Sentosa Development Corporation

Final Environmental Impact Assessment Report

(Part II – Main Report)

Tanjong Rimau Slope Stabilisation

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1. Introduction

Sentosa Development Corporation (SDC) has appointed Camphora Pte Ltd (Camphora) to undertake an Environmental Impact Assessment (EIA) for the proposed slope stabilisation works at Tanjong Rimau, Sentosa. This report presents the current condition of the coastal slopes and evaluates the engineering measures developed for stabilisation, followed by the identification of appropriate mitigation and monitoring measures, with an emphasis on incorporating nature-based solutions to enhance site stability and safety. The proposed interventions aim to implement sustainable slope improvement and toe protection measures guided by a risk-based assessment framework, while remaining aligned with project budget and timeline requirements. In parallel, the Project seeks to preserve the ecological research value and biodiversity of Tanjong Rimau, safeguard the historical significance of Fort Siloso structures, and maintain the integrity of the Tanjong Rimau Formation's geological outcrops. Accordingly, the design approach emphasises climate resilience, adaptability, cost-effectiveness, and constructability, with stabilisation proposed only at selected sites while other slopes are retained in their natural state.

1.1 Study Area

The Study Area is located at the northwest tip of Sentosa Island at Tanjong Rimau and comprises an approximately 400-metre-long, largely vegetated coastal slope facing the sea (**Figure 1-1**). Over the years, this section of coastline has experienced continued erosion, slope failures, and rockfalls, prompting Sentosa Development Corporation (SDC) to undertake detailed investigations to understand the existing conditions and the causes of instability. An engineering feasibility study conducted in 2024 identified key areas requiring attention, leading to the commencement of consultancy services in July 2025 to develop the detailed design for slope stabilisation works. The surrounding coastal environment includes sensitive and ecologically valuable habitats such as rocky shore, seagrass meadows and coral reefs; further underscoring the need for a carefully considered approach.

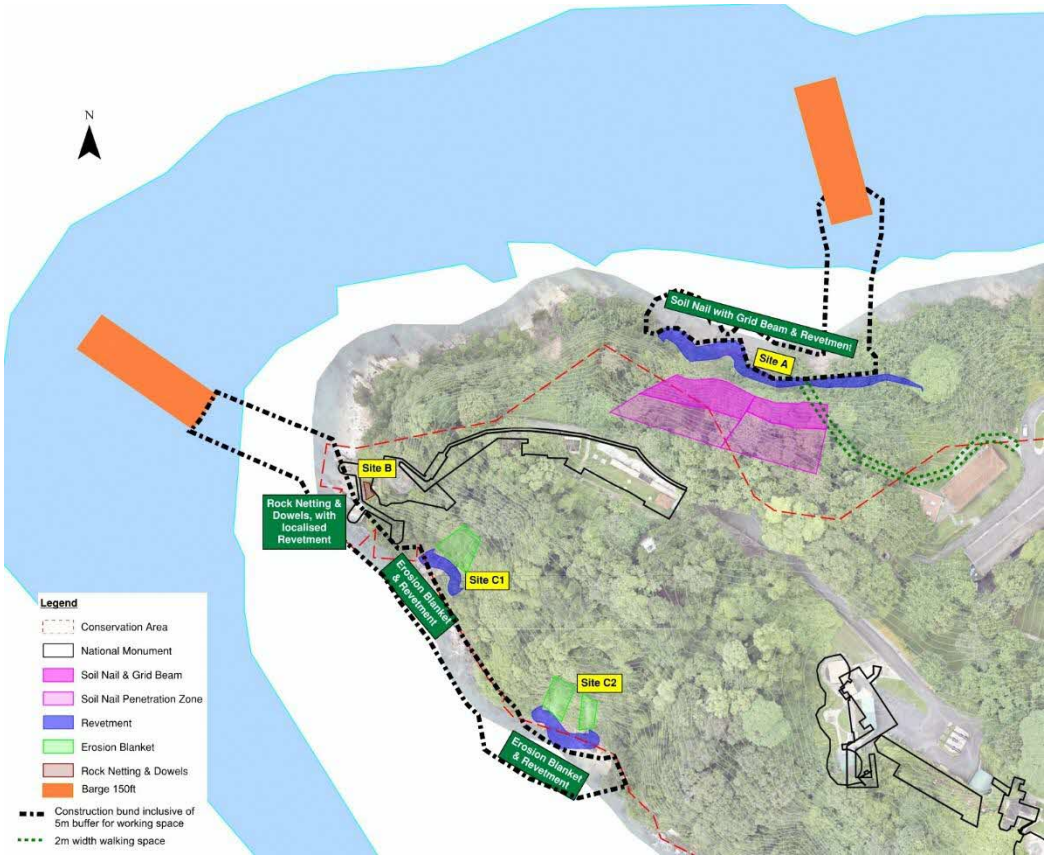


Figure 1-1 Study Area

1.1.1 Slope Stabilisation Works

Taking reference from engineering solutions for the slope stabilisation developed by ARUP, **Table 1-1** is a summary of the slope stabilisation works that will occur at each slope failure site—A, B, C1 and C2.

Table 1-1 Summary of slope stabilisation works at each slope failure site

Slope Failure Site	Slope Works	Construction Steps / Sequence
A	Soil Nails and Grid Beams	• Remove loose soil, damaged/collapsed concrete structures, and vegetation from slope surface. • Contractor to conduct slope survey after clearing for setting-out of soil nails and grid beam layout. • Install temporary staging for soil nailing works. • Drill and grout holes with steel rebar to form soil nails (6–15 m), installed progressively from top to bottom. • Cast grid beams following completion of soil nail and nail-cap installation. • Make good the slope surface and carry out vegetation reinstatement. • Remove temporary staging.
	Revetment	• Clear loose soil, loose rock, fallen trees, and soft material to prepare founding base. • Contractor to survey revetment extent after clearing. • Lay geotextile and underlayer rock. • Place XblocPlus units according to design specification. • Construct the rock toe to secure base of units.
B	Rock Netting and Dowels	• Remove loose soil and rock from slope surface. • Contractor to survey slope for setting-out of dowels and netting locations. • Install temporary staging for safe access.

		• Drill and grout holes with steel rebar to form rock dowels (2–5 m), installed progressively from top to bottom. • Install rock netting from top to bottom, securing it with steel hooks grouted into rock. Remove temporary staging.
C1 and C2	Erosion Control Blankets	• Remove loose soil/rock, damaged concrete structures, and vegetation. • Contractor to survey slope after clearing for correct placement of erosion control blankets. • Install temporary staging. • Lay erosion control blanket from top to bottom and secure with pins. • Cast cascading drains where required to manage water flow. • Carry out vegetation works. • Remove temporary staging.
	Revetment	• Clear loose soil, loose rock, fallen trees, and soft material to prepare founding base. • Contractor to survey revetment extent after clearing. • Lay geotextile and underlayer rock. • Place XblocPlus units according to design specification. • Construct the rock toe to secure base of units.

1.1.2 Construction Pathway

To support the implementation of the slope stabilisation works, dedicated construction access routes are required to facilitate the delivery of machinery, equipment, and materials to the work areas. Two types of access will be employed—terrestrial access and marine access (**Figure 1-2**).

Terrestrial access will be used only for Site A, providing a safe route for workers to reach the work area from the top of the cliff. The access path will be approximately 2 m wide, and only minimal vegetation clearance is anticipated along this corridor.

A marine-based access route will serve as the primary means for transporting machinery and construction materials to all sites. At each marine access route, a barge approximately 45 m by 15 m in size, will be transported by a tugboat to the temporary bunds where the materials and machinery will be offloaded onto the bunds and transported to the worksites. Barge movements are expected to occur no more than twice daily during high tide under a worst-case scenario. The barge may be stationed at the temporary bund using spud down piles throughout the construction phase. After which the excavators will operate directly on the bund to undertake the stabilisation works.

Materials and equipment required for soil nailing and other construction activities will be delivered primarily by the marine route, while workers will continue to access the site via terrestrial entry points where applicable. This construction access arrangement and delivery sequence will also be adopted for Sites B, C1, and C2, where the temporary bund will be constructed as a continuous structure along the full extent of the working frontage. The temporary bund will be constructed with the same materials as the rock armour to achieve a flat surface for the machinery to move and work on.

Figure 1-2 Map showing location of slope stabilisation works and construction pathways

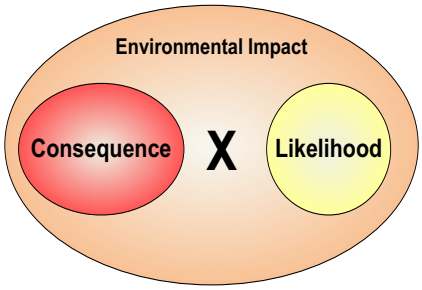
1.2 Baseline Data Collection

To accurately assess the Study Area, baseline data was collected through surveys that are detailed in **Section 3.1** and **4.1** for Biodiversity and Physical Environment respectively. These data were then used to assess the impact of the incoming slope stabilisation works.

1.3 Impact Assessment Evaluation

Key potential environmental impacts arising from the proposed slope stabilisation work are assessed using the Impact Significance Matrix in **Table 1-2** as detailed below and in the following sections:

- **Impact Consequence (Section 1.3.1):** The consequence of an impact is a function of a range of considerations including impact spread, impact duration, impact intensity and nature, legal and guideline compliance.
- **Likelihood of Occurrence (Section 1.3.2):** The likelihood of the impact occurring during the Project construction period; which takes into account the probability of the event happening as well as duration of the event.



This approach is aligned with established EIA methodologies and NParks BIA Guidelines (2024) [1].

1.3.1 Impact Consequences Matrix

In evaluating the consequence of environmental impacts, the following aspects are taken into consideration:

- **Receptor Sensitivity** Sensitivity is informed by ecological value, conservation status, regulatory protection, and functional importance. Those of high ecological value were assigned the Priority 1 sensitivity level, while those of moderate or low ecological value were assigned the Priority 2 or 3 sensitivity levels, respectively.
- **Impact Intensity:** Defines the magnitude of the impact and the status of the impact in relation to regulations (e.g. discharge limits), standards (e.g. environmental quality criteria) and guidelines. The factors to consider for impact intensity are listed in **Table 4.11** of the NParks BIA Guidelines (2024) [1].

Table 1-2 Impact consequence matrix

Sensitivity / Impact Intensity	Priority 3	Priority 2	Priority 1
Negligible	Imperceptible	Very Low	Very Low
Low	Very Low	Low	Low
Medium	Very Low	Medium	Medium
High	Low	High	High

1.3.2 Likelihood of Occurrence

The likelihood of occurrence assesses the probability that an identified impact will materialise during the construction or operational phases of the Project. This includes consideration of the nature of the works, construction methods, site conditions, and the potential for events to occur under both routine and non-routine scenarios. The Likelihood criteria is listed in **Table 1-3**.

Table 1-3 Likelihood criteria

Likelihood Criteria	Definition for All Environmental Parameters
Unlikely/Remote	Would be unlikely or remotely to occur during construction phase.
Less Likely/Rare	Would less likely/ rarely occur during construction phase.
Possible/ Occasional	Would possibly/ occasionally occur during construction phase.
Likely/Regular	Would likely occur or would occur on a regular basis during construction phase.
Certain/Continuous	Would be certain to occur or would occur continuously during construction phase.

1.3.3 Significance of Impact

The significance of each impact is determined by assessing the impact consequence against the likelihood of the impact occurring using the Impact Significance Assessment Matrix. A simple risk-based matrix was used for summation of consequence and likelihood, a sample of which was shown in **Table 1-4**.

Impacts assessed as Negligible or Minor in general would require no additional management or mitigation measures (on the basis that the magnitude of the impact was sufficiently small, or that the receptor was of low sensitivity and/or that adequate controls were already included in the propose incoming activities). Negligible and Minor impacts are therefore deemed to be “Insignificant”. Impacts evaluated as Moderate or Major would require the adoption of management or mitigation measures. Major impacts are therefore deemed to be “Significant” and Moderate impact as “Relatively Significant”. Major and Moderate impacts mostly require further management or mitigation measures to minimise or reduce the impact to an acceptable level.

Table 1-4 Impact significance matrix

Consequence / Likelihood	Imperceptible	Very Low	Low	Medium	High
Unlikely/ Remote	Negligible	Negligible	Negligible	Negligible	Negligible
Less Likely/ Rare	Negligible	Negligible	Minor	Minor	Minor
Possible/ Occasional	Negligible	Minor	Minor	Moderate	Moderate
Likely/ Regular	Negligible	Minor	Moderate	Moderate	Major
Certain/ Continuous	Negligible	Minor	Moderate	Major	Major

1.4 Mitigation of Significant Impacts and Residual Impact Assessment

Where the implementation of minimum controls is insufficient to alleviate any significant environmental construction impacts (Moderate to Major impacts), project-specific mitigation measures, in consultation with the NParks and relevant Authorities, will be proposed.

Mitigation measures will be proposed in accordance with the following hierarchy in line with Biodiversity Impact Assessment ("BIA") Guidelines published by NParks [1]:

- **Avoid** – Where changes to the Project design and construction methodology can be made to eliminate or avoid an identified impact (e.g. optimisation or reduction of construction footprint, shift or elimination of construction site in critical areas, etc.). If a full elimination is not possible, the next level of mitigation is to minimise the identified impact.

- **Minimise** – Where changes to the Project design and construction methodology cannot affect impact elimination or avoidance, use of alternative construction methodology or any enhancement measures can be adopted to minimise for identified impacts. For e.g. a wildlife shepherding plan is put in place to allow any animals trapped on the site to escape into the surrounding vegetation.

- **Remedy/ Repair/ Restore** – Where changes to the Project design and construction/ operation cannot affect impact avoidance and impact minimization, restoration methodology can be applied after construction is completed to remedy/ repair/ restore the ecological habitat as much as possible. For e.g. after construction, appropriate trees and shrubs are replanted in appropriate locations on the impacted site to restore part of the habitat.

Compensation/ Offset – Where measures taken to compensate or offset the residual impacts after implementing the first three steps of the mitigation hierarchy, wherever technically and financially feasible, e.g. transplanting of rare shrubs or trees to elsewhere in consultation with government authorities, etc.

An "acceptable level" is the reduction of a major impact to a moderate one after mitigation. In seeking to mitigate moderate impacts, the emphasis is on demonstrating that the impact has been reduced to a level that is as low as reasonably practicable. It will not always be practical to reduce moderate impacts to minor ones in consideration of the cost-ineffectiveness of such an approach (due to the diminishing return of a reduction of impact versus cost). Residual impact assessment will be conducted for those

parameters where impact from the activity is identified to be significant and additional mitigation measures are recommended. Positive impacts were not assessed for significance. Assessment of residual impact will follow similar risk approach as outlined above.

1.5 Environmental Management and Monitoring Plan (EMMP)

An EMMP is developed to ensure that mitigation measures are implemented effectively throughout the construction phase. The plan outlines roles and responsibilities, environmental performance requirements, monitoring protocols, and reporting procedures. Monitoring indicators are selected based on key environmental parameters to verify compliance, track environmental conditions, and facilitate adaptive management if unforeseen impacts arise.

2. Desk Study

This section of the report comprises a literature review of all publicly available, site specific, and field observations to develop a baseline knowledge of site conditions. The review aims to assess the relevance and reliability of the information, and the implications for slope stability and environmental impact. It will also aim to highlight key areas and uncertainties that will be further investigation in the site inspection, geotechnical investigation, and environmental impact assessment.

2.1 Site History

The island of Sentosa plays an important role in Singapore's history due to its strategic location at the southern-most point of mainland Singapore. As such, it has a history of development related to its military importance. Prior to major development of the island, including major reclamation, in the latter part of the 20th Century, the island was significantly smaller, and the Study Area formed part of the natural coastline.

The first significant development on Sentosa Island occurred by the 1880's with the construction of the first fortifications, including Fort Siloso near the Study Area. The island was heavily fortified by 1930. Following the Japanese capture of Singapore in 1942, the island was a prisoner of war camp for Allied troops during the occupation. Following the surrender of Japanese forces in 1945 the island remained a military base for British and the Singaporean forces until the 1970's when the government started development of the island. The island was renamed Sentosa in 1970 (formerly Pulau Belakang Mati) and major development of the island commenced in 1972. On 15 February 2022, Fort Siloso gazetted as Singapore's 74th national monument.

The Study Area remains as one of Singapore's last remaining coastal cliff and rocky shore [2]. It supports seagrass meadows and coral reefs and is a significant area of conservation [3].

A series of historical maps obtained from NUS Libraries [4] and Streetdirectory [5] at the Study Area is shown in **Figure 2-1**. Fort Siloso was first mentioned on the 1978 map. No significant development at the Study Area has been captured on the maps.

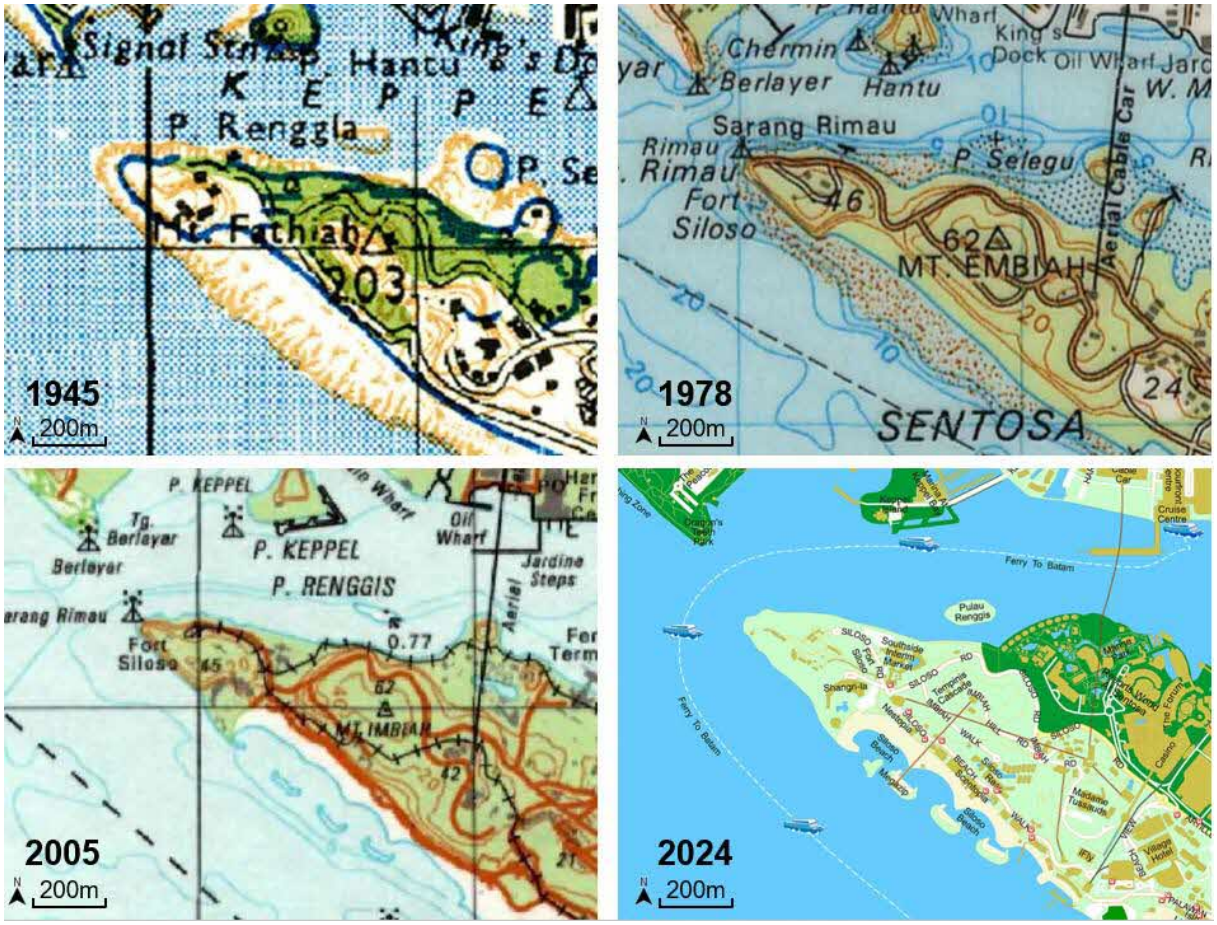


Figure 2-1 Historical maps (NUS Libraries, 2024 [4], Streetdirectory, 2024 [5])

2.2 Environmental Information

Tanjong Rimau is located at the northwestern tip of Sentosa Island. It is the home to corals, seagrass and a large variety of marine wildlife. As one of Singapore's remaining natural rocky shore and coastal cliff habitat, its species richness and the unique geology of the intertidal zone of Tanjong Rimau make it a consistently popular site for nature lovers [3-4]

The species on the shores of Tanjong Rimau are resilient. They survived several coastline changes, including the construction of Resort World at Sentosa from 2007- 2010 [6]. The hard corals, soft corals and sea anemones also survived local mass bleaching events in 2016 and 2020 [7].

The literature review data consisted of nine academic papers, nine blogs, and two other websites that are not blogs, data from five EIA reports and one set of data previously surveyed by Camphora. Data collected from this literature review were published from 2005- 2024.

A total of 210 marine fauna previously recorded along the Tanjong Rimau were extracted through literature review data. These species cover a range of taxa, including 3 arthropods, 1 barnacle, 31 cnidarians, 19 decapods, 8 echinoderms, 13 fishes, 40 molluscs, 2 platyhelminthes, 3 polychaetes, 7 porifera and 1 spider. A total of three species of algae and four species of seagrass was also extracted.

Among the marine faunal groups, 18 conservation significant (CS) species were identified – 12 nationally Vulnerable, five nationally Endangered, and one nationally Critically Endangered fauna were listed (**Table 2-1**). These CS species statuses are mostly based on the Red Data Book 3rd Edition (RDB3) [8].

A total of 107 flora species excluding seagrass were previously recorded, among them, 25 terrestrial flora CS species were identified – 5 nationally Vulnerable, 14 nationally Endangered and six nationally Critically Endangered flora are listed (**Table 2-2**). Many of these species are associated with the rare coastal cliff habitats. Critically Endangered terrestrial flora species listed the following: *Fagraea ridleyi,* white-leafed fig *(Ficus binnendijkii)*, *Garcinia nigrolineata*, *Gnetum latifolium*, *Lindsaea orbiculata* and nyireh (*Xylocarpus rumphii*). The complete list of all species can be found in **Appendix A**.

This literature review will focus on hard corals and seagrasses as they more heavily impacted by the scope of works and provide a long list of ecosystem services, including coastal protection and providing a shelter, protection and food for juvenile fish. At Tanjong Rimau, 21 coral species were identified, including the coral mole mushroom coral (*Polyphyllia talpina*), which is nationally Vulnerable, and the smooth cauliflower coral (*Stylophora pistillata*), which is nationally Critically Endangered (**Table 2-3**). When comparing the coral communities across the coast at Keppel Island, the recent environmental study report published in February 2025 recorded 15 of coral genera were not recorded in the literature reviews for Tanjong Rimau [9]. The list can be found in the **Table 2-4.** Similarly, all but one seagrass species is of conservation significance (**Table 2-5**).

Some of the species recorded at Tanjong Rimau are associated with its habitat. For example, the nationally Vulnerable common sea star (*Archaster typicus*) is often sighted in areas with seagrass habitats [10]. The nationally Vulnerable marine spider (*Desis martensi*) hides among corals and coral rubbles [7], and snapping shrimp (Alpheidae Family) [7] are commonly sighted and heard at rock shores. Blacktip reef sharks (*Carcharhinus melanopterus*) have been sighted in shallow habitats [11], and a shark egg was also found on the shores of Tanjong Rimau. This indicates that the unique habitats of Tanjong Rimau are essential for supporting the growth and development of our local biodiversity.

Table 2-1 List of conservation significant marine fauna recorded at Tanjong Rimau based on literature review

Common name	Scientific Name	Taxon	National Status
Coastal horseshoe crab	*Tachypleus gigas*	Arthropod	Vulnerable
Pink-spotted bead anemones	*Anthopleura buddemeieri*	Cnidarian	Endangered
Mole mushroom coral	*Polyphyllia talpina*	Cnidarian	Vulnerable
Smooth cauliflower coral	*Stylophora pistillata*	Cnidarian	Critically Endangered
Brown egg crab	*Atergatis floridus*	Decapod	Vulnerable
Red egg crab	*Atergatis integerrimus*	Decapod	Vulnerable
Red-eyed reef crab	*Eriphia ferox*	Decapod	Vulnerable
Masked burrowing crab	*Gomeza bicornis*	Decapod	Vulnerable
Little African sea cucumber	*Afrocucumis africana*	Echinoderm	Vulnerable
Common sea star	*Archaster typicus*	Echinoderm	Vulnerable
Black sea cucumber	*Holothuria leucospilota*	Echinoderm	Endangered
Galloping sand star	*Stellaster childreni*	Echinoderm	Vulnerable
Blacktip reef shark	*Carcharhinus melanopterus*	Fish	Endangered
Three-spot frogfish	*Lophiocharon trisignatus*	Fish	Endangered
Blue-spotted fantail ray	*Taeniura lymma*	Fish	Vulnerable
Tiger cowrie	*Cypraea tigris*	Mollusc	Endangered
Dawn flatworm	*Pseudobiceros hancockanus*	Platyhelminthes	Vulnerable
Marine spider	*Desis martensi*	Spider	Vulnerable

Table 2-2 List of terrestrial flora species recorded on the cliffs of Tanjong Rimau based on literature review

Common name	Scientific Name	Taxon	National Status
Climbing belinjau	*Gnetum microcarpum*	Gnetaceae	Endangered
-	*Garcinia nigrolineata*	Guttiferae	Critically Endangered
Penaga laut	*Calophyllum inophyllum*	Guttiferae	Endangered
-	*Garcinia forbesii*	Guttiferae	Endangered
-	*Fagraea ridleyi*	Loganiaceae	Critically Endangered
Delek air	*Memecylon edule var. edule*	Melastomataceae	Endangered
Nyireh	*Xylocarpus rumphii*	Meliaceae	Critically Endangered
White-leafed fig	*Ficus binnendijkii*	Moraceae	Critically Endangered
-	*Ficus caulocarpa*	Moraceae	Endangered
Malayan banyan	*Ficus kerkhovenii*	Moraceae	Endangered
-	*Ficus vasculosa*	Moraceae	Vulnerable
-	*Myrsine capitellata*	Myrsinaceae	Endangered
Pelawan	*Tristaniopsis whiteana*	Myrtaceae	Endangered
Raffles' Pitcher-Plant	*Nepenthes rafflesiana*	Nepenthaceae	Vulnerable
-	*Pittosporum ridleyi*	Pittosporaceae	Vulnerable
Sea teak	*Podocarpus polystachyus*	Podocarpaceae	Endangered
-	*Pyrrosia angustata*	Polypodiaceae	Endangered
-	*Dibridsonia conferta*	Rubiaceae	Endangered
White gutta	*Palaquium obovatum var. obovatum*	Sapotaceae	Vulnerable
Tongkat ali	*Eurycoma longifolia*	Simaroubaceae	Endangered
-	*Symplocos adenophylla*	Symplocaceae	Endangered
River Tarenna	*Tarenna fragrans*	Rubiaceae	Endangered
-	*Lindsaea orbiculata*	Lindsaeaceae	Critically Endangered

Table 2-3 List of hard corals (Order Scleractinia) recorded at Tanjong Rimau based on literature review

Common name	Scientific Name	National Status
Acropora coral	*Acropora sp.*	-
Meteor coral	*Cyphastrea sp.*	Least Concern
Flat lettuce coral	*Echinophyllia aspera*	Least Concern
Faviid	*Favia sp.*	-
Goniopora coral	*Goniopora sp.*	-
Boulder horn coral	*Hydnophora exesa*	Least Concern
-	*Montipora sp.*	-
-	*Pectinia sp.*	-
-	*Platygyra sp.*	-
Mole mushroom coral	*Polyphyllia talpina*	Vulnerable
Porites	*Porites sp.*	-

Crinkled sandpaper coral	*Psammocora contigua*	Near Threatened
Smooth cauliflower coral	*Stylophora pistillata*	Critically Endangered
Flowery disk coral	*Turbinaria peltata*	Least Concern

Table 2-4 List of hard corals (Order Scleractinia) recorded at Keppel Island but not recorded at Tanjong Rimau based on literature review

Common name	Scientific Name	National Status
Brain coral	*Acanthastrea sp.*	-
-	*Astreopora sp.*	-
Anemone coral	*Bernardpora stutchburyi*	Least Concern
-	*Dipsastraea sp.*	-
Pagoda coral	*Duncanopsammia peltata*	Least Concern
-	*Echinopora sp.*	-
Torch anchor coral	*Euphyllia sp.*	-
Mushroom coral	*Fungia sp.*	-
Galaxy coral	*Galaxea sp.*	Least Concern
Tongue mushroom coral	*Herpolitha limax*	Least Concern
-	*Leptastrea sp.*	Least Concern
-	*Lithophyllon sp.*	-
-	*Lobophyllia sp.*	-
-	*Mycedium elephantotus*	Least Concern
-	*Oxypora sp.*	-
-	*Pavona sp.*	-
Bracket mushroom coral	*Podabacia sp.*	-
-	*Pseudosiderastrea sp.*	-

Table 2-5 List of seagrass recorded at Tanjong Rimau based on literature review

Common name	Scientific Name	National Status
Tape seagrass	*Enhalus acoroides*	Critically Endangered
Spoon seagrass	*Halophila ovalis* complex	Least Concern
Sickle seagrass	*Thalassia hemprichii*	Endangered
Needle seagrass	*Halodule uninervis*	Vulnerable

3. Biodiversity

3.1 Field Survey Methodology

3.1.1 Flora

All plants observed within the Study Area were identified to species whenever possible, and a checklist of all the plant species recorded (**Figure 3-1**). The survey dates and locations are listed in **Table 3-1**. The nomenclature and national conservation status will follow that of the Third Edition of the Singapore Red Data Book, NParks (2024) [8] Lindsay et al. (2022) [12], Chong et al. (2009) [13], and/or other published papers with information on the updated assessment of the species nomenclature and/or conservation status, where relevant. Other information on the plant species will also be cross-checked with online databases, namely, the NParks Flora and Fauna Web [14] and LKCNHM's Biodiversity of Singapore [15].

For plants that could not be immediately identified with certainty in the field, photographs and/or voucher specimens was taken. These were then identified using identification keys, taxonomic descriptions, online plant photo databases, with the help of taxonomic experts, and/or by matching the pressed and dried collected specimens with existing specimens in the Singapore Botanic Gardens' Herbarium (SING). For very tall unidentifiable trees with leaves that are too high in the canopy to photograph, dried leaves matching these trees was collected from the forest floor and used to aid in species identification.

3.1.1.1 Flora Species of Conservation Significance

The geographic coordinates of plants of conservation significance were marked using a GPS receiver (Garmin GPSMap® 64s), which records locations with an accuracy of ± 4 m, during floristic surveys. Where there are clusters of plants of conservation significance—i.e., more than one individual occurring within 5 m or less of another individual—the geographic coordinates of the approximate centre of the area will be marked using the GPS receiver (Garmin GPSMap® 64s).

3.1.1.2 Large Plant Specimens

Similarly, the GPS receiver (Garmin GPSMap® 64s) was used to record locations of all trees of ≥ 3 m girth, as well as bamboo clusters, palm clusters, and strangling *Ficus* species of ≥ 3 m spread. Individuals were identified to species whenever possible. The girth (for trees) and spread (for bamboo clusters, palm clusters, and strangling *Ficus* species) were also be measured and/or estimated. The estimated height of the specimens was recorded.

3.1.1.3 Other Plant Specimens of Value

Locations of other plants that are of value but do not meet the minimum size requirement, as detailed in the above sub-section, was recorded using GPS receiver (Garmin GPSMap® 64s). Examples of such include bamboo clusters of <3 m spread that may be important refugia for rare bamboo bats, exotic trees of <3 m girth with active raptor nests, amongst others.

3.1.2 Tree Verification and Assessment

All trees and single-stemmed palms (i.e., defined as having one obvious and erect stem) of ≥ 1.0 m girth was verified with topological data provided by Client's appointed topographical survey team along the 2 m wide terrestrial access route to Site A. The girth (for trees) and spread (for palm clusters and strangling figs) were measured and estimated, respectively. The height of all specimens was also estimated. Subsequently, arboriculture assessment of the trees was conducted by Certified Arborists. Plant health and structural stability were assessed by observing for damage, decay and/ or canopy asymmetry, of which, if present, may compromise plant longevity and stability. The survey dates and locations are listed in **Table 3-1.**

3.1.3 Opportunistic Terrestrial Fauna

Opportunistic records of terrestrial fauna were collected each time any of the surveyors were within the Study Area. All fauna encountered was identified to species, or to the next lowest taxonomic level possible, with the location of each sighting recorded using a handheld GPS (Garmin GPSMap® 64s). Key local and/ or regional references for the various taxonomic groups are listed in **Table 3-2**. The number of individuals observed was documented along with any other notable behaviour or characteristics.

Table 3-1 Terrestrial flora and arboriculture survey schedule and location

Terrestrial Surveys	Date	Location
Flora Surveys	10-Oct-25	Intertidal
	18-Sep-25	Coastal Forest
Arboriculture Surveys	18-Sep-25	Coastal Forest

Table 3-2 Key references for the nomenclature and taxonomy for each terrestrial taxonomic group

Taxon	Key References
Herpetofauna (amphibians and reptiles)	Figueroa et al., 2023 [16]
Birds	Gill et al., 2022 [17]
Mammals	NParks, 2024 [8]

3.1.4 Intertidal

The intertidal habitat is typically dominated by organisms adapted to fluctuations in water levels, supporting a diverse range of flora and fauna such as algae, hard corals, sponges, and numerous benthic species including gastropods and crustaceans. When environmental conditions are favourable, such as when the site is sheltered from strong wave action, has an appropriate substrate, and retains some water during low tide, seagrasses can also flourish within the intertidal zone [18].

3.1.4.1 Intertidal Walk

At the same time as seagrass mapping (**Section 3.1.6.2**), faunal species as well as corals were recorded opportunistically. Due to limited low-tide exposure, only large coral colonies (size class 4 and above ≥25 cm) were mapped. A GPS receiver (Garmin GPSMap® 64s) was used to record the location of any animals found during this survey.

Table 3-3 Intertidal survey schedule and location

Intertidal Surveys	Date	Cycle	Location	Latitude	Longitude
Quadrat	27-Jul-25	1	I01	1.25996	103.80784
	27-Jul-25	1	I02	1.25947	103.80664
	26-Jul-25	1	I03	1.25909	103.80687
	26-Jul-25	1	I04	1.25866	103.807209
	26-Jul-25	1	I05	1.25798	103.80785
	12-Aug-25	2	I01	1.25996	103.80784
	12-Aug-25	2	I02	1.25947	103.80664
	12-Aug-25	2	I03	1.25909	103.80687
	11-Aug-25	2	I04	1.25866	103.807209
	11-Aug-25	2	I05	1.25798	103.80785

Intertidal walk and seagrass mapping	27-Jul-25	Whole site
	10-Oct-25	

3.1.5 Subtidal

The subtidal consist of reef-building coral reefs that provide habitat for a wide variety of marine life, including fishes, sponges, gastropods, molluscs, crustaceans, echinoderms and tunicates, along with abiotic substrates such as rocks, rubble, sand, and silt. A typical reef has distinct zones, the reef flat, crest, slope, and lower reef. The sunlit areas support photosynthetic organisms like corals and algae, while the deeper, darker zones host filter feeders such as sponges and sea fans. In this study, line intercept and belt transect methods were employed to examine the corals and marine organisms in the subtidal zone.

3.1.5.1 Coral Reef Fish and Mobile Invertebrates Surveys – Belt Transect

Belt transect was conducted at three locations, S01 – 03 following methods as described in English et al. (1997) [19] where fish and mobile invertebrates within a 5 m wide belt were recorded together with their abundance (**Figure 3-1**). Each location, two 100 m transects were established parallel to the reef crest and approximately 3 m below the crest. The subtidal field schedule is listed in **Table 3-4**. Where possible, photos of rare species or species of conservation significance were taken. The presence of hard corals was also recorded opportunistically in the survey. The size of each hard coral was measured and estimated along its widest axis or diameter according to the eight size classes outlined in **Table 3-6**. All species encountered were identified to their lowest taxonomic classifications where possible using the references listed in **Table 3-7**. The conservation status of all taxon was determined based on the Singapore Red Data Book version 3 by NParks (2024) [8] and the IUCN Red List [20].

Table 3-4 Subtidal survey schedule and location

Subtidal Surveys	Date	Location	Latitude	Longitude
LIT and Belt Transect	27-Aug-25	S01_Crest	1.26036	103.80791
	28-Aug-25	S01_Slope	1.26004	103.80891
	28-Aug-25	S02_Crest	1.26032	103.80612
	29-Aug-25	S02_Slope	1.25974	103.80585
	29-Aug-25	S03_Crest	1.25704	103.80791
	29-Aug-25	S03_Slope	1.25694	103.80785

Figure 3-1 Study Area with survey locations

3.1.6 Habitat Survey

3.1.6.1 Intertidal Habitat Survey—Quadrat

Intertidal quadrat surveys were conducted at five locations, I01 – 05, during low tide levels of less than 0.3 m to allow as much of the intertidal zone to be exposed as possible (**Figure 3-1**). The survey dates and locations are listed in **Table 3-3**. I01 – 04 are locations of the slope works while I05 is located further away from the works and can be used as a monitoring point during construction phase. At each location, 50 m transect were laid perpendicular to shoreline and quadrats of 50 cm by 50 cm were surveyed at every 5 m along the transect. The percentage cover of target organisms such as hard coral, soft coral, sponge, seagrass and algae was recorded together with other sessile fauna and abiotic components (sand, rock, and rubble). Examples of other sessile fauna include tunicates. The survey dates and locations are listed in **Table 3-3**.

Each hard coral encountered was measured along its widest axis and assigned to a size category, as presented in **Table 3-6**. Rocks within the quadrat, were flipped to ensure that invertebrates beneath were accounted for. When the species of invertebrates cannot be identified on site, a specimen per morphotype was collected for off-site identification—through the help of taxonomic experts, and/or by matching collected specimens with existing specimens in the Lee Kong Chian Natural History Museum (LKCNM). Species that were recognized as conservational significance was not collected.

3.1.6.2 Seagrass Mapping

The distribution of seagrass along the intertidal zone was mapped by walking the intertidal zone at low tide, ensuring thorough coverage. The survey dates and locations are listed in **Table 3-3**. A GPS receiver (Garmin GPSMap® 64s) was used to record boundaries of seagrass patches.

3.1.6.3 Subtidal Habitat survey—Line Intercept Transect (LIT)

LIT was carried out by SCUBA diving at three locations, S01 – 03 (**Figure 3-1**). S01 and S02 are locations of potential barge locations while S03 is located further away from the works and can be used as a monitoring point during construction phase. The subtidal field schedule is listed in **Table 3-4**. At each location, five 20 m line-intercept transects were established parallel to the reef, positioned at the reef crest and approximately 3 m below the crest. The transition points between successive, predetermined benthic lifeforms occurring directly beneath the transect tape was recorded, as described by English et al. (1997) [19]. The individual benthic lifeform categories used to characterise the benthic morphology of the sites are described in **Table 3-5**. All species encountered was identified to their lowest taxonomic classifications where possible using the references listed in **Table 3-7**. The conservation status of all taxon was determined based on the Singapore Red Data Book version 3 by NParks (2024) [8] and the IUCN Red List [20].

Table 3-5 Individual benthic categories used in the LIT survey

Major Benthic Category	Individual Category	Remarks/Comments
Targeted taxon	Hard Coral	All hard corals from order Scleractinia and blue coral (Helipora sp.). This includes mushroom coral that are solitary and free-living coral
	Soft coral	Soft-bodied corals from the order Alcyonaceae
	Sponges	A group of mostly filter-feeding sessile marine invertebrates from the phylum Porifera
	Algae	Including turf algae, coralline algae, macroalgae, algae assemblage (non-distinct mass of algae consisting of more than 1 species)
	Seagrass	From families Hydrocharitaceae and Cymodoceaceae
Targeted abiotic	Rubble	Unconsolidated coral fragments
	Rock	Non-carbonate, e.g., Granite rock
	Silt	Particles with grain size <63 µm; settles slowly when disturbed
	Sand	Particles with grain size >63 µm; settles fast when disturbed
Others	Others sessile fauna	Ascidians, anemone, giant clams, zoanthids etc.

Table 3-6 Hard coral size classes

Size Class	Diameter (cm)
1	<5
2	5 to 10
3	10 to 25
4	25 to 50
5	50 to 75
6	75 to 100

7	>100
8	>100; Consists of mono-specific stands

Table 3-7 Key references for the nomenclature and taxonomy for each marine taxonomic group

Taxon	Key References
Hard Coral	Veron & Pichon, 1976 [21]; WoRMS, 2025 [22]
Soft Coral	LKCNHM's Biodiversity of Singapore [15]
Sponges	Lim et al., 2008 [23]; LKCNHM's Biodiversity of Singapore [15]
Fish	WildSingapore, 2025 [24]; LKCNHM's Biodiversity of Singapore [15]
Algae	AlgaeBase, 2025 [25]; Lee et al., 2015 [26]; LKCNHM's Biodiversity of Singapore [15]
Ascidians	Lee et al., 2016 [27]; LKCNHM's Biodiversity of Singapore [15]
Anemone	Yap et al., 2019 [28]; LKCNHM's Biodiversity of Singapore [15]
Seagrass	Seagrass-Watch, 2025 [29]
All others	LKCNHM's Biodiversity of Singapore [15]; Wild Singapore [30]

Data Processing and Analysis

LIT Benthic Cover Determination

Raw data collected in the field will be transcribed into a datasheet and verified before being analysed. A morphological picture or description of the reef will be determined by expressing the benthic categories as a percentage of transect length. The percentage cover for each benthic category will be calculated as follows:

$$\text{Percent cover} = \frac{\text{Total length of category}}{\text{Length of transect (20m)}} \times 100\%$$

3.2 Baseline Results

3.2.1 Terrestrial

3.2.1.1 Flora

A total of 90 species were recorded, of which 24 species were of conservation significance (CS). Two of the species—*Psychotria* cf. *sarmentosoides* and *Thrixspermum* sp.—were identified based on the vegetative sample. Although species confirmation are pending due to a lack of fertile samples, a conservative approach has been adopted by including it in the CS species list. *Psychotria* cf. *sarmentosoides* is assessed as Presumed Nationally Extinct in the Red Data Book 3 while all *Thrixspermum spp.* in the Red Data Book 3 are assessed as either Critically Endangered or Presumed Nationally Extinct. The full species list of all the flora species recorded can be found in **Appendix B.**

Due to terrain and safety (risk of slope failure), most of the coastal forest were not accessible. Only slope failure site A was accessible from the top of the cliff. Yet the visibility was also limited. Slope failure location B, C1 and C2 were viewed primarily from the bottom of the cliff. Location of all CS species that were recorded during the survey are shown in **Figure 3-2** , with reference to slope failure locations.

Some species of interest include the four specimens of *Xylocarpus rumphii*, with location distributed across the southern part of the Study Area; where one location—before Site C2—had present both mothering tree and smaller tree, presumed to be from the mothering tree. These specimens if affected should be recommended to be avoided as much as possible.

Nine flora CS species are expected to be affected by the slope stabilisation work (more details can be found in **Section 3.3.4.1.2**). These include commonly seen species such as nationally Endangered *Podocarpus polystachyus* and *Tristaniopsis whiteana*, each with 20 and 37 specimens recorded on site respectively (**Figure 3-3**). While rare flora CS that are likely to be affected include species such as nationally Endangered *Garcinia celebica* and nationally Vulnerable *Syzygium* palembanicum, each only sighted once on site (**Figure 3-3**). Though these numbers can give some preliminary insight into the "rarity" of a species on site, it should be noted that it is not representative of its population on site or within Singapore. Other species likely affected include climber species such as *Nepenthes rafflesiana* (**Figure 3-3**).

Fortunately, species that are not expected to be affected by the slope stabilisation works include mostly nationally Critically Endangered species like *Fagraea ridleyi*, *Lindsaea orbiculata*, *Dalbergia junghunii* and *Parastemon urophyllus* and the Presumed Nationally Extinct *Psychotria* cf. *sarmentosoides*.

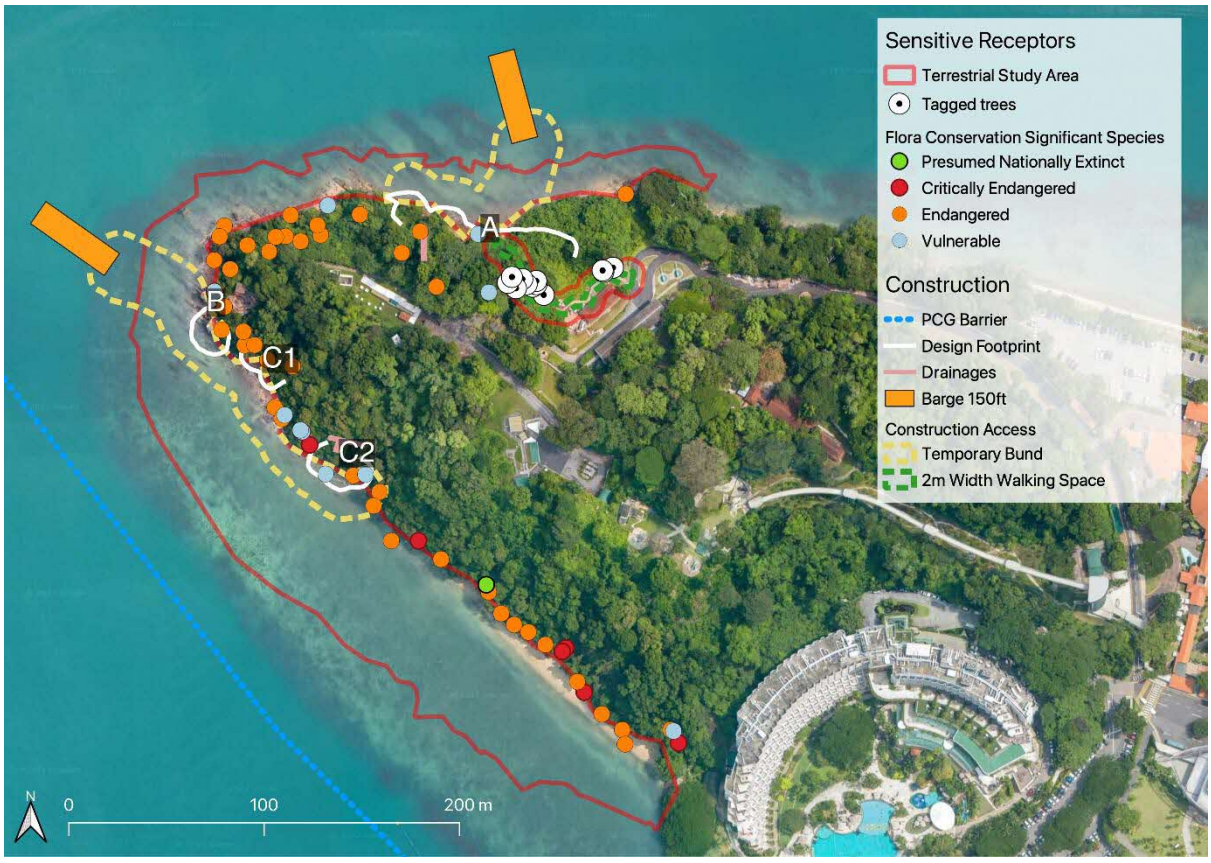


Figure 3-2 Flora species of conservation significance

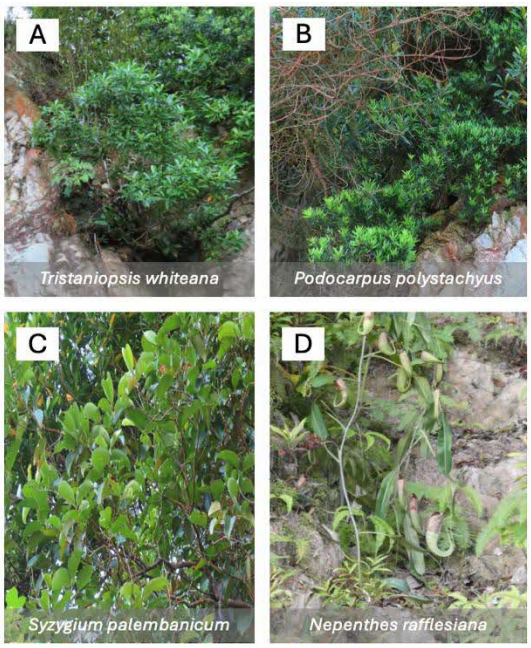


Figure 3-3 Flora species affected by slope failure works

3.2.1.2 Tree Verification and Assessment

A total of 12 trees comprising of 5 species were tagged within the costal forest, more specifically along the proposed terrestrial pathway with 1 m buffer on both sides (**Figure 3-4**; **Table 3-8**). No species of conservation significance was observed.

The full species list of all the tagged trees can be found in **Appendix C.**

Table 3-8 List of trees tagged within propose terrestrial pathway

Tree ID	Species	Origin
AFP1088	*Alstonia angustiloba*	Native
AFP1089	*Senna siamea*	Exotic
AFP1090	*Senna siamea*	Exotic
AFP1091	*Syzygium grande*	Native
AFP1092	*Adenanthera pavonina*	Exotic
AFP1093	*Adenanthera pavonina*	Exotic
AFP1094	*Senna siamea*	Exotic
AFP1095	*Adenanthera pavonina*	Exotic
AFP1096	*Adenanthera pavonina*	Exotic
AFP1097	*Alstonia angustiloba*	Native
AFP1098	*Terminalia catappa*	Native
AFP1099	*Adenanthera pavonina*	Exotic

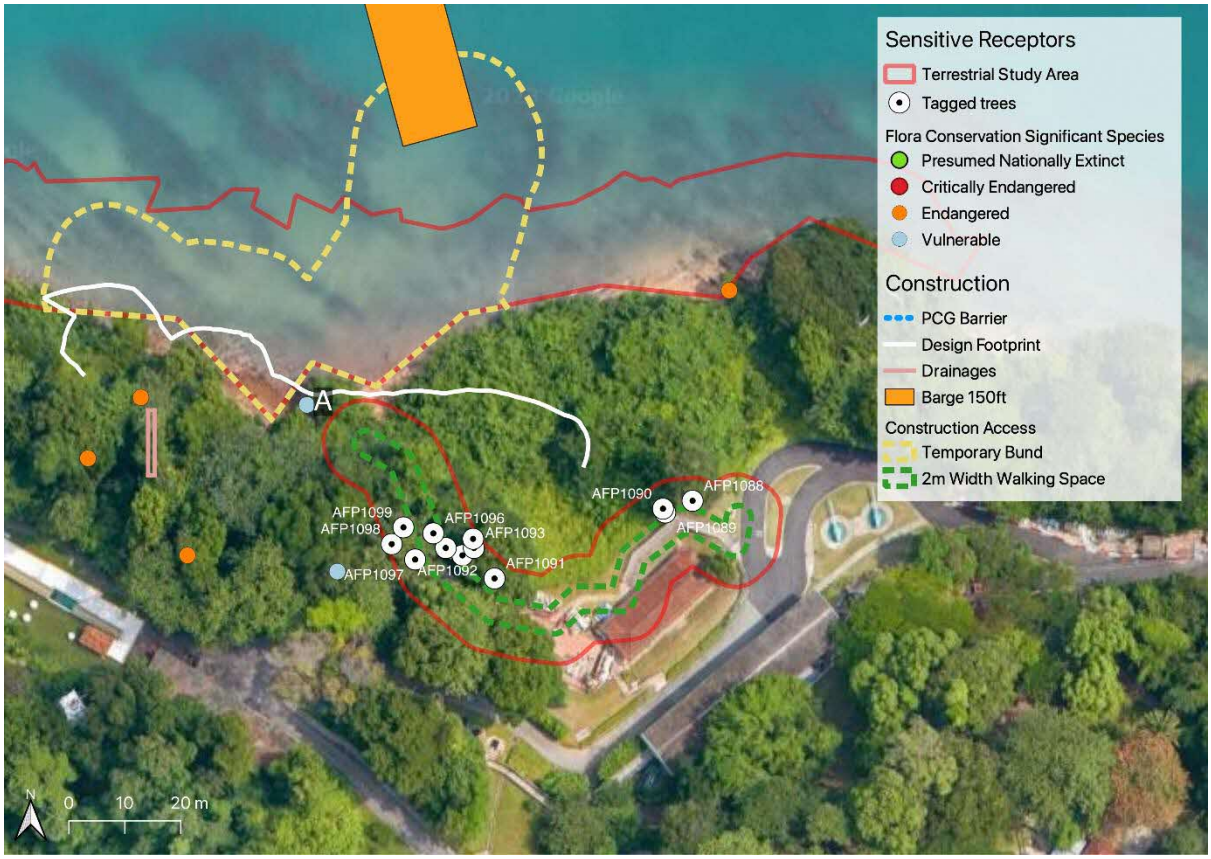


Figure 3-4 Tagged trees along terrestrial pathway

3.2.1.3 Opportunistic Fauna

A total of 12 species, 10 birds, one mammal and one reptile, were recorded opportunistically during the duration the field surveys. Out of the 10 bird species, three are of conservation significance (**Figure 3-5, Table 3-9**). The little tern (*Sternula albifrons*) which is nationally Endangered, is a shorebird commonly found along the coastal areas and open seas of Singapore. The nationally Vulnerable common sandpiper (*Actitis hypoleucos*) is a common winter migrant and a passage migrant to Singapore and is often seen near various forms of water bodies such as mudflat and intertidal habitats [31]. The large-billed crow (*Corvus macrorhynchos*) is also nationally Vulnerable. Unlike the house crow (*Corvus splendens*), it is less adapted to urban environments. As a result, the large-billed crow is uncommon and has a smaller population.

The sole species of mammal recorded was the smooth-coated otter (*Lutrogale perspicillata*). It is both nationally and globally Endangered. In Singapore they can often be found near mangroves, mudflats and coastal areas and may be using Tanjong Rimau as a foraging habitat [32] (**Figure 3-6** and **Appendix D**)

Table 3-9 Species list of terrestrial opportunist fauna

Type	Scientific name	Common name	Global status	National status
Bird	*Accipiter trivirgatus*	Crested goshawk	Least Concern	Near Threatened
Bird	***Actitis hypoleucos***	**Common sandpiper**	**Least Concern**	**Vulnerable**
Bird	*Butorides atricapilla*	Little heron	Least Concern	Near Threatened
Bird	*Cinnyris ornatus*	Ornate sunbird	Least Concern	Least Concern

Bird	***Corvus macrorhynchos***	**Large-billed crow**	**Least Concern**	**Vulnerable**
Bird	*Corvus splendens*	House crow	Least Concern	NA
Bird	*Haliastur indus*	Brahminy kite	Least Concern	Least Concern
Bird	*Pavo cristatus*	Indian peafowl	Least Concern	NA
Bird	***Sternula albifrons***	**Little tern**	**Least Concern**	**Endangered**
Bird	*Todiramphus chloris*	Collared kingfisher	Least Concern	Least Concern
Non-marine lizard	*Varanus salvator*	Water monitor	Least Concern	Least Concern
Non-marine mammal	***Lutrogale perspicillata***	**Smooth-coated otter**	**Vulnerable**	**Endangered**

*** Bold species are of conservation significance**

Figure 3-5 Location of conseveration significant terrestrial fauna

Figure 3-6 Smooth-coated otter (*Lutrogale perspicillata*) sighted within the Study Area

3.2.2 Intertidal

3.2.2.1 Quadrat Survey

Seven main substrate types were identified, (1) hard coral, (2) soft coral, (3) sponge, (4) seagrass, (5) algae, (6) abiotic substrates that comprise of sand, rock, and rubble, and (7) other sessile animals such as tunicates. The intertidal quadrat survey data can be found in **Appendix D**.

