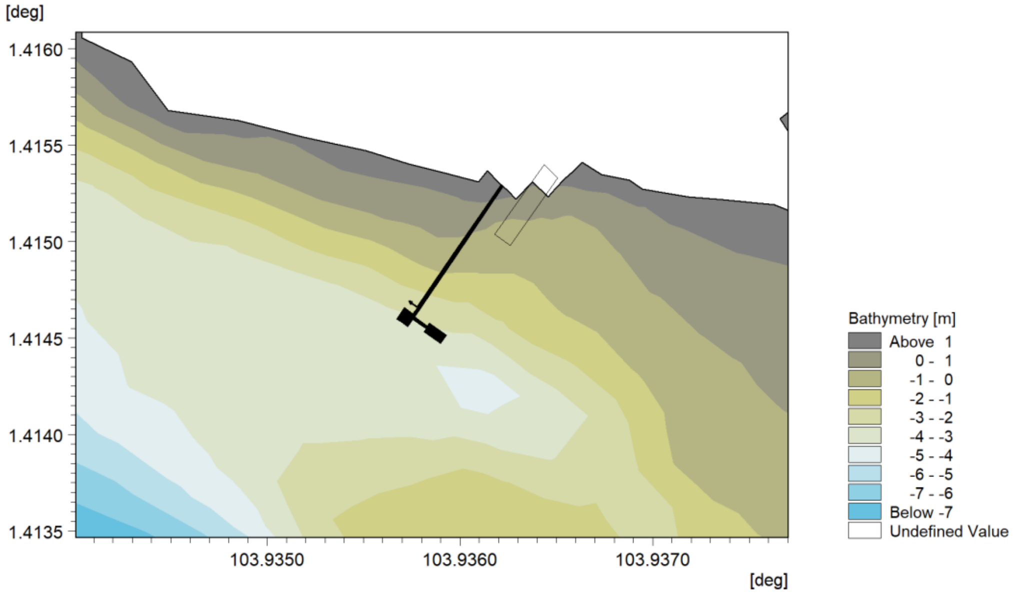


Figure 5.1 Bathymetry in the vicinity of the Project area

5.1.2 Currents

The tidal water level in Singapore in general and in East Johor Strait is predominantly semi-diurnal with two high and two low waters in a day. Based on data collected at Tanjong Changi tidal station, the predominantly semi-diurnal tidal range is commonly 2.2 m during spring tide with Mean High Water Springs (MHWS) at 3.0 m CD and Mean Low Water Springs (MLWS) at 0.8 m CD.

Current conditions in the slipway area are generally mild. According to DHI's hydrodynamic simulations, the mean current speed of up to 0.1 m/s at the OBS Camp 2 slipway and jetty and up to 0.3 m/s further out into Serangoon Harbour. The 95th percentile current speeds at these locations are up to 0.2 m/s and up to 0.6 m/s respectively. Figure 5.2 shows the snapshot of current field in the area during peak flood and peak ebb tides during northeast monsoon. Ebb current is in general stronger, up to 0.30 m/s at the project area, as compared to 0.15 m/s during flood tide.

This characteristic implies that hydrodynamic changes and hydrodynamic-driven changes induced by the Project, such as sediment plume, are likely localised.

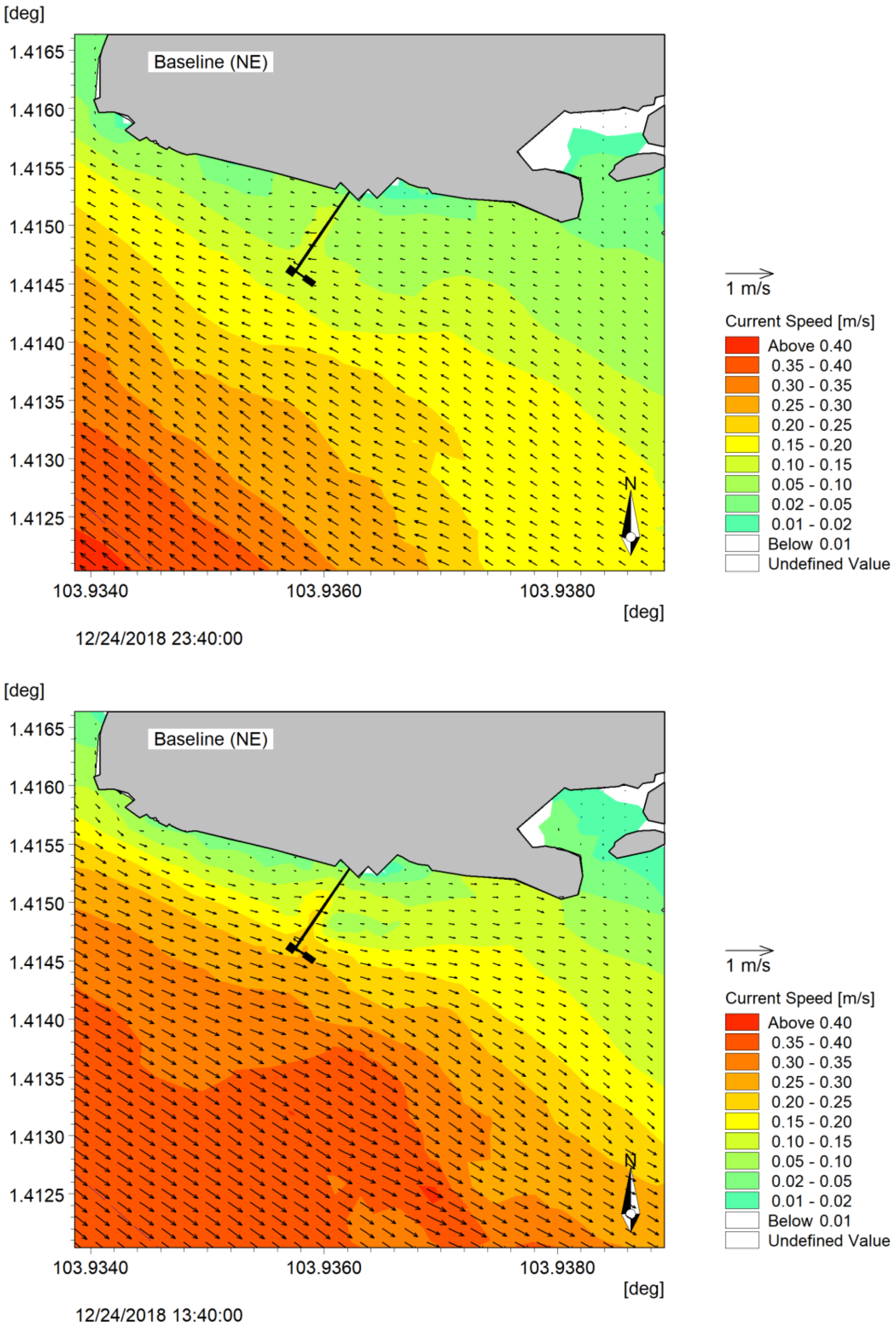


Figure 5.2 Snapshot of current vectors around project area during flood tide (top) and ebb tide (bottom), both during north-east monsoon

5.2 Marine Water Quality

Marine water sampling was carried out in July 2022 to investigate the pre-construction water quality in the study area. Sampling was carried out at one (1) location (Figure 5.3), covering both spring and neap tides.

Six (6) water quality parameters were measured *in-situ* and twenty (20) parameters were measured *ex-situ* (in the laboratory), covering a range of chemical and biochemical parameters. The *in-situ* measurements and laboratory results are presented in this section and benchmarked against the ASEAN Marine Water Quality Criteria (MWQC).

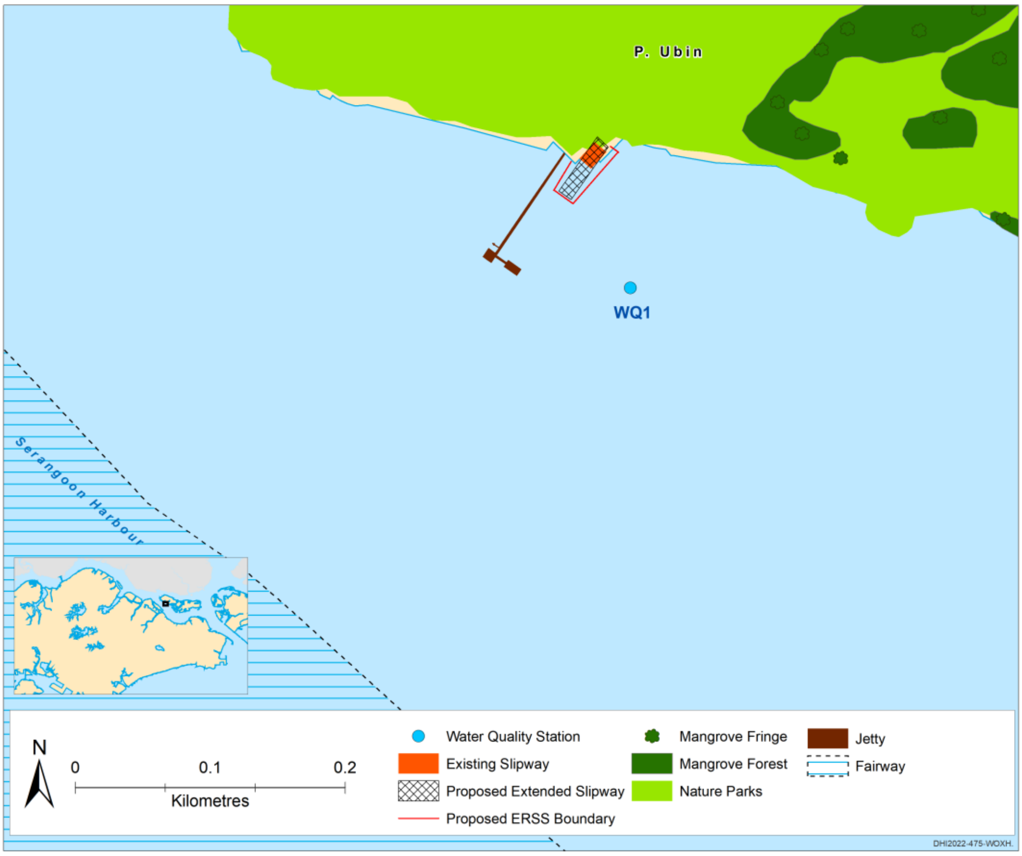


Figure 5.3 Location of marine water quality survey

5.2.1 *In-situ* Water Quality Results

In-situ physical-chemical water quality parameters presented in this section include water temperature, salinity, dissolved oxygen, pH and turbidity and Secchi depth. These parameters were measured using an EXO multi-parameter probe programmed to collect discrete physical-chemical measurements throughout the water column.

Based on the measurements, it can be observed that there was no temperature, salinity, pH, or dissolved oxygen stratification of the water column at WQ1 (Figure 5.4 to Figure 5.7), hence depth-averaged results are discussed. The summary of *in-situ* readings is provided in Table 5.1.

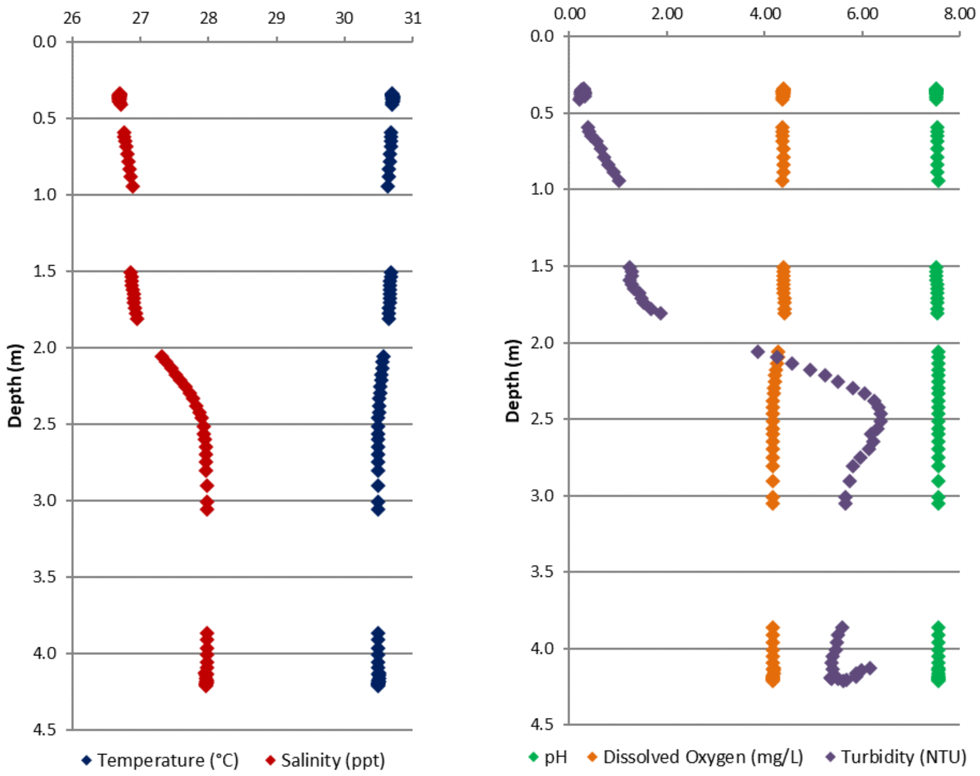


Figure 5.4 Temperature, salinity, pH, dissolved oxygen and turbidity profile at WQ1 during a neap ebb tide

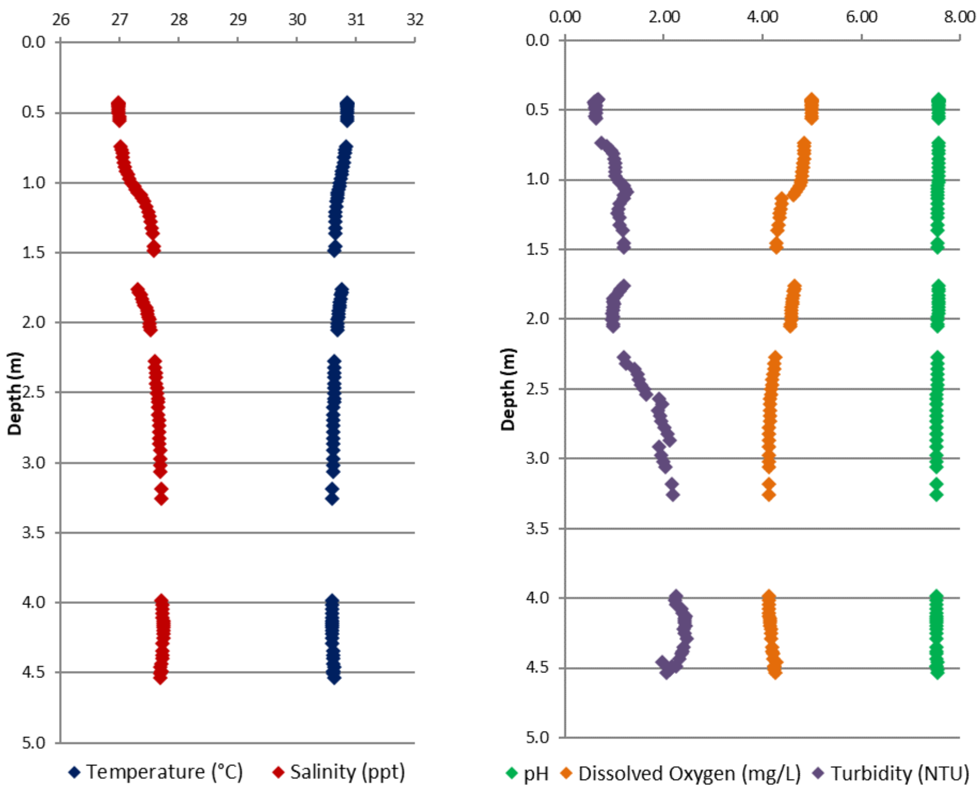


Figure 5.5 Temperature, salinity, pH, dissolved oxygen and turbidity profile at WQ1 during a neap flood tide

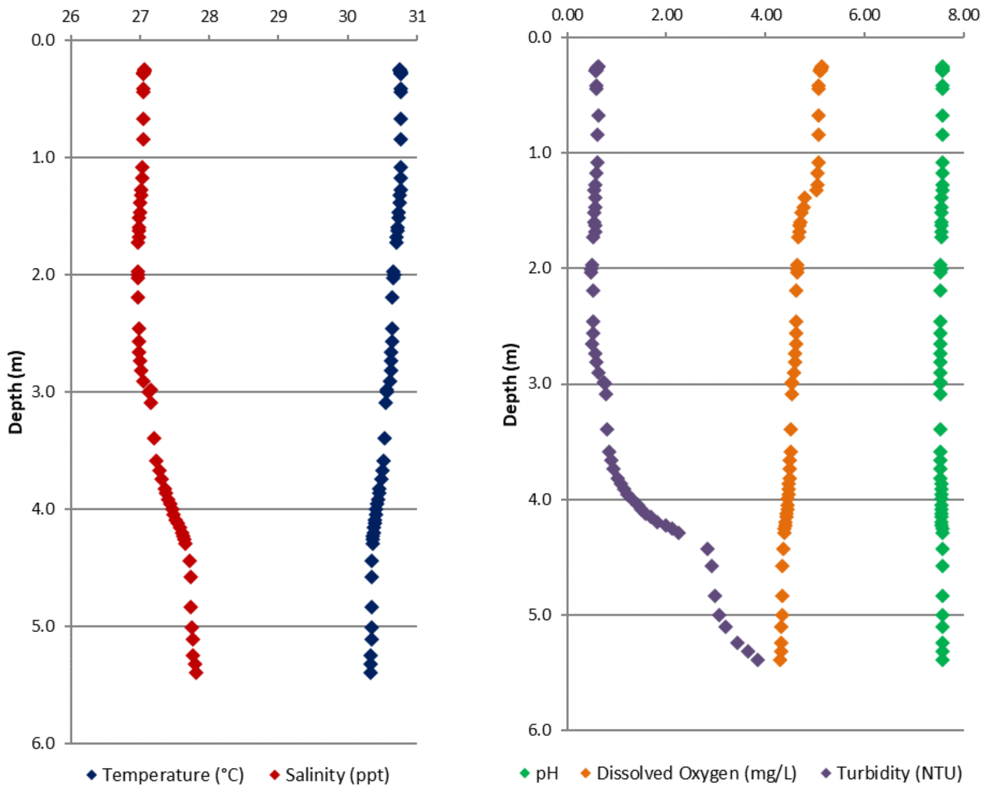


Figure 5.6 Temperature, salinity, pH, dissolved oxygen and turbidity profile at WQ1 during a spring ebb tide

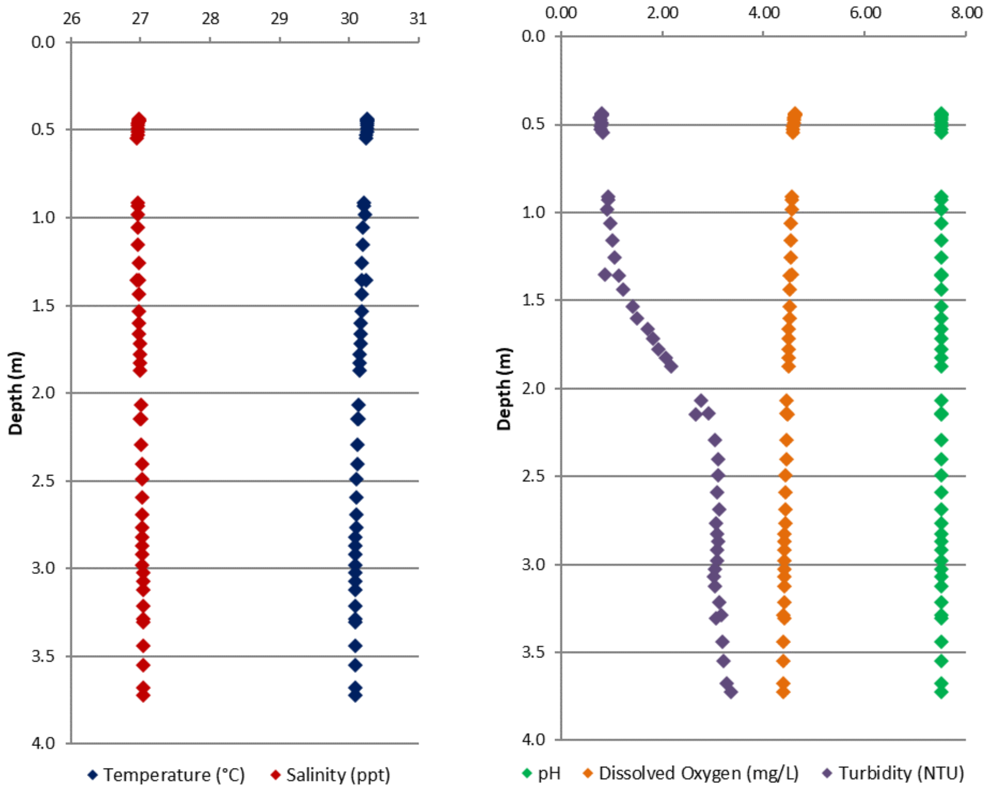


Figure 5.7 Temperature, salinity, pH, dissolved oxygen and turbidity profile at WQ1 during a spring flood tide

Table 5.1 Summary of *in situ* water quality results at station WQ1 during spring and neap tide, flood and ebb tide

Reading	Spring Tide		Neap Tide		ASEAN MWQC
	Flood	Ebb	Flood	Ebb	
Depth (m)					
Maximum	4.6	4.4	4.9	4.6	-
Secchi	3.0	2.7	2.3	2.1	
Temperature (^{0}C)					
Average	30.16	30.57	30.69	30.59	Increase not more than 2 ^{o}C above the maximum ambient temperature.
Standard Deviation	0.06	0.16	0.09	0.09	
Maximum	30.27	30.77	30.85	30.71	
Minimum	30.09	30.34	30.59	30.49	
Salinity (ppt)					
Average	27.00	27.25	27.45	27.35	-
Standard Deviation	0.03	0.29	0.27	0.56	
Maximum	27.04	27.81	27.74	27.98	
Minimum	26.95	26.97	26.98	26.69	
Dissolved Oxygen (mg/L)					
Average	4.49	4.65	4.46	4.28	> 4 mg/L
Standard Deviation	0.08	0.27	0.32	0.10	
Maximum	4.63	5.14	5.00	4.40	
Minimum	4.40	4.30	4.13	4.16	
pH					
Median	7.50	7.55	7.54	7.56	-
Maximum	7.51	7.56	7.56	7.57	
Minimum	7.50	7.52	7.53	7.52	

Reading	Spring Tide		Neap Tide		ASEAN MWQC
	Flood	Ebb	Flood	Ebb	
Turbidity (NTU)					
Average	2.05	1.18	1.46	3.29	-
Standard Deviation	1.02	0.93	0.62	2.51	
Maximum	3.35	3.85	2.46	6.38	
Minimum	0.77	0.48	0.60	0.22	

Temperature

Temperature is a key driver of water quality directly influencing dissolved oxygen concentrations, salinity, and to a lesser extent pH which although affected by temperature is also coupled to diurnal cycles and associated photosynthetic activity. The range of depth averaged water temperatures observed at WQ1 was between 30°C (flood spring) and 31°C (flood neap).

Salinity

The salinity of the water provides an indication of the extent of mixing and the presence of salinity stratification which may occur when there is significant freshwater run-off. As mentioned above, there was no clear stratification, although slight increases in salinity were observed with depth in some profiles (greater than 1 ppt only during neap ebb tide measurements). The depth averaged salinity at WQ1 was consistently below 28 ppt during both ebb and flood tides and spring and neap tides and this could be due to low flushing within the project area.

Dissolved Oxygen

The concentration of dissolved oxygen is used as an indicator to determine the ecological condition of waters. It is primarily maintained through bio-physical processes such as wind driven agitation of surface waters, tidal exchange and biological processes such as photosynthesis from aquatic flora (algae, seagrass and phytoplankton). The depth averaged dissolved oxygen concentrations were consistently higher than the ASEAN MWQC of 4.0 mg/L and hence it is considered that the waters around project site are generally well oxygenated.

pH

pH is a key physiological driver for many species of aquatic biota. The pH of marine waters should fall within the range of 7.0 to 8.7 units (Canadian Water Quality Guidelines for the Protection of Aquatic Life, 1999) and adverse physiological stress for marine biota is likely to occur when beyond this range. The depth averaged pH measured at WQ1 was around 7.5 which falls within the typical range of marine waters and therefore deemed tolerable for sustaining marine biota.

Turbidity

Turbidity is an indicator for water clarity. It is a measure of the degree to which the water loses its transparency due to the presence of suspended particulates and dissolved organic matter in water. Generally, the turbidity readings at WQ1 were below 10 NTU across flood and ebb tide and spring and neap tides. Additionally, turbidity increased with increasing water depth at WQ1 (Figure 5.4 to Figure 5.7) which was similarly observed in Total Suspended Solids (TSS) results where higher TSS readings were obtained at water depth bottom.

Secchi Depth

Secchi depth provides an indication of the water clarity, which is influenced by various factors that will affect visibility of the disc underwater e.g., plankton, suspended sediment and cloud cover. Secchi disc depth measurements at WQ1 indicated moderate water turbidity (Table 5.2). Water clarity as indicated by Secchi depth was compliant with the 0.5 m target depth for non-recreational waters and 1.2 m target depth for recreational waters.

Table 5.2 *Secchi disc depth measurement assessed at WQ1 during water quality baseline survey*

Tide	Weather condition	Site depth (m)	Secchi disc depth (m)
	Neap Tide		
Ebb	Cloudy	4.6	2.1

Tide	Weather condition	Site depth (m)	Secchi disc depth (m)
Flood	Cloudy	4.9	2.3
Spring Tide			
Ebb	Cloudy	4.4	2.7
Flood	Cloudy	4.6	3.0

5.2.2 *Ex-situ* Water Quality Results

This section summarizes the analytical water quality parameters at WQ1. The analytical water quality parameters include TSS, TN, TP, NH_3-N, PO_4-P, NO_3-N, NO_2-N, BOD_5, As, Cd, Cr, Cu, Pb, Hg, Ni, Zn, oil and grease, faecal coliform, enterococci and chlorophyll-a. Laboratory analyses of water quality samples were undertaken by Singapore Laboratory Accreditation Scheme (SINGLAS) accredited laboratory in accordance with the Singapore Accreditation Council requirements for standard procedures.

The analytical results are summarized in Table 5.3. Reported concentrations of BOD_5 and oil and grease are below the detection limits and hence will not be discussed in this section. Generally, WQ1 was characterised by high concentrations of nutrients and bacteria. Nitrates, nitrites, and phosphate were above ASEAN guidelines. Elevated levels of faecal coliforms and enterococci were also observed, exceeding ASEAN guidelines for recreational waters. This is consistent with conditions in the East Johor Strait (Gin *et al.,* 2000), which have been found to be similarly eutrophic in other studies conducted by DHI.

Table 5.3 *Ex-situ* parameters assessed at WQ1 during water quality baseline survey. Cells highlighted orange indicate exceedance of ASEAN MWQC for Aquatic Life Protection in Coastal areas.

Parameters	Unit	Depth	Spring Tide		Neap Tide		ASEAN MWQC
			Flood	Ebb	Flood	Ebb	
Total Suspended Solids (TSS)	mg/L	Surface	4.8	3.7	2.9	6.1	≤ 10% increase over seasonal average concentration
		Bottom	5.7	4.0	17.8	8.2	
Total Nitrogen (TN)	mg/L	Surface	0.87	0.74	0.56	0.59	-
		Bottom	0.64	0.63	0.35	0.43	
Nitrate as NO_3-N	mg/L	Surface	0.093	0.095	0.072	0.067	0.06
		Bottom	0.090	0.095	0.100	0.074	
Nitrite as NO_2-N	mg/L	Surface	0.096	0.104	0.060	0.062	0.055
		Bottom	0.099	0.090	0.049	0.053	
Ammonia as NH_3-N	mg/L	Surface	0.005	0.006	0.006	0.006	0.07
		Bottom	0.005	0.005	0.004	0.003	
Total Phosphorus (TP)	mg/L	Surface	0.059	0.055	0.043	0.038	-
		Bottom	0.053	0.056	0.043	0.039	
Phosphate as PO_4-P	mg/L	Surface	0.049	0.048	0.038	0.035	0.015
		Bottom	0.048	0.046	0.037	0.032	
Biological Oxygen Demand (BOD_5)	mg/L	Surface	<1.0	<1.0	<1.0	<1.0	-
		Bottom	<1.0	<1.0	<1.0	<1.0	
Chlorophyll-a	µg/L	Surface	0.77	1.14	1.38	1.37	-
		Bottom	0.52	0.72	1.47	1.29	
Arsenic	µg/L	Surface	2.45	2.26	2.36	2.65	-
		Bottom	2.07	2.14	1.91	2.93	

Parameters	Unit	Depth	Spring Tide		Neap Tide		ASEAN MWQC
			Flood	Ebb	Flood	Ebb	
Cadmium	µg/L	Surface	<0.1	0.19	0.12	0.19	10
		Bottom	0.18	0.18	<0.1	0.15	
Chromium	µg/L	Surface	1.43	1.39	2.99	2.76	50
		Bottom	1.32	1.29	2.80	2.95	
Copper	µg/L	Surface	1.30	1.31	1.37	1.99	8
		Bottom	1.36	1.30	1.21	1.27	
Lead	µg/L	Surface	1.53	0.87	<0.1	0.47	8.5
		Bottom	6.36	0.69	0.32	0.12	
Mercury	µg/L	Surface	<0.05	<0.05	<0.05	0.075	0.16
		Bottom	<0.05	<0.05	<0.05	<0.05	
Nickel	µg/L	Surface	2.29	2.10	2.79	2.83	-
		Bottom	2.26	2.23	2.32	2.26	
Zinc	µg/L	Surface	1.92	1.24	3.00	4.77	-
		Bottom	2.12	1.81	2.53	2.49	
Oil and grease	mg/L	Surface	<10	<10	<10	<10	0.14
		Bottom	<10	<10	<10	<10	
Faecal Coliform	MPN/ 100 mL	Surface	540	1,600	1,600	350	100*
		Bottom	280	79	540	79	
Enterococci	CFU/ 100 mL	Surface	56	63	14	20	35*
		Bottom	29	12	6	2	

* Value for recreational water

Total Suspended Solids (TSS)

TSS are solid materials, including organic and inorganic, that are suspended in the water. Although similar to the measure of turbidity, TSS is more useful because it provides an actual weight of the particulate material present in the sample. Natural sources of TSS include runoff, erosion and transportation of sediments through riverine and estuarine processes, and decomposition of organic material. Elevations in TSS values through anthropogenic related activities include point source discharges of pollutants from effluent, sewage, run-offs from site clearances and marine construction projects. High concentrations of TSS can lower water quality by absorbing light. Waters then become warmer and lessen the ability of the water to hold oxygen necessary for aquatic life. TSS can also smother benthic environments, clog fish gills, reduce growth rates, decrease resistance to disease, and prevent egg and larval development.

TSS at WQ1 during the baseline surveys conducted by DHI in July 2022 ranged between 2.9 mg/L and 17.8 mg/L during neap tide and fluctuates in a smaller window of 3.7 mg/L to 5.7 mg/L during spring tide. ASEAN MWQC suggests no more than 10% increase over seasonal average TSS concentration. This criterion is to be taken note of when assessing impact from the Project.

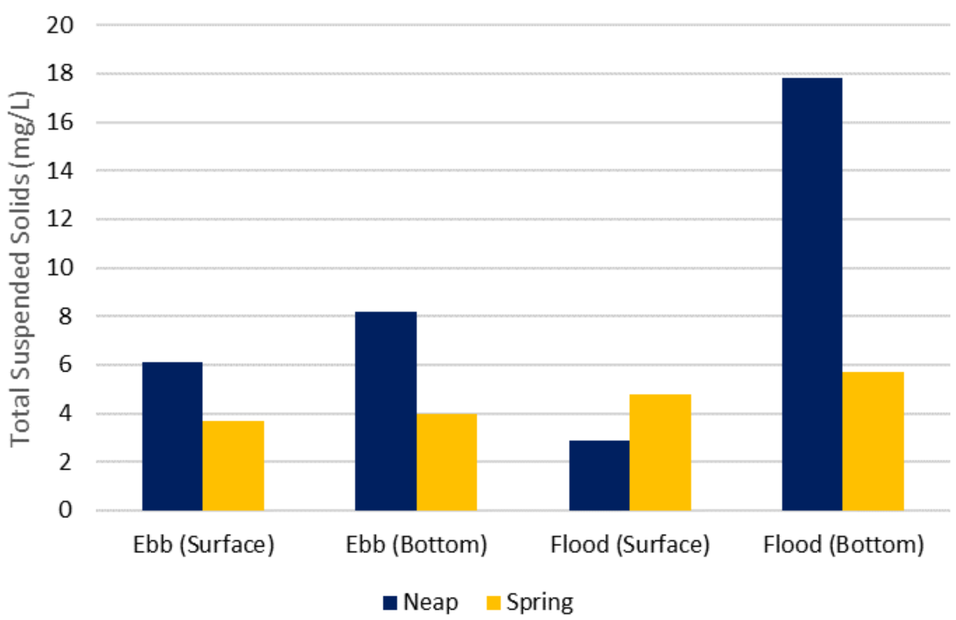


Figure 5.8 TSS concentrations measured at WQ1

Chlorophyll-a

Chlorophyll, in various forms, is bound within the living cells of phytoplankton (microalgae) found in surface water. Chlorophyll-a levels, with an examination of other parameters (e.g. total phosphate), can be an indicator of possible eutrophic conditions and project-induced changes, so this parameter should be closely examined despite the lack of ASEAN or other standards in Singapore.

During the baseline surveys, chlorophyll-a concentrations ranged from 0.52 µg/L to 1.47 µg/L, indicating some presence of algae (phytoplankton) in the water column (Figure 5.9). There is no marine water quality criteria for chlorophyll-a.

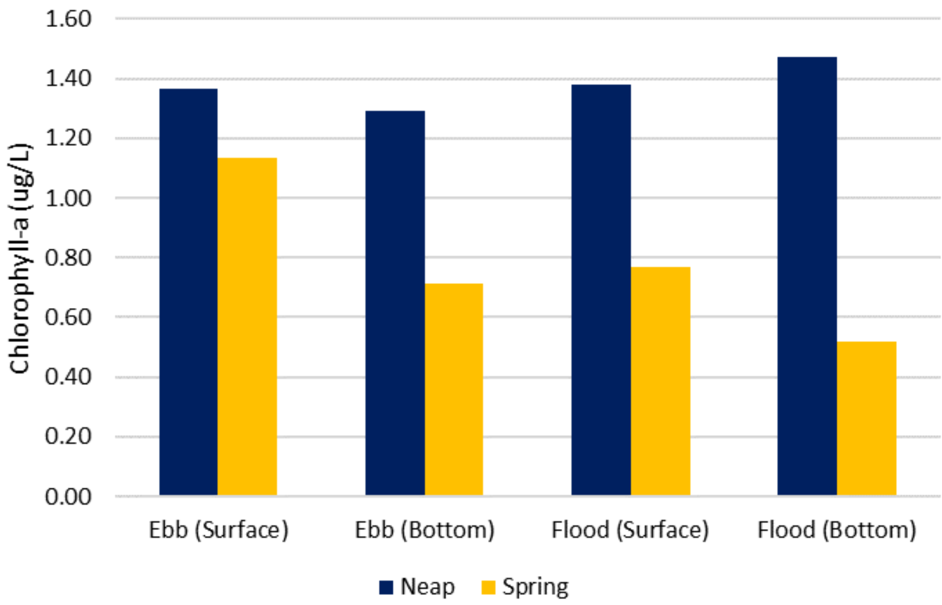


Figure 5.9 Chlorophyll-a concentrations measured at WQ1

Nitrogen

Nitrogen compounds are necessary for plant and algal growth. It is often a limiting factor in the growth of phytoplankton in marine waters. Excess quantities of nitrogen can lead to undesirable algal blooms resulting in incidents of oxygen depletion (hypoxia). Nitrogen parameters include ammonia (as NH_3-N), nitrate, nitrite and Total Nitrogen (TN). There is no available ASEAN criterion for TN whereas ammonia readings at WQ1 were below the ASEAN criteria of 0.07 mg/L and both nitrate and nitrite were above the ASEAN criteria of 0.062 mg/L and 0.055 mg/L respectively.

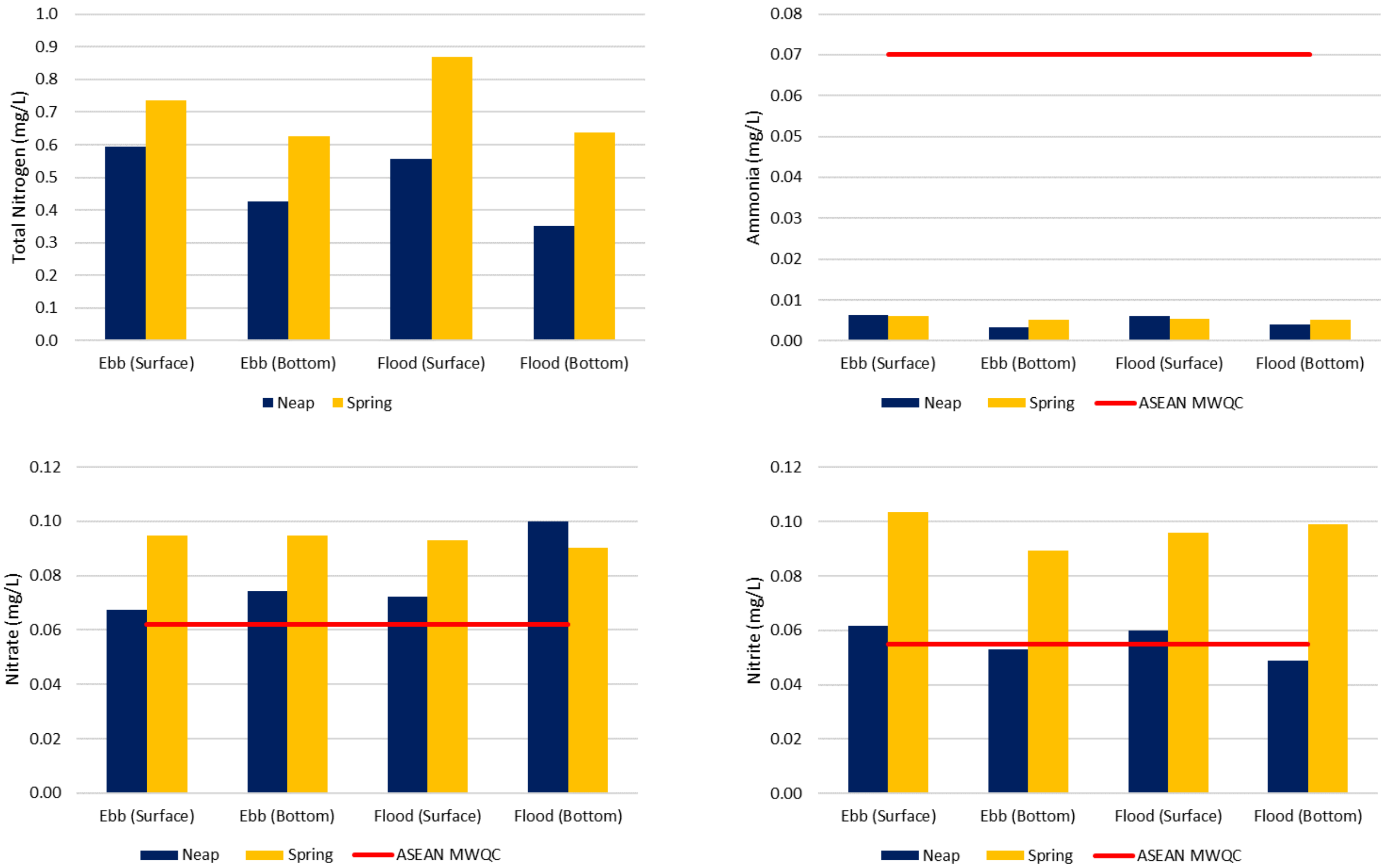


Figure 5.10 Nitrogen parameters concentrations measured at WQ1

Phosphorous

Phosphorous, like nitrogen, is also necessary for plant and animal growth. As such, an abundance of phosphorous-based nutrients (such as phosphate) can lead to excessive growth of aquatic plants such as phytoplankton and other algal species in warm tropical waters.

The concentrations of phosphate found during the survey ranged between 0.03 mg/L and 0.05 mg/L, consistently higher than the ASEAN MWQC for coastal habitats of 0.015 mg/L.