Survey Location I01 (**Figure 3-8**)

I01 is an algae-dominated rocky shore**,** with algae accounting for approximately 22% of total cover and abiotic substrate contributing around 70%. Biotic groups such as hard corals, soft corals, and sponges are present minimally (<2%), while seagrass cover remains low (7%). The site reflects a highly exposed rocky habitat with extensive algal turf development.

Survey Location I02 (**Figure 3-8**)

Like I01, I02 supports an algae-dominated rocky shore with algae forming about 27% of the cover and abiotic components comprising roughly 67%. Sponge cover reaches the highest among all survey location at approximately 6%, while seagrass, hard corals, and other sessile fauna remain low (<1%). The site shows moderate diversity but remains largely abiotic and algae-driven.

Survey Location I03 (**Figure 3-8**)

I03 represents a seagrass-associated intertidal habitat, with seagrass contributing the highest coverage across the survey location at approximately 16%. Algal cover remains substantial (42%), while abiotic

substrate makes up 39%. Other sessile taxa (corals, sponges) occur only at minor levels (<5%). The site suggests a semi-sheltered environment supporting mixed substrate and a more structured biological community.

Survey Location I04 **(Figure 3-8)**

I04 shows a habitat composition broadly like I01 and I02, with algae (52%) and abiotic substrate (42%) forming the dominant components. However, unlike I01 and I02, biotic elements are present albeit only at minimal levels (<5%), including small amounts of corals, sponges, and seagrass.

Survey Location I05 (**Figure 3-8**)

I05 has reduced abiotic presence (27%) compared to other sites but still shows high algal cover (68%). Similar to I04, biotic elements are present albeit only at minimal levels (<6%).

Overall (**Figure 3-9**)

Across the five intertidal survey stations (I01–I05), habitat composition reflects a gradient from exposed algal-dominated rocky shore to more sheltered mixed habitats with seagrass presence. Survey location I01, I02, and I04 are characterised primarily by algae (45–70%) and abiotic substrate (45–60%), indicating hard-substrate environments with limited sessile faunal diversity. In contrast, I03 supports the greatest structural complexity, with the highest seagrass cover (16%) and moderate algal presence (42%), reflecting a more sheltered and biologically productive zone. I05 represents a habitat with moderate algae (25–30%), lower abiotic exposure (30–35%), and minor seagrass presence (3–5%). Overall, the intertidal zone at Tanjong Rimau is dominated by rocky shore and algal communities, with localized patches of seagrass contributing to habitat diversity and ecological value. General habitat photos can be found in **Figure 3-7**.

Subsequently, a total of 12 species of algae were recorded, with the hairy green seaweed (*Bryopsis* sp.) being the most dominant. When algae were dense enough to form a substrate type, they were primarily composed of hairy green seaweed (*Bryopsis* sp.), calcareous algae (order Corallinales), Mermaid's Fan (*Padina* sp.), and *Sargassum* sp.

The full species list of all the intertidal species recorded can be found in **Appendix D**.

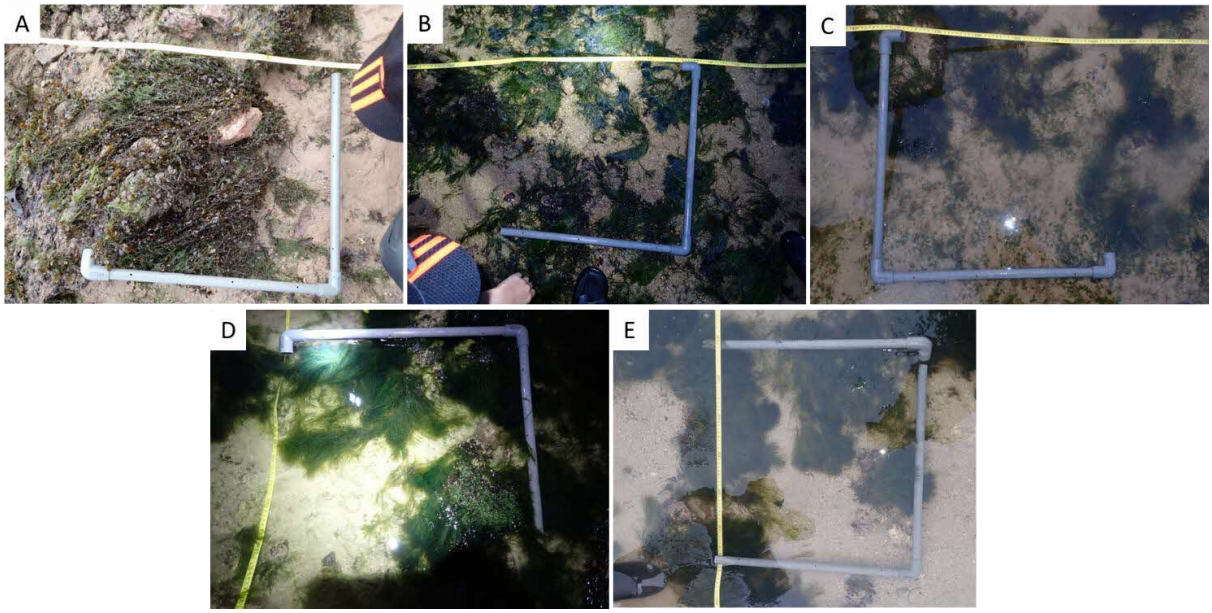


Figure 3-7 Quadrat images from A: I01, B: I02, C: I03, D: I04, E: I05 at 15m along the transect

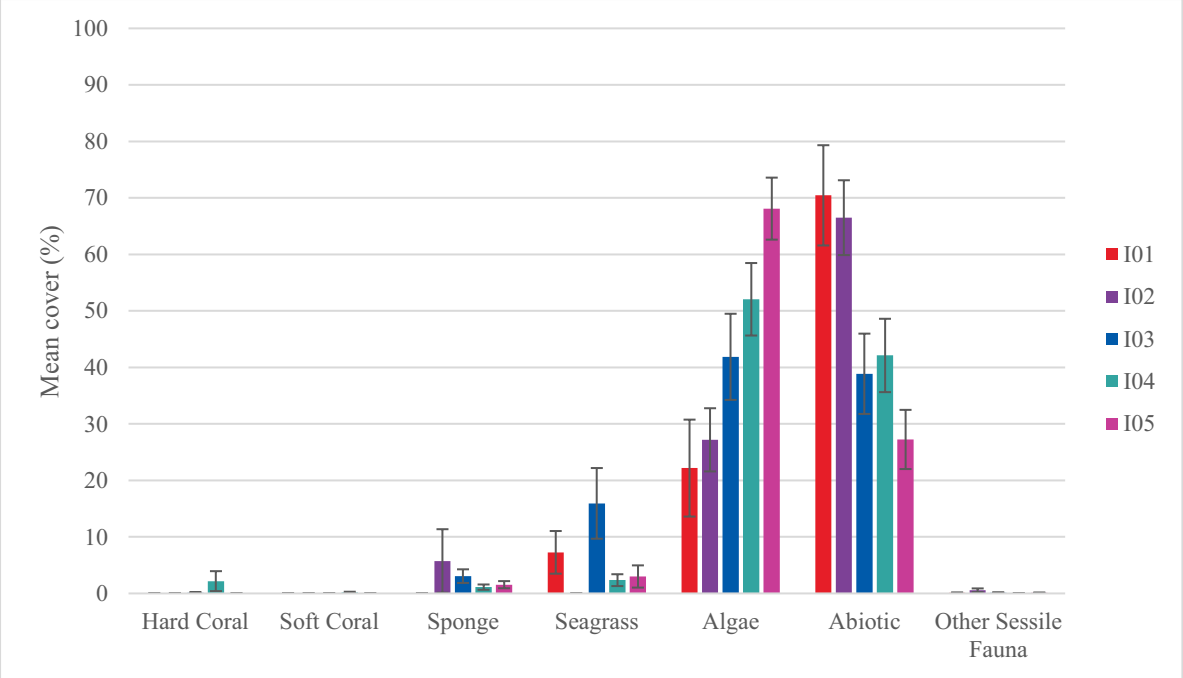


Figure 3-8 Mean (± SE) percentage cover of intertidal benthic categories recorded from Site I01-I05 during the intertidal quadrat surveys

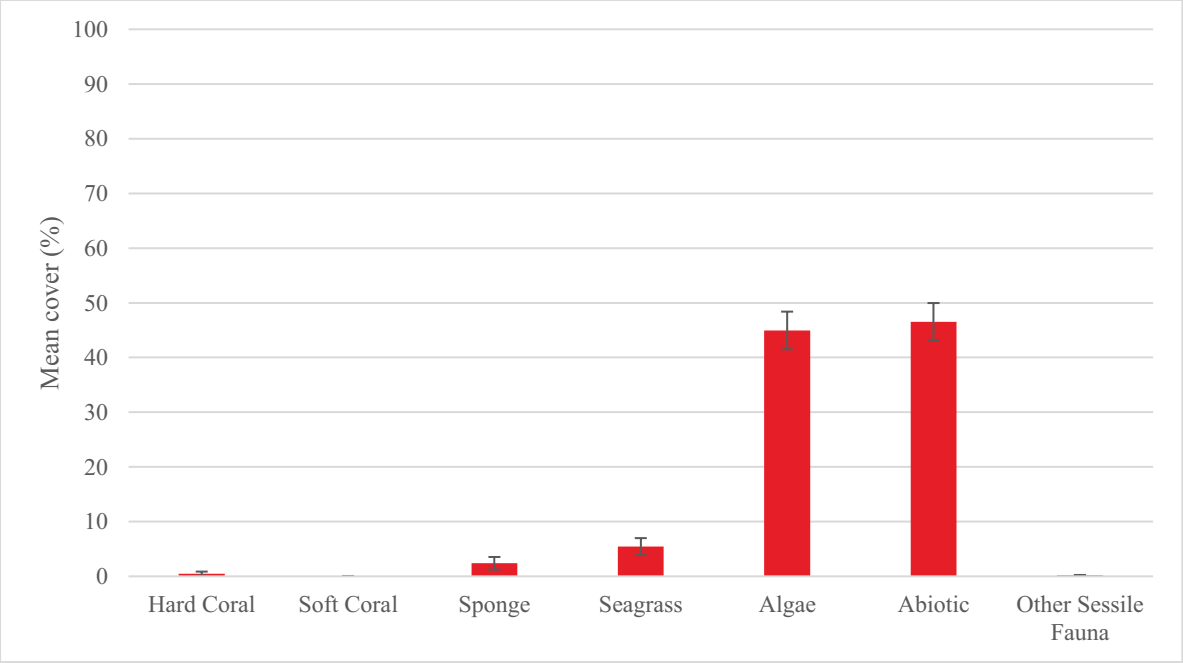


Figure 3-9 Mean (± SE) percentage cover of the entire intertidal survey as recorded during the intertidal quadrat surveys

3.2.2.2 Seagrass Mapping

Four seagrass species were recorded when mapping the intertidal zone (**Figure 3-10**). Of these, three species are of conservation significance, the tape seagrass (*Enhalus acoroides*) is nationally Critically Endangered while the sickle seagrass (*Thalassia hemprichii*) is nationally Endangered and the needle seagrass (*Halodule uninervis*) is nationally Vulnerable. Each conservation significant species is

highlighted in unique colour in **Figure 3-11**. However, spoon seagrass (*Halophila ovalis*), though most dominant throughout the Study Area was not assigned a colour in **Figure 3-11** as this species was not of conservation significant.

At the Study Area, the seagrass meadows occur in two distinct patches. At Site A, the meadow consists solely of spoon seagrass (*Halophila ovalis*). It is likely that this isolated patch is separated from the main seagrass meadow by large rocks in the intertidal zone, which restricts the rhizome extension.

The main and larger seagrass meadow extends from Site C1 to the end of the Study Area and comprises of mixed species (i.e. *E. acoroides, H. uninervis* and *T. hemprichii*) with spoon seagrass (*H.ovalis*) being the most dominant. More specifically, at Site C1, a patch of needle seagrass (*H. uninervis*) occurs within a mixed meadow with tape seagrass (*E. acoroides*) and spoon seagrass (*H. ovalis*). While end of the Study Area, adjacent to Rasa Sentosa, an isolated (and only) patch of sickle seagrass (*T. hemprichii*) was found within a mixed meadow of tape seagrass (*E. acoroides*) and sparse spoon seagrass (*H. ovalis*). Some areas within this main seagrass meadow are patchy, but can be considered continuous, as rhizomes can extend and colonise adjacent bare areas.

Figure 3-10 Seagrass map; Different colours indicate Seagrass species of conservation significance

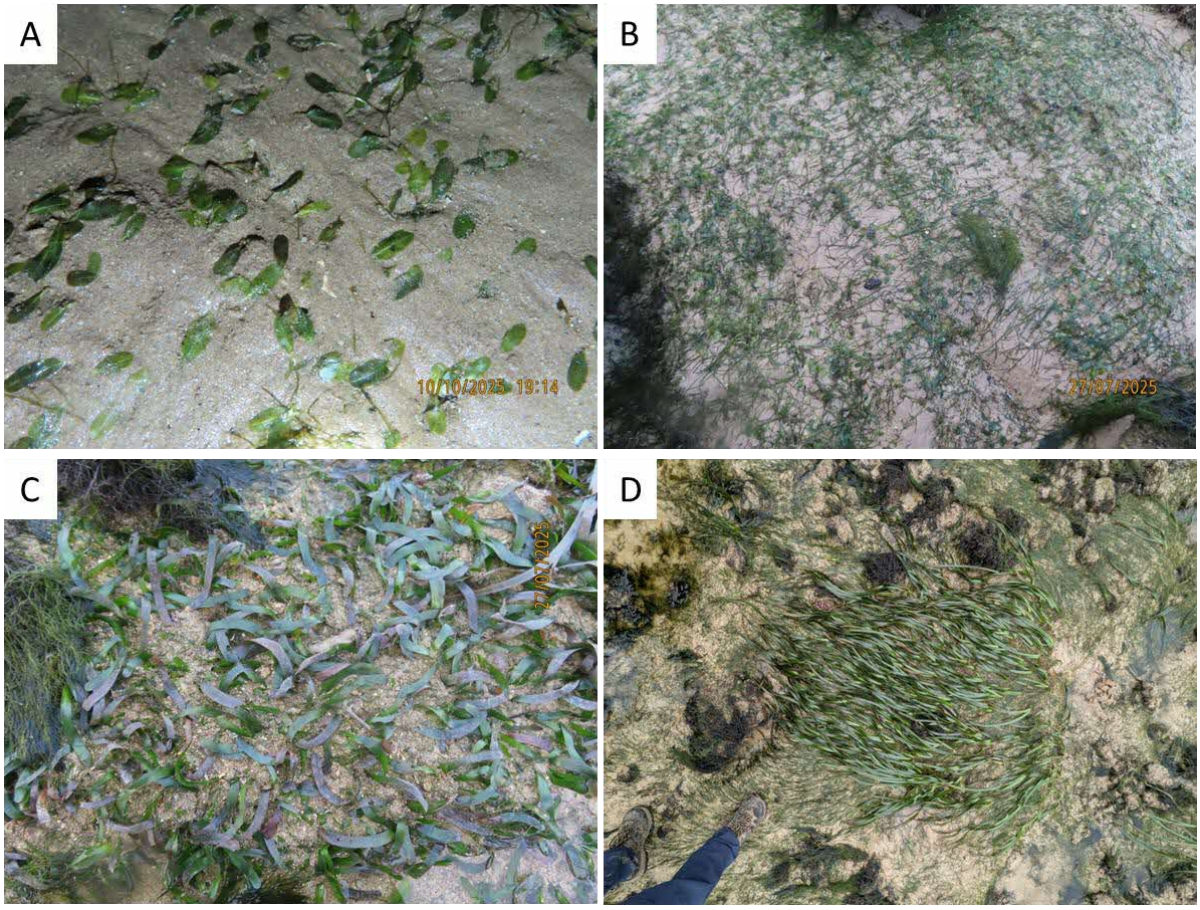


Figure 3-11 Seagrass A: spoon seagrass (*Halophila ovalis*), B: needle seagrass (*Halodule uninervis*), C: sickle seagrass (*Thalassia hemprichii*), D: tape seagrass (*Enhalus acoroides*) found on site

3.2.2.3 Other Intertidal Diversity

156 other species were recorded while carrying out the quadrat survey and mapping seagrass (**Table 3-10**, **Appendix D**). Of which, 11 are species of conservation significance and their locations are shown in **Figure 3-12** (**Table 3-11**). Among the species of conservation significance, five are fishes. The cloudy grouper (*Epinephelus erythrurus*), gold-spotted mudskipper (*Periophthalmus chrysospilos,* **Figure 3-13**), brown sweetlips (*Plectorhinchus gibbosus*), and blue-spotted fantail ray (*Taeniura lymma,* **Figure 3-13**) are classified as nationally Vulnerable, while the yellow-striped sweetlips (*Plectorhinchus chrysotaenia*) is listed as nationally Endangered. Notably, six blue-spotted fantail rays (*T. lymma*) of varying sizes were sighted during a single session. The gold-spotted mudskipper (*P. chrysospilos*) was observed near the rocky shore in front of slope failure A, where gaps between rocks provided shelter from strong currents, while the yellow-striped sweetlips (*P. chrysotaenia*) was seen foraging among rocks and algae. Juvenile cloudy groupers (*P. chrysotaenia*) and brown sweetlips (*P. gibbosus*) were also observed taking refuge within patches of seagrass and algae.

Two crabs were of conservation significance, the green/floral egg crab (*Atergatis floridus,* **Figure 3-13**) and the red-eyed reef crab (*Eriphia ferox,* **Figure 3-13**). Both are nationally Vulnerable, nocturnal, and typically found on coral reefs and rocky shore in the intertidal area, similar to those at Tanjong Rimau.

Two sea cucumber species were also recorded: the little African sea cucumber (*Afrocucumis africana*), which is nationally Vulnerable, and the black long sea cucumber (*Holothuria leucospilota*), which is nationally Endangered. Both species are affected by habitat loss and fragmentation. The Merten's carpet anemone (*Stichodactyla mertensii*), a nationally Endangered cnidarian, was also recorded in the area.

Additionally, the Von Martens' reef spider (*Desis martensi*), a species described from Sentosa and classified as nationally Vulnerable, was observed. This spider inhabits natural rocky shore, and its continued presence on Sentosa indicates the survival of a remnant patch of the island's original intertidal ecosystem, which remains under pressure from coastal development and land reclamation.

None of the 12 recorded algae species were of conservation significance however, it is worth noting that hairy green seaweed (*Bryopsis sp*.) was blooming during the survey period.

Table 3-10 list of other species (excluding seagrass) that we recorded in the intertidal zone

	Species	CS
Targeted Taxon		
Hard Coral	16	
Soft Coral	5	
Sponge	8	
Fish	25	5
Algae	12	
Others		
Annelida	1	
Bivalve	9	
Cephalopod	2	
Crustacea	27	2
Echinoderm	3	2
Gastropod	33	
Nemertea	1	
Other Cnidaria	9	1
Polychaete	2	
Spider	1	1
Tunicate	2	

Table 3-11 List of species of conservation significance that was found in the intertidal zone

No	Type	Scientific name	Common name	National status	Global status
1	Anemone	*Stichodactyla mertensii*	Merten's Carpet Anemone	Endangered	Not Listed
2	Crab	*Atergatis floridus*	Green egg crab/ Floral egg crab	Vulnerable	Not Listed
3	Crab	*Eriphia ferox*	Red eyed reef crab	Vulnerable	Not Listed
4	Fish	*Epinephelus erythrurus*	Cloudy grouper	Vulnerable	Least Concern
5	Fish	*Periophthalmus chrysospilos*	Gold-spotted mudskipper	Vulnerable	Least Concern
6	Fish	*Plectorhinchus chrysotaenia*	Yellow-striped sweetlips	Endangered	Not Listed
7	Fish	*Plectorhinchus gibbosus*	Brown sweetlips/ harry hotlips	Vulnerable	Least Concern

8	Fish	*Taeniura lymma*	Blue-spotted fantail ray	Vulnerable	Least Concern
9	Sea cucumber	*Afrocucumis africana*	Little African sea cucumber	Vulnerable	Not Listed
10	Sea cucumber	*Holothuria leucospilota*	Black long sea cucumber	Endangered	Least Concern
11	Spider	*Desis martensi*	Von Martens' Reef Spider	Vulnerable	Not Listed

Figure 3-12 location of intertidal species of conservation significance

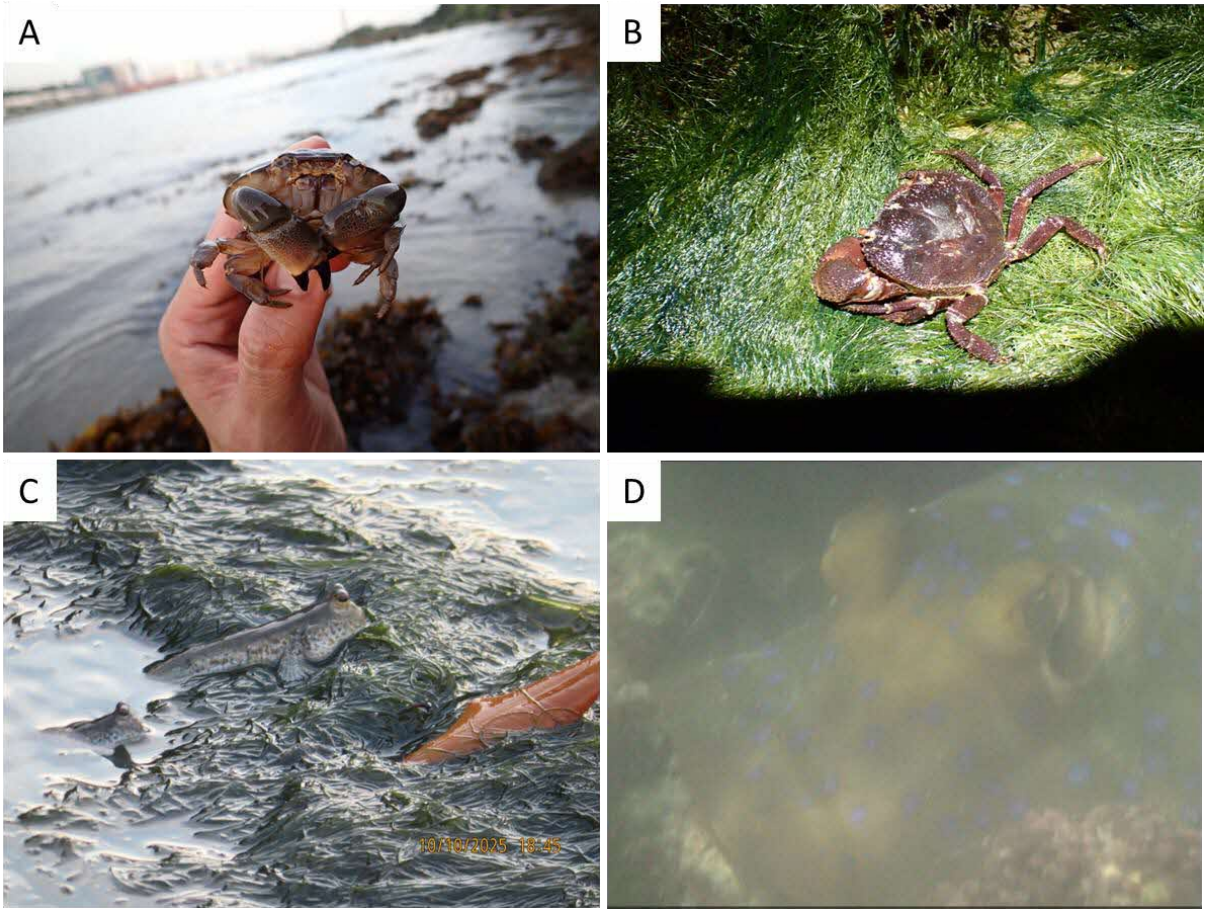


Figure 3-13 Species of conservation significance, A; green egg crab/ floral egg crab (*Atergatis floridus*), B: red eyed reef crab (*Eriphia ferox)*, C: gold-spotted mudskipper (*Periophthalmus chrysospilos*), D: blue-spotted fantail ray (*Taeniura lymma)* found in the intertidal zone.

3.2.3 Subtidal

3.2.3.1 Line Intercept Transect

Like the intertidal composition, seven main substrate types were identified, (1) hard coral, (2) soft coral, (3) sponge, (4) seagrass, (5) algae, (6) abiotic substrates that comprise of sand, rock, and rubble, and (7) other sessile animals such as tunicates.

Survey Location S01 (**Figure 3-14**)

S01 is characterised by a mixed subtidal habitat comprising a blend of coarse and fine substrates. Silt is the dominant component (46%), followed by rock (10%) and sand (7%). Biotic cover is present but relatively low, with hard corals (7%), sponges (4%), and algae (3%) occurring in scattered patches. Seagrass presence is minor (5%). Overall, S01 represents a sediment-influenced subtidal zone with low to moderate biological cover.

Survey Location S02 (**Figure 3-14**)

S02 supports a more structurally diverse subtidal environment, with sand (25%) and silt (18%) forming the primary substrate types. Rock substrate is also present at around 20%, providing attachment surfaces for sessile organisms. Hard coral cover is comparatively higher here (13%), and soft corals are present (1%). Sponges (3%) and algae (2%) occur at low levels. The habitat reflects a moderately developed subtidal community with a balance of hard substrate and soft sediments.

Survey Location S03 (**Figure 3-14**)

S03 is characterised by a dominance of rubble substrate, accounting for approximately 48%, making it the most structurally complex site among the three stations. Sand constitutes another 25%, while silt is lower (8%). Biotic cover is relatively low, with hard corals (1%), sponges (3%), and algae (3%) occurring sporadically. Seagrass presence is minimal (<2%). The site represents a rubble-dominated subtidal habitat offering heterogeneous substrate but with limited biological cover.

Overall

The benthic community in the Study Area was dominated by abiotic substrates, which consist of rock, rubble, sand, and silt (**Figure 3-14, Appendix D**). When combining data from the reef crest and reef slope, Site S01 consisted of 66.5% abiotic components (9.9% rock, 3.7% rubble, 7.1% sand, and 45.8% silt). Site S02 was 80.2% abiotic (20.4% rock, 17.4% rubble, 24.2% sand, and 18.1% silt), while Site S03 had the highest proportion, with 91% abiotic cover (9.9% rock, 49.2% rubble, 24.5% sand, and 7.6% silt). General habitat photos can be found in **Figure 3-15**.

The dominant biotic substrate was hard coral, with the highest cover recorded at Site S02 (12.5%), nearly double that of Site S01 (7%) and considerably higher than S03 (1.1%). Algae were most abundant at S01 (12.8%), showing a notable difference compared to S02 (2.4%) and S03 (3.4%). Seagrass (*Halophila ovalis*) was present only at S01, where it covered 5.2% of the benthic community. No soft coral was recorded at S03, while minimal cover was observed at S02 (0.1%) and S01 (0.5%). Sponge cover was relatively consistent across the sites, with 4.7% at S01, 3.4% at S02, and 3.1% at S03.

Along the LIT, a total of 30 coral species were recorded. All the corals recorded by LIT were less than 5 cm (size class 1). At Site S01, nine species were identified, including one species of conservation significance, the lesser valley coral (*Platygyra lamellina*), which is listed as nationally Vulnerable. Site S02 had the highest diversity, with 27 recorded species, two of which are of species of conservation significance: the boulder sandpaper coral (*Psammocora nierstraszi*) and the lesser valley coral (*P. lamellina*), both nationally Vulnerable. In contrast, Site S03 recorded only five species with no species of conservation significance. All the other species found would be discussed in **Section 3.2.3.3**.

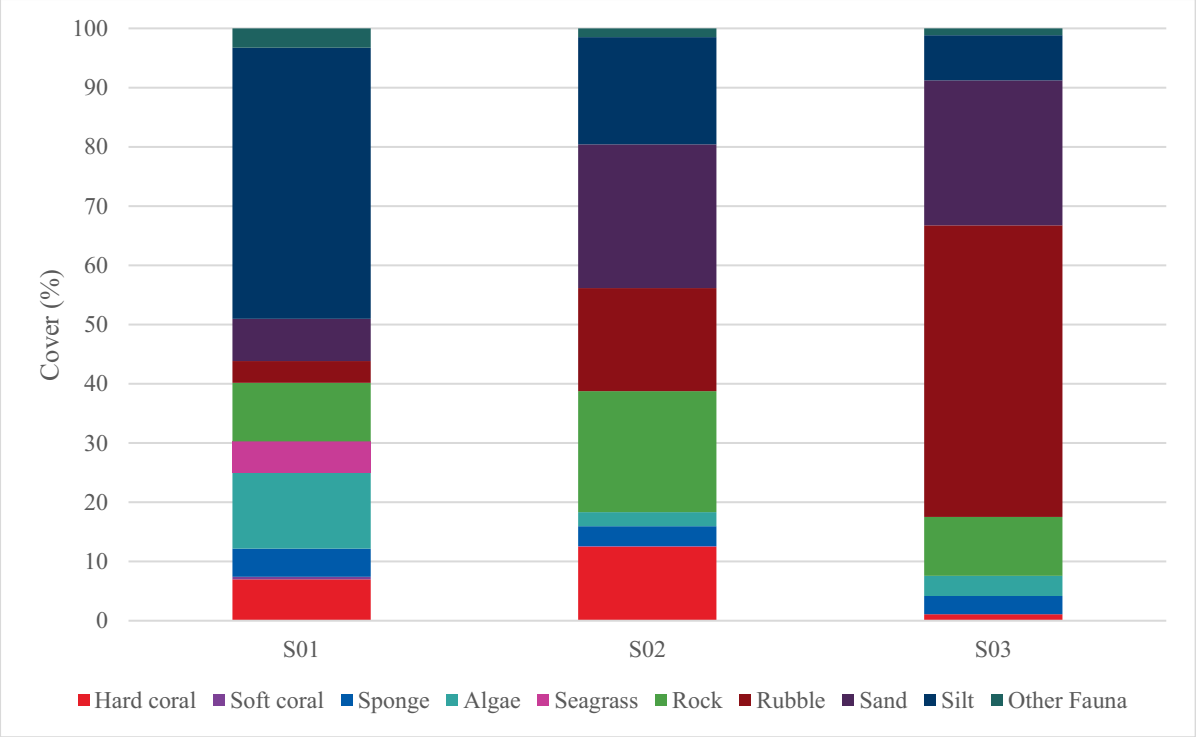


Figure 3-14 Percentage cover of the major benthic categories recorded at in the crest in S01, S02 and S03

Figure 3-15 General habitat of Site A: S01, B: S02 and C: S03

3.2.3.2 Corals

A total of 256 hard coral colonies from 48 species including eight blue corals (*Heliopora coerulea*) were recorded across all surveys within the Study Area, (**Figure 3-16**). Of these, six species are of conservation significance (**Figure 3-18**). The full species list of coral species recorded can be found in **Appendix D**.

Although blue coral (*H. coerulea*) is taxonomically classified as an octocoral, it was analysed alongside hard corals due to its calcium carbonate skeleton and its similar ecological roles and habitat functions within the Study Area.

The size class distribution of corals, analysed for as many colonies as possible, is presented in **Figure 3-17** and **Figure 3-16**, offering insights into the overall age structure, growth, and ecological stability of the coral community.

A total of 42 hard coral species, including all six species of conservation significance (**Table 3-12**), were recorded during the LIT, belt transect, and incidental observations made during subtidal surveys (for LIT results only, refer to **Section 3.2.3.1**). At survey location S01, 18 species were recorded, including *Caulastraea echinulata*, *Plerogyra sinuosa*, *Platygyra lamellina*, and *Lobophyllia hemprichii*, all species of conservation significance. The size class distribution included 16 colonies in class 1, six in class 2, four in class 3, seven in class 4, and one each in classes 5, 6, and 7, with none in class 8.

Survey location S02 recorded the highest diversity, with 36 species, including five species of conservation significance: *P. sinuosa*, *Psammocora nierstraszi*, *P. nierstraszi*, *L. hemprichii*, and *Dipsastraea lizardensis*. The size class distribution was dominated by smaller colonies, with 58 in class 1, eight in class 2, six in class 3, three in class 4, six in class 5, and one in class 6, with none in class 7 or 8.

At survey location S03, nine hard coral species were recorded, none of which were of conservation significance. The size class distribution comprised five colonies in class 1, two in class 2, and one each in classes 3 and 6.

In the intertidal zone, 92 coral colonies representing 18 species were recorded during quadrat sampling and incidental observations while mapping seagrass. None were species of conservation significance. Due to limited low-tide exposure, only large colonies (size class 4 and above, ≥25 cm) were mapped. A total of 87 colonies were recorded within these larger size classes: 29 in class 4, 23 in class 5, 19 in class 6, and 16 in class 7, with no colonies in class 8.

Table 3-12 List of corals species of conservation significance

No.	Family	Species	Common name	National status	Global status
1	Merulinidae	*Caulastraea echinulata*	NA	Near threatened	Endangered
2	Merulinidae	*Platygyra lamellina*	Lesser Valley Coral	Vulnerable	Least Concern
3	Merulinidae	*Plerogyra sinuosa*	Pearl Bubble Coral	Vulnerable	Least Concern
4	Merulinidae	*Psammocora nierstraszi*	Boulder Sandpaper Coral	Vulnerable	Least Concern
5	Diploastreidae	*Dipsastraea lizardensis*	NA	Least Concern	Endangered
6	Lobophylliidae	*Lobophyllia hemprichii*	Lobed Brain Coral	Least Concern	Endangered

Figure 3-16 Diversity of corals and size at the Study Area

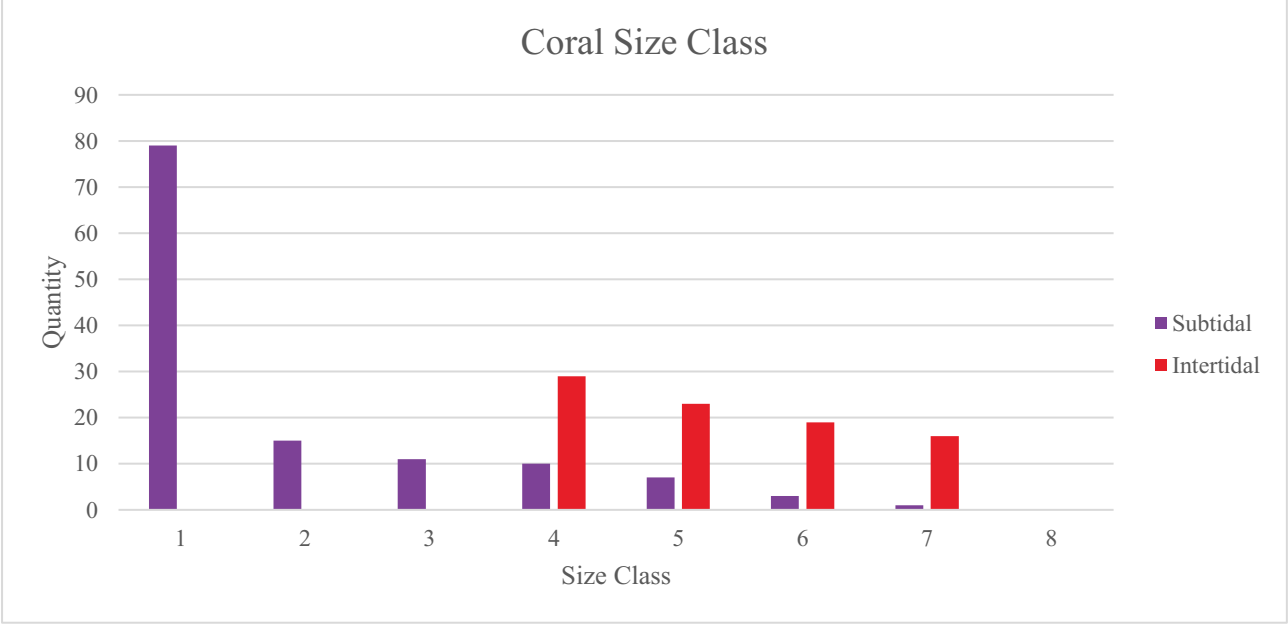


Figure 3-17 Size class distribution of hard corals at the Study Area

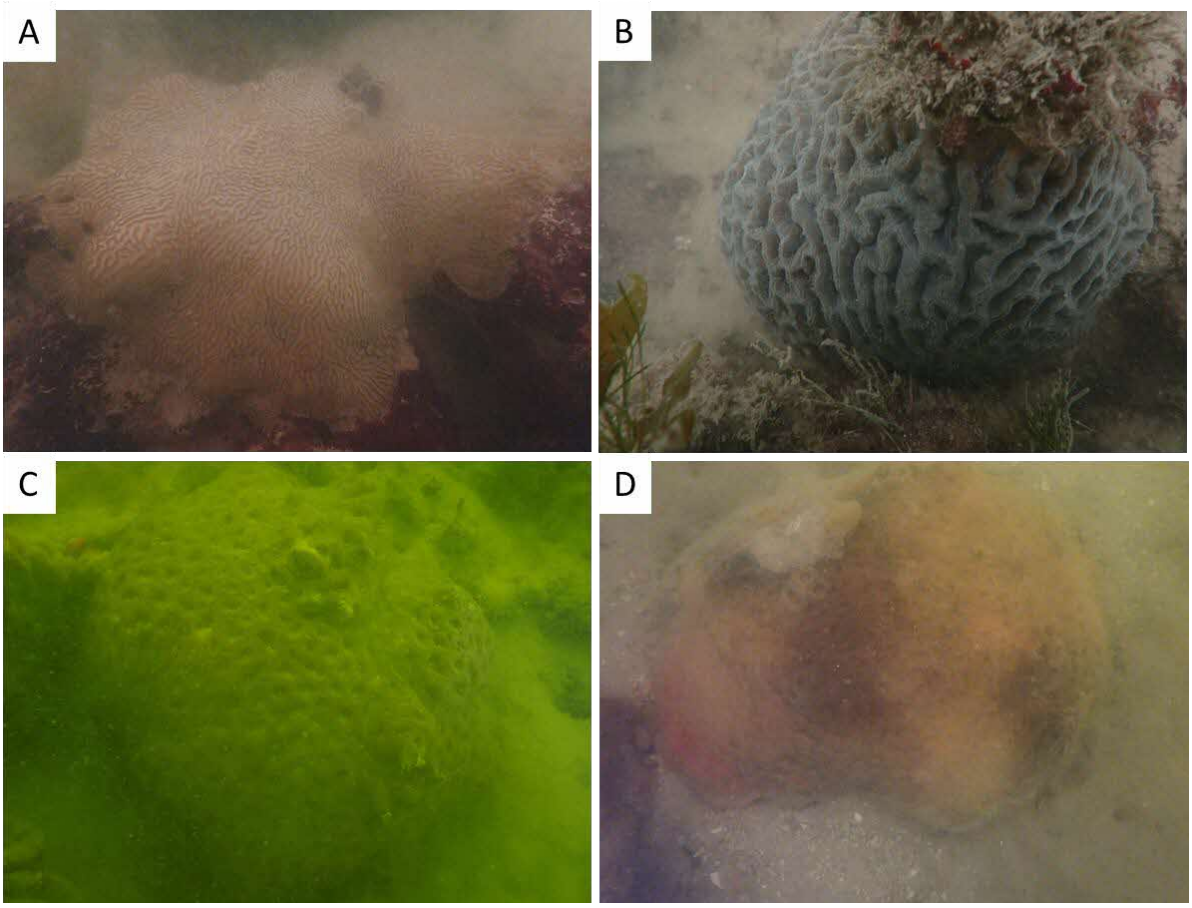


Figure 3-18 Hard corals of conservation significance A: Lesser valley coral (*Platygyra lamellina*), B: Lobed Brain Coral (*Lobophyllia hemprichii*), C: *Caulastraea echinulate*, D: *Dipsastraea lizardensis*

3.2.3.3 Other Subtidal Diversity

A total of 75 other species (excluding hard corals) were recorded in the Study Area during the subtidal fish and mobile invertebrate survey **(Table 3-13**). In total, 98 individual animals were observed, with fishes comprising the largest taxonomic group. All seven species of conservation significance recorded were fishes (

Table 3-14). Among this, the bigeye snapper (*Lutjanus Lutjanus***, Figure 3-19**), blue-lined hind (*Cephalopholis formosa*, **Figure 3-19**), blue-spotted fantail ray (*Taeniura lymma*), peacock hind (*Cephalopholis argus*), reticulated pufferfish (*Arothron reticularis*, **Figure 3-19),** and yellow shrimp goby (*Cryptocentrus cinctus*) are nationally Vulnerable. The talang queenfish (*Scomberoides commersonnianus*) is nationally Endangered.

Five algal species were recorded during the survey; none are species of conservation significance. The most dominant was the hairy green seaweed (*Bryopsis sp*.) which was seen blooming in the intertidal zone (see **Section 3.2.2.3**). Red algae were also commonly encountered with *Gracilaria sp.* and *Halymenia sp.* growing among rocks and *Lithothamnion sp.* encrusting rocks and rubbles.

Six species of soft corals were identified, none of which are of conservation significance. However, a high density of sea fans and sea whips was recorded at survey location S02 with lower densities also observed at survey location S01 and S03. These taxa provide a habitat for whipcoral gobies (*Bryaninops sp*.), whose survival, size and density are closely associated with the size and abundance of their host-

the sea whips and sea fans [33]. As such, these soft corals may be regarded as keystone species within the surveyed habitats. The full list of species recorded in this survey can be found in **Appendix D**.

Table 3-13 list of other species (excluding corals) that we recorded in the subtidal area

	Species	CS
Targeted Taxon		
Soft Coral	6	
Sponge	9	
Fish	30	7
Algae	5	
Others		
Bivalve	1	
Seagrass	1	
Crustacea	5	
Echinoderm	5	
Flatworm	1	
Gastropod	4	
Other Cnidaria	5	
Polychaete	1	
Tunicate	2	

Table 3-14 List of species of conservation significance that was found in the subtidal area (excluding hard corals)

No	Site	Taxon	Scientific name	Common name	National status	Global status
1	S01	Fish	*Arothron reticularis*	Reticulated pufferfish	Vulnerable	Least Concern
2	S01	Fish	*Cryptocentrus cinctus*	Yellow shrimp goby	Vulnerable	Least Concern
3	S01	Fish	*Scomberoides Commersonnianus*	Talang queenfish	Endangered	Least Concern
4	S02	Fish	*Cephalopholis argus*	Peacock hind	Vulnerable	Least Concern
5	S02	Fish	*Lutjanus lutjanus*	Bigeye snapper	Vulnerable	Least Concern
6	S03	Fish	*Cephalopholis formosa*	Blue-lined hind	Vulnerable	Least Concern
7	S03	Fish	*Taeniura lymma*	Blue-spotted fantail ray	Vulnerable	Least Concern

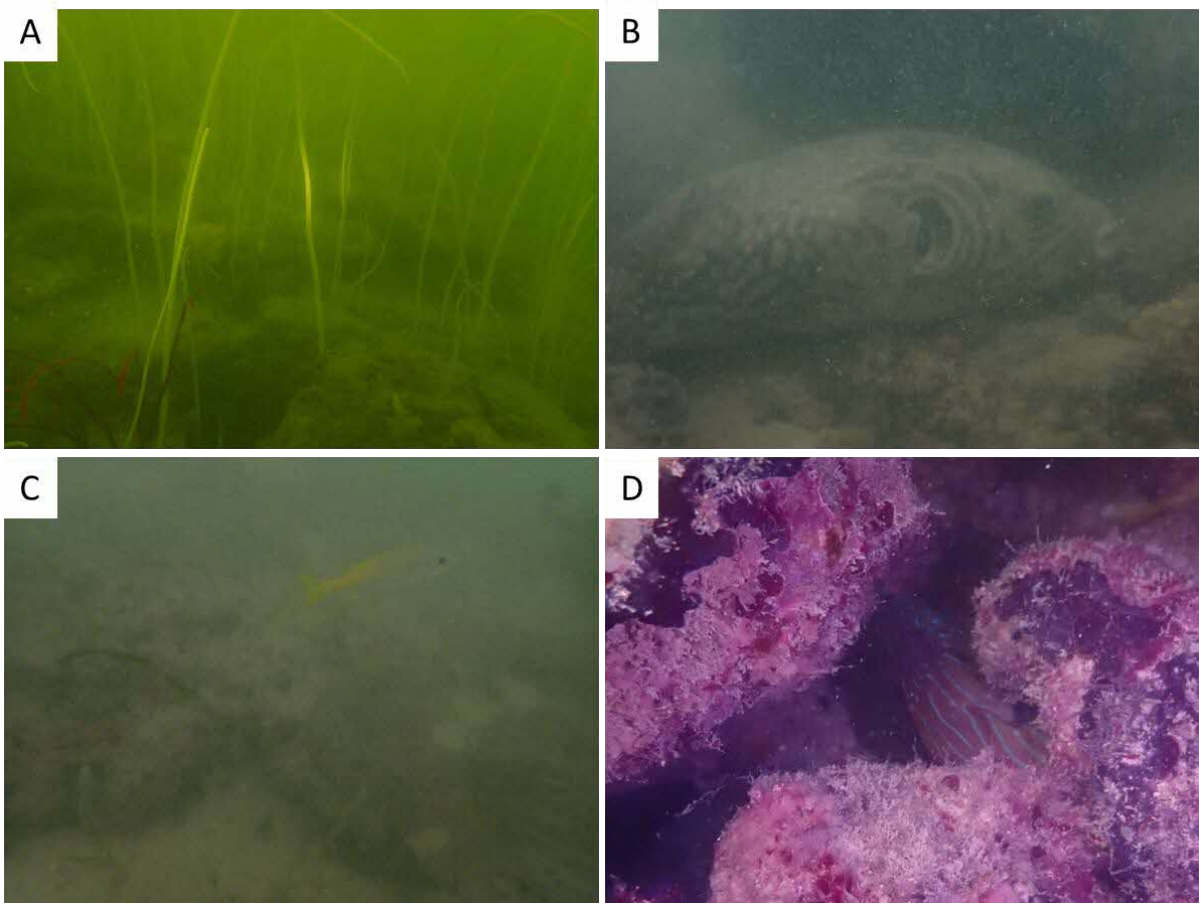


Figure 3-19 Fauna recorded in the subtidal area A: Sea whip in S02, conservation significance B: reticulated pufferfish (*Arothron reticularis*), C: bigeye snapper (*Lutjanus Lutjanus*) and D: Blue-lined hind (*Cephalopholis formosa)*.

3.2.4 Assessment of Ecological Value

Sensitive receptors are receptors within or in the vicinity of the Study Area which may potentially be impacted by the activities intended and proposed activities during the construction phase of the Project. Environmentally sensitive receptors are categorised into three categories: Priority 1, Priority 2 and Priority 3 (from the most sensitive to the least). The identification of sensitive receptors for each environmental parameter was developed based on the findings of the environmental reconnaissance surveys, baseline surveys and review of the proposed Study Area.

3.2.4.1 Habitats

The ecological value of three marine and one terrestrial habitat types within the EIA Study Area were assessed according to the criteria set out in Singapore Biodiversity Accounting Metric [41-42].

Seagrass meadows and coral reefs were assessed to be of very high ecological value (Priority 1). While the rocky shore and coastal forest were assessed to be of high ecological value (Priority 2). A summary of the assessment of ecological value is detailed in the respective paragraphs below and summarised in **Table 3-15**.

Table 3-15 National assessment of ecological value of each habitat type in the EIA Study Area

Criterion	Marine habitat	Terrestrial habitat

	Seagrass meadows	Coral reefs	Rocky shore	Coastal forest
Flora and fauna species richness	3	3	2	1
Irreplaceability	3	3	2	2
National rarity of habitat	3	3	3	3
Unique flora and fauna species	3	3	2	2
Total score	**12**	**12**	**9**	**8**
Ecological value (Sensitivity)	**Very High (Priority 1)**	**Very High (Priority 1)**	**High (Priority 2)**	**High (Priority 2)**

Seagrass meadows (Very High Ecological Value, (Priority 1)

Seagrass meadows are intertidal habitat with a contiguous seagrass patch of at least 0.2 ha. Three of the four species of seagrasses found on site are species of conservational significance. The seagrass meadows on site were also utilised by diverse group of species. Seagrass meadows generally have high flora and fauna species richness (Score 3), are difficult to re-create (Score 3), are a rare habitat type in Singapore (Score 3) and support many flora and fauna species (Score 3). With all four criteria assessed to be high (Score 3), the overall score for the seagrass meadows habitat is 12. This translates to very high ecological value.

Coral reefs (Very High Ecological Value, (Priority 1)

Coral reefs are a diverse community of invertebrates and coral species held together by calcium carbonate structures secreted by hard corals. 48 species of hard corals, 30 species of fishes, nine sponge and six soft corals species was found on site this adds to the high flora and fauna species richness (Score 3), coral reefs are difficult to re-create (Score 3), are a rare habitat type in Singapore (Score 3) and support many flora and fauna species (Score 3). With all four criteria assessed to be high (Score 3), the overall score for the coral reefs habitat is 12. This translates to very high ecological value.

Rocky shore (High Ecological Value, (Priority 2)

Intertidal habitat with loose natural rock fragments or coral rubble. Some sections along Tanjong Rimau have abiotic composition of more than 70%. Such rocky shore habitats are rare in Singapore (Score 3). Rocky shore is generally moderate richness in flora and fauna species (Score 2), the habitat is moderately difficult to re-create (Score 2) and support some flora and fauna species (Score 2). With one criterion assessed to be high (Score 3) and three accesses to be medium (Score 2), the overall score for the rocky shore habitat is 9. This translates to high ecological value.

Coastal forest (High Ecological Value, (Priority 2)

Found along coasts where the forest is on sandy or rocky substrate. Dominated by hardy plants which can withstand higher temperatures, strong winds and salt sprays. The coastal forest at Tanjong Rimau is unique as it is along the cliffs. The coastal forest generally has low flora and fauna species richness (Score 1), is fairly difficult to re-create (Score 2), are a rare habitat type in Singapore (Score 3) and support some flora and fauna species (Score 2). With all but one criterion assessed to be high (Score 3), two assessed to be medium (Score 2) and one assessed to be low (Score 1), the overall score for the coastal forest habitat is 8. This translates to high ecological value.

3.2.4.2 Flora

The ecological value of 94 flora species that were recorded during the field assessment were assessed. 24 terrestrial CS species and four seagrass species were deemed to be of high ecological value and accorded as Priority 1 sensitivity. These species are predominantly of conservation significance, with the exception of one seagrass species (*Halophila ovalis*) which, although not of conservation concern,

was assigned high ecological value due to its substantial contribution to the formation and extent of seagrass meadow habitats within the Study Area.

3.2.4.3 Fauna

The ecological value of 251 fauna species that were recorded during the field assessment or deemed of probable occurrence (species of conservation significance only) was assessed. A total of 71 species were designated as Priority 1 sensitivity due to their high ecological value. This classification includes 28 species of conservation significance recorded during the terrestrial, intertidal and subtidal surveys, 27 coral species measuring size 4 or larger and four keystone species of sea whip and sea fan and an additional 16 probable species identified in literature were also included in this priority group, even though they were not observed during current surveys. The full species list in **Appendix G**.

3.3 Prediction and Evaluation of Impacts on Ecological Receptors

3.3.1 Potential Sources of Impact

There are two main categories in which the impact types fall under, namely (1) direct, i.e., impacts to habitats and species within the development footprint; and (2) indirect, i.e., impacts to habitats and species outside the development footprint but within the Study Area.

Subsequently, short-term impacts are impacts arise during the construction phase, expected to be for approximately nine months. Long-term impacts are impacts during operational phase and can be permanent or last for an extended period (i.e., more than 10 years). Summary of potential impacts on biodiversity at construction and operational phase can be found in **Table 3-16** and **Table 3-17** respectively.

Table 3-16 Potential impacts on biodiversity from construction phase

Receptor	Impact type	Description	Impact category
Construction phase			
Habitat	Loss of habitats	Habitat removal resulting from construction works	Direct
	Habitat degradation	Changes in water quality, including changes in sedimentation/hydrodynamics resulting in morphological changes in the habitat	Indirect
	Changes in microclimatic conditions	Changes in microclimatic conditions (such as temperature, light and humidity) of the habitat due to construction activities	Indirect
Flora Species (Terrestrial)	Mortality	Removal of flora species for construction activities	Direct
Fauna Species	Loss of/ reduction in habitats and food sources	Habitat removal resulting from construction works or changes in water quality, including changes in sedimentation/hydrodynamics resulting in morphological changes in the habitat	Direct / Indirect
	Accidental injury or mortality	Collisions with machineries, entrapments in construction materials and structures (such as exposed pits or drains) and accidental kills by construction personnel	Direct
	Human-wildlife conflict	Negative consequences of human-wildlife interactions, such as deliberate killing and depopulation of fauna species perceived as nuisances or threats by construction personnel	Indirect

	Loss/ reduction of fauna movement	Changes in tidal regime/hydrodynamics that impedes connectivity of waterbodies due to construction activities	Indirect
	Light disturbances	Increase in light levels from construction activities	Indirect
	Human disturbances	Increase in human traffic flow, such as workers and site personnel	Indirect

Table 3-17 Potential impacts on biodiversity from operational phase

Receptor	Impact type	Description	Impact category
Operational phase			
Habitat	Habitat degradation	Changes in water quality, including changes in sedimentation/hydrodynamics resulting in morphological changes in the habitat	Indirect
Flora Species (Terrestrial)	NA*	NA*	NA*
Fauna Species	Loss/ reduction of fauna movement	Changes in tidal regime that impedes connectivity of waterbodies due to operational activities and/or permanent structures (such as revetments, jetties, etc)	Indirect

Note: *At operational phase, there is no long-term impacts to flora species within the Study Area.

3.3.2 Identification of Sensitive Receptors

3.3.2.1 Habitats

Following the assessment of ecological value for habitats (**Section 3.3.4**), all habitats within the Study Area were identified as sensitive receptors. There are four habitat types within this area, namely, (1) coastal forest, (2) seagrass meadows, (3) coral reefs, (4) rocky shore.

3.3.2.2 Flora

Following the assessment of ecological value of flora species (**Section 3.3.4**), 28 species assessed as having high ecological value (Priority 1) were selected for the assessment of ecological impacts.

3.3.2.3 Fauna

Following the assessment of ecological value of fauna species (**Section 3.3.4**), all species with a Priority 1 ecological value were identified as sensitive receptors. Species of conservation significance deemed of probable occurrence were also identified as sensitive receptors. A total of 71 sensitive receptors, comprising species of probable occurrence, were assessed. This includes species from 12 taxon which are listed in **Table 3-18**. The full species list in **Appendix G**.

Table 3-18 Number of sensitive receptors per in each taxon

Taxon	Species
Bird	3
Crustacea	3
Echinoderm (sea cucumber and sea star)	4
Fish	15
Flatworm	1
Gastropod	1
Hard coral	33
Mammal	2
Other Arthropods (Horseshoe crab & Spider)	2
Other Cnidaria (Anemone)	2
Soft Coral	4
Turtle	1

3.3.3 Minimum Controls

This section lists biodiversity-specific minimum control measures that are commonly implemented in Singapore for construction activities. These are assumed to be implemented for the purpose of the impact assessment and should be proposed in tandem with the measures proposed for other environmental receptors (e.g., hydrology, noise). Minimum controls for each potential impact occurring from the construction phase are listed in **Table 3-19**. The main construction activities that would likely occur at all worksites include vegetation clearance and excavation, followed by below and above ground construction.