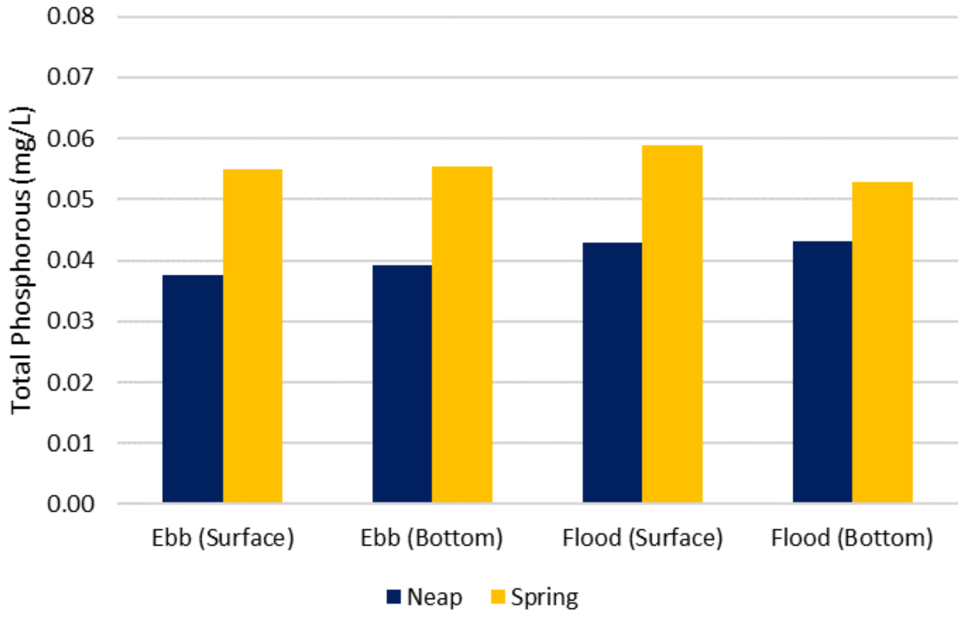


Figure 5.11 Total phosphorous concentrations measured at WQ1

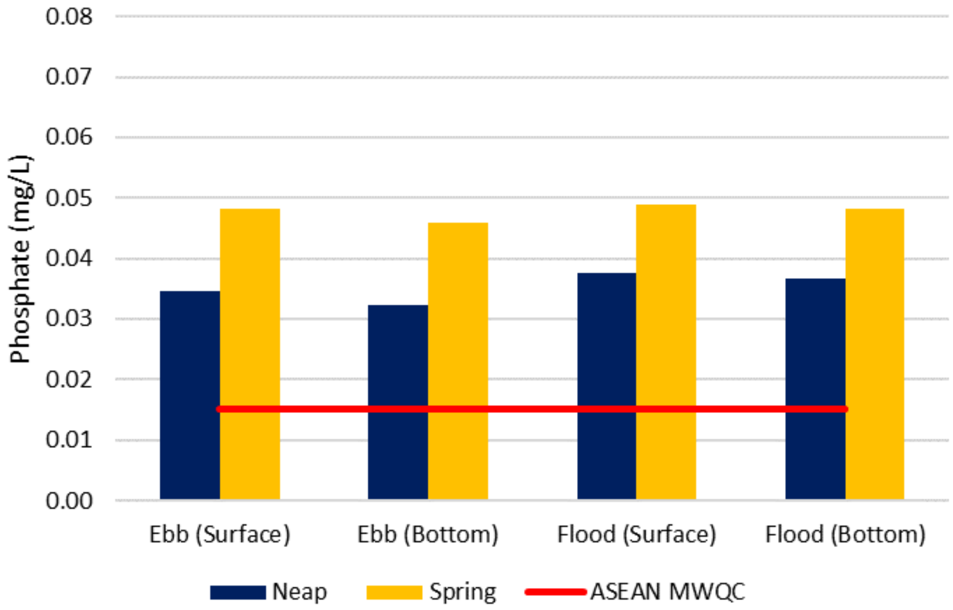


Figure 5.12 Phosphate concentrations measured at WQ1

Faecal Coliform and Enterococci

Bacterial counts of faecal coliform and enterococci are commonly used in water quality monitoring as indicators of water hygiene and faecal contamination. Faecal coliform and enterococci concentrations are used to determine risks to human health. Enterococci results are considered more relevant for marine environments since they survive better in saline environments. ASEAN MWQC states that concentrations of 100 MPN/mL and 35 CFU/100mL for faecal coliforms and enterococci should apply, respectively.

Faecal coliform concentrations as high as 1,600 MPN/100 mL were observed at surface depth of WQ1. Exceedances of enterococci were also observed during neap tide, with a maximum of 63 CFU/100 mL. Despite this, it is important to note that there are limitations to spot sampling in water quality assessments due to localised factors that can affect readings and that analysis of longer-term trends are required for a more conclusive assessment of water quality (WHO, 2003).

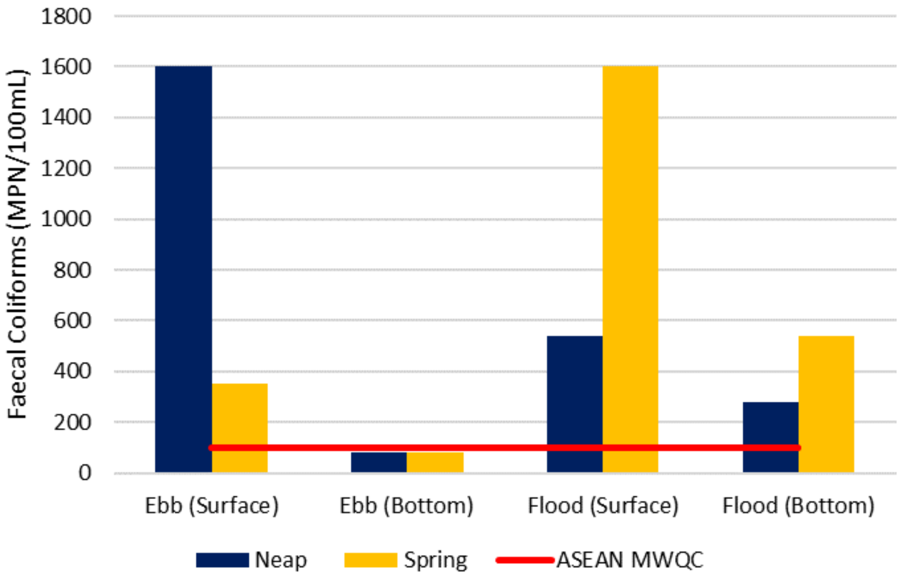


Figure 5.13 Faecal coliform measured at WQ1

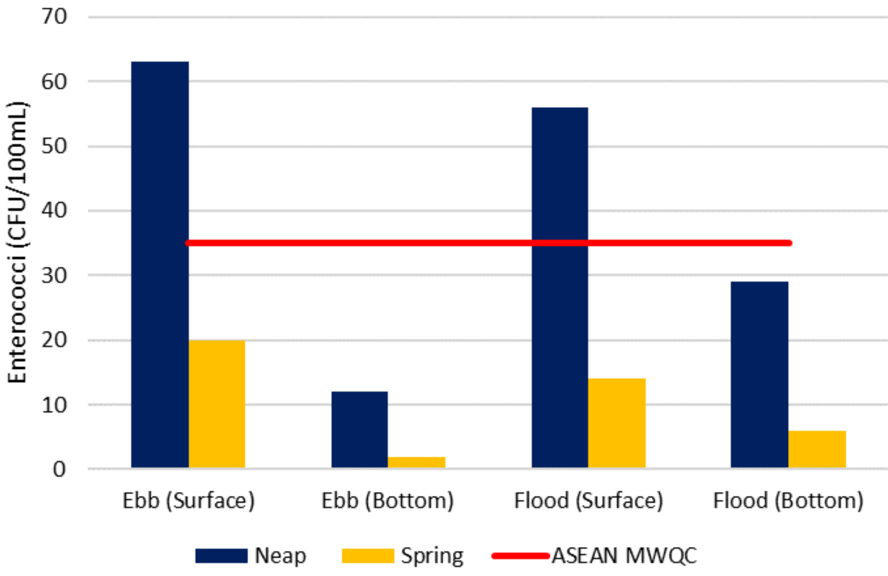


Figure 5.14 Enterococci measured at WQ1

Heavy Metals

Sources of these metals can be diverse and include for example storm water runoff carrying catchment-based contaminants, vessels waste and wastewater releases, or re-suspension as a legacy of historical activities.

Heavy metals results from the water quality survey are presented in Figure 5.15. Generally, the heavy metal results at WQ1 showed low concentrations. Recorded concentrations of cadmium, chromium, copper, lead and mercury were below the corresponding ASEAN MWQC. Arsenic, nickel and zinc were recorded at WQ1, ranging from 1.91 to 2.93 µg/L, 2.10 to 2.83 µg/L and 1.24 to 4.77 µg/L respectively. No ASEAN MWQC exist for these heavy metals.

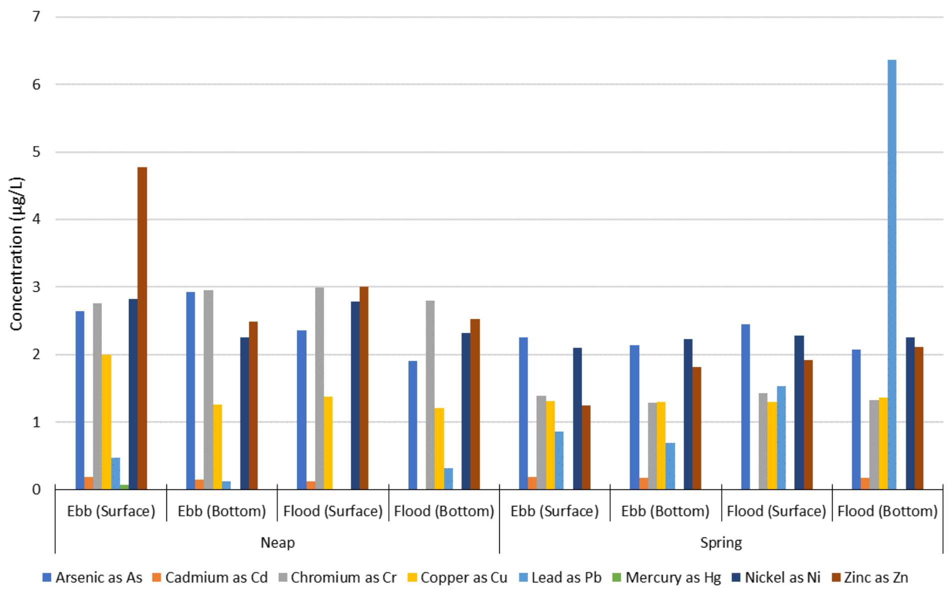


Figure 5.15 Heavy metals concentrations measured at WQ1

5.3 Seabed Sediment Quality

The purpose of the sediment quality survey is to provide important input to sediment plume modelling and the assessment of the resulting water quality changes. A sediment quality survey was carried out on 22 July 2022.

The results of the sediment quality survey are used to provide information on the chemicals and heavy metals bound to the seabed sediments. During the proposed construction works, sediment will be re-suspended into the water column, thus potentially affecting the water quality off OBS Camp 2. Possible effects related to this re-suspension include release of heavy metals or other chemicals attached to sediments. Sampling was conducted at one (1) sampling site. Sediments were graded according to grain size, and sediment chemistry was assessed against the 'General guidelines on the requirements for application on dredging and dumping works' under MPA (hereinafter referred to as the MPA Guidelines).

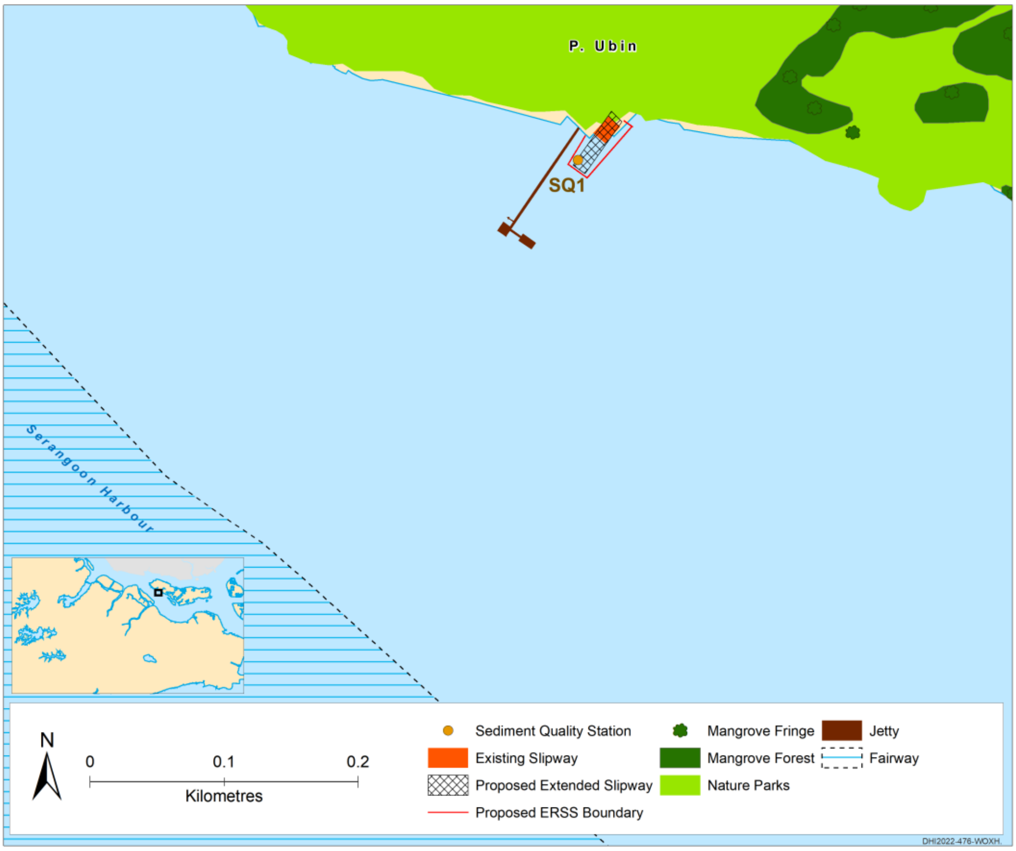


Figure 5.16 Location of sediment quality survey

5.3.1 Sediment Grading

The sediment material at SQ1 can be classified as sandy with 79% sand composition. Values are presented in Table 5.4.

Sediments in the Johor Strait have been reported to be black, strongly smelling of hydrogen sulfide, and anoxic in nature, especially around the causeway, whereas areas around the east of the Johor Strait have higher sediment porosity and lower hydrogen sulfide content (Wood *et al*., 1997). This is consistent with the results found at SQ1, where sediments showed a higher sand composition.

Table 5.4 Results of sediment grading analysis at SQ1

Material	Clay	Silt	Sand	Gravel
Percentage, %	6	9	79	6

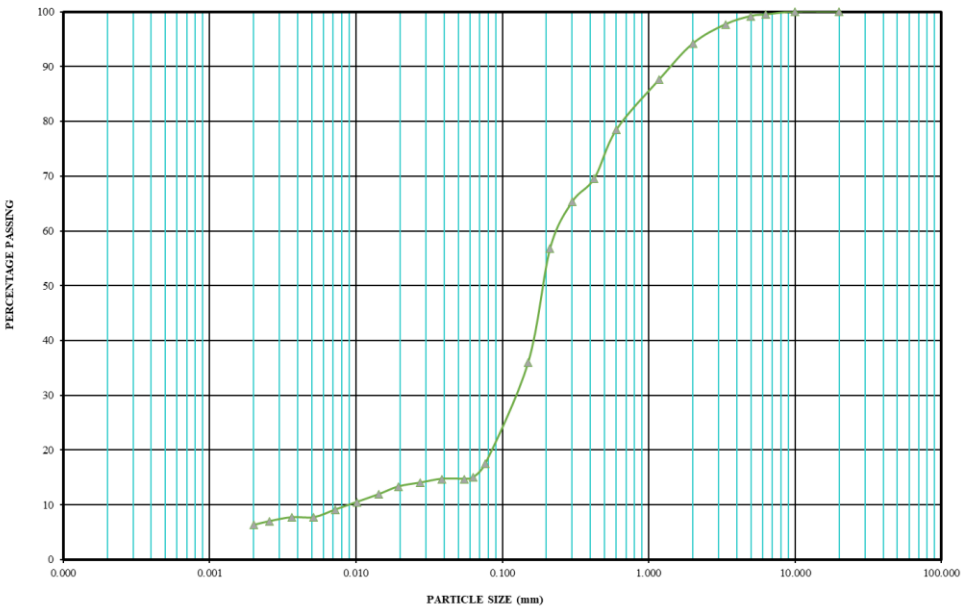


Figure 5.17 Sediment profiles at SQ1 showing the particle size distribution of sediments found

5.3.2 Heavy Metals

To document the sediment toxicity data, the results have been reviewed against the MPA Guidelines. The sediment quality results are indicated in Table 5.5 for heavy metals analysis.

None of the MPA Guidelines for heavy metals were exceeded at SQ1. Therefore, no additional measures are required for handling the material.

Table 5.5 Heavy metal concentration recorded at SQ1

Test Parameter	Unit	SQ1	MPA Guidelines
Arsenic as As	mg/kg	5.92	30
Cadmium as Cd	mg/kg	0.29	1
Chromium as Cr	mg/kg	10.17	50
Copper as Cu	mg/kg	18.48	55
Lead as Pb	mg/kg	10.26	65
Mercury as Hg	mg/kg	0.03	0.8
Nickel as Ni	mg/kg	8.03	35
Zinc as Zn	mg/kg	99.28	150

5.4 Air Quality and Noise

5.4.1 Air Quality

Ambient air quality monitoring in Singapore was initiated in 1972 and is undertaken by the NEA (NEA, 2002). There are air monitoring stations strategically located to capture the air quality of different parts of Singapore accurately, one of which is located at Pulau Ubin. This station is classed as urban station, and therefore record air quality parameters including sulphur dioxide (SO_2), nitrogen oxides (NO_x), ozone (O_3), carbon monoxide (CO), particulate matter ($PM_{2.5}$ and PM_{10}) and a variety of volatile organic compounds (VOCs).

Each year key environmental statistics are released by the Ministry of Sustainability and the Environment (MSE) for Singapore. These statistics include a summary of the air quality statistics collected through the NEA network. Latest statistics published in the 2022 report are presented in Table 5.6. In 2020 and 2021, the annual mean PM_{10} and $PM_{2.5}$ levels exceeded the WHO Air Quality Guideline (2005) values. However, they were lower as compared to previous year and was likely due to the decline in economic activities and vehicular traffic resulted from the COVID-19 pandemic.

Table 5.6 Clean air statistics for Singapore 2019 to 2021 (Source: MSE, 2022)

Parameter	Averaging time	Unit	2019	2020	2021	WHO AQG*
Sulphur dioxide, SO_2	24-hour	µg/m^3	57	30	89	20
Nitrogen dioxide, NO_2	1-hour	µg/m^3	156	118	123	200
	Annual	µg/m^3	23	20	25	40
Carbon monoxide, CO	1-hour	mg/m^3	2.3	1.6	1.3	30
	8-hour	mg/m^3	1.7	1.2	1.2	10
Ozone, O_3	8-hour	µg/m^3	125	145	176	100
Particulate matter, PM_{10}	24-hour	µg/m^3	90	43	51	50
	Annual	µg/m^3	30	25	28	20
Particulate matter, $PM_{2.5}$	24-hour	µg/m^3	62	24	28	25
	Annual***	µg/m^3	16	11	12	10

* *World Health Organisation (WHO) Air Quality Guidelines (AQG)*

** *Singapore's Sustainable Development Blueprint 2020 target for SO_2 (annual) is 15 µg/m^3*

*** *Singapore's Sustainable Development Blueprint 2020 target for $PM_{2.5}$ (annual) is 12 µg/m^3*

The Pollutant Standards Index (PSI), intended as a public information tool to advise the public about the general health effects associated with different pollution levels, is used to report daily air pollutant concentrations in Singapore since 1991. The PSI converts the measured SO_2, NO_x, CO, O_3 and respirable suspended particulate concentrations to a number on a scale of 0 to 500, with a PSI level under 50 representing good air quality, 51 to 100 indicating moderate, 101 to 200 indicating pollution in an unhealthy range, 201 to 300 in a very unhealthy range, and PSI of 300+ as Hazardous.

Air quality in Singapore in terms of PSI readings from 2011 to 2020 are shown in Figure 5.18. Air quality was in the "Good" and "Moderate" ranges on all the days of 2020. One of the possible reasons for the improvement in air quality from the past years is the reduction of economic and transport activities due to the COVID-19 situation over most of 2020.

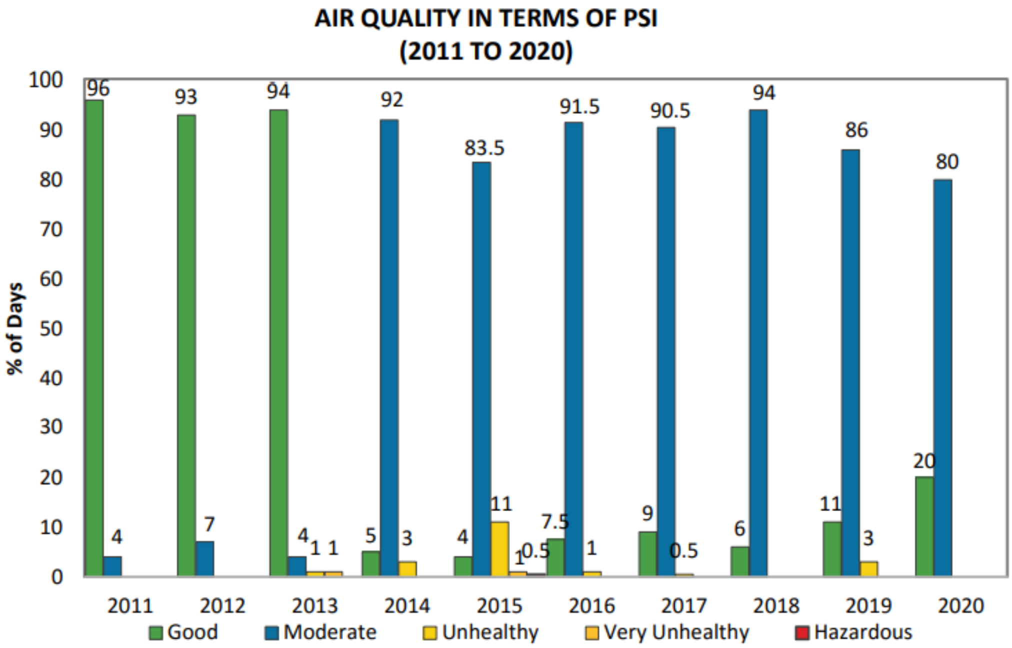


Figure 5.18 Air quality in Singapore from 2011 to 2020 in terms of PSI (Source: NEA, 2021)

DHI had recently done an air quality baseline survey at Ubin Living Lab (ULL) - to the southeast of OBS Camp 2 over a measurement period of seven (7) days. The measured air quality parameters include particulate matter, gases and VOCs. All measurements were well below the WHO guidelines as stated in Table 5.6. VOC was not detected throughout the survey period.

5.4.2 Noise

The background ambient noise level of a habitat varies according to the local ecology. Tropical rainforests are among the most diverse habitat where multiple species of fauna signallers are likely to be active simultaneously. Ambient noise levels in tropical rainforest are heavily proportion due to the signalling activity of insects (Ellinger & Hödl, 2002).

DHI had also done an airborne noise baseline survey at ULL over a measurement period of seven (7) days. Buildings in the ULL area have since been demolished and the area has been mostly unoccupied. The immediate surroundings of ULL consist of intertidal areas and forested land, bounded by a thin strip of mangrove fringe. The environmental conditions are comparable to the vicinity of OBS Camp 2. The measurements at ULL ranged from 45 dBA to 84 dBA, with L_{10} of 62 dBA where L_{10} is the noise level exceeded for 10% of the measurement duration, thus representing peak noise.

5.5 Ecology and Biodiversity

5.5.1 Macrobenthos

5.5.1.1 Findings

A total of 233 individual organisms were recorded from three (3) grab samples at one (1) sampling site which is the same as seabed sediment quality survey location. An overall mean density of 233 individuals/m^2 (SD = 116.16) was recorded at the sampling site. Four (4) taxonomic classes were recorded, Ophiuroidea, Bivalvia, Polychaeta, and Oligochaeta. Of these recorded classes, brittle stars (Ophiuroidea) were the most abundant, having a mean of 40.1 individuals/m^2 (SD = 80.42). There were no species of conservation significance found during the macrobenthos survey.

Table 5.7 Density distribution of benthic fauna at MB1

Taxonomic Class	Density (individuals/m^2)	Mean	SD	SE
Ophiuroidea	201.06	40.21	80.42	35.97
Bivalvia	15.87	3.17	6.35	2.84
Polychaeta	10.58	2.12	4.23	1.89
Oligochaeta	5.29	1.06	2.12	0.95

Ophiuroidea (brittle star)

Bivalve (clam)

Polychaete (bristleworm)

Oligochaeta (earthworm)

Figure 5.19 Representative photos of benthic fauna at MB1

5.5.2 Mangroves and Coastal Vegetation

5.5.2.1 Methodology

Mangrove surveys were carried out during suitable low tides along the shoreline to the western and eastern sides of the project area as shown in Figure 5.20.

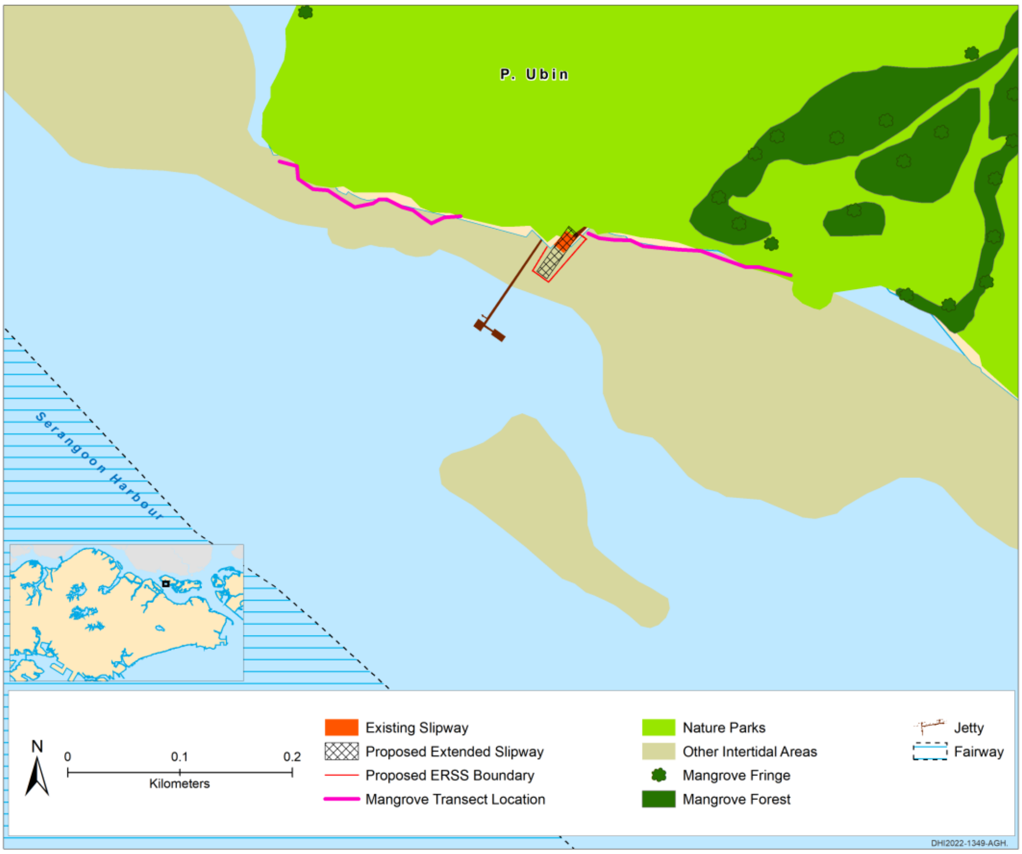


Figure 5.20 Mangrove survey transects

A total of 400 m of Pulau Ubin's shoreline was surveyed qualitatively by walking along the shoreline during the low tide (Figure 5.21). Surveyors assessed and recorded fauna and flora species encountered along the shoreline.

Figure 5.21 General condition of shorelines adjacent to OBS Camp 2

The Singapore Red Data Book (SRDB) is the main reference for local faunal conservation status, with the most recent SRDB 2nd Edition (hereinafter referred as 'SRDB2') being published in 2008. Since then, multiple independent scientific studies have been carried out in preparation for an updated SRDB (3rd Edition) to be published in the future with latest conservation statuses. These updated statuses (hereinafter referred as 'SRDB3') are already published for several taxa on NParks Species List (Red Data Book List) (NParks, 2022d). For this Study, local conservation status for fauna was determined using the latest available status for each respective taxon. The Flora of Singapore - Checklist and bibliography (Lindsay et. al., 2022) was referenced for the conservation status of flora.

5.5.2.2 Findings

Flora

The shoreline was mostly sandy at both east and west areas where the survey was conducted. Mangroves were denser on the eastern shoreline as compared to the western shoreline. The eastern area of the survey site was dominated by mangroves while the western area was dominated by minor mangrove species and coastal trees. Major mangrove species are differentiated from minor mangrove species by the possession of special adaptations and their exclusivity to mangrove area (Alappatt, 2008). As defined by Tomlinson (1986), major mangroves are plants which are (1) ecologically restricted to tidal swamps, (2) the major element of the community usually forms pure stands, (3) morphologically adapted with aerial roots and viviparity, (4) physiologically adapted for salt exclusion or excretion, and (5) taxonomically isolated from terrestrial relatives. Selected photographs showing the key flora are presented in Figure 5.22.

Locally 'Endangered' *Xylocarpus moluccensis*

Locally 'Vulnerable' *Nypa fruticans*

Locally 'Endangered' *Scyphiphora hydrophylacea*

Xylocarpus granatum

Bruguiera gymnorrhiza

Avicennia rumphiana

*Local status based on Lindsay et. al., 2022

Figure 5.22 Selected photos of the mangrove species recorded during DHI's baseline survey

In the eastern part of the survey area, seven (7) major mangrove species and two (2) minor mangrove species were recorded (Table 5.8). Among them, locally 'Vulnerable' *Nypa fruticans* was also observed with at least nine (9) individual trees. Locally 'Endangered' *Xylocarpus moluccensis* was also recorded.

Table 5.8 A checklist of the diversity of mangrove floral observed at the eastern survey site

Type	Species		Conservation status (Lindsay et. al., 2022)
	Scientific name	Common name	
Major Mangrove	*Nypa fruticans*	Nipah	VU
	Avicennia rumphiana	Api-api bulu	LC
	Bruguiera cylindrica	Bakau putih	LC
	Bruguiera gymnorhiza	Tumu	LC
	Rhizophora apiculata	Bakau minyak	LC
	Rhizophora mucronata	Bakau kurap	LC
	Sonneratia alba	Perepat	LC
Minor Mangrove	*Xylocarpus granatum*	Nyireh bunga	LC
	Xylocarpus moluccensis	Nyireh batu	EN

Note: VU: Vulnerable; LC: Least Concern; EN: Endangered

In the western area of the survey site, one (1) major mangrove species, two (2) minor mangrove species were recorded, one with conservation significance; locally "Endangered" *Scyphiphora hydrophylacea* (Table 5.9).

Table 5.9 A checklist of the diversity of mangrove floral observed at the western survey site

Type	Species		Conservation status (Lindsay et. al., 2022)
	Scientific name	Common name	
Major Mangrove	*Bruguiera cylindrica*	Bakau putih	LC
Minor Mangrove	*Xylocarpus granatum*	Nyireh bunga	LC
	Scyphiphora hydrophylacea	Chengam	EN

Note: LC: Least Concern; EN: Endangered

Of the 34 species of mangroves which can be found at Pulau Ubin (Yang *et al*., 2011), a total of 10 species was recorded in this study. Despite the small study area surveyed, our finding of 10 species represents 29.4% of all mangrove species found on Pulau Ubin. The locations of the mangroves of conservation significance are illustrated in Figure 5.23.

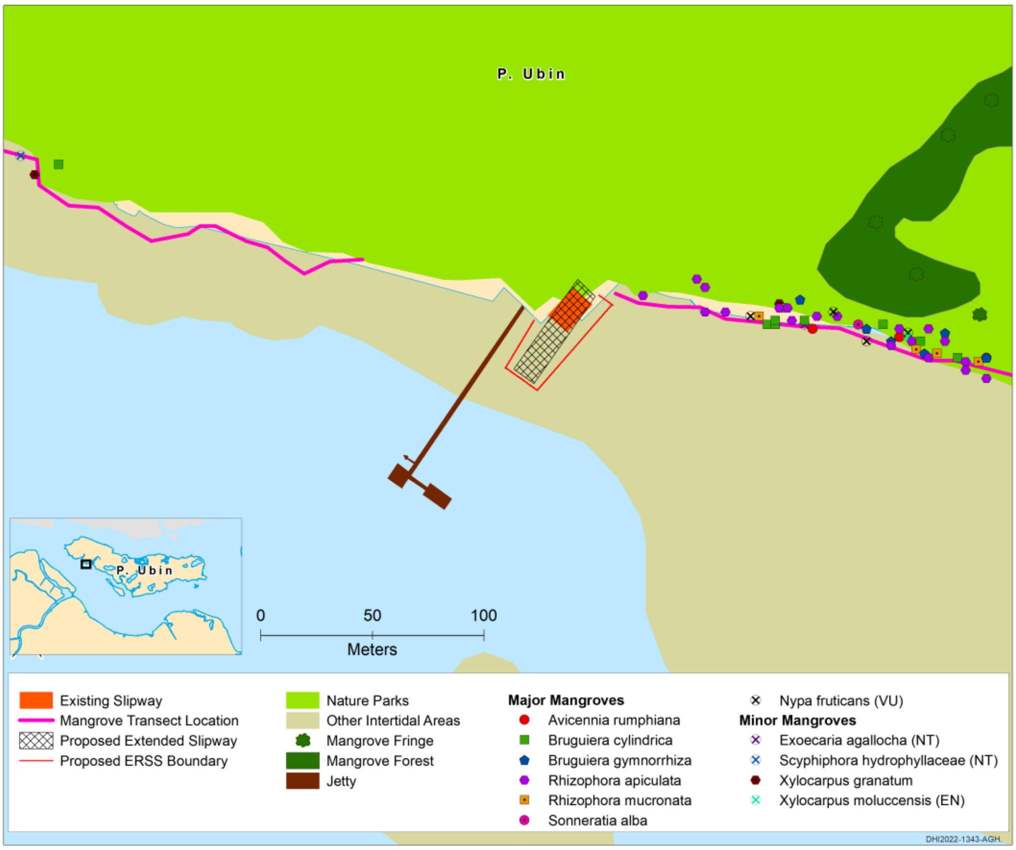


Figure 5.23 Mangroves of conservation significance at surveyed sites

Fauna

Fauna surveys were carried out on a single day along the same walking route used for the mangrove flora survey. A total of 10 species were observed from three (3) different taxa, the most speciose being avifauna, with a total of eight (8) species observed.

There was no fauna of local conservation significance observed. This is expected, given the one-off nature of the survey and that the area surveyed is relatively small and represent edge habitats, which are more suited for generalist species rather than specialist species which likely inhabit interior habitats such as the secondary forests to the north.

Table 5.10 Fauna species observed at both the eastern and western survey sites

Taxon	Species		Abundance	Conservation status	
	Common Name	Scientific Name		IUCN	SRDB3
Arthropoda	Carpenter bee	*Xylocopa sp*	1	N.A.	N.A.
Aves	Swiftlets	*Apogonidae sp*	13	N.A.	N.A.
	Collared kingfisher	*Todiramphus chloris*	3	LC	LC
	Zebra dove	*Geopelia striata*	1	LC	LC
	Javan myna	*Acridotheres javanicus*	1	VU	N.A.
	Ashy tailorbird	*Orthotomus ruficeps*	1	LC	LC
	White bellied sea eagle	*Haliaeetus leucogaster*	1	LC	LC
	Oriental white-eye	*Zosterops palpebrosus*	1	LC	N.A.
	Scaly breasted munia	*Lonchura punctulata*	1	LC	LC
Mammalia	Wild boar	*Sus scrofa*	1	LC	LC

Note: VU: Vulnerable; LC: Least Concern

5.6 Socio-Economy

This section describes the existing social and recreational aspects of the project area. The Project site is inaccessible to the public except for OBS staff and participants. It is well understood that the recreational areas in eastern Singapore are a popular social resource, contributing to the quality of life in Singapore. The proposed development may have socio-economic impacts with respect to offshore activities such as kayaking and, fishing, as well as to the nearby aquaculture farms.

5.6.1 Social and Recreational

OBS Camps 1 and 2 cover an area of approximately 240 ha of land on western Pulau Ubin. The school organizes camps for both schools and corporate groups where participants engage in both land and sea-based activities such as rock-climbing and kayaking.

Other recreational receptors found along the southern shoreline of Pulau Ubin include Jelutong Campsite, as well as mangrove kayaking in which participants kayak through Sungei Jelutong to Sungei Besar and exit on the northern shoreline of Pulau Ubin. Jelutong Campsite is located to the west of Ubin Main Jetty (approximately 5 km away from the Project site) and is publicly accessible. A narrow stretch of rocky beach can be found along the shoreline at Jelutong Campsite. Members of the public also participate in recreational fishing along the coastline of Pulau Ubin, with Ubin Main Jetty being one of the more popular spots for recreational fishermen.

Two recreational parks are also found on mainland Singapore which are in the vicinity of Pulau Ubin, namely Pasir Ris Park and Changi Beach Park. However, the nearest points from the Pasir Ris Park and Changi Beach Park are more than 2 km away from the Project site. As such, the anticipated localised impacts to the environment from the construction and post-construction phase are not expected to extend to these areas.

5.6.2 Aquaculture

Clusters of fish farms are situated in the waters between Pulau Ubin and mainland Singapore. The majority of these are found closer to the Pulau Ubin shoreline, with the remaining located off the waters of Pasir Ris Park. The nearest fish farm is approximately 800 m away from the Project site.

5.6.3 Maritime Activities

A designated vessel navigation area, Serangoon Harbour, is found in the waters between Pulau Ubin and mainland Singapore and is mainly used by vessels travelling between the Port of Pasir Gudang in Malaysia and Singapore.

5.6.4 International Border

There could be sensitive receptors across the Singapore-Malaysia border. Since their exact locations are not known, the assessment of all the impacts on these receptors will be based on model results and analyses at the Singapore-Malaysia border which is approximately 2.5 km away from the Project site.

6 Prediction and Evaluation of Environmental Impacts (Construction Phase)

Coastal environments are governed by the dynamics of the natural processes of waves, tides, surges, erosion and deposition. The extension of slipway will slightly alter the shoreline in the area, as well as potentially generating suspended sediments from the piling activities.

The assessment of impacts is therefore aimed at analysing the level of changes in the surrounding marine areas due to the development and highlighting if any of these changes can be expected to have secondary consequences, for example to ecology and biodiversity, or marine facilities. The assessment comprises the quantification of relevant deviations from baseline coastal conditions including considerations on water quality, currents and sediment plume associated with the construction phase of the Project.

This section discusses the specific impacts from construction phase which could potentially result in relevant short-term impacts to project area currents; and also impacts to ecology and biodiversity, and other sensitive receptors identified in Section 5.

6.1 Hydrodynamics

This section presents the methodology for analysing changes in currents, identifies relevant baseline features and key receptors, describes the evaluation framework related to changes in current regime, and finally discusses the outcomes of the hydrodynamic analysis.

6.1.1 Relevant Receptors

The only group of receptors that is relevant to changes in hydrodynamic conditions is maritime transport and infrastructure (such as jetties). The sections below discuss methodology of hydrodynamic modelling and present the model results in term of predicted changes due to the Project. Impact from the predicted changes on maritime transport are assessed in the corresponding section for this receptor group (Section 6.6).

6.1.2 Methodology

To quantify the level of change to the hydrodynamic conditions (current speeds, flow patterns) due to the project, DHI's well calibrated and validated hydrodynamic model of the Singapore Straits will be applied. The model is based on MIKE 21 HD FM model from MIKE Powered by DHI suite of numerical models.

For the construction (process) impact assessment, the MIKE 21 base hydrodynamic model for the intermediate stage of development provides quantification of the current conditions and as well as input to the sediment plume for the short-term sediment spill processes and sedimentation impact assessment.

Based on the construction methodology (Section 2.3.1), the worst-case scenario during the construction stage is likely with the presence of ERSS using sheet piles. Hence, the sheet piles layout with total blockage of current flow into the slipway construction site is simulated in the hydrodynamic model.

The current modelling scenarios include simulations over a period of 14 days, covering one spring-neap tidal cycle, during both North-East (NE) and South-West (SW) monsoons in order to cover seasonal variations in currents that may affect the model results.

6.1.3 Assessment Framework

To examine hydrodynamic changes arising from the Project, several current characteristics are selected based on industry practices in assessing impacts from current changes on navigation and berthing activities. They include:

- Current fields
- Mean current speeds
- 95^{th} percentile current speeds
- Representative current speeds (< 0.5, 2.0 and 3.5 knots)

Tolerance limits of navigation and berthing activities against hydrodynamic changes are presented in further detail in section 6.6, along with the impact assessment.

6.1.4 Results and Discussions

The impacts to currents around the project area are represented in terms of changes to current fields, current statistics (mean and 95^{th} percentile) and representative current speeds. Overall:

- Current speeds are generally low in the study area, due to its sheltered location.
- The ERSS is predicted to cause negligible changes to hydrodynamic parameters in the study area. This observation holds for both NE and SW monsoons.

These changes will be described in the following sections. Impacts arising from these changes, if any, are evaluated in the respective receptor sections in this report.

General Change in Current Fields

This section describes the simulated absolute current field (current vectors) at each reference tidal stage for the Baseline and the intermediate stage in order to provide an overview of the impact of the construction process on the current field. For the purposes of the current impact assessment, the current field can be classified according to two (2) main stages of the tide which are characterised as peak flood and peak ebb tide. The definition of flood and ebb is the rise and fall of the tide, respectively, and the direction follows the dominant flow direction in the Singapore Strait, with ebb tide also referred to as east-going tide, and flood tide also referred to as west-going tide.

Figure 6.1 to Figure 6.2 illustrate flow speed and vectors for peak ebb and peak flood. Changes to current field arising from the ERSS are highly localised around the slipway area. No change is observed in Serangoon Harbour.

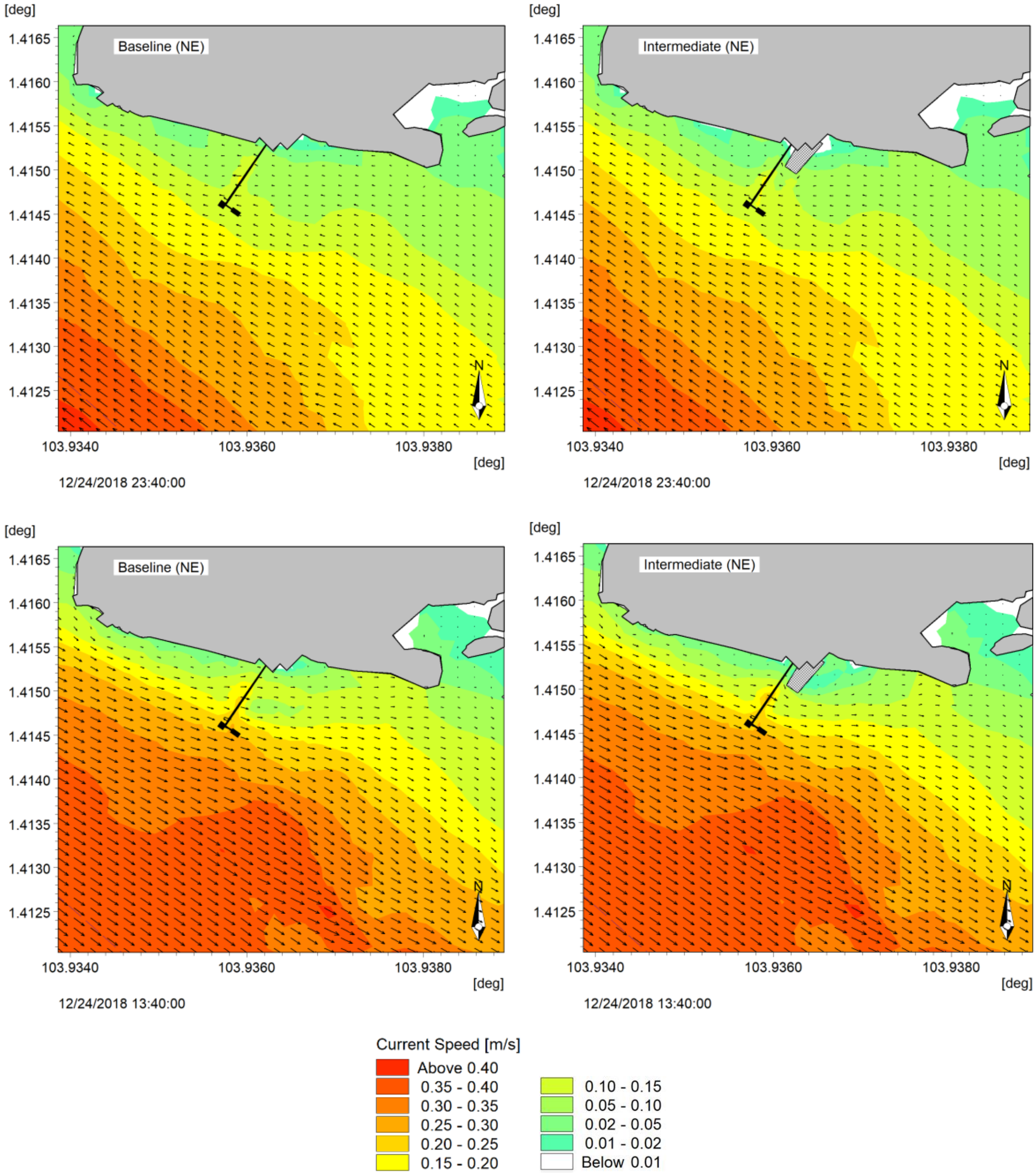


Figure 6.1 Change in current field due to intermediate stage: Peak ebb (top) and peak flood (bottom) during NE Monsoon

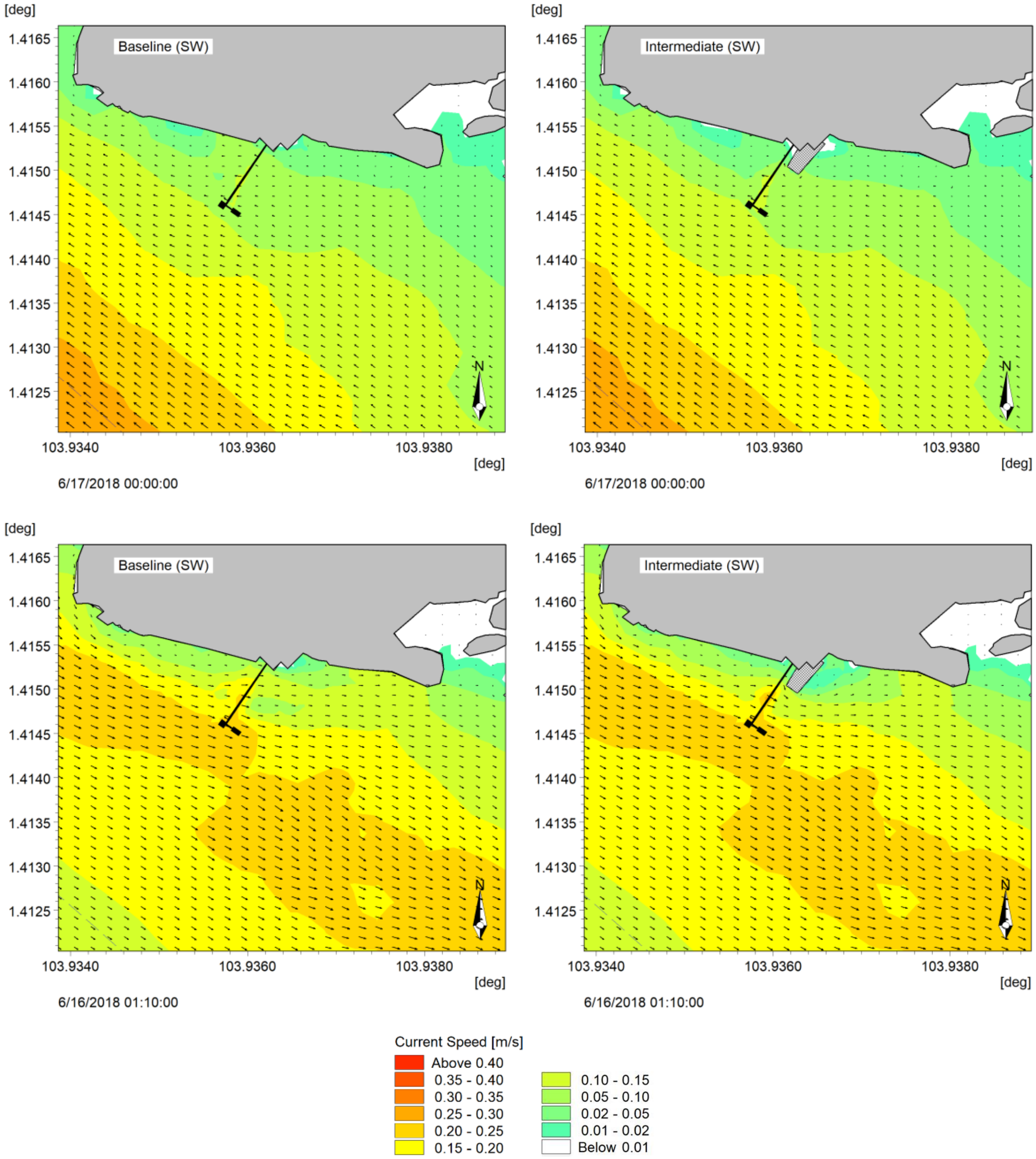


Figure 6.2 Change in current field due to intermediate stage: Peak ebb (top) and peak flood (bottom) during SW Monsoon

Change in Mean Current Speeds

This section describes the impact, with respect to baseline conditions, to mean current speeds as a result of the intermediate stage. Figure 6.3 illustrates the mean current speeds for the Baseline and Construction Phases (top and middle respectively), and the predicted change in mean current speeds (bottom) in relation to Baseline during the NE monsoon. Figure 6.4 presents model results for SW monsoon.

The average current speed prior to any construction works (i.e. baseline) are typical of patterns described in Section 5.1.2. The project area is predicted to have average speeds of 0.01 m/s to 0.10 m/s with the latter occurring at the OBS Camp 2 jetty platform. Erection of the ERSS is predicted to result in less than 0.05 m/s change in mean current speed in both local project area and the entire study area.

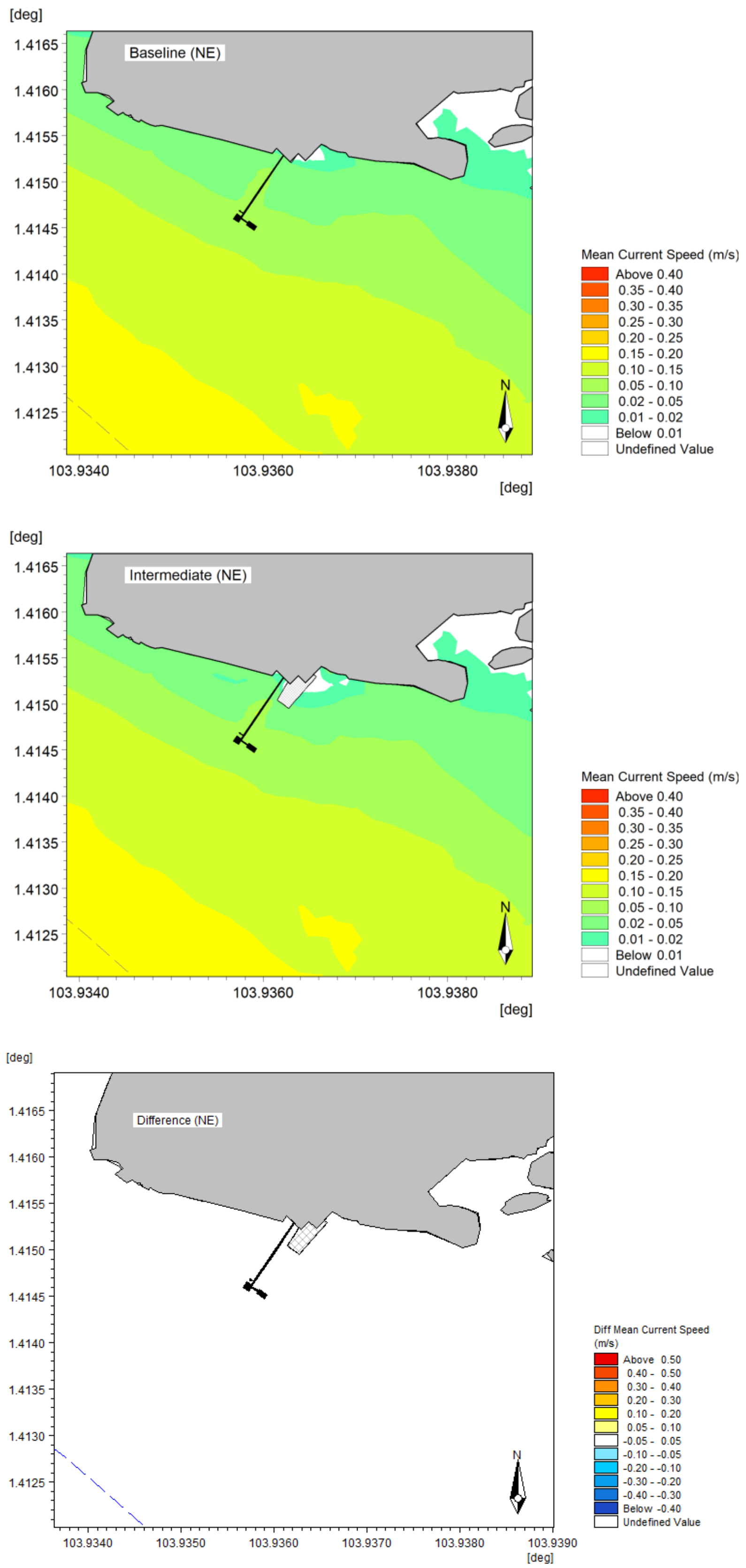


Figure 6.3 Mean current speed during NE monsoon. Top: Baseline. Middle: Construction Phase. Bottom: Difference between Construction Phase and Baseline.

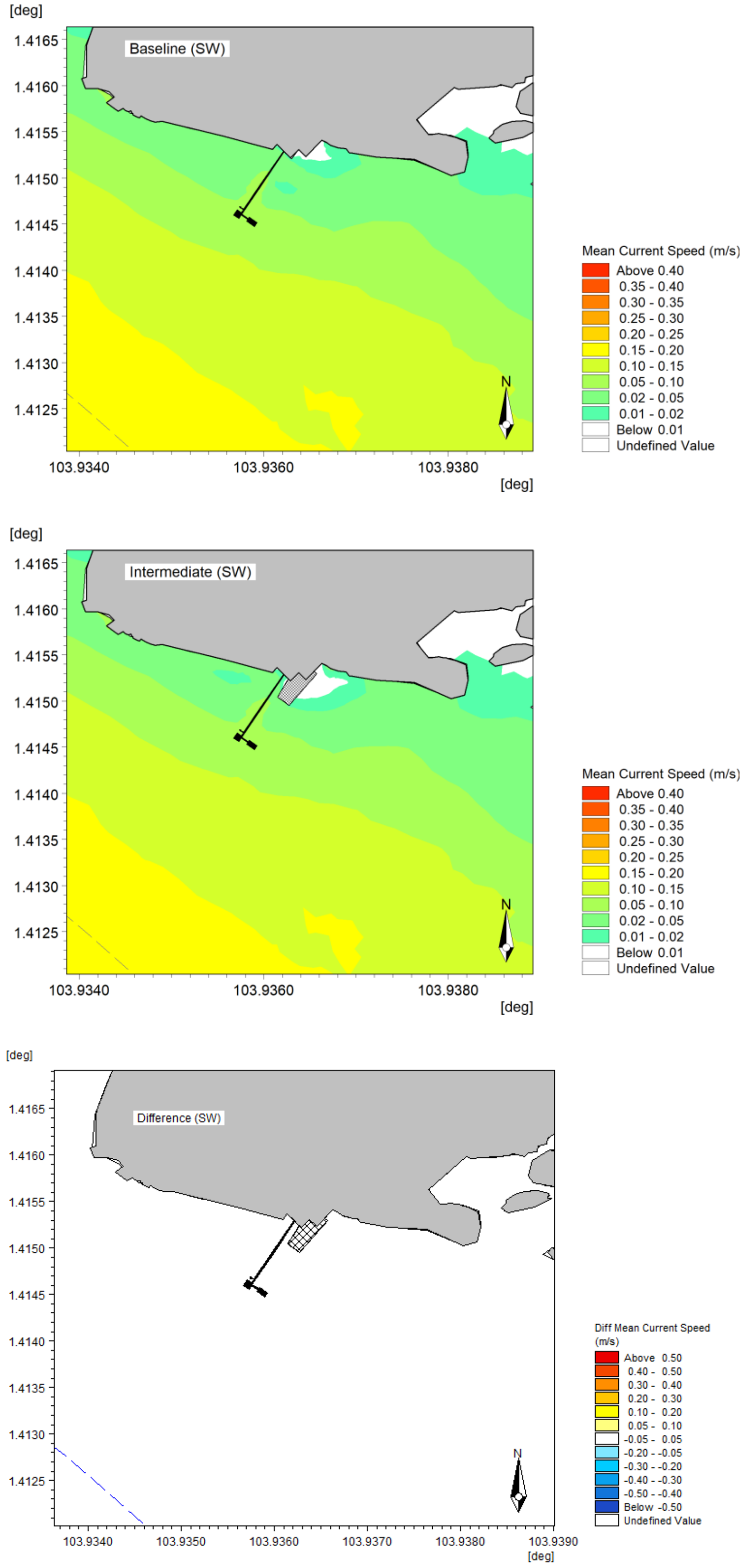


Figure 6.4 Mean current speed during SW monsoon. Top: Baseline. Middle: Construction Phase. Bottom: Difference between Construction Phase and Baseline

Change in 95th Percentile Current Speeds

The corresponding plots for the 95th percentile current speeds are presented in this section and address the current speeds that may occur up to 95% of the time. Figure 6.5 illustrates the maximum (at 95th percentile) current speeds for the Baseline (top) and Construction Phases (middle), and the predicted change in max current speeds (bottom) as compared to Baseline during the NE monsoon. Figure 6.6 shows the results for SW monsoon.

Predicted maximum current speeds in both the Baseline and Construction Phase are generally low along the shore of Pulau Ubin with currents attain speeds up to 0.12 m/s. The predicted difference in maximum current speed between the Baseline and Construction Phase (i.e. with the sheet piles) for both NE and SW monsoons is less than 0.1 m/s.

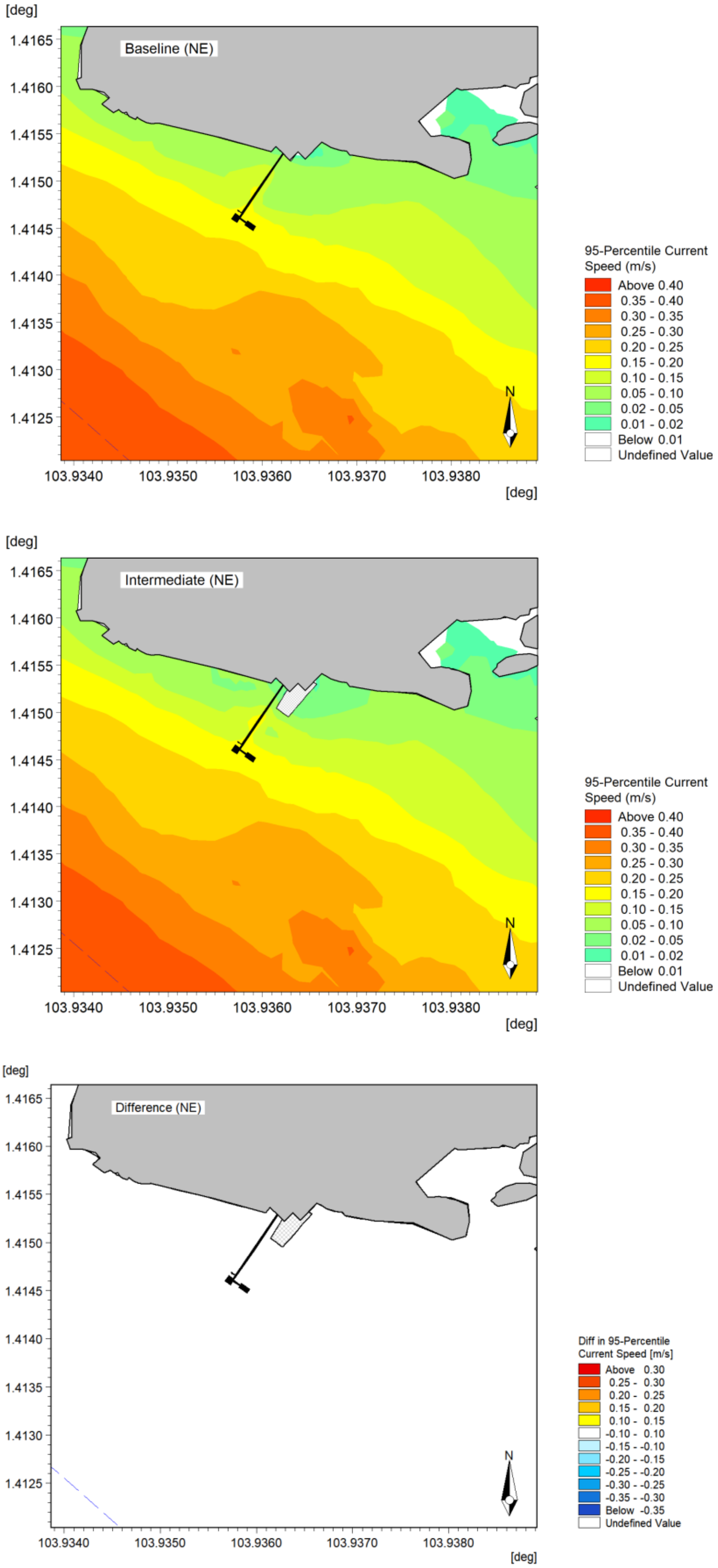


Figure 6.5 95th percentile current speed during NE monsoon. Top: Baseline. Middle: Construction Phase. Bottom: Difference between Construction Phase and Baseline

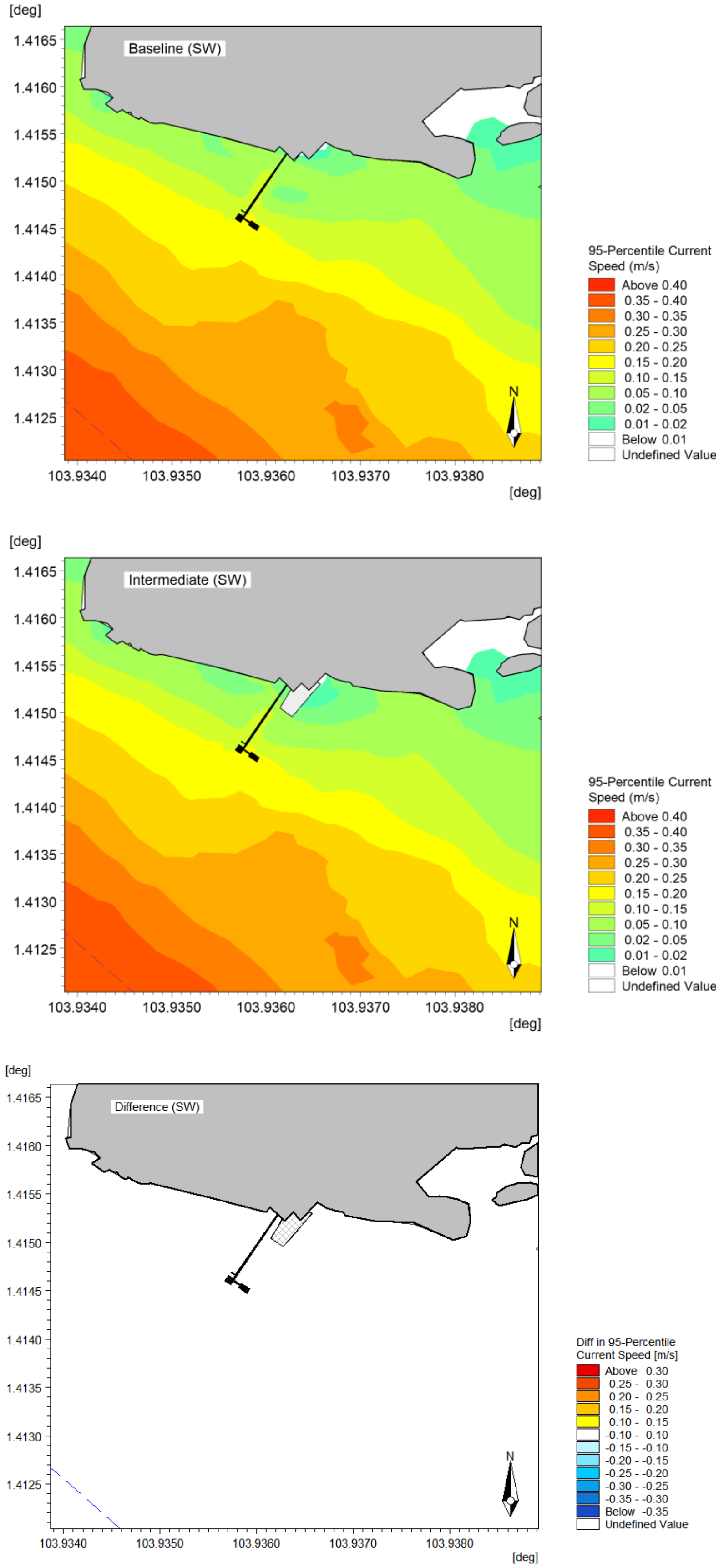


Figure 6.6 95th percentile current speed during SW monsoon. Top: Baseline. Middle: Construction Phase. Bottom: Difference between Construction Phase and Baseline.

Change in Representative Current Speeds

As an alternative to the analysis of mean and 95th percentile current speeds, a measure of the level of change to the exceedance of selected representative current speeds is provided in this section. This alternative is meant to provide additional understanding of the scale of change in current speeds, and for this purpose, the speeds of 3.5 knots (1.8 m/s), 2.0 knot (1 m/s) and below 0.5 knot (0.25 m/s) were used. Current speed lower than 0.5 knot is generally referred to as slackwater.

Figure 6.7 and Figure 6.8 present slackwater duration in the study area for Baseline, Construction Phase and the difference between them, during NE and SW monsoons respectively. It's evident that the current at OBS Camp 2 slipway and jetty is in slack condition for more than 90% of time and that does not change during the Construction Phase. The presence of ERSS is predicted to cause in less than 2% change in slackwater duration in the entire study area.

With regards to exceedance of 2.0 knot and 3.5 knots, it is evident from Figure 6.9 to Figure 6.12 that current speed in the study area only exceeds these representative current speeds for less than 4% of time, during both monsoon seasons assessed in this study. The model shows that the ERSS will result in no more than 2% change to the duration current speed in the study area exceeding 2.0 knots and 3.5 knots.

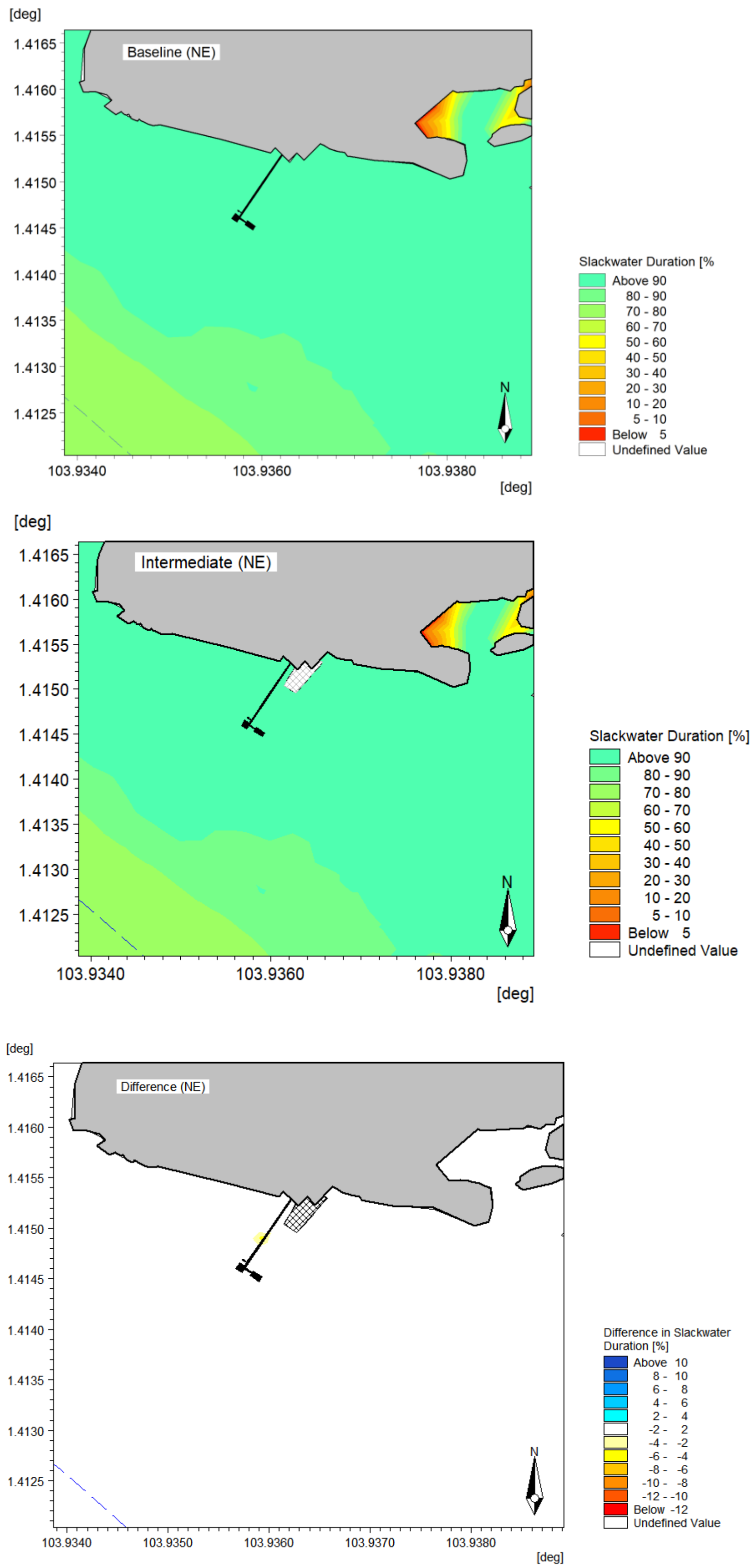


Figure 6.7 Slackwater duration during NE monsoon. Top: Baseline. Middle: Construction Phase. Bottom: Difference between Construction Phase and Baseline

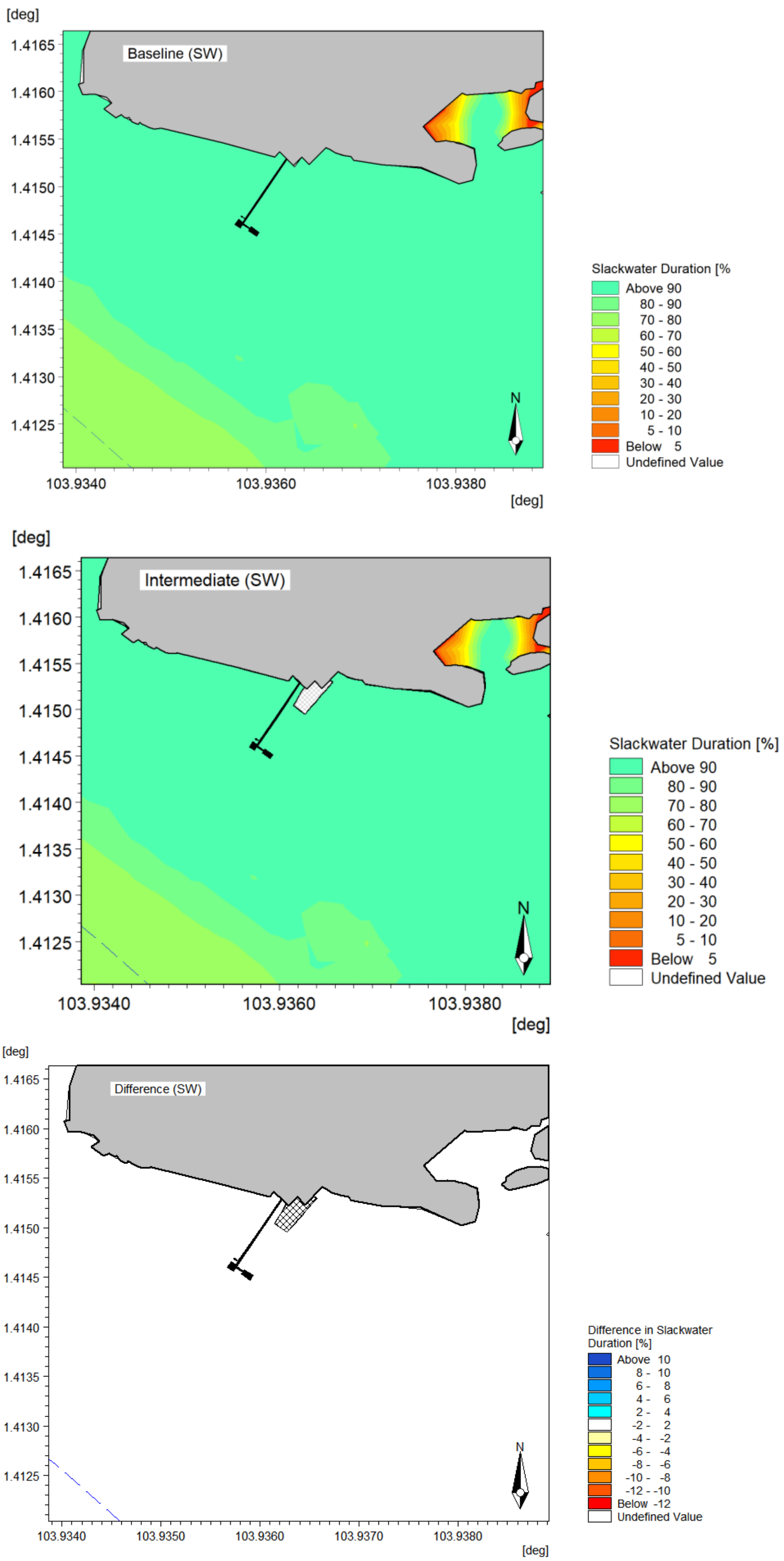


Figure 6.8 Slackwater duration during SW monsoon. Top: Baseline. Middle: Construction Phase. Bottom: Difference between Construction Phase and Baseline.

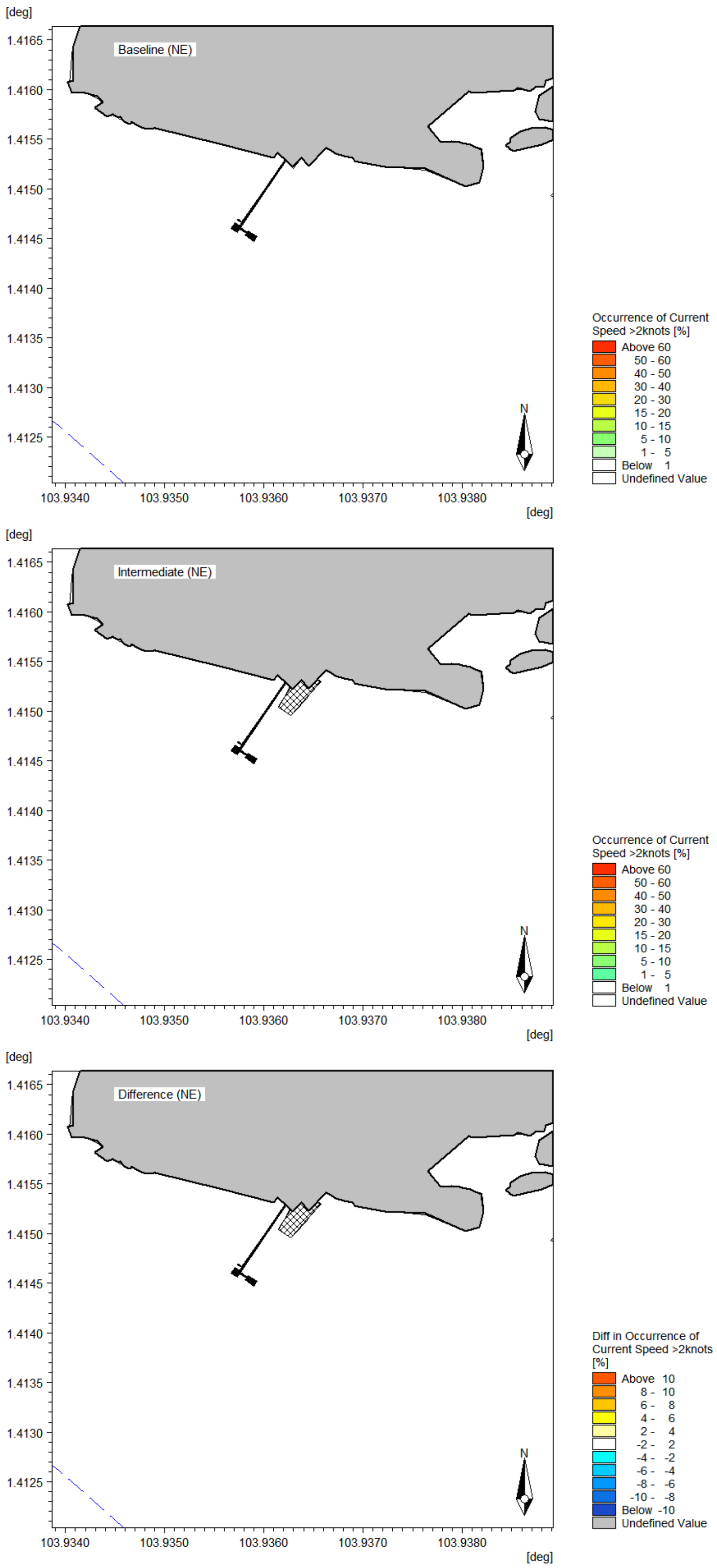


Figure 6.9 Percentage of time current speed exceeding 2.0 knots during NE monsoon. Top: Baseline. Middle: Construction Phase. Bottom: Difference between Construction Phase and Baseline

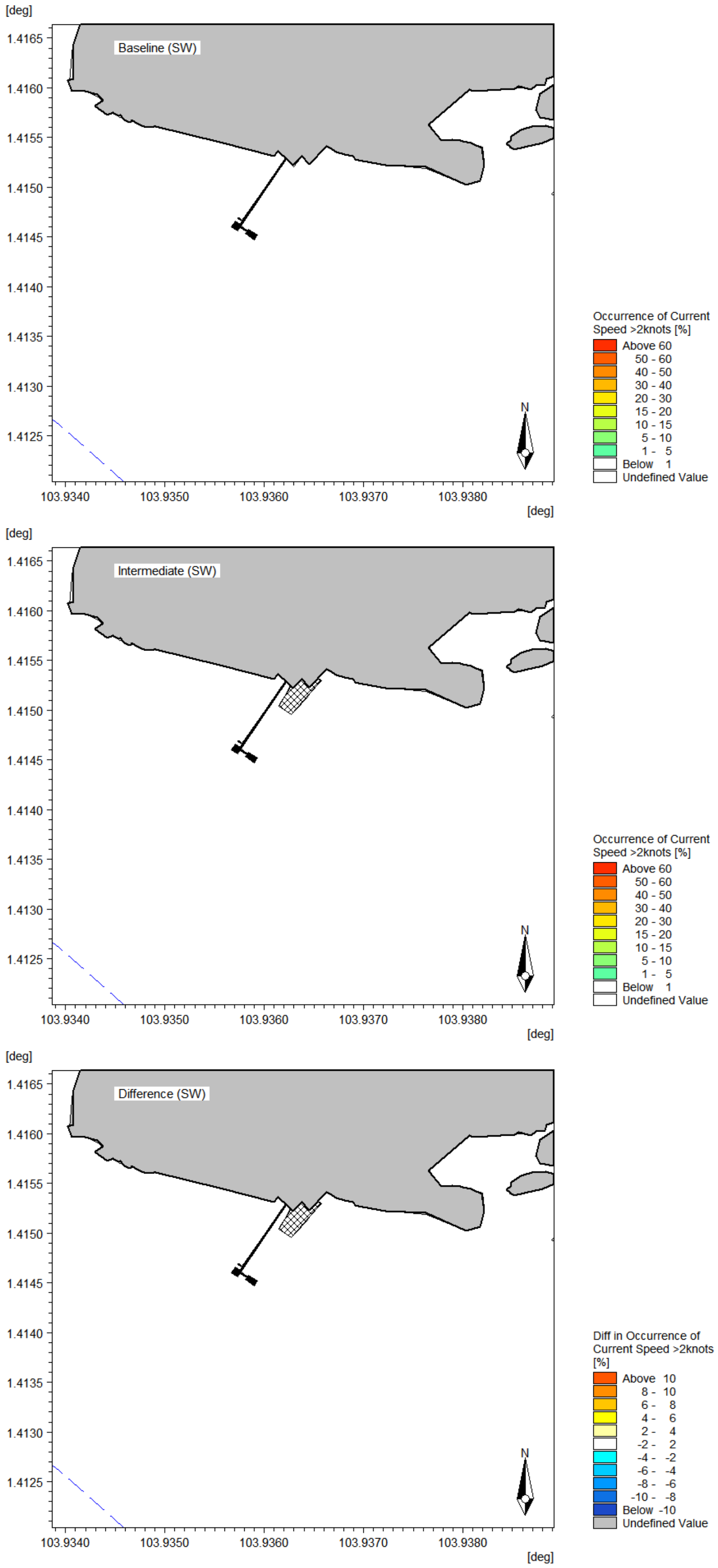


Figure 6.10 Percentage of time current speed exceeding 2.0 knots during SW monsoon. Top: Baseline. Middle: Construction Phase. Bottom: Difference between Construction Phase and Baseline.

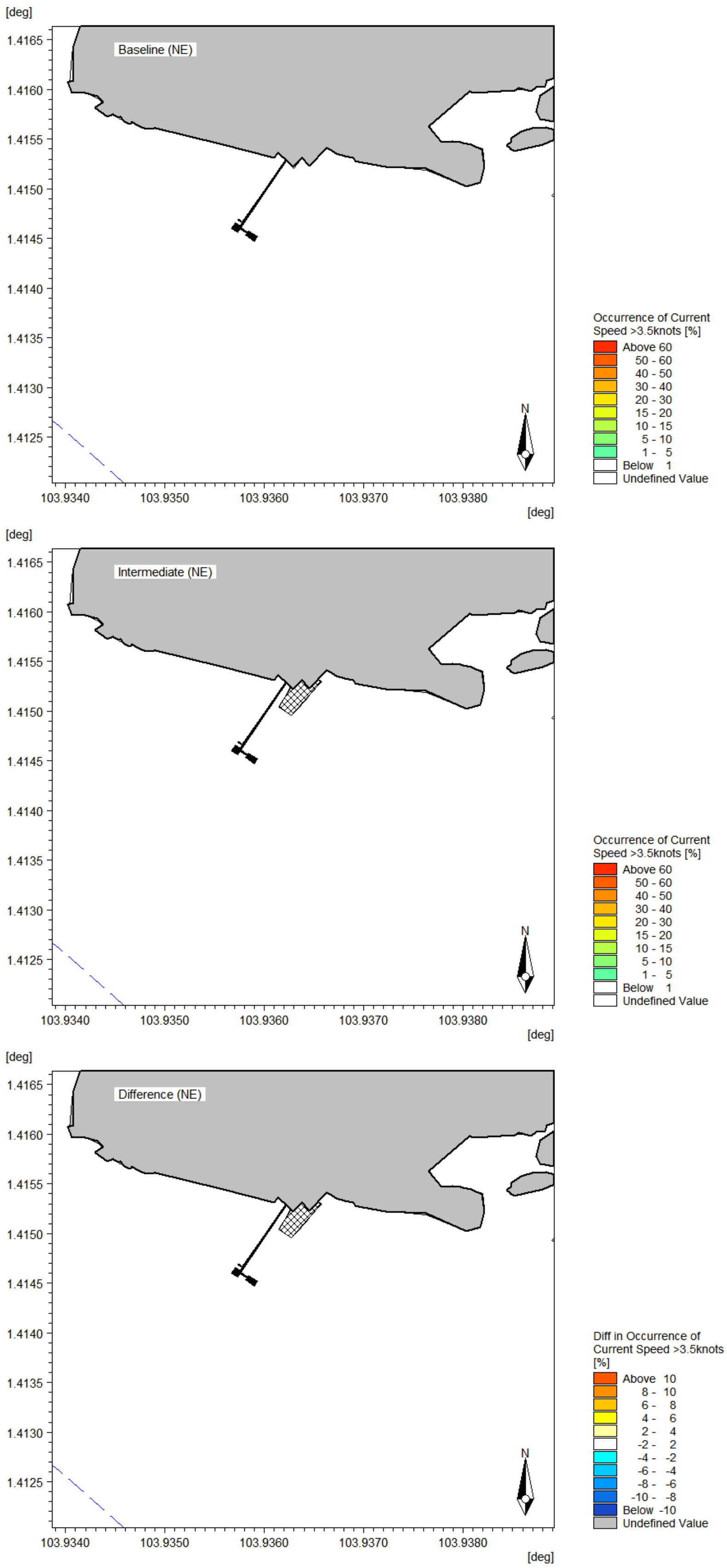


Figure 6.11 Percentage of time current speed exceeding 3.5 knots during NE monsoon. Top: Baseline. Middle: Construction Phase. Bottom: Difference between Construction Phase and Baseline.