Table 3-19 Minimum control measures for the construction phase

Work activities	Minimum controls for construction phase

General	• Execute wildlife response plan when a trapped/ injured/ dead/ dangerous animal is encountered around or within the worksites according to Section 10 of the Wildlife Act
Vegetation Clearance	• Set up Tree Protection Zones (TPZs) around trees or other plant specimens to be retained within the worksites, if any, within which no construction works are allowed. This should be executed by Certified Arborists and in accordance with NParks' guidelines [1] • Before vegetation clearance, pre-felling fauna inspection should be conducted by an Ecologist who is able to identify wildlife or nesting structures that are being actively used such as bird nests, tree hollows, burrows and bamboos clusters; in compliance with Section 10 Wildlife Act • Soil erosion control measures (e.g. implementation of biodegradable erosion control blankets, ECM tanks, etc.) are to be executed once vegetation has been removed and soil is exposed.
Excavation	• Implement soil erosion control measures • Implement dust control measures • Implement noise barrier • For more details, refer to Section 4.3.3
Below and Above Ground Construction	• Proper storage of materials that are likely to leech harmful chemicals and fuel-powered equipment away from waterbodies or sensitive habitat

3.3.4 Assessment of Ecological Impacts

Identified biodiversity sensitive receptors were evaluated based on impact intensity and likelihood, which eventually gives the impact significance. The impact intensity of each impact type during construction and operational phase are defined for habitats (**Table 3-20** and **Table 3-21**) flora species (**Table 3-22**) and fauna species (**Table 3-23** and **Table 3-24**) receptors below. While likelihood follows the generic table that was presented in **Section 1.3**, **Table 1-3**.

Table 3-20 Definitions of each level of impact intensity for impact types during construction for habitat receptors

Impact Type	Negligible	Low	Medium	High
Loss of habitat	The habitat does not overlap with the worksites	≤ 10% of the habitat overlaps with the worksites	10–40% of the habitat overlaps with the worksites	>40% of the habitat overlaps with the worksites
Habitat degradation (marine)	Takes reference from results from hydrodynamic modelling in Section 5.4			
Habitat degradation (Terrestrial)	The habitat type does not overlap with areas 30 m from the worksites	≤ 10% of the habitat type overlaps with areas 30 m from the worksites	10–40% of the habitat type overlaps with areas 30 m from the worksites	> 40% of the habitat type overlaps with areas 30 m from the worksites

Changes in microclimatic conditions	Duration of shading <1 day	Duration of shading <1 to 3 days	Duration of shading 4 to 10 days	Duration of shading >10 days

Table 3-21 Definitions of each level of impact intensity for impact types during operational for habitat receptors

Impact Type	Negligible	Low	Medium	High
Habitat degradation	Takes reference from results from hydrodynamic modelling in Section 5.6			

Table 3-22 Definitions of each level of impact intensity for impact types during construction for plant species receptors

Impact Type	Negligible	Low	Medium	High
Mortality	No plant specimens of this species are within the worksites	Less than 50% of all plant specimens of this species are within the worksites	More than or exactly 50% of all plant specimens of this species are within the worksites	All plant specimens of this species are within the worksites

Table 3-23 Definitions of level of impact intensity for all impact types during construction for fauna species receptors

Impact type	Negligible	Low	Medium	High
Loss of/ reduction in habitats and food sources	No loss of habitat, raptor nests, or roosts	Loss of <10% of habitat, or roosts	Loss of 10–40% of habitat, or roosts	Loss of >40% of habitat or roosts; loss of any raptor nests
Accidental injury or mortality	Species with negligible susceptibility to accidental injury/mortality from construction activities (large vehicles, excavation and piling, etc.)	Species with low susceptibility to accidental injury/mortality from construction activities (large vehicles, excavation, piling, etc.) – Subtidal fishes – Birds	Species that are mobile but possibly susceptible to accidental injury/mortality from construction activities (large vehicles, excavation, piling, etc.) – Other fishes (ray & mudskipper) – Crab – Spider	Species with high susceptibility to accidental injury/mortality from construction activities (large vehicles, excavation, piling, etc.) – Soft Coral – Hard corals – Anemone – Echinoderm – Goby – Smooth-coated otter
Human-wildlife conflict	Species that are not perceived as nuisances or threats by construction personnel – Hard corals	Species that are possibly perceived as both nuisances and threats by construction personnel, less tolerant of human	Species that are typically perceived as nuisances and possibly as threats by construction personnel, highly tolerant of human presence and urban environments, and	Species that are typically perceived as both nuisances and threats by construction personnel, highly tolerant of human presence and urban environments, and are

	– Soft corals – Some fishes – Crabs – Echinoderm – Birds (excluding crow)	presence and urban environments – More defensive fishes and crab species	frequently implicated in human-wildlife conflict – Smooth-coated otter – Spider – Stingray – Large-billed crow	frequently implicated in human-wildlife conflict – Triggerfish – Shark
Loss of/ reduction of movement	Not dependent on connected habitats for forging and mating and able to traverse marine habitats – Smooth-coated otter – Birds	Slightly dependent on connected habitats forging and mating and adaptable to traverse marine infrastructures if needed – Subtidal fishes	Dependent on connected habitats for forging and mating – Spider – Crabs – Echinoderm	Highly dependent on connected habitats for forging and mating – Hard corals – Soft Corals – Anemone – Mudskipper – Goby
Light disturbances	Species that are not sensitive to changes in light levels at night – Subtidal soft corals	Species that are slightly sensitive to changes in light levels – Mammals – Fishes – Other soft corals – Hard corals – Birds (non-migratory) – Spider	Species that are sensitive to changes in light levels: – Echinoderm	Species that are extremely sensitive to changes in light levels – Turtle – Migratory birds
Human disturbances	Species that are not sensitive to human presence	Species that are slightly sensitive to human presence – Fishes – Crabs – Smooth-coated otter – Birds – Spider	Species that are sensitive to human disturbance – Echinoderm – Soft coral	Species that are extremely sensitive to human presence – Nesting birds – Hard corals – Anemone – Goby – Mudskipper

Table 3-24 Definitions of level of impact intensity for all impact types during operational for fauna species receptors

Impact type	Negligible	Low	Medium	High
Loss of/ reduction of movement	Not dependent on connected habitats for forging and mating and able to traverse marine habitats – Smooth-coated otter – Birds	Slightly dependent on connected habitats forging and mating and adaptable to traverse marine infrastructures if needed – Subtidal fishes	Dependent on connected habitats for forging and mating – Spider – Crabs – Echinoderm	Highly dependent on connected habitats for forging and mating – Hard corals – Soft Corals – Anemone – Mudskipper – Goby

3.3.4.1 Construction phase

3.3.4.1.1 Habitats

Three impact type have been identified during the construction phase, (1) Habitat loss, (2) Habitat degradation and (3) Changes in microclimatic conditions, the impact significance ranged from **Minor** to **Moderate**. Only the most substantive impact for each impact type is presented below. A summary of the habitat receptors impacted during the construction phase is shown in **Table 3-25**. The detailed evaluation for each species is provided in **Appendix E**.

Loss of habitat

It is expected that 12.4% of seagrass meadows (Medium impact intensity), 3 % of the coral reefs (Low impact intensity) and 21% of the rocky shore (Medium impact intensity) will be affected by the temporary bund within the intertidal area. The most substantive impact significance of **Moderate** is assessed as a result of Medium impact intensity expected in the seagrass habitat (Priority 1 Sensitivity) together with likelihood of Possible.

It important to note that these **Minor to Moderate** impacts are temporary for the duration of the construction. After construction, more than half of the area lost will have the chance to recover as the temporary bund will be removed and the permanent revetment will only occupy 0.05 ha of the rocky shore.

No large habitat loss is expected in the coastal forest. For access along the 2 m width footpath, no trees are expected to be felled or removed, only clearance of some undergrowth to make the path safety for workers to travel on is likely to happen. Subsequently, surface drainage will also be provided at Site A to manage runoff and minimise water accumulation along the stabilised slope. While at Site C2, drainage will be incorporated by utilising existing gullies that have naturally formed onsite to facilitate surface water conveyance and reduce erosion along the slope face. These drainages are not expected to be typical C7 drains as seen along roadside. Instead, it is intended to be similar to bioswales—vegetated channels designed to slow, convey, and infiltrate surface runoff while maintaining a more natural profile and reducing erosion along the slope. Therefore, in terms of habitat loss in the coastal forest, it is expected to be **Minor**.

Habitat degradation

Modelling results will be used to assess habitat degradation for marine habitats. Taking reference from sediment plume models in **Section 5.4.1**:

- Coral reefs: According to the SSC tolerance limits for coral reefs shown in **Table 5-3**, most coral reefs will not be affected by sediment plumes. A few corals near Site A may experience slight impacts during construction, and some specimens could see minor impact during the inter-monsoon period.
- Seagrass meadows: Based on the tolerance limits for seagrasses outlined (**Table 5-4**), the incremental SCC remains below 5 mg/L at seagrass area during construction. Accordingly, no sediment plume impacts to seagrass are anticipated.

Together with the likelihood of Possible, the most substantive impact significance is assessed to be **Minor**.

Subsequently, in the terrestrial and intertidal area, habitat degradation will be based on percentage of habitat overlap with areas 30 m from the worksites.

- Coastal forest: The 2 m width footpath access in the coastal forest is only expected to have minimal vegetation clearance to ensure that the footpath is safe for workers to get to Site A; no transport of machinery or materials will be expected along this access. Similarly, works for the surface drainage provided at Site A and C2 is not expected to results in large changes in the landscape, therefore habitat degradation is expected to be minimal and is assessed to be Minor.
- Rocky shore: 10- 40% overlap with areas 30 m from worksites, resulting in Medium impact intensity. Together with the likelihood of Possible, the impact significance is assessed to be **Minor.**
- Seagrass meadows: More than 40% overlap with areas 30 m from worksites, resulting in High impact intensity. Together with the likelihood of Possible, the impact significance is assessed to be **Moderate.**

Changes in microclimatic conditions

Duration of shading will be used to assess impact intensity for "changes in microclimatic conditions" in the marine habitats; and impact is only assessed for the subtidal habitat (i.e. coral reefs). The parking of the barge onsite, can resulting in shading of the corals beneath. Taking the conservative approach, it is assumed that the barge will be parked on site for the duration of the construction (i.e. 9 months), resulting in High impact intensity. Together with the likelihood of Less Likely, the impact significance is assessed to be **Minor.**

Table 3-25 Summary of impact significance for habitat receptors during the construction phase

Habitat receptor	Priority level and other relevant status	Total area within Study Area (ha)	Direct impact (% of total habitat type within Study Area)	Impact significance
Coral reefs	Priority 1	6.533	2.8% (0.181 ha)	**Minor** for all impact types.
Seagrass meadows	Priority 1	0.704	12.4% (0.087 ha)	**Moderate** for all impact types
Rocky shore	Priority 2	2.191	20.7% (0.454 ha)	**Minor** for all impact types
Coastal forest	Priority 2	NA	NA	**Minor** for all impact types

3.3.4.1.2 Flora

Mortality is the only impact identified and assessed for the flora receptors. Impact significance was assessed for the flora receptors. A summary of flora receptors impacted during construction phase is shown in **Table 3-26** detailed evaluation for each species is provided in **Appendix F**.

Mortality

A total of 12 species are likely to experience **Moderate** to **Major** impacts due to mortality. Being the only specimen recorded within the Study Area, *Garcinia celebica* and *Syzygium palembanicum* is therefore assessed to have **Major** impact. Whilst ten other species are likely to experience **Moderate** impact as slope works is likely to remove less than 100% of its specimen within the Study Area.

Memecylon edule var. *edule, Podocarpus polystachyus* and *Tristaniopsis whiteana* that have less than 50% of specimens located within the proposed worksites, which gives a Low impact intensity. *Dibridsonia conferta, Entada spiralis, Nepenthes rafflesiana,*and *Xylocarpus rumphii whiteana* have more than 50% of specimens located within the proposed worksites, which gives a Medium impact intensity. Similarly, seagrass species— *Enhalus acoroides*, *Halodule uninervis* and *Halophila ovalis*— is also assessed at **Moderate** impact significance.

However, it is also Likely (likelihood) for these specimens to be removed, the resulting impact significance is therefore **Moderate**.

The remaining 16 species are likely to experience **Negligible** impacts as all the specimens are located outside of the proposed worksites. This includes the nationally Endangered sickle seagrass (*Thalassia hemprichii*). Hence, they will not be impacted by mortality.

Table 3-26 Summary of construction phase impacts to flora species receptors

Impact Type	Number of Species			
	Major	Moderate	Minor	Negligible
Mortality	2	10	0	16

3.3.4.1.3 Fauna

Six construction phase impacts were identified and assessed for fauna receptors: (1) loss of/ reduction in habitats and food sources, (2) accidental injury or mortality, (3) human-wildlife conflict, (4) loss of/ reduction in ecological connectivity for fauna movement, (5) light disturbances and (6) human disturbances. The impact significance ranged from **Negligible** to **Minor**. The most substantial impacts arising from each impact type is discussed below. A summary of the impact to fauna receptors is given in **Table 3-27** and a detailed evaluation can be found in **Appendix G**.

Assumptions made include:

Minimum controls are properly implemented and enforced.

Loss of/ or Reduction in Habitats and Food Sources

The large-billed crow (*Corvus macrorhynchos*) and the long-tailed macaque (*Macaca fascicularis*) are not reliant on the site's habitats, so the loss of habitat and food sources is assessed to have **Negligible** impact significance for these species. Five recorded and probable species will experience a **Moderate** impact significance loss of habitat and food sources. The gold-spotted mudskipper/ golden-spotted mudskipper (*Periophthalmus chrysospilos),* coastal horseshoe crab (*Tachypleus gigas*), masked burrowing crab (*Gomeza bicornis*), common sea star (*Archaster typicus*) and the galloping sand star (*Stellaster children*), will experience loss of 10–40% (Medium impact intensity) of their habitat and food sources. The remaining species 64 species, will experience the possibility of the loss of <10% of habitat (Low impact intensity), or roosts and will therefore experience **Minor** impact significance.

Accidental Injury or Mortality

14 species of fauna will experience **Moderate** impacts due to accidental injury or mortality. This includes the yellow shrimp goby (*Cryptocentrus cinctus*) that nest on the ground. Very slow-moving animals such as little African sea cucumber (*Afrocucumis africana*), black long sea cucumber (*Holothuria leucospilota*) and the tiger cowrie (*Cypraea tigris*), dawn flatworm (*Pseudobiceros hancockanus,* common sea star (*Archaster typicus*) and galloping sand star (*Stellaster children*) with makes them highly susceptibility to accidental injury/mortality from construction activities (High impact intensity). The smooth-coated otter (*Lutrogale perspicillata*) and long-tailed macaque (*Macaca fascicularis*) are also highly susceptible to injury or mortality due to its curious nature. The green egg crab/ floral egg crab (*Atergatis floridus*), red eyed reef crab (*Eriphia ferox*), Von Martens' reef spider (*Desis martensi*), coastal horseshoe crab (*Tachypleus gigas*) and masked burrowing crab (*Gomeza bicornis*) are mobile but possibly susceptible to accidental injury/mortality (Medium impact intensity). Likelihood for most species was deemed Possible with the exception of 39 species of sessile hard corals, soft corals and anemone which was Unlikely as they are not in within the construction footprint. Consequently, these sessile species were assessed as having **Negligible** impact significance.

Human-wildlife Conflict

Only the long-tailed macaque (*Macaca fascicularis*) will experience **Moderate** intensity to human-wildlife conflict. This species is typically perceived as nuisances and possibly as threats by construction personnel, they are highly tolerant of human presence and urban environments, and frequently implicated in human-wildlife conflict (Medium impact intensity). The likelihood was deemed Possible, and the impact significance is therefore **Moderate**.

Loss of/ Reduction of Fauna Movement

All species recorded and probable species will experience a **Minor or Negligible** impacts due to loss of/ reduction in ecological connectivity within the Study Area. As the construction footprint is small, most species are Unlikely to experience a loss of/ reduction in ecological connectivity for fauna

movement. With the exception of the yellow shrimp goby (*Cryptocentrus cinctus*), gold-spotted mudskipper/ golden-spotted mudskipper (*Periophthalmus chrysospilos*), dawn flatworm (*Pseudobiceros hancockanus*) that are highly dependent on connected habitats for foraging and mating (High impact intensity). In addition, small and/ or slow-moving invertebrates such as gastropod, crab, sea cucumber, coastal horseshoe crab and sea start are dependent on connected habitats for foraging and mating (Medium Impact Intensity) and the hawkbill turtle (*Eretmochelys imbricata*) are Less Likely to experience the loss of ecological connectivity therefore have **Minor** impact significance.

Light Disturbances

20 fauna species are expected to experience **Moderate** impacts as a result of light disturbances. These include the migratory **c**ommon sandpiper (*Actitis hypoleucos*) and the hawksbill turtle (*Eretmochelys imbricata*), both of which are nocturnal and highly sensitive to changes in light levels (High impact intensity). The remaining 18 species are nocturnal, motile fish that show sensitivity to artificial lighting (Moderate impact intensity). Because night-time work is planned for the site, the likelihood of impact for all species is assessed as Possible, resulting in an overall impact significance of **Moderate** for the 20 light-sensitive species.

Human Disturbances

59 species of fauna will experience **Moderate** impacts due to human disturbances. These include hard corals, soft corals and sea anemones, which are sessile and highly sensitive to human presence (High impact intensity). Other affected groups include fishes, sea cucumber, sea star, crabs and snails that might be perceived as food sources, as well as the coastal horseshoe crab (*Tachypleus gigas*), smooth-coated otter (*Lutrogale perspicillata*) and long-tailed macaque (*Macaca fascicularis*) all of which are sensitive to human disturbance (Medium impact intensity). As the proposed worksites will be directly adjacent to these remaining habitats, the likelihood of disturbance is assessed as Possible, resulting in a **Moderate** impact significance for all 59 species.

Table 3-27 Summary of construction phase impact to fauna receptors

Impact Type	No. of Species			
	Major	Moderate	Minor	Negligible
Loss of/ reduction in habitats and food sources	0	5	64	2
Accidental injury or mortality	0	14	18	39
Human-wildlife conflict	0	1	9	61
Loss of/ reduction in ecological connectivity for fauna movement	0	0	14	57
Light disturbances	0	20	51	0
Human disturbances	0	59	12	0

3.3.4.2 Operational Phase

3.3.4.2.1 Habitats

Habitat degradation is the only operational phase impact identified. The detailed evaluation for each species is provided in **Appendix E**.

Habitat degradation

For the marine habitats (i.e. coral reefs, seagrass meadows and rocky shore), the modelling results indicate that sedimentation will remain unchanged across all habitats. The hydrodynamic model also

shows no alteration in the tidal regime. Consequently, all habitats are expected to experience a **Negligible** impact.

During operational phase, all works would have been completed and entry into the coastal forest would not be necessary—therefore the coastal forest is unlikely to experience any impacts at the operational phase.

3.3.4.2.2 Flora

At operational phase, there is no long-term potential impacts identified to flora species within the Study Area.

3.3.4.2.3 Fauna

Loss of/ Reduction in Ecological Connectivity for Fauna Movement

As the revetment footprint is generally small (0.05 ha of rocky shore habitat), the likelihood of loss of/ reduction in ecological connectivity for fauna movement remains unlikely to occur and hence impact significance is **Negligible** for species.

3.3.5 Recommended Mitigation Measures

In this section, mitigation measures applicable to all aspects of the construction phase for the slope stabilisation at Tanjong Rimau. Mitigation measures should be considered in the order of the mitigation hierarchy: (1) avoidance, (2) minimisation, and (3) rehabilitation/ restoration. Avoidance of the impact is first attempted. If avoidance is not possible, the impacts will be minimised. Finally, if avoidance or minimisation are not possible, rehabilitation/ restoration of the remaining and/ or nearby habitats should be considered.

3.3.5.1 Avoid

The recommended mitigation measures to avoid biodiversity impacts through the concept design of the proposed development are presented in **Table 3-28**.

Table 3-28 Key recommended design measures to avoid biodiversity impacts

Receptor	Impact Types	Mitigation Measures

Habitats	• Loss of habitat
	• Habitat degradation
		• Design optimisation – The slope stabilisation design was carefully reviewed to ensure that works are limited strictly to those required for safety, while also minimising the overall footprint and avoiding any compromise to the integrity of the coastal structures.
		• Avoid high value habitats:
		  ○ The marine construction access route was carefully selected to avoid sensitive ecological receptors, including the terrestrial plants, coral colonies, seagrass meadows, and rocky shore habitats, as far as practicable.
		  ○ On-site pegging will be conducted to verify whether the temporary bund alignment can be adjusted to avoid the Critically Endangered *Enhalus acoroides* seagrass meadows patch, corals and large rocks that act as micro-habitats for invertebrates.

Fauna Species	• Loss of/ reduction in habitats and food sources	

		○ As the barge are required to be anchored to spud down piles to minimise rocking and lateral movements of the barge, spud down pile locations should also be inspected by Marine Specialist to ensure minimal damage to coral reef / seafloor. An area with radius of 10 m should be inspected to allow for some room of error. This should be done once just before the first spud down event.
Flora Species	• Mortality	• Retention of large *Xylocarpus rumphii* specimens – The temporary bund alignment will be adjusted to avoid three notable *Xylocarpus rumphii* trees, with appropriate Tree Protection Zones (TPZs) established on site to ensure their continued preservation throughout the construction.

3.3.5.2 Minimise

The recommended mitigation measures to minimise biodiversity impacts during the construction phase—through the careful application of engineering solutions and responsible site practices—are summarised in **Table 3-29**. More importantly, mitigation measure should be integrated concurrently and seamlessly with mitigation measures recommended in **Section 4.3.3**.

Table 3-29 Key recommended design measures to minimise biodiversity impacts

Receptor	Impact Types	Mitigation Measures
Habitat	• Habitat degradation • Changes in microclimatic conditions	• Placement of turbidity curtains and silt fences: ○ Turbidity curtains are recommended along the designated marine access route within the subtidal zone to contain suspended sediment generated by vessel movements, if feasible. ○ Silt fences are recommended at the slope toe within the intertidal zone to intercept any accidental discharge of silty water arising from slope stabilisation construction activities. • Review of construction methodology – Assess opportunities to optimise marine operations, such as reducing barge size or minimising the number of daily trips, to further lower potential environmental impacts. Site setting-out and verification by the EMMP consultants. • Construction boundary site to avoid seagrasses. If not possible, seagrass within the construction impact area will be salvaged for seagrass researchers. • Transplanting of corals that will be affected by construction footprint, if needed. After which, regular coral health monitoring should be included as part of the post-transplantation monitoring plan. • Engine idling control – Engines should be switched off whenever practicable to minimise propeller wash and reduce sediment resuspension impacts.
Flora Species	• Mortality	• Plant salvaging – salvage conservation significant species that is to be affected by the slope stabilisation works whenever possible.

		• Construction stage environmental monitoring in accordance with the EMMP.
Fauna Species	• Accidental injury or mortality • Human-wildlife conflict • Loss/ reduction of fauna movement • Light disturbances • Human disturbances	• Site setting-out and verification by the EMMP consultant. • Clear identification of sensitive species to be avoided or retained, using visible markers on land and buoys for subtidal specimens. • Biodiversity awareness training to be provided for all construction personnel. • Strict adherence to designated access routes, with matting or temporary boardwalks used to minimise trampling impacts. • Construction-stage environmental monitoring in accordance with the EMMP. • Restricting all boat activities (for construction, monitoring or any other activities) and night work during coral spawning season which is typically three or four nights after the full moon in late March or April. The exact dates will be stipulated by NParks. During this period, carry out water quality, intertidal, subtidal and sedimentation monitoring before the spawning event.

3.3.5.3 Rehabilitate / Restore

The recommended rehabilitation/ restoration measures through the design of the proposed development are summarised in **Table 3-30**.

Table 3-30 Key recommended design measures for biodiversity rehabilitation/ restoration

Receptor	Impact Types	Mitigation Measures
Habitats	• Loss of habitat	• Removal of temporary bund will eventually allow the rocky shore to re-colonise. • Habitat creation and enhancement (refer to paragraphs below for more details).
Fauna species	• Loss of/ reduction in ecological connectivity for faunal movement	

Vegetation Restoration and Slope Planting

As part of the ecological restoration strategy, the stabilised slopes will be replanted using a curated palette of native species. Species selection prioritises climbers and shrubs with fast growth rates to ensure rapid soil binding and canopy establishment, while also considering commercial availability to support procurement and maintenance practicality. This approach mirrors successful NParks implementations—such as the Fort Canning Park slope rehabilitation project—where stabilised soil surfaces and grid beam structures were effectively revegetated using native plantings. The reinstated vegetation will enhance slope stability, reduce surface erosion, and contribute to long-term ecological resilience. Subsoil drainage infrastructure will also be incorporated to support healthy plant establishment and sustained vegetation performance. Before planting, the proposed plant palette should be reviewed in consultation with NParks, SDC and the Board's EMMP Specialists.

Habitat Creation and Enhancement

To compensate for habitat loss and enhance ecological value on the conventional armour rock and XblocPlus revetment, eco-engineered microhabitats should be integrated to increase surface complexity and reintroduce habitat features lost during construction.

At Tanjong Rimau, natural rocky shores contain a range of burrow sizes, including small (5–10 cm), medium (11–20 cm), and larger features such as crevices and tidal pools, which provide habitat for invertebrates and algae. To replicate these conditions, it is recommended to retain as many natural rocks on-site as possible and integrate them into the newly constructed revetment. If any, precast, textured and modular habitat units should be installed across tidal- heights, incorporating rock pools, pits, grooves, crevices, and ledges of varying sizes and orientations across the tidal gradient. These features are intended to mimic the heterogeneity of natural rocky shores and support a higher diversity of sessile and mobile invertebrates, as well as algal communities. Design references and international examples can be taken from installations in Sydney, San Diego, and ECOncrete systems.

Further enhancements include deliberately roughening rock surfaces and retaining or enlarging void spaces between armour rocks to create shaded, moist refuges for intertidal fauna. Artificial rock pools should be incorporated at different tidal levels, including shallow pools at the mid- to high-shore that drain at low tide and refill during high tide, and deeper pools near chart datum that remain submerged or damp throughout most of the tidal cycle.

Collectively, these interventions are expected to partially restore habitat functionality lost during construction, increase species richness and functional diversity relative to unmodified armour rock, and align the revetment with best-practice ecological enhancement of coastal defence structures, while maintaining its primary coastal protection function.

3.3.6 Residual Impacts

3.3.6.1 Construction Phase

3.3.6.1.1 Habitats

The assessment of residual impacts took into consideration the mitigation measures for habitats assessed in **Section 3.3.6.1.2.** It also assumes minimum controls are properly implemented and enforced. A summary of the key biodiversity habitat receptors impacted during construction phase is shown in **Table 3-31**. The detailed evaluation for each habitat is provided in **Appendix E**.

Loss of habitat

The impact on seagrass meadows remains as **Moderate** as the area impacted cannot be further optimised and avoided. However, mitigation measure has still been proposed to salvaged affected seagrasses out of the site if possible**.**

Habitat degradation

Mitigations measure to reduce habitat degradation have been recommended to reduce habitat degradation. Some examples include engine idling control, where tugboat engine should be switched off whenever practicable to minimise propeller wash and reduce sediment resuspension impacts to seagrass and corals. Clear worksite boundary and biodiversity awareness training should also be established to prevent workers from entering sensitive habitats such as coastal forest, seagrass meadows and rocky shore. These mitigation measure can reduce likelihood from Possible to Less Likely, resulting in **Minor** impact significance.

Table 3-31 Summary of residual impact assessment for habitat receptors during the construction phase

Habitat receptor	Priority level and other relevant status	Total area within Study Area (ha)	Direct impact	Impact significance	Changes in impact significance

			(% of total habitat type within Study Area)		
Coral Reefs	Priority 1	6.533	3.3% (0.215 ha)	**Minor** for all impact types	NA
Seagrass Meadows	Priority 1	0.704	12.4% (0.087 ha)	Habitat loss: **Moderate** Habitat degradation: **Minor**	Habitat degradation has been reduced from **Moderate** to **Minor**.
Rocky Shore	Priority 2	2.191	20.7% (0.454 ha)	**Minor** for all impact types	NA
Coastal Forest	Priority 2	NA	NA	**Minor** for all impact types	NA

3.3.6.1.2 Flora

A summary of the residual impacts to flora species receptors in Site A is provided in Table **3-32** and the detailed evaluation for each flora species is provided in **Appendix F**.

Mortality

With implementation of appropriate mitigation measures discussed in **Section 3.3.5** i.e., salvage and/or transplant plant specimens where suitable—the mortality impact intensity remains the same (i.e. High or Medium) as it still possible that a mistake can result in loss of (all) specimens within the Study Area. Therefore, the impact intensity remains but the likelihood that these specimens would be lost reduces from Likely to Possible. This reduces the impact significance from **Major** to **Moderate** for two species—*Garcinia celebica* and *Syzygium palembanicum*—and **Moderate** to **Minor** for three species.

Recommendations will be made to avoid *Xylocarpus rumphii* which will reduce the impact intensity to Negligible and likelihood to Unlikely. This reduces the impact significance from **Moderate** to **Negligible**.

Table 3-32 Summary of construction phase residual impacts to flora receptors

Impact Type	Number of Species			
	Major	**Moderate**	**Minor**	**Negligible**
Mortality	0 (2)	8 (10)	3 (0)	17 (16)

* The number of species assessed to experience the various impact significance levels pre-mitigation is indicated in parentheses

3.3.6.1.3 Fauna

The impact intensity of Medium for to the loss of/ reduction in habitats and food sources stays the same for five faunal species that used the seagrass meadows. The habitat loss on seagrass meadows cannot be avoided. Therefore, the impact significance will remain as **Moderate.**

The **Moderate** impact significance of accidental injury or mortality can be reduced to **Minor** for two species, smooth-coated otter (*L. perspicillata*) and long-tailed macaque (*M. fascicularis*), with the implementation worksite hoarding and conducting biodiversity awareness training for workers, a Wildlife Response Plan, and regular inspections to ensure hoarding integrity. These mitigation measures would reduce the likelihood of such accidents occurring from **Possible** to **Less Likely**. For the remaining 12 species, the mitigation measures are not likely to reduce the risk.

The **Moderate** impact due to human-wildlife conflict for long-tailed macaque (*M. fascicularis*) can be reduced to **Minor** with the implementation of mitigation measures including conducting biodiversity

awareness trainings, ensuring good housekeeping, and implementing a Wildlife Response Plan. These measures would reduce the likelihood of such conflicts occurring from **Possible** to **Less Likely**.

The **Moderate** impact due to light disturbances can be reduced to **Minor** if a Light Management Plan and light monitoring as part of EMMP monitoring are implemented. This would reduce the likelihood of light disturbances occurring from **Possible** to **Less Likely.**

With the implementation of biodiversity awareness trainings, the likelihood of human disturbances occurring will chance from **Possible** to **Less Likely**. This would change the impact significance of 12 species from **Minor** to **Negligible** and 59 species from **Moderate** to **Minor.**

The residual impacts to faunal receptors are summarised in **Table 3-33** and detailed in **Appendix G**.

Table 3-33 Summary of construction phase residual impacts to faunal receptors

Impact Type	No. of Species			
	Major	Moderate	Minor	Negligible
Loss of/ reduction in habitats and food sources	0 (0)	5 (5)	64 (64)	2 (2)
Accidental injury or mortality	0 (0)	12 (14)	20 (18)	39 (39)
Human-wildlife conflict	0 (0)	0 (1)	10 (9)	61 (61)
Loss of/ reduction in ecological connectivity for fauna movement	(0)	(0)	(14)	(57)
Light disturbances	0 (0)	0 (20)	71 (51)	0 (0)
Human disturbances	0 (0)	0 (59)	59 (12)	12 (0)

* The number of species assessed to experience the various impact significance levels pre-mitigation is indicated in parentheses

3.3.6.2 Operational Phase

As impacts to all habitat and fauna receptors were assessed to be Negligible to Minor, there were no further reduction in impact significance.

3.3.7 Summary of Impacts during Construction and Operational Phase of the Project

Habitat

For habitat receptors, three types of impact were assessed during the construction phase, namely (1) Temporary habitat loss (2) Habitat Degradation (3) Changes in microclimatic conditions—the impact significance categories pre-mitigation ranged from **Minor** to **Moderate**.

Pre-mitigated impact significance for habitat loss and habitat degradation was **Moderate** for seagrass meadows and **Minor** for all remaining habitats (i.e. coral reefs, rocky shore and coastal forest). As mitigation measure of avoiding the seagrass meadows was not possible, the impact of habitat loss to seagrass meadows remains at **Moderate**. While mitigation measures proposed were deemed able to reduce habitat degradation for seagrass meadows, reducing impacts from **Moderate** to **Minor**.

Overall, residual impacts to habitats range from **Minor** to **Moderate** (**Table 3-31**).

Flora

For flora species receptors, mortality is the only impact assessed during the construction phase and the impact significance categories range from **Negligible** to **Major.**

Transplanting and/or salvaging plant specimens of ecological importance can help reduce the **Moderate** to **Major** impact of mortality to **Minor** to **Moderate** for 11 species and completely avoid mortality for one species—*Xylocarpus Rumphii*.

Overall, residual impacts to habitats range from **Negligible** to **Moderate** (**Table 3-32**).

Fauna

For fauna receptors, six types of impact were assessed during construction phase— (1) loss of or reduction in habitats and food sources, (2) human-wildlife conflict, (3) accidental injury or mortality, (4) loss of or reduction in ecological connectivity for fauna movement, (5) light disturbances and (6) human disturbances.

The impact significance for the loss of or reduction in habitats and food sources ranges from **Negligible** to **Moderate**. As no mitigation measure is applied for seagrasses, all five **Moderate** species will stay as **Moderate** impact significance on the loss of or reduction in habitats and food sources.

With the implementation worksite hoarding and conducting biodiversity awareness training for workers, a Wildlife Response Plan, and regular inspections to ensure hoarding integrity, the **Moderate** impact significance of accidental injury or mortality can be reduced to **Minor** for two of the 14 species. For the remaining 12 species, the mitigation measures are not likely to reduce the impact significance any further.

Human-wildlife conflict will have a Moderate impact on one species (long-tailed macaque (*M. fascicularis*)), Minor impact on 10 species and Negligible impact on 61 species. With the implementation of mitigation measures including conducting biodiversity awareness trainings, ensuring good housekeeping, and implementing a Wildlife Response Plan. These would reduce the impact significance of *M. fascicularis* to **Minor** while the other species retained their impact significance.

All 71 species will have between **Negligible** to **Minor** impact significance to loss of/ reduction in ecological connectivity for fauna movement.

Twenty species are expected to have **Moderate** impact due to light disturbances but it was reduced to **Minor** with Light Management Plan and light monitoring as part of EMMP monitoring in implement. Thus, resulting in all 71 species having **Minor** impact on light disturbance.

Human disturbance was likely to have a **Moderate** impact significance on 59 species and **Minor** impact on 12 species. With the implementation of biodiversity awareness trainings, this would change the impact significance of 12 species from **Minor** to **Negligible** and 59 species from **Moderate** to **Minor.**

At Operational phase, modelling of sedimentation and hydrodynamics shows that all habitats are expected to experience a **Negligible** impact on habitat degradation. As for the loss of/ reduction in ecological connectivity for fauna movement of fauna, the revetment footprint is generally small, the likelihood of loss of/ reduction in ecological connectivity for fauna movement remains unlikely to occur and hence impact significance is **Negligible** for species.

4. Physical Environment

4.1 Baseline Surveys Methodology

To support the Environmental Impact Assessment (EIA) for the proposed slope stabilisation works at Tanjong Rimau, baseline surveys was implemented to characterise the existing physical environment. The surveys focused on four key environmental aspects that may be affected by the Project, namely marine water quality, ambient air quality, ambient noise and ground vibration. The survey locations (see **Figure 4-1**) were selected to be representative of conditions within and adjacent to the proposed construction footprint, as well as at sensitive receptors such as Fort Siloso and Shangri La Rasa Sentosa Resort.

For marine water quality, grab samples were collected at three stations (S1, S2 and S3) located in the nearshore waters fringing the Tanjong Rimau. Sampling was undertaken during a spring tide on 8 September 2025 and during a neap tide on 29 September 2025, with S1, S2 and S3 sampled sequentially during each tidal condition. This approach provides baseline data that reflect variability in marine water quality associated with different tidal states and coastal hydrodynamics.

Ambient air quality was measured at two locations, A1 near Fort Siloso and A2 near Shangri La Rasa Sentosa Resort. Continuous measurement was conducted for seven consecutive days at each location, from 14 to 20 October 2025 at A1 and from 22 to 28 October 2025 at A2. The parameters measured included particulate matter with aerodynamic diameter less than or equal two point five micrometres ($PM_{2.5}$) and ten micrometres (PM_{10}), as well as key combustion related pollutants such as nitrogen dioxide, ozone, carbon monoxide and sulphur dioxide. These baseline data establish the prevailing ambient air quality in the vicinity of the Project and allow comparison with applicable ambient air quality targets.

Ambient noise levels were measured at two monitoring points, N1 at Fort Siloso and N2 at Shangri La Rasa Sentosa Resort, over seven consecutive days, from 14 to 20 October 2025 at N1 and from 22 to 28 October 2025 at N2, respectively. The measurements covered daytime, evening and night-time periods, and recorded A-weighted equivalent continuous sound levels (LAeq) over 5-minute, 1-hour and 12-hour intervals. The results provide a comprehensive description of the existing acoustic climate and its variability over typical weekdays and weekends.

Ground vibration was characterised at two measurement points, V1 at Fort Siloso and V2 at Shangri La Rasa Sentosa Resort. Each location was monitored continuously over a 24-hour period on 14 October 2025 for V1 and 16 October 2025 for V2. Dominant frequency and peak particle velocity were recorded along three orthogonal axes to describe the existing vibration climate and to provide a benchmark for comparison during construction.

Together, these baseline surveys provide an understanding of the current physical environmental conditions at Tanjong Rimau. The baseline datasets form the baseline reference against which potential changes due to the proposed slope stabilisation works are predicted and evaluated in the subsequent impact assessment sections.

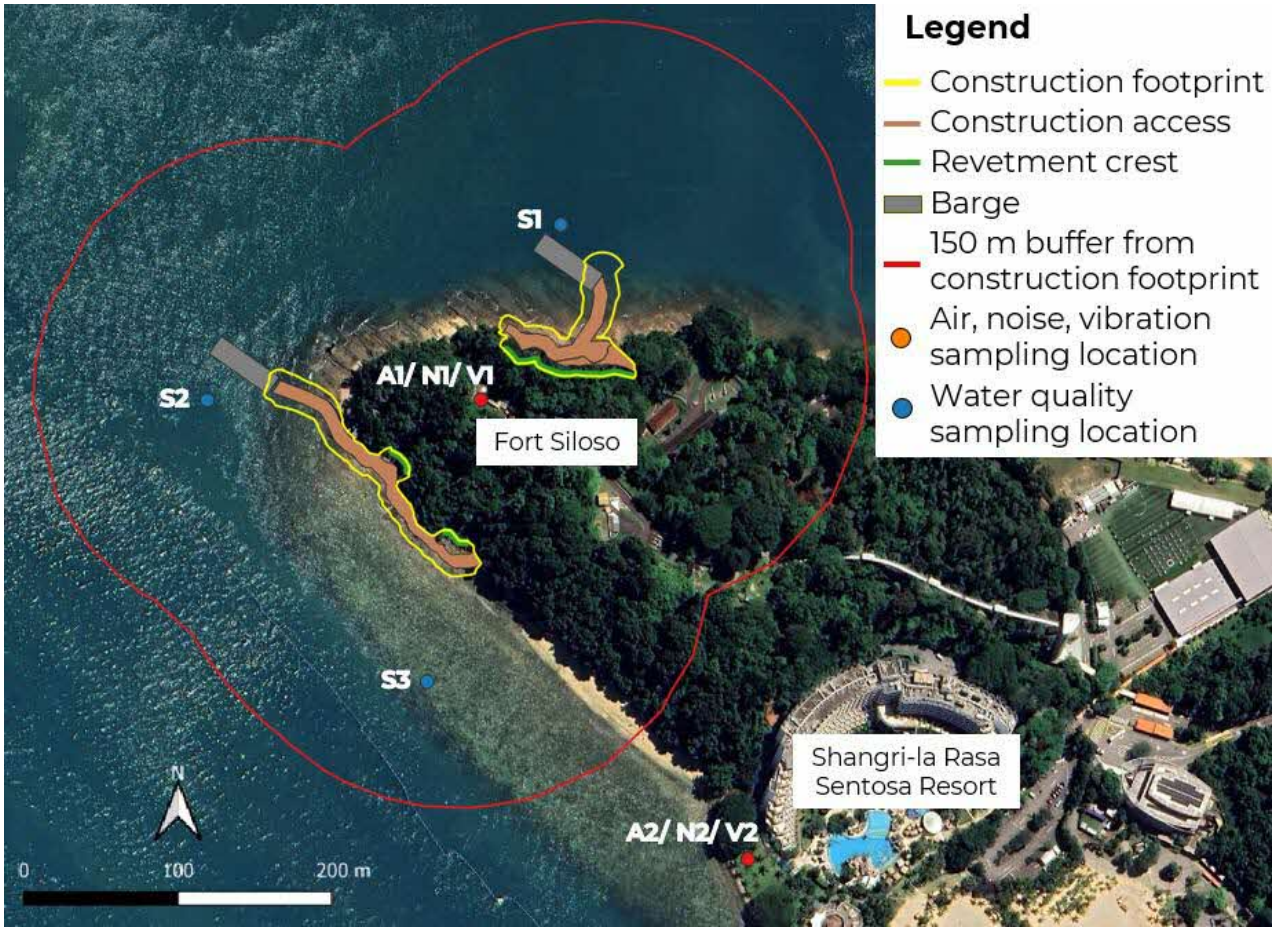


Figure 4-1 Baseline survey locations for physical environment

4.1.1 Marine Water Quality

In-situ measurements and grab sampling for marine water quality was taken at three locations (i.e., S1, S2 and S3) (**Figure 4-1**) off Tanjong Rimau during two strategically selected windows. These windows are designed to bracket the highest and lowest anticipated suspended sediment concentration (SSC) levels which is a key indicator of marine water quality. This approach will enable us to capture potential worst-case and baseline sediment conditions under realistic environmental scenarios. **Table 4-1** shows the summary of the marine water quality sampling schedule.

Table 4-1 In-situ marine water quality measurement and sampling schedule

Sampling Goal	Monsoon	Preferred Window & Tide Predictions	Expected SSC	Why This Window?
Worst Case	Southwest (Jun–Sep)	**Spring ebb** (Mon 8 Sept 2025, ~05:30–06:30 SGT) Tide Predictions: 1. Low: ~05:52 (+0.16 m) 2. High: ~12:08 (+2.60 m) 3. Low: ~17:43 (+0.72 m) 4. High: ~23:52 (+2.94 m)	Very High	This full-moon spring tide is expected to generate the strongest ebb currents. Combined with sediment-laden inflows from Sumatra during the s Monsoon, this window likely represents the peak SSC conditions for the year.
Baseline	Southwest (Jun–Sep)	**Neap flood** (Mon 29 Sept 2025, ~14:20–15:30 SGT) Tide Predictions: 1. High: ~07:00 (+2.30 m) 2. Low: ~10:00 (+1.80 m) 3. High: ~15:00 (+2.60 m) 4. Low: ~23:27 (+0.49 m)	Lowest	Occurring during the last-quarter lunar phase, this neap tide generates weak flood currents with minimal sediment resuspension, providing a strong baseline SSC profile under similar seasonal conditions.

The in-situ measurements at each point were performed on-site using a calibrated multi-parameter probe and Secchi disk, and comprise of the following parameters:

- Water temperature
- Salinity
- Specific conductivity
- Dissolved oxygen (DO)
- pH value
- Secchi depth
- Turbidity

A marine water sample was collected by grab sampling technique at a depth of 1 m at each point using a horizontal Van Dorn water sampler (**Figure 4-2**).

Figure 4-2 Marine water quality sampling at Tanjong Rimau

A total of six marine water samples were collected and sent to a SINGLAS accredited laboratory for parameters listed in the ASEAN Marine Water Quality Criteria (AMWQC) (see **Table 4-2**). The results obtained are compared against the limits stated in the AMWQC [34].

Table 4-2 Ex-situ parameters analysed in collected marine water samples

Test Parameter	Test Method	ASEAN Marine Water Quality Criteria (For Aquatic Life Protection)
Ammonia as NH_3-N	APHA 4500-NH3 (H)	70 ug/L
Cadmium as Cd	APHA 3120B / 3125B	10 ug/L
Chromium (VI)	APHA 3500-Cr (B)	50 ug/L
Copper as Cu	APHA 3120B/ 3125B	8 ug/L
Cyanide as CN	APHA 4500-CN (N)	7 ug/L
Lead as Pb	APHA 3120B / APHA 3125B	8.5 ug/L
Mercury as Hg	APHA 3125B	0.16 ug/L
Nitrate as NO_3-N	APHA 4500-NO3 (I)	60 ug/L
Nitrite as NO_2-N	APHA 4500-NO3 (I)	55 ug/L
Oil and Grease	Accredited In-house Method: MLS-SOP-WQ-033 (adapted from APHA 5520C)	0.14 mg/L
Total Phenol	Accredited In-house Method: MLS-SOP-WQ-009 / APHA 5530D	0.12 mg/L

Phosphate as PO_4-P	APHA 4500-P (G)	15 ug/L (Coastal) 45 ug/L (Estuarine)
Tributyltin	APHA 6710B	10 ng/L
Total Suspended Solids	APHA 2540D	Permissible 10% maximum increase over seasonal average concentration
Faecal Coliform, cfu/100mL	APHA 9222D	100 cfu/100mL
Enterococci, cfu/100mL	APHA 9230C	35 cfu/100mL

4.1.2 Ambient Air Quality

Baseline ambient air quality survey was carried out continuously for seven consecutive days at two designated locations using the Kunak Air Pro ambient air quality measurement device. The ambient air quality measurement device was mounted on a tripod at least 1.5 m above ground surface.

The selected baseline ambient air quality measurement points were Point A1: Fort Siloso and Point A2: Shangr iLa Rasa Sentosa Resort (**Figure 4-1**). These locations have been identified as air-sensitive receptors due to their respective characteristics:

- **Fort Siloso (Point A1)** is a nationally preserved heritage site and a popular tourist destination, frequently visited by families, school groups, and elderly individuals (
- **Figure 4-3**). These groups may be more sensitive to environmental disturbances such as ambient air pollution. In addition, the site's historical significance, educational function, and generally quiet setting require careful preservation of ambient air quality to maintain the visitor comfort, experience, and the heritage character of the area.
- **Shangri La Rasa Sentosa Resort (Point A2)** is a high-end beachfront resort that accommodates both local and international guests, including children and individuals who may be more susceptible to ambient air pollution (**Figure 4-4**). As a hospitality establishment prioritizing rest, wellness, and recreational enjoyment, it is critical to ensure that ambient noise levels remain within acceptable thresholds to protect the comfort and well-being of both guests and staff.

Designating these areas as air-sensitive receptors ensures that baseline ambient air quality data was collected where potential human exposure is high and where vulnerable populations may be present. The data obtained will help assess any potential impacts from the proposed slope stabilisation work and guide the implementation of necessary mitigation measures to prevent or minimise ambient air pollution.

Figure 4-3 Baseline survey for ambient air quality at A1

Figure 4-4 Baseline survey for ambient air quality at A2

The primary air pollutants of concern associated with the proposed slope stabilisation works are particulate matter less than 10 micrometres in aerodynamic diameter (PM_{10}) and particulate matter less than 2.5 micrometres in aerodynamic diameter ($PM_{2.5}$), which are expected to be generated mainly during earthwork activities. To establish an accurate baseline and support impact assessment, we have measured PM_{10} and $PM_{2.5}$ levels as part of the baseline ambient air quality survey. The recorded PM_{10} and $PM_{2.5}$ data are compared against the Singapore Ambient Air Quality Targets (SAAQT) (see **Table 4-3**).

Other air pollutants such as carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and ozone (O_3) are not anticipated to be significant concerns for this Study Area. This is because the construction activities are not anticipated to involve the use of stationary fuel-burning equipment (e.g., incinerators, boilers, or furnaces). Furthermore, all construction vehicles and portable power generators deployed on-site will be subject to National Environment Agency (NEA) regulations, which mandate compliance with Euro VI emission standards and off-road diesel engine emission limits, thereby minimising emissions of combustion-related pollutants. However, baseline concentrations of CO, NO_2, SO_2, and O_3 have also been measured to provide a more comprehensive characterization of existing ambient air quality conditions within the Study Area. The recorded O_3, NO_2, SO_2, and CO data are compared against the SAAQT [35].

Table 4-3 Singapore ambient air quality targets (SAAQT)

Pollutant	Singapore Targets by 2020	Long Term Targets
Particulate Matter ($PM_{2.5}$)	Annual mean: 12 µg/m3 (Sustainable Singapore Blueprint target)	Annual mean: 10 µg/m3
	24-hour mean: 37.5 µg/m3 (WHO Interim Target)	24-hour mean: 25 µg/m3 (WHO Final)
Particulate Matter (PM_{10})	Annual mean: 20 µg/m3	
	24-hour mean: 50 µg/m3 (WHO Final)	
Carbon Monoxide (CO)	8-hour mean: 10 mg/m3	
	1-hour mean: 30 mg/m3 (WHO Final)	
Nitrogen Dioxide (NO_2)	Annual mean: 40 µg/m3	

Pollutant	Singapore Targets by 2020	Long Term Targets
	1-hour mean: 200 µg/m3 (WHO Final)	
Sulphur Dioxide (SO_2)	24-hour mean: 50 µg/m3 (WHO Interim Target)	24-hour mean: 20 µg/m3 (WHO Final)
Ozone (O_3)	8-hour mean: 100 µg/m3 (WHO Final)	

Note: Sustainable Singapore Blueprint annual target for PM2.5 of 12µg/m3 will be retained and aligned with WHO Interim Target of 37.5 µg/m3 for 24-hour mean.

4.1.3 Ambient Noise

Baseline ambient noise survey was carried out continuously for seven consecutive days at two designated locations, using the National Environment Agency (NEA) approved Type 1 sound level meter. The sound level meter was mounted on a tripod at least 1.5 m above ground surface.

The selected baseline airborne noise survey points are Point A1: Fort Siloso and Point A2: Shangri La Rasa Sentosa Resort (**Figure 4-1**). These locations have been identified as noise-sensitive receptors due to their respective characteristics:

- **Fort Siloso (Point A1)** is a nationally preserved heritage site and a popular tourist destination, frequently visited by families, school groups, and elderly individuals (**Figure 4-5**). These groups may be more sensitive to environmental disturbances such as ambient noise pollution. In addition, its historical significance and open-air environment necessitate the preservation of a quiet soundscape to maintain visitor comfort, experience, and the heritage character of the area.
- **Shangri La Rasa Sentosa Resort (Point A2)** is a high-end beachfront resort that accommodates both local and international guests, including children and individuals with potential sensitivities to noise disturbances (**Figure 4-6**). As a hospitality venue focused on health, comfort, and recreation, it is essential to ensure that the ambient noise levels remain within acceptable limits to protect the comfort and well-being of both guests and staff.

Designating these locations as noise sensitive receptors ensures that baseline ambient noise data is collected in areas where potential human exposure is high and where occupants or visitors may be more vulnerable to ambient noise disturbances.

Figure 4-5 Baseline survey for ambient noise at N1

Figure 4-6 Baseline survey for ambient noise at N2

The baseline ambient noise survey measures the following parameters:

- **LAeq 5-minute** (A-weighted equivalent continuous sound level over 5-minute intervals)
- **LAeq 1-hour** (A-weighted equivalent continuous sound level over 1-hour intervals)
- **LAeq 12-hour** (A-weighted equivalent continuous sound level over 12-hour intervals)

These parameters are selected in alignment with the Environmental Protection and Management (Control of Noise at Construction Sites) Regulations, which stipulated maximum permissible noise levels for construction sites in Singapore. The recorded baseline ambient noise data will be compared against the maximum permissible noise levels stated in the regulations.

All construction sites are required to abide by the permissible noise limits set by NEA under the Environmental Protection and Management (Control of Noise at Construction Sites) Regulations, which are progressively more stringent after 7pm and 10pm [36]. The maximum permissible noise levels from construction sites are shown in the **Table 4-4**. For instance, construction work at the worksites must not exceed the noise limit of 90 dBA (Leq-5mins) over any 5-minute period between 7am to 7pm, and must not exceed 75 dBA (Leq-12hr) at the end of the specified period from 7am to 7pm (12 hr).

Table 4-4 Maximum permissible noise levels for construction work Mondays to Saturdays

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

Sundays and Public Holidays

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

Note:

- *Leq refers to the equivalent continuous noise level over the specified period, i.e. 5-minute, 1-hour or 12-hour.
- #dBA refers to an A-weighted decibel which is an expression of the relative loudness of sounds as perceived by the human ear.

The data obtained will support the assessment of potential ambient noise impacts arising from the proposed slope stabilisation works and inform the design and implementation of mitigation measures to prevent or minimise ambient noise pollution.

4.1.4 Ground Vibration

A baseline ground vibration survey was conducted continuously over one day at two designated locations, using triaxial ground vibration sensors. Each vibration sensor was securely installed on a firm, level surface, with proper coupling to the ground to ensure accurate measurement.

The selected baseline airborne noise survey points are Point V1: Fort Siloso and Point V2: Shangri La Rasa Sentosa Resort (**Figure 4-1**). These locations were identified as vibration-sensitive receptors due to their functional characteristics and the presence of populations or structures potentially susceptible to vibration-induced impacts:

- **Fort Siloso (Point V1)** is a nationally preserved heritage site and a popular public attraction, often visited by families, school groups, and elderly individuals (**Figure 4-7**). Its historical structures and open-air setting demand careful preservation, and it is crucial to establish baseline ground vibration levels to ensure that future construction activities, particularly those involving heavy machinery or piling, do not cause structural damage or undue disturbance.
- **Shangri La Rasa Sentosa Resort (Point V2)** is a luxury beachfront hotel that hosts both local and international guests seeking rest, wellness, and relaxation (**Figure 4-8**). Guests and staff may be sensitive to ground-borne vibrations transmitted through structural elements of the resort. Establishing a vibration baseline is therefore essential to maintain comfort levels and prevent undue disturbance.

Designating these locations as vibration-sensitive receptors ensures that baseline vibration data is collected in areas where potential human comfort and structural integrity may be affected by potential construction-related ground vibrations.

Figure 4-7 Baseline survey for ground vibration at V1

Figure 4-8 Baseline survey for ground vibration at V2

The baseline ground vibration survey measures Peak Particle Velocity (PPV) in millimetre per second (mm/s). These parameters are standard in construction vibration surveys and will serve as a reference for comparison against construction-phase ground vibration levels.

The recorded baseline ground vibration data are compared against the British Standard (BS) 5228-2:2009+A1:2014 - Code of practice for noise and vibration control on construction and open sites - Part 2: Vibration [37] (see **Table 4-5** and **Table 4-6**).

Table 4-5 BS 5228-2:2009 - Transient vibration guide values for cosmetic damage

Type of Building	Peak component particle velocity in frequency range of predominant pulse

	4 Hz to 15 Hz	15 Hz and above
Reinforced or framed structures (industrial and heavy commercial buildings)	50 mm/s at 4 Hz and above	50 mm/s at 4 Hz and above
Unreinforced or light framed structures (residential or light commercial buildings)	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

Table 4-6 BS 5228-2:2009 - Guidance on effects of vibration levels

Vibration Level	Effect
0.14 mm/s	Vibration might be just perceptible in the most sensitive situations for most vibration frequences associated with construction. At lower frequencies, people are less sensitive to vibration.
0.3 mm/s	Vibration might be just perceptible in residential environments.
1.0 mm/s	It is likely that vibration of this level in residential environments will cause complaint, but can be tolerated if prior warning and explanation has been given to residents
10 mm/s	Vibration is likely to be intolerable for any more than a very brief exposure to this level in most building environments

The data obtained will support the assessment of potential ground vibration impacts from the proposed slope stabilisation works and inform the development of appropriate ground vibration control measures to safeguard both structural and human receptors.

4.2 Baseline Physical Environment Conditions

4.2.1 Marine Water Quality

Baseline in-situ and ex-situ marine water quality results for the three monitoring stations (i.e., S1, S2 and S3) during the spring tide (8 September 2025) and neap tide (29 September 2025) surveys are summarised in **Table 4-7**. Overall, the data indicate that coastal waters off Tanjong Rimau are generally of good quality and largely comply with the ASEAN Marine Water Quality Criteria (AMWQC) for aquatic life protection, with localised elevations of nitrate and a single elevated Enterococci result that are treated as existing background conditions. See **Appendix H** for details of the marine water quality test report issued by Marchwood Laboratory Services Pte Ltd (MLS).

Table 4-7 Marine Water Quality Baseline Data

Parameter	Unit	Spring Tide (Ebb)			Neap Tide (Flood)			ASEAN Marine Water Quality Criteria (AMWQC)
		S1	S2	S3	S1	S2	S3	
		8/9/2025	8/9/2025	8/9/2025	29/9/2025	29/9/2025	29/9/2025	
		4.50 am	5.30 am	5.50 am	2.38 pm	3 pm	3.30 pm	
Temperature	°C	29.34	29.41	29.42	30.20	29.89	29.21	Increase not more than 2 °C above the maximum ambient temperature
Dissolved Oxygen	mg/L	5.73	5.76	5.76	6.41	6.04	6.08	>4
Specific Conductivity	µS/cm	47196	47014	46863	64011	46281	46252	-
pH		7.96	7.91	7.9	7.92	7.93	7.96	-
Turbidity	NTU	6.29	8.43	6.62	1.64	1.54	1.47	-
Salinity	PSU	31.26	31.12	31.01	30.39	30.58	30.56	-
Secchi Depth	m	1.5	1.27	1.3	2.37	3.03	2.37	-
Ammonia as NH_3-N	µg/L	14	<10	<10	<10	<10	<10	70
Cadmium as Cd	µg/L	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2	10
Chromium as Cr(VI)	µg/L	<25	<25	<25	<25	<25	<25	50
Copper as Cu	µg/L	<5	<5	<5	<5	<5	<5	8
Cyanide as CN	µg/L	<5	<5	<5	<5	<5	<5	7
Lead as Pb	µg/L	<5	<5	<5	<5	<5	<5	8.5
Mercury as Hg	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.16
Nitrate as NO_3-N	µg/L	**91**	**89**	**98**	54.9	37.4	**72**	60
Nitrite as NO_2-N	µg/L	<20	<20	<20	<20	<20	<20	55
Oil and Grease	mg/L	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.14
Phenolic Compounds as Phenols	mg/L	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.12
Phosphate as PO_4-P	µg/L	10.3	10.5	11	<10	<10	10.8	15
Tributyltin	ng/L	<10	<10	<10	<10	<10	<10	10
Total Suspended Solids (TSS)	mg/L	10.9	7.45	15	2.2	2.5	2.4	10% increase maximum over seasonal average concentration
Faecal Coliform	cfu/100mL	33	23	47	3	2	2	100
Enterococci	cfu/100mL	**176**	4	16	<1	2	5	35

Note: Numbers in bold, red and underlined indicate values that exceed the AMWQC.

4.2.1.1 General Physico- Chemical Conditions

Surface water temperature ranged from 29.21 to 30.20 degree Celsius (°C) across all stations and both tide conditions, which is typical of coastal waters in the region and establishes the ambient temperature envelope for subsequent impact assessment. Dissolved oxygen concentrations were between 5.73 and 6.41 milligram per litre (mg/L), comfortably above the ASEAN criterion of greater than 4 milligram per litre, indicating that the receiving waters are well oxygenated and suitable for sustaining aquatic life.

Specific conductivity (approximately 46250 to 64000 microSiemens per centimetre (µS/cm)) and salinity values (30.39 to 31.31 practical salinity units (PSU)) are consistent with open coastal marine conditions and show no evidence of significant freshwater dilution during the surveys. Measured pH values were stable and slightly alkaline, ranging from pH 7.90 to 7.96, which is within the normal range for marine systems and not indicative of acidification or unusual biochemical activity.

Water clarity indicators show a clear distinction between the two survey windows. During the spring tide, turbidity ranged from 6.29 to 8.43 Nephelometric Turbidity Unit (NTU) and Secchi depth from 1.27 to 1.50 metre (m), while during the neap tide turbidity was much lower at 1.47 to 1.64 NTU with Secchi depth between 2.37 and 3.03 m. These results confirm that the spring tide window captured higher suspended sediment conditions, while the neap tide window represents clearer baseline conditions with reduced resuspension, in line with the intended monitoring design.

Total suspended solids (TSS) concentrations showed a similar pattern. Spring tide TSS values ranged from 7.45 to 15 mg/L, whereas neap tide concentrations were between 2.2 and 2.5 mg/L. These levels are typical of coastal waters influenced by tidal resuspension. The baseline data set will be used to define seasonal average conditions for comparison against the AMWQC criterion of a maximum 10 percent allowable increase over seasonal average concentration during construction.

4.2.1.2 Nutrients

Dissolved inorganic nitrogen and phosphorus were present at low to moderate levels. Ammonia as NH_3-N ranged from less than 10 to 14 microgram per litre (µg/L), well below the AMWQC of 70 µg/L. Nitrite as NO_2-N was below 20 µg/L at all stations, meeting the criterion of 55 µg/L.

Nitrate as NO_3-N showed the most notable deviation from AMWQC. Concentrations during the spring tide were 91, 89 and 98 µg/L at S1, S2 and S3 respectively, and 54.9, 37.4 and 72 µg/L at the same stations during the neap tide. The AMWQC for nitrate is 60 µg/L. Four of the six samples exceeded this value, namely all three spring tide samples and the neap tide sample at S3. The remaining two neap tide samples at S1 and S2 were below the criterion.

The consistent elevation of nitrate across all stations during Spring tide indicates a regional, tide-driven pattern rather than a localised pollution source. Spring tides generate stronger mixing and resuspension of seabed sediments, which can mobilise naturally occurring nitrate. This interpretation is supported by higher turbidity measurements during Spring Tide. During Neap Tide, nitrate levels decreased substantially at S1 (37 µg/L) and S2 (55 µg/L) but remained elevated at S3 (72 µg/L). In contrast to spring tide, turbidity and TSS during neap tide were lower across all stations, indicating minimal sediment disturbance due to weaker tidal energy. The overall pattern i.e., regional elevation during spring tide and isolated retention at S3 during neap tide, indicates that the nitrate fluctuations are driven by natural tidal processes rather than anthropogenic inputs.

Phosphate as PO_4-P ranged from less than 10 to 11 µg/L, which is below the AMWQC of 15 µg/L for coastal waters. Overall, the nutrient data suggest generally low to moderate enrichment, with localised elevations in nitrate that likely reflect existing regional influences such as offshore currents, upstream inputs and vessel traffic, rather than project specific effects. These elevated nitrate levels will be treated as part of the existing baseline condition in the impact assessment, with a focus on ensuring that project activities do not result in further significant increases.

4.2.1.3 Trace Metals and Toxic Substances

All measured trace metals and toxic substances were either below laboratory detection limits or well within the AMWQC for aquatic life protection. Ammonia, cadmium, chromium (VI), copper, cyanide, lead and

mercury were all reported at levels significantly lower than their respective criteria, providing a comfortable margin of compliance.

Oil and grease concentrations were at or below 0.1 mg/L at all stations, which is below the AMWQC of 0.14 mg/L, indicating no evidence of hydrocarbon contamination in the surveyed area at the time of sampling. Phenolic compounds as phenols were reported as less than 0.025 mg/L in all samples, again below the criterion of 0.12 mg/L. Tributyltin was reported as less than 10 nanogram per litre (ng/L) at all stations. Given that the AMWQC is 10 ng/L, these results indicate that tributyltin, if present, is at or below the guideline level and does not represent a significant concern in the current baseline.

4.2.1.4 Microbiological Quality

Microbiological indicator bacteria were generally low. Faecal coliform concentrations ranged from 2 to 47 colony forming units (CFU) per 100 millilitres (ml) across all stations and both tide conditions, which is below the AMWQC of 100 CFU per 100 ml.

Enterococci showed one elevated result during the spring tide at S1, with a concentration of CFU per 100 ml, exceeding the AMWQC of 35 CFU per 100 ml. All other Enterococci measurements were between less than 1 and 16 CFU per 100 ml, which comply with the guideline. The isolated exceedance at S1 is likely related to short term or localised influences, such as recreational use, vessel activity or episodic runoff, and is considered to represent an existing background condition rather than a project related effect. The impact assessment will adopt a precautionary approach by ensuring that construction activities do not increase the frequency or magnitude of such exceedances.

4.2.1.5 Overall Assessment of Baseline Marine Water Quality

In summary, the baseline surveys show that marine waters in the vicinity of Tanjong Rimau are generally of good quality and largely meet the AMWQC for protection of aquatic life and recreational use. Physico-chemical parameters, trace metals, toxic substances, TSS and faecal coliforms are all within acceptable guideline levels. Localised elevations in Nitrate and one elevated Enterococci result at S1 during the spring tide are the only parameters exceeding guideline values and are interpreted as part of the existing background condition driven by regional and local influences.

These baseline findings provide an important reference for the subsequent assessment of potential impacts from the proposed slope stabilisation works. During construction, predicted changes in dissolved oxygen, TSS, nutrients and microbiological indicators will be evaluated against this established baseline to ensure that marine water quality is maintained within acceptable limits and that the AMWQC, including the 10 percent allowable increase in TSS over the seasonal average, are not exceeded.

4.2.2 Ambient Air Quality

Continuous seven-day ambient air quality measurement was carried out at Fort Siloso (A1) (from 22 to 28 Oct 2025) and Shangri La Rasa Sentosa Resort (A2) (from 14 to 20 Oct 2025), recording hourly concentrations of particulate matter PM_{10} and $PM_{2.5}$, carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and ozone (O_3). The results were processed into 24-hour, 8 hour and 1-hour averages for comparison against the Singapore Ambient Air Quality Targets (SAAQT) (see **Table 4-8**). A summary of the observed ranges at each receptor is presented in the baseline ambient air quality table. Overall, the data show that ambient air quality in the Study Area is generally good and, with the exception of SO_2 at A2 on certain days, complies with the relevant long-term targets. See **Appendix I** for details of the ambient air quality test report issued by MLS.

Table 4-8 Summary of Ambient Air Quality Baseline Results

Pollutant	Averaging Period	Unit	Range of Ambient Air Quality Baseline Over 7 Consecutive Days		SAAQT (Long Term Targets)
			A1	A2	
PM_{10}	24 hours	µg/m^3	5.6 - 12.3	6.5 - 12.1	50
$PM_{2.5}$	24 hours	µg/m^3	2.3 - 7.2	3.2 - 7.3	25
CO	1 hour	mg/m^3	0.22 - 1.13	0.21-0.83	30

Pollutant	Averaging Period	Unit	Range of Ambient Air Quality Baseline Over 7 Consecutive Days		SAAQT (Long Term Targets)
			A1	A2	
CO	8 hours	mg/m^3	0.19 - 0.33	0.19 - 0.36	10
NO_2	1 hour	$\mu g/m^3$	51.6- 68.7	55.9 - 110.4	200
SO_2	24 hours	$\mu g/m^3$	<8 - 19.7	<8 - **46.6**	20
O_3	8 hours	$\mu g/m^3$	22.1 - 57.5	54.8 - 89	100

Note: Numbers in bold, red and underlined indicate values that exceed the SAAQT.

4.2.2.1 Particulate Matter PM_{10} and $PM_{2.5}$

At both receptors, 24-hour average PM_{10} concentrations were low, ranging from about 5.6 to 12.3 microgram per cubic metre ($\mu g/m^3$) at A1 and 6.5 to 12.1 $\mu g/m^3$ at A2. These values are well below the long-term PM_{10} target of 50 $\mu g/m^3$, and also comfortably below the interim 24-hour PM_{10} target.

Similarly, 24-hour average $PM_{2.5}$ concentrations ranged from 2.3 to 7.2 $\mu g/m^3$ at A1 and 3.2 to 7.3 $\mu g/m^3$ at A2, which is far below the long-term $PM_{2.5}$ target of 25 $\mu g/m^3$. Hourly profiles show the expected diurnal pattern with slightly higher particulate concentrations during daytime and early evening periods, likely associated with regional background activity and local human presence, but no sustained episodes of elevated particulate matter were observed. These results indicate that baseline particulate levels in the vicinity of both receptors are representative of a relatively clean coastal environment.

4.2.2.2 Carbon Monoxide

Gaseous combustion related pollutants were also low. One hour average CO concentrations ranged from approximately 0.22 to 1.13 $\mu g/m^3$ at A1 and 0.21 to 0.83 $\mu g/m^3$ at A2, which are much lower than the SAAQT one hour target of 30 $\mu g/m^3$.

The corresponding 8-hour average CO concentrations at both sites were in the range 0.19 to 0.36 $\mu g/m^3$, well below the 8-hour target of 10 $\mu g/m^3$. These data indicate that there is no significant contribution from intense local combustion sources such as heavy traffic or industrial stacks within the immediate Study Area.

4.2.2.3 Nitrogen Dioxide

For nitrogen dioxide, the highest one-hour average concentrations were 68.7 $\mu g/m^3$ at A1 and 110.4 $\mu g/m^3$ at A2. Both values are below the one-hour NO_2 target of 200 $\mu g/m^3$ and are typical of regional urban background influenced by wider traffic and shipping emissions in the Straits, rather than by any localised point sources within the Study Area.

4.2.2.4 Sulphur Dioxide

Sulphur dioxide was generally low at Fort Siloso (A1), with 24-hour average concentrations between less than 8 and 19.7 $\mu g/m^3$, which is marginally below the long term SO_2 target of 20 $\mu g/m^3$.

At Shangri La Rasa Sentosa (A2), 24-hour average SO_2 concentrations ranged from less than 8 to 46.6 $\mu g/m^3$. The 24-hour SO_2 averages at A2 exceeded the long-term target on 2 out of the 7 measurement days. However, these daily averages (maximum 46.6 $\mu g/m^3$) remained well below concentrations typically associated with acute health effects, such as the World health organisation (WHO) 10-minute SO_2 guideline of 500 $\mu g/m^3$ ([38]) and the US EPA 1-hour standard of 196 $\mu g/m^3$ [39].

The hourly data show that these higher 24-hour averages were driven by a small number of short duration SO_2 peaks, which are likely related to transient plumes from external combustion sources such as passing marine vessels, or off-site industrial activities, rather than conditions attributable to the proposed slope stabilisation works (**Figure 4-9** and **Figure 4-10**). These episodes will be treated as part of the existing background condition and will be taken into account when assessing incremental project related impacts.

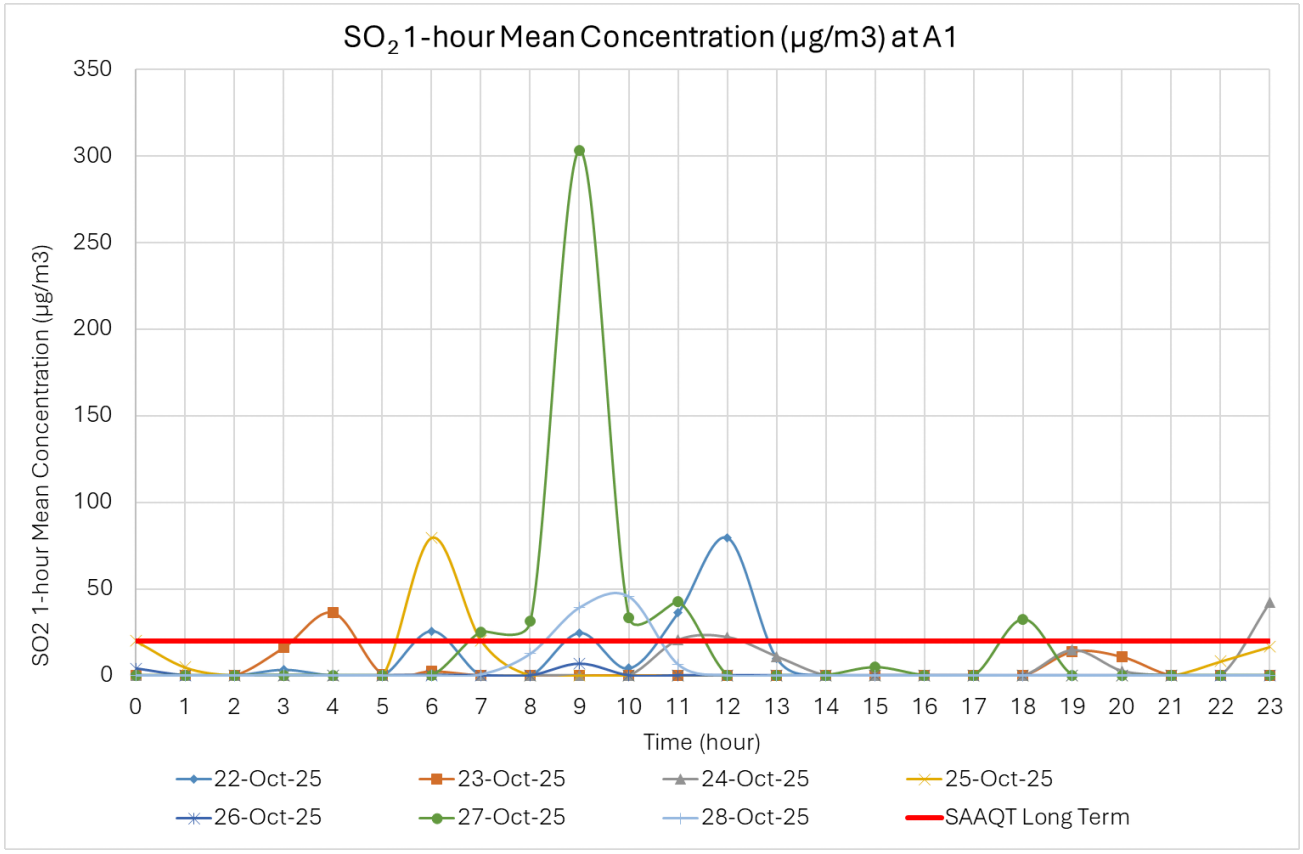


Figure 4-9 SO_2 1-hour mean concentration at A1

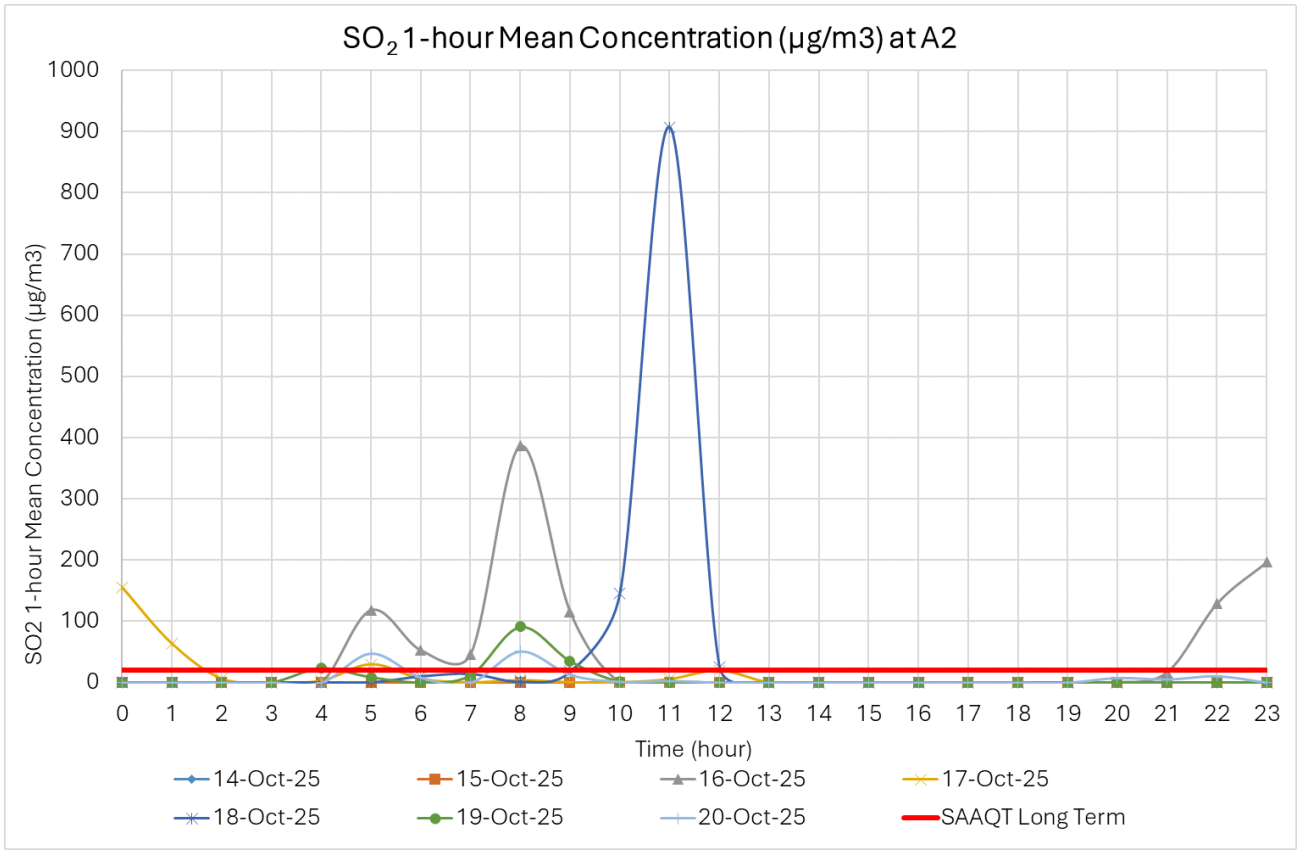


Figure 4-10 SO_2 1-hour mean concentration at A2

4.2.2.5 Ozone

Ozone concentrations showed a clear daytime increase, reflecting regional photochemical formation. Eight-hour average O_3 concentrations ranged from 22.1 to 57.5 µg/m^3 at A1 and 54.8 to 89 µg/m^3 at A2, all within the SAAQT 8-hour target of 100 µg/m^3. The higher O_3 levels at A2 compared to A1 are consistent with its more open coastal setting and greater exposure to regional background air masses.

4.2.2.6 Overall Assessment of Baseline Ambient Air Quality

Comparing the two receptors, pollutant levels at A2 are generally slightly higher than at A1, particularly for SO_2 and O_3, while particulate matter and NO_2 are of similar magnitude at both locations. This pattern is consistent with A2 being more directly exposed to regional shipping lanes and coastal air masses, whereas A1 is more sheltered by topography and vegetation within Fort Siloso. Nonetheless, even at A2, measured PM_{10}, $PM_{2.5}$, CO, NO_2 and O_3 concentrations remain comfortably within the relevant SAAQT long-term targets.

In summary, the baseline monitoring confirms that ambient air quality within the Study Area is generally good, with low particulate and gaseous pollutant concentrations typical of a coastal recreational setting. Existing ambient air quality pressures are limited to occasional elevations in SO_2, particularly at A2, associated with external sources unrelated to the proposed project. These baseline conditions provide an important reference for subsequent assessment of construction phase emissions from the slope stabilisation works. The impact assessment will focus on ensuring that project related contributions do not cause exceedances of the SAAQT targets, taking into account the observed background variability and existing episodic SO_2 events.

4.2.2.7 Co-Location with US EPA Reference Instrument

Marchwood Laboratory Services Pte Ltd (MLS) was appointed to carry out the baseline ambient air quality survey. To verify the performance of the Kunak Air Pro monitor deployed for this Project, MLS conducted a co-location study with United States Environmental Protection Agency (US EPA) reference instruments at Marine Terrace HDB estate from 4 to 11 September 2025. The MLS technical memorandum, which documents the monitoring period and location, the US EPA reference instruments used and the detailed results of the co-location, is provided in **Appendix J**.

During the seven-day co-location study, the Kunak Air Pro unit (subsequently used at Tanjong Rimau, Sentosa Island) was installed adjacent to the US EPA instruments (a Met One BAM-1020 for particulate matter and Horiba 370-series analysers for gaseous pollutants) and operated under the same conditions. The results show that the Kunak Air Pro tracked the US EPA reference instruments closely for all target pollutants, with correlation coefficients in the range of approximately 0.80 to 0.97 (accepted values are ≥0.50 – 0.70). Using the derived gain and offset correction factors from this co-location, the Kunak Air Pro is considered suitable and fit for purpose for the ambient air quality baseline monitoring at Tanjong Rimau.

4.2.3 Ambient Noise

Baseline ambient noise levels at Fort Siloso (N1) and Shangri La Rasa Sentosa Resort (N2) were measured continuously for seven consecutive days (14 to 20 Nov 2025 at N1, and 14 to 20 Oct 2025 at N2) and compared against the NEA's maximum permissible noise levels for construction sites for the category "Other Building" as summarised in **Table 4-9**. For each monitoring point and period, equivalent continuous sound pressure levels LAeq were derived over 5-minute, 1-hour and 12-hour periods for daytime (7 am to 7 pm), evening time (7 pm to 10 pm) and nighttime (10 pm to 7 am).

At both monitoring locations, all 12-hour LAeq values for day, evening and night periods are below the corresponding NEA permissible noise limits. Short duration 5-minute LAeq levels are also generally within permissible limits, with two notable exceedances: one at N1 during weekday nighttime and one at N2 during weekday evening. These isolated exceedances are interpreted as arising from existing activities and represent the prevailing acoustic environment prior to the proposed works.

Table 4-9 Summary of ambient noise baseline results

Measurement Point	Type of Affected Premises	Period	Parameter	Maximum Baseline Noise Level (dBA)			Maximum Permissible Noise Level (dBA)		
				Day Time (7 am - 7 pm)	Evening Time (7 pm - 10 pm)	Nighttime (10 pm - 7 am)	Day Time (7 am - 7 pm)	Evening Time (7 pm - 10 pm)	Nighttime (10 pm - 7 am)
N1	(c) Other Building	Weekday	LAeq 5 min	80.3	61.2	74.2	90	70	70
			LAeq 1 hour	72.2	54.5	68.9	-	-	-
			LAeq 12 hour	63.9	58.9	58.9	75	65	65
		Sunday	LAeq 5 min	82.5	58.9	60.9	90	70	70
			LAeq 1 hour	72.4	52.9	53.1	-	-	-
			LAeq 12 hour	63.4	50.8	50.8	75	65	65
N2	(c) Other Building	Weekday	LAeq 5 min	74.0	73.8	65.4	90	70	70
			LAeq 1 hour	64.6	64.9	58.8	-	-	-
			LAeq 12 hour	61.6	57.2	57.2	75	65	65
		Sunday	LAeq 5 min	67.9	61.5	62.0	90	70	70
			LAeq 1 hour	62.0	57.3	55.5	-	-	-
			LAeq 12 hour	59.5	54.5	54.5	75	65	65

Note: Shangri La Rasa Sentosa Resort is located approximately 230 m from the nearest proposed construction site (Site C2) and therefore does not fall under Category (b) “Residential buildings located less than 150 m from the construction site.

4.2.3.1 Ambient Noise at Fort Siloso (N1)

At Fort Siloso (N1), which is classified as "Other Building", weekday daytime LAeq 5-minute reached a maximum of 80.3 dBA, remaining below the NEA daytime limit of 90 dBA. Weekday evening LAeq 5-minute was 61.2 dBA, also below the evening limit of 70 dBA (**Figure 4-11**). Weekday nighttime LAeq 5-minute reached 74.2 dBA, which exceeds the applicable nighttime limit of 70 dBA (**Figure 4-11**).

The longer-term indices indicate generally lower levels. Weekday 1-hour LAeq values range from 54.5 dBA in the evening to 72.2 dBA in the day, while 12-hour LAeq values are 63.9 dBA for daytime and 58.9 dBA for both evening and nighttime. All 12-hour values are comfortably within the corresponding NEA limits of 75 dBA for daytime and 65 dBA for evening and nighttime.

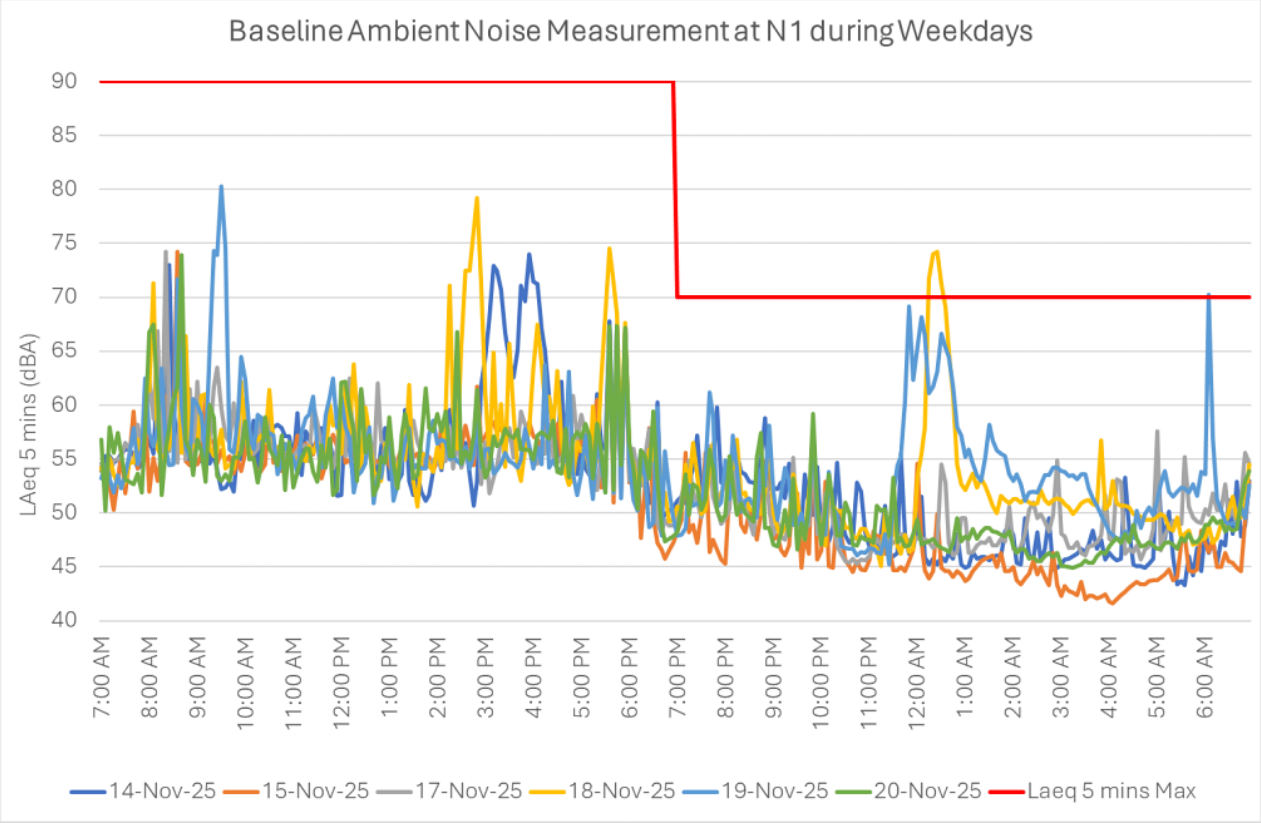


Figure 4-11 Baseline ambient noise measurement at N1 during Weekdays for LAeq 5-minute

On Sundays, N1 shows a similar pattern with slightly higher short-term levels during the day. Day time LAeq 5-minute reached 82.5 dBA, while evening and nighttime LAeq 5-minute were 58.9 dBA and 60.9 dBA respectively, all within their respective permissible limits (**Figure 4-12**). Sunday 12-hour LAeq values of 63.4 dBA day, and 50.8 dBA for both evening and night, are well below the NEA limits (**Figure 4-12**).

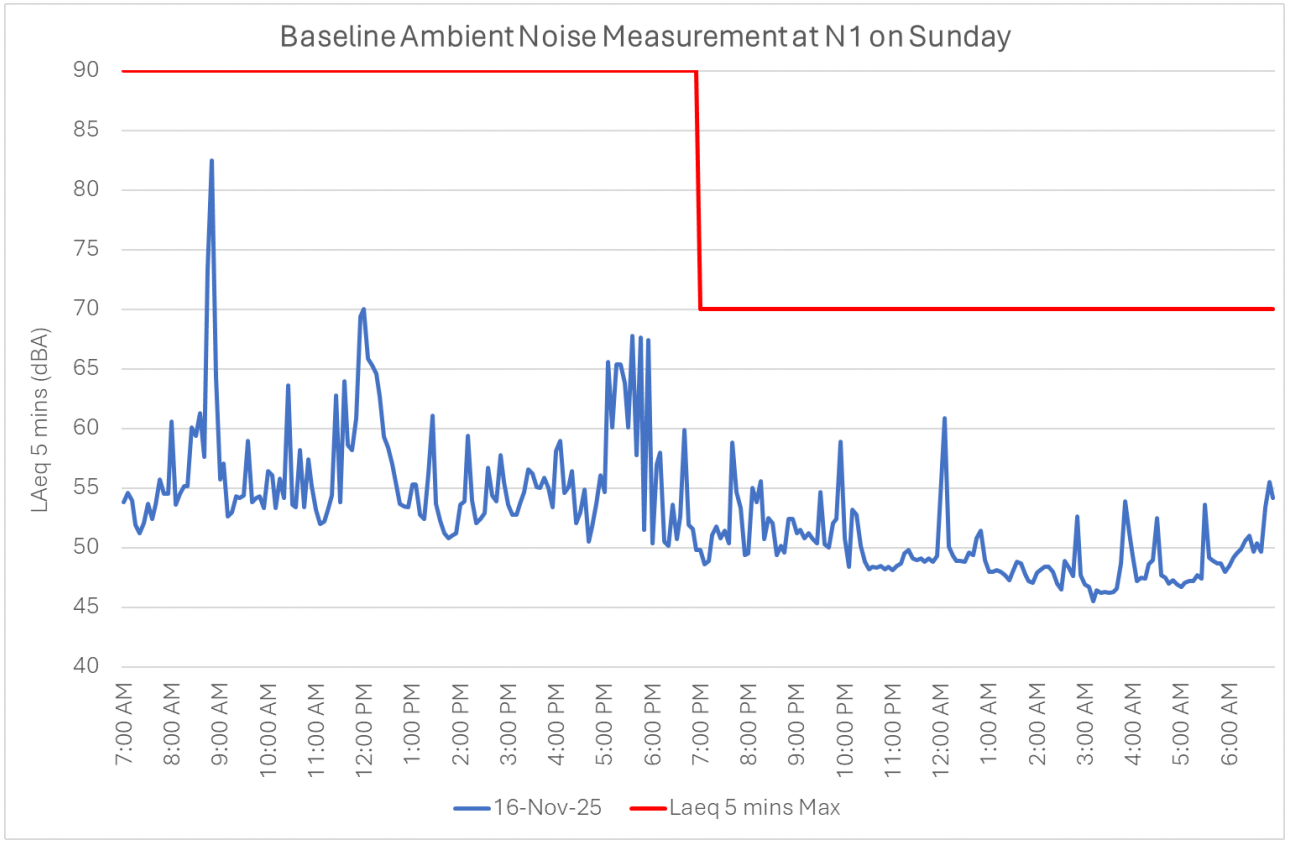


Figure 4-12 Baseline ambient noise measurement at N1 on Sunday for LAeq 5-minute

These results indicate that Fort Siloso is generally a quiet to moderately noisy environment on a long-term basis but can experience brief periods of elevated noise at night during weekdays, likely associated with natural sources such as animals, wind or surf.

4.2.3.2 Ambient Noise Shangri La Rasa Sentosa Resort (N2)

At Shangri La Rasa Sentosa Resort N2, weekday daytime LAeq 5-minute reached 74.0 dBA, below the daytime limit of 90 dBA (**Figure 4-13**). The highest weekday evening LAeq 5-minute was 73.8 dBA, which marginally exceeds the evening limit of 70 dBA. Weekday nighttime LAeq 5-minute reached 65.4 dBA, below the nighttime limit of 70 dBA (**Figure 4-13**).

Weekday 1-hour LAeq values at N2 range from 58.8 dBA at night to 64.9 dBA in the evening, and 12-hour LAeq values are 61.6 dBA day and 57.2 dBA for both evening and night. All 12-hour indices are within the NEA limits of 75 dBA for day and 65 dBA for evening and night, indicating compliance on a long-term basis.

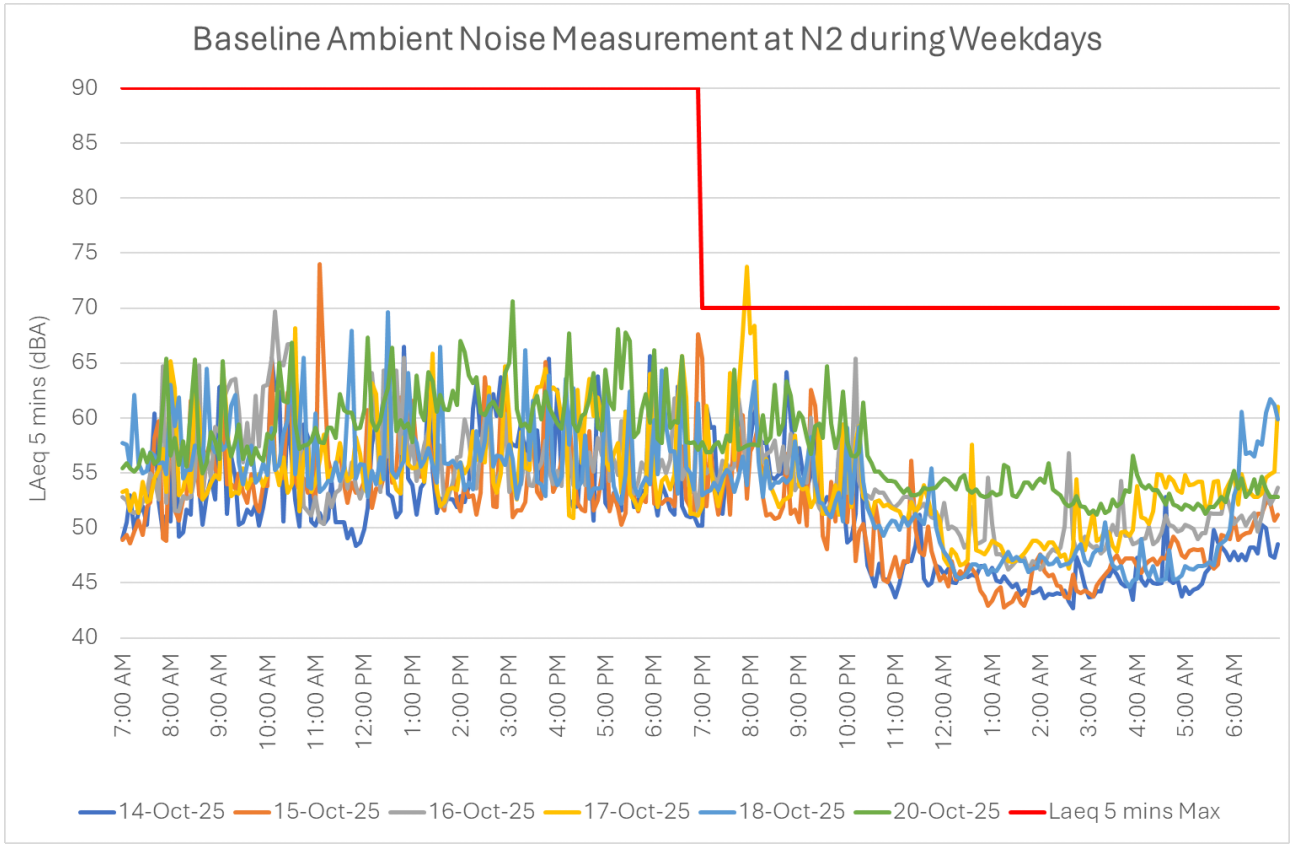


Figure 4-13 Baseline ambient noise measurement at N2 during Weekdays for LAeq 5-minute

On Sundays, all short term and long-term noise indices at N2 comply with permissible levels (**Figure 4-14**). The maximum Sunday LAeq 5-minute values are 67.9 dBA by day, 61.5 dBA in the evening and 62.0 dBA at night, each below the respective limits. Sunday 12-hour LAeq values of 59.5 dBA by day and 54.5 dBA for evening and night also remain well within the NEA thresholds.

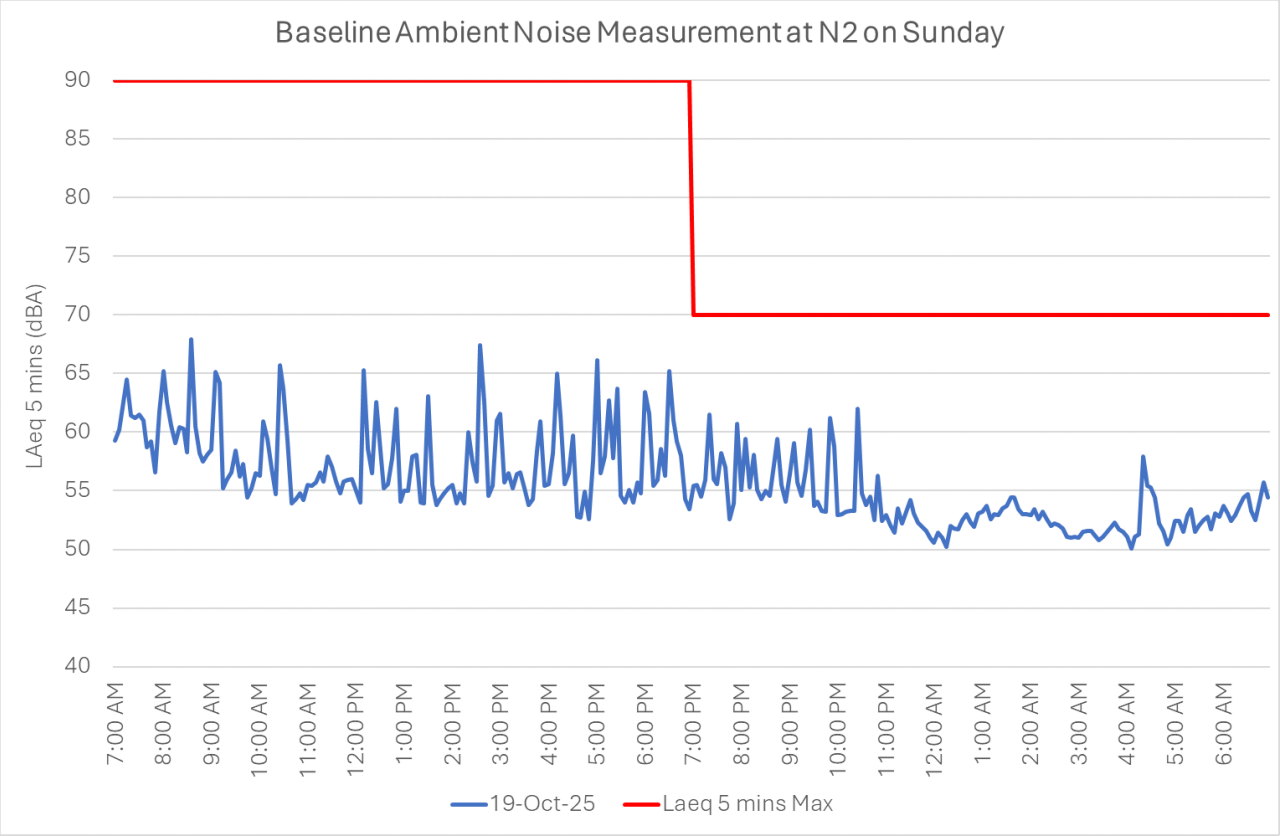


Figure 4-14 Baseline ambient noise measurement at N2 on Sunday for LAeq 5-minute

The results confirm that the ambient noise at the resort is characterised by moderate levels of ambient noise consistent with hotel operations, guest activities, coastal surf and other localised sources, with one weekday evening period where short duration levels marginally exceed the construction noise evening criterion.

4.2.3.3 Overall Assessment of Baseline Ambient Air Quality

Comparing both monitoring points, N1 exhibits slightly higher maximum short term levels during weekday nighttime, while N2 exhibits a marginal exceedance during weekday evening. In all cases, 12-hour LAeq values at both locations are comfortably below NEA limits, indicating that sustained noise exposure is within regulatory thresholds, and the exceedances are confined to short-term 5-minute intervals.

From an impact assessment perspective, these baseline conditions show that the receptors already experience occasional peaks close to or above the permissible short-term limits, even in the absence of construction activity. The slope stabilisation works will therefore need to be planned and managed so that project related noise contributions, when combined with these existing background levels, do not lead to frequent or significant breaches of the NEA construction noise limits, particularly during evening and night periods. This will be addressed through the development of appropriate construction scheduling, equipment selection and noise control measures in the subsequent mitigation section.

4.2.4 Ground Vibration

Baseline ground vibration was monitored at two vibration sensitive receptors: V1 (Fort Siloso) from 0000 to 2359 on 16 Oct 2025, and V2 (Shangri La Rasa Sentosa Resort) from 0000 to 2359 on 14 Oct 2025. Triaxial sensors recorded peak particle velocity (PPV) along the X, Y and Z axes together with dominant vibration frequency (see **Table 4-10**). See **Appendix K** for details of the ground vibration test report issued by MLS.

Table 4-10 Summary of ground vibration baseline results

Description	V1			V2		
	X-Axis	Y-Axis	Z-Axis	X-Axis	Y-Axis	Z-Axis
Dominant Frequency (Hz)	7	8	7	14	8	8
PPV (mm/s)	1.3	1.4	2.2	1.4	3.2	7.8
Date of Detection	16-Oct-25	16-Oct-25	16-Oct-25	14-Oct-25	14-Oct-25	14-Oct-25
Time of Detection	3:07	13:27	18:27	14:57	14:57	14:57

At Fort Siloso (V1), dominant frequencies ranged between 7 and 8 Hz with corresponding PPV values of 1.3 mm/s (X axis), 1.4 mm/s (Y axis) and 2.2 mm/s (Z axis).

At Shangri La Rasa Sentosa Resort (V2), dominant frequencies were 8 to 14 Hz, with PPV values of 1.4 mm/s (X axis), 3.2 mm/s (Y axis) and 7.8 mm/s (Z axis).

The largest measured vibration at both locations occurred in the vertical (Z) direction, which is typical for ground borne vibration from external sources. These PPV values characterise the existing vibration climate at the receptors prior to commencement of the proposed slope stabilisation works.

4.2.4.1 Comparison with Structural Damage Criteria

The baseline results were compared against the cosmetic damage guide values in BS 5228-2:2009 (see

Table 4-5). For unreinforced or light framed buildings, the guide values are 15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz, and 20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above. For reinforced or framed industrial and heavy commercial buildings, the guide value is 50 mm/s at 4 Hz and above. All measured PPV values at both V1 and V2 are at least an order of magnitude lower than the most stringent cosmetic damage threshold for unreinforced or light framed buildings. At Fort Siloso, the maximum PPV of 2.2 mm/s at about 7 Hz is well below the 15–20 mm/s guide value applicable at these frequencies. At Shangri La Rasa Sentosa Resort, the highest PPV of 7.8 mm/s at about 8 Hz is also significantly below the same threshold.

These comparisons confirm that the existing vibration levels do not pose a risk of cosmetic damage to building structures at either receptor, and that there is substantial headroom before BS 5228-2 cosmetic damage criteria would be approached.

4.2.4.2 Comparison with Human Perception Guidance

BS 5228-2:2009 also provides guidance on the likely human response to vibration (see **Table 4-6**). Vibration levels of approximately 0.14 mm/s are described as just perceptible in the most sensitive situations, 0.3 mm/s as just perceptible in typical residential environments, 1.0 mm/s as a level at which complaints are likely in residential environments (though tolerable with prior warning), and 10 mm/s as likely to be intolerable for more than a very brief exposure in most building environments.

The baseline PPV values of 1.3–2.2 mm/s at Fort Siloso and 1.4–7.8 mm/s at Shangri La Rasa Sentosa Resort therefore lie above the “complaint likely” threshold of 1.0 mm/s but below the “intolerable” level of 10 mm/s. This indicates that vibrations within the existing environment are likely perceptible to occupants and visitors and may occasionally be noticeable enough to cause concern, particularly at the higher values recorded at V2. However, they remain within a range that BS 5228-2 considers tolerable, especially when the occurrence is intermittent and occupants are aware of the source.

In practice, these baseline levels are likely to reflect a combination of existing influences such as building services, vehicular movements, coastal wave action and other routine activities within and around the receptors rather than any project related effects.

4.2.4.3 Overall Assessment of Baseline Ground Vibration

In summary, the baseline survey demonstrates that:

- Structural risk is very low, as all measured PPV values at both receptors are substantially below BS 5228-2 cosmetic damage thresholds for both unreinforced and reinforced structures.

- Existing ground borne vibrations are likely perceptible and, at times, may approach levels at which human complaints are possible, particularly at Shangri La Rasa Sentosa Resort where the highest PPV of 7.8 mm/s was recorded in the vertical axis. However, it still considers tolerable.

For the impact assessment, these findings imply that the primary concern for ground vibration during the slope stabilisation works will be human comfort rather than structural damage. Predicted construction vibration levels will therefore be evaluated against both the BS 5228-2 cosmetic damage criteria and the human perception guidance, with the objective of ensuring that construction activities do not materially increase the frequency or magnitude of perceptible vibration events above the existing baseline conditions at Fort Siloso and Shangri La Rasa Sentosa Resort.

4.3 Prediction and Evaluation of Impacts on Physical Environment

4.3.1 Potential Sources of Impact

The construction of the proposed slope stabilisation and coastal protection works at Sites A, B, C1 and C2 will introduce temporary changes to the physical environment compared with the baseline conditions described in **Sections 4.2** to **4.3.** These changes are mainly associated with marine based construction of the revetments and XblocPlus system, slope works on the coastal escarpment, and the movement and operation of construction equipment and barges.

The key potential sources of impact on marine water quality, ambient air quality, ambient noise and ground vibration during the construction phase, and their possible consequences for human and biodiversity receptors are described in **Table 4-11** for construction phase, and

Table 4-12 for operational phase. These potential impacts will be evaluated using a risk-based impact assessment framework adopted for the Project.

Table 4-11 Potential sources of impact on physical environmental parameters during construction phase

Environmental Aspects	Potential Source(s) of Impacts	Potential Associated Impact on Environmental Parameter	Potential Associated Impacts on Human and Biodiversity Receptors
Marine Water Quality	• Construction of armour rock revetment and XblocPlus at Sites A, B, C1 and C2, including formation and removal of the temporary bund and movement of barges and excavators in shallow coastal waters. • Surface runoff from exposed slopes, soil stockpiles and working platforms during soil nailing, rock netting and erosion control blanket installation, if not adequately intercepted and treated before discharge. • Discharge or accidental spillage of fuels, lubricants, hydraulic oil, grout, wet concrete, cement wash water and other construction related chemicals from barges, equipment maintenance and material handling on land and at sea. • Inappropriate storage, handling or disposal of construction waste and domestic sewage from site facilities and work vessels.	• Localised increase in suspended solids, turbidity and sedimentation in the nearshore water column adjacent to the works, particularly during bund formation and armour placement. • Short term changes in dissolved oxygen, nutrients and organic load if sediment is mobilised or if untreated runoff and wastewater enter the sea. • Localised increase in concentrations of oil and grease and selected metals in the water column or sediments in the event of poor housekeeping or accidental spills.	**Human receptors** • Short term reduction in water quality along the shoreline, which may affect the recreational experience of visitors and resort guests if plume is visible at the surface. • Possible odour or surface sheen in the unlikely event of a fuel or chemical spill. **Biodiversity receptors** • Increased turbidity and sediment deposition may reduce light penetration for seagrass and algal communities and can smother intertidal and subtidal benthic fauna and corals along the Tanjong Rimau shoreline. • Changes in water quality such as reduced dissolved oxygen or elevated nutrients can stress sensitive marine organisms and may cause temporary avoidance of the area by fish and mobile invertebrates. • Accidental spills of fuel or concrete wash water could cause localised toxicity to sessile organisms and eggs or larvae in the water column.

Environmental Aspects	Potential Source(s) of Impacts	Potential Associated Impact on Environmental Parameter	Potential Associated Impacts on Human and Biodiversity Receptors
Ambient Air Quality	• Generation of fugitive dust from drilling for soil nails and rock dowels, minor excavation, trimming of loose material, handling and stockpiling of aggregates and armour rock, and movement of construction vehicles on unpaved or partially paved surfaces. • Combustion emissions from diesel powered construction plant and marine vessels, including excavators, compressors, generators, barges and tugboats used to transport and place revetment materials. • On site handling of cement, grout and other fine powdered materials.	• Short term elevation of particulate concentrations PM10 and PM2.5 in the immediate vicinity of the work fronts and haul routes, especially during dry windy conditions, potentially above typical background levels. • Localised increases in gaseous pollutants such as nitrogen dioxide, carbon monoxide and sulphur dioxide near operating plant and marine vessels, particularly when equipment is operated at high load or idling in confined areas.	**Human receptors** • Temporary dust nuisance and minor reduction in local air quality for workers, visitors to Fort Siloso, users of the coastal trails and resort guests when works are close to these receptors. • Potential short-term eye or throat irritation for sensitive individuals if dust control is inadequate. **Biodiversity receptors** • Deposition of dust on leaves can temporarily reduce photosynthetic efficiency of nearby coastal vegetation and epiphytes and may affect flowering or fruiting if persistent. • Fine particulate matter and combustion gases may cause minor, short term respiratory stress to small terrestrial fauna such as birds, bats and arboreal mammals that forage near active work areas, although such effects are expected to be localised and reversible due to generally low emission rates and good dispersion in the coastal setting.

Environmental Aspects	Potential Source(s) of Impacts	Potential Associated Impact on Environmental Parameter	Potential Associated Impacts on Human and Biodiversity Receptors
Ambient Noise	• Operation of powered mechanical equipment for slope stabilisation such as drilling rigs for soil nailing and rock dowels, rock breaking where necessary, installation of erosion control blankets, movement of excavators on the slope and along the shoreline, and operation of generators and compressors. • Marine activities associated with revetment and XblocPlus installation, including tugboat manoeuvring, barge positioning and loading or unloading of armour rocks and units. • Construction traffic accessing the work areas via existing roads.	• Short term increase in equivalent continuous noise levels at Fort Siloso Monitoring Point N1 and Shangri La Rasa Sentosa Resort Monitoring Point N2 relative to baseline, particularly during simultaneous operation of several items of powered mechanical equipment or during marine operations close to shore. • Potential exceedance of maximum permissible noise levels for other buildings during specific noisy activities or if nighttime works are required for tidal reasons, in the absence of additional controls.	**Human receptors** • Temporary annoyance and disturbance to hotel guests, resort staff, visitors to Fort Siloso and users of coastal trails, especially during evenings and nighttime if activities are audible within rooms or quiet outdoor areas. • Possible disruption to outdoor interpretation activities or guided tours at Fort Siloso due to raised background noise and reduced speech intelligibility. **Biodiversity receptors** • Acoustic disturbance to terrestrial and coastal fauna such as birds, bats, squirrels, monkeys and amphibians, which may temporarily avoid noisy areas, alter foraging routes or change calling behaviour. • Repeated loud events could interfere with communication of some species, for example bird song or bat echolocation, and may cause short term displacement from roosting or nesting sites close to the works, though such effects are expected to be reversible once noisy activities cease.