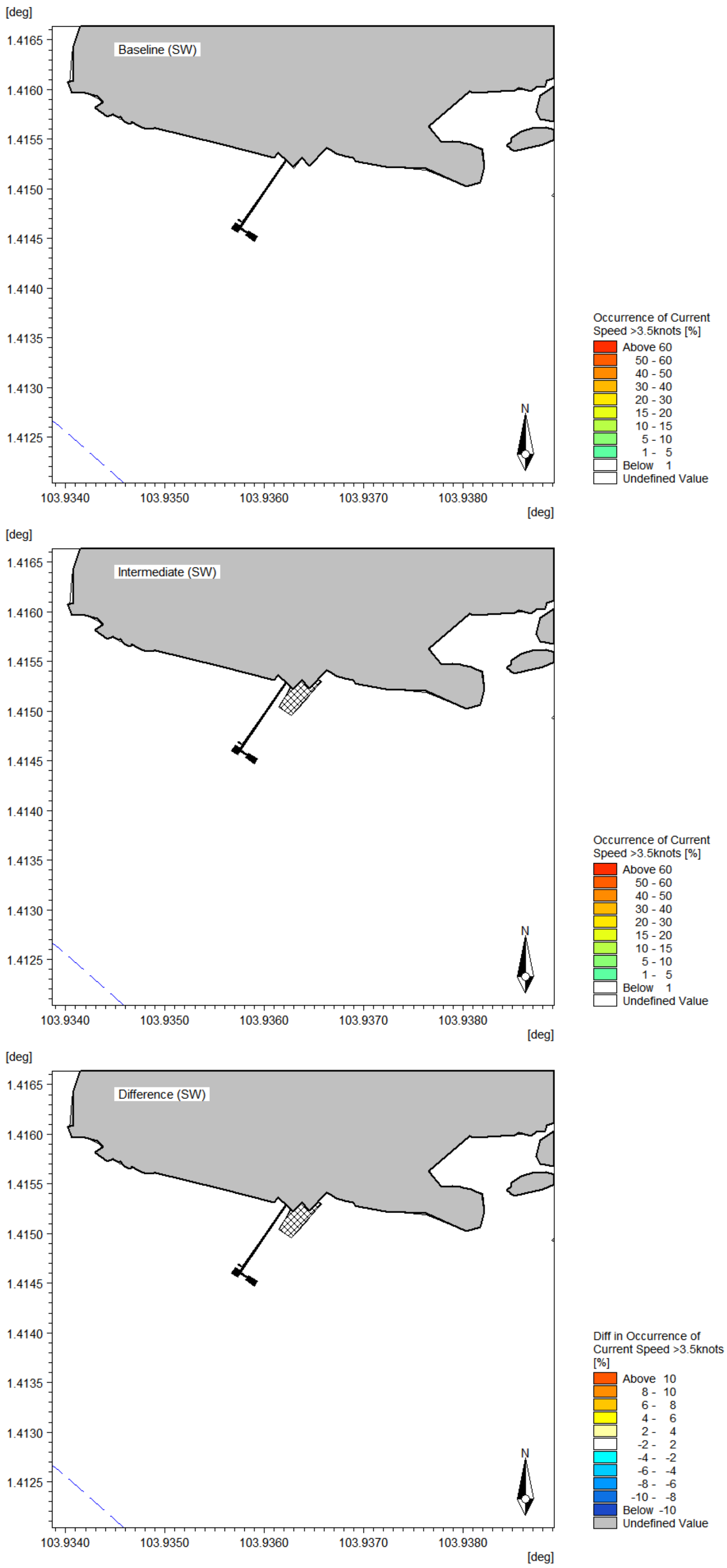


Figure 6.12 Percentage of time current speed exceeding 3.5 knots during SW monsoon. Top: Baseline. Middle: Construction Phase. Bottom: Difference between Construction Phase and Baseline.

6.1.5 Hydrodynamics Summary

Overall, the Project is located in a sheltered area and characterised by low current speed in general. DHI's hydrodynamic simulations predict that its construction phase will result in local and negligible changes to various hydrodynamic parameters in the study area. Assessment of impact arising from these small changes is presented in sections later in this chapter, corresponding to the relevant sensitive receptors to hydrodynamic changes.

6.2 Sediment Plume and Sedimentation

Marine works during construction phase of the Project may result in resuspension of seabed sediment. These sediments will form a plume that if not managed properly may disperse to and settle at nearby sensitive receptors.

6.2.1 Relevant Receptors

The receptors that are considered sensitive to sediment plume include:

- Maritime transport
- Aquaculture facilities
- Marine ecology and biodiversity (macrobenthos, marine fauna and intertidal habitat)
- Recreational activities

The sections below discuss methodology of hydrodynamic modelling and present the model results in term of predicted changes due to the Project. Impact from the predicted changes on the above-listed receptors are assessed in the corresponding sections for these receptor groups (Section 6.6, 6.7, 0 and 6.10).

6.2.2 Methodology

Based on the construction methodology (Section 2.3.1), the site will be hoarded up by ERSS using sheet piles at the seaside and seawater will be pumped out to create and maintain dry working condition during the slipway construction. As pumped water consists of marine water, heightened levels of sediment are not expected and thus not modelled. The selected scenario for model assessment focused mainly on disturbance of seabed associated with piling works.

DHI's MIKE 21 Mud Transport Model has been used to simulate the spatial and temporal variation in suspended sediment concentrations (SSC) subject to hydrodynamic transport and settling, deposition and re-suspension processes. The background sediment concentrations are assumed to be zero in the model thus only incremental sediment concentrations (resulting from the construction activities) are simulated. The simulation period was 14 days to cover one full tidal cycle. The models were run for both NE and SW monsoons to cover the seasonality effect.

6.2.3 Assessment Framework

A set of characteristics is selected to assist the assessment of sediment plume impacts. These characteristics are chosen according to the tolerance limits of the relevant receptors listed in the earlier section against suspended sediments and sedimentation. Sediment plume model results in this EIA are analysed according to the following statistical descriptors:

- Mean incremental SSC (mg/l)
- Percentage of time SSC concentrations exceeding 5 mg/l, 10 mg/l and 25 mg/l
- 14-day and annual sedimentation (mm/14 days and mm/year)

Tolerance limits of the relevant receptors are discussed in the respective receptor sections, along with the impact assessment.

6.2.4 Results and Discussions

This section presents and discusses sediment plume model results, both in terms of suspended sediment concentration (SSC) and sedimentation rates. Impacts arising from these changes, if any, are evaluated in the respective receptor sections in this report.

Suspended Sediment

Sediment plume model results are presented in Figure 6.13 to Figure 6.16. Figure 6.13 shows mean contribution of SSC from the project piling works. The subsequent figures present the model results in terms of percentage of time that SSC contribution from the Project is exceeding 5 mg/l, 10 mg/l and 25 mg/l are exceeded. These model plots are for that reason also referred to as exceedance plots.

Overall, sediment plume from the piling activities is very localised at the OBS Camp 2 slipway and jetty areas. It is evident from the model plots that mean incremental SSC due to the piling activities goes above 20 mg/l only within the immediate piling area during both NE and SW monsoons. The predicted exceedance of 5 mg/l, 10 mg/l and 25 mg/l, during both NE and SW monsoons is up to 30%, 20% and 20% respectively.

Beyond the project area, the model predicts that mean incremental SSC remains below 1 mg/l and SSC exceeds 5 mg/l, 10 mg/l and 25 mg/l for less than 2.5% of time.

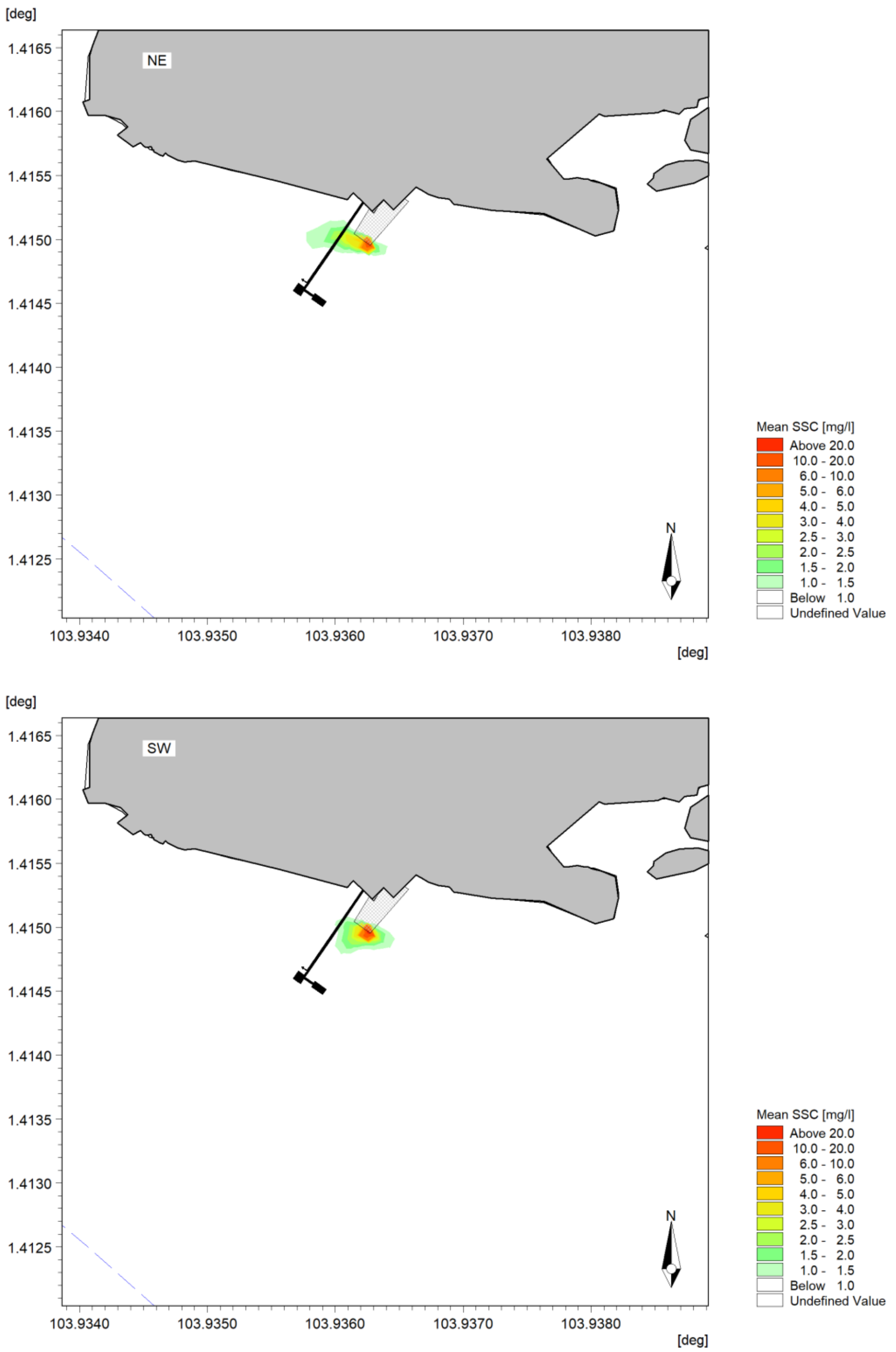


Figure 6.13 Mean SSC from piling works. Top: NE monsoon. Bottom: SW monsoon.

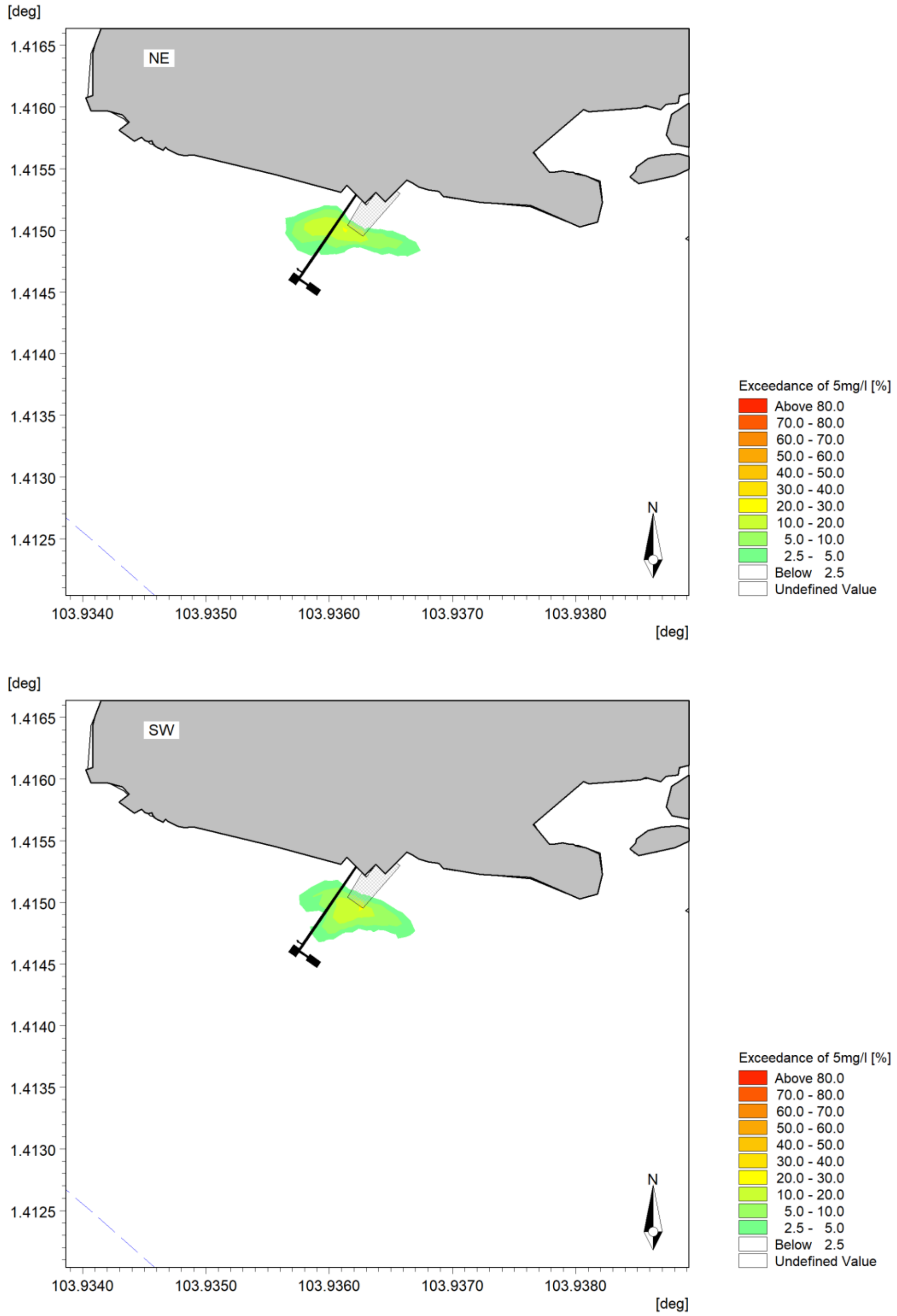


Figure 6.14 Percentage of time SSC from piling works exceeding 5 mg/l. Top: NE monsoon. Bottom: SW monsoon.

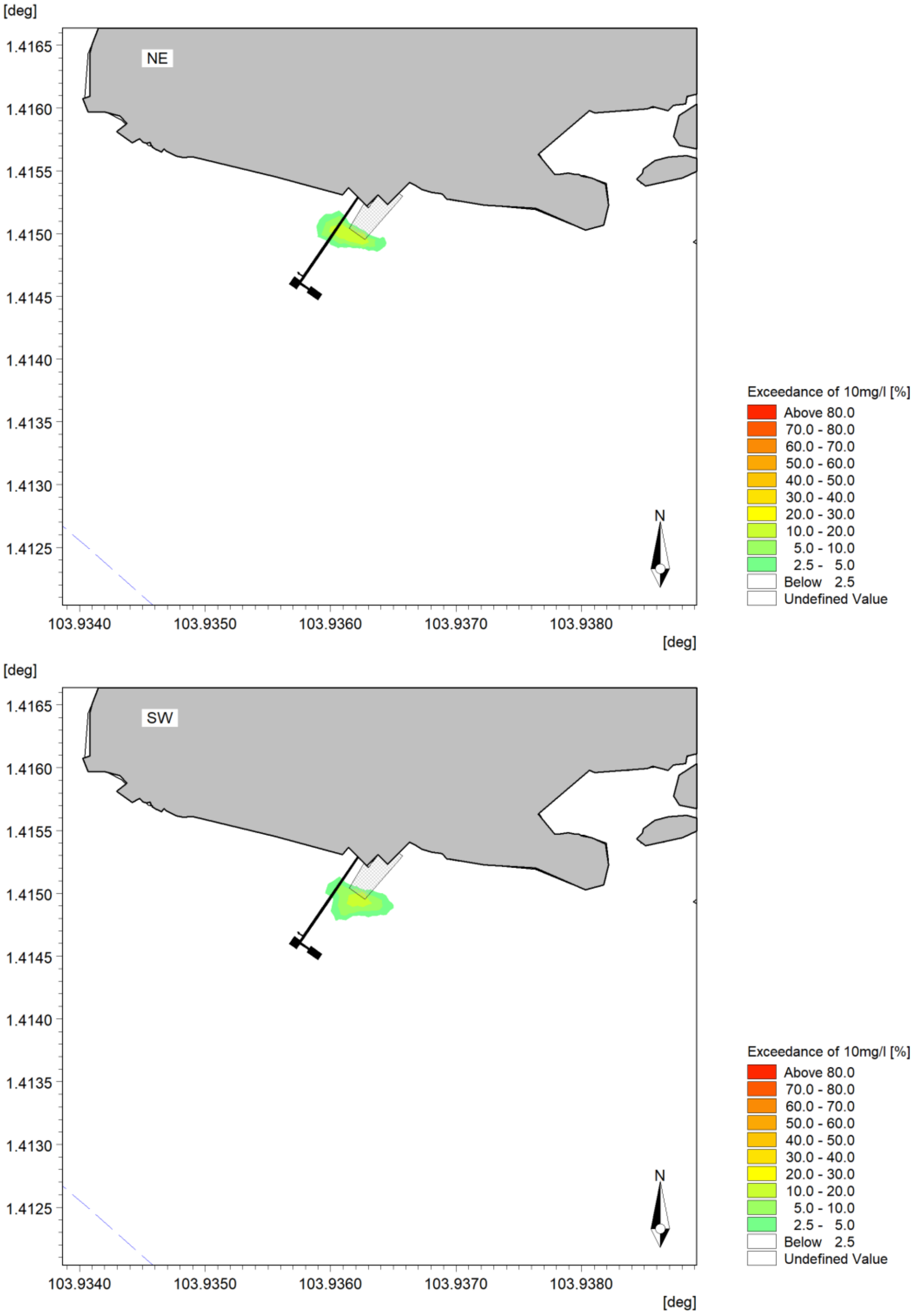


Figure 6.15 Percentage of time SSC from piling works exceeding 10 mg/l. Top: NE monsoon. Bottom: SW monsoon.

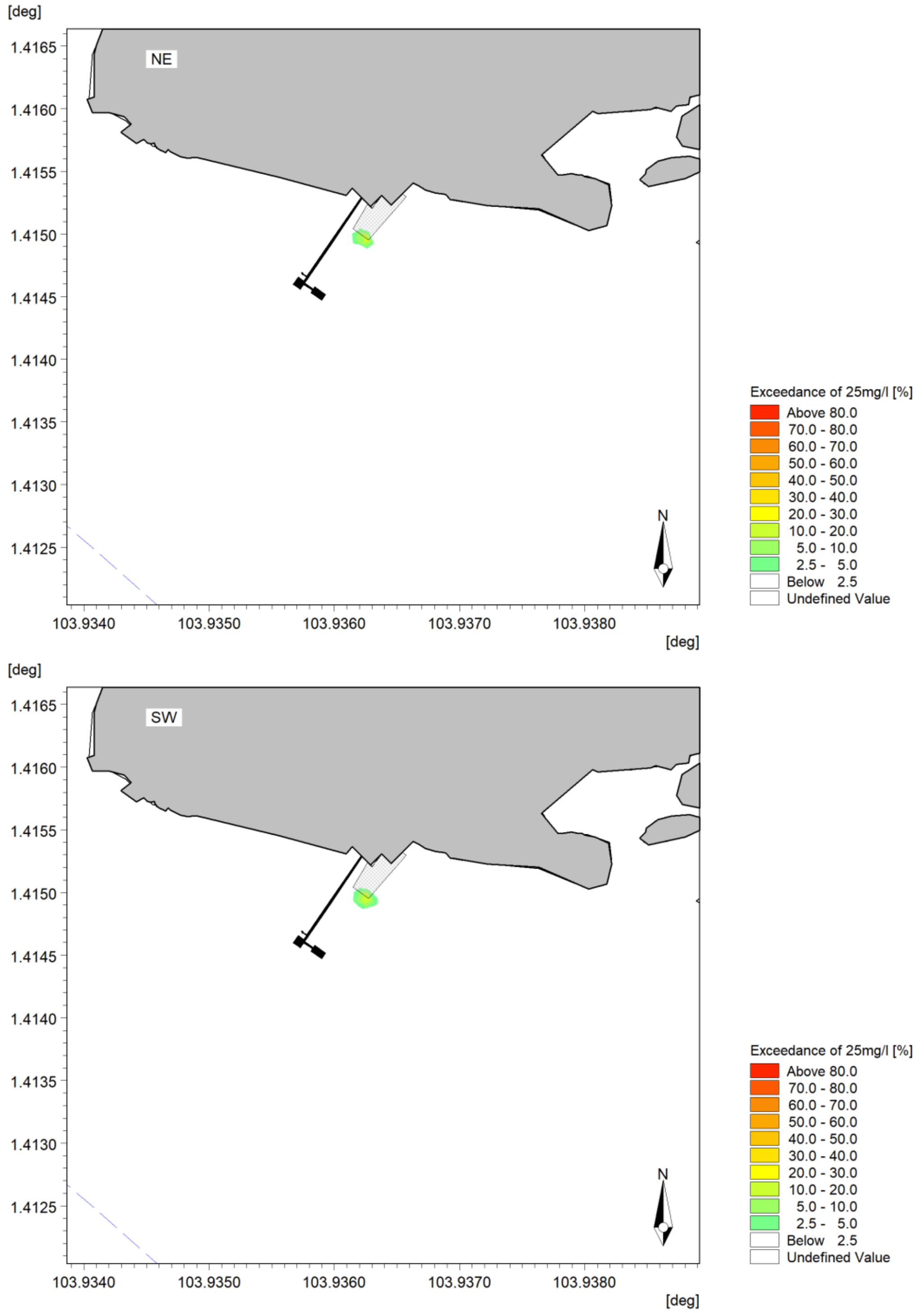


Figure 6.16 Percentage of time SSC from piling works exceeding 25 mg/l. Top: NE monsoon. Bottom: SW monsoon.

Sedimentation

A related parameter to assess is sedimentation. Prolonged presence of sediment plume may result in settling of sediments in another area causing sedimentation beyond the project area. The modelled sedimentation rates over 14 days are presented in Figure 6.17, showing above 35 mm sedimentation at the immediate vicinity of the piling area. No sedimentation is expected beyond 100 m of the project area.

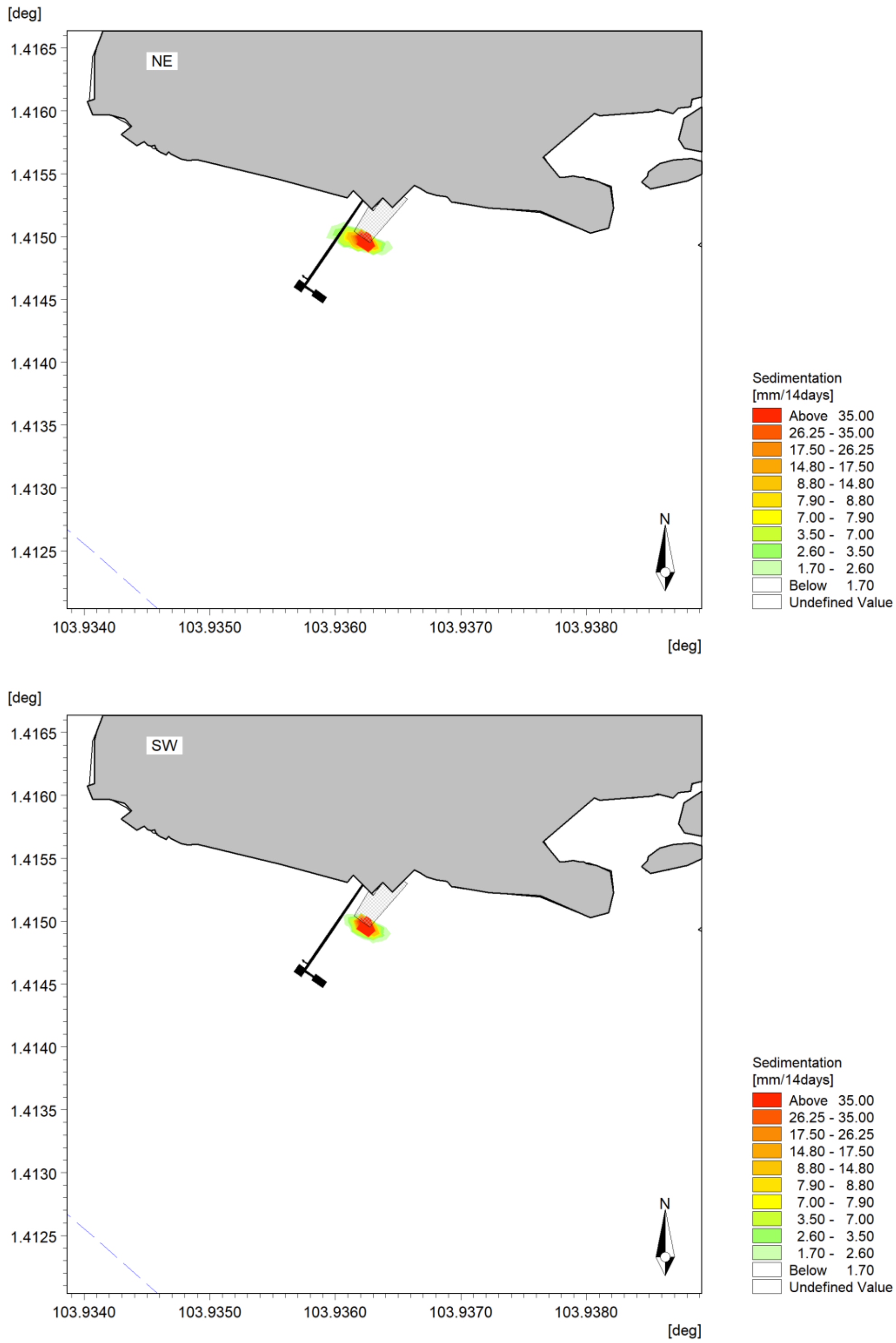


Figure 6.17 Net sedimentation in mm per 14-day from piling activities. Top: NE monsoon. Bottom: SW monsoon.

6.2.5 Sediment Plume Summary

During construction phase, sheet piles will be constructed around the work area, sediment plume only arises from piling works. It has been proven through sediment plume simulations that the piling works will result in localised and minimal plume. Changes in SSC (mean, exceedance of 5 mg/l, 10 mg/l and 25 mg/l) and sedimentation are predicted at areas in immediate vicinity of the slipway. No change is predicted for areas beyond this.

6.3 Air Quality

The key air quality effects from the construction project have identified to come from dust emission from demolition, general construction works and vehicle movements. The EIA did not prioritize quantification of emissions of CO, NO2, SO2 from heavy vehicles and powered machinery because the effects of such emissions are expected to be minimal. With effect from 1 July 2012, all off-road diesel engines (including construction machinery) imported into Singapore must comply with the EU Stage II, US Tier II or Japan Tier I off-road diesel engine emission standards, according to Environmental Protection and Management (Off- Road Diesel Engine Emissions) Regulations 2012.

This section outlines the methodology for semi-quantitatively analysing dust emissions from the construction of Project and later discusses the analysis results.

6.3.1 Relevant Receptors

The key receptors for air quality changes are ecology and biodiversity, and public health. The sections below discuss methodology and results of air quality assessment conducted in this Study. Impact from the predicted changes on the relevant receptors are assessed in the corresponding section for these receptor groups (Section 6.8 and 6.10).

6.3.2 Methodology

For the assessment of potential dust (i.e. PM_{10} and $PM_{2.5}$) impacts, DHI refers to the Institute of Air Quality Management (IAQM)'s Guidance on the Assessment of Dust from Demolition and Construction (the Guidance). No air quality modelling is conducted.

The process suggested in the Guidance includes the following steps:

Step 1: Screening the requirement for a more detailed assessment. This was carried out by setting a study boundary of 350 m followed by the identification of relevant receptors, both social-economic and ecological, within the established study area.

Step 2: Assessing the risk of dust impacts from each of the anticipated emission sources during Project construction by determining the potential dust emission sources and magnitude, i.e., small, medium, large, based on an estimated scale of the work and nature of receptors.

Step 3: Prescribing site-specific mitigation measures to abate anticipated air quality impacts

Step 4: Determining the significance of the residual impacts to each of air quality sensitive receptors

Step 1 has been completed in the expert scoping exercise for this Study, as presented in Section 4.2.1, and Steps 3 and 4 are discussed if significance of predicted impact is higher than acceptable level. Assessment framework for Step 2 is discussed in the next section.

6.3.3 Assessment Framework

According to IAQM's Guidance on the Assessment of Dust from Demolition and Construction, activities on construction sites that will potentially result in dust impact include demolition, earthworks, construction and trackout. In the context of this construction project, no earthworks will be carried out. Demolition, construction and trackout are considered in this assessment.

The Guidance provides quantitative definitions of magnitude of emissions, as summarized in Table 6.2. The magnitude classifications include ‘small’, ‘medium’ and ‘large’, requiring some adaptation for use in the RIAM framework adopted by DHI that includes 5 ratings of magnitude (Table 6.1).

Table 6.1 Evaluation Framework for Magnitude of Change in Air Quality

Score	IAQM Risk of Impacts Classification	Generic Definition	Customised Definition
-4	Large	Major negative disadvantage or change	• Severe effects on air quality which are likely to be long lasting, typically widespread in nature and requiring significant intervention to return to baseline • Air quality is likely to routinely exceed baseline criteria levels or allowable criteria
-3		Moderate negative disadvantage or change	• Potential effects on air quality which are likely to be long last, typically widespread in nature and requiring moderate intervention to return to baseline • Air quality is likely to occasionally exceed baseline criteria levels or allowable criteria
-2	Medium	Minor negative disadvantage or change	• Short term localised effects on air quality but which are likely to return to equilibrium conditions within a short timeframe (hours or days at most) • Air quality is likely to be within baseline criteria levels or allowable criteria
-1	Small	Slight negative disadvantage or change	• Short term localised effects on air quality but likely to be highly transitory (lasting hours) and well within natural fluctuations • Air quality is likely to be well within baseline criteria levels or allowable criteria
0	Negligible	No change	• Status quo

Table 6.2 IAQM's Definition of Potential Dust Emission Magnitude

Type of Activity	Dust Emission Magnitude Classification Reference		
	Large	**Medium**	**Small**
Demolition	• Total building volume >50,000 m^3 • Potentially dusty construction material (e.g., concrete) • On-site crushing and screening [a] • Demolition activities >20 m above ground level	• Total building volume 20,000 m^3 - 50,000 m^3 • Potentially dusty construction material • Demolition activities 10-20 m above ground level	• Total building volume <20,000 m^3 • Construction material with low potential for dust release (e.g., metal cladding or timber) • Demolition activities <10 m above ground • Demolition during wetter months
Construction	• Total building volume >100,000 m^3 • On site concrete batching [a] • Sandblasting	• Total building volume 25,000 m^3 - 100,000 m^3 • Potentially dusty construction material (e.g., concrete) • On site concrete batching [a]	• Total building volume <25,000 m^3 • Construction material with low potential for dust release (e.g., metal cladding or timber)
Trackout	• >50 heavy duty vehicle (HDV) (>3.5 tonnes) outward movements [b] in any one day [c] • Potentially dusty surface material (e.g., high clay content) • Unpaved road length >100 m	• 10-50 HDV outward movements [b] in any one day [c] • Moderately dusty surface material (e.g., high clay content) • Unpaved road length 50 m - 100 m	• <10 HDV outward movements [b] in any one day [c] • Surface material with low potential for dust release • Unpaved road length <50 m

[a] Mobile crushing equipment and concrete batching plants can be significant sources of dust. Professional judgement will be required to determine how the use of crushing and screening equipment or on site concrete batching will affect the dust emission magnitude.

[b] A vehicle movement is a one-way journey, i.e. from A to B, and excludes the return journey

[c] HDV movements during a construction project vary over its lifetime, and the number of movements is the maximum not the average

6.3.4 Results and Discussions

Key dust emitting activities identified for this construction project include:

- Demolition of the existing concrete slipway
- General construction works
- Vehicle movement

These sources of air pollution are discussed below.

Demolition

The existing slipway will be demolished before the new slipway is constructed. The demolition works will likely take several days. Dust emissions are thus expected during the concrete breaking and handling of debris, above water. With the current slipway length is approximately 20 m x 10 m, removal of concrete surface of about 1 m makes total demolition volume much lower than 20,000 m^3 which is the limit for Small emission according to the IAQM guideline, or Slight Negative magnitude in RIAM definition.

Trackout

It is expected that dust and dirt from the construction/demolition site, if unmanaged, may accumulate and then re-suspended into the air by vehicles using the road network. It is planned that pickup lorries will be deployed to transport waste/debris from the work area to OBS Camp 1 for centralized disposal. Number of dump trips per day is not available at the time of writing. Given that the demolition works are relatively small in scale and that the debris will likely be rehandled within the site, it is assumed that there will be less than 10 HDV outward movements a day. Paved road network also exists in Pulau Ubin, it is reasonable to assume that the trucks will take these routes and movement on unpaved roads is limited. These assumptions lead to a classification of Small dust emission magnitude, or Slight Negative in RIAM definition.

Construction

Construction of new structures is known to generate dust. Given that the marine water will be pumped out before the slipway construction commences, the construction of the new slipway will be conducted in a semi-dry open area and is thus expected to generate varying levels of dust to the ambient environment. However, the key issues when determining the potential dust emission magnitude during the construction phase include the size of the building or infrastructure, method of construction, construction materials, and duration of build. For this assessment, a classification of Small (or Slight Negative in RIAM definition) dust emission magnitude is assigned.

6.3.5 Air Quality Impact Summary

The construction works are expected to have only a minimal transient impact on air quality, which should be maintained through application of the management and mitigation measures as recommended in the respective receptor sections.

6.4 Airborne Noise

Noise is defined as unwanted sound that disrupts normal activities or that diminishes the quality of the environment. It is usually caused by human activity and detracts from the natural acoustic setting of an area, sometimes known as the soundscape. Noise sources that contribute to regional ambient noise levels are typically moving transportation-related sources, including vehicular traffic, ship traffic, and aircraft flyovers. In contrast, noise sources that contribute to local ambient noise levels are generally from fixed point sources, including construction sites, industrial sites, or other places where heavy equipment or noise-generating machinery is used.

6.4.1 Relevant Receptors

The key receptors for noise level changes are ecology and biodiversity (see Section 6.6) and public health (see Section 6.10). The sections below discuss methodology and results of noise assessment conducted in this Study. Noise impacts on these key receptors are discussed separately within their respective chapters.

6.4.2 Methodology

Environmental pressures such as noise emissions will be quantified via an adoption of conservative empirical equations publicly available in relevant international standards and guidelines.

The general approach for assessing noise impacts related to the construction activities consisted of the following sequential steps:

- Identification of relevant noise sources and establishing representative scenario of their usage
- Calculation of nearfield noise level of the identified sources
- Calculation of the propagation of the above-mentioned noise levels in relation to the selected representative receptor
- The resulting noise level results will be compared with tolerance limits of the relevant receptors, or in absence of which, benchmarked against available environmental quality guidelines, either local or international (see next section).

In the assessment of noise, a common statistical descriptor is LAeq. LAeq, which is the constant average noise level which would result in the same total sound energy produced over a period of time. The total equivalent sound level for a given period of time during a particular Construction Phase can be computed as follows:

Equation 1: $L_{Aeq} = 10 \times \log 10 \sum [\, 10^{(LAeq\ i\ /\ 10)}]$ **(dB)**

Where,

$L_{Aeq,\ total}$ = the total equivalent noise level during a given period;
$L_{Aeq,\ i}$ = the equivalent noise level for equipment type, i.

The equation for noise level propagation over a distance is:

Equation 2: $Lp_2 = Lp_1 - 20 \text{ Log } r_2 / r_1$

Where,

Lp_1 = the measured sound pressure level at distance r_1 from the source.

Lp_2 = the calculated sound pressure level at distance r_2 from the source.

r_1 , r_2 = distance from source to measurement Lp_1 and Lp_2, respectively

The following sequence of noise prediction was performed:

- Using Equation 1, the total equivalent sound level / noise emission level for multiple equipment sources was computed. In this case, sound level source refers to powered construction equipment.
- Using Equation 2, total equivalent sound level for equipment, Lp1 (result from Equation 1) was further propagated over a distance at receptors to obtain noise level at receptors due to the equipment (Lp2).
- Using Equation 1, the resultant noise level at receptors due to the equipment (result from Equation 2) was added with background / baseline noise level to obtain cumulative noise level at the receptors.

The predicted cumulative noise level at the receptors will be compared against relevant standard / defined assessment limits to evaluate the potential noise impact to the sensitive receptors.

6.4.3 Assessment Framework

The assessment of noise impacts is discussed in detail in Sections 6.9.2 (for ecological receptors) and 6.10.2 (for human health). This assessment framework references NEA's Environmental Protection and Management (Control of Noise at Construction Sites) Regulations which stipulates construction noise limits in Leq or equivalent sound pressure level (Table 6.3 and Table 6.4). Leq is the average sound pressure level during a period of time, i.e. 5 minutes, 1 hour or 12 hours.

Table 6.3 Maximum Permissible Noise Levels for Construction Site – Weekday (Monday to Saturday)

Types of Affected Buildings	Maximum Permissible Noise Levels dBA		
	7 am - 7 pm	7 pm - 10 pm	10 pm - 7 am
(a) Hospitals, schools, institutions of higher learning, homes for the aged sick.	60 (Leq 12 hrs)	50 (Leq 12 hrs)	50 (Leq 12 hrs)
	75 (Leq 5 mins)	55 (Leq 5 mins)	55 (Leq 5 mins)
(b) Residential buildings located less than 150m from the construction site.	75 (Leq 12 hrs)	65 (Leq 1 hr)	55 (Leq 1 hr)
	90 (Leq 5 mins)	70 (Leq 5 mins)	55 (Leq 5 mins)
(c) Buildings other than those in (a) and (b) above.	75 (Leq 12 hrs)	65 (Leq 12 hrs)	65 (Leq 12 hrs)
	90 (Leq 5 mins)	70 (Leq 5 mins)	70 (Leq 5 mins)

Table 6.4 Maximum Permissible Noise Levels for Construction Site – Sunday and Public Holidays

Types of Affected Buildings	Maximum Permissible Noise Levels dBA		
	7 am - 7 pm	7 pm - 10 pm	10 pm - 7 am
(a) Hospitals, schools, institutions of higher learning, homes for the aged sick	60 (Leq 12 hrs)	50 (Leq 12 hrs)	50 (Leq 12 hrs)
	75 (Leq 5 mins)	55 (Leq 5 mins)	55 (Leq 5 mins)
(b) Residential buildings located less than 150m from the construction site	75 (Leq 12 hrs)	65 (Leq 1 hr)	55 (Leq 1 hr)
	75 (Leq 5 mins)	55 (Leq 5 mins)	55 (Leq 5 mins)
(c) Buildings other than those in (a) and (b) above	75 (Leq 12 hrs)	65 (Leq 12 hrs)	65 (Leq 12 hrs)
	90 (Leq 5 mins)	70 (Leq 5 mins)	70 (Leq 5 mins)

This Study conservatively calculates equivalent sound pressure level from various construction activities assuming at any one time, all the equipment involved in an activity will operate at the same time and that they operate throughout the construction hours. With that, the results presented below are Leq 5 mins and at the same time Leq 1 hr and Leq 12 hrs. In the subsequent impact assessment on human health, the calculated noise levels at the relevant receptors will be benchmarked against Leq 12 hrs (limits with lowest numerical values).

6.4.4 Results and Discussions

Key activities anticipated to be carried out during the Construction Phase for each stage of the development are:

- Demolition of the existing concrete slipway
- Excavation of bedrock over the area of the new slipway where required
- Construction of new reinforced concrete side walls anchored to the bedrock
- Filling and compaction of rock fill material between the walls
- Preparation of the rock fill surface to receive the slipway slab
- Construction of reinforced concrete slipway slab

Detailed construction equipment and activities are not available at time of writing. Four (4) main construction activities are defined in this noise study, each with an assumed list of equipment as outlined in Table 6.5 below. Typical noise levels from this equipment (at 10 m away) are as per Table 6.6.

Table 6.5 Four construction stages and activities considered in this noise assessment

Activity	Description	Assumed Construction Equipment
1	Demolition of Existing Concrete Slipway	1 Breaker 1 Excavator 1 Dump Truck 2 Water Pumps

Activity	Description	Assumed Construction Equipment
2	Excavation of Bedrock + Cofferdam Construction	1 Excavator 1 Dump Truck 2 Piling Rigs 2 Barge 2 Water Pumps
3	Construction of the new reinforced concrete side walls	1 Concrete Mixer Truck + Pump 1 Dump Truck 1 Poker Vibrator 2 Water Pumps
4	Construction of reinforced concrete slipway	1 Concrete Mixer Truck + Pump 1 Poker Vibrator 2 Water Pumps

Table 6.6 Typical sound levels from construction equipment. Sound levels are at 10 m from source. Reference: BS 5228-1:2009 Code of practice for noise and vibration control on construction and open sites.

Equipment	Sound Level (dBA)
Barge	85*
Sheet Steel Piling	63
Breaker	90
Excavator	85
Water Pump	65
Dump Truck	81
Concrete Mixer Truck + Pump	75
Poker Vibrator	78

* Maximum acceptable sound pressure levels (in dBA) on board ships in workspaces

With the typical noise emission data in Table 6.6, the total equivalent noise level for each activity is computed using Equation 1. The calculated total noise emission level from each activity, at 10 m distance, is presented in Table 6.7 below.

Table 6.7 Total noise levels from construction activities at 10 m distance

Activity	Description	Total Noise Level (dBA) at 10 m distance
1	Demolition of Existing Concrete Slipway	91.6
2	Excavation of Bedrock + Cofferdam Construction	90.4
3	Construction of the new reinforced concrete walls	83.6
4	Construction of reinforced concrete slipway	80.0

Equation 2 is then used to compute the resulting noise levels at the relevant noise receptors which includes the nearest mangrove fauna, terrestrial fauna and recreational receptor at OBS Camp 2. The predicted noise levels at the receptors are tabulated in Table 6.8 below. It should be noted that the predicted values are based on a worst-case situation where attenuation or obstacles are not considered. Assessment of noise impacts on these receptors will be discussed in relevant receptor sections (Sections 6.8 and 6.10).

Table 6.8 Predicted noise levels at relevant receptors

Activity	Predicted Noise Emission level (dBA) at Receptor		
	Mangrove fauna (10 m away)	Terrestrial fauna (100 m away)	OBS Camp 2 (220 m away)
Activity 1	91.6	71.6	64.8
Activity 2	90.4	70.4	63.6
Activity 3	83.6	63.6	56.8
Activity 4	80.0	60.0	53.2

6.4.5 Airborne Noise Impact Summary

Noise emissions from construction of the slipway may cause disruption to mangrove fauna and avifauna in the vicinity and nuisance to visitors at OBS Camp 2. The resulting noise levels at these receptors have been calculated, ranging from 80.0 to 91.6 dBA at the former and 53.2 to 64.8 dBA at the latter. Impacts on the noise receptors are assessed in the corresponding receptor sections later in this report (Section 6.8 and 6.10).

6.5 Underwater Noise

This section presents the methodology adopted for quantifying underwater noise resulting from construction piling works, along with the results.

6.5.1 Relevant Receptors

The key receptors for underwater noise changes are aquaculture and marine ecology and biodiversity. The sections below discuss methodology and results of underwater noise assessment conducted in this Study. Impact from the predicted changes on the relevant receptors are assessed in the corresponding section for these receptor groups (Section 6.7 and 6.8).

6.5.2 Methodology

This EIA adopts an acoustic calculation tool that was set up for National Oceanic and Atmospheric Administration (NOAA) Marine Fisheries Service (NMFS) Southeast Regional Office. The tool provides an extensive database of underwater acoustic measurements from a number of marine projects and various behavioural and physiological thresholds for ecological receptors (including fish). The tool estimates potential impact zone of pile driving works through calculation of the distance within which peak sound pressure level or sound exposure level (SEL) has potential to create behavioural or physiological effects on fish.

Inputs to the calculation include:

- Steel sheet pile
- Impact pile driving
- Pile size of approximate 60 cm
- Erection of 1 pile a day
- Seabed is silty sand with hard clay layer
- Transmission loss constant applicable to shallow water

6.5.3 Assessment Framework

Tolerance limits for marine fish are typically expressed in several terms:

- Peak sound pressure level: the largest absolute value of the instantaneous sound pressure expressed in decibels reference to 1 microPascal (dB re: 1 µPa) in water.

- Root Mean Square (RMS): the square root of the average squared pressures over the duration of a pulse.

- Cumulative sound exposure level (cSEL): the energy accumulated over multiple strikes or continuous vibration over a period of time; the cSEL value is not a measure of the instantaneous or maximum noise level but is a measure of the accumulated energy over a period of time to which an animal is exposed.

Outputs from this underwater noise assessment are expressed in those listed statistical metrics to facilitate the assessment of impact significance.

6.5.4 Results and Discussions

It is predicted that sound pressure or exposure levels within 300 m from the work area have potential to create onset of physical injury to fish. Shift in fish behaviour could be expected for up to 4.6 km from the site. Receptor specific assessments (consider sensitivity and distance) are presented in Section 6.7 (aquaculture) and Section 6.8 (marine ecology and biodiversity).

Table 6.9 Calculation of distance at which peak sound pressure level and cumulative sound exposure level meet threshold value of fish

	Onset of Physical Injury			Fish Behavior
	Peak (dB)	Cumulative SEL (dB)		RMS (dB)
	Fish	Fish ≥ 2 g	Fish < 2 g	
Threshold value	206	187	183	150
Distance to threshold (m)	8.6	161.7	298.9	4,641.6

6.5.5 Underwater Noise Impact Summary

Underwater noise emissions from piling works may cause onset of physical injury to fish within 300 m from the work area and shift in fish behaviour beyond 4 km from the project site. Impacts on the underwater noise receptors are assessed in the corresponding receptor sections later in this report (Section 6.7 and 6.10).

6.6 Maritime Transport and Infrastructure

The short-term impacts arising from the Project on maritime transport and infrastructure are assessed within this section. Specifically, impacts on the following receptors will be assessed:

- OBS Camp 2 Jetty
- Serangoon Harbour (navigation channel)

6.6.1 Relevant Pressures

Marine navigation and berthing/unberthing activities are sensitive to the following pressures:

- Alteration in space available for berthing/unberthing
- Hydrodynamic changes
- Sedimentation

Short-term hydrodynamic changes and sedimentation are predicted using robust numerical tools. Model results are presented in Sections 6.1 and 6.2. Impacts from these changes and from the potential reduction of navigational space are assessed herein, along with the relevant assessment framework.

6.6.2 Assessment Framework

There is no evaluation framework for assessing impact from reduced space for navigation activities. The assessment presented in this report is based on DHI's expert judgement and experience in marine navigation risk studies. The sections below present the evaluation framework for change in current speed and for sedimentation.

The assessment also requires a framework for ranking importance of this group of receptors. For this purpose, the standard definitions of Importance in the RIAM framework (Section 4.3.2) are adopted.

Hydrodynamic Changes

The main environmental changes affecting navigation and their thresholds indicating significant impact are presented in Table 6.10. Changes in current conditions can affect the safe passage and manoeuvring of vessels.

Table 6.10 Environmental changes affecting navigation

Environmental change	Thresholds and objectives for navigation
Changes to mean current speeds	Changes in mean current speed less than 0.05 m/s are typically considered as "No Change"
Changes to maximum current speeds	Changes in 95th percentile current speed less than 0.1 m/s are typically considered as "No Change"
Exceedance of 2.0 and 3.5 knots	Minimal increases in current speeds. Changes in exceedance of these representative current statistics of less than 2% to 4% are typically considered as 'No Change.'

Environmental change	Thresholds and objectives for navigation
Slackwater duration	Maintenance of berthing and unberthing windows. Changes of less than 2% to 4% are typically considered as 'No Change.'
Shear Zones and eddy currents	Their presence may indicate an impact

Sedimentation

Navigation channels and berthing areas are susceptible to incremental sedimentation, which may result in increased maintenance costs associated with maintenance dredging.

In the field, redistribution mechanisms such as the effect of propeller wash and the inherent accuracy limits of bathymetric surveys make detecting small incremental changes to sedimentation against background variability very difficult, with a potential measurable change typically being taken as about 150 mm. For this EIA, 150 mm/year has thus been set as the lower limit for measurable change labelled as 'Minor Change,' and other limits set are presented in Table 6.11.

It is noted that there is presently a degree of uncertainty in the suitability of 50 mm/year reflecting 'No Impact'. Although this is well below the limit that can be reliably measured in the field, some facility operators claim realised impacts for changes in the order of 10 mm/year or less. Whilst standard practice cannot support such low limits, the fact that claims have been made on changes falling in the 'Slight' or 'No Impact' categories must be flagged as a risk factor in the application of the proposed tolerance limits for EIA/ES purposes.

Table 6.11 Tolerance limits for marine infrastructure to excess (i.e., in addition to background) sedimentation

Magnitude	Definition
No Change	• Less than 50 mm/year
Slight Negative Change	• Between 50 to 150 mm/year
Minor Negative Change	• Between 150 to 300 mm/year
Moderate Negative Change	• Between 300 to 500 mm/year
Major Negative Change	• More than 500 mm/year

6.6.3 Results and Discussion

Reduction in Navigation Space

During construction phase, an additional width of 70 m of sea space, as work area, is required beyond the sheet pile boundary (Figure 2.4). The work area is required to accommodate working barges and construction equipment such as piling rigs for the purpose of constructing and extracting the sheet piles. The maritime transport receptors of concern are limited to the boats owned by OBS, assessing the OBS Camp 2 jetty.

The presence of the work area potentially affects marine transport and navigation at the floating pontoon primarily through the reduction of sea space available for vessels to manoeuvre given a 20 m gap in between. Given that the area designated for construction works is not expected to be occupied 100%, a large enough sea space for a vessel to turn around remains available. In the worst case where work area is occupied, the berthing/unberthing operation could still take place at the jetty which is at the opposite side of the working area. Additionally, as the project area and its vicinity are assessed only by OBS boats, it is not expected that the other vessels plying the nearby area will be affected. This effect is therefore assessed as 'Minor Change' considering it is observable on-site during construction phase.

Hydrodynamic Changes

It is evident from the model results presented in Section 6.1 that changes to current field induced by the Project are confined to a local area around the slipway. Changes to other hydrodynamic statistical parameters are tabulated in Table 6.12.

Table 6.12 Changes in mean and 95th percentile current speed and in representative current speed arising from construction phase at key maritime transport and infrastructure receptors to the Project.

Receptor	OBS Camp 2 Jetty	Serangoon Harbour
Change in mean current speed (m/s)	<0.05	<0.05
Change in 95th percentile current speed (m/s)	<0.1	<0.1
Change in exceedance of 3.5 knot (% time)	<2%	<2%
Change in exceedance of 2 knot (% time)	<2%	<2%
Change in slackwater duration (% time)	<2%	<2%

Based on the evaluation framework presented in Section 6.6.2, these changes are assessed as 'No Change'.

Sedimentation

The sedimentation results presented in Section 6.2 show that sedimentation due to the piling activities is highly confined to the vicinity of the project area, showing up to 35 mm sedimentation over 14 days at the immediate vicinity of the piling area. Little sedimentation is observed at the approach channel to OBS Camp 2 Jetty and in Serangoon Harbour. It is understood that the piling activities occur only during the erection and removal of the sheet piles which take place approximately over 2 weeks during the beginning and end of the construction phase. Given the short construction timeframe and localized sedimentation rate observed, it is therefore assessed that the predicted change is classified as 'No Change'.

6.6.4 Maritime and Transport Impact Summary

The relevant impacts on maritime transport and infrastructure receptors have been assessed and summarized in Table 6.13. The predicted changes to hydrodynamic conditions and sedimentation will likely result in No Impacts to OBS Camp 2 Jetty operation and to the nearby navigation channel, i.e., Serangoon Harbour.

Table 6.13 RIAM results for construction phase impacts on maritime transport and infrastructure.

Impact on Receptors	Predicted impacts without Mitigation							Mitigation Measures	Mitigated Impact Significance
	Impact Significance	ES	I	M	P	R	C		
Navigation space constraint at OBS Camp 2 Jetty	Slight Negative	**-24**	2	-2	2	2	2	None required	Slight Negative
Hydrodynamic impact on OBS Camp 2 Jetty	No Impact	**0**	2	0	2	2	2		No Impact
Hydrodynamic impact on Serangoon Harbour	No Impact	**0**	4	0	2	2	2		No Impact
Sedimentation impact on OBS Camp 2 Jetty	No Impact	**0**	2	0	2	2	2		No Impact
Sedimentation impact on Serangoon Harbour	No Impact	**0**	4	0	2	2	2		No Impact

6.7 Aquaculture

This section presents the evaluation framework and assessment of short-term impacts on the nearby aquaculture receptors, specifically the fish farms south of Pulau Ketam.

6.7.1 Relevant Pressures

The relevant pressures in this assessment include:

- Short-term increase in suspended sediment
- Underwater noise from marine construction works
- Water pollution resulting from unplanned accidents (spills/leaks)

The model-predicted incremental suspended sediments and underwater noise are discussed in earlier sections of this report. The sections below describe the relevant assessment framework and discusses the effects of these environmental changes on the nearby aquaculture farms, at Pulau Ketam.

6.7.2 Assessment Framework

In this assessment, no receptor-specific Importance evaluation framework is adopted. The standard definitions of Importance in the RIAM framework (Section 4.3.2) are used.

For the evaluation of Magnitude of Change, the following tolerance limits are referenced (relevant for suspended sediments and underwater noise). There are no tolerance limits for assessing impacts from accidental spills or leaks – the general definitions of Magnitudes of Change as per RIAM framework apply.

Suspended sediments

The tolerance of fish to suspended sediments varies widely from species to species. In general, fish in open water environments will move away from areas of high suspended sediment concentration (so-called turbidity barriers) to seek new habitats. If there has been no permanent damage to a fish's natural habitat in a given area (e.g., coral reef), the fish will eventually return after the suspended sediment loading has been removed.

The situation is clearly different for cage culture as the fish cannot move out of the affected area. Elevated concentrations will predominantly affect respiration of the fish, which will have effects on growth rates under sub-lethal loading. Other issues relate to the clogging of the nets surrounding the cages with resultant depression in water quality within the cage due to reduced flushing. This clogging will increase in areas with high SSC.

The limit above which an impact to aquaculture from incremental suspended sediment levels may occur is a daily mean incremental increase of 3.9mg/l per continuous 7-day period. Any incremental increase below 3.9mg/l does not constitute an impact.

Table 6.14 Tolerance limits of aquaculture fish to suspended sediment

Severity	Definitions
No Impact	• Excess Daily Suspended Sediment Concentration < 3.9 mg/l daily mean over continuous 7-day period
Slight Impact	• Excess Daily Suspended Sediment Concentration > 3.9 mg/l daily mean over continuous 7-day period

Underwater Noise

One of the most important factors when considering the impact of sound exposure in fish is the presence or absence of a gas bladder in the body. The presence of a gas bladder, and its anatomical location within the body, make fish more susceptible to pressure-mediated injury to the ears and general body tissues than species that lack gas bladders (Carlson, 2012). Fish species with gas bladders are also likely to be able to detect sounds over a broader frequency range and at a greater distance from the source than fish without such structures, thereby increasing the range from the source over which man-made sound sources have the potential to exert influence (Popper et al., 2014).

Under Popper et al.'s (2014) guidelines, mortality and potential mortal injury is expected at 207 dB re $1\mu Pa^2 s$ while temporary threshold shifts (TTS) in hearing can be expected at 186 dB re $1\mu Pa^2 s$. Similar thresholds were reported for fish in the earlier referenced tool used by NOAA. Onset of physical injury in fish is reported to be at cumulative sound exposure level of 187 dB re $1\mu Pa^2 s$ for fish larger than 2 g and 183 dB re $1\mu Pa^2 s$ for smaller fish. Injury onset can also happen if peak sound pressure exceeds 206 dB re $1\mu Pa^2 s$. The NOAA guidance also provides a threshold for behaviour shift in fish (without injury onset), at root mean squared sound pressure of 150 dB re $1\mu Pa^2 s$. This Study adopts the thresholds reported by NOAA.

6.7.3 Results and Discussions

Suspended Sediments

It has been concluded in Section 6.2.4 that increase in mean SSC is limited and is confined to a very localised area around the project footprint. This is due to the plan that sheet piles will be erected around the work area to contain sediment plume from otherwise marine works. The only sediment plume that may be generated is from sheet pile erection process or piling works. At the nearest aquaculture receptors which are about 800 m away, the mean incremental SSC is predicted to be less than 1 mg/l (Table 6.15). According to the tolerance limits presented above, this level of change is assessed as 'No Change'.

Table 6.15 Predicted mean incremental SSC (mg/l) (above background concentrations) at aquaculture farms south of Pulau Ketam

Aquaculture Receptor	Mean incremental SSC (mg/l)	
	NE Monsoon	SW Monsoon
Pulau Ketam Aquaculture Farms	< 1.0	< 1.0

Underwater Noise

It is discussed in Section 6.5 that the planned sheet piling works create underwater disturbances in the study area. The potential impact zone for fish is up to 300 m from the noise source, beyond which some behavioural effects should be expected.

The nearest aquaculture farm to the Project is about 800 m away, on Pulau Ubin side of the channel, and 2.3 km away, on Pasir Ris side. The farthest ones are 2.7 km and 3.6 km away. All the farmed fish are therefore out of the major impact zone but still within behavioural impact zone. This magnitude of change is assessed as 'Slight Negative'.

Vessel Collision

Movements of construction vessel for OBS Camp 2 marine works might increase the risk of collision with the fish farms south of Pulau Ubin and Pulau Ketam as these vessels transit their way into the working area. There might also be collision risk towards fish farmers' boats plying in this area.

Based on the preliminary construction plan at the time of writing, only two (2) barges will be deployed for the purpose of constructing and removing ERSS and these activities take place for two (2) weeks at the beginning and towards the end of the construction period. During the period of slipway construction within the ERSS boundary, these barges will be berthed within the designated area as shown in Figure 2.4 and no other marine vessel movement outside the designated area is expected. The level of change is assessed to be 'No Change' given the low frequency of construction vessel movements and that they shall comply with the local navigation guidelines and requirements.

Spill and Leaks

There is also a risk from impact of an oil spill incident arising from the vessels. Construction activities typically involve machineries and equipment with fuel inventory. In the event of accident, the current in the area may bring the spilled fuel or chemical to the nearby fish farms. It is qualitatively assessed that an oil spill at the slipway construction area will likely cause measurable change in water quality at the farms.

However, the assessment also considers the likelihood of such event. Oil spill risk presently exists in the current usage of OBS Camp 2 slipway and jetty. Addition of a few construction vessels may alter this risk. It should be noted that there are standard fuel and hazardous material handling practice and regulations that the contractor shall comply with. These procedures, and the plan to use sheet piles to contain construction works, will likely control the risk of water pollution. With that, it is assessed that the risk of oil spill impact on aquaculture farm is a Slight Change.

6.7.4 Aquaculture Impact Summary

The Construction Phase impacts from the Project construction works on aquaculture receptors have been summarised in Table 6.16. No impacts are predicted to the aquaculture farms at Pulau Ubin as a result of sediment plume or underwater noise from the proposed piling works. Slight Negative Impact is predicted in relation to unplanned loss of inventory containment.

Table 6.16 RIAM results for Construction Phase (short-term) impacts from the Project on aquaculture receptors, with and without mitigation measures.

Impact on Receptors	Predicted impacts without Mitigation							Mitigation Measures	Mitigated Impact Significance
	Impact Significance	ES	I	M	P	R	C		
Sediment plume impact on caged fish	No Impact	0	3	0	2	2	2	None required	No Impact
Underwater noise impact on caged fish	Slight Negative	-18	3	-1	2	2	2		Slight Negative
Vessels collision	No Impact	0	3	0	2	2	2		No Impact
Impacts from unplanned water pollution (spills/leaks)	Slight Negative	-18	3	-1	2	2	2		Slight Negative

6.8 Marine Ecology and Biodiversity

Construction activities associated with marine works can result in changes in hydrodynamics, and in the sediment, concentration loads in the surrounding water. Sediment spill from piling works may temporarily increase the concentration of suspended sediments, resulting in increased turbidity. Additionally, temporary construction laydown area and operating equipment on terrestrial grounds can produce varying levels of noise and air pollution that propagate towards adjacent terrestrial habitats and cause impacts to terrestrial fauna.

This section will examine the impacts of environmental changes arising from the slipway construction activities, including increase in SSC and other environmental deteriorations such as air and noise pollution. Direct impacts, which are a result of a project's direct coverage or physical removal of ecological resources within the project areas as a result of the development, including excavation works, are addressed in the Section 7, as these are a long-term or produce permanent effect.

6.8.1 Relevant Pressures

To evaluate the short-term impacts of construction activities from the development to the marine and terrestrial ecological receptors in the area, the following sources of "pressure" have been assessed:

- Airborne noise which likely impacts mangrove fauna adjacent to the work area
- Increased suspended sediments and sedimentation
- Disturbance to marine flora and fauna as a result of underwater noise, construction light, anchor damage, boat-strike and vessel grounding
- Secondary impacts due to changes to marine environmental quality as a result of accidental spills and leaks

6.8.2 Assessment Framework

The assessment of impacts on marine ecology and biodiversity adopts the same Importance evaluation framework as presented for terrestrial ecology (Section 6.8).

For the evaluation of Magnitude of Change, tolerance limits of mangrove fauna towards airborne noise and of fish towards underwater noise pollution are as presented in the sections for terrestrial fauna (Section 6.8) and aquaculture (Section 6.7), respectively. Tolerance of mangroves towards suspended sediment and sedimentation is discussed below. There are no tolerance limits for assessing impacts from accidental spills, leaks or general environmental degradations – the general definitions of Magnitudes of Change as per RIAM framework apply.

Tolerance to Suspended Sediment

A study carried out in Cairns, Australia, demonstrated that 80% of suspended sediments brought to the mangroves from coastal waters at spring flood tide were trapped in the mangroves (Furukawa *et al.* 1997). Sediment particles are carried in suspension into mangrove forests during high tide where they are maintained in suspension due to the turbulence caused by mangrove structures. The particles settle in the mangroves only around low tide, when water turbulence is reduced and when water velocity is not large enough to carry the particles back to the estuary (Kathiresan 2003, Wolanski 1995). However, the vertical accretion of suspended particles also depends on concentration and rare events such as tropical cyclones or floods in nearby rivers (Furukawa *et al.* 1997).

Further observations at Cocoa Creek, a mangrove creek system near Townsville, Australia suggest a complex but strong relationship existing between tidal hydrodynamics, sediment transport and geomorphology (Bryce *et al.* 2003). Given this complexity, there are no clear estimates of thresholds for sediment fluxes in mangroves.

Tolerance to Sedimentation

Mangroves are able to withstand gradual sediment accumulation, as this is part of their natural, dynamic state. However, acute increases in sedimentation due to natural or anthropogenic dumping of material can result in burial of pneumatophores, reducing their ability to supply oxygen to the root system (Wolanski 1995). The most sensitive components of the mangrove ecosystem to sedimentation impacts are seedlings and pneumatophores, as both have a relatively small vertical extent, and may therefore be partially or fully buried by high sedimentation rates within a short period of time.

In simple terms, there are two main types of mangrove root structures: those with stilt roots (e.g. *Rhizophora*) and those with pneumatophores (e.g. *Avicennia*). Mangrove root structures with pneumatophores are normally located on the outer fringe of the mangrove forest with higher tidal range and are thus at higher risk of sediment ingress.

Some field data regarding tolerance levels of mangroves to levels of sedimentation are available. A study by Terrados *et al.* (1997) showed that sediment burial of 8cm and above retarded growth and increased mortality of *Rhizophora apiculata* seedlings as a result of altered oxygen supply to the hypocotyl root system. Experimental field work in Thailand carried out by Thampanya *et al.* (2002) on seedlings of *Avicennia officinalis*, *Rhizophora mucronata* and *Sonneratia caseolaris* showed that *Avicennia officinalis* was five times more sensitive to burial than *Sonneratia caseolaris*, whilst *Rhizophora mucronata* showed no significant difference between the control and burial treatments (0, 4, 8, 16, 24 and 32cm). There was 100% mortality in *Avicennia officinalis* after 225 days at 32 cm burial, and almost 90% mortality at 24 cm.

These figures are consistent with the fact that the pneumatophores of *Avicennia* typically extend 10 cm but can reach 30 cm or more above ground level, such that it requires extensive and prolonged sedimentation to have any effect on respiration.

6.8.3 Results and Discussions

Airborne Noise

Fringing mangrove habitats exist adjacent to the work area, particularly towards the east of it, where several major mangrove trees and fauna species were recorded (Section 5.5.2.2; Table 5.8; Table 5.10). Nonetheless, the one-off nature of the baseline survey conducted there meant that no mangrove-obligate fauna species were recorded. Moreover, given the limited mangrove habitat availability and its fringing nature, the Importance of fauna receptors there was scored at 2.

During construction phase, the fauna and avifauna in this fringing mangrove habitat will be affected by elevated noise levels. It is estimated that sound level at this receptor varies from 80.0 dBA to 91.6 dBA depending on nature of the work, with slipway demolition work being the most noise intensive. Based on the tolerance limits presented in Section 6.8, these noise levels correspond to Moderate to Major Negative Change, therefore the impact significance is predicted to be Minor Negative. Mitigation measures follow the same as those for terrestrial fauna as listed in Table 6.20. Therefore, following mitigation, the residual impact significance is predicted to be Slight Negative (Table 6.17).

Suspended Sediments

The main source of suspended sediment during the Construction phase is from the proposed piling works. As observed in Section 6.2 above, excess suspended sediment concentration of 5 mg/l, 10 mg/l and 25 mg/l are expected to occur less than 2.5 % of the time at the mangrove areas (Figure 5.20 and Figure 5.23). Furthermore, mangroves are considered to be tolerant to varying levels of suspended sediment loading, hence the predicted impacts to mangroves due to very slight increase in suspended sediment in the water will only be very minimal. Therefore, the negligible increase in suspended sediment to the mangrove receptors from the piling works is expected to be No Impact during the Construction phase.

Sedimentation/Erosion

Mangroves can withstand gradual sediment accumulation, as this is part of their natural, dynamic state. However, acute increases in sedimentation due to natural or anthropogenic dumping of material can result in burial of pneumatophores, reducing their ability to supply oxygen to the root system. In this study, it is considered extremely unlikely that sedimentation rates generated from the proposed piling activities would cause undesirable stress on the mangroves found around the project area as sedimentation predicted only occurred at localised extent, away from the adjacent mangrove areas (see Section 6.2). Therefore, the effect of sedimentation to the mangrove receptors from the piling works is expected to be No Impact during the Construction phase.

Changes to seabed can also be induced through alteration of hydrodynamic parameters such as current speed. A question arises during EIA briefing with TAs regarding risk of erosion of Pulau Ubin shoreline (especially the mangrove shoreline to the east) as a result of the presence of the ERSS. From DHI's experience, the shoreline around OBS Camp 2 slipway and jetty is not experiencing erosion. The shoreline segment to the west of the slipway is stable and that to the east is accreting. Coastal morphology is a complex process and actual magnitude is determined by many factors.

Preliminary assessment of hydrodynamically-induced sedimentation and erosion risks is usually done through analysis of bed shear stress. Figure 6.18 presents the predicted changes to 95th percentile bed shear stress in relation to Baseline during NE and SW monsoon. Figure 6.19 presents the predicted changes to the mean bed shear stress. It is anticipated that the ERSS will alter the mean and the 95th percentile bed shear stress by less than 0.10 N/m^2 along the shoreline during both NE and SW monsoon. This magnitude of change does not alter erosion risk to the concerned mangroves.

Mean bed shear stress is predicted to change by less than 0.10 N/m^2 whereas larger but local changes (up to 0.30 N/m^2) are observed for the 95th percentile bed shear stress, underneath the jetty gangway. This magnitude of change could lead to some local redistribution of seabed materials, but rarely happens. With that, and the expected short construction period (~6 months), it is concluded that there will be No Impact on Pulau Ubin shoreline, in terms of erosion.

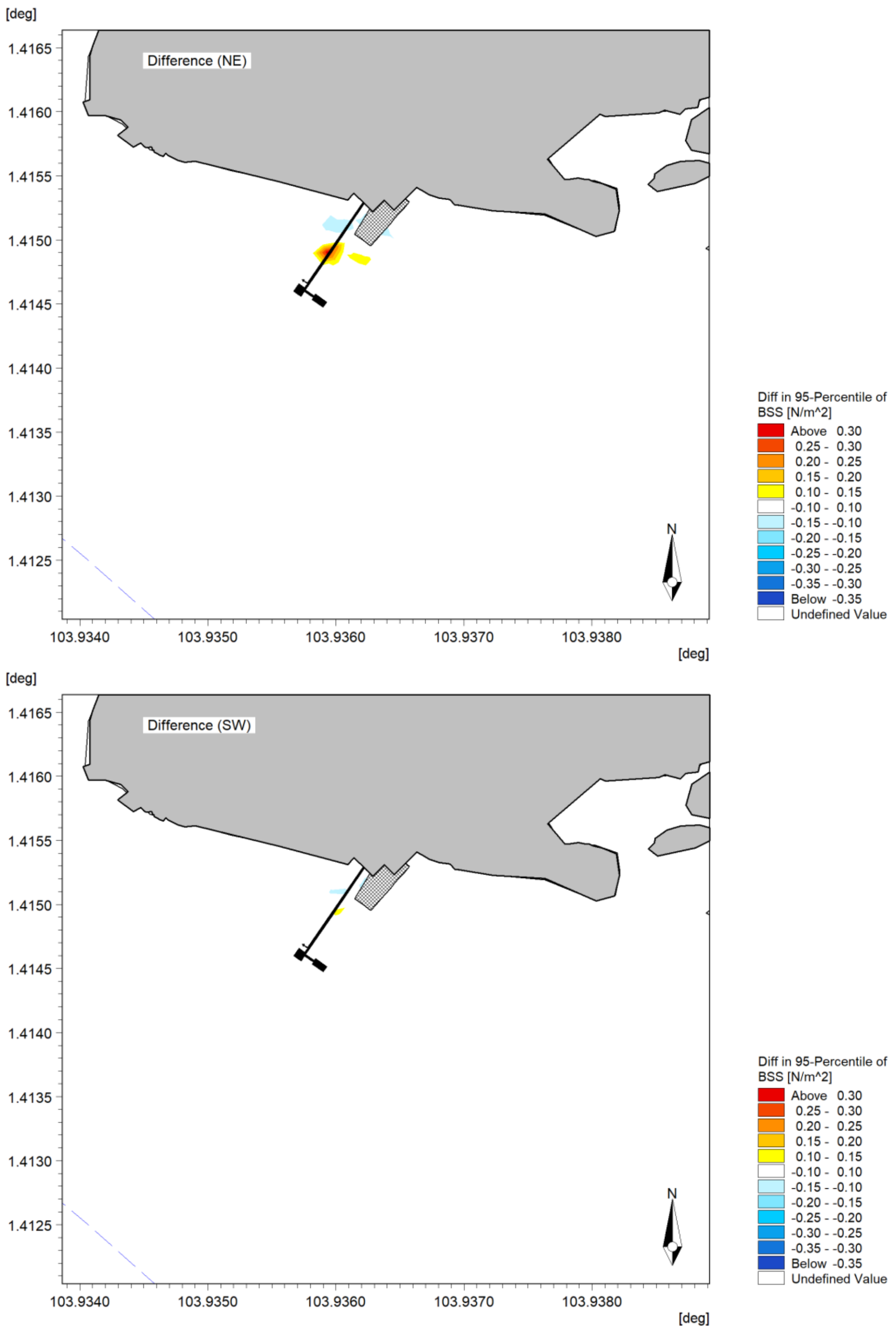


Figure 6.18 Difference in 95th percentile bed shear stress between Construction Phase and Baseline due to the presence of ERSS sheet piles. Top: NE monsoon. Bottom: SW monsoon.

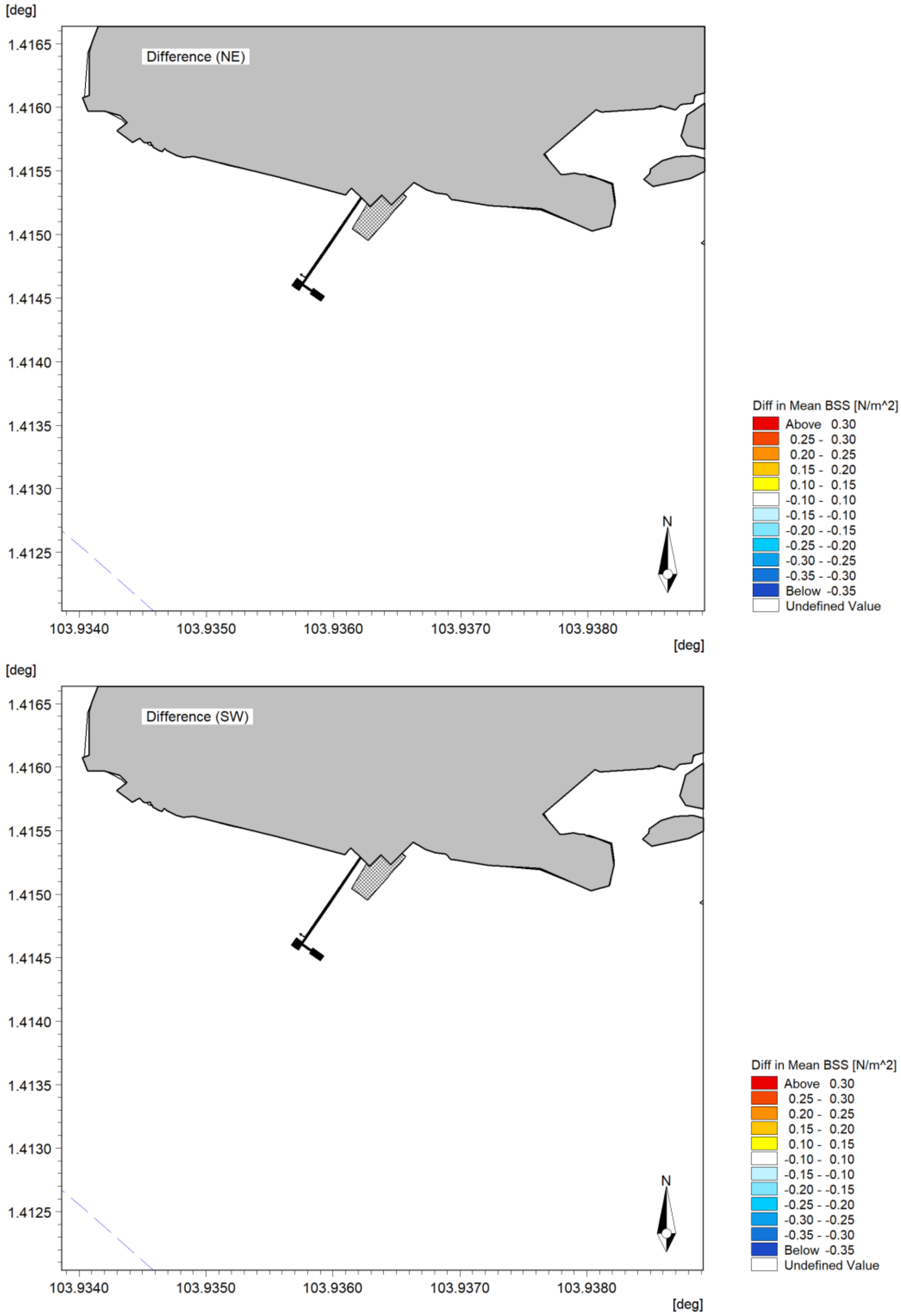


Figure 6.19 Difference in mean bed shear stress between Construction Phase and Baseline due to the presence of ERSS sheet piles. Top: NE monsoon. Bottom: SW monsoon.

Underwater Noise and Other Disturbances on Marine Fauna

Overall, physical and underwater noise disturbance is an issue for protection of key marine species or groups of species (such as mangrove associated fauna and marine fauna). Sheet piling works for the slipway construction has potential to create such disturbances to the marine fauna in vicinity of the project area.

While there are no marine mammals found in close proximity to the Project site, they are however active in Chek Jawa area and can transit marine areas close to the project site. With underwater sound levels within 300 m from the work area exceeds injury threshold for fish and shift in fish behaviour beyond 4 km (Section 6.5), it is an indication that such effect may take place for fish and general marine fauna in vicinity of the project, particularly to marine mammals that use sound / echolocation to communicate. It is assessed that resulting impacts from underwater noise is Minor Negative Impact.

Nevertheless, as marine mammals are mobile, they will likely vacate or avoid the construction area in the scheduled 3-month construction stage where the construction impacts are transient in nature. The displaced marine mammals will likely find refuge in adjacent areas given the presence of large tracts of suitable marine habitats.

Regarding light pollution, all construction works are planned to be conducted during daylight hours. Therefore, the usage of artificial lighting resulting in light spillage is not expected to occur.

Accidental Spills and Trade Effluent (washdown of cement and concrete dust)

There will be a designated onsite storage and handling of pollutive liquids and construction materials such as fuel, lubricant, grouting and cement at land side. If these chemicals and construction materials are not properly stored or handled due to leakages, accidental spillage or poor handling and management practices, they could be washed into the surrounding marine waterbody during a rainfall event. Marine vessel collisions, marine vessel grounding and leaks onboard vessels can all result in uncontrolled release of oil, diesel or oily wastes to the marine environment. While the likelihood of these events is relatively low, piling rigs and barges are expected in the project area during construction, there is some increase in the likelihood of these events compared to the baseline situation. In terms of trade effluent, concrete dust washout into adjacent watercourses may occur during demolition of slipway, while washdown of concrete may occur during construction of slipway.

Spillage of chemicals, drop of waste materials and washdown of concrete increases the concentrations of oil and grease and COD and changes the pH, if uncontrolled and hence the nature of impact is anticipated to be negative. Given the lack of detailed construction plans at the time of writing, it is assumed that there is no hazardous material management and mitigation measures in place. Therefore, the risk of impact is attributed as Slight negative. Nevertheless, the duration of the impact is expected to be short term as the impact only occurs during the construction phase and is controllable with proper site management and reversible upon clean ups. Therefore, the risk of spills and leak impact on marine ecology and biodiversity are not expected to exceed Slight Negative Impact provided the recommended mitigation and preventive measures described in Section 6.11 are followed.

6.8.4 Management and Mitigation Measures

It is assessed that the slipway construction will likely result in several Minor Negative Impacts, related to airborne noise and underwater noise. The mitigation measures for airborne noise and water pollution are as recommended in Section 6.8. Underwater noise impact can be managed through soft start (ramp up) to gradually increase sound pressure levels to drive fish and marine fauna away from the area.

6.8.5 Marine Ecology and Biodiversity Impact Summary

The Construction Phase impacts from the Project construction works on marine ecology and biodiversity have been summarised in Table 6.17. Overall, the impact significance ranges from No Impact to Minor Negative Impact. After mitigation is implemented, the magnitude of change and Environmental Score are reduced for some identified impacts, to Slight Negative.

Table 6.17 RIAM Summary for Construction Phase impacts on marine ecological receptors, with and without mitigation measures.

Impact on Receptors	Predicted impacts without Mitigation							Mitigation Measures	Mitigated Impact Significance
	Impact Significance	ES	I	M	P	R	C		
Airborne noise impact on mangrove fauna	Minor Negative	-48	2	-4	2	2	2	Section 6.9.4	Slight Negative
Suspended sediment impact on mangrove incl. macrobenthos	No Impact	0	4	0	2	2	2	None required	No Impact
Sedimentation /erosion impact on mangrove/ coastline	No Impact	0	4	0	2	2	2	None required	No Impact
Disturbances to wildlife (physical disturbance, underwater noise)	Minor Negative	-72	3	-4	2	2	2	Section 6.8.4	Slight Negative
Accidental spills and trade effluent	Slight Negative	-28	4	-1	2	2	3	Refer to Section 6.11.5	Slight Negative

6.9 Terrestrial Ecology and Biodiversity

The short-term impacts arising from the Project development on identified sensitive terrestrial ecological receptors, specifically fauna and avifauna, are assessed within this section.

6.9.1 Relevant Pressures

To evaluate the short-term impacts of construction activities from the development to the terrestrial ecological receptors in the area, the following “pressures” have been assessed:

- Air pollution from demolition and general construction works
- Airborne noise pollution from mainly piling activities
- Soil pollution due to unplanned spills/leaks

Air and noise emissions have been predicted and discussed in Sections 6.3 and 6.4. The sections below describe the relevant assessment framework and discuss the effects of these environmental changes on the nearby terrestrial biodiversity.

6.9.2 Assessment Framework

Evaluation of Receptor Importance

The generic evaluation of the Importance of ecological and biodiversity receptors, as derived from the BIA Guidelines (NParks 2020), is customised as outlined in Table 6.18. The customisation of receptor Importance considers the context-specificity of Singapore’s ecological landscape, and its constituent biodiversity, habitat types, and conservation values.

Table 6.18 Evaluation of importance of ecological and biodiversity receptors in accordance with the Rapid Impact Assessment Matrix methodology

Score	Generic Definition	Customised Definition
5	Important to national/international interests	• Nationally or internationally designated sites, habitats of biological and ecological importance, e.g. designated Nature Reserves, ASEAN Heritage Park • Natural freshwater streams and freshwater swamps, mangroves • Limited potential for substitution, harbours many species of with a highly restricted distribution range • Contains a high proportion of conservation-significant taxa/species, e.g. listed Critically Endangered in the Singapore Red Data Book • IAQM Site Sensitivity Classification: High
4	Important to regional/national interests	• Large, forested sites (≥30 ha) with closed canopy cover, outside of designated nature reserves • NParks designated Nature Areas • Key habitats for several conservation-significant taxa/species, e.g. listed Critically Endangered in the Singapore Red Data Book • Important for the functioning and integrity of adjacent habitats.

Score	Generic Definition	Customised Definition
		• IAQM Site Sensitivity Classification: High
3	Important to areas immediately outside the local condition	• Forested sites ≥5 ha • Considered to be endangered or vulnerable in the Singapore Red Data Book. • Medium importance and rarity on a national level. • Limited potential for substitution. • Important for the functioning and integrity of adjacent habitats. • IAQM Site Sensitivity Classification: High
2	Important only to the local condition (within a large direct impact area)	• Forested sites ≥1 ha • Habitats with some local biodiversity and potential for substitution. • Modified habitats with limited biodiversity and ecological value, e.g. grasslands and shrubland • Species that are considered least concern in the Singapore Red Data Book. • IAQM Site Sensitivity Classification: Medium
1	Important only to the local condition (within a small direct impact area)	• Species of no national importance • High proportion of weedy/invasive species • Limited ecological importance • Highly modified or fragmented habitats of little to no biodiversity value, e.g. managed turf • IAQM Site Sensitivity Classification: Low

Evaluation of Magnitude of Change

The generic evaluation of the Magnitude of change on ecological and biodiversity receptors, as derived from the BIA Guidelines (NParks 2020), is customised as outlined in Table 6.19. This customised evaluation of the Magnitude of change is based on available and applicable legal standards, international guidelines, and applicable ecological tolerance limits as described in this section. However, it should be noted that such standards, guidelines, and limits do not encompass all ecological considerations, and so expert judgment of the local ecological context and relevant scientific literature also supports the ecological impact assessment where necessary.

Table 6.19 also includes assessment limits related to airborne noise. For terrestrial and freshwater fauna receptors, there are no specific guidelines or thresholds stipulated globally or in Singapore, partly because the effects of noise on most fauna species are poorly understood (Larkin *et al.* 1996, Brown 2001), hence guidance is taken from relevant organisations, literature, and expert judgement. For example, The Nature Conservancy (2015) recommends noise levels to be ideally as low as 55 dB within 100 m from source to protect sensitive animal species. Other studies have suggested that higher noise levels of around 68 dB may reduce birds' foraging ability and eventually lead them to avoid and abandon the habitat (Ortega, 2012). Given that different species have varied tolerance to anthropogenic noise and noise levels (Parris and Schneider, 2008), a noise level of 60 dB is taken as the threshold for terrestrial fauna receptors in this Study, above which detectable changes are predicted. In these scenarios where predicted noise levels at terrestrial fauna receptors exceeds 60 dB, the Magnitude of change, following the RIAM methodology, will be predicted following the framework listed in Table 6.19.

There are no tolerance limits for assessing impacts from accidental spills or leaks – the general definitions of Magnitudes of Change as per RIAM framework apply.

Table 6.19 Criteria used for the scoring of Magnitude of change on biodiversity and ecological receptors. Where multiple criteria result in multiple possible scores, the more conservative score (higher Magnitude) is adopted.