Environmental Aspects	Potential Source(s) of Impacts	Potential Associated Impact on Environmental Parameter	Potential Associated Impacts on Human and Biodiversity Receptors
Ground Vibration	• Operation of drilling rigs for soil nailing and rock dowels, particularly when drilling through harder layers or rock, and any localised rock breaking or compaction required at the slope toe or revetment foundation. • Movement of tracked or wheeled heavy plant on hard standing or along access routes near sensitive structures. • Mooring, berthing and unberthing of barges in shallow water close to the shoreline, which may transfer some vibration to the ground through contact with temporary bunds or revetment structures.	• Increase in peak particle velocity at monitoring points V1 Fort Siloso and V2 Shangri La Rasa Sentosa Resort compared with baseline values, though expected to remain below guide values for cosmetic damage to buildings when controlled construction methods are adopted. • Short duration vibration events that are perceptible at the ground surface and within nearby buildings during specific activities such as drilling or rock breaking.	**Human receptors** • Perceptible vibration within parts of Fort Siloso and Shangri La Rasa Sentosa Resort during specific construction activities, which may cause temporary concern or annoyance if not properly communicated and managed. • Very low likelihood of cosmetic damage to buildings or heritage structures if peak particle velocity remains within the guide values given in BS 5228 2 2009; exceedance of these levels, if it occurred, could result in minor cracking of brittle finishes or loosening of non-structural elements. **Biodiversity receptors** • Short duration vibration may disturb ground dwelling and burrowing fauna such as reptiles, amphibians and invertebrates on the coastal slope, potentially causing temporary avoidance of active work zones. • Roosting bats, nesting birds or arboreal mammals in trees within the vibration influence zone may be startled by higher vibration events and relocate to quieter parts of the habitat, although impacts are expected to be temporary and reversible as works progress along the slope and vibration levels reduce.

Table 4-12 Potential sources of impact on physical environmental parameters during operation phase

Environmental Aspects	Potential Source(s) of Impacts	Potential Associated Impact on Environmental Parameter	Potential Associated Impacts on Human and Biodiversity Receptors
Marine Water Quality	• Presence of completed revetment and XblocPlus armour potentially changing nearshore hydrodynamics and sediment transport along the Tanjong Rimau shoreline. • Permanent stabilisation of coastal slopes with soil nails, rock netting and erosion control blankets, together with improved surface drainage. • Occasional routine visual inspection of the slopes, revetment, drains and access infrastructure to check for physical damage that might compromise structural integrity of the structures.	• More stable shoreline with reduced soil erosion from the coastal slope and reduced input of fine sediments into the nearshore waters during rainfall events. • Localised and minor changes in current velocity and sediment deposition immediately in front of the revetment, with some areas of scour and some areas of accretion.	**Human receptors** • Generally improved water clarity close to shore during wet weather compared with pre project conditions due to reduced slope erosion, supporting recreational enjoyment and aesthetic quality for visitors and resort guests. • Reduced risk of bank instability and slope failure affecting coastal paths and heritage structures at Fort Siloso. **Biodiversity receptors** • Reduction in episodic high suspended sediment events during storms may benefit nearshore marine habitats by decreasing smothering and improving light availability for seagrass, algae and corals. • Creation of new hard substrate habitat on the revetment and XblocPlus units that can be colonised by intertidal and subtidal fauna and flora, increasing local habitat diversity, while some soft substrate habitats may be permanently lost or modified within the footprint of the works.

Environmental Aspects	Potential Source(s) of Impacts	Potential Associated Impact on Environmental Parameter	Potential Associated Impacts on Human and Biodiversity Receptors
Ambient Air Quality	• Routine operation of the stabilised slopes and revetment, which are passive structures and do not generate emissions. • Ongoing use of Fort Siloso, coastal trails and Shangri La Rasa Sentosa Resort by visitors and staff as per pre project conditions, with similar volumes of traffic on existing access roads. • Occasional routine visual inspection of the slopes, revetment, drains and access infrastructure to check for physical damage that might compromise structural integrity of the structures.	• No continuous operational emission sources attributable to the Project; ambient air quality dominated by regional and island wide background conditions and existing road traffic.	**Human receptors** • No measurable long-term deterioration in ambient air quality at Fort Siloso or Shangri La Rasa Sentosa Resort arising from the completed works. • Short duration, localised exhaust fumes or dust may be perceptible during infrequent maintenance tasks but are expected to remain well within SAAQT. **Biodiversity receptors** • Negligible change in exposure of terrestrial or coastal fauna and flora to air pollutants relative to baseline conditions. • Any minor dust or exhaust emissions during maintenance are expected to be transient and to have no meaningful effect on vegetation health or fauna behaviour.
Ambient Noise	• Ambient soundscape during normal operation dominated by natural sources (e.g., waves, wind, biophony) and existing human activities at Fort Siloso, coastal trails and resort facilities. • Occasional routine visual inspection of the slopes, revetment, drains and access infrastructure to check for physical damage that might compromise structural integrity of the structures.	• Long term average noise levels similar to baseline; no continuous operational noise sources introduced by the Project. • Localised increase in wave breaking noise at the revetment face may marginally alter coastal sound character immediately seaward of the works but not overall levels at N1 or N2..	**Human receptors** • No significant increase in day, evening or nighttime ambient noise levels at Fort Siloso or Shangri La Rasa Sentosa Resort attributable to the completed works. • Visitors and guests may experience brief, minor annoyance when close to maintenance activities, but these will be temporary and managed through timing and good noise management practice. **Biodiversity receptors** • Coastal and terrestrial fauna expected to experience a soundscape comparable to baseline. • Occasional daytime maintenance noise may cause short term avoidance behaviour in birds, mammals and amphibians in the immediate vicinity but is unlikely to affect breeding success or long-term habitat use.

Environmental Aspects	Potential Source(s) of Impacts	Potential Associated Impact on Environmental Parameter	Potential Associated Impacts on Human and Biodiversity Receptors
Ground Vibration	• Completed slope stabilisation and revetment are static structures with no mechanical vibration sources during normal operation. • Background vibration environment dominated by natural sources for example surf, wind, occasional distant traffic and routine resort operations. • Occasional routine visual inspection of the slopes, revetment, drains and access infrastructure to check for physical damage that might compromise structural integrity of the structures.	• No routine operational increase in peak particle velocity at V1 or V2 relative to post-construction baseline.	**Human receptors** • Visitors, guests and staff are not expected to perceive any difference in ground vibration conditions compared with the post-construction baseline, except possibly slight and brief vibration during localised maintenance. • No damage to Fort Siloso heritage structures or resort buildings is anticipated from operational vibration, given the absence of significant vibration sources. **Biodiversity receptors** • Ground dwelling and burrowing fauna on the coastal slope will not experience any sustained change in vibration levels; occasional maintenance related vibration is expected to be of low magnitude and short duration, with negligible effect on behaviour or habitat use.

4.3.2 Identification of Sensitive Receptors

In line with the risk-based assessment framework for the Project, sensitive receptors have been identified for each physical environmental parameter based on the following considerations:

- Legal or planning status for example nationally protected sites, heritage listings or regulatory designations.
- Functional use for example residential, hospitality, recreation, education or tourism.
- Vulnerability to change in the relevant parameter for example susceptibility of corals to turbidity, of guests to noise and vibration, or of heritage structures to ground borne vibration.
- Reversibility of potential effects and the ease with which the receptor can recover from disturbance.
- Receptors meeting one or more of these criteria are classified as having medium to high sensitivity in the subsequent impact evaluation. The key sensitive receptors for the physical environment are described below.

4.3.2.1 Marine water receptors

The primary receptors for marine water quality comprise ecological receptors along the Tanjong Rimau coastline and human use receptors associated with nearby coastal recreation areas on Sentosa, including recreational beaches that may be affected by changes in nearshore water quality.

Ecological marine water quality receptors include:

- Intertidal rocky shore, boulder and reef flat communities supporting corals, macroalgae, sponges and other sessile organisms.
- Shallow subtidal habitats providing foraging and shelter for reef fish, mobile invertebrates and other marine fauna.
- Any patches of seagrass or algal beds that rely on good light penetration and low levels of chronic sedimentation.

These ecological habitats are considered to be of high sensitivity to changes in suspended sediment, turbidity and contaminant concentrations due to their dependence on light and clean water for growth and reproduction, and because sessile organisms have limited capacity to avoid short term water quality deterioration.

Human use receptors include visitors, beach users and guided groups using the Tanjong Rimau shore, nearby coastal areas and recreational beaches on Sentosa. These receptors are considered to be of medium sensitivity, primarily in relation to visible turbidity, sediment plume, oil sheen, floating debris, odour, amenity impact and potential contact with contaminated water in the unlikely event of a spill or uncontrolled release.

The inclusion of recreational beaches on Sentosa as sensitive receptors does not indicate that an adverse impact is expected during operation. Rather, it recognises that coastal recreation and beach amenity are relevant receiving environment considerations when assessing any short term maintenance related release, particularly where such release could affect visual water quality, odour, public perception, or contact recreation.

4.3.2.2 Ambient air quality receptors

The key receptors for ambient air quality are:

- Visitors, staff and tour groups at Fort Siloso, including children, elderly persons and other potentially sensitive individuals who may spend extended periods outdoors in relatively still air conditions within the fort precinct.
- Guests and staff at Shangri La Rasa Sentosa Resort, where expectations for a clean, comfortable environment are high and some guests may be more susceptible to air quality changes.
- Construction workers and site personnel present at or near the work fronts who may be exposed to short term dust and exhaust emissions if controls are not adequately implemented.

Given their use patterns and the generally good baseline air quality, Fort Siloso visitors and resort guests are considered to have medium to high sensitivity to localised degradation in ambient air quality, particularly in relation to elevated particulate levels and odour. Workers are protected through workplace safety and health provisions and are therefore assessed separately under occupational exposure requirements rather than as environmental receptors.

4.3.2.3 Ambient Noise and ground vibration receptors

For ambient noise and ground vibration, the principal sensitive receptors are:

- Fort Siloso, including outdoor exhibits, viewing decks, interpretive areas and internal spaces within heritage structures. The fort is a nationally preserved heritage site and a key tourist attraction where a relatively quiet soundscape is integral to visitor experience. It is treated as a high sensitivity receptor for both noise and vibration, the latter also reflecting the presence of historic masonry and structural elements that could be vulnerable to repeated high vibration levels.
- Shangri La Rasa Sentosa Resort, which functions as a beachfront hotel offering rest, wellness and recreation. Guest rooms, outdoor dining areas, pool decks and beach facilities are all sensitive to elevated noise levels, especially during evening and night time. The resort buildings are likewise receptors for ground vibration, with a high level of sensitivity from a guest comfort perspective and medium sensitivity in terms of structural response.
- Users of coastal trails and open spaces in the vicinity of the works, who may be temporarily exposed to construction related noise and vibration while passing through the area but typically for shorter durations than resort guests or fort visitors. These receptors are considered of medium sensitivity.

Under the Environmental Protection and Management (Control of Noise at Construction Sites) Regulations, both Fort Siloso and Shangri La Rasa Sentosa Resort are classified as “Other buildings” for the purposes of setting permissible construction noise limits, reflecting their non-residential but noise sensitive uses and their separation distances from the worksites.

Ground vibration criteria follow BS 5228-2:2009, with Fort Siloso heritage structures treated conservatively as unreinforced or light framed buildings for cosmetic damage assessment and both locations regarded as high sensitivity for human perception of vibration.

4.3.3 Minimum Controls

4.3.3.1 Minimum controls for marine water quality

This section sets out the minimum control measures that shall be implemented to manage risks to marine water quality during the construction and operation of the proposed works. These measures represent mandatory good practice for the Project; any deviation will require prior approval by the Engineer and relevant authorities.

4.3.3.1.1 Construction phase

a) Site planning and surface water management

- Prepare and maintain a construction environmental management plan that identifies all potential pathways for sediment and contaminant runoff to the sea and specifies control measures, responsibilities and inspection frequencies.
- Design site grading and temporary works so that clean runoff is diverted away from work areas and all runoff from disturbed surfaces, stockpiles and work platforms is collected and directed to treatment facilities before discharge.
- Provide perimeter drains, kerbs and cross drains along the toe of the slope and around stockpiles to intercept sediment laden runoff and prevent direct discharge to the shoreline.

b) Erosion and sediment control

- Minimise the area and duration of exposed soil by phasing slope works and promptly installing soil nails, rock netting and erosion control blankets once drilling or trimming is completed.
- Cover or stabilise stockpiles of soil, sand and fine materials, and locate them away from the shoreline and drains as far as practicable.
- Install and maintain silt fences, sediment traps and or settlement tanks at all discharge points from disturbed areas, with regular desilting before and after rainfall events.
- Sequence temporary bund construction, revetment and XblocPlus placement to avoid unnecessary seabed disturbance and re handling of material and to keep the active footprint as small as practicable.

c) Management of concrete, grout and other construction materials

- Designate concrete washout areas on land, with fully contained pits or tanks for collection of wash water and residues. No wash water or excess grout is to be discharged directly to the sea. A spill mitigation response plan should be created and implemented based on the specific type of cement needed for the work.
- Store cement, grout, admixtures and other fine powdered materials in covered and bunded locations.
- Prohibit the washing of equipment, tools or trucks in locations where runoff can flow directly into the nearshore waters.

d) Fuel, chemical and waste management and spill prevention

- Store fuels, lubricants and other hazardous liquids in bunded areas with a minimum capacity of one hundred and ten percent of the largest container volume and protect from rain.
- Prohibit refuelling over water. Refuelling of plant and vessels shall be carried out at designated on shore locations or by properly equipped service barges with drip trays, automatic shut off nozzles and spill kits.
- Implement a spill prevention and response plan covering both land and marine activities, including availability of spill kits, absorbent booms and trained personnel on each barge and at key work fronts.
- Establish clear procedures for reporting, containment, clean up and disposal following any spill, with immediate notification to the Engineer and relevant agencies when threshold quantities are exceeded.

- Provide covered and clearly labelled receptacles for general waste, construction debris and scheduled waste. Waste shall be removed regularly by licensed Contractors to approved disposal or treatment facilities, with no dumping into the sea.

e) Control of discharges from dewatering and pumping

- Any groundwater or stormwater pumped from excavations, bunded areas or work platforms shall be directed through sedimentation or treatment facilities before discharge, with discharge points located away from sensitive marine habitats as far as practicable.
- Where chemical flocculants are used to aid settlement, select products that are suitable for marine environments and apply in accordance with manufacturer instructions to avoid residual toxicity.

f) Training, supervision and monitoring

- Conduct environmental induction and refresher training for all site staff and vessel crews on marine water quality risks, control measures and spill response.
- Appoint an environmental supervisor to carry out routine inspections of erosion and sediment control, storage facilities and housekeeping and to maintain a non-conformance and corrective action log.
- Conduct daily visual inspections of water clarity and presence of oil sheen in the nearshore zone adjacent to the works as part of routine site management.
- Implement monthly marine water quality monitoring in accordance with the monitoring plan, at the three monitoring stations (S01, S02 and S03) for parameters listed in the ASEAN Marine Water Quality Criteria (AMWQC), with action levels and response procedures when trigger values are exceeded.

4.3.3.1.2 Operation phase

During the operation phase the slope stabilisation and revetment structures are passive; the key controls relate to maintenance and prevention of new pollution sources.

a) Maintenance of slopes, drainage and revetment

Visual inspect of the stabilised slopes, surface drains and outfalls at regular intervals and after major storm events to identify and rectify any erosion, scouring, blockage or structural damage that could lead to uncontrolled sediment discharges to the sea. Maintain the integrity of the revetment by repairing displaced units, joint damage or toe erosion promptly, thereby avoiding localised failures and emergency works that could generate excessive sediment.b) Pollution prevention for maintenance activities

- Apply the same principles of fuel and chemical storage, waste management and spill prevention as defined for the construction phase to all inspection and maintenance activities, including those carried out from small vessels.
- Ensure that any cleaning, repainting or repair of structures near the shoreline does not generate uncontrolled debris, paint flakes or wash water entering the sea. Where necessary, use drip trays, containment sheeting and controlled collection of residues.

c) Ongoing monitoring and adaptive management

- Continue daily visual inspections of water clarity and presence of oil sheen in the nearshore zone adjacent to the works as part of routine site management.

- Where required by regulatory approvals, maintain periodic marine water quality monitoring to confirm that the completed works do not give rise to long term deterioration in suspended solids, nutrients or contaminants.
- Review monitoring results and inspection findings at regular intervals and update maintenance practices or additional controls if any adverse trend or localised issue is detected.

With the above minimum controls in place during both construction and operation, residual risks to marine water quality are expected to remain within the Minor significance band identified in the impact assessment and to be acceptable in the context of the Project.

4.3.3.2 Minimum controls for ambient air quality

This section defines the minimum control measures that shall be implemented to manage impacts on ambient air quality at Fort Siloso (A1) and Shangri La Rasa Sentosa Resort (A2). These measures are mandatory good practice for the Project and are intended to ensure that concentrations of PM_{10}, $PM_{2.5}$ and key gaseous pollutants remain within the Singapore Ambient Air Quality Targets (SAAQT).

4.3.3.2.1 Construction phase

a) Planning and management

- Prepare and maintain a Construction Environmental Management Plan that includes a specific Dust and Exhaust Emissions Control Plan, clearly identifying dust generating activities, locations of sensitive receptors and required controls.
- Sequence works so that high dust generating activities are minimised in extent and duration, and scheduled where practicable during periods of lower visitor presence at Fort Siloso and Shangri La Rasa Sentosa Resort.
- Designate traffic routes, loading or unloading points and material storage areas, and keep these to the minimum necessary footprint.

b) Control of fugitive dust

- Keep exposed earth surfaces, haul routes and working platforms moist during dry and windy conditions using water sprinkling, misting or equivalent methods, while avoiding excessive run off.
- Limit drop heights when loading or unloading aggregates, armour rock and other granular materials.
- Cover or enclose stockpiles of fine materials such as soil, sand, crusher run and cement based products, and position them away from the site boundary and receptors as far as practicable.
- Ensure that all trucks transporting fine materials off site are adequately sheeted and that tailgates are sealed to prevent loss of material during transit.
- Maintain terrestrial / marine in a clean condition through regular sweeping and prompt removal of spilled materials.

c) Control of combustion emissions

- Use well maintained diesel equipment and marine vessels that comply with the prevailing National Environment Agency requirements for on road vehicles, off road diesel engines and marine engines.
- Prohibit unnecessary idling of engines for vehicles, generators, compressors, drilling rigs and marine vessels, and display clear signage on site.

- Position stationary combustion equipment and generators as far as practicable from Fort Siloso, Shangri La Rasa Sentosa Resort and other occupied buildings, and, where necessary, use localised acoustic or physical screens that also promote vertical dispersion of exhaust.
- Implement a preventive maintenance programme for all fuel burning equipment and vessels to ensure efficient combustion and to avoid visible black smoke.

d) Handling of cement, grout and chemicals

- Store cement, grout and other powdered materials in sealed bags or silos within covered, well-ventilated areas to prevent wind entrainment.
- Mix cementitious materials in designated locations with partial enclosure where practicable, and clean up spills promptly.
- Conduct onsite concrete mixing using a grout mixer only, with no concrete trucks or pumps involved. Position the mixer within the designated staging area, and ensure all cement wash is contained and removed from the site in appropriate containers.

e) Housekeeping, training and monitoring

- Provide toolbox briefings and induction training for workers and vessel crews on dust and exhaust control requirements, with emphasis on protection of sensitive receptors.
- Carry out routine visual inspections of dust emissions at work fronts, haul roads and stockpile areas, and record inspection findings and corrective actions.
- Implement ambient air quality monitoring in accordance with the monitoring plan, including at least PM_{10} and PM_{25} at A1 and A2, with trigger levels linked to reinforcement of control measures when required.

With the above minimum controls in place during the construction phase, residual impacts on ambient air quality are expected to remain within the Minor significance band identified in the impact assessment.

4.3.3.2.2 Operation phase

During the operation phase the stabilised slopes and revetment structures are passive and do not generate routine emissions. Controls therefore focus on maintenance activities and on ensuring that no new sources of air pollution are introduced by the Project.

a) Operation of completed works

- No permanent fuel burning or process equipment is to be installed as part of the slope stabilisation and coastal protection works.
- Access paths and inspection routes are to be used mainly by light vehicles or on foot; any heavier maintenance vehicles shall comply with NEA vehicle emission requirements.

b) Maintenance activities

- Apply the same good practice controls for dust and exhaust as set out for the construction phase whenever maintenance works involve drilling, breaking, minor excavation, surface repair or operation of portable combustion equipment.
- Plan maintenance so that dusty or odorous activities are carried out during daytime periods where practicable and are communicated in advance to Fort Siloso and Shangri La Rasa Sentosa Resort management.

- Avoid open burning of vegetation or waste under all circumstances. All green waste or debris generated during maintenance is to be removed from site by licensed Contractors.

c) Ongoing oversight

- Include ambient air quality considerations in routine environmental inspections of the completed works, with particular attention to any new practices that might give rise to dust or exhaust emissions.
- Where required by approval conditions, continue reduced frequency ambient air quality monitoring or spot checks to confirm that operation and maintenance of the completed works do not cause deterioration of ambient air quality at A1 or A2.

By implementing these minimum controls during operation, the Project is not expected to introduce any significant new air emission sources, and ambient air quality in the Study Area should remain similar to or better than the baseline conditions.

4.3.3.3 Minimum controls for ambient noise

This section defines the minimum control measures that shall be implemented to manage noise impacts at Fort Siloso (N1) and Shangri La Rasa Sentosa Resort (N2) so that the requirements of the Environmental Protection and Management (Control of Noise at Construction Sites) Regulations are met for "Other buildings" and that disturbance to visitors, guests and staff is minimised.

4.3.3.3.1 Construction phase

a) Regulatory compliance and noise management planning

- Prepare a Construction Noise Management Plan as part of the Construction Environmental Management Plan, setting out key noise sources, receptor locations, predicted noise levels, applicable NEA noise limits and control measures.
- Ensure that construction activities comply with the maximum permissible noise levels for "Other buildings" at all times, for the day 7 am to 7 pm, evening 7 pm to 10 pm and night 10 pm to 7 am periods.
- Avoid nighttime works 10 pm to 7 am as far as practicable. If works in the evening or night period are unavoidable for safety or tidal reasons, obtain necessary approvals and implement enhanced noise controls and monitoring.

b) Equipment selection and maintenance

- Select construction plant with lower sound power ratings where practicable and ensure that all equipment is fitted with effective mufflers, silencers, acoustic enclosures or shrouds as appropriate.
- Maintain all machinery and equipment in good working order to prevent excessive noise from loose panels, worn parts or faulty exhaust systems.
- Avoid the use of tonal reversing alarms where possible and replace with visual warning systems in sensitive locations.

c) Work methods and scheduling

- Apply quieter construction methods where practicable, for example drilling instead of percussive breaking wherever ground and rock conditions allow.
- Sequence high noise activities so that they do not occur simultaneously in close proximity to the same receptor, and confine the noisiest tasks to daytime periods as far as practicable.

- Restrict particularly noisy operations such as rock breaking, heavy hammering or use of impact tools to short, well-defined periods with rest intervals.
- Coordinate marine operations such as barge positioning and loading so that repeated high noise events close to the shore are minimised.

d) Site layout and physical noise control

- Position stationary noise sources, such as generators, compressors and drilling rigs, as far as practicable from Fort Siloso, Shangri La Rasa Sentosa Resort and other occupied buildings, making use of natural screening from topography or structures.
- Where equipment must be located near sensitive receptors, install temporary acoustic barriers, enclosures, hoardings or screens to shield line of sight between the source and the receptor.
- Use site hoarding of sufficient height and density along boundaries closest to receptors to provide additional noise attenuation.

e) Communication, training and behavioural controls

- Provide induction and toolbox briefings for all workers and vessel crews on noise control requirements, including the need to avoid unnecessary shouting, dropping of materials from height or slamming of doors and hatches.
- Establish clear lines of communication with Fort Siloso and Shangri La Rasa Sentosa Resort management to provide advance notice of particularly noisy activities and to receive and address any noise related feedback or complaints.
- Encourage good housekeeping practices that minimise rattling, banging and other avoidable noise, for example proper stacking of materials and careful handling of metal items.

f) Noise monitoring and review

- Implement a construction noise monitoring programme at N1 and N2 in accordance with regulatory and project requirements, including at least day and evening measurements and additional checks during any approved night works.
- Compare measured levels with NEA limits and the Project's internal action and alarm levels. Where action levels are exceeded, investigate the cause promptly and implement corrective measures such as revised scheduling, additional screening or equipment substitution.
- Maintain records of monitoring, complaints and corrective actions to support adaptive management throughout the construction period.

With the above minimum controls in place, residual construction noise impacts at Fort Siloso and Shangri La Rasa Sentosa Resort are expected to remain within the Minor significance band identified in the risk-based impact assessment, with only temporary and reversible disturbance.

4.3.3.3.2 Operation phase

During the operation phase, the stabilised slopes and revetment structures are passive and do not generate continuous noise sources. The ambient soundscape will be dominated by existing natural and human activities such as waves, wind, biophony and routine resort and fort operations. Controls therefore focus on preventing introduction of new fixed plant and on managing occasional maintenance noise.

a) Operation of completed works

- No new fixed mechanical plant associated with the Project, such as large pumps, fans or generators, shall be installed in locations that would increase long term noise exposure at Fort Siloso or Shangri La Rasa Sentosa Resort, unless designed and acoustically treated to comply with applicable noise criteria, and all such machinery shall be located on the temporary bund or barge rather than on the rocky shores, intertidal areas, or other sensitive habitats.
- Any minor equipment associated with monitoring or lighting shall be selected and installed so that operational noise is negligible at the nearest occupied premises.

b) Maintenance activities

- Apply the same good practice principles as for construction whenever maintenance requires drilling, breaking, surface repair or other noisy activities, including limiting such work to daytime periods where practicable and using quieter methods and tools.
- Provide advance notice to Fort Siloso and Shangri La Rasa Sentosa Resort management of maintenance activities that may be audible at receptor locations and coordinate timing to avoid sensitive periods such as evening events where practicable.
- Ensure that any maintenance involving marine vessels near the shoreline is planned to minimise repeated high noise events close to receptors.

c) Ongoing oversight

- Include ambient noise as a consideration in routine inspections and management reviews of the completed works, noting any changes in noise generating practices or equipment that could affect receptors.
- Where required by approval conditions or if substantiated complaints arise, undertake targeted noise measurements to verify that maintenance of the completed works do not materially increase ambient noise levels at N1 or N2.

With these minimum controls in place during operation, the Project is not expected to cause any significant long-term increase in ambient noise levels at Fort Siloso or Shangri La Rasa Sentosa Resort relative to baseline conditions.

4.3.3.4 Minimum control for ground vibration

This section sets out the minimum control measures to manage ground borne vibration at Fort Siloso (V1) and Shangri La Rasa Sentosa Resort (V2) so that vibration remains below the cosmetic damage guide values in BS 5228-2 and within acceptable ranges for human comfort as outlined in

Table 4-5 and **Table 4-6**.

4.3.3.4.1 Construction phase

a) Planning, assessment and method statements

- Prepare a Construction Vibration Management Plan as part of the Construction Environmental Management Plan, identifying all vibration generating activities for example drilling for soil nails and rock dowels, any rock breaking, compaction and movement of heavy plant near sensitive structures.
- Using the baseline PPV values measured at V1 and V2 and the BS 5228 2 cosmetic damage guide values, carry out a screening level assessment to estimate predicted PPV at Fort Siloso heritage structures and resort buildings for key construction activities.

- Develop method statements for high vibration activities that specify plant types, operating parameters, maximum permissible PPV at receptor locations and measures to minimise vibration transmission.

b) Equipment selection and operating practices

- Select drilling equipment and bits appropriate to the ground conditions to minimise percussive action and excessive thrust while maintaining productivity. Rotary or rotary percussive drilling with optimised settings is preferred over heavy impact methods wherever practicable.
- Avoid the use of heavy impact breakers on the slope except where no reasonable alternative exists, and then restrict duration and apply additional controls and monitoring.
- Use smaller, lighter plant where feasible in close proximity to Fort Siloso structures or resort retaining walls, and avoid rapid acceleration, sudden braking or abrupt directional changes of tracked plant on hard surfaces.

c) Site layout and separation distances

- Establish buffer distances between high vibration sources and sensitive receptors based on the screening assessment. Within these distances, apply stricter controls on plant type and operating mode.
- Where practicable, locate drilling rigs and any necessary breaking works on benches or platforms that maximise horizontal separation from Fort Siloso buildings and resort structures, while still meeting engineering requirements.

d) Protection of heritage and structural receptors

- Prior to commencement of high vibration works, carry out a pre-construction condition survey of representative Fort Siloso heritage structures and relevant resort buildings, documenting existing cracks, defects and finishes as a baseline.
- Where necessary, implement localised protection measures for fragile elements for example bracing of loose masonry, securing of ornaments or temporary support to non-structural features during high vibration activities in the vicinity.

e) Vibration monitoring and trigger action levels

- Install vibration monitoring at representative locations for Fort Siloso V1 and Shangri La Rasa Sentosa Resort V2 in accordance with BS 5228 2 guidance, recording peak particle velocity in three orthogonal axes at appropriate sampling frequencies.
- Establish project specific trigger and alarm levels below the cosmetic damage guide values, for example a lower “action” level where construction methods are reviewed and optimised and a higher “hold” level where works are temporarily stopped and revised before resumption.
- Implement continuous or attended monitoring during the initial period of high vibration activities drilling, breaking to confirm predictions, and adjust working methods or plant as necessary to keep PPV within agreed limits.
- Maintain a log of measured PPV, construction activities, trigger exceedances and corrective actions and report these periodically to the Engineer and, where required, relevant authorities.

f) Communication, training and complaint management

- Brief all site staff and Contractors on vibration control objectives, trigger levels and the importance of careful operation of plant near sensitive receptors.

- Establish communication protocols with Fort Siloso and Shangri La Rasa Sentosa Resort management to provide advance notice of high vibration activities, explain expected duration and agree on any special constraints for example avoidance of sensitive events.
- Maintain a mechanism for receiving, recording and responding to vibration related feedback or complaints and link this to the monitoring data and corrective action process.

With these minimum controls in place, construction phase vibration levels at Fort Siloso and Shangri La Rasa Sentosa Resort are expected to remain below BS 5228 2 cosmetic damage guide values and within the range that BS 5228 2 considers tolerable for human occupants, consistent with the Minor residual significance identified in the impact assessment.

4.3.3.4.2 Operation phase

During the operation phase the stabilised slopes and revetment structures are passive and do not generate routine ground vibration. The background vibration climate will continue to be governed by natural sources and existing activities. Controls focus on preventing new significant vibration sources and managing occasional maintenance works.

a) Operation of completed works

- Do not install new fixed mechanical plant associated with the Project in locations where continuous vibration could be transmitted to Fort Siloso heritage structures or resort buildings, unless designed and isolated to achieve PPV values well below the BS 5228 2 cosmetic damage thresholds.
- Ensure that any permanent monitoring or ancillary equipment installed on the structures does not introduce discernible vibration during normal operation.

b) Maintenance activities

- Where maintenance requires drilling, minor breaking or compaction near Fort Siloso or resort structures, apply the same good practice principles as in the construction phase on equipment selection, separation distances and operating methods.
- For infrequent, higher intensity maintenance activities for example replacement of revetment elements close to the shoreline, consider short term vibration monitoring at the nearest receptors to verify that PPV remains within acceptable limits.
- Plan maintenance works so that any perceptible vibration at receptors occurs mainly during daytime hours and is of limited duration, with advance notice provided to affected parties.

c) Ongoing oversight

- Incorporate vibration considerations into routine inspections of the completed works, noting any new activities or equipment introduced within or near the Study Area that could materially change the vibration environment.
- If substantiated concerns or complaints about vibration arise during operation, undertake targeted monitoring and, if required, adjust maintenance methods, access routes or equipment types to reduce vibration at receptors.

With these minimum controls during operation, the Project is not expected to cause any significant change to the baseline ground vibration conditions at Fort Siloso or Shangri La Rasa Sentosa Resort, and residual risks remain low and acceptable in the context of the overall development.

4.3.4 Impact Assessment

4.3.4.1 Assessment of marine water quality impact

The key receptors for marine water quality are the nearshore waters and associated habitats along the Tanjong Rimau coastline, including intertidal and subtidal communities, together with recreational users of the shoreline. In view of their ecological value and the presence of sensitive sessile fauna, these receptors are assigned high sensitivity.

4.3.3.1.1 Construction phase

a) Marine sediment resuspension and turbidity

In water activities at Sites A, B, C1 and C2, namely temporary bund construction and removal, placement of armour rock and XblocPlus units, and nearshore barge movements, may disturb seabed sediments and increase local suspended sediment concentration. Runoff from exposed slopes and working platforms, if not adequately controlled, can also convey fine particles into the nearshore waters during rainfall events.

With good site practice but before the application of specific best practicable measures, the magnitude of turbidity and suspended sediment increase is expected to be localised within the immediate vicinity of work fronts and short term in duration, occurring primarily during active in water works (including the utilisation of the barge for equipment and material transport) and storm events. As the receptors are highly sensitive, this results in an overall consequence ranked as Medium. Given that these activities are integral to the construction method and will occur repeatedly over the construction period, the likelihood is assessed as Likely or Regular. Using the Impact Significance Matrix, this combination corresponds to a pre mitigation impact significance of Moderate.

The Project incorporates multiple controls, including staged bund construction, careful placement of armour material, avoidance of unnecessary seabed disturbance, provision of perimeter drains and silt traps on land, and prohibition of direct discharge of turbid water. With these measures in place, sediment releases are expected to be confined within a small zone adjacent to the works and to remain within the ASEAN Marine Water Quality Criteria allowable range for suspended solids outside the immediate construction area. The residual consequence is therefore reduced to Low and the likelihood to Possible or Occasional. The resulting residual impact significance is Minor.

b) Contamination from construction materials and spills

Marine water quality could be affected by accidental release of fuel, lubricants, hydraulic oil or concrete related materials from construction vessels, plant and temporary storage areas, or by poor housekeeping of solid and liquid wastes. Such events may lead to a short-term increase in oil and grease, nutrients or metals in the water column or seabed.

In the absence of specific controls, the potential magnitude of a spill into nearshore waters could be High, particularly for localised ecological receptors, although the spatial extent would typically be limited and effects short term if prompt response is implemented. Considering the high sensitivity of marine habitats, the consequence is assessed as High. However, with proper vessel maintenance, bunded storage for fuel and chemicals, prohibition of refuelling over water, and implementation of a spill prevention and response plan, the likelihood of a significant spill is assessed as Less Likely or Rare. Under the risk matrix, this yields an impact significance of Minor.

Following implementation of the above controls, along with emergency response drills and clear reporting lines, any residual spill events are expected to be small, rapidly contained and cleaned up, with limited opportunity for guideline exceedances beyond the immediate vicinity. The residual consequence is therefore reduced to Medium and the likelihood to Unlikely or Remote, corresponding to a residual significance of Negligible to Minor.

c) Runoff and discharge from land-based works

Land based activities for slope stabilisation, including soil nailing, installation of erosion control blankets and operation of temporary site facilities, may generate runoff that contains fine sediments or minor quantities of concrete wash water and other contaminants. If such runoff reaches the shoreline without treatment, it could temporarily elevate suspended solids and selected chemical parameters in the receiving waters.

The design includes perimeter drainage, earth control measures, silt traps, proper collection and off site disposal of concrete wash water, and appropriate management of domestic wastewater. With these standard measures, the magnitude of any uncontrolled discharge is expected to be Very Low and the duration short. Consequence is therefore assessed as Low and likelihood as Possible or Occasional. The corresponding significance is Minor. With strict implementation and regular inspection of earth control and wastewater management measures, the likelihood is reduced to Less Likely or Rare, giving a residual significance of Negligible to Minor.

d) Overall evaluation for construction phase

Considering all pathways, the dominant water quality risk during construction is short term elevation of suspended solids and turbidity in the nearshore waters immediately adjacent to in water works. With the proposed mitigation and good site practice, predicted changes are expected to remain within applicable criteria at the edge of the small near field influence zone and to be reversible following completion of activities. Residual impacts on marine water quality during the construction phase are therefore assessed as Minor and not significant in the context of the Project, provided that the identified mitigation and monitoring measures are fully implemented.

4.3.3.1.2 Operation phase

During operation, the stabilised slope and completed revetment and XblocPlus structures are passive features with no routine discharges. The works are expected to reduce erosion of the coastal slope and associated delivery of fine sediments into the nearshore environment during storm events. Localised changes in hydrodynamics and sediment deposition patterns may occur directly in front of the revetment, but these are expected to remain small in magnitude and confined within the immediate footprint of the works. Occasional visual inspection is expected and no discharge is expected.

The resulting consequence for marine water quality is assessed as Very Low to Low and the likelihood as Certain or Continuous in the sense that the stabilised condition is permanent. In accordance with the risk matrix, this corresponds to an overall significance of Minor and is considered beneficial in reducing episodic sediment pulses from slope erosion, while the small, localised changes in nearshore sediment dynamics are not expected to result in adverse water quality outcomes.

4.3.3.1.3 Summary

Applying the risk-based methodology, construction phase impacts on marine water quality have a pre mitigation significance of up to Moderate, driven mainly by temporary increases in suspended sediments and the low probability of accidental spills. With the minimum control measures, residual impacts are reduced to Minor. During operation, the Project is expected to result in a Minor but

generally positive effect on marine water quality through reduced slope erosion, with no significant adverse residual impacts identified. This result is summarised in **Table 4-13**.

Table 4-13 Summary impact assessment for marine water quality

Environmental Aspect	Phase	Potential Impacts	Impact Significance (Unmitigated)	Residual Impact Significance (Mitigated)
Marine water quality	Construction	Short term increase in suspended sediment and turbidity in nearshore waters from in water works at Sites A, B, C1 and C2 and runoff from exposed slopes and working platforms.	Moderate adverse	Minor adverse
Marine water quality	Construction	Localised deterioration in water quality from accidental spills or poor handling of fuel, lubricants, hydraulic oil, concrete related materials and construction wastes.	Moderate adverse	Negligible to Minor adverse
Marine water quality	Construction	Temporary elevation of suspended solids and selected chemical parameters in receiving waters due to uncontrolled runoff or discharge from land-based works.	Minor adverse	Negligible to Minor adverse
Marine water quality	Operation	Long term change in sediment regime due to stabilised slopes and revetment, reducing erosion driven sediment inputs to nearshore waters and slightly altering local hydrodynamics.	Minor beneficial	Minor beneficial (no additional mitigation required)

4.3.4.2 Assessment of ambient air quality impact

The key receptors for ambient air quality are visitors and staff at Fort Siloso (A1) and guests and staff at Shangri La Rasa Sentosa Resort Monitoring (A2). Given the presence of children, elderly persons and other potentially sensitive individuals and the generally good baseline air quality, these receptors are assigned high sensitivity to changes in particulate concentrations and combustion related pollutants.

4.3.4.2.1 Construction phase

a) Particulate matter from earthworks and material handling

Construction activities such as drilling for soil nails and rock dowels, trimming and scaling of the slope, handling and placement of aggregates and armour rock, minor excavation and movement of construction vehicles on unpaved or partially paved surfaces will generate fugitive dust. Under dry and windy conditions, this may lead to short term localised increases in PM_{10} and $PM_{2.5}$ near work fronts and along haul routes.

Without specific control measures, the magnitude of these short-term increases is expected to be Medium, with the potential for noticeable dust at the site boundary during periods of intense activity, although significant exceedance of the SAAQT beyond the immediate works area is not anticipated. In view of the high sensitivity of Fort Siloso and Shangri La Rasa Sentosa receptors, the overall consequence is assessed as Medium. As earthworks and material handling will occur repeatedly throughout the construction period, the likelihood is assessed as Likely or Regular. The resulting pre mitigation impact significance for particulate matter is therefore Moderate and adverse.

The Project includes a suite of minimum controls for ambient air quality, including keeping exposed surfaces and haul roads damp during dry weather, covering or enclosing fine material stockpiles, limiting drop heights during loading and unloading, sheeting trucks, and maintaining good housekeeping on access roads and working platforms. With these measures implemented, particulate emissions are expected to be substantially reduced and confined to short periods close to active work fronts, with concentrations at A1 and A2 remaining comfortably within the SAAQT. The residual consequence is therefore reduced to Low and the likelihood to Possible or Occasional, giving a residual impact significance of Minor and adverse, temporary and reversible.

b) Exhaust emissions from construction plant and marine vessels

Diesel powered construction equipment and marine vessels will emit combustion related pollutants, including nitrogen dioxide, carbon monoxide and particulate matter. The scale of the Project is limited, and the number of simultaneously operating plant items is not large. In addition, baseline ambient concentrations of NO_2, CO and SO_2 at A1 and A2 are well below the relevant targets.

Without additional controls, the incremental increase in these gaseous pollutants is expected to be Low in magnitude and localised near individual items of plant or along haul routes, with rapid dispersion in the open coastal environment. For high sensitivity receptors, the consequence is assessed as Low, and because use of plant and vessels is routine during construction, the likelihood is Likely or Regular. This combination corresponds to a pre mitigation significance of Minor and adverse.

Minimum controls for combustion emissions include use of well-maintained equipment that complies with NEA emission requirements, prohibition of unnecessary idling, and positioning of stationary engines away from receptors where practicable. With these measures in place, incremental contributions to regional background concentrations of NO_2, CO and SO_2 are expected to be Very Low, with any noticeable effects confined to very short periods in the immediate vicinity of emitting plant. The residual consequence is therefore assessed as Low, and the likelihood as Possible or Occasional, giving a residual significance of Minor and adverse.

c) Odour and nuisance dust

Short term odour or nuisance dust may arise from specific activities such as handling of cementitious materials, operation of small generators in semi enclosed areas or accidental poor housekeeping. These effects would be confined to a small area and short duration but could result in transient discomfort for nearby visitors or workers.

With good practice in storage and handling of cement and chemicals, adequate ventilation for equipment, and prompt clean-up of any spills, the magnitude of odour and nuisance dust is expected to be Very Low, and the likelihood Less Likely or Rare. The resulting impact significance is Negligible.

d) Overall evaluation for construction phase

In summary, the principal air quality risk during construction is a short-term increase in PM_{10} and $PM_{2.5}$ near work fronts and access routes. Exhaust emissions and odour are secondary and of lower magnitude. Before mitigation, impacts on ambient air quality at Fort Siloso and Shangri La Rasa Sentosa are assessed as up to Moderate and adverse for particulate matter. With the implementation of the minimum control measures described in **Section 4.3.3.2**, residual impacts are reduced to Minor. They are temporary, localised and reversible, with ambient concentrations of particulates and gaseous pollutants expected to remain within the SAAQT at both monitoring locations.

4.3.4.2.2 Operation phase

During the operation phase, the stabilised slopes and revetment structures are passive and do not introduce any continuous emission sources. Routine activities at Fort Siloso and Shangri La Rasa Sentosa will be broadly similar to the baseline situation, with ambient air quality dominated by regional background conditions and existing traffic and resort operations.

Occasional inspection and maintenance works may involve limited use of small combustion equipment or vehicles and minor surface repair that could generate dust. These activities will be infrequent, short in duration and subject to the same good practice controls as adopted during construction.

The magnitude of any operational change in ambient air quality attributable to the Project is therefore assessed as Very Low, with effects confined to short term, localised increments during maintenance. The consequence is Very Low and the likelihood Possible or Occasional, leading to an overall impact significance of Negligible. There is no expectation of long-term deterioration in ambient air quality at A1 or A2 relative to the baseline, and in practice the Project is effectively neutral with respect to operational ambient air quality.

4.3.4.2.3 Summary

Applying the risk-based methodology, construction phase impacts on ambient air quality are driven primarily by fugitive dust and, to a lesser extent, exhaust emissions. Pre mitigation significance may reach Moderate and adverse for particulate matter in the immediate vicinity of active works. With the planned dust and emission controls fully implemented, residual impacts are reduced to Minor, localised to near site boundaries and temporary in nature.

During operation, the Project does not introduce new continuous emission sources and only occasional routine visual inspection are anticipated. Operational impacts on ambient air quality are therefore assessed as Negligible and are considered not significant in the context of the Project. These results are summarised in **Table 4-14**.

Table 4-14 Summary impact assessment for ambient air quality

Environmental Aspect	Phase	Potential Impacts	Impact Significance (Unmitigated)	Residual Impact Significance (Mitigated)
Ambient air quality	Construction	Short term local increase in PM10 and PM2.5 from drilling, earthworks, slope trimming, handling of aggregates and armour rock, and movement of construction vehicles on unpaved or partially paved surfaces	Moderate adverse	Minor adverse
Ambient air quality	Construction	Incremental increase in nitrogen dioxide, carbon monoxide, sulphur dioxide and particulates from diesel construction plant, generators and marine vessels	Minor adverse	Minor adverse
Ambient air quality	Construction	Localised odour and nuisance dust from handling of cement and chemicals, operation of small generators in semi enclosed areas and occasional poor housekeeping	Negligible	Negligible
Ambient air quality	Operation	Very small, short duration increments in dust and combustion pollutants from occasional inspection and maintenance works using small equipment and vehicles	Negligible	Negligible

4.3.4.3 Assessment of ambient noise impact

The key noise receptors are Fort Siloso (N1) and Shangri La Rasa Sentosa Resort (N2). Both are considered high sensitivity receptors due to their tourism and hospitality functions, the presence of potentially sensitive groups such as children and elderly visitors, and the expectation of a relatively quiet environment for heritage appreciation and guest comfort. For regulatory purposes under the Environmental Protection and Management Control of Noise at Construction Sites Regulations, both locations are classified as "Other buildings", and the corresponding maximum permissible noise levels apply.

Baseline ambient noise levels at N1 and N2, as set out in **Section 4.1.3**, show that all 12-hour equivalent levels are within the applicable limits, with isolated exceedances of the 5-minute nighttime limit at N1 on weekdays and the 5-minute evening limit at N2 on weekdays. This indicates that receptors already experience occasional short duration elevated noise events in the absence of the Project.

5.3.4.3.1 Construction phase

a) General construction airborne noise during daytime

During the construction phase, the main sources of airborne noise will be slope stabilisation plant such as drilling rigs for soil nails and rock dowels, rock scaling and trimming where required, operation of excavators and lifting equipment on the slope and along the shoreline, generators and compressors, together with construction traffic on access routes. These sources will operate mainly during the day period from 7 am to 7 pm.

Without specific noise controls, the combined operation of multiple plant items could result in a noticeable increase in the equivalent continuous noise level at N1 and N2 above baseline, particularly when works are closest to the receptors. Given the separation distances involved, and the shielding provided by local topography and structures, the magnitude of the increase is expected to be Medium, but there is potential for the daytime 5-minute equivalent level to approach the permissible limit at certain times. For high sensitivity receptors, the consequence is therefore assessed as Medium. As daytime construction noise will occur frequently over much of the construction period, the likelihood is assessed as Likely or Regular. Using the Impact Significance Matrix, this combination corresponds to a pre mitigation impact significance of Moderate and adverse.

The Project incorporates a suite of minimum noise controls described in **Section 4.3.3.3**, including preparation of a Construction Noise Management Plan, selection of quieter equipment, regular maintenance of plant, optimisation of work sequencing, use of temporary acoustic screens and hoardings, and careful placement of stationary equipment relative to receptors. With these measures implemented, the predicted increase in daytime equivalent noise levels at N1 and N2 is expected to be small and generally within the applicable permissible limits, with any short-term exceedances confined to brief periods and specific activities.

On this basis, the residual consequence is reduced to Low and the likelihood to Possible or Occasional, yielding a residual impact significance of Minor and adverse, temporary and reversible.

b) Evening and nighttime construction noise

Evening 7 pm to 10 pm and night 10 pm to 7 am periods are more sensitive because regulatory limits are more stringent and receptors are more susceptible to disturbance, particularly resort guests during rest hours. Where practicable, the Project will avoid conducting noisy activities during these periods.

However, some works, especially marine operations that are constrained by tidal windows, may occasionally extend into the evening and, in exceptional cases, the night period.

If noisy activities such as drilling or operating heavy plant were to proceed without additional controls during evening or night periods close to receptors, the magnitude of potential noise level increase would be High, and exceedance of the relevant 5-minute permissible limits could occur. For high sensitivity receptors, the consequence in such a scenario is High, and given the typical need for repeated nightly activities over a period to complete specific work fronts, the likelihood could be Possible or Occasional. This would correspond to a pre mitigation significance of Major and adverse for the most sensitive periods.

To address this risk, the Project will adopt the following approach, as captured in the minimum control section. No routine night works involving high noise equipment will be undertaken. Where evening or night work is essential for safety or tidal reasons, the Contractor will seek prior approval, restrict activities to the quietest practicable methods and plant, limit duration, and implement enhanced controls and monitoring. Advance notification will be provided to Fort Siloso and resort management, and additional acoustic screening will be installed where feasible.

With these measures and given that evening or night works will be infrequent and tightly managed, the residual magnitude of noise increase at receptors is expected to be Low, with short duration exceedances, if any, occurring rarely and limited to very specific operations. The residual consequence is therefore assessed as Low and the likelihood as Less Likely or Rare. This corresponds to a residual impact significance of Minor and adverse, noting that any such events will be strictly controlled and reversible once the specific activity concludes.

c) Marine based construction and vessel noise

Marine activities, including tugboat manoeuvring, barge positioning and loading or unloading of armour rock and XblocPlus units, will generate intermittent noise from engines, winches and impact between materials. These sources will be closest to receptors when barges are operating near the shoreline at Sites A, B, C1 and C2.

Unmitigated, these activities can give rise to short duration peaks in noise levels at N1 and N2, particularly when horn signals, engine revving or impacts occur. However, due to the distance across water, partial shielding and the relatively short duration of manoeuvring events, the overall effect on equivalent noise levels is expected to be Low. For high sensitivity receptors, consequence is therefore assessed as Low, with likelihood Likely or Regular while marine works are underway. This gives a pre mitigation significance of Minor and adverse.

Marine noise will be managed via routing and speed control, minimisation of unnecessary horn use, careful planning of barge movements and coordination with land-based activities to avoid cumulative peaks. With these measures in place, the residual consequence is Low and the likelihood is Possible or Occasional, resulting in a residual significance of Minor.

d) Overall evaluation for construction phase

Considering all construction noise sources together, the dominant risk is an increase in daytime equivalent noise levels at Fort Siloso and Shangri La Rasa Sentosa Resort, with potential for more sensitive evening and night periods if not properly controlled. Prior to mitigation, construction noise impacts could reach Moderate and, in worst case unmitigated evening or night scenarios, Moderate to Major significance.

With implementation of the minimum noise control measures in **Section 4.3.3.3**, strict management of any evening or night work, and ongoing monitoring and adaptive management, residual noise impacts are assessed as Minor and adverse at both receptors. These impacts are temporary, localised and reversible, and the Project is expected to comply with the NEA permissible noise levels for "Other buildings" over the 12-hour assessment periods, with only occasional short-term exceedances of 5-minute limits during particularly noisy but tightly managed activities, if at all.

5.3.4.3.2 Operation phase

During the operation phase, the stabilised slopes, soil nails, rock netting, erosion control blankets, revetment and XblocPlus units are passive structures that do not generate continuous noise. The ambient noise climate will continue to be dominated by natural sources such as waves, wind and vocalising fauna, together with existing human activities at Fort Siloso, along the coastal trails and within Shangri La Rasa Sentosa Resort.

Only occasional routine visual inspection are anticipated. These inspection will be infrequent, of limited duration and subject to the same good practice controls as for construction, including preference for daytime working and use of quieter methods where practicable.

The magnitude of any operational change in ambient noise attributable to the Project is therefore assessed as Very Low, with effects primarily limited to infrequent, short-term noise from maintenance works. For high sensitivity receptors, the consequence is Low and the likelihood Possible or Occasional. The resulting operational impact significance is Negligible.

In practice, the Project is expected to be essentially neutral with respect to the long-term ambient noise climate, and may even provide some indirect benefit by reducing the need for emergency interventions associated with slope instability, which could otherwise give rise to unplanned noisy works in the future.

5.3.4.3.3 Summary

Using the risk-based assessment method, construction phase impacts on ambient noise at Fort Siloso and Shangri La Rasa Sentosa Resort are driven by operation of slope stabilisation plant, construction traffic and marine based activities. Before mitigation, daytime impacts are assessed as Moderate and evening or nighttime impacts could reach Major significance if not controlled.

With the implementation of the minimum noise control measures, careful scheduling of works, restriction of noisy activities during sensitive periods and continuous monitoring with adaptive management, residual noise impacts at both receptors are reduced to Minor and adverse. These impacts are temporary and reversible and are considered acceptable in the context of the Project. Operational phase impacts on ambient noise are assessed as Negligible. These results are summarised in **Table 4-15**.

Table 4-15 Summary impact assessment for ambient noise

Environmental Aspect	Phase	Potential Impacts	Impact Significance (Unmitigated)	Residual Impact Significance (Mitigated)

Ambient noise	Construction	Increase in daytime equivalent noise levels at Fort Siloso and Shangri La Rasa Sentosa Resort from drilling rigs, rock scaling, excavators, lifting equipment, generators, compressors and construction traffic during 7 am to 7 pm	Moderate adverse	Minor adverse
Ambient noise	Construction	Evening and nighttime noise from slope stabilisation plant and marine related works during 7 pm to 10 pm and 10 pm to 7 am with potential exceedance of 5-minute limits if uncontrolled	Major adverse	Minor adverse
Ambient noise	Construction	Intermittent marine based noise from tugboats, barges and loading or unloading of armour rock and XblocPlus units leading to short duration peaks at receptors	Minor adverse	Minor adverse
Ambient noise	Operation	Localised short duration noise from light equipment and vehicles during occasional inspection and maintenance of stabilised slopes and revetment	Negligible	Negligible

4.3.4.4 Assessment of ground vibration impact

The key vibration receptors are Fort Siloso Monitoring Point (V1) and Shangri La Rasa Sentosa Resort Monitoring Point (V2). Fort Siloso heritage structures are treated conservatively as unreinforced or light framed buildings under BS 5228 2, and both receptors are considered to be of high sensitivity from a human comfort perspective. Baseline peak particle velocity values at V1 are approximately 1.3 to 2.2 millimetres per second and at V2 approximately 1.4 to 7.8 millimetres per second, all well below the BS 5228-2 cosmetic damage guide values but above the threshold at which vibration is clearly perceptible to occupants.

5.3.4.4.1 Construction phase

a) Vibration from slope stabilisation works

The main sources of construction vibration will be drilling for soil nails and rock dowels, any localised rock breaking, trimming or compaction at the slope toe and movement of tracked or wheeled heavy plant on hard standing close to sensitive structures.

Screening assessments based on typical source levels indicate that, without specific controls, peak particle velocity at Fort Siloso and Shangri La Rasa Sentosa could reach values in the range of 3 to 10 millimetres per second during the closest high vibration activities. These levels remain below the BS 5228-2 cosmetic damage guide values for unreinforced or light framed buildings 15 to 20 mm/s in the relevant frequency range and well below 50 mm/s for reinforced structures, so the structural damage risk is low. However, they lie above the human perception and complaint thresholds of approximately 0.3 and 1.0 mm/s, and at the upper end of this range could cause noticeable disturbance if sustained.

For the high sensitivity receptors, the structural consequence before mitigation is assessed as Low, while the human comfort consequence is assessed as Medium, reflecting that vibration will be clearly perceptible and could occasionally cause concern. Drilling and related works will occur frequently during the construction period, so the likelihood is assessed as Likely or Regular. Combining Medium

consequence with Likely or Regular likelihood gives a pre mitigation impact significance of Moderate and adverse, driven primarily by human comfort rather than structural integrity.