Score	Generic Criteria	Specific Criteria
-4	Major negative disadvantage or change	• Affects the entire habitat or a significant proportion (>70%) of it and the long-term viability or function of the habitat is threatened • Affects entire population or a significant part of it causing a substantial decline in abundance or change in and recovery of the population (or another dependent on it) is not possible either at all or within several generations due to natural recruitment • Predicted noise level exceeded 85 dBA, likely resulting in death or injury of fauna receptors
-3	Moderate negative disadvantage or change	• Affects part of the habitat (40-70%) but does not threaten the long-term viability or function of the habitat • Effect causes a substantial change in abundance or reduction in distribution of a population over one or more generations but does not threaten the long-term viability or function of that population, or any population dependent on it • Predicted noise level cause an increase of greater than 10 dBA as compared to baseline level • Or predicted noise level of 75-85 dBA, resulting in evident physiological and anatomical changes, and low survivability and biological fitness of fauna populations
-2	Minor negative disadvantage or change	• Affects only a small area of habitat (10-40%) such that there is no loss of viability or function of the habitat • Effect does not cause a substantial change in the population of the species, or other species dependent on it • Predicted noise level cause an increase of up to 10 dBA as compared to baseline level • Or predicted noise level of 65-75 dBA, resulting in significant behavioural changes in fauna (change in feeding patterns, predator-prey interactions, reduced ability to maintain territories and increased aggression between individuals)
-1	Slight negative disadvantage or change	• Very limited loss of habitat (<10%) • Effect is within the normal range of natural variation accustomed to by the population of the species

Score	Generic Criteria	Specific Criteria
		• Predicted noise level cause an increase of up to 5 dBA as compared to baseline level • Or predicted noise level of 60-65 dBA, resulting in temporary/recoverable shifts in fauna behaviour (e.g., change in vocalisation pattern or avoidance of areas with acoustic pollution), which are not expected cause a substantial change in species population
0	No change	• Status quo or no loss of habitat • Predicted noise level cause an increase of up to 3 dBA as compared to baseline level • Or predicted noise level below 60 dBA, with no changes in fauna behaviour or populations expected

6.9.3 Results and Discussions

Air Pollution on Terrestrial Fauna

As discussed in Section 6.3, following the IAQM guideline, the dust emission magnitude generated from the demolition, trackout, and construction works of this Project are all predicted to be Small, or in RIAM definition, Slight Negative. Therefore, the risk to terrestrial fauna receptors from dust is correspondingly low as well.

A score of 4 for Importance was attributed to terrestrial fauna receptor given that Pulau Ubin represents a hotspot for mammals, birds, and amphibians in Singapore – taxa which are most sensitive to dust and air pollution. For example, Pulau Ubin represents a stronghold for the locally and globally threatened bird species – the Straw-headed Bulbul (Chiok et al., 2020). Critically Endangered mammal species such as the Malayan Porcupine and Leopard Cat also inhabits Pulau Ubin (Chung et al., 2016; Said et al., 2022).

Nonetheless, the Magnitude of change of air pollution impacts on terrestrial fauna is scored at -1, given the low dust emission magnitude predicted, and the limited spatial footprint of construction works, which does not directly overlap with significant terrestrial habitats. While prevailing southerly winds during the southwest monsoon can carry some of the emitted dust into terrestrial habitats to the north, it is expected to be transient in nature and affect primarily the edge fauna habitats to a marginal extent. Exhausted emission from diesel powered machines and construction vehicles is also expected to have insignificant impacts on terrestrial fauna.

A score of 2 for Permanence was attributed to terrestrial fauna given that increase in air-borne pollutant concentrations is expected to be short-term only during the construction phase. A score of 2 for Recoverability was attributed given that terrestrial fauna is likely to recover from short-term increase in air-borne pollutant concentrations. A score of 2 for Cumulative Impact was attributed given that there are no known construction activities in the vicinity which could have additive effects on ambient air quality at sensitive receptor areas. Therefore, the predicted impact significance of air pollution on terrestrial fauna is Slight Negative (Table 6.21).

Mitigation measures designed to reduce the potential impacts from vehicle emissions and dust generation from construction activities to terrestrial fauna receptors are outlined in Table 6.20 for developer's consideration if desired. With application of these measures, the Residual impact significance is expected to be reduced to No Impact for terrestrial fauna (Table 6.21).

Airborne Noise and Physical Disturbance on Terrestrial Fauna

The potential effects of noise pollution on fauna include physical damage to hearing organs, increased energy expenditure or physical injury while responding to noise, interference with normal animal activities, and impaired communication. The ongoing impacts of these effects can include habitat loss through avoidance, reduced reproductive success and increased mortality. Some fauna become stressed by noise, which can affect foraging or breeding, or they may leave an area, whereas other species or populations do not seem to be affected or may adjust to noise over time.

Noise sensitive fauna taxa includes mammals, avifauna, and herpetofauna. While construction noise is unlikely to cause direct trauma to mammals, studies have shown that noise can potentially damage auditory nerves and affect hearing capability (Slabbekoorn et al., 2018). Furthermore, noise generated during construction works could affect feeding, breeding, and movement patterns which could have negative impacts on long term population levels (Chen et al., 2015). Impacts of noise pollution on avifauna include behavioural changes and physiological responses in birds (Ortega 2012), and interference of auditory cues from prey resulting in reduced hunting success (Simers and Schaub, 2010). Bird activities tend to be affected by increased noise levels as there is masking of signals used for communication, mating and hunting (Bottalico et al., 2015). For herpetofauna, noise pollution impacts vocal taxa such as geckos and frogs by altering their vocal communication patterns, causing them to stop calls, call faster, or change their call frequency (Parris et al., 2009; Brumm & Zollinger 2017). For example, mating calls of frogs may get masked out by construction noises, resulting in reduced reproductive success, physiological stresses, and reduced individual fitness, potentially affecting subsequent population sizes (Bee and Swanson 2007, Tennessen et al., 2018).

Following the methodology in Section 6.4.1, the predicted noise level generated for construction works, for the worse-case scenario, for terrestrial fauna receptors located 100 m away is 71.6 dB. Given that the baseline noise level experienced by terrestrial fauna receptors is approximately 65 dB (see Section 5.4.2), the increment in noise level from baseline condition is taken to be 7 dB. As such, following the evaluation framework in Table 6.19, the Magnitude of change is scored at -2. This is a conservative scoring given the limited spatial extent of noise impacts on fauna, and the mobile nature of terrestrial fauna, which will likely retreat from the short-term noise generated during construction phase.

Consequently, prior to mitigation measures, the impact significance to fauna from noise attributable to the construction activities was predicted to be Minor Negative. A score of 2 for Permanence was attributed given that increase in airborne noise is expected to be short-term only during the construction phase. A score of 2 for Recoverability was attributed to terrestrial fauna, given that when the overall construction is completed, the terrestrial fauna will likely return to the affected edge habitats. A score of 2 for Cumulative Impact was attributed given that there are no known construction activities in the vicinity which could have additive effects on ambient noise level at sensitive receptor areas.

Mitigation measures designed to reduce the potential impacts from airborne noise generated from construction activities to terrestrial fauna receptors are outlined in Table 6.20. Nonetheless, despite the application of these measures, the Residual impact significance is predicted to remain at Slight Negative (Table 6.21), reflecting that a small degree of noise pollution will remain, particularly for the edge habitats nearest to the construction site.

Accidental Spills and Leaks on Terrestrial Ecology and Biodiversity

The containment of pollutive liquids and construction materials, and their potential negative impacts when accidentally released, are outlined previously in Section 6.8.3. Like marine systems, the risk of spills/leak impacts on terrestrial ecology and biodiversity would result in an impact Magnitude of '-1', giving Slight Negative Impact. However, due to the controllable, small, and short-term nature of these impacts, the impact can be reduced to

Slight Negative Impact or No Impact, provided the recommended mitigation and preventive measures described in Section 6.11 are followed.

6.9.4 Management and Mitigation Measures

Considering the assessments above, the following mitigation measures in Table 6.20 are recommended to minimise the potential impacts to ecology and biodiversity receptors.

Table 6.20 Mitigation measures to minimise impacts to ecology and biodiversity during the construction phase

Aspect	Mitigation Measure
Air pollution on terrestrial fauna	• Comply with relevant environmental regulations, including the Environmental Protection and Management Act and any other regulations and guidelines come into effect when the time of construction works commencement. • Suppress and minimise fugitive dust emissions by misting/spraying of exposed earth, particularly during prolonged dry spells/windy conditions • Earth stockpiles should be covered with tarpaulin when not in use • Machineries used on site shall be properly and regularly inspected and maintained to control dust and air pollutants emission. • As part of the machinery's inspection, gaseous pollutants such as CO, NO2 and SO2 should be measured at the emission of machineries and compare against the equipment specification. • Minimize traffic delays caused by movement of construction vehicles by planning transport route and transport period that avoid congested areas and peak hours of road use.
Noise pollution on terrestrial fauna	• No construction works beyond 7pm to avoid impacts of noise pollution on nocturnal fauna • All vehicles and machinery should be properly serviced and maintained to ensure good working condition, thereby reducing noise levels. • Quieter construction equipment and method shall be adopted as much as possible, with reference to NEA's Guideline on Quieter Construction Fund Annex 1 and Annex 2. • Install localised noise barriers or noise enclosures for applicable construction machinery • Site noisy fixed-location equipment (generator sets) as far away from sensitive fauna habitats as possible • Consideration should be given to piling methodologies with the lowest noise emission characteristics
Environmental Quality	• Implement a Major Accident Prevention Plan (MAPP) / Emergency Response Plan for general site activities that covers all incidences of a potential spill or leaks resulting from project activities and equipment.

Aspect	Mitigation Measure
	• Implementation of the recommendations listed in Section 6.11 below in managing risks associated to construction waste and use of hazardous material. • Communication to be established with MPA for the reporting of any oil spill incidents.

6.9.5 Terrestrial Ecology and Biodiversity Impact Summary

The Construction Phase impacts from the Project construction works on terrestrial ecology and biodiversity have been summarised in Table 6.21. Overall, the importance of the identified ecology and biodiversity receptors, within Singapore's terrestrial ecological context, are high, given that Pulau Ubin is designated Nature Area which harbours many threatened flora and fauna species, and also substantial tracts of relatively mangrove and intertidal habitats such as mudflats and seagrass meadows. Nonetheless, despite the high ecological importance, the Magnitude of change was generally low or below defined tolerance limits, given the limited spatial and temporal extent of this Project, and the non-overlap of the project footprint with sensitive ecological habitats. Therefore, the resultant impact significance is predicted to range between No Impact and Slight Negative. After mitigation is implemented, the magnitude of change and Impact Score are reduced for some identified impacts, which are shown in Table 6.21.

Table 6.21 RIAM Summary for Construction Phase impacts on terrestrial ecological receptors, with and without mitigation measures.

Impact on Receptors	Predicted impacts without Mitigation							Mitigation Measures	Mitigated Impact Significance
	Impact Significance	ES	I	M	P	R	C		
Air pollution on terrestrial fauna	Slight Negative	-24	4	-1	2	2	2	Refer to Section 6.9.4	No Impact
Noise pollution and disturbances on terrestrial fauna	Minor Negative	-48	4	-2	2	2	2		Slight Negative
Accidental spills and trade effluent	Slight Negative	-24	4	-1	2	2	2	Refer to Section 6.11.5	Slight Negative

6.10 Recreational and Public Health

The short-term impacts arising from the Project development on social and recreational receptors located in the vicinity of the project area are assessed within this section. Specifically, impacts on the following receptors will be assessed:

- Participants and staff at OBS Camp 2
- Recreational users (e.g., kayaking)

6.10.1 Relevant Pressures

To evaluate the short-term impacts of construction activities from the development to the recreational receptors and human health in the area, the following "pressures" have been assessed:

- Air pollution from demolition and general construction works
- Airborne noise pollution from general construction works
- Short-term increase in suspended sediment, in relation to visual impact.

Sediment plume and air and noise emissions have been predicted and discussed in Sections 6.2, 6.3 and 6.4 respectively. The sections below describe the relevant assessment framework and discuss the effects of these environmental changes on the nearby human receptors.

6.10.2 Assessment Framework

Evaluation of Receptor Importance

The evaluation of importance of socio-economic receptors adopts the framework as presented in Table 6.22. The assessment of air quality impact follows sensitivity definitions as per IAQM framework. The UK framework's definitions are mapped into RIAM scoring system to facilitate the subsequent environmental scoring.

Table 6.22 Evaluation Framework for Sensitivity and Importance of Socio-Economic Receptors. IAQM's definitions of receptor sensitivity are also included.

Score	IAQM Site Sensitivity Classification	Generic Definition	Customised Definition
5	High	Important to national/ international interests	The receptors affected are specifically protected by national or international policies or legislation and are of significance at the regional or national scale
4	High	Important to regional/national interests	Locations where more sensitive members of the public are exposed for eight hours or more in a day, e.g., hospital and residential-care homes
3	High	Important to areas immediately outside the local condition	Locations where members of the public are exposed for eight hours or more in a day, for example, residential properties and schools
2	Medium	Important only to the local condition	Locations where the people exposed are workers and they may be exposed for eight hours or

Score	IAQM Site Sensitivity Classification	Generic Definition	Customised Definition
		(within a large direct impact area)	more in a day, for example, office and shop workers
1	Low	Important only to the local condition (within a small direct impact area)	Receptors with transient exposure, e.g., recreational users of parks and playgrounds, visitors to place of worship

Evaluation of Magnitude of Change

Air Quality

Magnitude of air pollution is in Section determined to be Small based on an assessment framework by the Institute of Air Quality Management of the UK. i

Airborne Noise

To assess the magnitude of noise impact to human receptors, the predicted noise levels are compared against the criteria stated in NEA's Environmental Protection and Management (Control of Noise at Construction Sites) Regulations. The resulting exceedance is interpreted and categorised into different significance levels as described in Table 6.23. The thresholds presented takes guidance from the Fundamentals of Acoustics adopted by WHO which indicate a change in sound pressure level of 3 dB is just perceptible to the human ear and that of 5 dB is clearly noticeable (Hansen, 1951).

Table 6.23 Evaluation Framework for Magnitude of Change in noise level for human and fauna receptors. Where multiple criteria result in multiple possible scores, the more conservative score (higher Magnitude) is adopted in evaluating the Magnitude of Change.

Score	Generic Criteria	Specific Criteria
-4	Major negative disadvantage or change	• Predicted noise level at NSR exceeded the limit by more than 10 dBA
-3	Moderate negative disadvantage or change	• Predicted noise level at NSR exceeded the limit by between 5 to 10 dBA • Or predicted noise level at NSR cause an increase of greater than 10 dBA as compared to baseline level
-2	Minor negative disadvantage or change	• Predicted noise level at NSR exceeded the limit by between 3 to 5 dBA • Or predicted noise level at NSR cause an increase of up to 10 dBA as compared to baseline level
-1	Slight negative disadvantage or change	• Predicted noise level at NSR exceeded the limit by between 1 to 3 dBA

Score	Generic Criteria	Specific Criteria
		• Or predicted noise level at NSR cause an increase of up to 5 dBA as compared to baseline level
0	No change	• Predicted noise level at NSR exceeded the limit by up to 1 dBA • Predicted noise level at NSR cause an increase of up to 3 dBA as compared to baseline level

Suspended Sediments and Visual Impacts

Piling activities during the construction phase of the Project will generate suspended sediment plumes, which may affect the visual amenity of the area for recreational users. Such impacts are determined through quantitative assessment based on the results of the sediment plume modelling (Section 6.2) and best environmental practice.

In terms of the visual impact caused by suspended sediment plumes generated during construction activities at recreation and tourism locations, the tolerance limits for visual aesthetics provided in Table 6.24 will be adopted for this study.

Table 6.24 Magnitude of condition matrix for visual impact from suspended sediments on recreational receptors during daylight hours

Receptor type	Definition of "No Visual Impact"
Recreational area	Excess SSC > 5 mg/l for less than 2.5% of the time

6.10.3 Results and Discussions

Air Pollution

IAQM framework classifies receptor sensitivity into High, Medium and Low. The classification considers factors such as *exposure duration* (e.g. whether members of the public are expected to spend a substantial amount of time at the location), *sensitivity to exposure* (e.g. workers already exposed to dust in the workplace are less sensitive than the general public, given that they would already have precautions in place under the workplace safety and health regulations), and *importance* (e.g. national parks and nature reserves would be considered sensitive receptors by nature of their importance). The air sensitive receptor here is office occupants who may be exposed to construct dust for only limited number of hours a day. Another possible receptor group is recreational visitors whose exposure is highly transient, hence Low sensitivity.

The sensitivity of the area to human health effects, ecological effects, and dust soiling effects, are determined by assessing the classification of the receptor sensitivity (discussed above) together with other considerations such as *number of receptors*, *distance* from the source, and prevailing *background* concentrations.

Recreational and community sensitive receptors within the 350 m buffer from the Project area include the participants and staff at OBS Camp 2 on the land side and kayakers around Pulau Ubin on the marine side. OBS Camp 2 office occupants are about 220 m away. With the construction activities at the site, likely the recreational receptors (kayak activities) will not be close to the site. It is reasonable to assume they will be at least 50 m away. Combining such information with low number of office occupants/recreational receptors, background concentration from the baseline study (Section 5.4), the risk of air quality impact on human health is assessed to be Low.

Airborne Noise Pollution

The evaluation of importance of noise sensitive human receptor follows the same framework as presented in Table 6.22. The evaluation of magnitude of noise impact is based on the resulting exceedance compared against the permissible construction noise limits and categorised into different significance levels as described in Table 6.23.

Section 6.4 has identified the different construction activities and computed the respective construction noise emission level propagated over a distance at the receptor. The activity with the highest predicted noise emission level at OBS Camp 2 which is the nearest noise sensitive human receptor would generate 64.8 dBA which is just below the maximum permissible noise level of 65 dBA.

As such, the impact Magnitude is rated 0 as the predicted noise contribution from the works are below the defined threshold limit. The significance from noise attributable to the construction activities to human receptors are considered to be ‘No Impact’. Nonetheless, the mitigation measures proposed in Section 6.10.4 should be implemented throughout the works to ensure the construction noise levels are kept within an acceptable range.

Visual Impact from Suspended Sediment Plumes

The piling activities at the marine area have the potential to emit visible sediment plumes that travel away from the project site and impact recreational users. Kayakers are susceptible to visual aesthetic appearance of the waters that could be compromised by the incremental SSC found. Visual aesthetic impact on recreational receptors is primarily assessed based on the percentage of time that incremental SSC exceeds 5 mg/L in comparison to the visual impact tolerance limits as described in Table 6.24.

Based on the sediment plume results of construction works (Section 6.2), the exceedance of 5 mg/L is generally confined within the vicinity of the piling works area due to the low current conditions and low piling production rate. The public recreational users are not expected to kayak near to the OBS Camp 2 jetty or slipway. It is hence assessed that the exceedance of 5 mg/L is predicted to be below the tolerance limit for visual impact.

6.10.4 Management and Mitigation Measures

Considering the assessments above, the following mitigation measures in Table 6.25 are recommended to minimise the potential impacts to human receptors.

Table 6.25 Mitigation measures to minimise impacts to human receptors during the construction phase

Aspect	Mitigation Measure
Air pollution on human receptors	• Comply with relevant environmental regulations, including the Environmental Protection and Management Act and any other regulations and guidelines come into effect when the time of construction works commencement. • Suppress and minimise fugitive dust emissions by misting/spraying of exposed earth, particularly during prolonged dry spells/windy conditions • Earth stockpiles should be covered with tarpaulin when not in use • Machineries used on site shall be properly and regularly inspected and maintained to control dust and air pollutants emission. • As part of the machinery’s inspection, gaseous pollutants such as CO, NO_2 and SO_2 should be measured at the

Aspect	Mitigation Measure
	emission of machineries and compare against the equipment specification.
Airborne Noise Pollution on human receptors	• To comply with relevant environmental regulations, including the Environmental Protection and Management Act and any other regulations and guidelines come into effect when the time of construction works commencement. • Quieter construction equipment and method shall be adopted as much as possible, with reference to NEA's Guideline on Quieter Construction Fund Annex 1 and Annex 2. • Install localised noise barriers or noise enclosures for applicable construction machinery • Site noisy fixed-location equipment (generator sets) as far away from the site boundary as possible

6.10.5 Recreational and Public Health Impact Summary

With the above proposed mitigation measures, the magnitude of change is re-evaluated, and the residual impact significance is presented in Table 6.26.

Table 6.26 RIAM results for Construction Phase (short-term) impacts from the Project on recreational and public health receptors, with and without mitigation measures.

Impact on Receptors	Predicted impacts without Mitigation							Mitigation Measures	Mitigated Impact Significance
	Impact Significance	ES	I	M	P	R	C		
Air pollution on human health	Slight Negative	-12	2	-1	2	2	2	Refer to Section 6.10.4	No Impact
Airborne noise pollution on human receptors	No Impact	0	2	0	2	2	2	None required	No Impact
Visual impact from SSC	No Impact	0	2	0	2	2	2	None required	No Impact

6.11 Hazardous Material & Waste Management

This section provides an overview of the hazardous materials and waste relevant to this project, assess the potential impacts to the identified sensitive receptors and outline the measures recommended for mitigating these impacts.

The International Finance Corporation (IFC) General EHS Guidelines definitions for both materials are as follows:

Hazardous materials

- Any materials that represent a risk to human health, property, or the environment due to their physical or chemical characteristics. Examples of these materials include spent oil from petrol and diesel engines, hydraulic oil from machine cylinder, fuel and oil required for machinery upkeep.

Waste materials

- Any solid, liquid or contained gaseous material that is being discarded,
- Inert construction / demolition materials such as metal scrap, excavated material and scrap concrete (except those previously used to contain hazardous materials which should, in principle, be managed as a hazardous waste)
- Under the same Guidelines, it defines hazardous waste as wastes that share the properties of a hazardous material (e.g. ignitability, corrosivity, reactivity, or toxicity), or other physical, chemical, or biological characteristics that may pose a potential risk to human health or the environment if improperly managed.

6.11.1 Assessment Framework

To assess the potential impacts from hazardous materials and construction wastes, an inventory of the waste and hazardous materials associated with proposed project construction activities are compiled. The predicted environmental risks and impacts associated with these materials are outlined and assessed according to the magnitude of the potential environmental pressures.

The following regulations, code of practices and guidelines were referred to for the creation of mitigation measures:

- SS 593: 2013, Code of practice for pollution control
- NEA, Management of Toxic Industrial Wastes in Singapore
- G.N. No. S 159/1999, Environmental Protection and Management (Hazardous Substances) Regulations Revised Edition 2008
- G.N. No. S 116/1989, Environmental Public Health (General Waste Collection) Regulations
- NEA, Guidelines on Enhanced Security Measures for Facilities Storing Hazardous Substances
- IFC 2007, General EHS Guidelines

6.11.2 Hazardous Material & Waste Inventory

The Project comprises land works (demolition of partial slipway) and marine works (sheet piling works and construction of slipway). The wastes generated would require corresponding management procedures and destinations.

Land-based construction waste during the construction phase can be mainly categorized as solid and non-hazardous waste and, hazardous waste. Marine-based construction waste from marine works would be the excavated seabed materials, as well as oily wastes and greywater discharges from the vessels. In terms of hazardous materials, these mainly include fuel, lubricants and cleaning agents for the land-based construction equipment and for the marine vessels.

6.11.2.1 Solid Waste and Non-hazardous Waste from Land Works

Solid and non-hazardous wastes comprise the majority of waste generated during construction. The following is a list of non-hazardous construction wastes that are expected:

- General construction wastes (broken rocks, concrete, bricks, concrete moulds etc.)
- Excavated seabed materials
- Ferrous and non-ferrous scrap metal items
- Packaging/wrapping/containers (plastic, cardboard, paper, metal, wood etc.) for imported operational/materials
- General wastes (food, paper, plastic, metals, and other packaging etc.) relating to site workers and supervisors

6.11.2.2 Excavated Materials from Marine Works

Excavated materials will be generated from the seabed levelling works in preparation of graded stone backfilling. The excavated materials are planned to be backfilled on-site and re-purposed for the slipway construction.

6.11.2.3 Hazardous Material and Wastes

Hazardous wastes classified as Toxic Industrial Wastes (TIW) in Singapore are regulated under the Environmental Public Health (Toxic Industrial Waste) Regulations 1988, and have the potential to cause serious environmental, health, and safety hazards (toxic effects, fire hazard, and so on) unless they are handled, stored, transported, and disposed in accordance with best practice protocols. Construction activities may result in the generation of a variety of hazardous wastes including the following:

- Diesel /fuel for vehicle/vessel operations
- Chemical additives and cleaning agents for vehicle/vessel maintenance
- Spent oil and oil contaminated materials
- Oil and grease from spills or leakages
- Used containers, bags and process equipment contaminated by chemicals from construction activities
- Anti-corrosive and antifouling paints

- Electrical component waste (e.g., used batteries, accumulators)
- Medical / bio-hazardous waste

The environmental impact is not expected to have any long-term or permanent consequences since the transient negative impacts (induced by construction) will be removed once construction is completed. However, if not properly managed environmental pollution may result.

There is limited information on the hazardous materials that will be present during construction. However, the types of hazardous materials are likely to include gasoline, diesel, batteries, degreasers, solvents, and other chemicals.

6.11.3 Influence of Hazardous Material & Waste on Environmental Receptors

The receptors may include the following, depending on their pathway:

- Marine flora and fauna around the project area
- Terrestrial flora and fauna around the project area
- Human comfort and public health

The significance of any changes is discussed in each respective receptor chapter.

6.11.4 Construction Phase Impacts

Based on the inventory provided in Section 6.11.2, a majority of the identified hazardous materials predicted to be used during the construction stage are centred around vehicle maintenance and refuelling activities. The risks and potential impacts associated with these items are outlined in Section 6.11.4.1.

For the purposes of this EIA, all hazardous / toxic wastes (i.e., wastes that share properties of hazardous or toxic materials) shall be assessed alongside other waste types in Section 6.11.4.2 below.

6.11.4.1 Generation and Disposal of Hazardous Materials

The impacts and risks associated with hazardous materials during the construction phase are primarily related to the loss of containment (LOC) events such as spillages and leaks. Table 6.27 below presents plausible contamination events alongside the estimated likelihood and impacts associated with these events. Given the lack of detailed construction plans at the time of writing, it is assumed that no hazardous material management and mitigation measures will be in place when characterising the impacts and risks associated with construction phase activities.

Table 6.27 Characterisation of plausible contamination / loss of containment events

Material Type	Plausible Contamination Event	Event Likelihood (Without Mitigation Measures)	Risk / Impact Level
Paints Solvents Oil & Grease Chemical additives & Cleaning agents	Hazardous material spillages during on-site maintenance activities due to	Likelihood: Moderate due to significant handling Impact: Dispersion and exposure may vary depending on severity and frequency of LOC events. Substantial or persistent LOC events may	Moderate

Material Type	Plausible Contamination Event	Event Likelihood (Without Mitigation Measures)	Risk / Impact Level
	improper handling	contaminate soils and marine water affecting shoreline ecological receptors and nearby marine aquaculture receptors.	
Diesel / Petrol	Fuel spillage during on-site refuelling activities	Likelihood: Moderate due to significant handling and high frequency of refuelling Impact: Dispersion and exposure may vary; substantial or persistent LOC events may contaminate soils and marine water affecting shoreline ecological receptors and nearby marine aquaculture receptors.	Moderate
Diesel / Petrol Paints Solvents Oil & Grease Chemical additives & Cleaning agents	Loss of containment of inventoried hazardous material during marine transport to project site	Likelihood: Low to moderate due to the potential for unsecured hazardous material containers to topple during transport Impact: Loss of containment of hazardous material directly into the surrounding waters would lead a slick that would quickly disperse due to influences from wind and current. Exposure to shoreline and marine ecological receptors including nearby marine aquaculture receptors is possible.	Moderate
Oil & Grease	Accidental leaks of oils or hydraulic oils due to faulty heavy equipment	Likelihood: Moderate to High as oil leaks due to malfunctioning equipment is relatively common Impact: Typical oil leaks are relatively low in volume therefore dispersion and receptor exposure are limited in nature.	Minor

6.11.4.2 Generation of General Waste (Non-Hazardous & Hazardous)

The risks and impacts associated with construction phase waste management are largely dependent on the classification of the waste material. The impacts and risks associated with hazardous wastes (i.e., wastes that share the properties of a hazardous material) are primarily related to the loss of containment (LOC) events such as spillages and leaks whilst non-hazardous waste impacts are typically associated with increasing unnecessary pressure on existing landfill facilities. Table 6.28 below present plausible impact vectors and risk levels associated with the various waste types inventoried. It is assumed that no construction phase waste management plan will be in place when characterising the risk and impacts due to the lack of detailed construction plans at the time of writing.

Table 6.28 Characterisation of plausible waste management related impact events

Waste Type	Waste Classification	Plausible Impact Vectors (Without Mitigation Measures)	Risk / Impact Level
Domestic / general waste (e.g. household materials and food waste)	Non-hazardous	Improper application of waste minimisation and waste reuse, recovery and recycling leading to unnecessary pressures on existing landfill facilities (i.e. Semakau Landfill).	Minor
Decommissioned / demolished materials	Non-hazardous	Improper application of recovery and recycling leading to unnecessary pressures on existing landfill facilities (i.e. Semakau Landfill).	Minor
General construction waste (e.g., re-bar, wires, concrete moulds)	Non-hazardous	Improper application of waste minimisation and waste reuse, recovery and recycling leading to unnecessary pressures on existing landfill facilities (i.e., Semakau Landfill).	Minor
Excavated seabed material	Non-hazardous	Dumping of excavated material in non-designated dumping areas can lead to direct impacts to ecological receptors within the dumping site as well as the surrounding areas.	Minor
Contaminated excavated seabed material	Hazardous	Dumping of contaminated excavated material can lead to the resuspension of heavy metals which may lead to human health concerns through bioaccumulation along the food chain.	Moderate
Maintenance waste (e.g., spent oil, oil contaminated products)	Hazardous	Improper hazardous waste management facilities causing LOC of inventoried hazardous waste which may contaminate surrounding soils and marine waters. Impacts to nearby shoreline ecological receptors, benthic receptors and marine aquaculture receptors is possible.	Moderate
Hazardous material containers and packaging (e.g., waste metal drums with residual solvent / oil)	Hazardous	Improper handling and insufficient hazardous waste management facilities leading to spills / leakages of residual hazardous waste. Contamination of surrounding soils and nearby marine waters is possible. Impacts to nearby shoreline ecological receptors, benthic receptors and marine aquacultural receptors is possible.	Minor
Electrical component waste (e.g., used	Hazardous	Improperly designed and managed hazardous waste facilities may lead to LOC of inventoried hazardous waste (e.g. battery acid) with potential impacts	Minor

Waste Type	Waste Classification	Plausible Impact Vectors (Without Mitigation Measures)	Risk / Impact Level
batteries, accumulators)		to nearby shoreline ecological receptors, benthic receptors and marine aquacultural receptors.	
Medical / bio-hazardous waste	Hazardous	Improper handling of medical waste may cause the spread of human transmissible diseases. Human health impacts to social and recreational receptors are possible.	Moderate

6.11.5 Recommended Mitigation Measures

A Waste Management Plan will be required to be prepared by the Contractor to estimate and log the waste types and volumes for the project and plan for proper handling, storage and disposal methods. Proper segregation and management for each type of waste is needed to sort out recyclable materials and allow cost-efficient treatment and disposal of the waste by licenced waste management organisations. Waste and hazardous materials management shall comply with local regulations and guidelines as listed in Section 3. Below are some management and mitigation measures that shall be observed during construction in handling hazardous material and wastes.

6.11.5.1 Hazardous Materials Mitigation Measures

Table 6.29 presents on overview of the control measures that should be in place regarding hazardous materials during the construction phase of the project.

Table 6.29 Recommended mitigation measures for hazardous materials during the construction phase

Aspect	Mitigation Measure
Management	• An inventory of all anticipated hazardous materials should be created with records of stock movements in accordance with formats specified by National Environment Agency - Chemical Control and Management Department (CCMD) • It is recommended that the construction environmental management plan include a hazardous material management plan with the following: ○ Dedicated hazardous material management procedures for the transport and handling of hazardous materials ○ Dedicated hazardous material management procedures for refuelling ○ Dedicated hazardous material management procedures for the storage of hazardous material ○ Dedicated emergency response procedures specific to the itemised hazardous materials • A training programme be provided for all personnel who handle hazardous material • Standard Operating Procedures (SOPs) be put in place for management of secondary containment structures specifically in

Aspect	Mitigation Measure
	relation to the removal of any accumulated non-hazardous fluid to ensure that the intent of the system is not breached • An inspection and maintenance program be implemented to verify the integrity of containment infrastructure
General Handling and Storage	• Materials should be stored in accordance with their Material Safety Data Sheets (MSDS) • Containers must be designed, manufactured and tested in accordance to an internationally-acceptable standards and affixed with approved labelling • Designated hazardous material storage areas should possess the following features: o Impervious or resistant flooring constructed of combustible, chemically resistant material o Separate fire-resistant compartments for the storage of substances that can react dangerously with one another o Provide sufficient protection to stored hazardous materials from environmental exposure • Areas storing hazardous liquids should at a minimum include the following features: o Possess liquid-tight secondary containment structures capable of containing up to 110% of the largest tank or 25% of the combined storage volume, whichever is greater o Have secondary containment structures designed to prevent contact between substances which can react dangerously with one another o No apertures directly connecting to the sewage system, surface drainage or water body o Fill points for hazardous liquids should be located inside the secondary containment reservoir. o Possess readily accessible spill kits and firefighting equipment appropriate for use with inventoried hazardous material (e.g. oil only, chemical only, general use)
Transport	• It is required that hazardous material transportation methods are designed, constructed and maintained in accordance with approved code of practice • It is necessary that adequate precautionary measures are taken to prevent hazardous substances from exploding, catching fire, spilling, dropping or being released during transportation. • It is required that suitable and efficient fire extinguishers be located on an easily accessible section of the vehicle transporting the hazardous material
Equipment Cleaning and Maintenance	• Cleaning and maintenance activities that involve hazardous materials should be conducted over an impervious bunded surface • Contaminated materials generated during cleaning and maintenance (e.g. oily rags, oil filters, spent oil) should be segregated and disposed of according to the waste management plan

Aspect	Mitigation Measure
Terrestrial Refuelling Area Design	• The following physical measures are recommended for the refuelling area: ○ Automatic shut off bowser nozzles be used when refuelling to decrease risk of overfilling ○ The refuelling area should be located within a secondary containment area that is isolated from surface water drainage ○ The surface of the refuelling area should be constructed of non-combustible, fuel resistant liquid tight material ○ Readily accessible spill kits and firefighting equipment
Security Measures	• It is recommended that enhanced security measures be implemented for facilities storing hazardous substances. Security measures include but are not limited to: ○ Monitoring and detection systems such as CCTV cameras and human based monitoring ○ Security lighting to increase visibility at access points and sensitive locations (i.e. hazardous material storage) ○ Access control to limit access to hazardous materials (i.e. regulated key access, sign-in and sign-out procedures) ○ Documentation and reporting procedures for non-routine incidents

The hazardous material impacts associated with the proposed Pulau Ubin Camp 2 Slipway are primarily associated with the risk of loss of containment (LOC) events. The application of industry best practices, EHS guidelines and national code of practices are required to assure that the residual risks do not result in LOC events and subsequent impacts to ecological receptors.

If diligently applied, the recommended mitigation measures can reduce the risk of hazardous material LOC events to satisfactory **Slight negative** impact levels. These impact levels are considered acceptable for the proposed project operations.

6.11.5.2 Waste Management Mitigation Measures

Table 6.30 outlines the recommended mitigation measures pertaining to waste management during the construction phase.

Table 6.30 Recommended mitigation measures for construction phase waste management

Aspect	Mitigation Measure
Management Plans and Procedures	• It is recommended that a construction waste management plan be created with the following features: ○ An inventory of all anticipated wastes ○ Standard operating procedures (SOPs) for segregation, storage, handling and disposal procedures for each relevant waste stream ○ SOPs for the management of storage facilities

Aspect	Mitigation Measure
	○ A programme in place to avoid the generation of intractable wastes and encourage waste minimisation ○ A programme in place promoting waste reuse, recovery and recycling • Ensure that waste collection schedules are managed to prevent the over capacity of waste storage on site
Storage Facilities	• Waste storage facilities should allow for the segregation of waste materials based on their waste type and classification. (e.g. concrete debris, metals, timber, plastics, recyclables, dredged material, hazardous materials) • Waste storage facilities should have measures in place to minimize the loss of waste material due to environmental conditions (e.g. enclosed skips, fencing) • At the minimum, the designated hazardous waste disposal area should take into account the following: ○ Impervious or resistant flooring that is constructed of non-combustible, chemical resistant material with a perimeter bund or gully leading to a sump (reservoir). ○ Secondary containment for each incompatible hazardous / toxic liquid waste with a minimum containment capacity of 110% of the volume of the largest container ○ The storage area shall be situated at sufficient distances from, and have no apertures connecting directly, onto any sewage system or surface drainage and water body (except for the purpose of collecting accidental spillage) ○ Be fenced or walled, with a roof to limit access and loss of waste material due to environmental conditions ○ Possess readily accessible spill kits and firefighting equipment appropriate for use with inventoried hazardous wastes (e.g. oil only, chemical only, general use)
Hazardous / Toxic Waste	• Ensure that a licensed toxic industrial waste collector is engaged for the collection and disposal of hazardous / toxic wastes • Hazardous / Toxic waste should be stored in containers composed of material suitable for the relevant waste. • Hazardous / toxic wastes should be stored taking into account their properties and compatibilities to prevent reactions during storage, incompatible materials should not be mixed in the same container • Ensure that any potentially biohazardous medical wastes (e.g. bloody bandages, needles) are segregated, stored in containers fit for purpose and collected by an biohazardous waste collector
Excavated / Dredged Material	• Excavated / dredged sediment, if stored on site, should be stored at a bunded temporary stockpile area with sediment control measures at the outlet (e.g. sediment dewatering bag, sediment geotextile filters) • Excavated / dredged sediment should either be reused for the purposes of land reclamation or dumped at offshore dumping and disposal sites

Aspect	Mitigation Measure
	• Chemical testing of the sediment samples is recommended prior to re-use or dumping to assess sediment contamination as per MPA dredging and dumping guidelines.

The impacts associated with waste management at the proposed Pulau Ubin Camp 2 Slipway are primarily associated with the risk of loss of containment (LOC) of stored hazardous / toxic waste and improper disposal, reuse and recycling of construction waste. The application of the above mitigation measures are recommended to ensure that the residual risks to the surrounding ecological receptors and socio-economic receptors do not come to fruition.

If diligently applied, the recommended mitigation measures can reduce the risk associated with waste management to satisfactory **Slight negative** impact levels. These impact levels are considered acceptable for the proposed project operations.

6.11.6 Hazardous Material & Waste Impact Summary

In summary, the quantities and types of wastes and hazardous materials being used during the construction phase are going to be limited due to the relatively small scale of the project. During the land-based construction works, the major type of waste expected is construction waste from the demolition of slipway. Throughout the land-based and marine-based construction, general waste, wastewater and small amount of hazardous waste will also be generated. Potential environmental impacts such as odour and pest nuisances, release of pollutants to the marine environment, can result if the wastes are not properly managed. With proper handling, storage, transport and disposal procedures as stated in Section 6.11.5 and compliance to local regulations and COPs, environmental impacts caused by waste management can be minimised.

Accidental leaks or spills of hazardous materials or wastes poses the greatest environmental risk. SOPs and ERPs should be in place for land-based and marine-based works to ensure that proper measures are implemented to prevent this, and to minimise any impacts in the event of a containment loss.

6.12 Transboundary Impacts

Transboundary impacts refer to any potential impacts that may cross an international border with a neighbouring country. Given the proximity of the project to Malaysia, this section focuses on assessment of the potential short-term changes during the Construction Phase in current direction and speed, suspended sediments, underwater noise and air quality across the border. Impact assessments related to transboundary impacts are guided by strict tolerance thresholds for any changes in these pressures.

6.12.1 Relevant Pressures

The assessment considers transboundary impacts resulting from short-term changes to the following environmental parameters, which may affect navigation, aquatic life and human safety in the waters and lands of the neighbouring country:

- Hydrodynamic changes (Section 6.1)
- Visual aesthetic value of the water as a result of sediment plume (Section 6.2)
- Sedimentation (Section 6.2)
- Water quality changes arising from potential spills and leaks from construction activities
- Effects from air quality (Section 6.3) and underwater noise (Section 6.5)

6.12.2 Evaluation Framework

Potential impacts on transboundary receptors are assessed via evaluating the predicted changes across the border, i.e. in relation to currents, water quality, suspended sediments, sedimentation or erosion, against their tolerance limits. The same sets of tolerance limits as presented in the earlier sections are adopted in this assessment.

For Visual transboundary impacts due to suspended sediment concentrations, given the marine and shoreline usage in the Malaysian waters closest to the proposed development are pre-dominantly non-recreational, a tolerance limit of < 5 % exceedance of 5 mg/l is considered appropriate.

6.12.3 Impact Assessment

6.12.3.1 Currents and Transboundary Navigation

As presented in Section 6.1, DHI's hydrodynamic simulations predict that its construction phase will result in very localized or negligible changes to various hydrodynamic parameters in the study area. Therefore, 'No Impact' is predicted to the currents and transboundary navigation.

6.12.3.2 Suspended Sediment and Transboundary Visual Impact

As presented in Section 6.2, it has been proven through sediment plume simulations that the piling works will result in localised and minimal sediment plume. No change is predicted for areas beyond this. Hence, 'No Impact' is predicted in terms of transboundary visual impact due to suspended sediments from the construction works.

6.12.3.3 Sedimentation and Transboundary Marine Infrastructure

As presented in Section 6.2, it has been proven through sediment plume simulations that sedimentation is predicted at areas in immediate vicinity of the slipway. No change is predicted for areas beyond this. Hence, 'No Impact' is predicted in terms of transboundary visual impact due to sedimentation from the construction works.

6.12.3.4 Water Quality Changes and Transboundary Aquatic Life

Any mismanagement of waste and hazardous materials or vessel collision along the East Johor Strait can lead to a spillage of chemicals or materials and measurable change in water quality. It is noted that the quantities and types of wastes and hazardous materials being used during the construction phase are going to be limited due to the relatively small scale of the project. With proper handling, storage, transport and disposal procedures and compliance to local regulations and COPs, environmental impacts caused by waste management can be minimised or eliminated.

6.12.3.5 Air Quality and Transboundary Human Health

As presented in Section 6.3, the construction works are expected to have only a minimal transient impact on air quality, which should be maintained through application of the management and mitigation measures as recommended in the respective receptor sections. Hence, 'No Impact' is predicted in terms of transboundary air quality impact due to the construction works.