The Project minimum controls for ground vibration include:

- optimisation of drilling methods and equipment settings to minimise impact energy while maintaining productivity.
- avoidance of heavy impact breaking near sensitive structures wherever practicable.
- routing of heavy plant away from the most sensitive buildings and control of speeds on access tracks.
- establishment of buffer distances and method constraints near Fort Siloso and resort structures.
- installation of vibration monitoring at V1 and V2 with project specific trigger and alarm levels below the BS 5228-2 cosmetic damage criteria and a clear trigger action response protocol.

With these measures implemented, predicted peak particle velocity at receptors during drilling and associated activities is expected to be kept within a range where structural risk remains very low and human comfort effects are managed, typically not exceeding about 5 mm/s at the building foundations. The residual structural consequence is therefore assessed as Very Low and the human comfort consequence as Low. Because high vibration activities will still occur but under close control and for limited durations, the residual likelihood is assessed as Possible or Occasional.

Under the risk matrix, Low consequence and Possible or Occasional likelihood correspond to a residual impact significance of Minor and adverse, temporary and reversible.

b) Vibration from construction traffic and plant movement

Movement of tracked excavators, trucks and other plant on access routes, ramps and working platforms can generate short duration vibration, especially when travelling over uneven surfaces, joints or ramps close to receptors.

In the absence of specific controls, peak particle velocity at building foundations from traffic movements near Fort Siloso or the resort is expected to be of similar order or lower than the baseline range, typically below about 3 to 4 millimetres per second, and of very short duration. For high sensitivity receptors this represents a Low consequence for human comfort and a Very Low consequence for structural response. Given the routine nature of traffic during the construction period, the likelihood is Likely or Regular, resulting in a pre-mitigation significance of Minor and adverse.

With implementation of traffic management measures routing heavy vehicles away from the most sensitive structures where practicable, maintaining low speeds near receptors and maintaining access surfaces to minimise bumps and discontinuities the magnitude of additional vibration from traffic is further reduced. The residual consequence is assessed as Very Low and the likelihood as Possible or Occasional, giving a residual significance of Negligible.

c) Vibration associated with marine construction activities

Marine works, including barge positioning, mooring and placement of armour rock and XblocPlus units, may generate some vibration when armour contacts the revetment or temporary bunds. Transmission of this vibration to Fort Siloso and the resort buildings will be attenuated by the distance and the water and soil medium.

Unmitigated peak particle velocity at building foundations from marine operations is expected to be Very Low compared with both the baseline and the BS 5228-2 cosmetic damage thresholds, and only occasionally perceptible to occupants closest to the shoreline. For high sensitivity receptors, consequence is therefore assessed as Low and likelihood as Likely or Regular while marine works are underway. This gives a pre mitigation significance of Minor and adverse.

Good practice in armour placement controlled lowering rather than dropping from height and careful barge manoeuvring will further limit vibration transmission, so residual impacts are expected to be Negligible.

d) Overall evaluation for construction phase

Considering all sources, the dominant vibration risk during construction is related to drilling and any localised breaking on the coastal slope. Before mitigation, human comfort impacts at Fort Siloso and Shangri La Rasa Sentosa are assessed as Moderate and adverse, although structural damage risk remains low. Construction traffic and marine activities contribute additional but smaller sources of vibration with pre mitigation significance in the Minor range.

With full implementation of the vibration controls described in **Section 4.3.3.4**, including method optimisation, separation distances, monitoring and adaptive management, residual impacts on ground vibration at both receptors are reduced to Minor and adverse. Structural peak particle velocity levels remain comfortably below the BS 5228-2 cosmetic damage guide values and within ranges considered tolerable for occupants when appropriate communication and scheduling are in place.

5.3.4.4.2 Operation phase

During the operation phase, the stabilised slopes, soil nails, rock netting, erosion control blankets, revetment and XblocPlus units are passive structures. There are no new permanent sources of ground vibration introduced by the Project, and the background vibration climate at Fort Siloso and Shangri La Rasa Sentosa will continue to be influenced primarily by natural sources wave action, wind and existing activities such as traffic and routine resort operations.

Only occasional routine visual inspection is anticipated. Vibration from these activities will be small in magnitude and highly localised, with peak particle velocity values expected to be comparable to or below those observed during the baseline survey and well within BS 5228 2 human perception guidance for tolerable events of short duration.

The magnitude of operational change in ground vibration attributable to the Project is therefore assessed as Very Low. For high sensitivity receptors, the consequence is Very Low and the likelihood Possible or Occasional, reflecting infrequent maintenance works. Under the risk matrix this corresponds to an operational significance of Negligible. In practical terms, the Project is essentially neutral with respect to long term ground vibration and may indirectly reduce the likelihood of emergency high vibration works associated with slope failure by providing a more stable coastal slope.

5.3.4.4.3 Summary

Using the risk-based methodology, construction phase impacts on ground vibration at Fort Siloso and Shangri La Rasa Sentosa are dominated by drilling and any localised breaking for slope stabilisation. Pre mitigation, these activities may generate clearly perceptible vibration at receptors, giving a Moderate adverse impact driven by human comfort rather than structural damage. Traffic and marine operations contribute smaller, Minor adverse effects.

With the minimum vibration control measures in place, including careful equipment selection and operation, separation distances, protection of heritage elements and real time vibration monitoring with defined trigger levels, residual vibration impacts are assessed as Minor and adverse, temporary and reversible. Operational phase impacts on ground vibration are assessed as Negligible and are not significant in the context of the Project. These results are summarised in **Table 4-16**.

Table 4-16 Summary impact assessment for ground vibration

Environmental Aspect	Phase	Potential Impacts	Impact Significance (Unmitigated)	Residual Impact Significance (Mitigated)
Ground vibration	Construction	Vibration at Fort Siloso (V1) and Shangri La Rasa Sentosa Resort (V2) from drilling for soil nails and rock dowels, localised rock breaking, trimming and compaction near sensitive structures	Moderate adverse (human comfort driven, structural risk low)	Minor adverse (temporary and reversible)
Ground vibration	Construction	Short-duration vibration from movement of tracked excavators, trucks and other plant on access routes, ramps and working platforms near receptors	Minor adverse	Negligible
Ground vibration	Construction	Low-level vibration transmitted from marine construction activities such as barge positioning, mooring and placement of armour rock and XblocPlus units	Minor adverse	Negligible
Ground vibration	Operation	Very small, localised vibration from occasional inspection and maintenance activities using light plant or vehicles on access paths and at the revetment toe	Negligible	Negligible (Project effectively neutral for long-term ground vibration)

5. Hydrodynamic Modelling

5.1 Hydrodynamic Impact Assessment Methodologies

The assessment of environmental impacts during both the construction and operational phases of the Project was primarily based on model simulations utilising a range of specific models covering the Study Area. At the core of all impact assessments is a hydrodynamic model that characterises potential impacts of the Project works on the currents and water levels. This base hydrodynamic model is applied to simulate key construction processes during construction stage to inform the impact assessments, including the modelling of sediment plumes resulting from propeller wash. For the operational phase, the hydrodynamic model is employed to evaluate impacts for the completed revetments, subsequently providing essential input for sediment transport modelling. The specific models used to assess the process and project impacts are detailed in **Table 5-1**.

Table 5-1 Summary of modelling tools to be employed for impact assessment

Project Phase	Key Environmental Concerns	Sensitive Receptors	Modelling software
Construction	• Propeller wash induced sediment plume - Potential localised seabed erosion and sedimentation - Potential sediment plume impact on sensitive receptors	• Corals and seagrasses nearby the proposed construction access • Recreational beaches, e.g. Siloso beach	• MIKE 21 HD hydrodynamic model of Singapore waters and MIKE 21 MT sediment plume model for assessing impacts of propeller wash induced sediment plume. • MIKE 21 MT morphological model of Singapore waters for assessing morphological impacts.
Operation	• Potential changes in current speed due to the proposed revetments • Potential morphological changes on seabed due to the proposed revetments	• Navigation channel • Corals and seagrasses nearby the proposed revetments	• HD hydrodynamic model of Singapore waters for assessing current impacts. • MIKE 21 MT morphological model of Singapore waters for assessing morphological impacts.

5.2 Model Setup

5.2.1 Hydrodynamic Modelling

A 2D hydrodynamic flow model has been established based on MIKE 21 Flexible Mesh (FM). For this EIA, the 2D hydrodynamic model has been used to drive the sediment plumes and sediment transport models.

The modelling system is based on the numerical solution of the two-dimensional shallow water equations – the depth-integrated incompressible Reyn-olds averaged Navier-Stokes equations. Thus, the model consists of continuity, momentum, temperature, salinity and density equations. In the horizontal domain, both Cartesian and spherical coordinates can be used.

The flexible mesh nested approach was adopted to correctly transform the offshore tidal signal into the model domain as shown in **Figure 5-1**. The computational triangular mesh of the model is made with sufficiently small cells of 2–5 m resolution to resolve the current flow conditions around the development site. Coarse grid cell size is applied at the further offshore area while a finer grid cell size is used for the Study Area and its surroundings as illustrated in **Figure 5-2**. The bathymetry data along the shoreline of Sentosa island and offshore area used in the model were provided by the client and obtained from nautical charts and global elevation models.

The boundary conditions of the model domain were generated from Global Tide Model (GTM) for coastal and marine modelling which is available in 0.125 degree resolution. The major constituents in the tidal spectra were extracted from the GTM at boundary locations. The extracted constituents consider the semidiurnal M2, S2, K2, N2, the diurnal S1, K1, O1, P1, Q1 and the shallow water constituent M4.

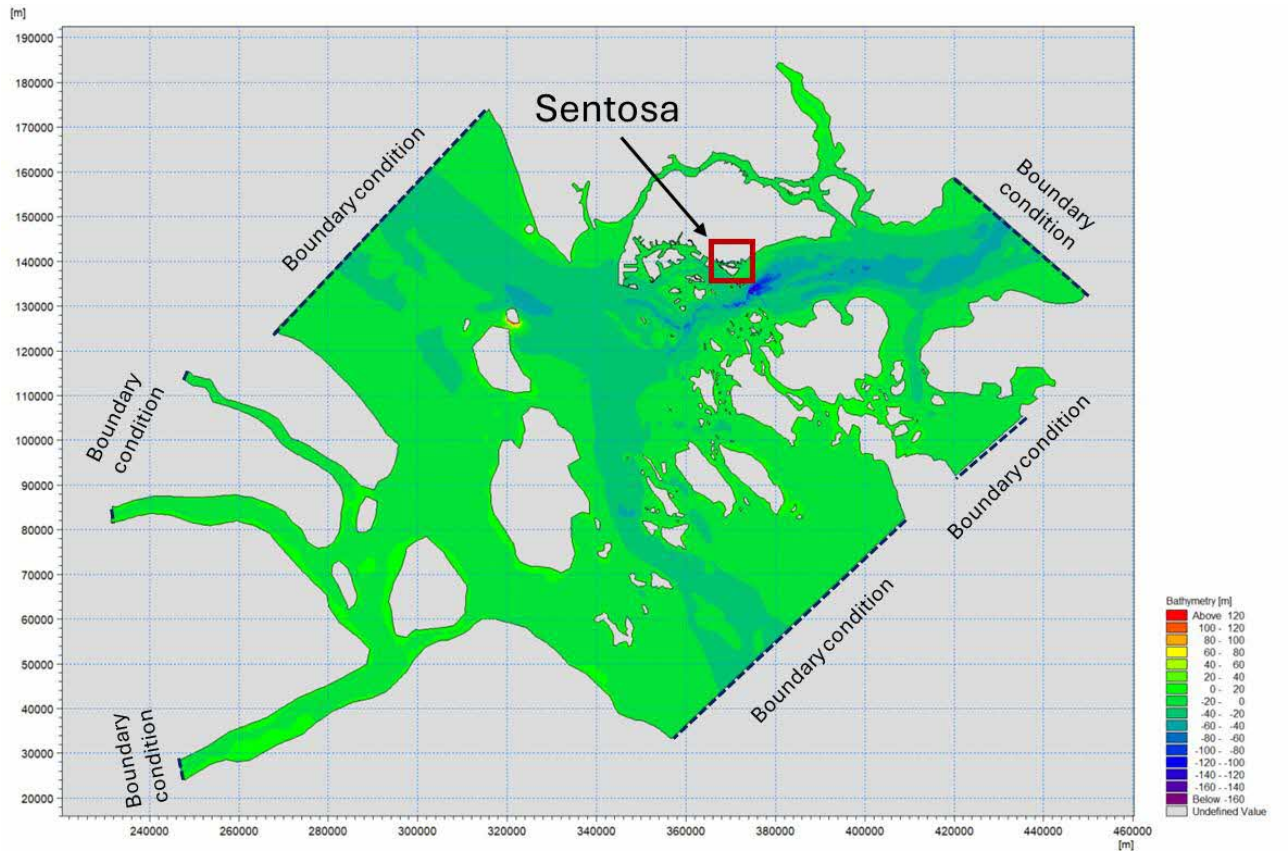


Figure 5-1 Model domain

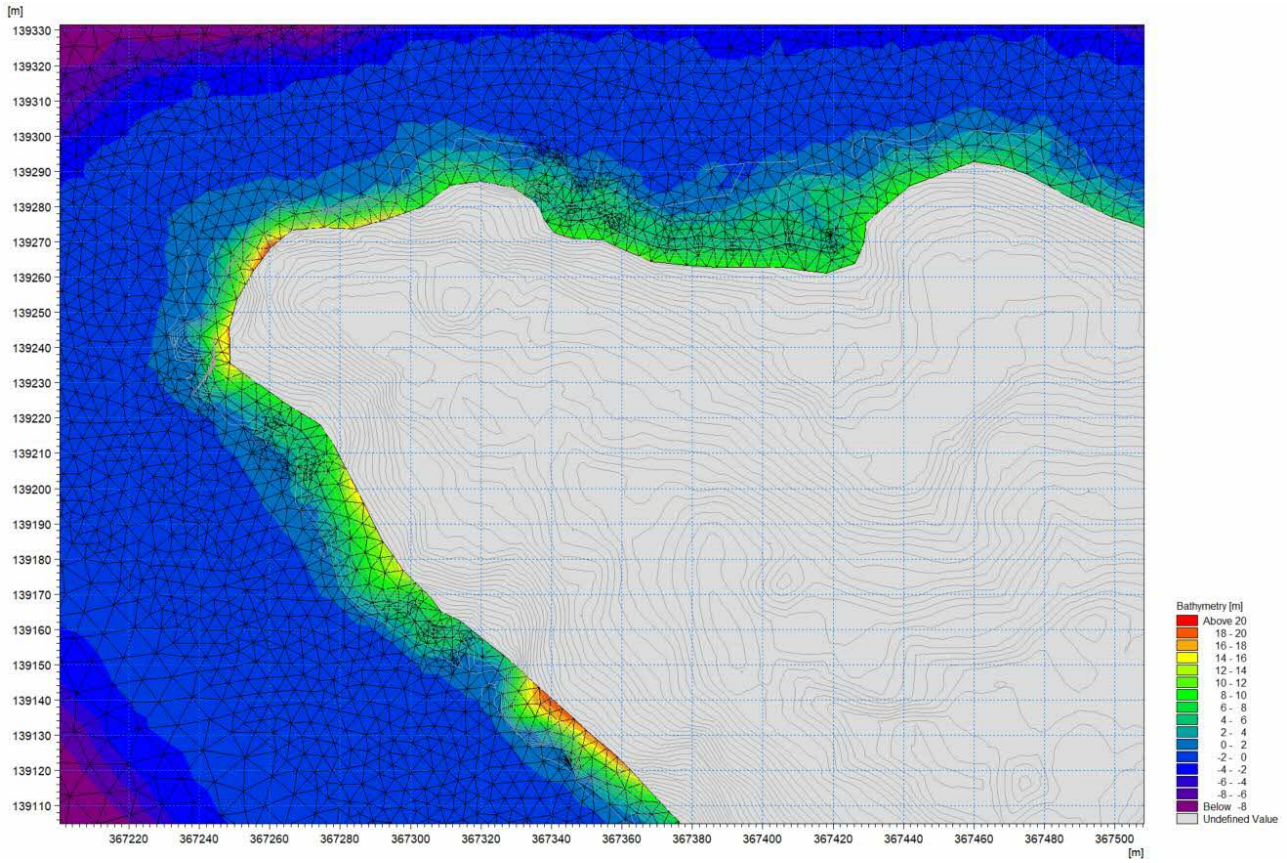


Figure 5-2 Model grid and bathymetry around the Study Area

5.2.2 Model Validation

The performance of model has been verified through model validation with the tidal measurements at the Tanjong Pagar tidal station and three ADCP measurements, i.e. A1, A2, and A3, located near the Project Site as can be seen in **Figure 5-3**. Measured data were monitored for the period from March to September 2019. The purpose of model validation is to identify the numerical expression of discrepancy between model and monitoring data. Traditionally, the evaluation of performance has been based on visual comparisons, e.g. by time series plots of modelling results and monitoring data. Furthermore, the study applied 'A Framework for Marine and Estuarine Model Specification in the UK', Ref FR0374, published by the UK Foundation for Water Research, to quantitatively assess the calibration and validation performance of the hydrodynamic model in detail.

In broad terms, this can be categorised by the following performance limits:

- Tidal elevations: Root Mean Square Error (RMSE) <10% of the spring tidal range for stations with measured time series of water level;
- Current speed deviation Root Mean Square Error (RMSE) <10 to 20% of the peak spring tide depth integrated tidal current for periods with current strength >0.2m/s; and
- Direction error Root Mean Square Error (RMSE) <20 deg for periods with current strength >0.2m/s (for areas not strongly affected by dynamic micro-eddies).

The visual comparisons of model performance for currents at the area of interest provided in **Figure 5-4**. Overall, the visual comparisons show satisfactory comparison. **Table 5-2** presents the quantitative

performance of the model at the current monitoring station. The RMSE for both water level, current speeds and current direction are within the proposed criterion.

Figure 5-3 Locations of tidal station and ADCP measurements

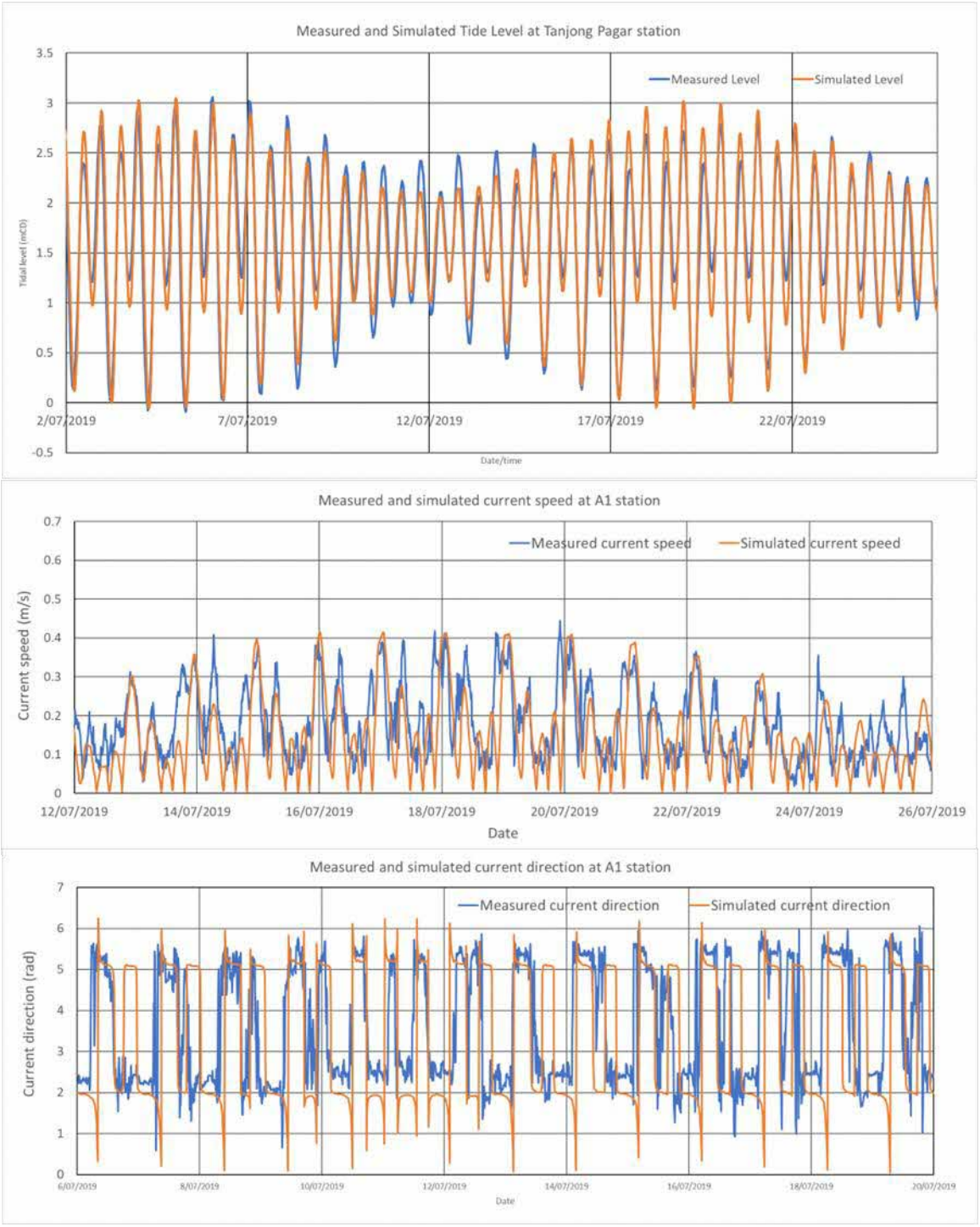


Figure 5-4 Comparison of water level, current speed and direction between hydrodynamic model and measured data

Table 5-2 RMSE of water level, current speed, and direction for the validation period of HD model

Parameter	Measured RMS Error	Reference Value	Normalized Error	FR0374 Criterion	Pass/Fail
Tidal Elevation	0.12 m	Spring range = 1.5 m	8%	<10% of spring range	Pass

Current Speed (at A1, A2, A3)	0.08–0.15 m/s	During flow >0.2 m/s	9–17%	<10–20% of peak speed	Pass
Current Direction (at A1, A2, A3)	12°–18°	During flow >0.2 m/s	—	<20°	Pass

5.3 Prediction of Marine Impacts

Based on the earlier understanding stated in **Section 5.1** (Hydrodynamic Impact Assessment Methodology), the impact assessment has been carried out under the following main categories:

Construction stage:

Section 5.4 – Sediment Plume and Sedimentation Impact

Operational stage:

Section 5.5 – Hydrodynamic Impact

Section 5.6 – Sedimentation Impact

5.4 Sediment Plume and Sedimentation Impact During Construction

Primary construction access will be via sea, with a barge transported by tugboat to deliver construction materials and equipment via the temporary bunds to the slope stabilisation worksites. There will two construction access, one to service Site A and another to service Site B, C1 and C2 (**Figure 5-5**). Barge movements are expected to occur no more than twice daily during high tide under a worst-case scenario, and the barge may be stationed at the bund over a period of three to four days at one time, using spud-down piles throughout the construction phase. The temporary bund and access paths will be removed upon completion, with no dredging or excavation required. Site preparation and rock placement are not expected to significantly disturb the seabed or generate notable sediment plumes. However, tugboat manoeuvring during loading and unloading may result in localised sediment resuspension in shallow areas due to propeller wash, with potential effects on nearby sensitive receptors, including coral reefs, seagrass meadows, and recreational beaches if not properly managed.

Figure 5-5 Proposed construction access

NParks' BIA 2024 [1] has established tolerance limits for coral reefs and seagrasses. Tolerance limits related to coral reefs and seagrass receptors including its tolerance to suspended sediment and sedimentation as listed from **Table 5-3** to **Table 5-6**.

Table 5-3 Impact severity matrix for SSC impact to coral reefs

Severity	Definition
No Impact	Excess SSC >5mg/L for less than 5% of the time OR Excess SSC <5mg/L
Slight Impact	Excess SSC >5mg/L for 5 to 20% of the time OR Excess SSC >10mg/L for less than 5% of the time
Minor Impact	Excess SSC > 5mg/L for more than 20% of the time OR Excess SSC > 10mg/L for less than 20% of the time
Moderate impact	Excess SSC >10mg/L for more than 20% of the time OR Excess SSC >25mg/L for more than 5% of the time
Major Impact	Excess SSC >25mg/L for more than 20% of the time OR Excess SSC >100mg/L for more than 1% of the time

Table 5-4 Impact severity matrix for SSC impact to seagrass

Severity	Definition
No Impact	Excess SSC >5mg/L for less than 20% of the time OR Excess SSC <5mg/L
Slight Impact	Excess SSC >5mg/L for more than 20% of the time OR Excess SSC >10mg/L for less than 20% of the time
Minor Impact	Excess SSC >25mg/L for less than 5% of the time
Moderate impact	Excess SSC >25mg/L for more than 20% of the time OR Excess SSC >75mg/L for more than 1% of the time
Major Impact	Excess SSC >75mg/L for more than 20% of the time OR

Table 5-5 Impact severity matrix for sedimentation impact to coral reefs

Severity	Definition
No Impact	Sedimentation <1.7 mm/14 days
Slight Impact	Sedimentation 1.7 - 3.5 mm/14 days
Minor Impact	Sedimentation 3.5 – 7.0 mm/14 days
Moderate impact	Sedimentation 7.0 – 17.5 mm/14 days
Major Impact	Sedimentation >17.5 mm/14 days

Table 5-6 Impact severity matrix for sedimentation impact to seagrass

Severity	Definition
No Impact	Sedimentation <3.5 mm/14 days
Slight Impact	Sedimentation 3.5 – 8.82 mm/14 days
Minor Impact	Sedimentation 8.82 – 17.5 mm/14 days
Moderate impact	Sedimentation 17.5 – 35.0 mm/14 days
Major Impact	Sedimentation >35.0 mm/14 days

5.4.1 Propeller Wash-induced Sediment Plume Modelling

The modelling of propeller wash-induced suspended sediments was carried out with MIKE 21 Mud Transport (MT) module. The model used the construction information (i.e., barge route and frequency, type, temporary access bunds etc.) as input for the simulation to predict the level of impact to the nearby sensitive receptors.

Model Scenarios

The sediment plume was modelled for three scenarios, i.e. northeast monsoon, southwest and inter monsoon, each covered a period of 14 days, a spring-neap tidal cycle. The barge and tugboat enter and leave the site twice daily at high tide, with the tugboat's propeller running throughout loading and unloading. Frequency and type assumptions are detailed in **Table 5-7**.

Table 5-7 Frequency, type and specifications of the barge and tugboat used as model input for the propeller wash assessment

Vessel	LOA (m)	Width (m)	Draft (m)	Propeller Diameter (m)	No. of trips per Day during high tide
Barge	45.0	15.0	2	N/A	2 (total of 3 – 4 hours/day)
Tugboat	20.0	6.0	2	1	2 (total of 3 – 4 hours/day)

Model Outputs

The following statistical descriptors over a 14-day period for northeast, southwest and inter monsoon were obtained:

- Mean and 95th percentile incremental SSC (mg/l)
- Percentage of time SSC concentrations exceeding 5 mg/l, and
- 14-day erosion/sedimentation (mm/14-day).

5.4.2 Propeller Wash-induced Sediment Plume Impact Assessment

This section summarises propeller wash-induced sediment plume model results for suspended sediment concentration and erosion or sedimentation rates.

5.4.2.1 Suspended Sediment

Propeller wash-induced sediment model results are presented in **Figure 5-6** to **Figure 5-8** for northeast monsoon, **Figure 5-9** to **Figure 5-11** for southwest monsoon, and **Figure 5-12** to **Figure 5-14** for inter monsoon. The excess mean SSC is below 5 mg/L during all monsoon. However, the maximum (95th percentile) excess SCC was found elevated near the loading/unloading location due to tugboat propeller activity causing local seabed disturbances. The area between Site A and Site B's parking locations may experience a 5–10 mg/L increase in 95th percentile SSC, but this occurs less than 15% of the time. Areas with incremental SSC above 10 mg/L are mainly near Site A and occurs less than 15% of the time. Most of the other area has no more than a 5 mg/L change, with an incremental SSC above 5 mg/L predicted 0% of the time.

According to the SSC tolerance limits for coral reefs shown in **Table 5-3**, most coral reefs will not be affected by sediment plumes. A few corals near Site A may experience slight impacts during construction, and some specimens could see minor impact during the inter-monsoon period.

Based on the tolerance limits for seagrasses outlined (**Table 5-4**), the incremental SCC remains below 5 mg/L at seagrass area during construction. Accordingly, no sediment plume impacts to seagrass are anticipated.

Generally, the barge movement at Site B is anticipated to have less impact compared to Site A, as the greater depth at Site B lowers the potential for seabed interaction and subsequent sediment resuspension.

Additionally, water quality at Siloso Beach will remain unaffected by sediment plume, as the predicted increase in SSC during construction is expected to be below 0.3 mg/L.

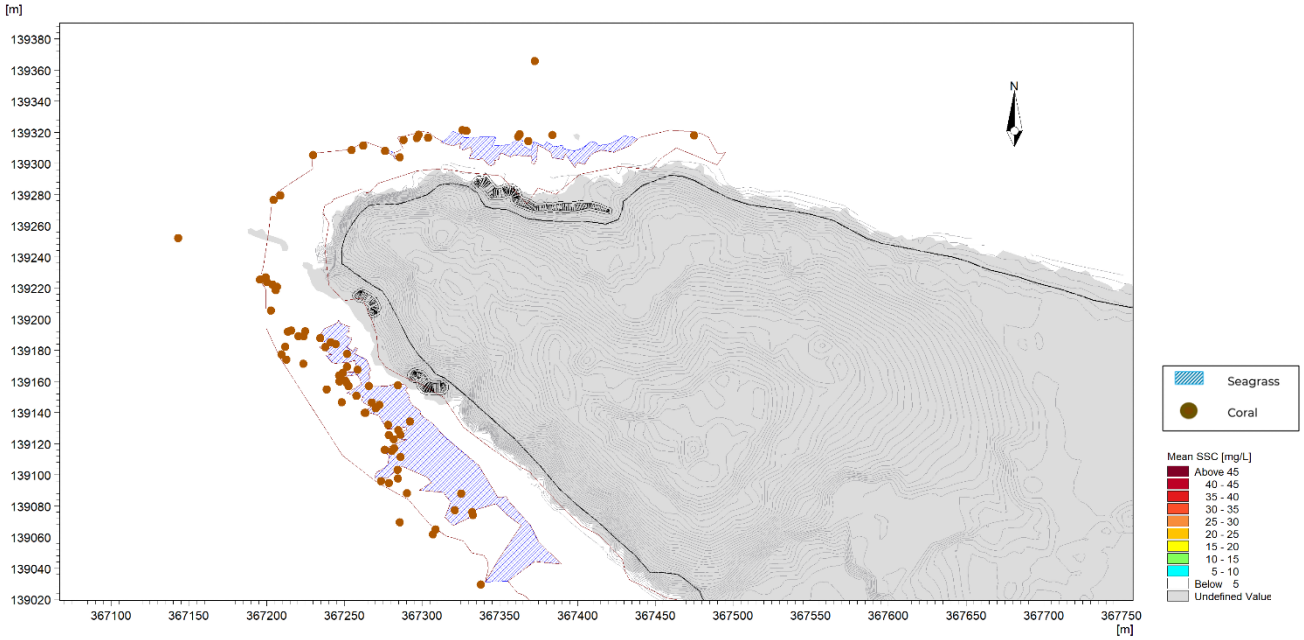


Figure 5-6 Mean incremental SSC from the barge and tugboat activities during construction, northeast monsoon

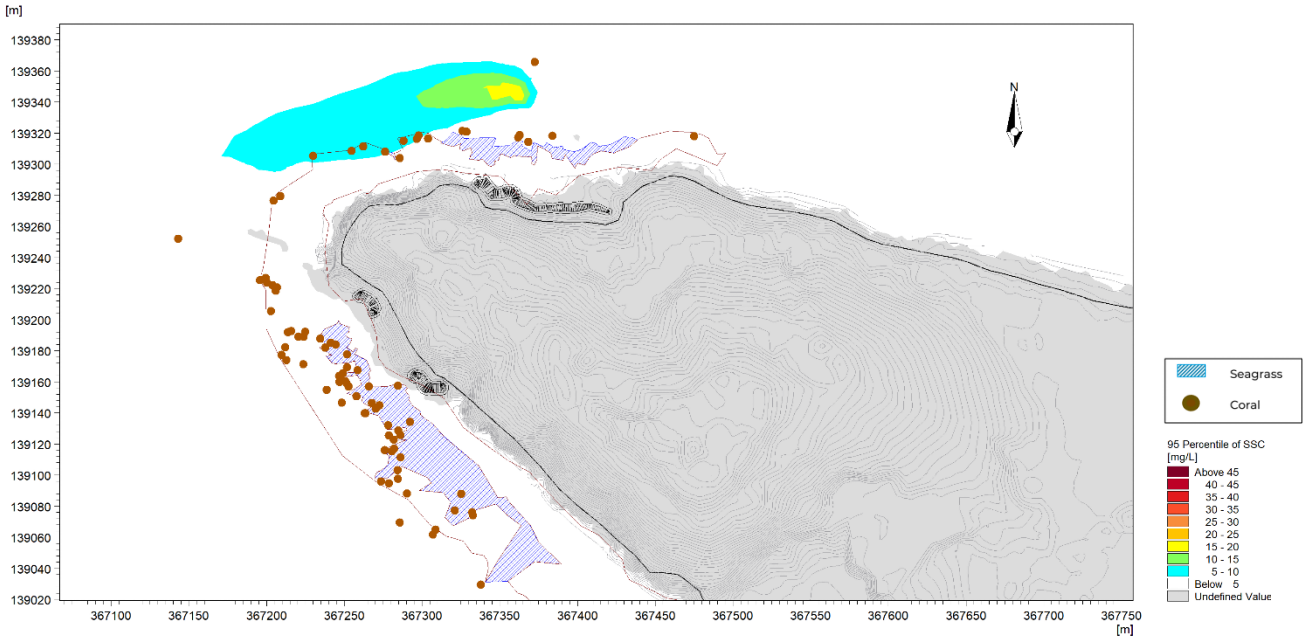


Figure 5-7 95th percentile incremental SSC from the barge and tugboat activities during construction, northeast monsoon

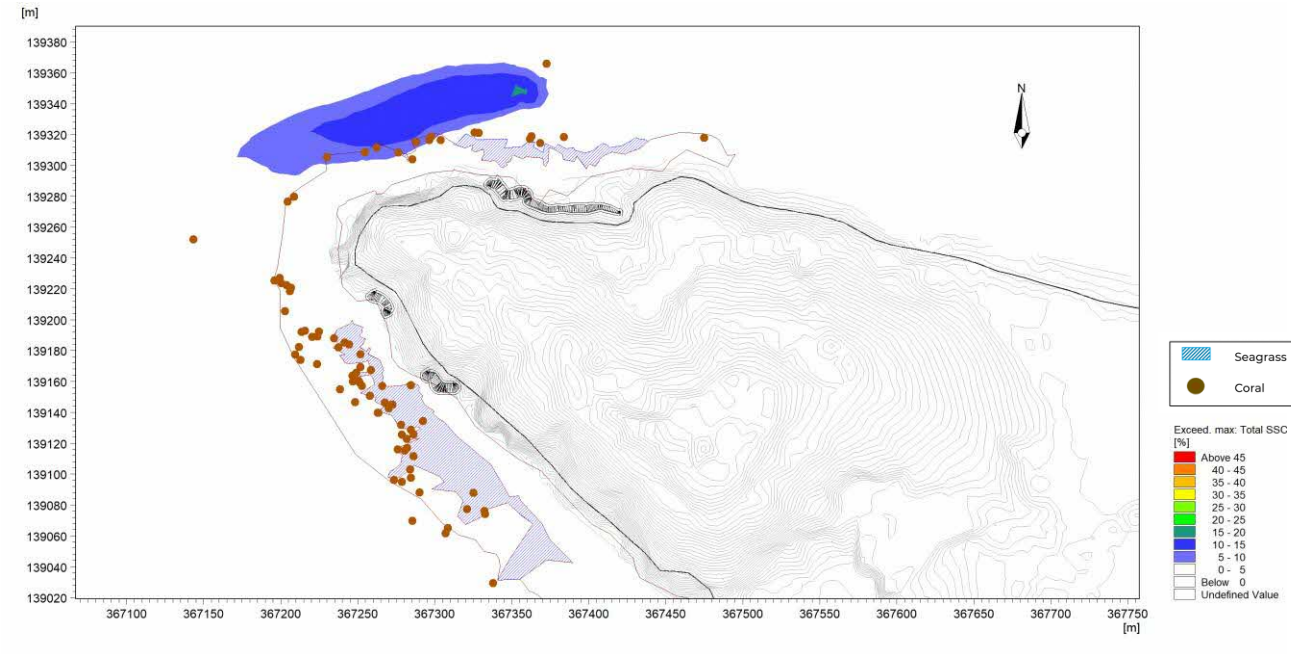


Figure 5-8 Percentage of time in exceedance of 5 mg/l for SSC from the barge and tugboat activities during construction, northeast monsoon

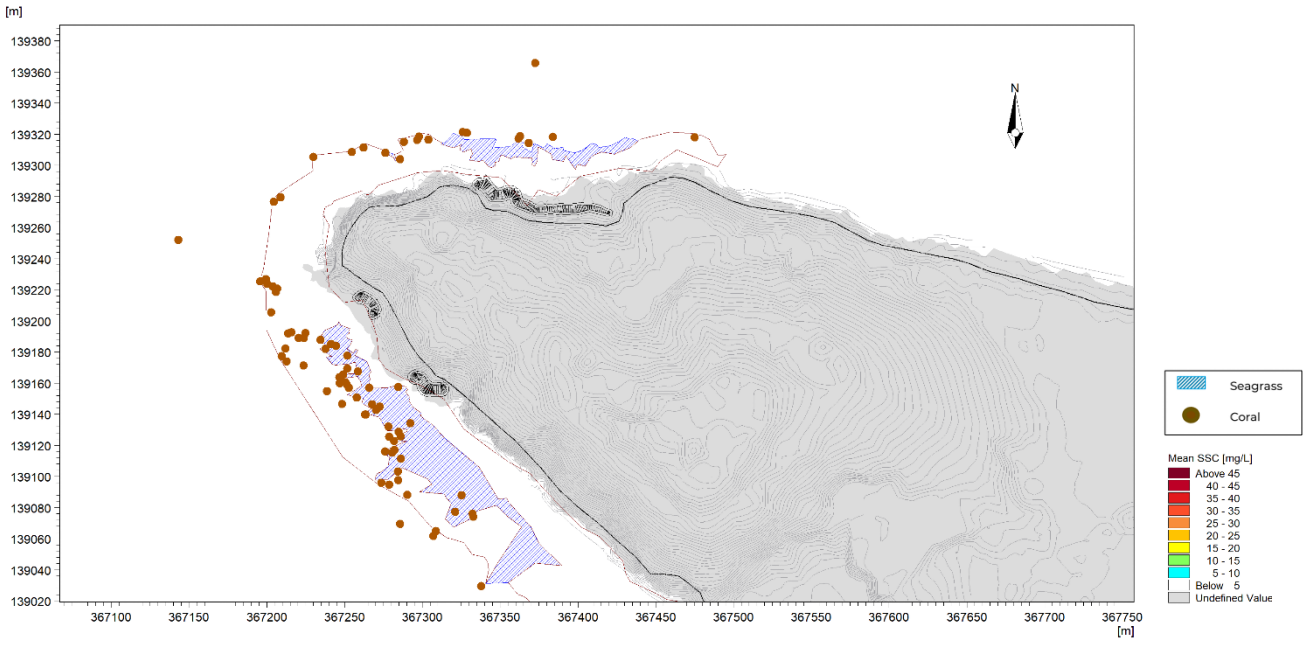


Figure 5-9 Mean incremental SSC from the barge and tugboat activities during construction, southwest monsoon

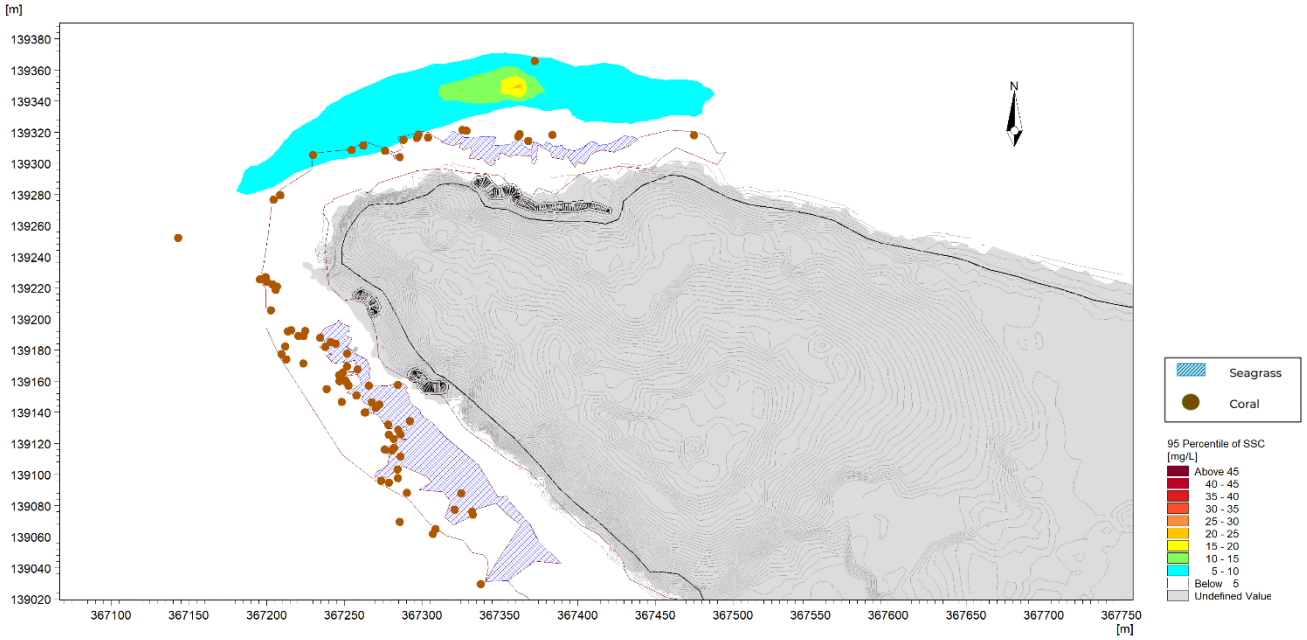


Figure 5-10 95th percentile incremental SSC from the barge and tugboat activities during construction, southwest monsoon

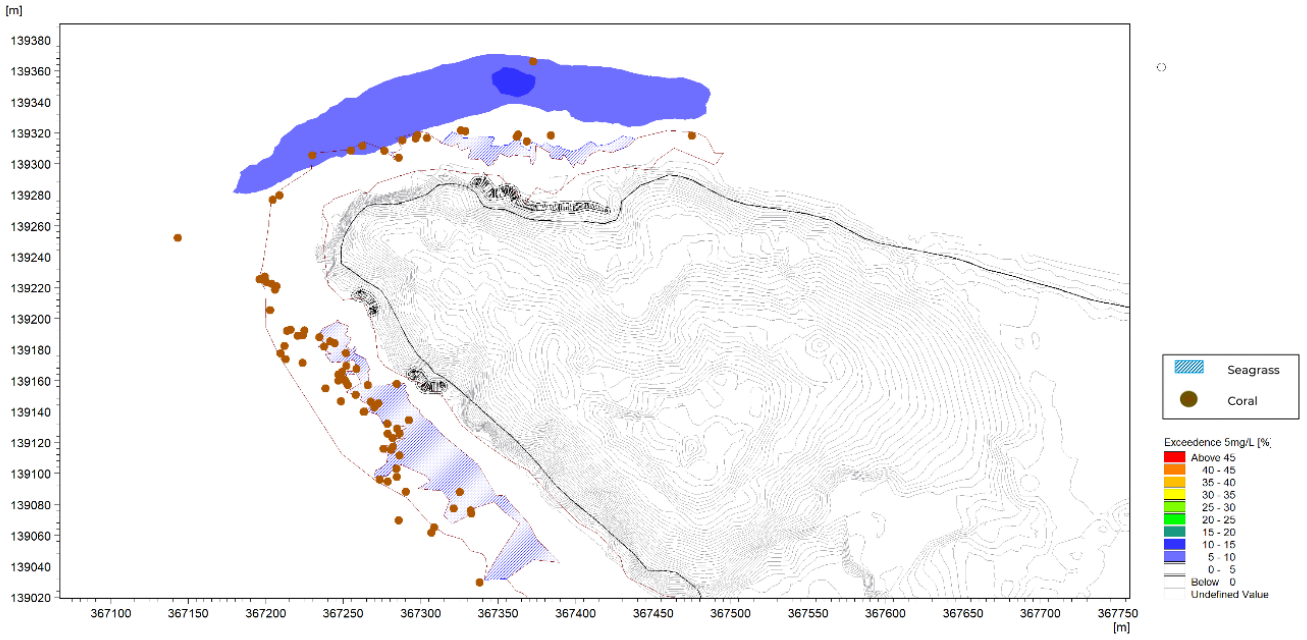


Figure 5-11 Percentage of time in exceedance of 5 mg/l for SSC from the barge and tugboat activities during construction, southwest monsoon

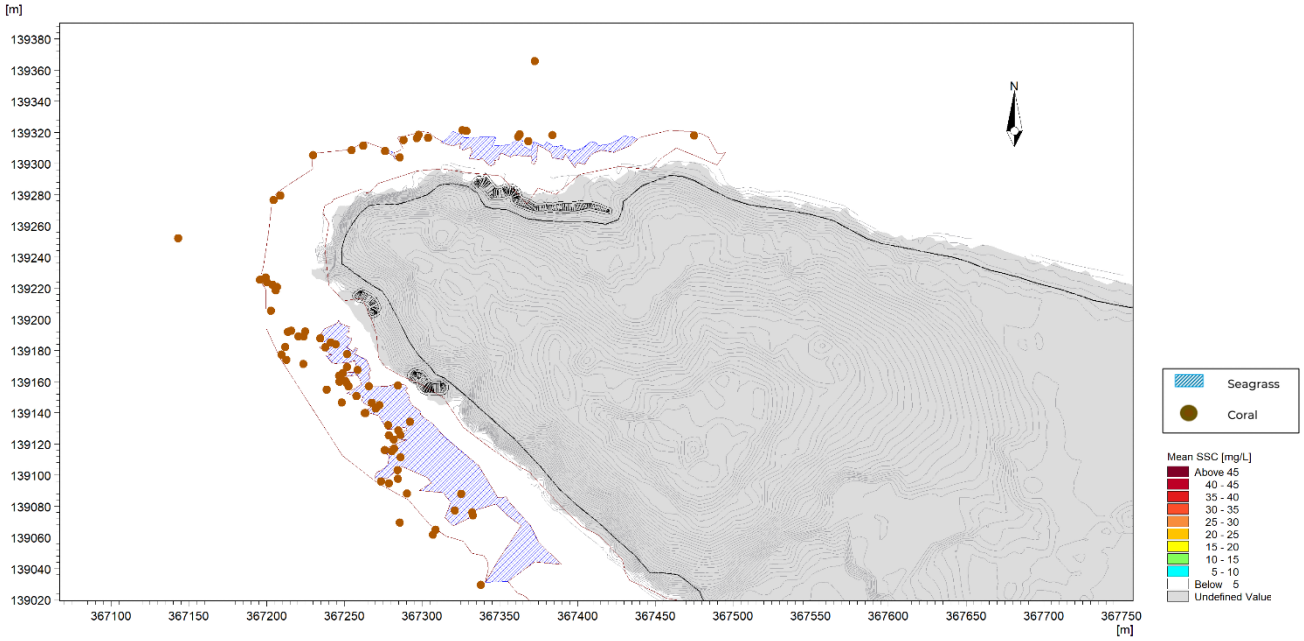


Figure 5-12 Mean incremental SSC from the barge and tugboat activities during construction, inter monsoon

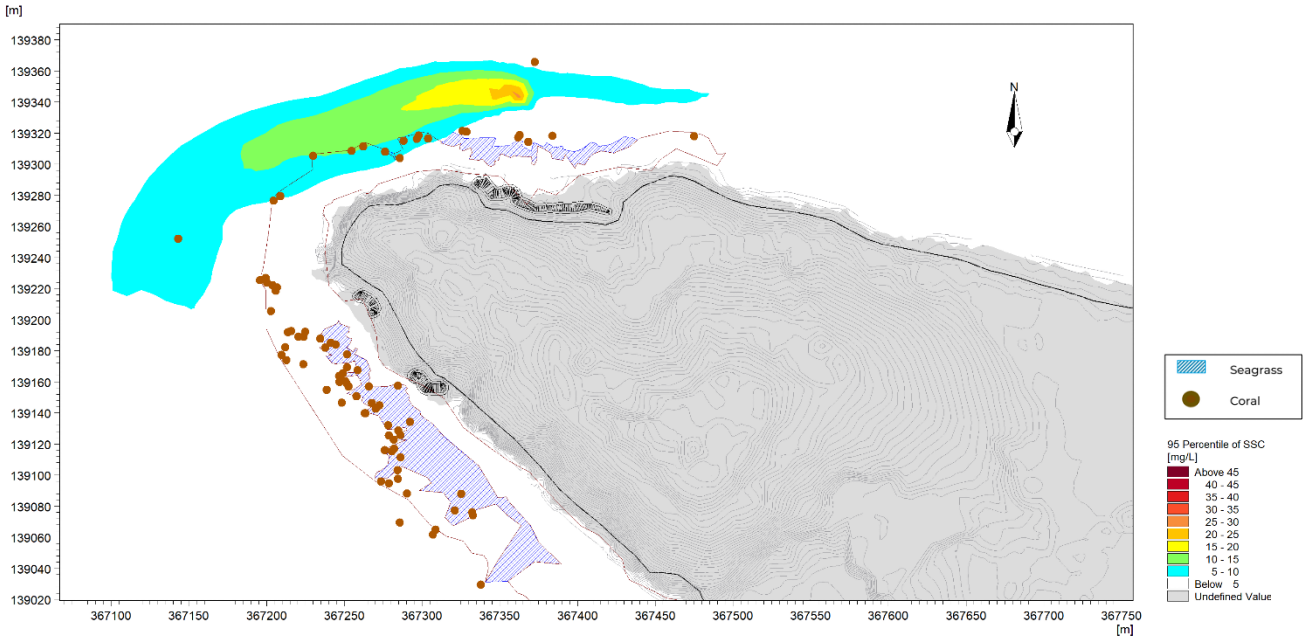


Figure 5-13 95th percentile incremental SSC from the barge and tugboat activities during construction, inter monsoon

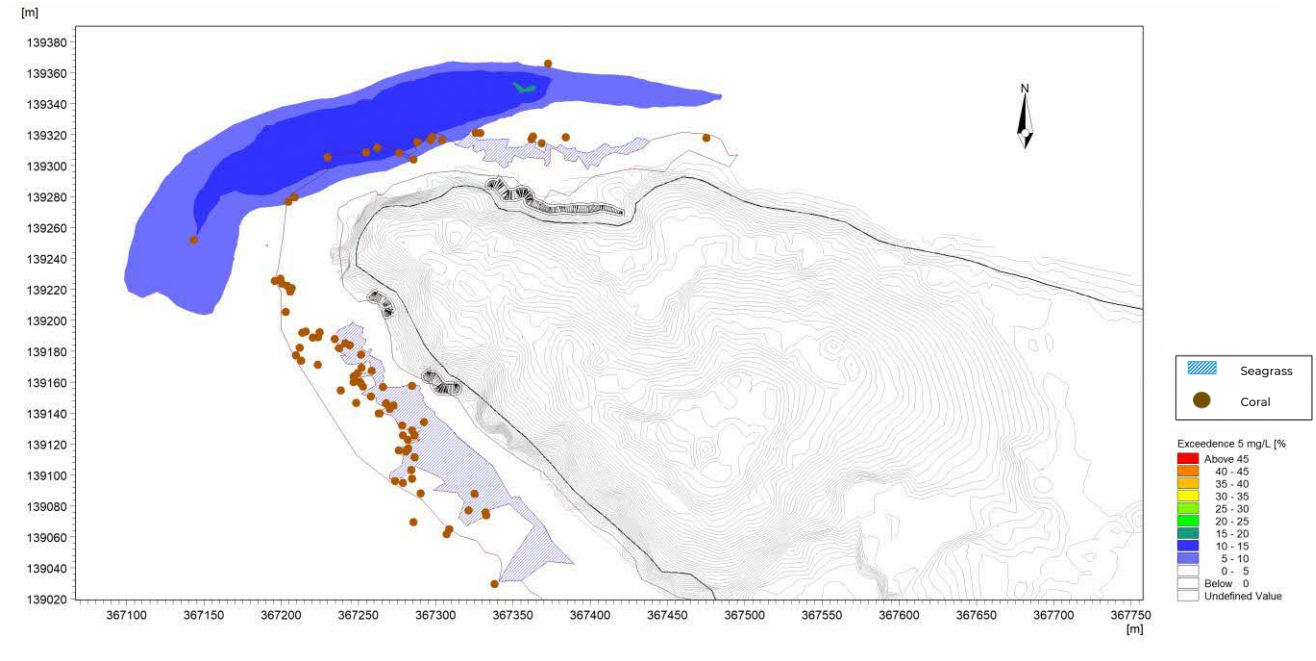


Figure 5-14 Percentage of time in exceedance of 5 mg/l for SSC from the barge and tugboat activities during construction, inter monsoon

5.4.2.2 Erosion and Sedimentation

Sediment-driven propeller wash can cause erosion or sedimentation in areas beyond the site. Erosion and sedimentation can be assessed in terms the total bed thickness change (mm/14 days).

Figure 5-15 to **Figure 5-17** illustrate changes in total bed thickness due to barge and tugboat activities during the northeast, southwest, and inter monsoon periods. Positive values represent sedimentation whereas negative values indicate erosion. Localized erosion occurs near barge parking locations at Sites A and Site B. Erosion magnitude decrease with distance from shore toward the deeper sea area. Eroded sediment material will be transported away and redeposited nearby. However, most corals in the area will experience minimal sedimentation, with predicted rates below 1.7 mm/14 days. Based on sedimentation tolerance limits indicated in **Table 5-5**, most of corals will not be impacted by sedimentation. Only one coral specimen near Site A's transport route and parking area may experience minor sedimentation impact.

There will be no sedimentation impact on seagrasses around the site as predicted sedimentation rates are below 1.7 mm/14-days, which indicates no sedimentation impact according to **Table 5-6**. No sedimentation impact on seagrasses is expected at the site, as predicted rates are under 1.7 mm/14 days, meeting the criteria of 'No impact' in **Table 5-6**.