6.12.3.6 Underwater Noise and Transboundary Aquatic Life

It is unlikely that any fish species/marine ecology found across the international border will suffer mortality given the relatively low noise levels predicted from the Project, and the significant distance from the Project site. Hence, underwater noise during the construction phase is not expected to have any measurable impact to the transboundary fish or marine ecology and is therefore considered a 'No Change'.

6.12.4 Transboundary Impact Summary

A summary of the RIAM scores for impacts at the international border is provided in Table 6.31.

Table 6.31 RIAM results for Construction Phase (short-term) impacts from the Project on transboundary receptors.

Impact on Receptors	Predicted impacts without Mitigation							Mitigation Measures	Mitigated Impact Significance
	Impact Significance	ES	I	M	P	R	C		
Changes in the currents speed affecting currents and transboundary navigation	No Impact	5	0	2	2	2	0	None required	No Impact

Impact on Receptors	Predicted impacts without Mitigation							Mitigation Measures	Mitigated Impact Significance
	Impact Significance	ES	I	M	P	R	C		
Visual aesthetic at transboundary due to suspended sediment plumes	No Impact	5	0	2	2	2	0		No Impact
Increased sedimentation at transboundary marine infrastructure	No Impact	5	0	2	2	2	0		No Impact
Loss of containment (accidental spill) scenario during construction	No Impact	5	0	2	2	2	0	Refer to Section 6.11.5	No Impact
Changes in air quality affecting transboundary receptors	No Impact	5	0	2	2	2	0	None required	No Impact
Underwater noise affecting the fish or marine ecology across border	No Impact	5	0	2	2	2	0		No Impact

7 Prediction and Evaluation of Environmental Impact (Post Construction Phase)

This section provides an analysis of pertinent post-construction phase impacts in relation to the following:

- Hydrodynamics
- Ecology
- Marine Navigation and Infrastructure

Impacts to the above profiles are in line with the scoping results described in Table 4.3 above.

7.1 Hydrodynamics

As discussed previously in Section 6.1, the underlying model of the marine impact analyses is DHI's well calibrated and validated MIKE 21 hydrodynamic model of the Singapore Strait. Modelling scenarios for the selected profiles include simulations over a period of 14 days, covering one spring-neap tidal cycle, both during northeast and southwest monsoons.

7.1.1 Relevant Receptors

As discussed in 6.1, the only group of receptors that is relevant to changes in hydrodynamic conditions is maritime transport and infrastructure (such as jetties), including OBS Camp 2 Jetty and Serangoon Harbour. Impact from the predicted changes on maritime transport are assessed in the corresponding section for this receptor group (Section 7.3).

7.1.2 Methodology

To quantify the level of change to the hydrodynamic conditions (current speeds, flow patterns) due to the project, DHI's well calibrated and validated hydrodynamic model of the Singapore Straits will be applied. The model is based on MIKE 21 HD FM model from MIKE Powered by DHI suite of numerical models.

For the post-construction impact assessment, the MIKE 21 base hydrodynamic model for the final stage of development provides quantification of the current conditions.

The current modelling scenarios include simulations over a period of 14 days, covering one spring-neap tidal cycle, during both NE and SW monsoons in order to cover seasonal variations in currents that may affect the model results.

7.1.3 Assessment Framework

The evaluation framework for the impact assessment for changes to currents is described previously in Section 6.1.

7.1.4 Results and Discussions

The impacts to currents around the project area are represented in terms of changes to current fields, current statistics (mean and 95th percentile) and representative current speeds. Overall:

- Current speeds are generally low in the study area, due to its sheltered location.
- The new slipway is predicted to cause negligible changes to hydrodynamic parameters in the study area. This observation holds for both NE and SW monsoons.

These changes will be described in the following sections. Impacts arising from these changes, if any, are evaluated in the respective and subsequent receptor sections.

General Change in Current Fields

This section describes the simulated absolute current field (current vectors) at each reference tidal stage for the Baseline and the Final stage in order to provide an overview of the long-term changes due to the slipway profile on the current fields. For the purposes of the current impact assessment, the current field can be classified according to two (2) main stages of the tide which are characterised as peak flood and peak ebb tide. The definition of flood and ebb is the rise and fall of the tide, respectively, and the direction follows the dominant flow direction in the Singapore Strait, with ebb tide also referred to as east-going tide, and flood tide also referred to as west-going tide.

Figure 7.1 and Figure 7.2 illustrate flow speed and vectors for peak ebb and peak flood. Changes to current field arising from the new slipway are highly localised around the slipway area. No change is observed in Serangoon Harbour.

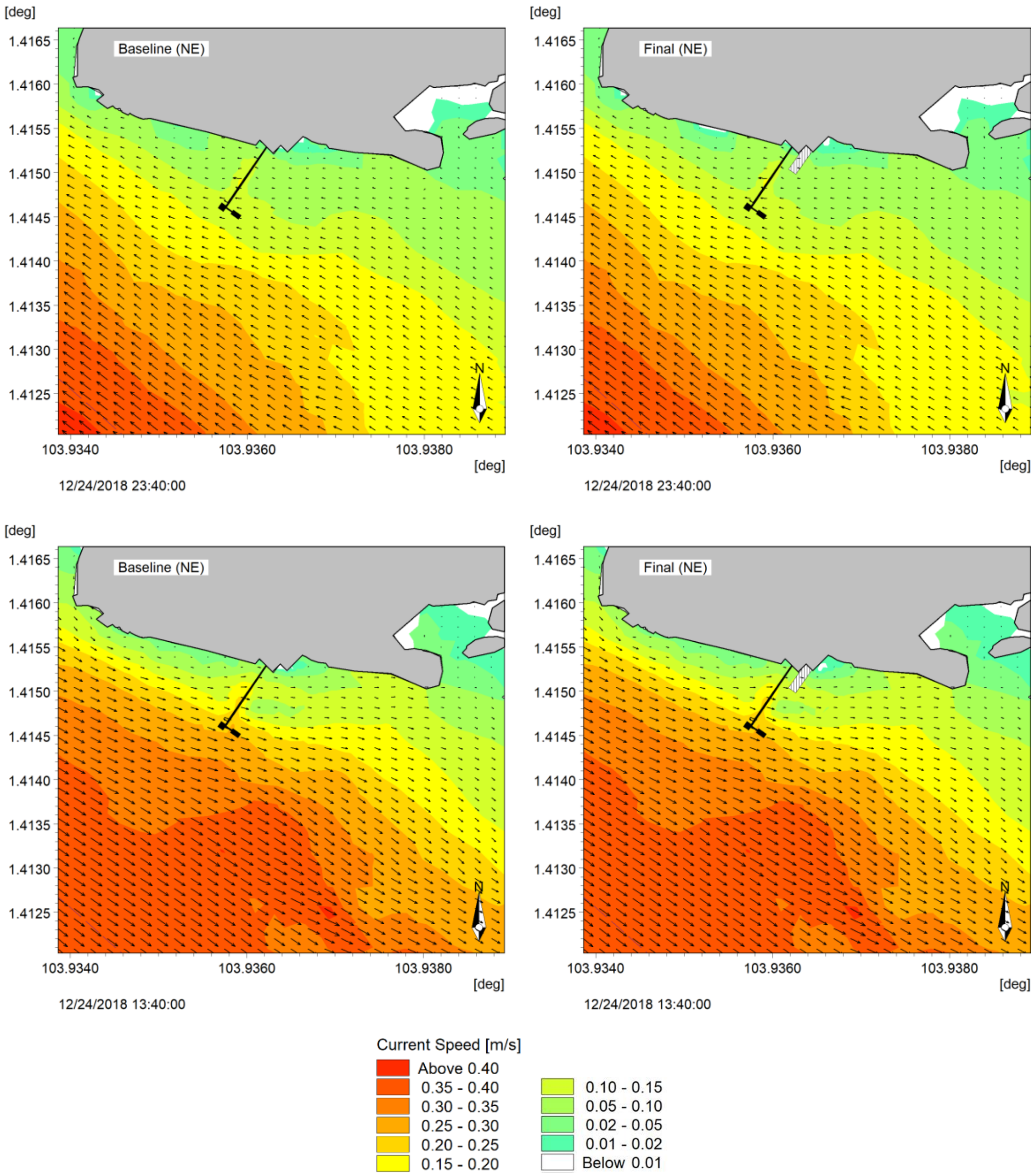


Figure 7.1 Change in current field due to final stage: Peak ebb (top) and peak flood (bottom) during NE Monsoon

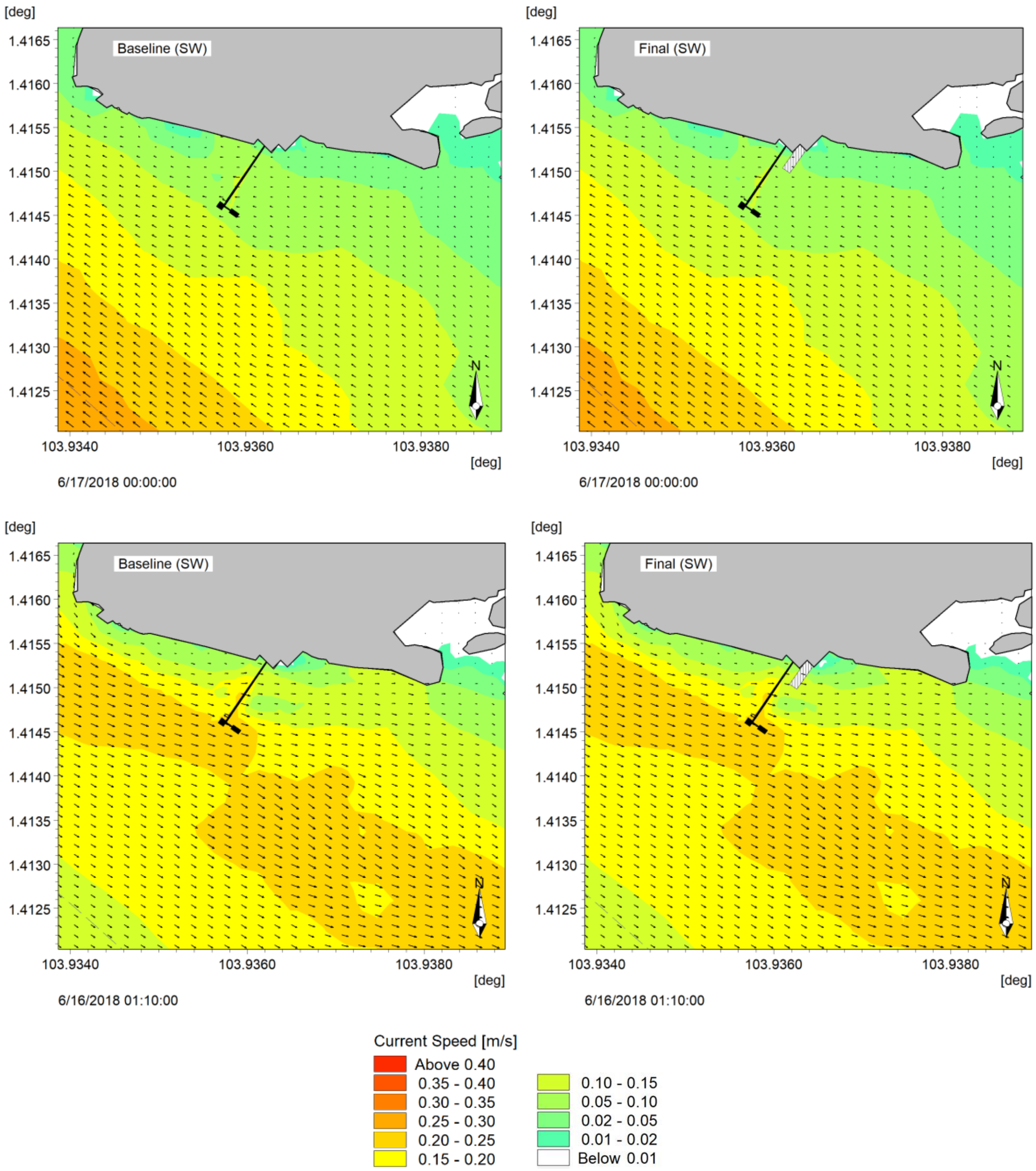


Figure 7.2 Change in current field due to final stage: Peak ebb (top) and peak flood (bottom) during SW Monsoon

Change in Mean Current Speeds

This section describes the impact, with respect to baseline conditions, to mean current speeds as a result of the final stage. Figure 7.3 illustrates the mean current speeds for the Baseline and Post-Construction Phase (top and middle respectively), and the predicted change in mean current speeds (bottom) in relation to Baseline during the NE monsoon. Figure 7.4 presents model results for SW monsoon.

The average current speed prior to any construction works (i.e. baseline) are typical of patterns described in Section 5.1.2. The project area is predicted to have average speeds of 0.01 m/s to 0.10 m/s with the latter occurring at the OBS Camp 2 jetty platform. The presence of the refurbished slipway is predicted to result in less than 0.05 m/s change in mean current speed in both local project area and the entire study area.

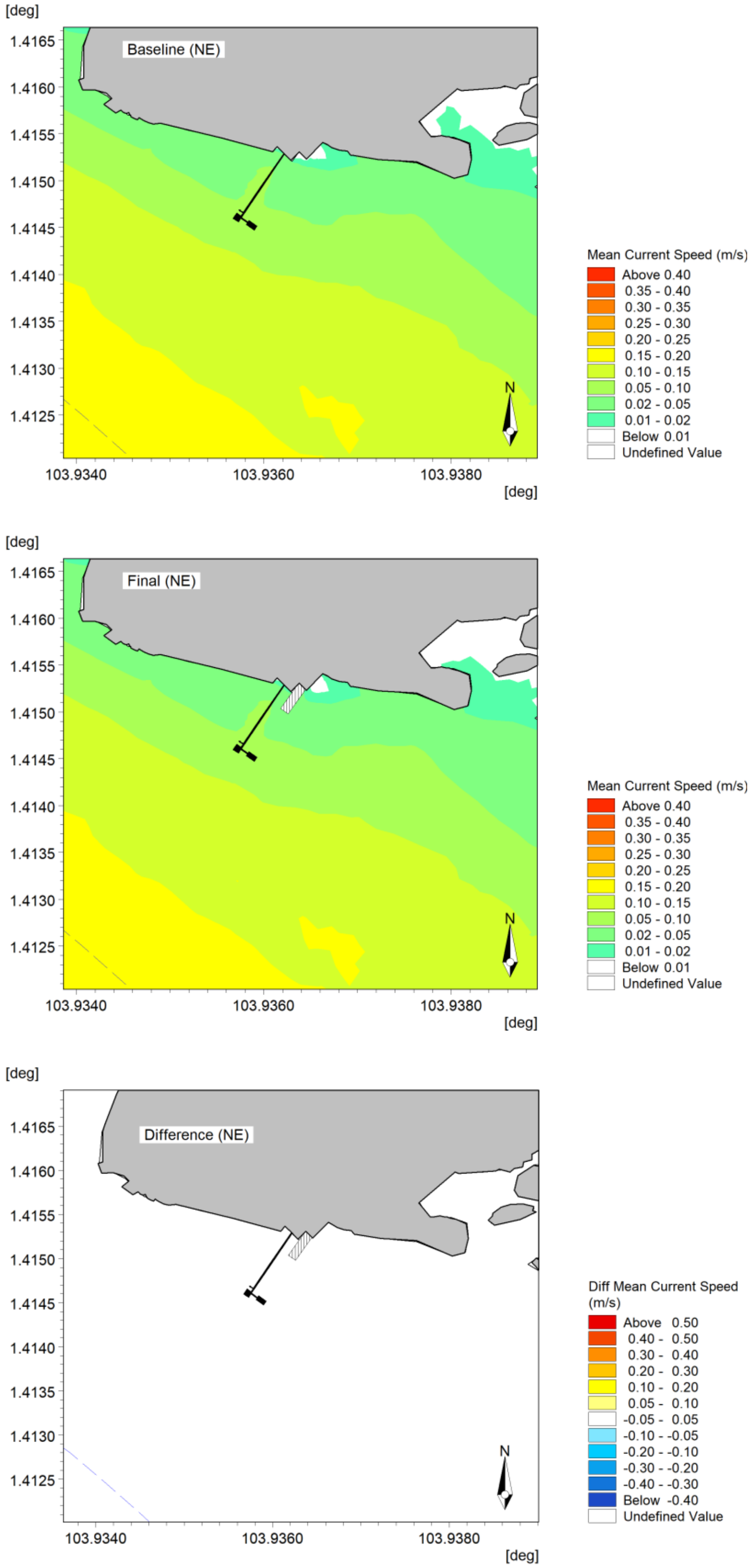


Figure 7.3 Mean current speed during NE monsoon. Top: Baseline. Middle: Construction Phase. Bottom: Difference between Final Stage and Baseline

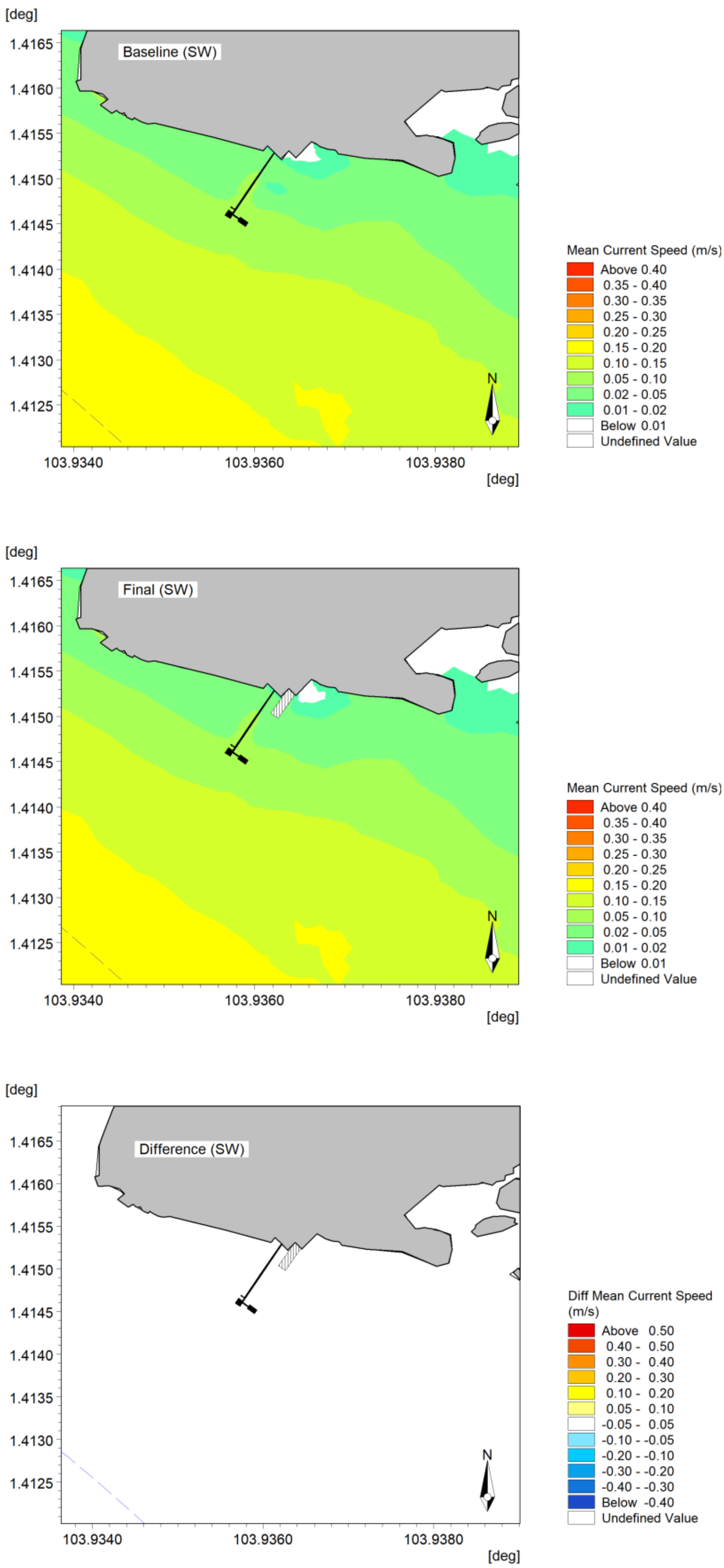


Figure 7.4 Mean current speed during SW monsoon. Top: Baseline. Middle: Construction Phase. Bottom: Difference between Final Stage and Baseline

Change in 95th Percentile Current Speeds

The corresponding plots for the 95th percentile current speeds are presented in this section and address the current speeds that may occur up to 95% of the time. Figure 7.5 illustrates the maximum (at 95th percentile) current speeds for the Baseline (top) and Post-Construction Phase (middle), and the predicted change in max current speeds (bottom) as compared to Baseline during the NE monsoon. Figure 7.6 shows the results for SW monsoon.

Predicted maximum current speeds in both the Baseline and Post-construction Phase are generally low along the shore of Pulau Ubin with currents attain speeds up to 0.12 m/s. The predicted change in maximum current speed between the Baseline and Post-construction Phase (i.e. with the new slipway) for both NE and SW monsoons is less than 0.1 m/s.

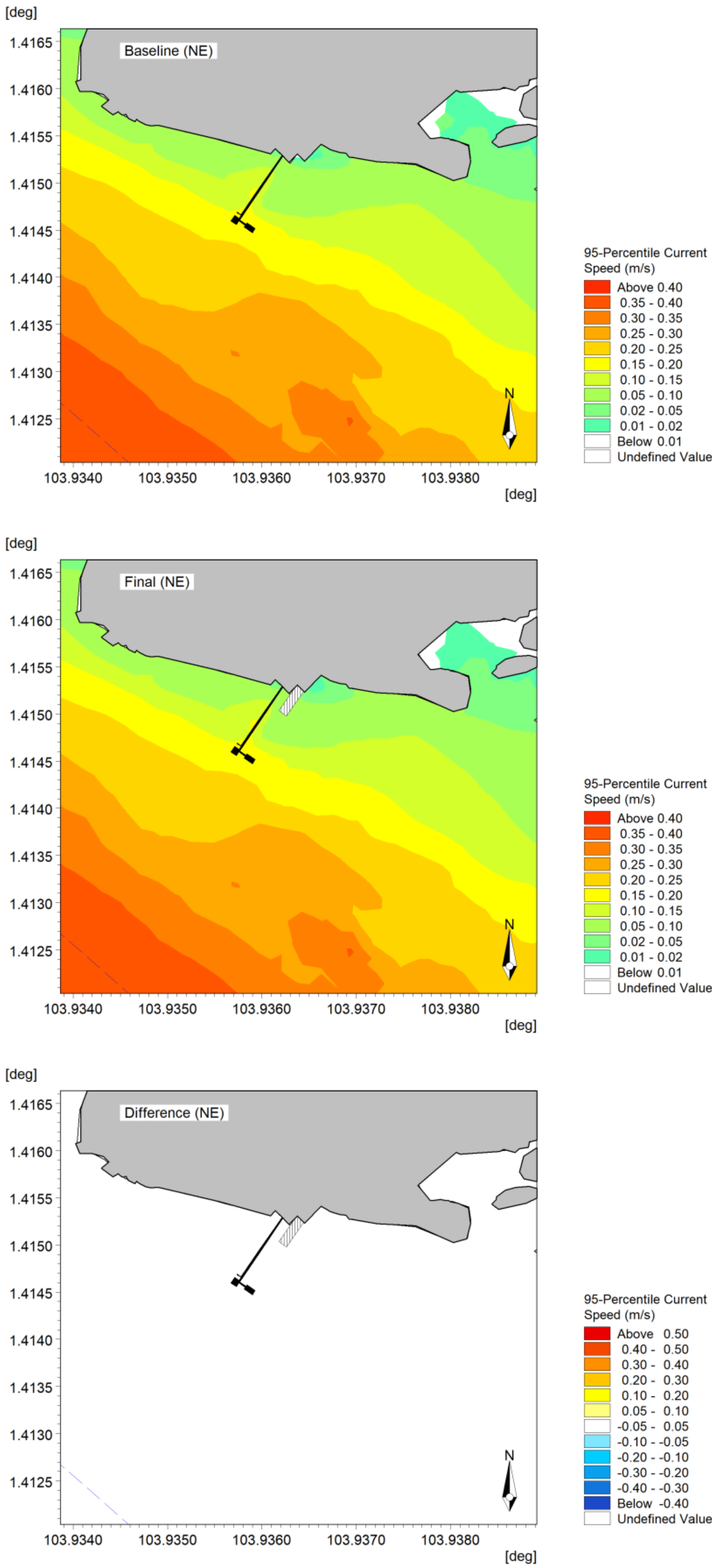


Figure 7.5 95th percentile current speed during NE monsoon. Top: Baseline. Middle: Construction Phase. Bottom: Difference between Final Stage and Baseline

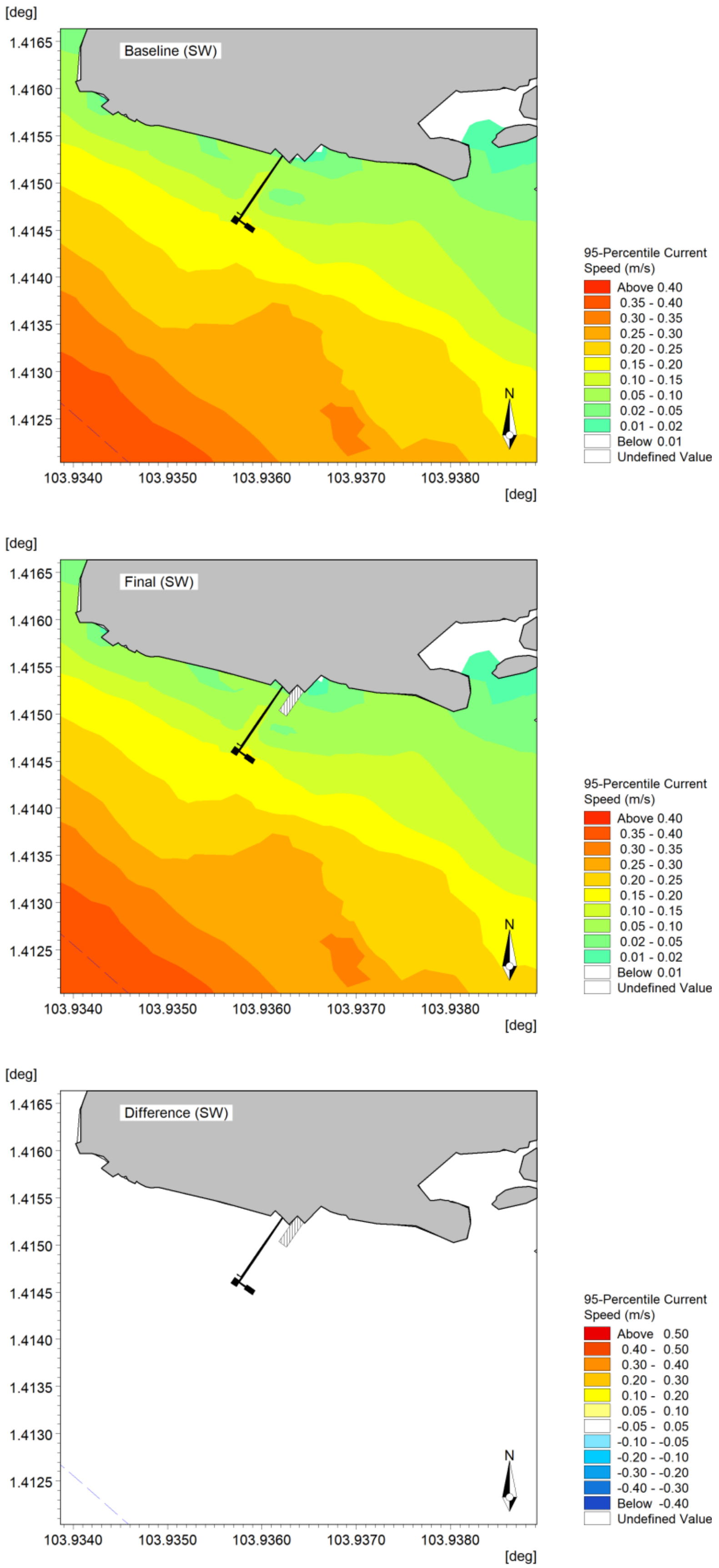


Figure 7.6 95th percentile current speed during SW monsoon. Top: Baseline. Middle: Construction Phase. Bottom: Difference between Final Stage and Baseline

Change in Representative Current Speeds

As an alternative to the analysis of mean and 95th percentile current speeds, a measure of the level of change to the exceedance of selected representative current speeds is provided in this section. This alternative is meant to provide additional understanding of the scale of change in current speeds, and for this purpose, the speeds of 3.5 knots (1.8 m/s), 2.0 knot (1 m/s) and below 0.5 knot (0.25 m/s) were used. Current speed lower than 0.5 knot is generally referred to as slack water.

Figure 7.7 and Figure 7.8 present slackwater duration in the study area for Baseline, Final Stage and the difference between them, during NE and SW monsoons respectively. It's evident that the current at OBS Camp 2 slipway and jetty is in slack condition for more than 90% of time and that does not change during the Final Stage. The presence of the new slipway is predicted to cause in less than 2% change in slackwater duration in the entire study area.

With regards to exceedance of 2.0 knot and 3.5 knots, it is evident from Figure 7.9 to Figure 7.12 that current speed in the study area only exceeds these representative current speeds for less than 4% of time, during both monsoon seasons assessed in this study. The model shows that the new slipway will result in no more than 2% change to the duration current speed in the study area exceeding 2.0 knots and 3.5 knots.

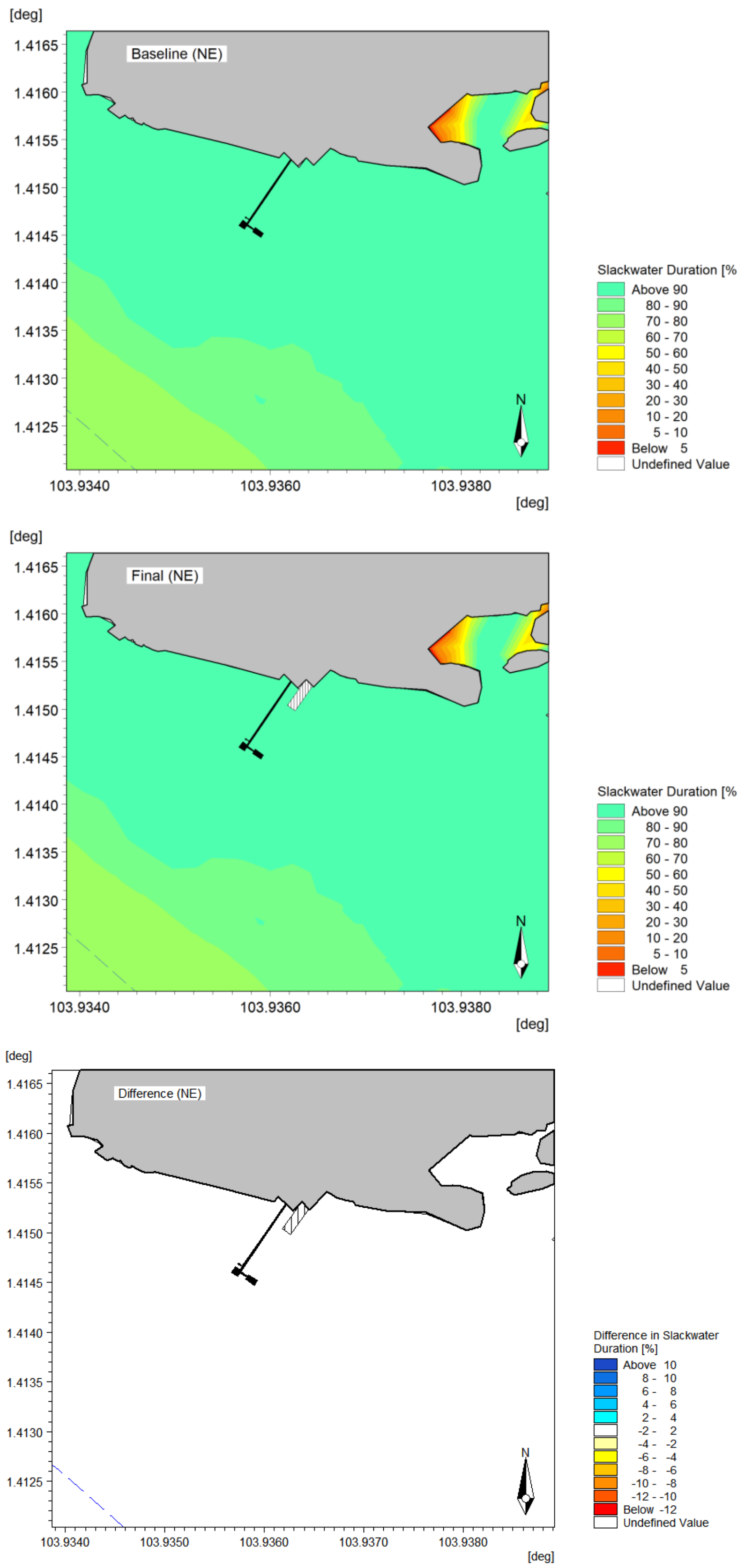


Figure 7.7 Slackwater duration during NE monsoon. Top: Baseline. Middle: Construction Phase. Bottom: Difference between Final Stage and Baseline

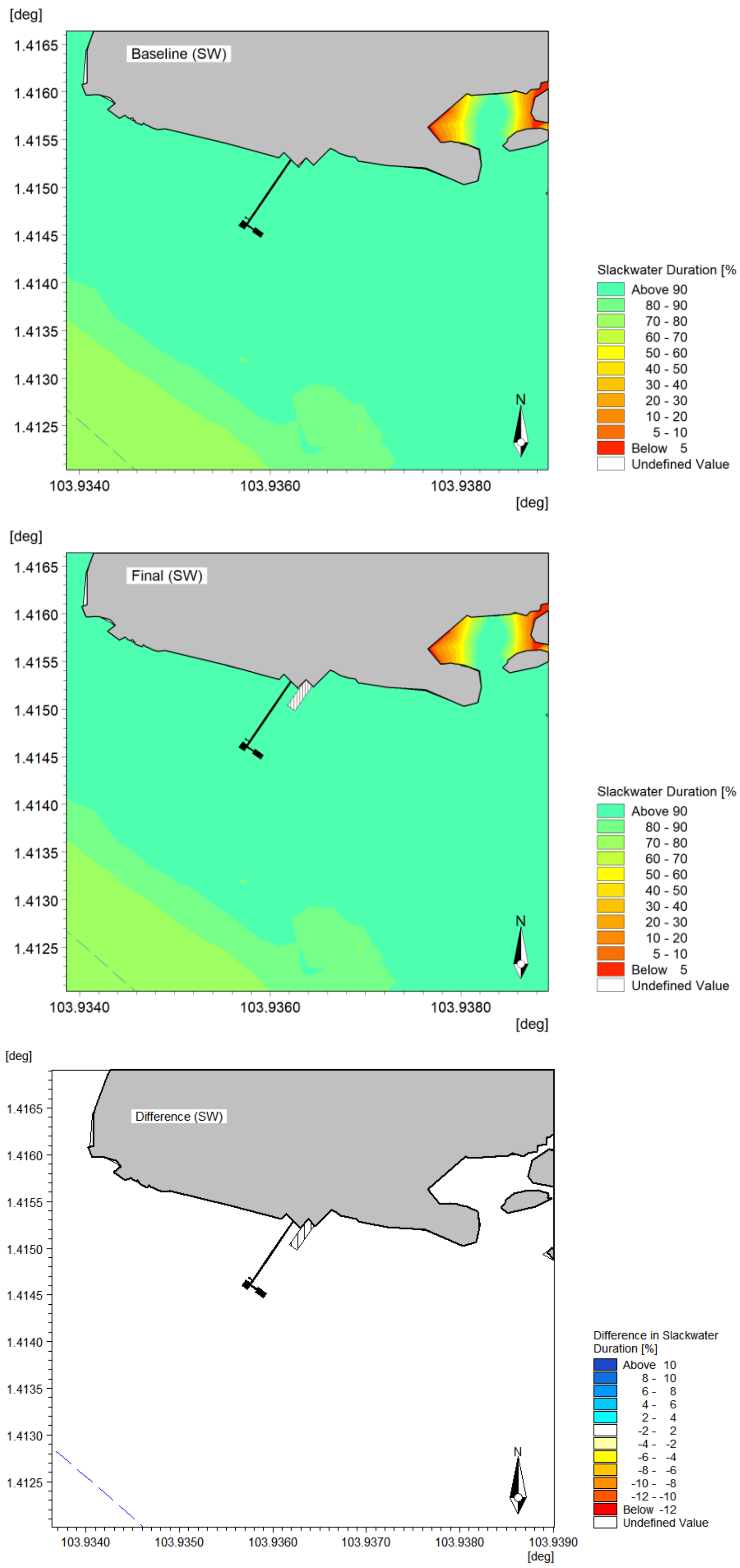


Figure 7.8 Slackwater duration during SW monsoon. Top: Baseline. Middle: Construction Phase. Bottom: Difference between Final Stage and Baseline

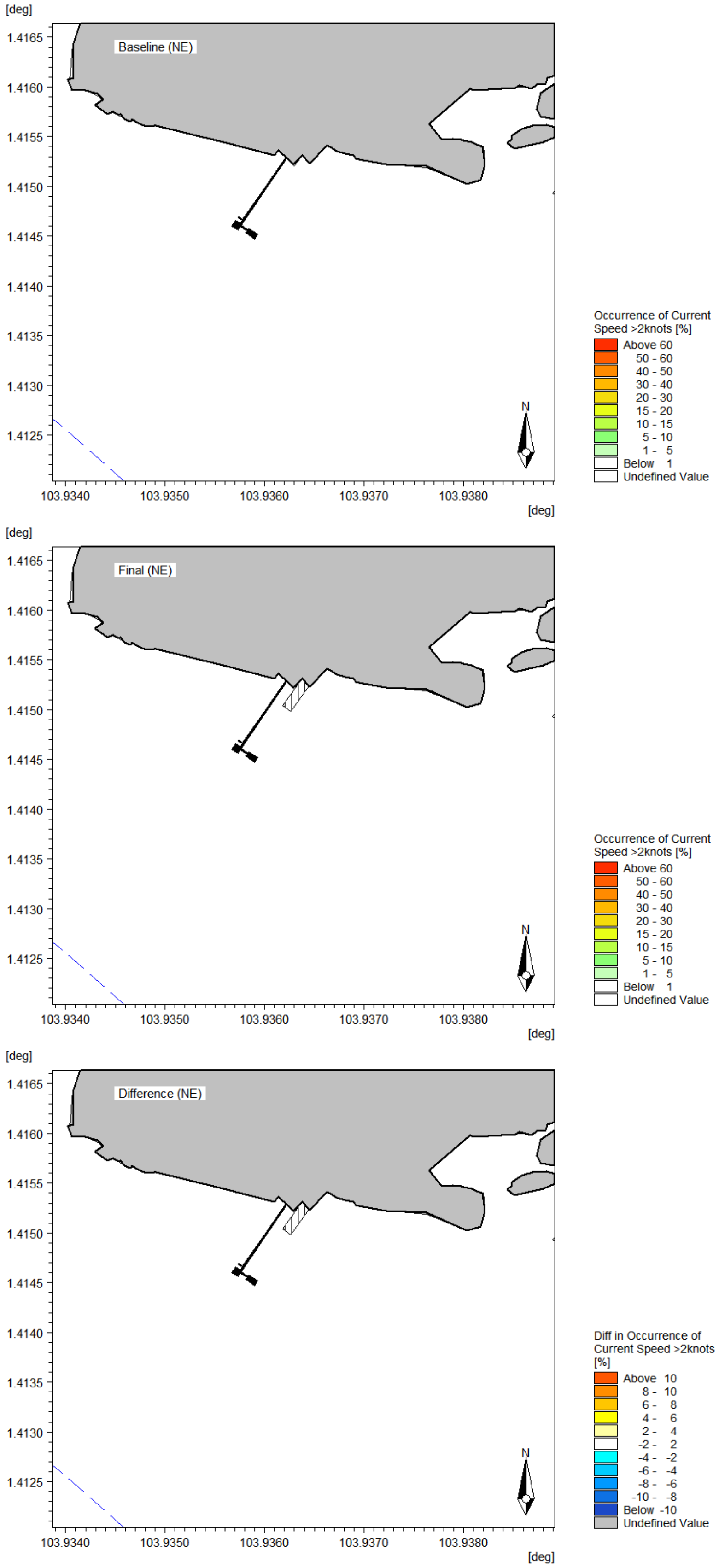


Figure 7.9 Percentage of time current speed exceeding 2.0 knots during NE monsoon. Top: Baseline. Middle: Construction Phase. Bottom: Difference between Final Stage and Baseline

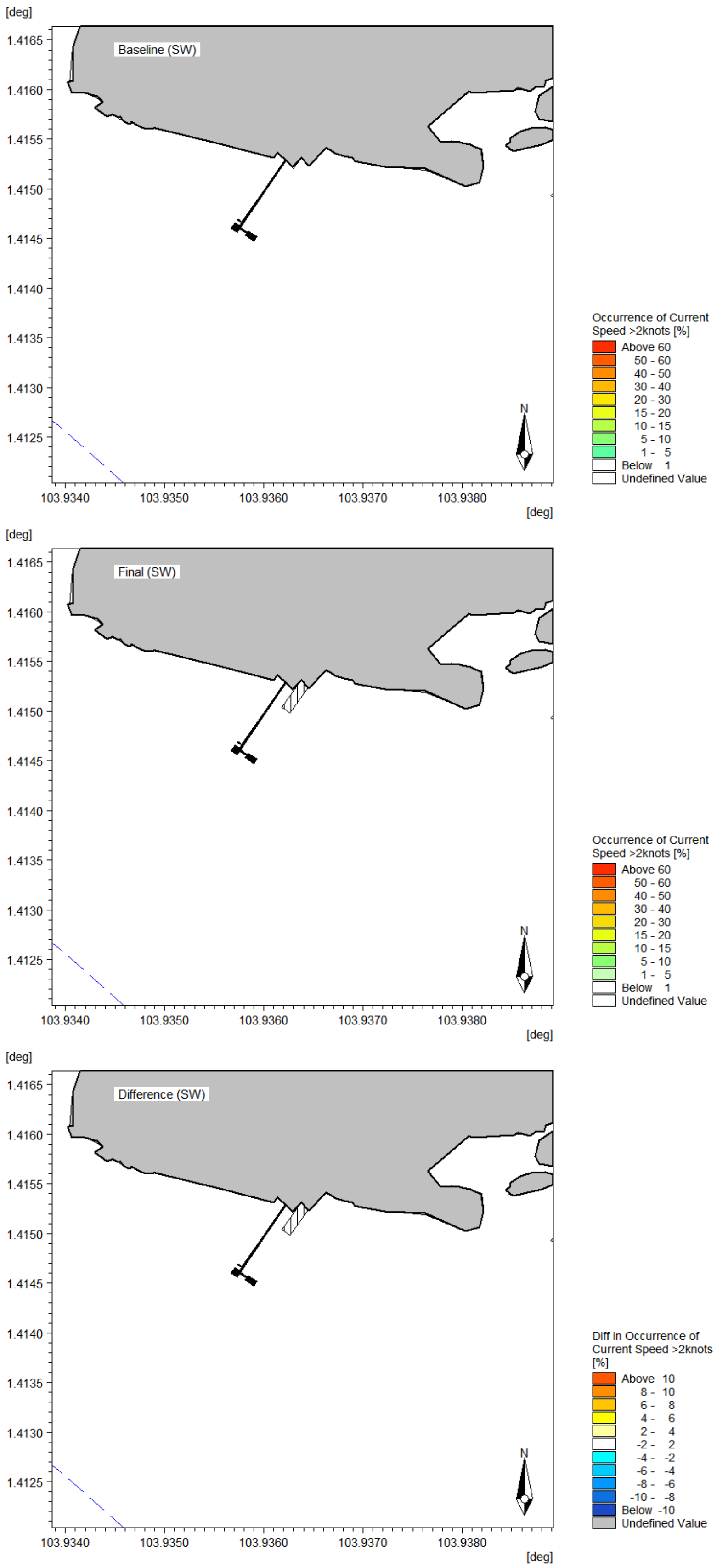


Figure 7.10 Percentage of time current speed exceeding 2.0 knots during SW monsoon. Top: Baseline. Middle: Construction Phase. Bottom: Difference between Final Stage and Baseline

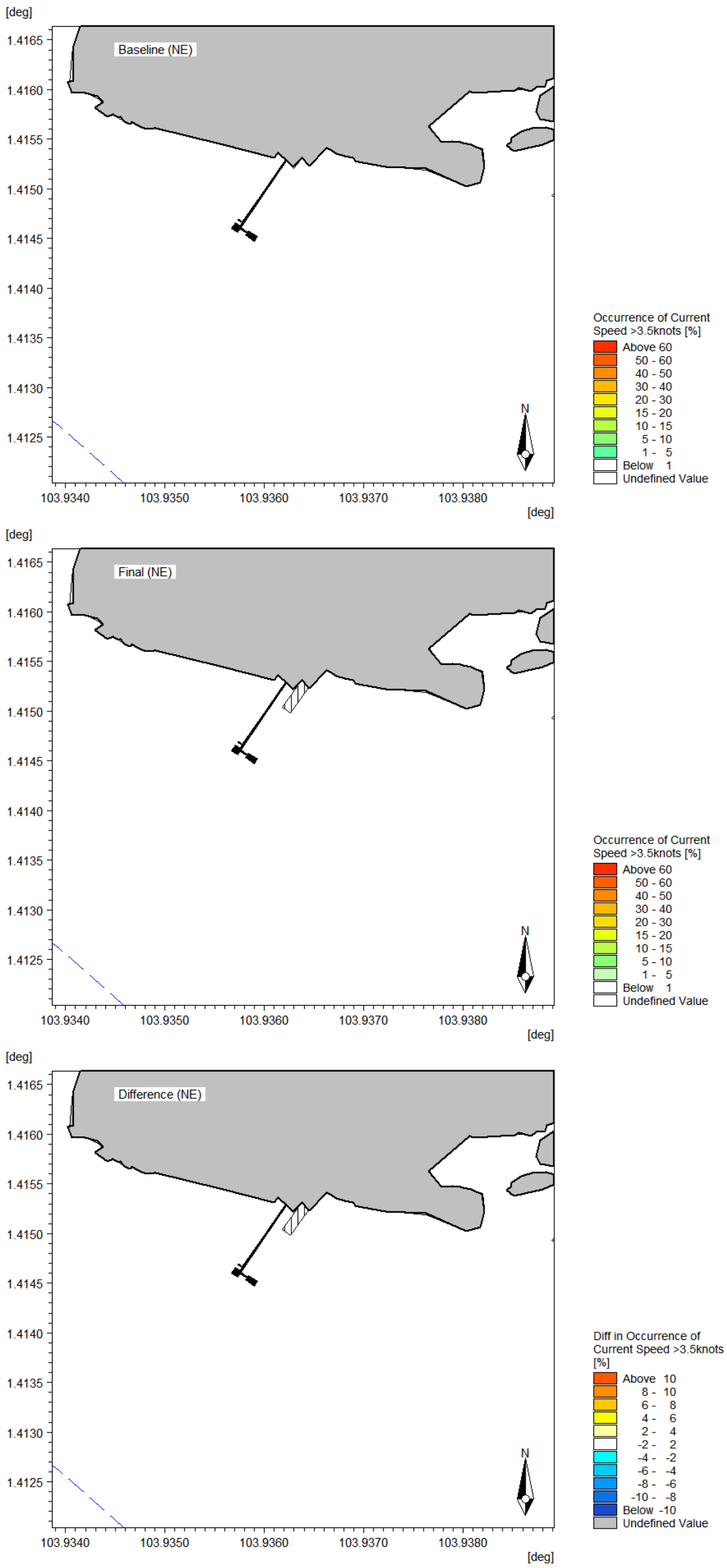


Figure 7.11 Percentage of time current speed exceeding 3.5 knots during NE monsoon. Top: Baseline. Middle: Construction Phase. Bottom: Difference between Final Stage and Baseline.