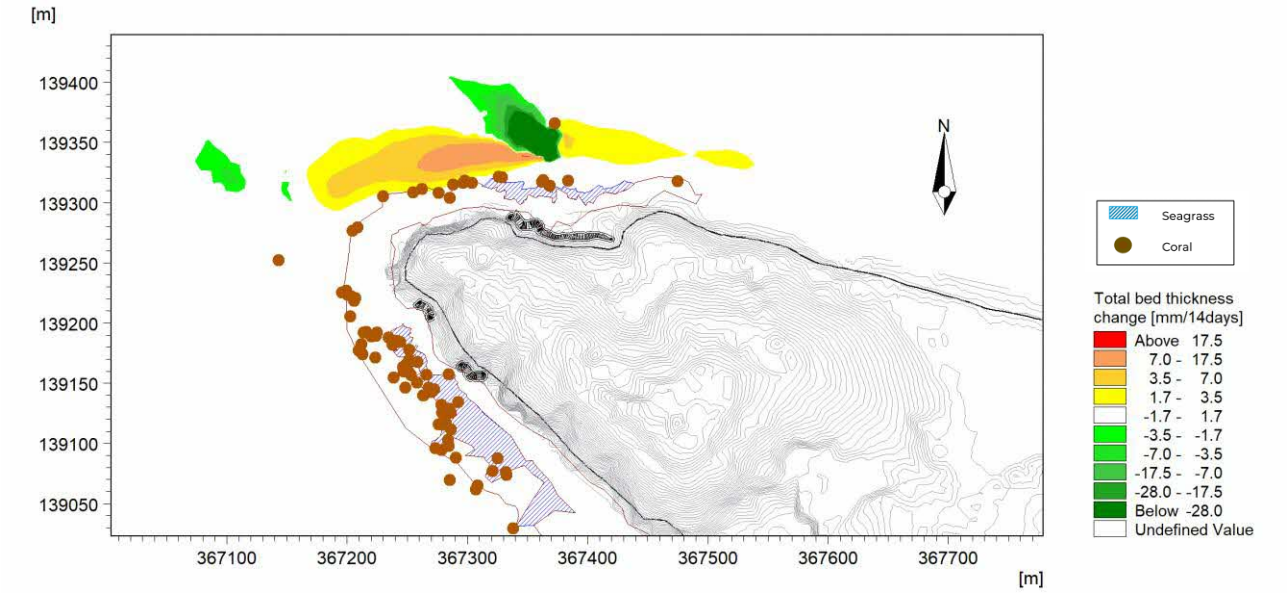


Figure 5-15 Total bed thickness change from the barge and tugboat activities during construction, northeast monsoon

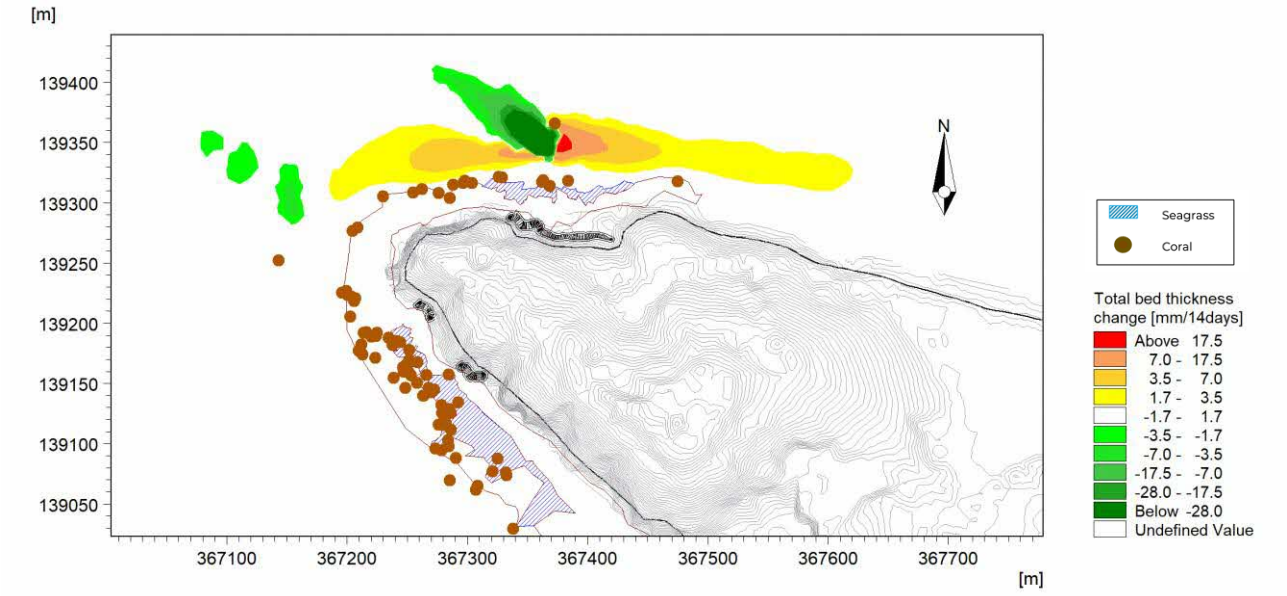


Figure 5-16 Total bed thickness change from the barge and tugboat activities during construction, southwest monsoon

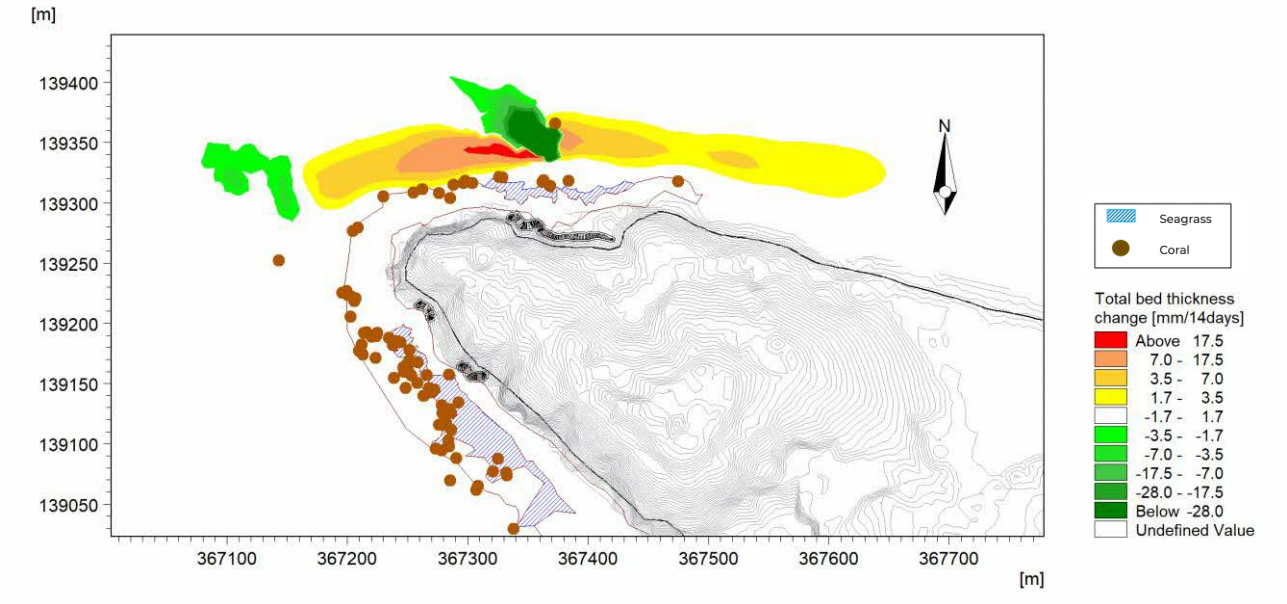


Figure 5-17 Total bed thickness change from the barge and tugboat activities during construction, inter monsoon

5.5 Hydrodynamic Impact During Operation

This section presents the quantitative assessment results for the hydrodynamic impact arising from the operational phase of the project.

The hydrodynamic model applied to the Study Area describes the effect of the revetments proposed at Site A, Site C1 and Site C2 on the sea current regime.

Model simulations were performed using a full 14-day spring-neap tidal cycle for representative northeast, southwest and inter monsoon. Model scenarios included both baseline (pre-development) and operational phases of the project (up to complete construction of the revetments).

Changes to currents were analysed based on the following evaluation criteria:

- Changes to the mean and maximum (i.e. 95th percentile) current speeds
- Changes to representative current speeds.

5.5.1 Changes to 95th Percentile Current Speed

Figure 5-18 and **Figure 3-19** show the maximum (95th percentile) currents during the baseline and operational phases under southwest monsoon conditions, while **Figure 5-20** displays the differences in 95th percentile current speeds between these two phases. For the northeast and inter-monsoon periods, **Figure 5-21** and **Figure 5-22** present the differences in 95th percentile current speeds between the baseline and operational phases.

Model results indicate that changes to the maximum (95th percentile) current speed at the site and surrounding areas are minimal, generally less than ±0.1 m/s. At the navigation channel, coral reefs and seagrass meadows, there is minimal to no change predicted in the 95th percentile current speeds. This is because the proposed revetments will be constructed further inland and designed to follow the existing topography, thereby minimising significant interactions with longshore currents. Minor decrease in current speed, usually less than 0.2 m/s, are seen only near the proposed revetments. These

reductions are not expected to have any negative hydrodynamic impacts on the revetments or the areas around them.

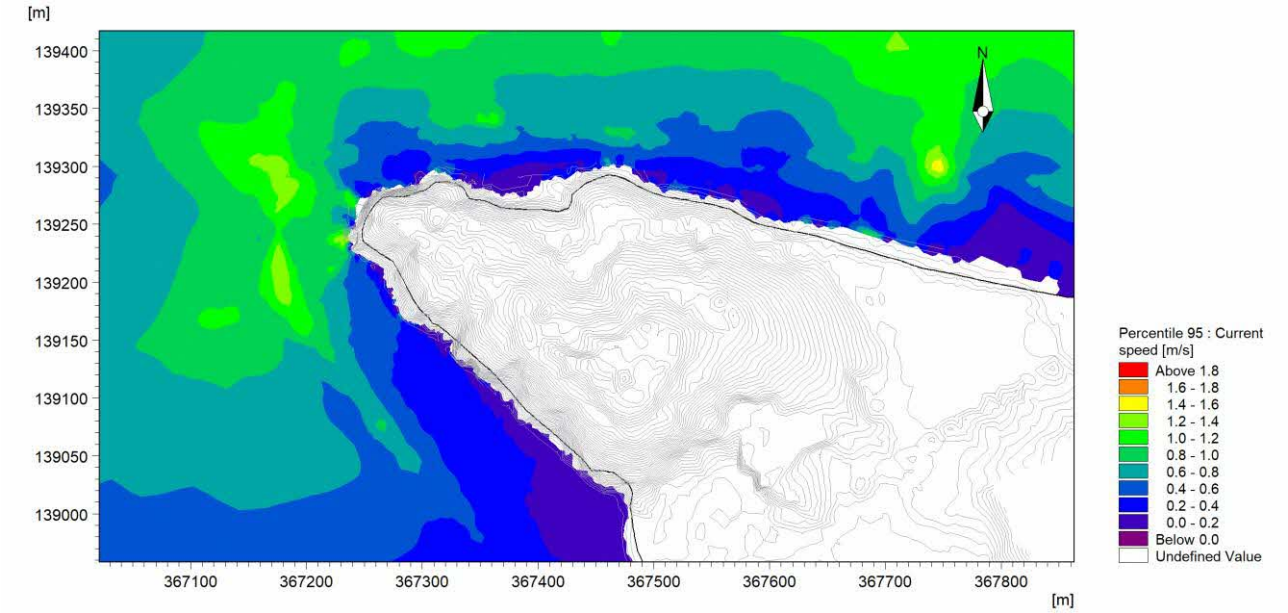


Figure 5-18 95th percentile current speed for southwest monsoon conditions: baseline

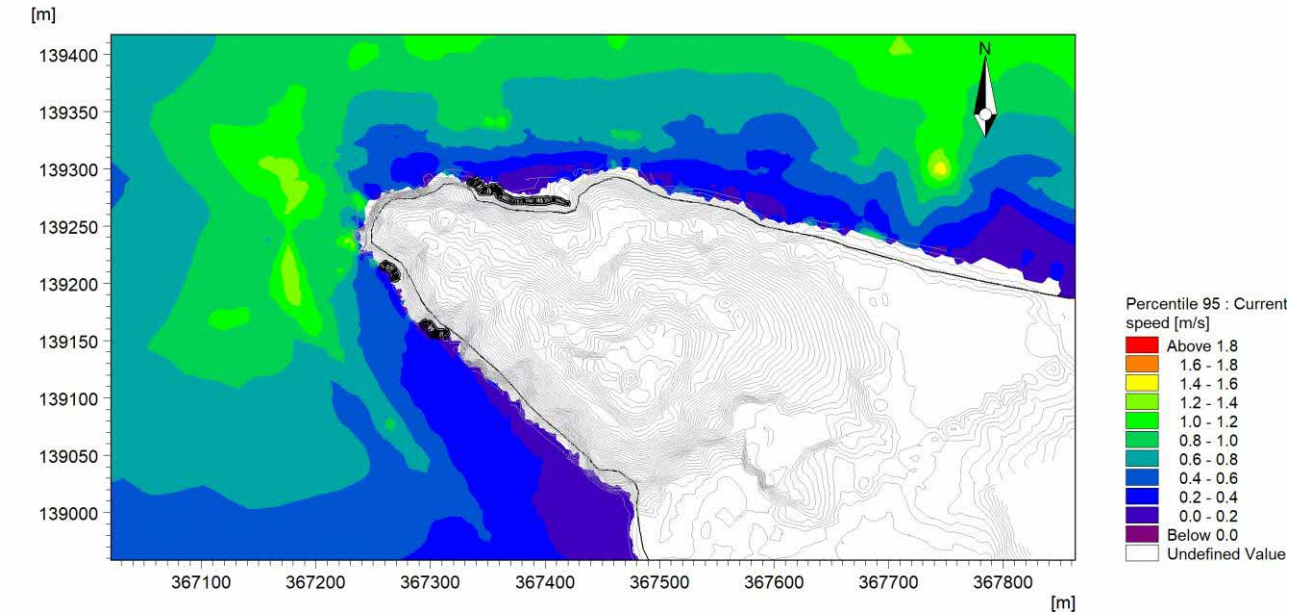


Figure 5-19 95th percentile current speed for southwest monsoon conditions: operation phase

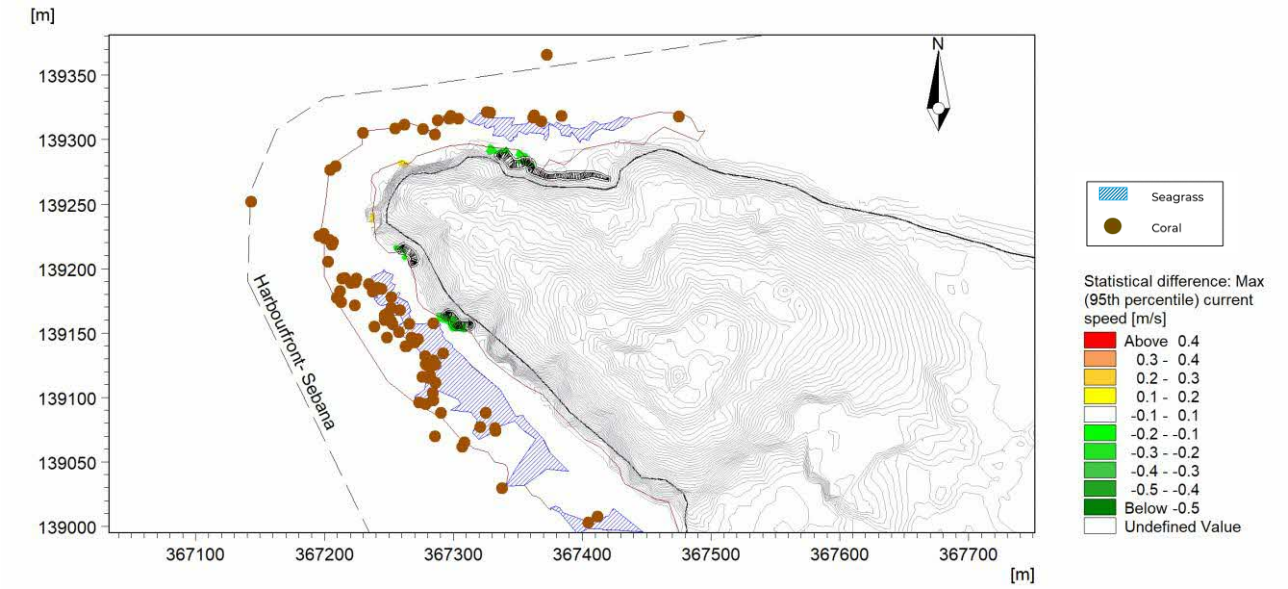


Figure 5-20 Difference in 95th percentile current speed for southwest monsoon conditions between baseline and operation phases

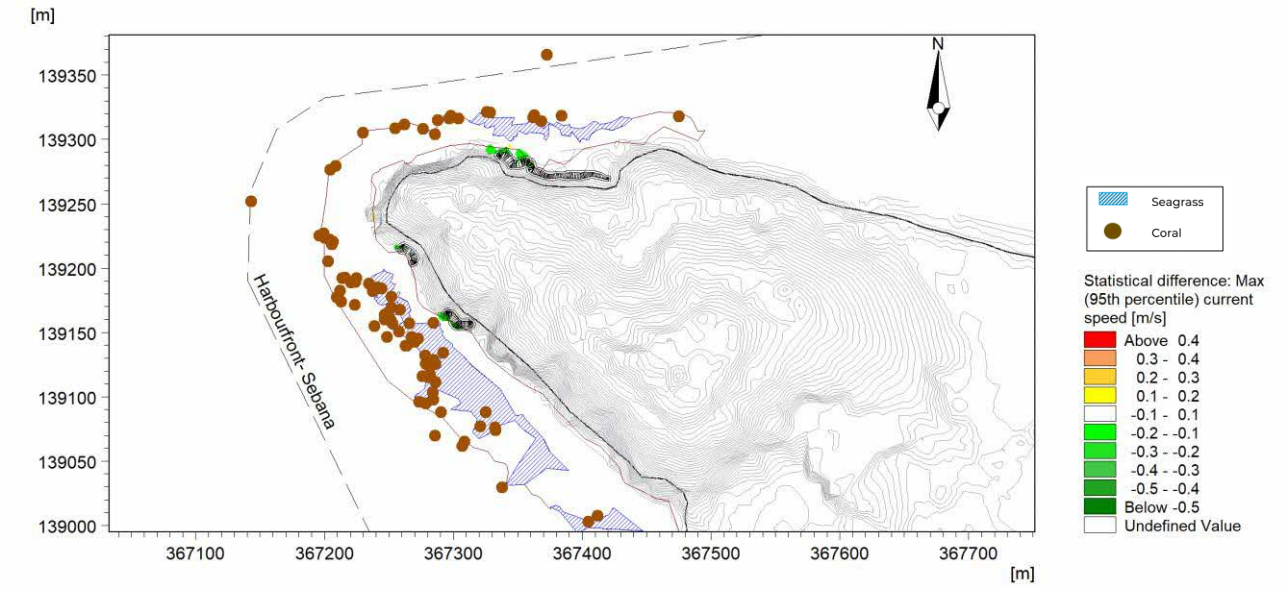


Figure 5-21 Difference in 95th percentile current speed for northeast monsoon conditions between baseline and operation phases

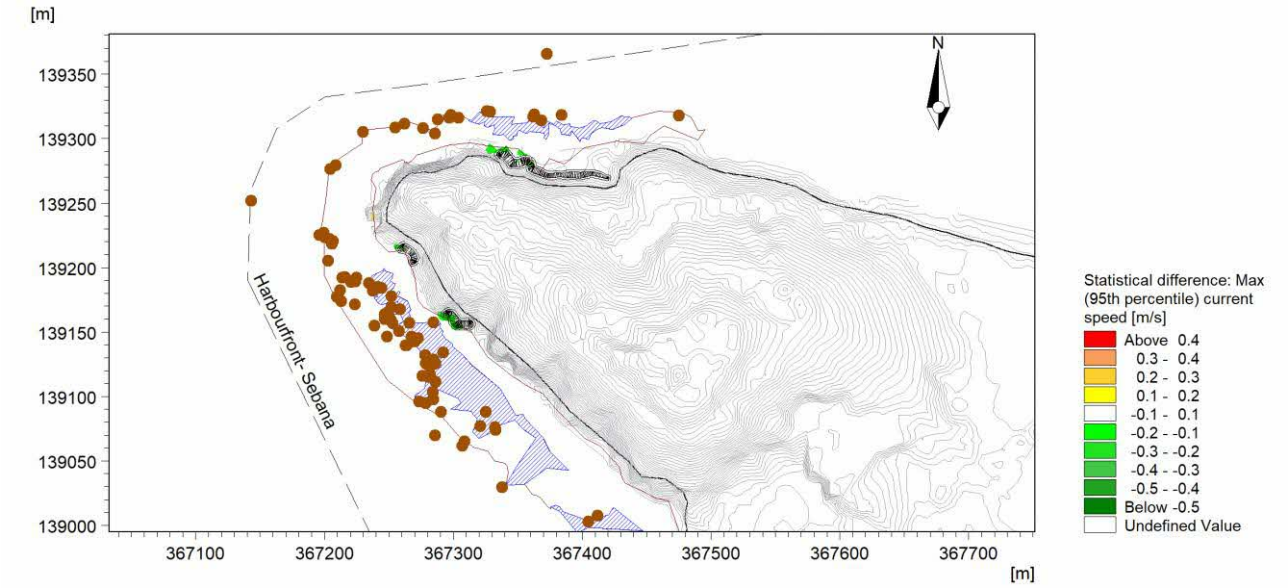


Figure 5-22 Difference in 95th percentile current speed for inter monsoon conditions between baseline and operation phases

5.5.2 Changes to Mean Current Speed

The mean currents for baseline and the operation phase over southwest monsoon conditions are depicted in **Figure 5-23** and **Figure 5-24**, and the differences in the mean current speeds between baseline and the construction phase is presented in **Figure 5-25**. For the northeast and inter monsoon periods, **Figure 5-26** and **Figure 5-27** present the differences in mean current speeds between the baseline and operational phases.

As with the 95th percentile current speed, there are expected to be minimal changes in mean current speed at the navigation channel, coral reefs, and seagrass meadows. Only a few localised reductions in current speed are observed near the proposed revetments, but these are not anticipated to cause any negative hydrodynamic impacts on the revetments or their immediate vicinity.

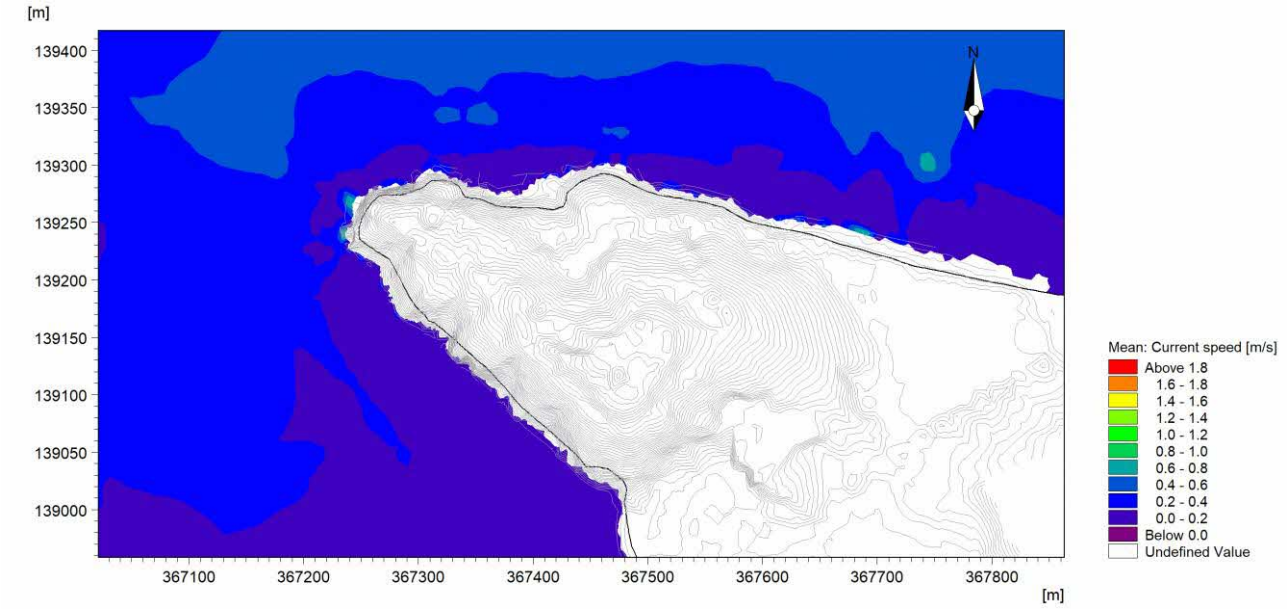


Figure 5-23 Mean current speed for southwest monsoon conditions: baseline

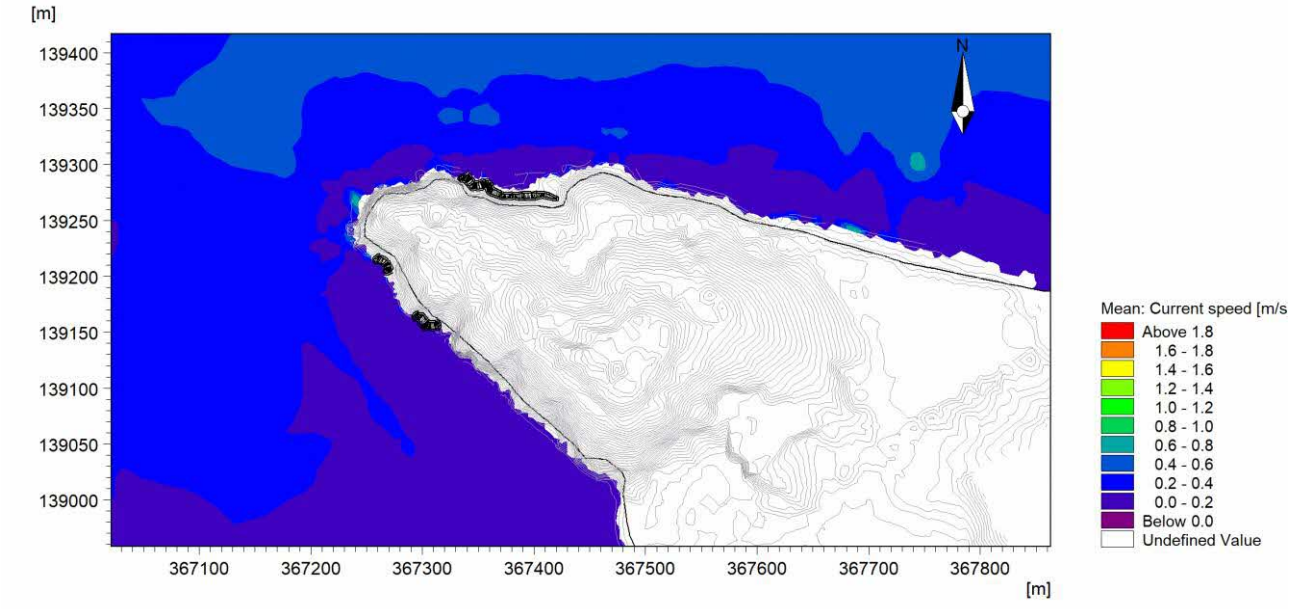


Figure 5-24 Mean current speed for southwest monsoon conditions: operation phase

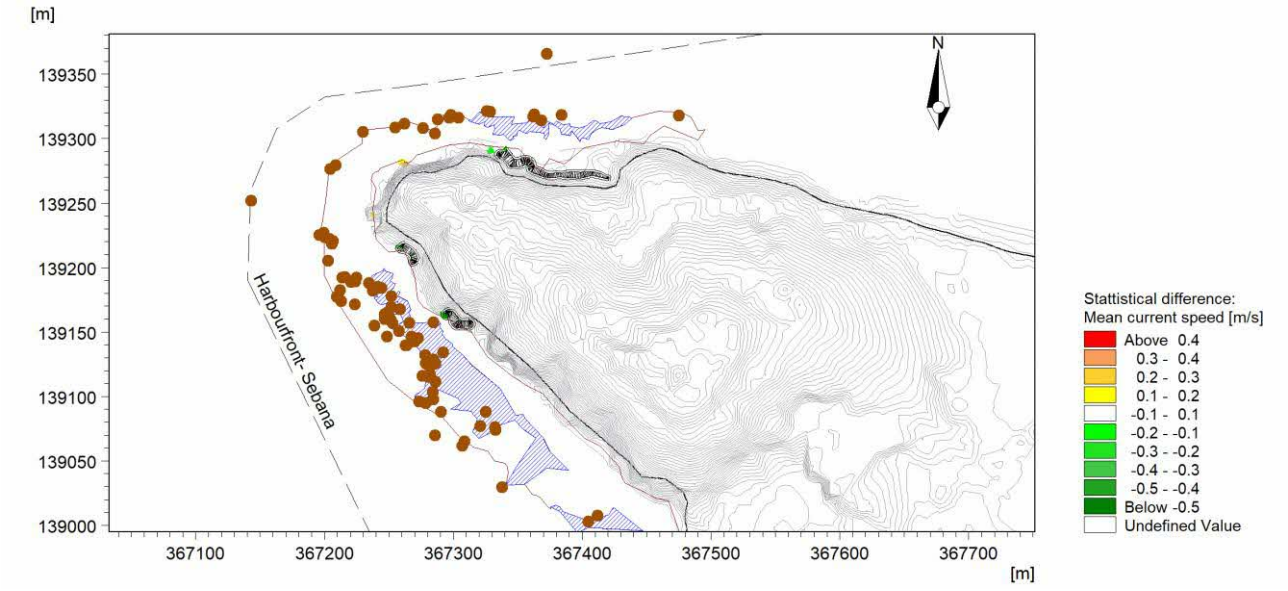


Figure 5-25: Difference in mean current speed for southwest monsoon conditions between baseline and operation phases

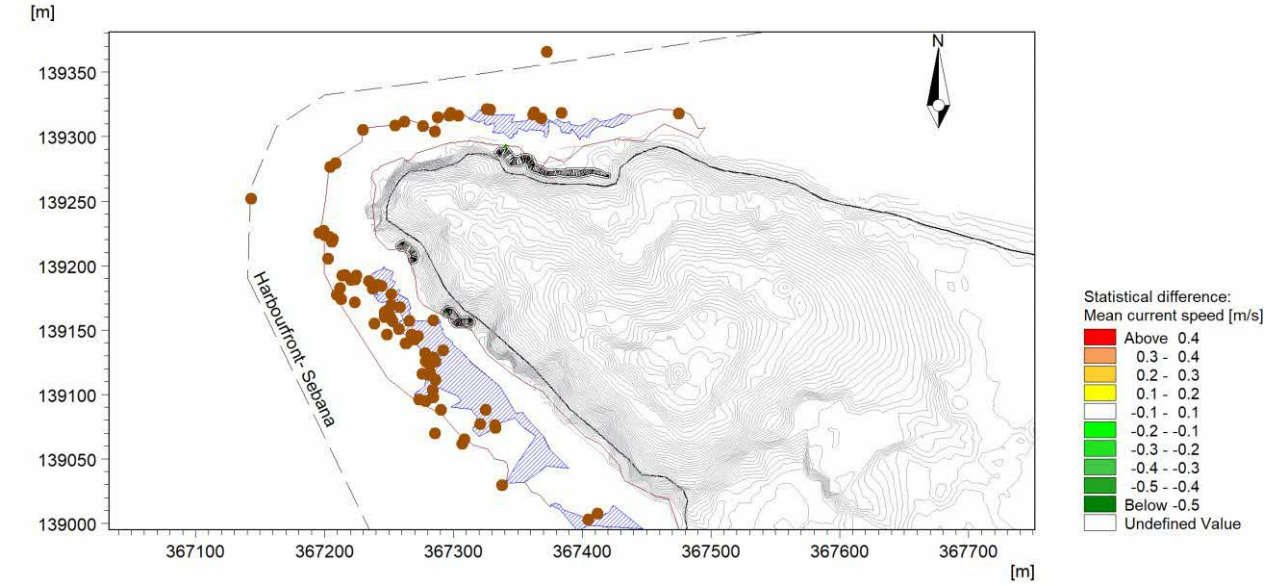


Figure 5-26 Difference in mean current speed for northeast monsoon conditions between baseline and operation phases

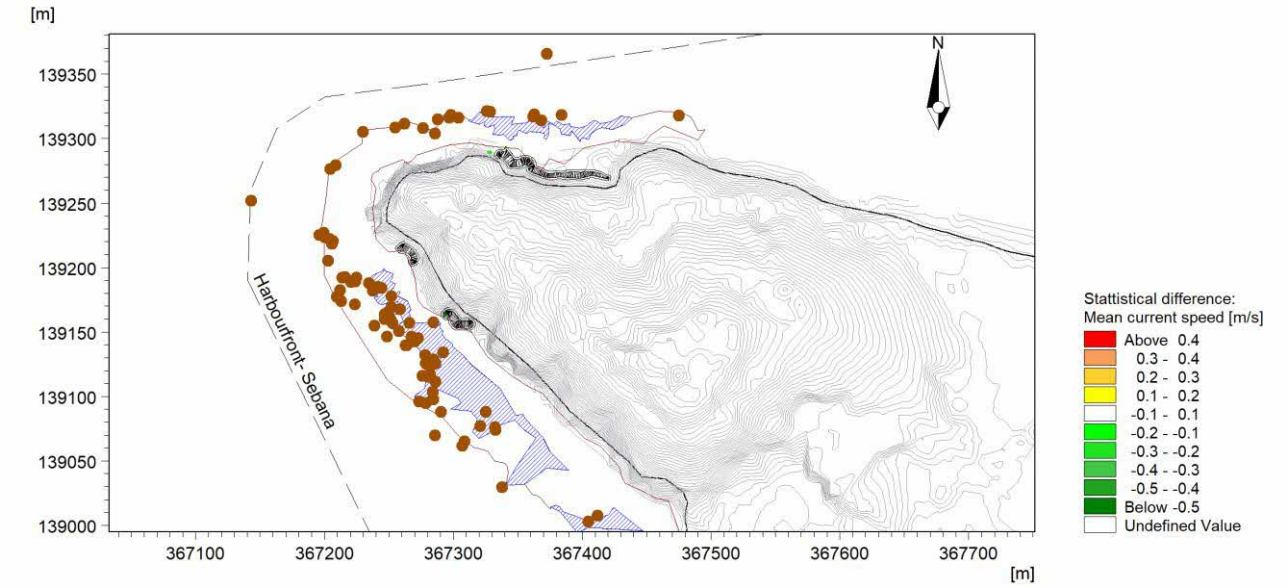


Figure 5-27 Difference in mean current speed for inter monsoon conditions between baseline and operation phases

5.5.3 Changes to 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 representative current speed is provided in this section. This alternative is meant to provide additional understanding of the scale of change in the current speeds, with relevance to navigation.

Figure 5-28 and **Figure 5-29** present the baseline and operation phases for slack water conditions for southwest monsoon, defined as current speeds below 0.5 knots (~ 0.25 m/s). **Figure 5-30** to **Figure 5-32** illustrate slack water duration changes across southwest, northeast, and inter monsoon. Results indicate that slack water duration within the navigation channel and at sensitive ecological sites, such as coral reefs and seagrasses, will change by less than 1% during all monsoon periods. There will be some localised changes in slack water duration found at the proposed revetments with less than 8% of the time. These changes will not impact navigation activities or any nearby ecological receptors.

Additionally, **Figure 5-33** and **Figure 5-34** present the exceedance of current speeds greater than 1.5 knots (~ 0.75 m/s) for baseline and operational phases. **Figure 5-35** to **Figure 5-37** illustrate potential changes in these durations across southwest, northeast, and inter monsoon periods. The predicted change is within ±1% of the time, indicating a negligible effect on current speeds over 1.5 knots in the Study Area.

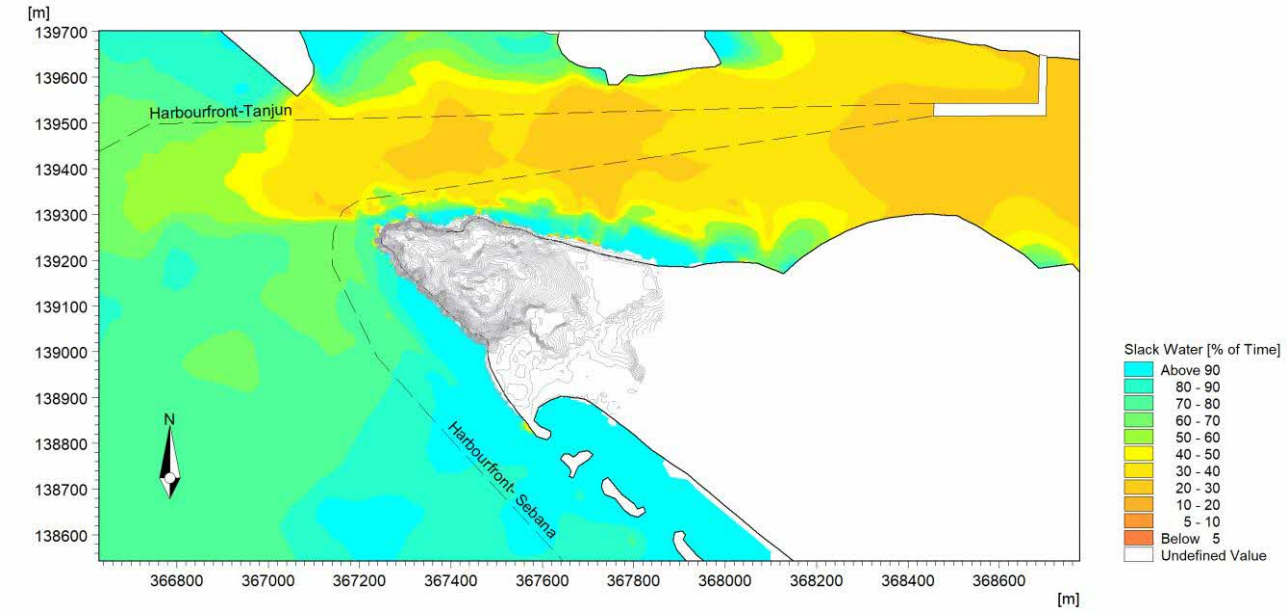


Figure 5-28 Slack water exceedance for southwest monsoon: baseline phase

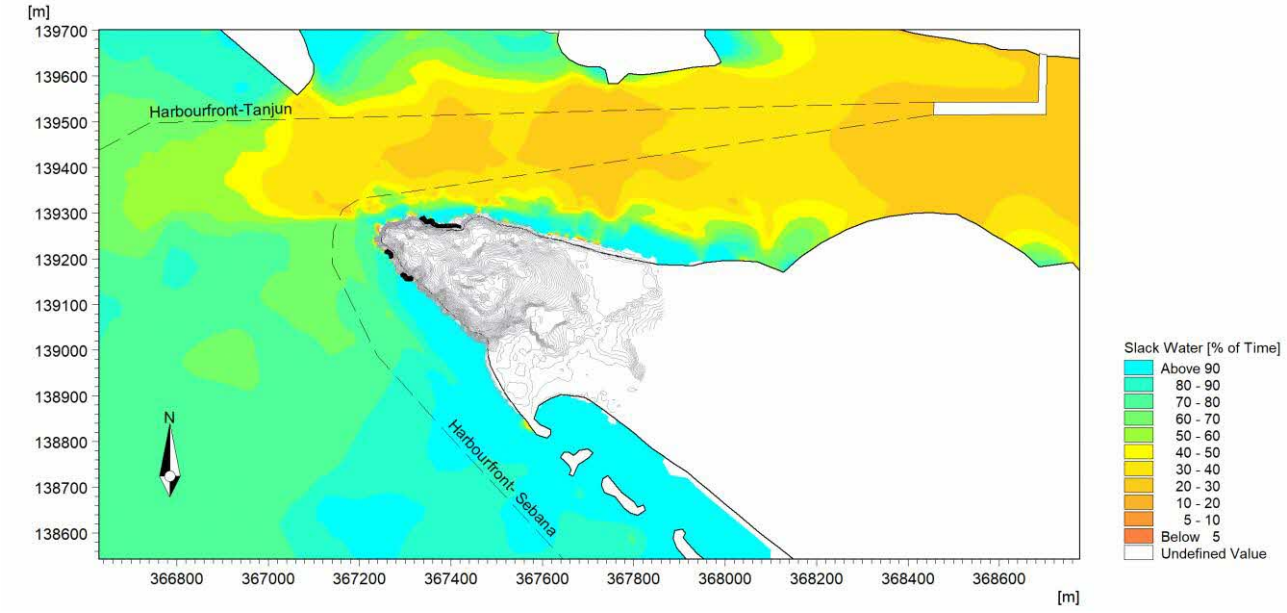


Figure 5-29 Slack water exceedance for southwest monsoon: operation phase

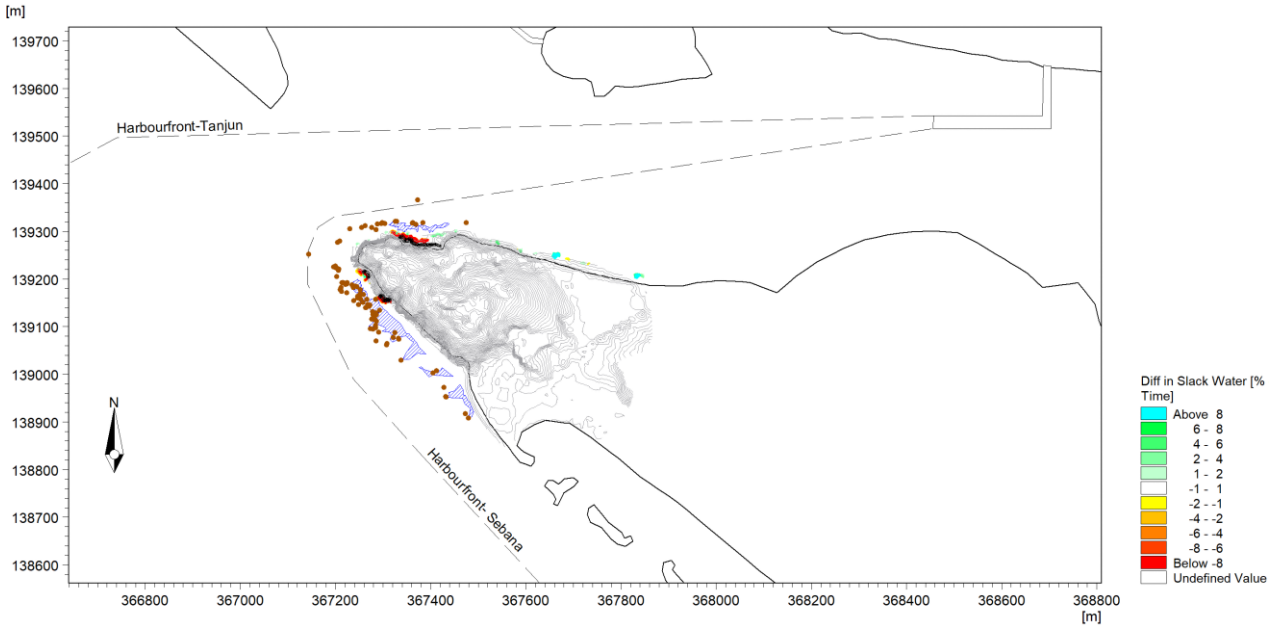


Figure 5-30 Difference in duration of exceedance for slack water conditions between baseline and operation phase for southwest monsoon

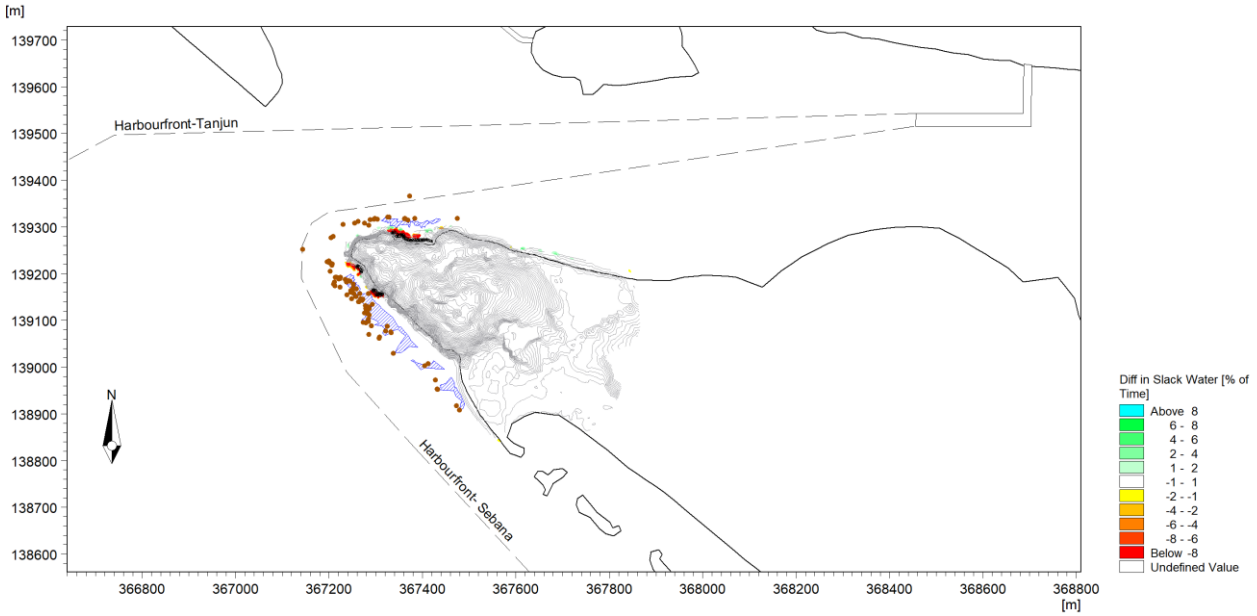


Figure 5-31 Difference in duration of exceedance for slack water conditions between baseline and operation phase for northeast monsoon

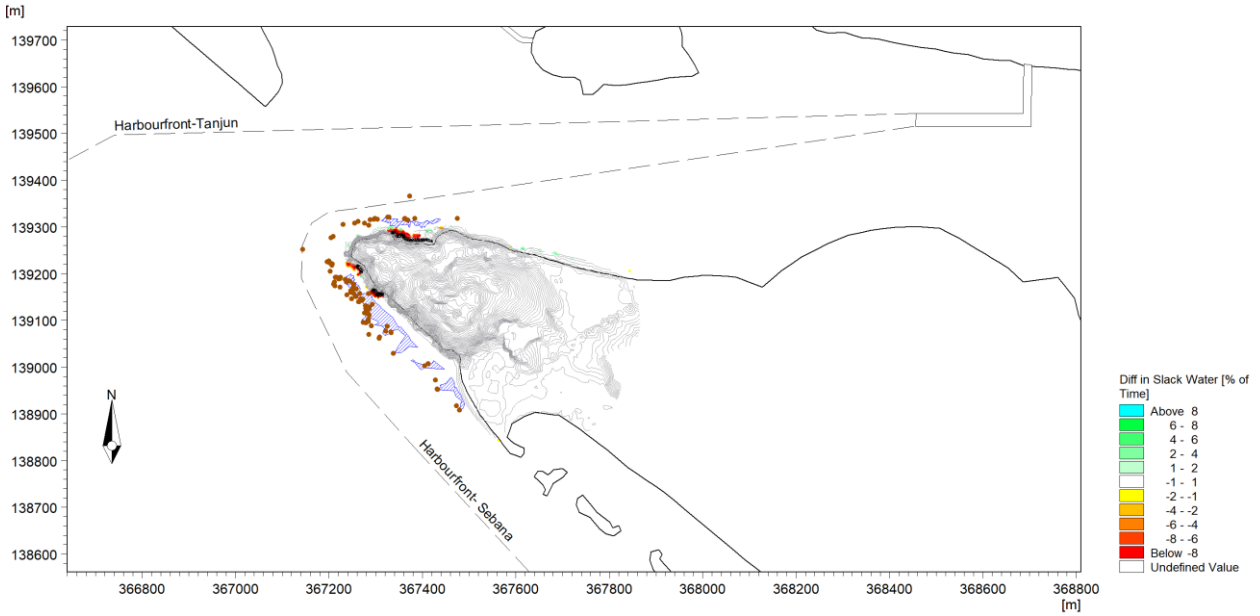


Figure 5-32 Difference in duration of exceedance for slack water conditions between baseline and operation phase for inter monsoon

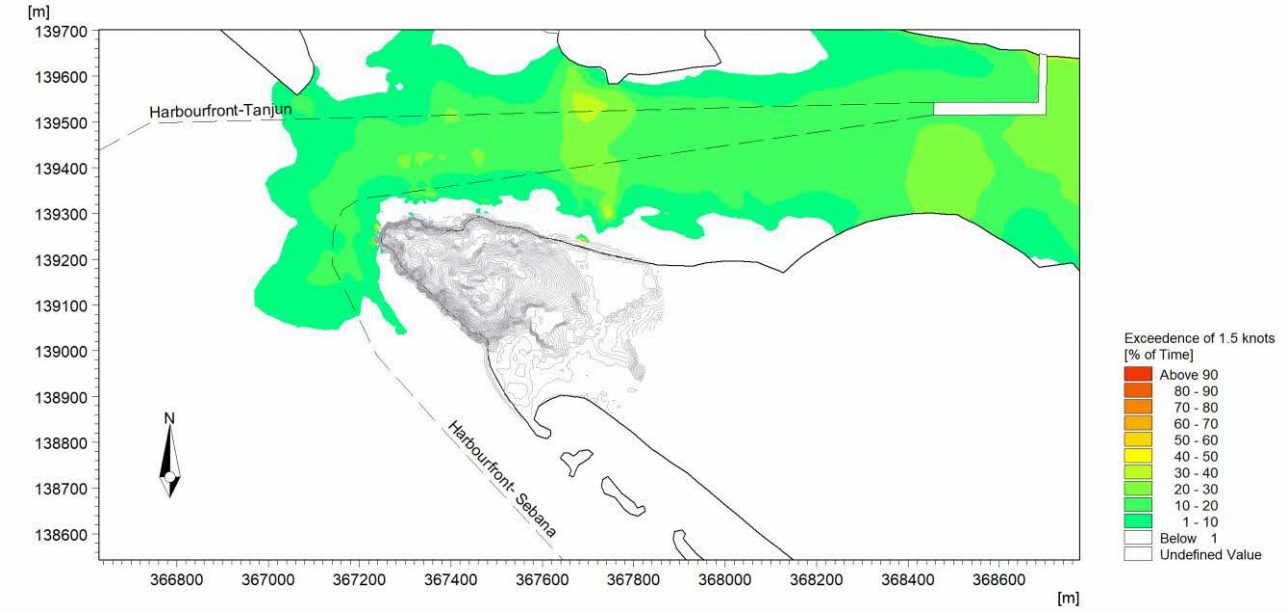


Figure 5-33 Exceedance of 1.5 knot for southwest monsoon: Baseline

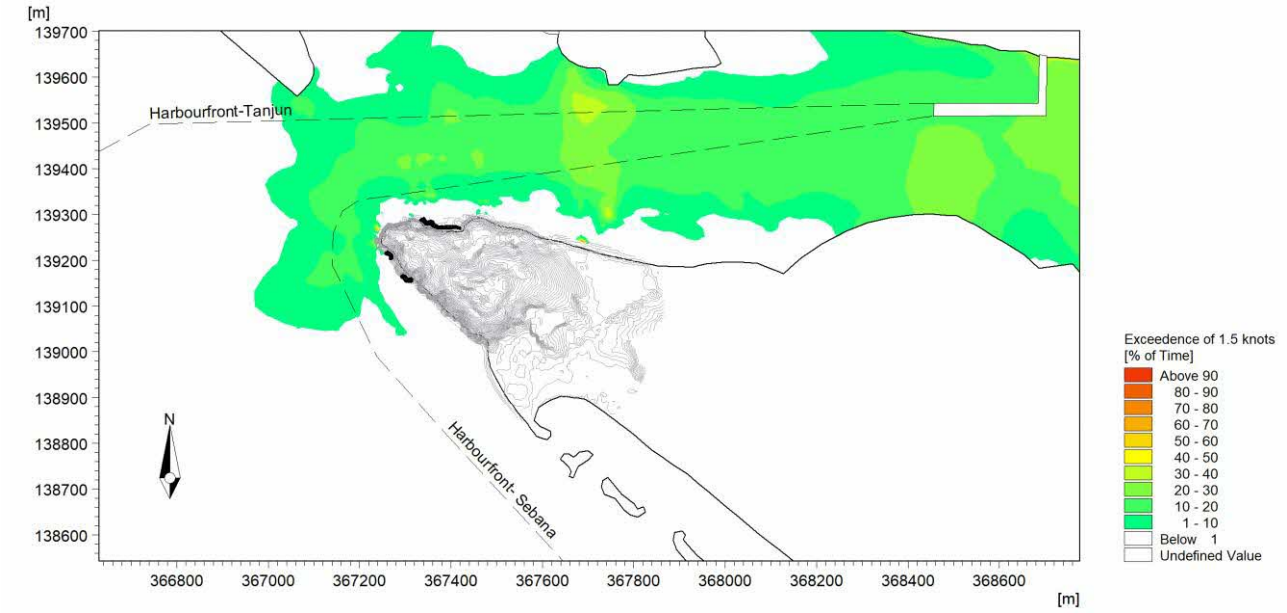


Figure 5-34 Exceedance of 1.5 knot for southwest monsoon: operation phase

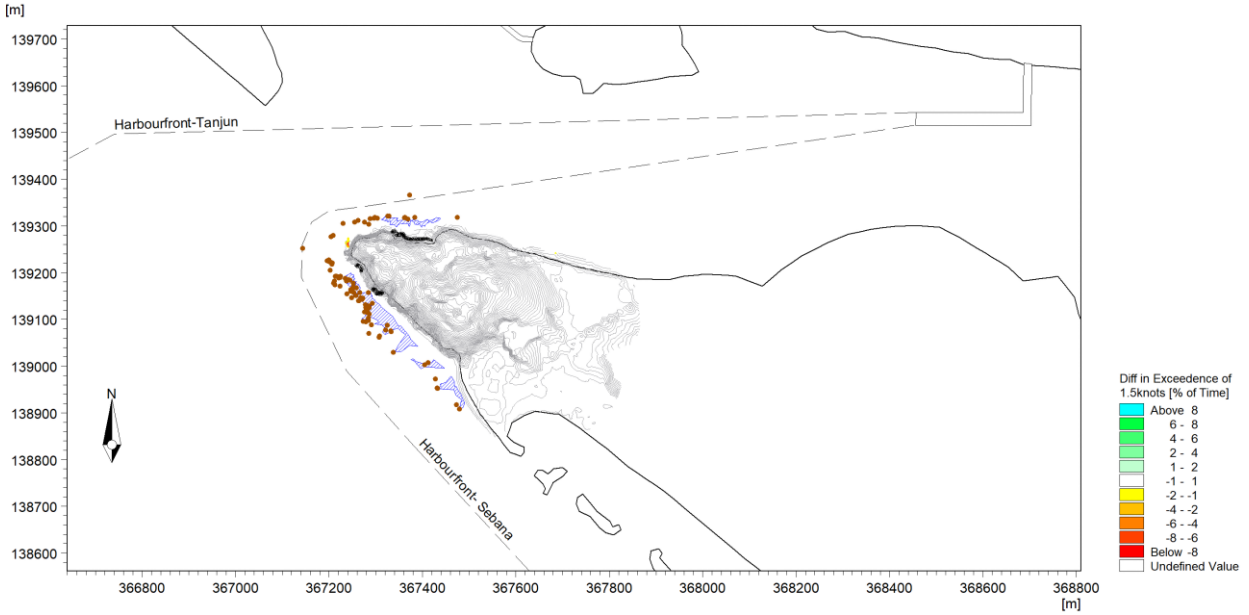


Figure 5-35 Difference in the duration of exceedance of 1.5 knot between baseline and operation phase for southwest monsoon

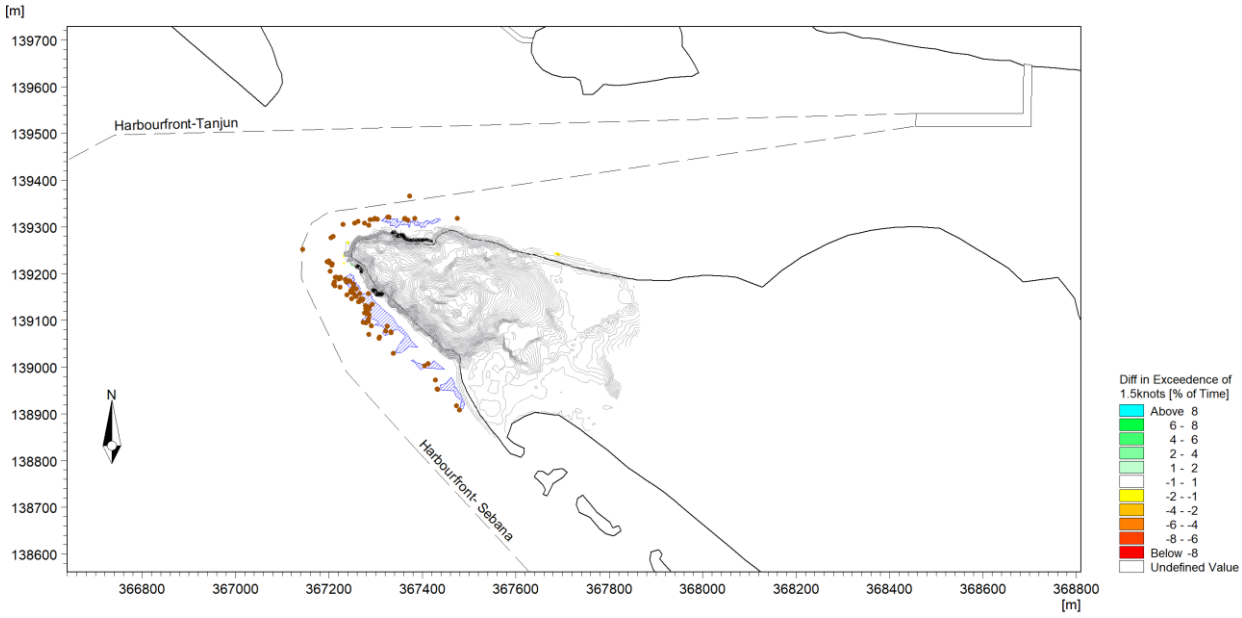


Figure 5-36 Difference in the duration of exceedance of 1.5 knot between baseline and operation phase for northeast monsoon

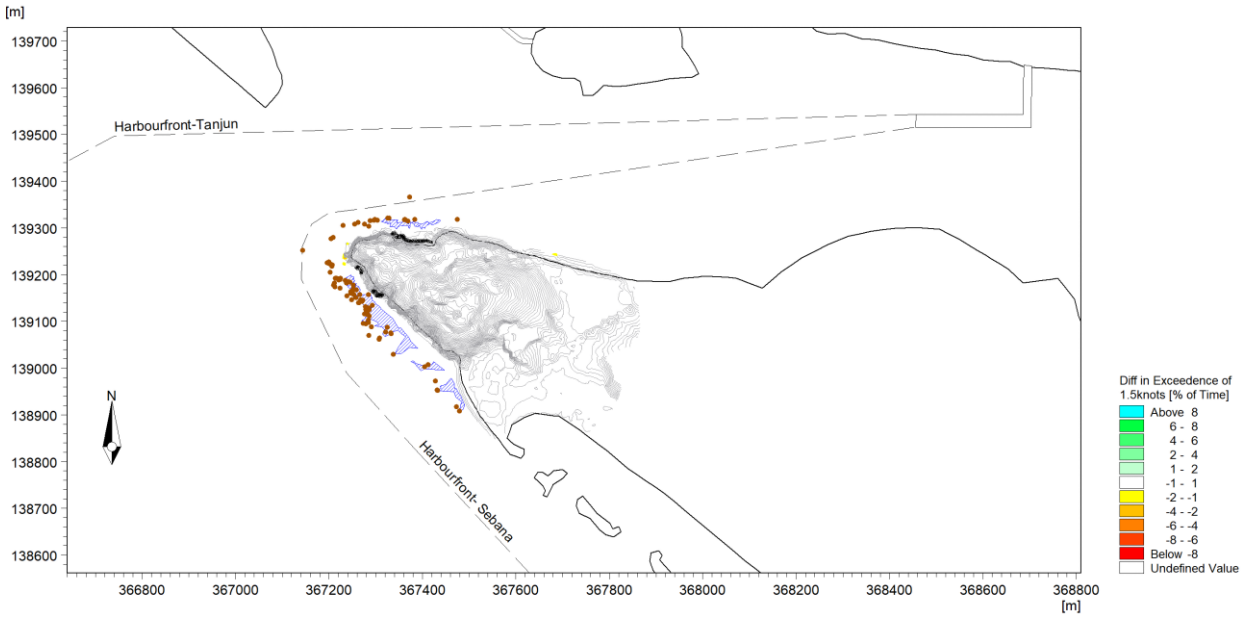


Figure 5-37 Difference in the duration of exceedance of 1.5 knot between baseline and operation phase for inter monsoon

5.5.4 Hydrodynamic Impact Assessment

The analysis in **Sections 5.5.1, 5.5.2**, and **5.5.3** shows that changes in current speeds, slack water duration, and exceedance of 1.5 knots are negligible across all monsoon periods. As a result, there will be no hydrodynamic impact on the navigation channel or nearby ecologically sensitive areas.