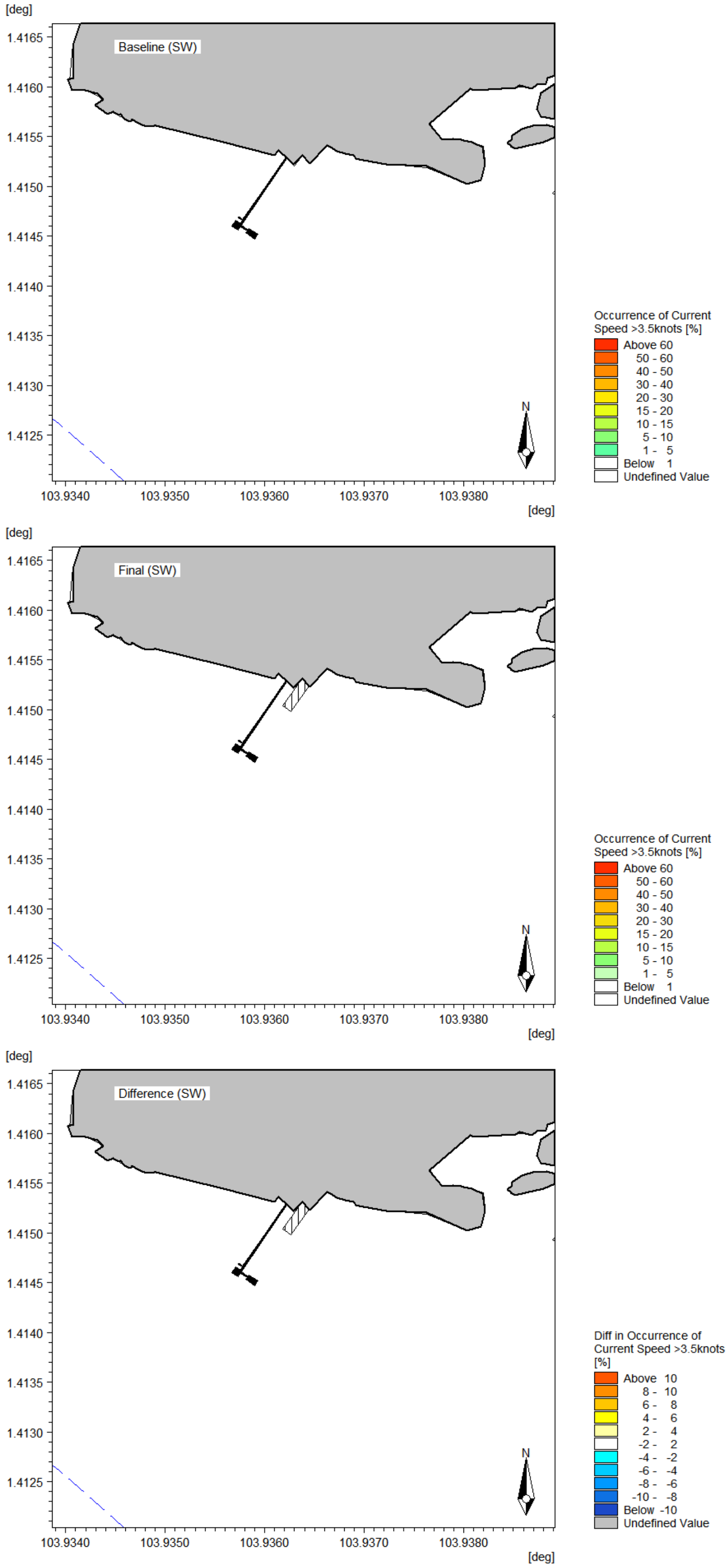


Figure 7.12 Percentage of time current speed exceeding 3.5 knots during SW monsoon. Top: Baseline. Middle: Construction Phase. Bottom: Difference between Final Stage and Baseline

7.1.5 Hydrodynamics Summary

Overall, the Project is located in a sheltered area and characterised by low current speed in general. DHI's hydrodynamic simulations predict that its Post-Construction Phase will result in local and negligible changes to various hydrodynamic parameters in the study area. Assessment of impact arising from these small changes is presented in sections later in this chapter, corresponding to the relevant sensitive receptors to hydrodynamic changes.

7.2 Ecology and Biodiversity

The presence of the refurbished slipway will create long-term permanent impact on marine macrobenthos from loss of habitat. However, as the footprint considered does not deviate extensively from existing slipway (estimated additional footprint of 300 m^2), it is not anticipated that such impact would be significant. As post-construction phase has limited land-based activities, it is anticipated that impacts to terrestrial ecology would be minimal, if any. A **Slight Negative** impact is concluded for the permanent loss of marine ecological receptors during the post-construction phase (Table 7.1).

Figure 7.13 and Figure 7.14 present the predicted change in the maximum bed shear stress in terms of 95th percentile value and mean bed shear stress in relation to Baseline respectively. Both the predicted difference in maximum bed shear stress and mean shear stress due to the presence of refurbished slipway during both NE and SW monsoon is less than 0.10 N/m^2 in both local project area and the entire study area. Therefore, the effect of erosion to the mangrove fringes and the coastline from the new slipway is expected to be **No Impact** during the post-construction phase.

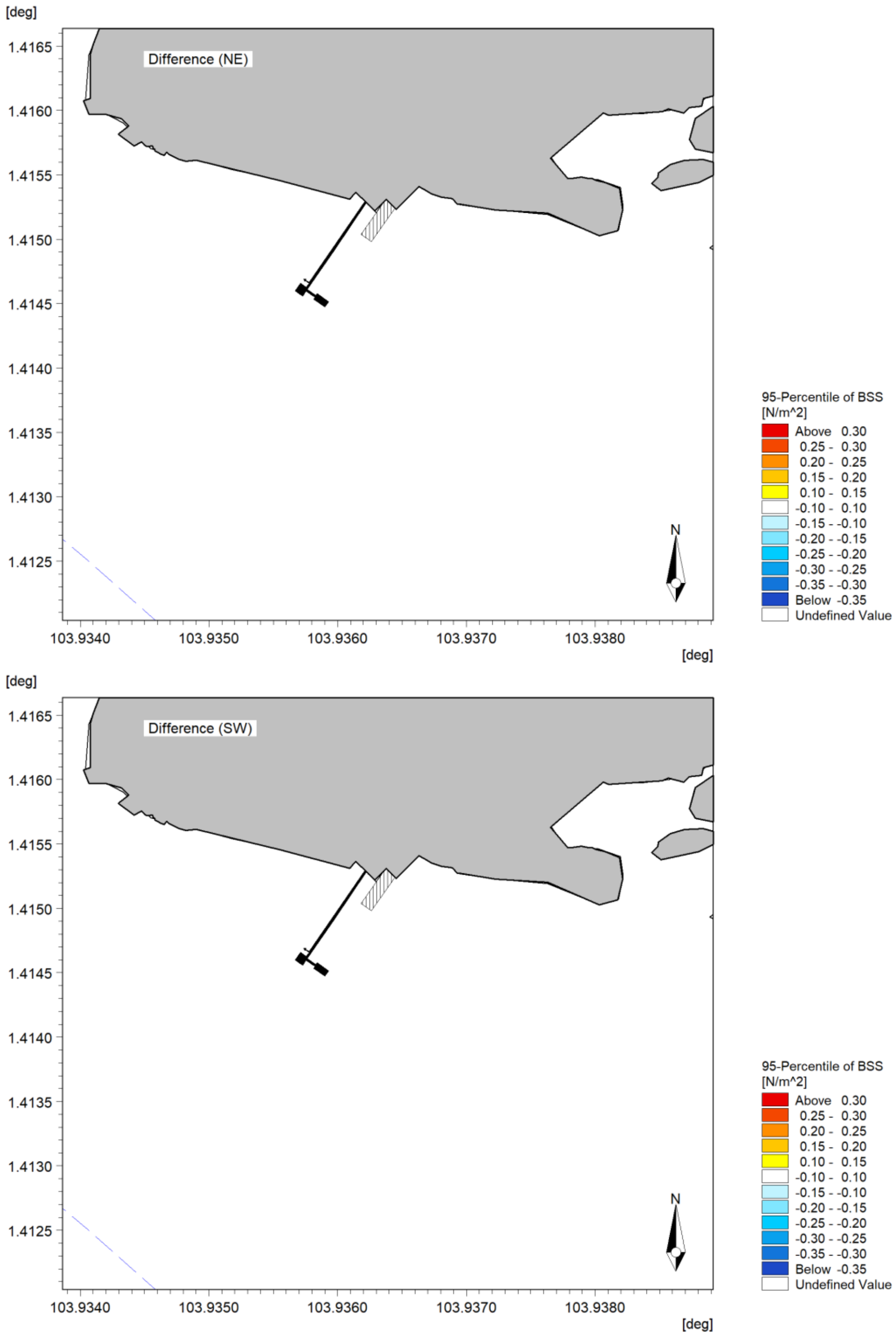


Figure 7.13 Difference in 95th percentile bed shear stress between Post-Construction Phase and Baseline, due to the presence of refurbished slipway. Top: NE monsoon. Bottom: SW monsoon.

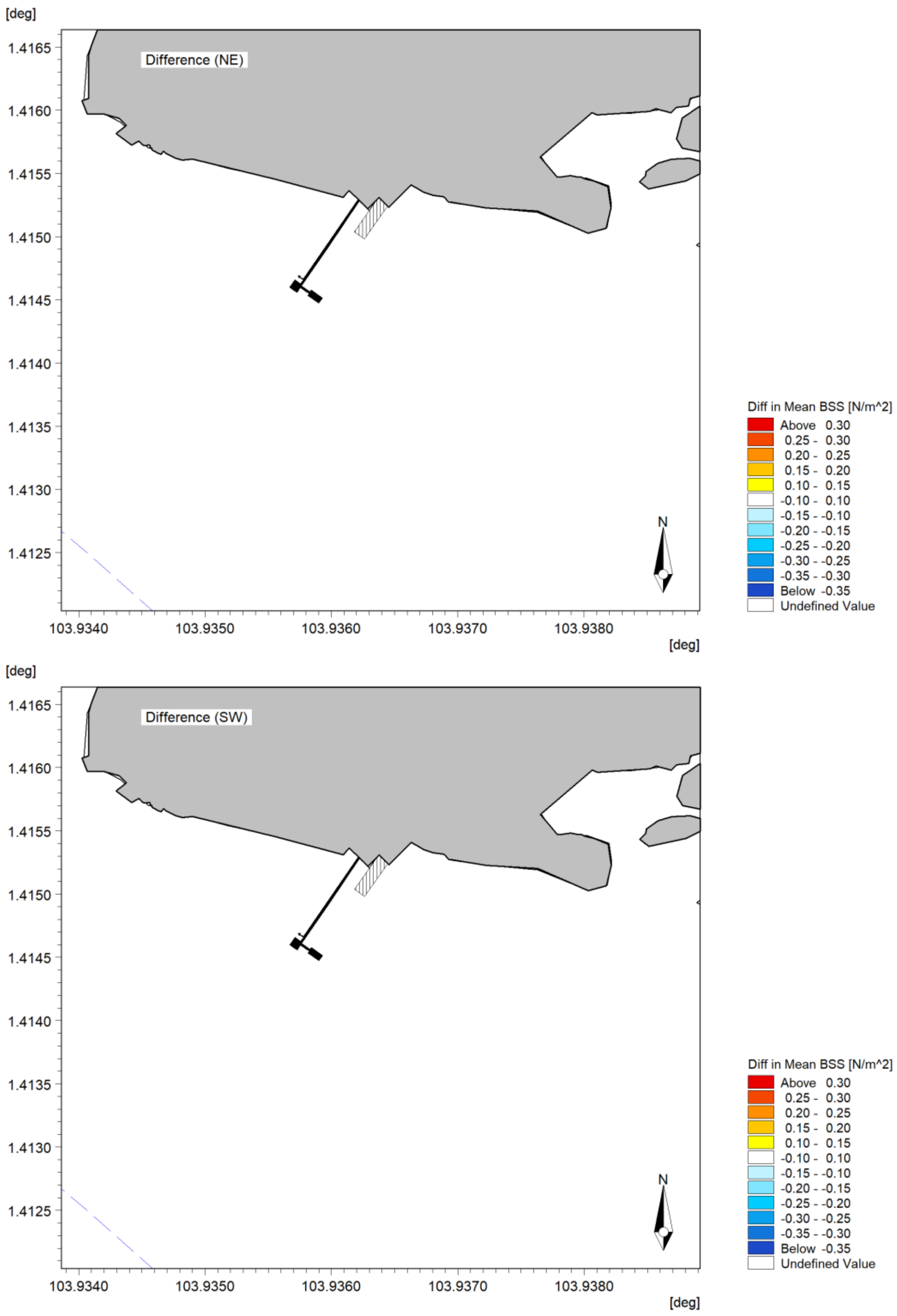


Figure 7.14 Difference in mean bed shear stress between Post-Construction Phase and Baseline, due to the presence of refurbished slipway. Top: NE monsoon. Bottom: SW monsoon.

Table 7.1 RIAM Summary for Post-Construction phase impacts on ecological receptors

Impact on Receptors	Predicted impacts without Mitigation							Mitigation Measures	Mitigated Impact Significance
	Impact Significance	ES	I	M	P	R	C		
Permanent loss of habitat	Slight Negative	-18	2	-1	3	3	3	None required	Slight Negative
Sedimentation /erosion impact on mangrove/ coastline	No Impact	0	4	0	2	2	2		No Impact

7.3 Marine Navigation and Infrastructure

Based on the predicted model results shown in Section 7.1, no significant change to baseline currents is expected from the presence of the refurbished slipway. It can therefore be inferred that impacts to marine navigation would not be very different than baseline conditions. As no change is expected, it is concluded that Post-Construction Phase impacts to marine navigation and infrastructure is minimal to none.

Table 7.2 RIAM results for Operational Phase (long-term) impacts from the Project on maritime transport

Impact on Receptors	Predicted impacts without Mitigation							Mitigation Measures	Mitigated Impact Significance
	Impact Significance	ES	I	M	P	R	C		
Changes in Currents at nearby navigation receptors	No Impact	0	3	0	3	3	2	None required	No Impact

7.4 Transboundary Impacts

This section focuses on assessment of the potential long-term changes after the extended slipway is reconstructed in current direction and speed conditions across the border. Impact assessments related to transboundary impacts are guided by strict tolerance thresholds for any changes in these pressures.

Aforementioned, no significant change to baseline currents is expected from the presence of the refurbished slipway. As no change is expected, it is concluded that ‘No Impact’ is predicted to the currents and transboundary navigation.

Table 7.3 RIAM results for Operational Phase (long-term) impacts from the Project on transboundary receptors.

Impact on Receptors	Predicted impacts without Mitigation							Mitigation Measures	Mitigated Impact Significance
	Impact Significance	ES	I	M	P	R	C		
Final refurbished slipway affecting the transboundary currents and navigation	No Impact	0	5	0	3	3	2	None required	No Impact

8 Environmental Management and Monitoring Plan

This Environmental Management and Monitoring Plan section provides a cohesive framework to ensure that the environmental impacts of the proposed project construction activities be mitigated to the lowest practicable level through application of standard 'Plan-Do-Act-Check' principle (Figure 8.1)

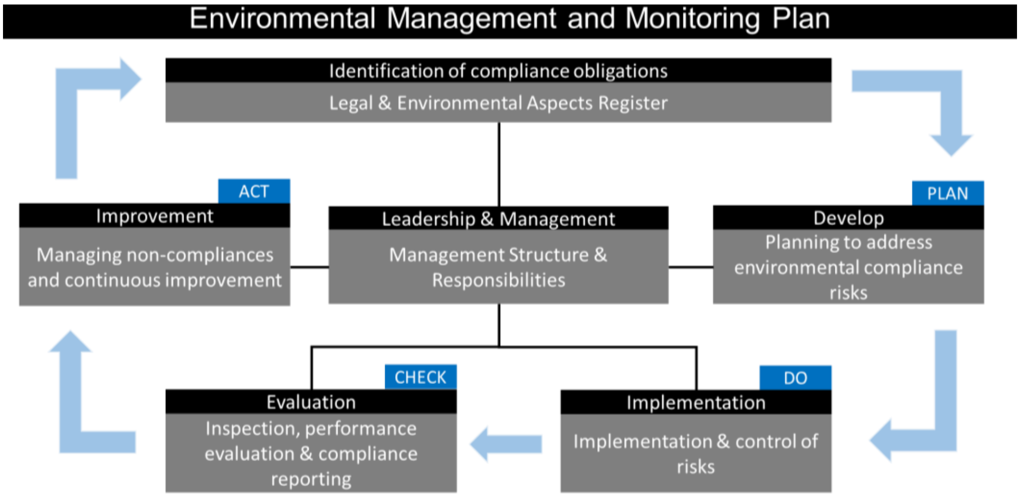


Figure 8.1 EMMP Framework

To ensure that the elements of the EMMP are properly implemented and produce the desirable benefits and/or outcome, the present framework provides an overview of the following pertinent components:

- EMMP Roles and Responsibilities
- Impact Mitigation and Monitoring
- Grievance Management
- Management of Change
- Environmental Auditing
- Non-Compliance and Remedial Action
- Environmental Impact Register

These are further described below.

8.1 EMMP Roles and Responsibilities

8.1.1 Employer

It will be the responsibility of the Employer to ensure implementation of the EMMP by the Contractors or any third party during the construction periods of the proposed project. References within the EMMP to the "Employer" are to NYC as the proposed Project Developer. References to the "Contractor" are to the main contractors for the construction phase, and also include any sub-contractors under their control.

8.1.2 Contractor

The Contractor will be responsible for establishing an Environmental Team that comprises different relevant environmental specialists to work with the regulatory authorities in Singapore to comply with regulations, policies and guidelines related to environmental affairs. This includes formulating an EMMP that covers all proposed construction activities during the construction phase. The Contractor will take ownership of the EMMP and ensure that all staff are familiar with the relevant parts of the EMMP.

While the EMMP sets out the requirements for environmental management during the construction phase, and the responsibilities for meeting them, the details of the actions to be taken in order to implement each aspect of the EMMP will need to be developed and specified by the Contractor in its method statements. These method statements demonstrate how compliance with the requirements of the EMMP is to be achieved. These method statements need to be submitted to the Employer for approval and distribution to relevant regulatory authorities as appropriate.

The Contractor will also be responsible for the provision and installation of all monitoring instruments required under the EMMP specifications, together with the necessities to ensure smooth operation and accurate data and results, such as power supply, mounting, protective or weather-proof casing.

The Contractor will be responsible for developing and training staff in Emergency Management Procedures that cover potential incidents such as spills and leaks, and incidents of human-wildlife conflicts.

8.1.3 Environmental Control Officer

The Contractor shall engage a full-time Environmental Manager (EM) and Environmental Control Officer (ECO). The ECO shall be registered with the Commissioner of Public Health and discharge the duties set out in the Code of Practice for ECO. The ECO will contribute to devising practicable implementation plans for outlined mitigation measures and conduct daily site inspection in the following main areas: control of disease-bearing vectors and rodents; proper management and disposal of solid waste and liquid waste; control of noise and dust pollution; drainage control; general housekeeping; earth control measures and silt control.

At least three weeks before construction works commencement, the ECO will submit an Environmental Control Program. After works commence an ECO Report should be submitted every 2 weeks (on the 1st and 15th of the month) to the Director General of Public Health. The ECO Report and Plan contains the information required by the Singapore Code of Practice for Environmental Control Officers.

8.1.4 Environmental Specialists

The Contractor will also be responsible where applicable to appoint Qualified Erosion Control Professional (QECP) (as required by PUB), Earth Control Measures Officer (ECMO), NEA-licensed Pest Control Officer (PCO), Public Relations Officer (PRO), ISA-certified Arborist, Wildlife Specialist, SINGLAS accredited laboratory, and waste collectors to implement the EMMP requirements.

The Contractor will be responsible to appoint qualified personnel (e.g. Fire Safety Manager, QECP, Traffic Management Specialist, etc) to prepare a fire protection plan, flood protection plan, and traffic management plan, and obtain all necessary approvals from relevant government agencies and stakeholders for the plans.

Any environmental specialist or company engaged by the Contractor to undertake the works under the EMMP, must be adequately experienced. Equipment or instrument used must be maintained and calibrated at manufacturer recommended frequencies. All the certifications, accreditation and quality assurance records must be gathered and documented if and when required by the Contractor.

8.1.5 EMMP Consultant

The EMMP Consultant is a third party to verify and audit the effectiveness of EMMP and will report to the Contractor. Where audit findings highlight a non-conformance, there will be an investigation and appropriate corrective action taken. All environmental audits will be clearly documented and filed internally. The EMMP Consultant is responsible for the overall quality and effectiveness of the EMMP, organising the EMMP audits and provision of comment clarifications and presentations when required with stakeholders and authorities.

8.2 Environmental Monitoring

Based on the assessed level of impacts in Section 6, it is clear that most impacts can be managed through proper application of the recommended mitigation measures. In addition to the regular site housekeeping and checks, environmental monitoring as tabulated Table 8.1 below shall be followed to ensure that the mitigation measures applied are effective.

Table 8.1 Recommended Environmental Monitoring

Environmental Parameters	Monitoring Requirements	Frequency
Water Quality	Water quality measurements should be taken at mid-depth for the following parameters: • pH • Temperature • Conductivity • Dissolved Oxygen Water samples shall also be taken for testing of the following parameters at SINGLAS accredited laboratory: • Oil & Grease • Total Suspended Solids	Every week
Noise	Continuous monitoring using calibrated Sound meter Class 1	During noise construction activities, e.g., piling and demolition works
Sediment Flux Survey	TSS concentration in the water column	• 1 survey during construction of sheet piles • 1 survey during removal of sheet piles

8.3 Grievance Management

The Contractor will establish a grievance management process to ensure that any complaints or feedback received from stakeholders are appropriately recorded, investigated, and resolved where required throughout the Project. The main components of the grievance process should include:

- Prompt acknowledgement and response to stakeholder complaints, keeping them informed of the progress and outcomes
- Accurate records of complaints, investigations and outcomes are maintained
- Resolution within a specified timeframe (proposed two-three weeks)
- An escalation mechanism in the event that grievance cannot be resolved within the specified timeframe
- Assign responsibility and accountability to individual(s) such as Public Relations Officer (PRO) within the Developer(s) for administering the grievance procedure
- Government Agencies to be kept informed of complaints, where required.

8.4 Management of Change

Deviations from the scope of work might occur during the project execution. Change is an inevitable part of project execution so managing and reviewing change during this phase is an important factor in project success. The overall aim of the EMMP is to ensure that environmental management is implemented, and its performance monitored. This means there must be scope for corrective action to be taken if required. It may be necessary to make modifications to the EMMP over the course of the Project when:

- Unanticipated environmental impacts are identified that require additional mitigation
- When mitigation proposed proves ineffective or unable to be implemented
- When the Project changes in a way that is substantially different to that described in the EIA (e.g. internal changes initiated by the project team, external changes initiated by the client; or external changes that are a result of third-party stakeholders)

The overall responsibility for the management of change to the EMMP during construction phase rests with the Employer in consultation with the relevant specialists and/or technical agencies where required. The steps for managing change to the EMMP are as follows:

- Identify and describe unanticipated impacts, ineffective mitigation or changes in the Project construction that requires updates to the EMMP
- Suggest mitigation to manage the identified issues
- Concerns/issues could, for example, be highlighted in site inspection reports or progress calls on an ongoing basis
- Review and update the EMMP in consultation with the relevant specialists and/or technical agencies
- Record recommended corrective action in a Minute of Meeting.

8.5 Environmental Auditing

An independent check will be conducted to ensure that appropriate environmental management is in place in accordance with statutory requirements and the EMMP. The environmental audit will review the results of monitoring undertaken during the construction phase to identify if there is a need to heighten the environmental management or mitigation measures. The scope of the Environmental Audit should cover all of the environmental issues relating to construction that are addressed in the EIA Report and by the EMMP.

The audit should be undertaken by the Employer. The activities to be undertaken as part of an environmental audit minimally include:

- Visual examination of the site, to examine working practices, environmental effects, mitigation measures and monitoring activities
- Examination of the environmental incidents and complaints log
- Examination of the Environmental Impact Register, including results of monitoring works
- Interviews with the Contractor’s Environmental Manager and other site staff as required
- Consultation with relevant statutory authorities, where appropriate

The frequency of the environmental audits should be specified by the Employer and should consist of a minimum of two unscheduled visits during the 10-month construction period.

8.6 Non-Compliance and Remedial Action

In the event of non-compliance, the following process / actions are recommended:

- The Employer to issue a notice of non-compliance to the Contractor, stating the nature and magnitude of the contravention.
- The Contractor to provide the Employer 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 Employer, to provide the Employer with documented evidence of the completed remedial actions and obtain the Employer’s approval for closure of the non-compliance notice.

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 Employer may take action (e.g. impose a penalty, require specific remedial action to be undertaken or stop work) based on the conditions of contract.

8.7 Environmental Impact Register

The objective of environmental monitoring will be to check for compliance with the EMMP by monitoring the construction activities of the Project. This includes monitoring of actual impact of activities on selected sensitive receptors so that impacts not anticipated in the EIA or impacts which exceed environmental quality objectives can be identified and appropriate mitigation measures can be adopted promptly. The Environmental Impact Register outlined in Table 8.2 is recommended as a management and monitoring tool. Compliance monitoring is recommended throughout the proposed project by both the Employer and Contractor.

Table 8.2 Environmental Impact Register

Environmental Aspect	Description of Receiver		Description of Potential Impact		Proposed Mitigation Measures	Implementation Agent	Residual Impact Significance	Proposed Monitoring Requirement	Reporting Requirements
	Receiver	Importance	Impact	Impact Significance					
Hydrodynamics	Serangoon Harbour	High	Current changes affecting navigation safety and berthing	No Impact	None required	NIL	NIL	NIL	NIL
	OBS Camp 2 Jetty	Low		No Impact					
	Mangrove/ coastline	High	Hydrodynamically-induced erosion	No Impact	None required	NIL	NIL	NIL	NIL
	Transboundary navigation	High	Changes in the currents speed affecting currents and transboundary navigation	No Impact	None required	NIL	NIL	NIL	NIL
Navigation Space	OBS Camp 2 Jetty	Low	Reduction in navigation space	Slight Negative	None required	NIL	Slight Negative	NIL	NIL
	Aquaculture	Moderate	Vessel collision	No Impact	None required	NIL	NIL	NIL	NIL
Sediment Plume	Mangrove	High	Increased suspended sediments	No Impact	None required	NIL	NIL	NIL	NIL
			Increased sedimentation	No Impact					
	Serangoon Harbour	High	Increased sedimentation	No Impact					
	OBS Camp 2 Jetty	Moderate							
	Recreational users (e.g., kayakers)	Low	Visual impact due to construction	No Impact					
	Aquaculture	Moderate	Increased suspended sediments	No Impact					
	Transboundary visual aesthetic	High	Visual impact due to construction	No Impact					
	Transboundary marine infrastructure	High	Increased sedimentation	No Impact					

Environmental Aspect	Description of Receiver		Description of Potential Impact		Proposed Mitigation Measures	Implementation Agent	Residual Impact Significance	Proposed Monitoring Requirement	Reporting Requirements
	Receiver	Importance	Impact	Impact Significance					
Water Quality	Marine ecology	High	Accidental spill leakage and trade effluent	Slight negative	• Implement a Major Accident Prevention Plan (MAPP) / Emergency Response Plan for general site activities that covers all incidences of a potential spill or leaks resulting from project activities and equipment. • Implementation of the recommendations listed in Section 6.11 in managing risks associated to construction waste and use of hazardous material. • Communication to be established with MPA for the reporting of any oil spill incidents.	• Contractor/ECO • EMMP Consultant	Slight negative	• Water quality measurements should be taken weekly at mid-depth for the following parameters: • pH • Temperature • Conductivity • Dissolved Oxygen • Water samples shall also be taken weekly for testing of the following parameters at SINGLAS accredited laboratory: • Oil & Grease • Total Suspended Solids	• Water quality monitoring results • Environmental Control Report • Monthly Environmental Performance Report
	Terrestrial fauna	High	Accidental spills and trade effluent	Slight negative			Slight negative		
	Aquaculture	Moderate	Unplanned water pollution (spills/leaks)	Slight negative	None required	NIL	Slight negative	NIL	NIL
	Transboundary aquatic life	High	Unplanned water pollution (spills/leaks)	No Impact	None required	NIL	No Impact	NIL	NIL
Air Quality	Terrestrial fauna	High	Deterioration of air quality due to construction activities	Slight negative	• Plants and machineries used on site shall be properly and regularly inspected and maintained to control dust and air pollutants emission. • Wheel washing bay shall be provided, and all trucks / vehicles shall be washed before leaving the construction site. • Minimize traffic delays caused by movement of construction vehicles by planning transport route and transport period that avoid congested areas and peak hours of road use • Where applicable, manual or mechanical methods shall be adopted for the demolition works as opposed to blasting so as to reduce volume of dust released. • Where applicable, all structures to be demolished shall be enclosed and demolition chutes and demolition waste receptacles shall be deployed. • Wet the working area prior to, during and after demolition	• Contractor/ECO • EMMP Consultant	No Impact	• Contractor to conduct daily visual inspection of dark smoke emissions from construction fuel burning equipment and transport • ECO to conduct site inspection and to submit a site environmental control report to the occupier of the construction at each site inspection every 2 weeks. • EMMP Consultant to conduct monthly site inspection ensure environmental mitigation measures have been effectively implemented by the Contractor	• ECO Site Environmental Control Report • Monthly Environmental Performance Report
	Recreational users (e.g., kayakers)	Low		Slight negative			No impact		
	OBS Camp 2 staff and participant	Low		Slight negative			No impact		
	Transboundary human health	High		No Impact	None required	NIL	No Impact	NIL	NIL

Environmental Aspect	Description of Receiver		Description of Potential Impact		Proposed Mitigation Measures	Implementation Agent	Residual Impact Significance	Proposed Monitoring Requirement	Reporting Requirements
	Receiver	Importance	Impact	Impact Significance					
Airborne Noise	Terrestrial fauna	High	Noise pollution generated from construction activities	Minor Negative	• To comply with relevant environmental regulations, including the Environmental Protection and Management Act and any other regulations and guidelines come into effect when the time of construction works commencement. • Quieter construction equipment and method shall be adopted as much as possible, with reference to NEA's Guideline on Quieter Construction Fund Annex 1 and Annex 2. • Install localised noise barriers or noise enclosures for applicable construction machinery • Site noisy fixed-location equipment (generator sets) as far away from the site boundary as possible	• Contractor/ECO • EMMP Consultant	Slight Negative	• Contractor to plan, monitor and mitigate noise emissions according to construction schedule. • ECO conduct daily visual inspection of the noise barrier integrity and performance of the machinery • ECO to conduct site inspection and to submit a site environmental control report to the occupier of the construction at each site inspection every 2 weeks. • EMMP Consultant to conduct monthly site inspection ensure environmental mitigation measures have been effectively implemented by the Contractor • Conduct continuous noise monitoring at the nearest affected NSRs to show compliance with the maximum allowable limits stated in the EPM (Control of Noise at Construction Sites) Regulations	• Environmental Control Report • Noise monitoring records • Monthly Environmental Performance Report
	Mangrove fauna	Low		Minor Negative			Slight Negative		
	Recreational users (e.g., kayakers)	Low		No Impact			No Impact		
	OBS Camp 2 staff and participant	Low		No Impact			No Impact		
Underwater Noise	Marine ecology	Moderate	Physical and underwater noise disturbance	Minor Negative	• Consideration should be given to piling methodologies with the lowest noise emission characteristics • Soft start (ramp up) to gradually increase sound pressure levels to drive fish and marine fauna away from the area.	• Contractor	Slight Negative	NIL	NIL
	Aquaculture	Moderate		Slight Negative			Slight Negative		
	Transboundary aquatic life	High		No Impact	None required	NIL	No Impact	NIL	NIL
Hazardous Material & Waste	Marine ecology	High	• Generation of non-hazardous waste such as soil from excavation and used packaging material that cannot be recycled or reused onsite	Slight Negative	• The construction site must be maintained clean; construction wastes must be disposed of quickly in bulk trash containers, which must be emptied daily • Contractor shall engage ECO to prepare and implement environmental control plan and programme specific to the construction works undertaken by the contractor according to the LTA Safety, Health and Environment (General	• Contractor/ECO	Slight Negative	• Contractor to conduct daily visual inspection of the construction site to prevent generation of hazardous waste • ECO to monitor and record all outgoing construction wastes to be transported licensed toxic industrial waste collector for hazardous wastes. • ECO to conduct site inspection and to submit a site environmental control	• ECO Site Environmental Control Report • Waste manifest record • Monthly Environmental Performance Report

Environmental Aspect	Description of Receiver		Description of Potential Impact		Proposed Mitigation Measures	Implementation Agent	Residual Impact Significance	Proposed Monitoring Requirement	Reporting Requirements
	Receiver	Importance	Impact	Impact Significance					
	Terrestrial ecology	High	and need to be sent for offsite disposal • Generation of hazardous waste such as used lubricating oil that cannot be recycled or reuse onsite and need to be sent for offsite disposal	Slight Negative	Specifications Appendix A), and NEA COP for Environmental Control Officers • The construction contractor should be required by contract to establish a solid waste management strategy that addresses the collection, recycling, and eventual disposal of all produced wastes in an ecologically appropriate way • Wherever possible, excess excavated material and inert wastes (soil, shattered rock, etc.) will be utilized on site as structural fill, landscaping, erosion control, and restoration elements • Metal scrap (welding rods, end caps, off-cuts, and so on) can be recovered and recycled as scrap • On-site waste must be kept separate from construction and hazardous materials in covered bins or compaction units. To minimize smell, pest, and litter impacts, the Contractor should use a licensed general trash collector to remove general garbage on a daily or every other day basis • Appropriate disposal of any toxic waste by licensed toxic waste collectors as per required in the Environmental Public Health Regulations		Slight Negative	report to the occupier of the construction at each site inspection every 2 weeks. • EMMP Consultant to conduct monthly site inspection ensure environmental mitigation measures have been effectively implemented by the Contractor	
	Human receptor	Moderate		Slight Negative			Slight Negative		

9 Conclusion

The following changes and impacts were predicted for the construction (process) phase:

- **Currents**: No change is expected due to changes in current fields and statistics. No mitigation is required.
- **Sediment plume:** Highly localized increased suspended sediments and sedimentation are predicted from piling works. No mitigation is required.
- **Air and noise quality:** The construction works are expected to have only a minimal transient impact on air and noise quality, which should be maintained through application of the recommended management and mitigation measures.
- **Ecology and biodiversity:** Highly localized increased SSC and sedimentation rates during construction are predicted to have No Impact on the immediate adjacent mangroves. Minor negative impacts are also associated with construction disturbance (underwater noise) and deterioration of environmental quality (airborne noise pollution) during the construction which could be reduced to Slight Negative through suitable mitigation. The increased risk of accidental oil spills due to increased vessel traffic is assessed as a Slight Negative impact. It is concluded that there will be No Impact on Pulau Ubin shoreline, in terms of erosion.
- **Navigation:** No Impact is predicted to navigation safety in Serangoon Habour and berthing at OBS Camp 2 jetty as a result of changed currents and increased suspended sediments. No Impact is assessed on vessel collision given the low frequency of construction vessel movements. Local navigation guidelines and requirements shall be complied.
- **Human receptors**: It is anticipated that the air quality impact from the construction works would have negligible to slight transient impact on the recreational and community receptors. The predicted noise contribution from the works is below the defined threshold limit, hence it is assessed No Impact on the OBS Camp 2 staff and participants and recreational users. Nonetheless, the proposed mitigation measures should be implemented throughout the works to ensure the construction noise levels are kept within an acceptable range. Sediment plume visual aspects are assessed as No Impact as the public recreational users are not expected to kayak near to the OBS Camp 2 jetty or slipway.
- **Aquaculture**: No impacts are predicted to aquaculture or fisheries receptors as a result of suspended sediments. All the identified farmed fish are out of the major impact zone but still within behavioural impact zone. This significance level is hence assessed as ‘Slight Negative’.
- **Waste and hazardous materials management**: The potential for an uncontrolled release of oil from a collision at sea requires additional mitigation in order to mitigate the impact to nearby marine ecology. Oil spills can be managed through application of navigational controls as part of a Major Accident Prevention Plan (MAPP) and by using dedicated spill response and emergency response procedures.
- **Transboundary:** ‘No Impact’ is predicted to all transboundary receptors due to construction works.

The following changes and impacts were predicted for the post-construction (project) phase:

- **Currents**: No change is expected due to changes in current fields and statistics. No mitigation is required.
- **Ecology and Biodiversity**: The presence of an extended slipway creates long-term permanent impact on marine macrobenthos from footprint-induced loss of habitat but not significant as the footprint does not expand extensively from original slipway. As post-construction phase has limited land-based activities, it is anticipated that impacts to terrestrial ecology would be minimal, if any. A Slight negative impact is concluded. The effect of erosion to the mangrove fringes and the coastline from the new slipway is expected to be No Impact.
- **Navigation**: No Impact is predicted to navigation safety in Serangoon Habour and berthing at OBS Camp 2 jetty as a result of changed currents.
- **Transboundary:** 'No Impact' is predicted to all transboundary receptors due to the presence of the refurbished slipway.

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