5.6 Sedimentation Impact During Operation

The sedimentation impact during operation was evaluated qualitatively using the construction phase sediment transport model outlined in **Section 5.4**, incorporating the proposed revetment designs at Sites A, C1, and C2. The simulation of propeller wash-induced sediment plumes for construction phase was removed from the model setup. Potential sedimentation rates within a 14-day period across all monsoon seasons were predicted and compared to the tolerance limits of coral reefs and seagrasses, as shown in **Table 5-5** and **Table 5-6**. **Figure 5-38** to **Figure 5-40** illustrate the predicted sedimentation rates over 14-day tidal cycle for southwest, northeast, and inter monsoon periods. Results indicate only minor and localised sedimentation or erosion occurring directly adjacent to the proposed revetments with the rate is less than ±0.5 mm/14 days. There will be no sedimentation impact on nearby corals and seagrasses. This is expected since the revetments are planned further inland and designed to align with existing topography, thereby reducing significant interactions with longshore currents and limiting potential sediment transport.

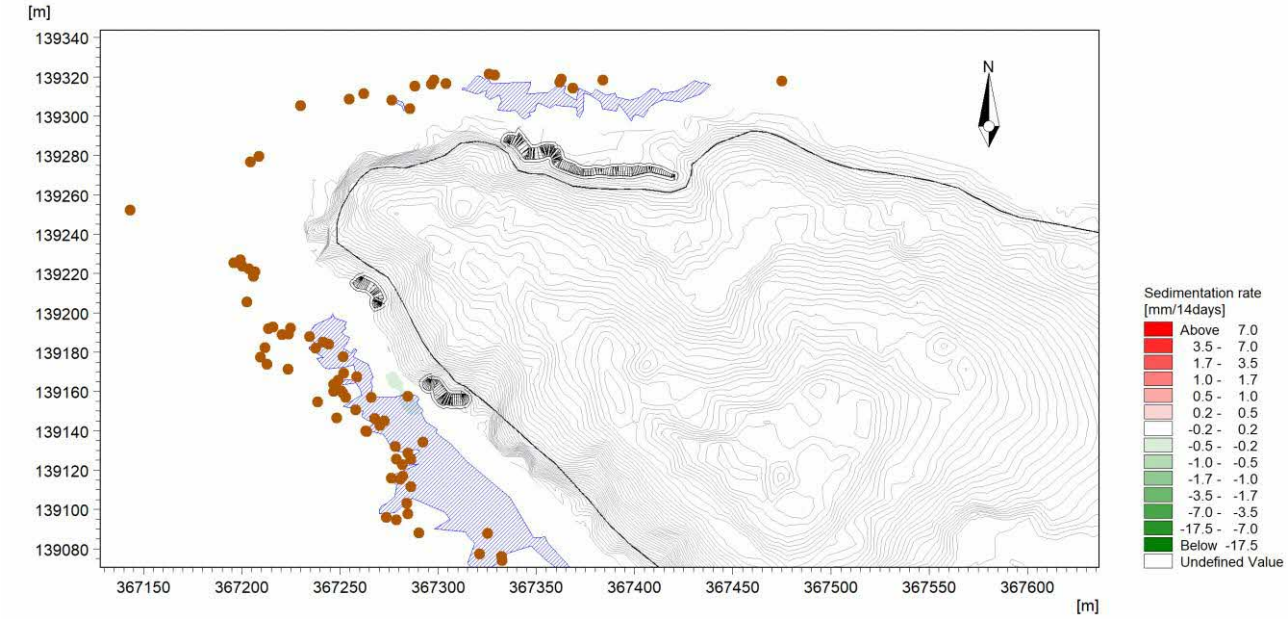


Figure 5-38 Total bed thickness change during operation, southwest monsoon

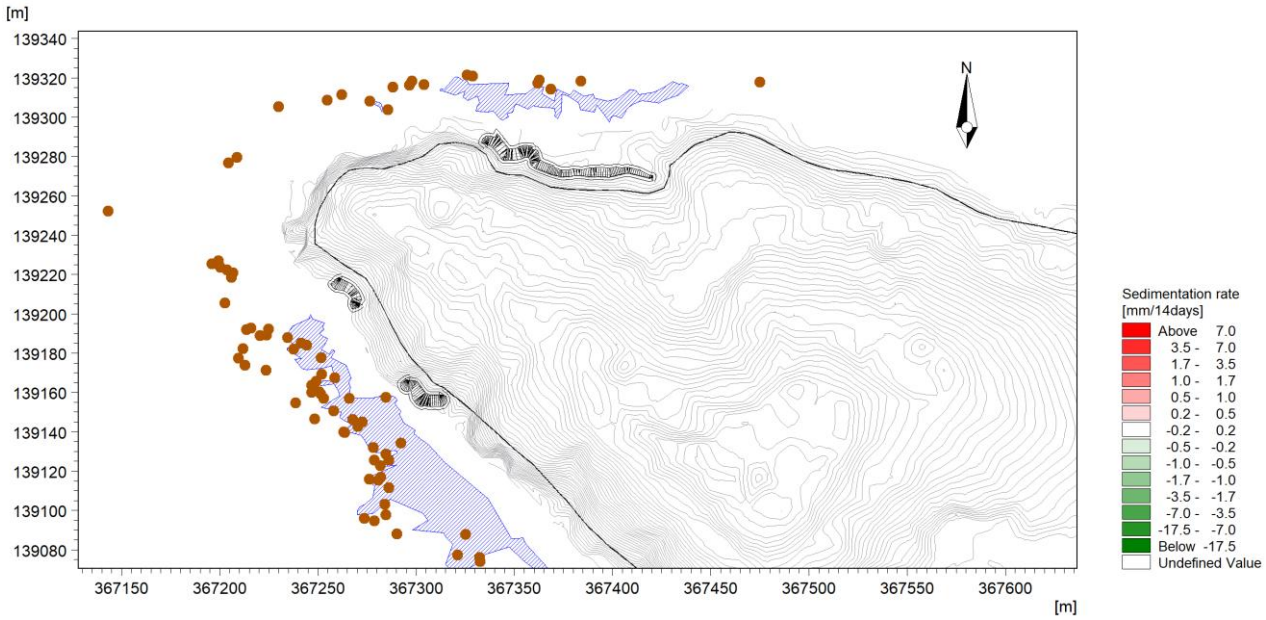


Figure 5-39 Total bed thickness change during operation, northeast monsoon

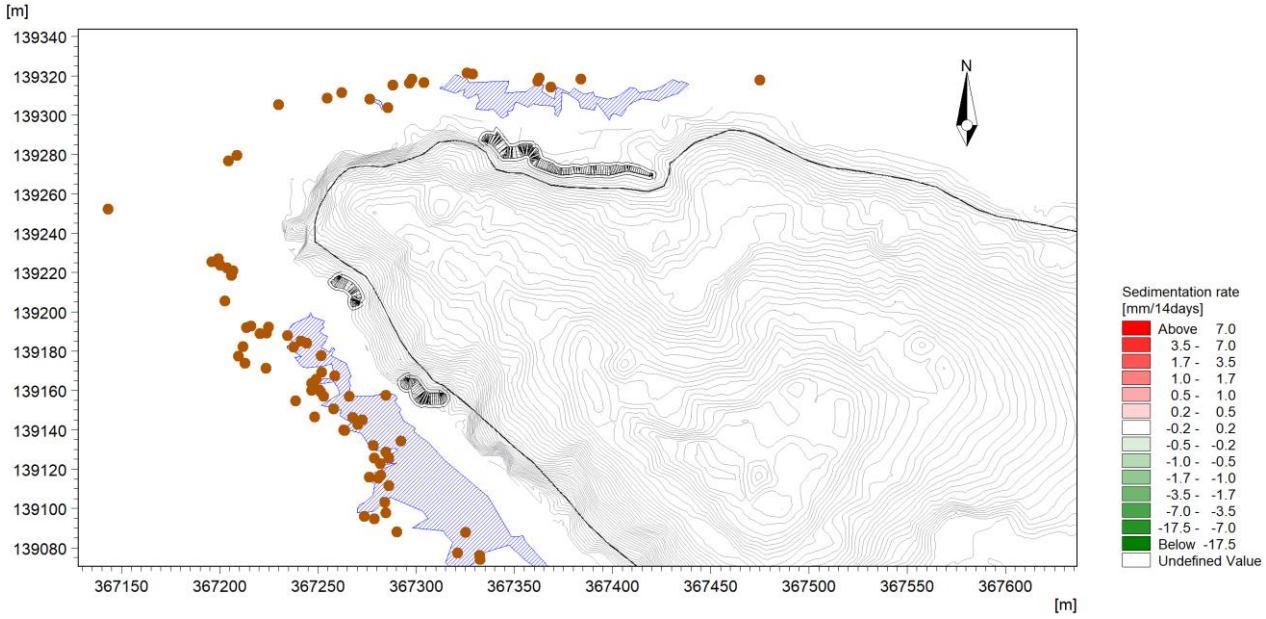


Figure 5-40 Total bed thickness change during operation, inter monsoon

5.7 Summary of Hydrodynamic Impact Assessment

Table 5-8 summarises the hydrodynamic impact assessment for construction and operation phases, including sediment plume, sedimentation, and hydrodynamic impacts.

Table 5-8 Summary of hydrodynamic impact assessment

Project Phase	Key Environmental Concerns	Sensitive Receptors	Impact Assessment

Construction	• Propeller wash induced sediment plume - Potential localised seabed erosion and sedimentation - Potential sediment plume impact on sensitive receptors	• Corals and seagrasses nearby the proposed construction access • Recreational beaches, e.g. Siloso beach	**Sediment plume impact:** • No sediment plume impact to most of the corals. • Some corals near the barge and outer rocky shore are expected to experience slight impacts. • No sediment plume impact to seagrasses. • No sediment plume impact to Siloso beach • Generally, barge movement at Site B is anticipated to have less impact compared to Site A, as the greater depth at Site B lowers the potential for seabed interaction and subsequent sediment resuspension. **Sedimentation impact:** • No sedimentation impact to most of coral reefs. • Minor sedimentation impact to one coral specimen located near the barge loading/unloading location. • No sedimentation impact to seagrasses.
Operation	• Potential changes in current speed due to the proposed revetments • Potential morphological changes on seabed due to the proposed revetments	• Navigation channel • Corals and seagrasses nearby the proposed revetments	**Hydrodynamic impact:** • No hydrodynamic impact to navigation channel. **Sedimentation impact:** • No sedimentation impact to coral reefs. • No sedimentation impact to seagrasses.

6. Proposed Environmental Management and Monitoring Plan

The proposed Environmental Management and Monitoring Plan (EMMP) is prepared for environmental impacts of the construction and operational phases associated with the Project that were assessed in this EIA, namely biodiversity and physical environment (marine water quality, ambient air quality and ambient airborne noise and ground vibration). The EMMP details how the recommended mitigation measures prepared for the impact assessment are to be implemented and specifies recommended monitoring measures to assess the effectiveness of the mitigation measures. This document is also intended to provide a broad framework for the Contractor to develop a more contract-specific EMMP herein referred to as contract-specific Construction EMMP (CEMMP), as per the responsibilities set out in the tender specification. CEMMP is the adaptive document (as its prepared prior to the construction phase), unlike the EMMP, which is a section within the EIA document (during the baseline study / prelim design phase).

This section outlines the objectives of the CEMMP, describes the roles and responsibilities relevant to implementation of the CEMMP and summarises the EMMP requirements for each discipline.

6.1 CEMMP Objectives

At the commencement of the Contract, the Contractor shall prepare a Construction EMMP (CEMMP) which is explicit, illustrative, action-oriented, time-bound and definitive to document biodiversity and environmental management and monitoring activities during the construction phase. The purpose of the CEMMP is to serve as a manual for implementing appropriate biodiversity and environmental controls and monitoring procedures during the construction phase of the Project. The Contractor shall be responsible to submit and obtain approval for CEMMP from the relevant technical agencies such as NParks and SDC before commencement of works.

The CEMMP shall be a live document that will be reviewed and updated as additional information becomes available and in the light of further consultation with regulatory authorities.

The objectives of the CEMMP are to have in place a documented plan to:

a) Ensure that the biodiversity and environmental management practices and mitigation measures required by the Contract are sufficiently implemented.
b) Monitor the actual biodiversity and environmental impact levels and provide prompt corrective actions to ensure the impacts are within the respective control limits.
c) Ensure compliance with statutory requirements, codes of practice, the Board's requirements, etc.
d) Provide regular documentation on the biodiversity and environmental performance of the Project to the Board and relevant agencies to ensure no deterioration of biodiversity and environmental controls.

The CEMMP shall consist of, as a minimum:

a) Roles and Responsibilities, including a list of key team members, organisation charts and description of roles and responsibilities.
b) Construction Site Layout and General Arrangements, including a site management plan, with location of eating/rest areas, chemical /waste storage plan, chemical inventory, emergency spill response etc.

c) Biodiversity and environmental management practices and mitigation measures.
d) Biodiversity and environmental monitoring scope and parameters, equipment and quality assurance.
e) Communication, Training and Awareness.
f) Environmental Incident Contingency Plans.
g) Wildlife Response Plans.
h) Grievance and Complaint Handling Plan.
i) EMMP inspection checklists, monthly report format, monitoring record templates, etc.

The implementation of the EMMP by the Contractor shall include, where necessary, the engagement of qualified specialists, subContractors, and service providers to supply labour, equipment, materials and professional services for the biodiversity and environmental management and monitoring works, in compliance with the relevant acts, standards, guidelines and procedures.

6.2 Responsibilities of the Contractor during Construction Phase

6.2.1 Contractor's Responsibilities

The Contractor shall be responsible for identifying, managing and mitigating all biodiversity and environmental impacts arising from the construction works. Such impacts include any form of pollution and excessive noise affecting those outside the site boundary.

The EMMP shall be implemented by the Contractor during the delivery of the Contract. The Contractor shall take note that strict compliance with the biodiversity and environmental requirements, including all necessary biodiversity and environmental mitigation measures, is his full responsibility. The Contractor shall, at his own cost, improve or take additional biodiversity and environmental mitigation measures if, arising from the Contractor's construction activities, the regulatory and specific biodiversity and environmental requirements are not met.

The Contractor will also be responsible for emergency planning as well as identifying the principal person amongst its site staff who has overall responsibility for ensuring and recording compliance with the CEMMP, and a deputy who will act in the capacity when the principal person is not on site. The Contractor must also ensure that its staff are familiar with the relevant parts of the CEMMP.

The Contractor shall comply with all relevant Acts, Regulations, Codes of Practice or amendments or re-enactment thereto including but not limited to:

a) Requirements of the Environmental Protection and Management Act and all subsidiary regulations, relating but not limited to control of air pollution, water pollution and noise pollution.
b) Requirements of the Environmental Public Health Act and all subsidiary regulations, relating but not limited to employment of competent person to act as Environmental Control Officer (ECO).
c) Requirements of the Sewage and Drainage Act and all subsidiary regulations, relating but not limited to the prohibition of discharge of silt into stormwater drainage systems.
d) Requirements of the Wildlife Act and all subsidiary regulations.
e) Code of Practice on ECO.
f) Code of Practice on Environmental Health.
g) Code of Practice for Noise Control on Construction and Demolition Sites.
h) Code of Practice on Pollution Control.
i) Code of Practice on Surface Water Drainage.
j) Public Utilities Board (PUB)'s Guidebook on Erosion & Sediment Control at Construction Sites.
k) National Environment Agency (NEA)'s Guidebook on Prevention of Mosquito Breeding.

l) NEA's Handbook of Scope of Works for Mosquito Control.

The Contractor shall adopt the following best environmental practices listed in the Development Plan Submission Requirements handbook, including guidelines on requirements on Conservation of Trees and all other relevant environmental guidebooks and guidance.

The Contractor shall:

a) Comply with the recommended mitigation measures in the EIA and adopt the more stringent requirement should there be differences between the EIA Report and the other relevant authorities' requirements, in addition to supplementary guidelines provided in **Appendix L** on Tree Protection Guidelines and **Appendix M** on Sapling Harvesting, Tree Transplantation and Tree Maintenance.
b) Provide justification and alternative measures to reduce the impacts to as low as reasonably practical for mitigation measures which could not be adhered to.
c) Maintain a CEMMP for execution of the recommended mitigation measures in the EIA.

6.2.2 Contractor's Environmental Manager

The Contractor shall note the following responsibilities when carrying out the EMMP:

a) Appoint an Environmental Manager who shall be responsible for carrying out the recommendations of the CEMMP.
b) Provide the necessary resources to the Environmental Manager to carry out the EMMP.
c) Provide relevant information and advice to SDC on potential activities that may potentially create adverse environmental conditions.
d) Submit regular biodiversity and environmental monitoring reports to SDC for review.
e) Submit proposals for mitigation measures should there be exceedances or incidents.
f) Implement approved mitigation measures to reduce the potential impact from exceedances or incidents.

The Environmental Manager shall have five years of post-registration as an ECO and relevant experience of managing biodiversity and environmental issues in marine sensitive sites. He/she shall oversee and manage the biodiversity and environmental impacts of all work sites throughout the project duration and to ensure all works comply with the biodiversity and environmental requirements.

The Environmental Manager shall be responsible for the following duties:

a) Oversee and ensure the implementation of the biodiversity and environmental management requirements in accordance with the environmental specifications, the CEMMP, and the Authorities' requirements.
b) Daily review of all work activities and their surroundings to ensure compliance with the CEMMP.
c) Recommend improvements in case of non-compliance/non-conformity and/or violation to improve site conditions, which shall be made within 24 hours for the Contractor to take immediate remedial actions and for reference.
d) Recommend to the SDC / Board's EMMP Specialist any further biodiversity and environmental data collection if deemed necessary, for example, to investigate non-compliance or damage caused by construction/workers' activities.
e) Attend regular meetings between SDC and the Contractor to report on the status of the EMMP implementation (at least once per month).

f) Prepare and submit weekly monitoring reports to the SDC / Board's EMMP Specialist, including weekly ECO inspection records, monitoring results, findings, recommended actions for improvement, and Contractor's close out action as well as effectiveness of corrective actions.
g) Notify the SDC / Board's EMMP Specialist should any environmental incidents, complaints or grievances occur on site.
h) Advise additional recommendations that will ensure good biodiversity and environmental management of the site work in accordance with good practices and local legislation.

6.2.3 Contractor's Arboriculture Contractors

The Contractor shall note the following responsibilities when carrying out the works:

a) The Contractor shall engage an International Society of Arboriculture (ISA) certified Tree Arborist to supervise and coordinate all tree planting, protection, and salvaging operations. The Contractor's Arborist is required to be on-site at all times during all stages of plantings, salvaging and tree protection to supervise and direct the work. Qualifications and field supervision experience shall be detailed and submitted for approval by the Superintending Officer (SO);
b) All arboriculture works should be carried out by skilled and trained arboriculture teams with at least eight years working experience in developments of similar size or complexity. Arboriculture Contractors should meet the Board's safety requirements for work at height, Land Transport Authority's requirements for temporary works along roadsides (where necessary) and have a certified arborist to supervise the pruning/felling/planting works.
c) All arboriculture workers engaged in tree climbing and chainsaw work shall possess a valid basic tree climbing certification base upon demonstrated competence in the Workforce Skills Qualifications (WSQ) module conducted by Centre for Urban Greenery and Ecology (CUGE) or an equivalent WSQ approved training organization.
d) Each Arboriculture crew shall possess the following VALID competences:
    i. Operation of chainsaw for ground work (LS-MT-103E-1)
    ii. Chainsaw safety and maintenance (LS-MT-102E-1)
    iii. Perform formative pruning of young trees (LS-MT-114E-1)
    iv. Provide Arboriculture support on site (LS-MT-116E-1)
    v. Workplace safety and health – operators (ES-WSH-101G- 1)
    vi. Respond to Emergency (LS-HM-208E-1)
    vii. Perform advance rigging and climbing techniques (LS- HM-308S-1)
    viii. Perform aerial tree access and aerial rescue skills (Ls-HM- 204S-1)
    ix. Implement and apply appropriate risk and safety management to sector practices (LS-BP-301S-1)
    x. Prepare risk assessment report (LS-HM-406S-1)
    xi. Operate and work from an elevated work platform (CUGE- ARB-3501)

6.2.4 Contractor's EMMP Specialist Team

The Contractor shall appoint an EMMP Specialist Team to support the implementation, monitoring and reporting of the biodiversity and environmental mitigation measures during the construction phase. The team shall comprise, at minimum, a Flora Specialist and a Marine Specialist, each possessing the relevant qualifications and experience for work in environmentally sensitive sites in Singapore.

The Flora Specialist shall meet the following requirements:

a) Possess a relevant tertiary qualification in Botany, Ecology, Environmental Science, Landscape Ecology, Arboriculture or an equivalent discipline.
b) Have a minimum of five years of relevant experience in Singapore, including terrestrial flora assessment, vegetation monitoring, habitat management and implementation of biodiversity mitigation measures.
c) Demonstrated familiarity with NParks' guidelines, including Conservation of Trees, Tree Protection Zones (TPZs), and other relevant national requirements.
d) Experience working within or adjacent to ecologically sensitive areas, including cliff vegetation, coastal forest, and intertidal flora communities.
e) Ability to supervise flora-related mitigation measures, provide technical advice, and support the Contractor in achieving compliance with the CEMMP and authority requirements.

The Marine Specialist shall meet the following requirements:

1. Possess a relevant tertiary qualification in Marine Biology, Marine Science, Environmental Science, Ecology or an equivalent discipline.
2. Have a minimum of five years of experience conducting marine ecological surveys in Singapore, including work on coral reefs, seagrass meadows, rocky shore and intertidal/subtidal habitats.
3. Demonstrated experience in implementing and monitoring marine biodiversity mitigation measures, including turbidity management, marine fauna protection and water quality monitoring.
4. Experience working on construction projects near sensitive marine ecosystems, particularly within the Southern Islands or similar Singapore coastal settings.
5. Where required for subtidal monitoring, possess valid scientific diving certification (e.g., AAUS, ADAS or equivalent commercial/scientific certification) and all applicable marine safety training.
6. Ability to provide technical advice to the Contractor on marine biodiversity management, evaluate real-time impacts arising from construction activities and support compliance with CEMMP and authority requirements.

The EMMP Specialist Team shall carry out the following duties:

a) Oversee and ensure the implementation of biodiversity and environmental management requirements in accordance with the environmental specifications, the CEMMP and all applicable Authorities' requirements.
b) Carry out biodiversity, marine water quality, ambient air quality, ambient noise, vibration and sedimentation monitoring before, during and post-construction.
c) Review Contractor's Environmental Manager's daily reviews of construction activities and surrounding site conditions to ensure compliance with the biodiversity and environmental requirements.
d) Recommend improvements or corrective actions within 24 hours in the event of non-compliance or potential violation, and support the Contractor in implementing the necessary remedial measures.
e) Recommend to SDC / Board's EMMP Specialist any additional data collection or survey work deemed necessary, including investigations into potential impacts or damage arising from construction activities.
f) Attend regular meetings with SDC and the Contractor to provide updates on EMMP implementation and site observations.

g) Prepare and submit monthly monitoring reports to SDC / Board's EMMP Specialist, including ECO inspection records, monitoring results, findings, recommended corrective measures and the effectiveness of the Contractor's close-out actions.
h) Notify SDC / Board's EMMP Specialist immediately of any environmental incidents, complaints or grievances arising on site.
i) Provide additional recommendations, where required, to enhance biodiversity and environmental management in accordance with best practices and Singapore's legislative requirements.

6.2.5 Board's EMMP and Biodiversity Specialists

The Contractor's performance in complying with the CEMMP will be supervised by Board's EMMP Specialists, engaged by SDC for the construction phase of the Project.

Board's EMMP Specialists will verify and monitor the mitigation measures process, such as the noise mitigation during construction, the proper management of waste to prevent contamination and measures to protect flora and fauna on site etc. Board's EMMP Specialists shall review monthly monitoring reports submitted by the Contractor and carry out investigations on major environmental incidents / infringements, and report thereon.

6.3 Biodiversity and Environmental Management Requirements during the Construction

6.3.1 General

During the construction phase, the Contractor shall take note and strictly adhere to the restrictions below:

j) No traversing through the intertidal or coastal habitat outside of the working area;
k) No bathing or washing in the sea;
l) No throwing, depositing or leaving behind any refuse, litter, object or article except in a litter bin provided for that purpose. Food waste bins and bin centres must be wildlife-proof. All litter and debris must be removed and disposed off-site daily;
m) No food consumption or resting/non-work-related activities outside designated eating and resting areas. Designated areas, where food and beverage are allowed to be consumed, must be enclosed and provided with wildlife-proof bins;
n) No soiling or defacing any building, structure, furniture, ornament, equipment or other property;
o) No smoking within any part of the site;
p) No hanging or affixing any light, bill, placard, notice or other thing on any plant, tree or structure;
q) No affixing, setting up or erecting any sign, shrine, altar, religious object, shelter structure or building;
r) No climbing of any wall, fence, barrier, railing, hedge, tree, post, or other structure;
s) No cutting, damaging, displacing, or marking (e.g., spray paint) any tree or plant or any part thereof;
t) No collecting, removing or wilfully displacing of any other organism;
u) No use of any animal, firearm, explosive, net, trap, hunting device or instrument or means whatever for the purpose of capturing any animal;
v) No carrying or have in the person's possession any explosive, net, trap or hunting device;
w) No bringing or introducing any animal;
x) No setting of fires;

y) No musical instrument, apparatus or thing producing sound or noise in such a manner as to cause annoyance, inconvenience or offence to people or animals;
z) No damage to the saplings or branches, aside from what is approved by SDC, when carrying out the works;
aa) No camping or staying overnight; and
bb) No feeding of any terrestrial or aquatic animals (e.g., long-tailed macaque, smooth-coated otter other birds, fish, etc).

Contractors are recommended to utilize a combination of a manual (where feasible) and miniaturisation strategy e.g., use of mini excavators, manual dumper, etc., for the construction works with the intent to reduce adverse impact to the environment and ecological receptors.

6.3.2 Marine Water Control

The Contractor shall ensure the following minimum controls are implemented for the Project during the construction phase to reduce impact to the marine water quality:

a) Site planning and surface water management

- Prepare and maintain a CEMMP that identifies all potential pathways for sediment and contaminant runoff to the sea and specifies control measures, responsibilities and inspection frequencies.
- Design site grading and temporary works so that clean runoff is diverted away from working areas and all runoff from disturbed surfaces, stockpiles and work platforms is collected and directed to treatment facilities before discharge.
- Provide perimeter drains, kerbs and cross drains along the toe of the slope and around stockpiles to intercept sediment laden runoff and prevent direct discharge to the shoreline.
- Barge access, parking, and movement should only be limited to the assigned locations.

b) Erosion and sediment control

- Minimise the area and duration of exposed soil by phasing slope works and promptly installing soil nails, rock netting and erosion control blankets once drilling or trimming is completed.
- Cover or stabilise stockpiles of soil, sand and fine materials, and locate them away from the shoreline and drains as far as practicable.
- Install and maintain silt fences, sediment traps and or settlement tanks at all discharge points from disturbed areas, with regular desilting before and after rainfall events. Consider installing turbidity curtain within the subtidal zone along the marine access route to contain spread of sediment plume.
- Adopt good practices such as turning off the boat engine whenever it is idle to minimise unnecessary disturbance to seabed.
- Sequence temporary bund construction, revetment and XblocPlus placement to avoid unnecessary seabed disturbance and re-handling of material and to keep the active footprint as small as practicable.
- Rocks used for temporary bunds, and rock revetment should be free from debris (i.e. rebar rods, excessive sediment).

c) Management of concrete, grout and other construction materials

- Designate concrete washout areas on land, with fully contained pits or tanks for collection of wash water and residues. No wash water or excess grout is to be discharged directly to the sea. A spill mitigation response plan should be created by the Contractor and implemented based on the specific type of cement needed for the work. SDC's Ecologist will review the plan as part of the CEMMP.
- Store cement, grout, admixtures and other fine powdered materials in covered and bunded locations.
- Prohibit the washing of equipment, tools or trucks in locations where runoff can flow directly into the nearshore waters.

d) Fuel, chemical and waste management and spill prevention

- Store fuels, lubricants and other hazardous liquids in bunded areas with a minimum capacity of one hundred and ten percent of the largest container volume and protect from rain.
- Any construction machinery or equipment requiring the use of fuel or chemicals (e.g. pumps, generators or similar plant) shall be located on the temporary bund or barge rather than on the rocky shore, intertidal zone, or other sensitive habitats.
- Prohibit refuelling over water. Refuelling of plant and vessels shall be carried out at designated on shore locations or by properly equipped service barges with drip trays, automatic shut off nozzles and spill kits.
- Implement a spill prevention and response plan covering both land and marine activities, including availability of spill kits, absorbent booms and trained personnel on each barge and at key work fronts.
- Establish clear procedures for reporting, containment, clean up and disposal following any spill, with immediate notification to the Engineer and relevant agencies when threshold quantities are exceeded.
- Provide covered and clearly labelled receptacles for general waste, construction debris and scheduled waste. Waste shall be removed regularly by licensed Contractors to approved disposal or treatment facilities, with no dumping into the sea.

e) Control of discharges from dewatering and pumping

- Any groundwater or stormwater pumped from excavations, bunded areas or work platforms shall be directed through sedimentation or treatment facilities before discharge, with discharge points located away from sensitive marine habitats as far as practicable.
- Where chemical flocculants are used to aid settlement, select products that are suitable for marine environments and apply in accordance with manufacturer instructions to avoid residual toxicity.

f) Training, supervision and monitoring

- Conduct biodiversity awareness trainingand refresher training for all site staff and vessel crews on marine water quality risks, control measures and spill response.
- Appoint an environmental supervisor to carry out routine inspections of erosion and sediment control, storage facilities and housekeeping and to maintain a non-conformance and corrective action log.
- Conduct daily visual inspections of water clarity and presence of oil sheen in the nearshore zone adjacent to the works as part of routine site management.

- Implement monthly marine water quality monitoring in accordance with the monitoring plan, at the three monitoring stations (S01, S02 and S03, **Figure 6-4**) for parameters listed in the ASEAN Marine Water Quality Criteria (AMWQC), with action levels and response procedures when trigger values are exceeded.

6.3.3 Ambient Air Control

The Contractor shall ensure the following minimum controls are implemented for the Project during the construction phase to reduce air pollution:

a) Planning and management

- Prepare and maintain a CEMMP that includes a specific Dust and Exhaust Emissions Control Plan, clearly identifying dust generating activities, locations of sensitive receptors and required controls.
- Sequence works so that high dust generating activities are minimised in extent and duration, and scheduled where practicable during periods of lower visitor presence at Fort Siloso and Shangri La Rasa Sentosa Resort.
- Designate traffic routes, loading or unloading points and material storage areas, and keep these to the minimum necessary footprint.

b) Control of fugitive dust

- Keep exposed earth surfaces, haul routes and working platforms moist during dry and windy conditions using water sprinkling, misting or equivalent methods, while avoiding excessive run off.
- Limit drop heights when loading or unloading aggregates, armour rock and other granular materials.
- Cover or enclose stockpiles of fine materials such as soil, sand, crusher run and cement based products, and position them away from the site boundary and receptors as far as practicable.
- Ensure that all trucks transporting fine materials off site are adequately sheeted and that tailgates are sealed to prevent loss of material during transit.
- Maintain terrestrial / marine access routes in a clean condition through regular sweeping and prompt removal of spilled materials.

c) Control of combustion emissions

- Use well maintained diesel equipment and marine vessels that comply with the prevailing National Environment Agency requirements for on road vehicles, off road diesel engines and marine engines.
- Prohibit unnecessary idling of engines for vehicles, generators, compressors, drilling rigs and marine vessels, and display clear signage on site.
- Position stationary combustion equipment and generators as far as practicable from Fort Siloso, Shangri La Rasa Sentosa Resort and other occupied buildings, and, where necessary, use localised acoustic or physical screens that also promote vertical dispersion of exhaust.
- Implement a preventive maintenance programme for all fuel burning equipment and vessels to ensure efficient combustion and to avoid visible black smoke.

d) Handling of cement, grout and chemicals

- Store cement, grout and other powdered materials in sealed bags or silos within covered, well-ventilated areas to prevent wind entrainment.
- Mix cementitious materials in designated locations with partial enclosure where practicable, and clean up spills promptly.

e) Housekeeping, training and monitoring

- Provide toolbox briefings and induction training for workers and vessel crews on dust and exhaust control requirements, with emphasis on protection of sensitive receptors.
- Carry out routine visual inspections of dust emissions at work fronts, haul roads and stockpile areas, and record inspection findings and corrective actions.
- Implement ambient air quality monitoring in accordance with the monitoring plan, including at least PM_{10} and $PM_{2.5}$ at P01 and P02 (**Figure 6-4**), with trigger levels linked to reinforcement of control measures when required.

6.3.4 Noise Control

The Contractor shall ensure the following minimum controls are implemented for the Project during the construction phase to reduce noise pollution:

a) Regulatory compliance and noise management planning

- Prepare a Construction Noise Management Plan as part of the CEMMP, setting out key noise sources, receptor locations, predicted noise levels, applicable NEA noise limits and control measures.
- Ensure that construction activities comply with the maximum permissible noise levels for "Other buildings" at all times, for the day 7 am to 7 pm, evening 7 pm to 10 pm and night 10 pm to 7 am periods.
- Avoid nighttime works 10 pm to 7 am as far as practicable. If works in the evening or night period are unavoidable for safety or tidal reasons, obtain necessary approvals and implement enhanced noise controls and monitoring.

b) Equipment selection and maintenance

- Select construction plant with lower sound power ratings where practicable and ensure that all equipment is fitted with effective mufflers, silencers, acoustic enclosures or shrouds as appropriate.
- Maintain all machinery and equipment in good working order to prevent excessive noise from loose panels, worn parts or faulty exhaust systems.
- Avoid the use of tonal reversing alarms where possible and replace with visual warning systems in sensitive locations.

c) Work methods and scheduling

- Apply quieter construction methods where practicable, for example drilling instead of percussive breaking wherever ground and rock conditions allow.
- Sequence high noise activities so that they do not occur simultaneously in close proximity to the same receptor, and confine the noisiest tasks to daytime periods as far as practicable.

- Restrict particularly noisy operations such as rock breaking, heavy hammering or use of impact tools to short, well-defined periods with rest intervals.
- Coordinate marine operations such as barge positioning and loading so that repeated high noise events close to the shore are minimised.

d) Site layout and physical noise control

- Position stationary noise sources, such as generators, compressors and drilling rigs, as far as practicable from Fort Siloso (P01), Shangri La Rasa Sentosa Resort (P02) and other occupied buildings, making use of natural screening from topography or structures.
- Where equipment must be located near sensitive receptors, install temporary acoustic barriers, enclosures, hoardings or screens to shield line of sight between the source and the receptor.
- Use site hoarding of sufficient height and density along boundaries closest to receptors to provide additional noise attenuation.

e) Communication, training and behavioural controls

- Provide induction and toolbox briefings for all workers and vessel crews on noise control requirements, including the need to avoid unnecessary shouting, dropping of materials from height or slamming of doors and hatches.
- Establish clear lines of communication with Fort Siloso and Shangri La Rasa Sentosa Resort management to provide advance notice of particularly noisy activities and to receive and address any noise related feedback or complaints.
- Encourage good housekeeping practices that minimise rattling, banging and other avoidable noise, for example proper stacking of materials and careful handling of metal items.

f) Noise monitoring and review

- Implement a construction noise monitoring programme at P01 and P02 (**Figure 6-4**) in accordance with regulatory and project requirements, including at least day and evening measurements and additional checks during any approved night works.
- Compare measured levels with NEA limits and the Project's internal action and alarm levels. Where action levels are exceeded, investigate the cause promptly and implement corrective measures such as revised scheduling, additional screening or equipment substitution.
- Maintain records of monitoring, complaints and corrective actions to support adaptive management throughout the construction period.

6.3.5 Vibration Control

The Contractor shall ensure the following minimum controls are implemented for the Project during the construction phase to reduce impacts from vibration:

a) Planning, assessment and method statements

- Prepare a Construction Vibration Management Plan as part of the CEMMP, identifying all vibration generating activities for example drilling for soil nails and rock dowels, any rock breaking, compaction and movement of heavy plant near sensitive structures.
- Using the baseline PPV values measured at V1 and V2 and the BS 5228 2 cosmetic damage guide values, carry out a screening level assessment to estimate predicted PPV at Fort Siloso heritage structures and resort buildings for key construction activities.

- Develop method statements for high vibration activities that specify plant types, operating parameters, maximum permissible PPV at receptor locations and measures to minimise vibration transmission.

b) Equipment selection and operating practices

- Select drilling equipment and bits appropriate to the ground conditions to minimise percussive action and excessive thrust while maintaining productivity. Rotary or rotary percussive drilling with optimised settings is preferred over heavy impact methods wherever practicable.
- Avoid the use of heavy impact breakers on the slope except where no reasonable alternative exists, and then restrict duration and apply additional controls and monitoring.
- Use smaller, lighter plant where feasible in close proximity to Fort Siloso structures or resort retaining walls, and avoid rapid acceleration, sudden braking or abrupt directional changes of tracked plant on hard surfaces.

c) Site layout and separation distances

- Establish buffer distances between high vibration sources and sensitive receptors based on the screening assessment. Within these distances, apply stricter controls on plant type and operating mode.
- Where practicable, locate drilling rigs and any necessary breaking works on benches or platforms that maximise horizontal separation from Fort Siloso buildings and resort structures, while still meeting engineering requirements.

d) Protection of heritage and structural receptors

- Prior to commencement of high vibration works, carry out a pre-construction condition survey of representative Fort Siloso heritage structures and relevant resort buildings, documenting existing cracks, defects and finishes as a baseline.
- Where necessary, implement localised protection measures for fragile elements for example bracing of loose masonry, securing of ornaments or temporary support to non-structural features during high vibration activities in the vicinity.

e) Vibration monitoring and trigger action levels

- Install vibration monitoring at representative locations for Fort Siloso P01 and Shangri La Rasa Sentosa Resort P02 (**Figure 6-4**) in accordance with BS 5228 2 guidance, recording peak particle velocity in three orthogonal axes at appropriate sampling frequencies.
- Establish project specific trigger and alarm levels below the cosmetic damage guide values, for example a lower “action” level where construction methods are reviewed and optimised and a higher “hold” level where works are temporarily stopped and revised before resumption.
- Implement continuous or attended monitoring during the initial period of high vibration activities drilling, breaking to confirm predictions, and adjust working methods or plant as necessary to keep PPV within agreed limits.
- Maintain a log of measured PPV, construction activities, trigger exceedances and corrective actions and report these periodically to the Engineer and, where required, relevant authorities.

f) Communication, training and complaint management

- Brief all site staff and Contractors on vibration control objectives, trigger levels and the importance of careful operation of plant near sensitive receptors.

- Establish communication protocols with Fort Siloso and Shangri La Rasa Sentosa Resort management to provide advance notice of high vibration activities, explain expected duration and agree on any special constraints for example avoidance of sensitive events.
- Maintain a mechanism for receiving, recording and responding to vibration related feedback or complaints and link this to the monitoring data and corrective action process.

6.3.6 Biodiversity

The Contractor shall ensure the following minimum controls are implemented for the project during the construction phase to reduce impacts to the biodiversity. It is also assumed that there will be night works (**Table 6-1**).

Table 6-1 Minimum Controls for each work activity.

Work Activities	Minimum Controls
General construction activities, including site preparation works, finishing works	• No fogging shall be allowed; preventive measures shall be implemented for mosquitos to remove sources of stagnant water or water-bearing receptacles (e.g., well-maintained pitched roof, clear discarded items daily, store materials appropriately, level up ground depression/uneven surfaces, ensure effective drainage flow). Should there be a mosquito problem on site, BTI and sand granular can be added to potential breeding habitats where water cannot be removed. • Practice due diligence in proper storage and handling of machinery to prevent release of chemicals, fuels or other potentially harmful materials. • Install and maintain turbidity curtain, sediment traps and or settlement tanks at all discharge points from disturbed areas, with regular desilting before and after rainfall events. If feasible, this includes installing turbidity curtain within the subtidal zone along the marine access route to contain spread of sediment plume. • Adopt good practices such as turning off the boat engine whenever it is idle to minimise unnecessary disturbance to seabed. • Daily checks by EM on site. • No trapping of wildlife and vectors (i.e., rats). • Execute Wildlife Response Plan (**Section 6.3.11**) when a trapped/ injured/ dead/ dangerous animal is encountered around or within the worksite according to Section 10 of Wildlife Act (Singapore Statutes Online, 1965).
Vegetation Clearance	• Establish Tree Protection Zones (TPZs) around retained trees or plant specimens, within which no construction activities are allowed. TPZ placement should follow NParks' guidelines [1] and be advised by certified arborists. As TPZs for this Project will be located in the intertidal zone, the design must also minimise trapping of marine debris. A lighter, more permeable barrier may therefore be used in place of conventional terrestrial TPZ structures. • Conduct inspections of fauna prior to felling or removal of vegetation. This should be done by an ecologist who is able to identify wildlife and/or active nesting structures, such as bird nests, tree hollows and/or burrows, and bamboo clusters. • Establish a Wildlife Response Plan (**Section 6.3.11**). • Clearly demarcate and adhere to the defined working area to prevent unnecessary vegetation clearance. Where practicable, minimise the footprint of the working area to avoid sensitive receptors such as the adjacent seagrass meadows.

	• Implement soil erosion control measures prior to vegetation clearance. The ECM plan should be formulated by a QECP.
Earthworks (excavation, aboveground construction)	• Implement soil erosion control measures (e.g. implementation of biodegradable erosion control blankets, ECM tanks, etc.) are to be executed once vegetation has been removed and soil is exposed. • Ensure proper storage of materials likely to leach harmful chemicals and fuel-powered equipment by storing them away from waterbodies and/or sensitive habitats. • Implement dust control measures. • Ensure noise levels are within approved limits, and to implement noise barriers where required.
Setting up of working area, stockpiling	• Locate facilities other than the proposed construction worksites (e.g., site offices, storage yards, rest areas, access routes) within the worksite itself or on existing built-up areas/agreed working spaces; no clearing of additional habitats.

In addition to the above minimum control measures, the Contractor shall implement the following mitigation measures to avoid and minimise biodiversity impacts.

a) Barge movements to be carried out only during high tide to minimise resting and scrapping of the seabed. A minimum boat's draft of 2 m is always required.
b) As the barge are required to be anchored to spud down piles to minimise rocking and lateral movements of the barge, spud down pile locations should also be inspected by Marine Specialist to ensure minimal damage to coral reef / seafloor. An area with radius of 10 m should be inspected to allow for some room of error. This should be done once just before the first spud down event.
c) If necessary, salvaging of saplings of conservation significance should be done in consultation with SDC, the Board's EMMP Specialists, the Contractor's Flora Specialist and NParks. The Contractor's Flora Specialist should include a Sapling Salvaging Plan in the CEMMP, taking reference to the supplementary guidelines provided **Appendix M** on Sapling Harvesting, Tree Transplantation and Tree Maintenance. Additionally, if re-planting of salvaged saplings has occurred within the Study Area, these specimens should be monitored for health and survival as part of the monthly flora inspections by the Contractor's Flora Specialist. Specific details should be included in the Sapling Salvaging Plan in the CEMMP.
d) Similarly, if there is a need for any tree transplantation, it should be done in consultation with SDC, the Board's EMMP Specialists, the Contractor's Arborist and NParks. The Contractor's Arborist should include a Tree Transplantation Plan in the CEMMP, taking reference to the supplementary guidelines provided in **Appendix L** on Tree Protection Guidelines and provided **Appendix M** on Sapling Harvesting, Tree Transplantation and Tree Maintenance. Additionally, if transplantation has occurred within the Study Area, these specimens should be monitored for health and survival as part of the monthly Arboriculture inspections by the Contractor's Arborist. Specific details should be included in the Tree Transplantation Plan in the CEMMP.
e) If necessary, salvaging of seagrass should be done in consultation with SDC, the Board's EMMP Specialists, the Contractor's Marine Specialist and NParks. It is likely that affected seagrass will be salvage and donated to seagrass scientist before commencement of construction activities. Similarly, the salvaging method shall be determined in consultation with SDC, the Board's EMMP Specialists, the Contractor's Marine Specialist and NParks.
f) If necessary, transplantation of corals that are directly affected by construction activities should be done in consultation with SDC, the Board's EMMP Specialists, the Contractor's Marine Specialist

and NParks. The Contractor's Marine Specialist should include a Coral Transplantation Plan in the CEMMP. Additionally, if transplantation has occurred within the Study Area, these specimens should be monitored for health and survival as part of the monthly fauna inspections. Specific details should be included in the Coral Transplantation Plan in the CEMMP.

g) During coral spawning season which is typically three or four nights after the full moon in late March or April or as stipulated by NParks, no boat activity (for construction activities, monitoring or for any other purposes) and no night work should be carried. Water quality, intertidal, subtidal monitoring and sedimentation should be carried out before the coral spawning season and not during the coral spawning event.
h) Retain ground cover for as long as possible before removal. When ground cover is removed, erosion control measures (ECM) is to be in place.
i) Where the use of erosion control blanket (ECBs) is necessary, use only fully biodegradable wildlife-friendly ECBS to avoid trapping fossorial fauna such as snakes. However, ECBs should be checked daily by the EM for fauna entrapment.
j) Regularly inspect hoarding and silt fence to ensure its structural integrity.
k) Ensure good housekeeping practices on site. This includes recommendations proposed to ensure good waste management practices.
l) Conduct biodiversity awareness training for site personnel for actions to take when encountering wildlife, particularly long-tailed macaque (*Macaca fascicularis*) and smooth-coated otter (*Lutrogale perspicillata*). Biodiversity awareness training should also emphasis the restriction of harvesting of intertidal flora and fauna.
m) Restrict entry of site personal into areas outside of the working area. This includes the intertidal, subtidal and coastal forest areas. .

As night works are anticipated for this Project, the proposed nightwork monitoring plan shall be submitted for SDC's and NParks approval, prior to commencement of night works. The Contractor shall ensure that:

- Artificial lighting is controlled to minimise light pollution spill over from the working areas.
- Lighting shall be directed downwards and towards the working areas.
- Light sources shall be the minimum required for on-site safety and security. When possible, guidelines state in NParks BIA Guideline Technical Notes for Light Management in Night Works (**Appendix O**) should be adhered to. This includes the use of warmer temperature lights (2000 to 3000 Kelvin) and LED light sources.
- Lighting of the site outside of the main construction period (i.e., 0800 – 1800 hours) should be as limited as possible.
- During coral spawning season which is typically three or four nights after the full moon in late March or April or as stipulated by NParks, no night work should be carried out.

6.3.7 Waste Management

The Contractor shall ensure:

a) Waste generated from the construction activities are only stored at designated areas;
b) No construction wastes (wastewater and solid wastes) will be disposed of into public drains;
c) Food waste bins and bin centres must be wildlife-proof;

d) Refuse bins for general waste will be easily accessible by workers and will be emptied at the end of every working day. A licensed general waste collector will be hired for the daily collection of general waste from the site;
e) Specialised containers for the collection of toxic chemical waste (if any) will be provided and these containers will not be accessible and kept under lock and key to prevent unauthorised access. A licensed hazardous waste collector will be hired to collect toxic waste when required;
f) Waste transfer manifest will be documented, maintained and made available for audit;
g) Recycling initiatives to be implemented, where possible;
h) Waste management inspections will be conducted to examine all aspects of waste management including waste generation, storage, recycling, treatment, transportation, disposal and their records;
i) Training will be included for all the construction personnel prior to the start of construction on the good practices of waste management (e.g., minimise waste generation and proper waste disposal). Information on how to effectively utilise the waste management facilities will be conveyed to them; and
j) Records and checklist shall be kept for records and made available for audit where required.

6.3.8 Vector Control

Fogging treatment and use of anti-malarial oil or equivalent chemicals is not permitted except in exceptional circumstances on approval of SDC (e.g., disease outbreak).

For mosquito control, the Contractor shall obtain approval from the Board prior to implementing *Bacillus thuringiensis israelensis* (Bti) programmes in consultation with a pest control vendor. The primary means of vector control should be prevention of mosquito breeding via proper housekeeping.

6.3.9 Site Layout

In carrying out the Works, due regard shall be paid to the sensitivity of the environment and the amenities of adjacent property and to the interests of owners, tenants, and occupiers.

The Contractor shall establish and submit a Site Layout Plan for acceptance by SDC before commencement of work on site to ensure that the working area is minimised to the extent possible, designed to minimise biodiversity and environmental impact to the surroundings, as well as promote efficiency of operations, safe work environment, worker safety and productivity. The relevant biodiversity and environmental requirements and considerations for the layout, planning and organisation of the site shall be described in detail. The Contractor shall resubmit for approval the updated typical site layout plan whenever conditions in the current approved plan have changed.

The typical site layout plan shall depict the proposed locations of temporary facilities within the construction site boundary—portable toilets, material storage areas, machinery parking areas, active work areas, tool and equipment areas, washing points, worker rest areas, vehicular access routes, access for workers and pedestrian walkways—as needed.

The size and location of the above areas shall take into consideration project needs, site conditions and applicable regulations to mitigate safety and health risks. The temporary facilities as stated below shall be clearly demarcated with signage and barricaded where possible.

6.3.9.1 Working Area

The Contractor shall keep the working area to the minimum necessary to complete the work. He shall at all times keep the working area free from accumulation of machinery not in regular use, waste materials, rubbish and stagnant water.

The Contractor shall take adequate steps to prevent trespass by his employees and shall be wholly responsible for making good any loss or damage caused by such trespass. The Contractor shall take all necessary steps to ensure that the activities of his employees (and those of his sub-contractors) do not encroach into the adjacent properties or have any detrimental effect on the surrounding environment. Worksites shall be clearly demarcated on-site, where feasible to avoid unnecessary vegetation clearance or impact to intertidal and/or subtidal area.

6.3.9.2 Site Access/Routes

Site access/egress and internal routes shall be restricted to those shown on the Site Layout Plan and demarcated clearly on-site. This includes barge parking locations. Recommendation should be taken from EIA, any deviation should seek approval from SDC (**Figure 6-1**).

Figure 6-1 Recommended site access assessed and accepted in the EIA

6.3.9.3 Storage Areas

Proper locations shall be identified for material storage on the bund The amount and type of material to be stored shall be indicated on the Site Layout Plan. The storage area shall be the minimum necessary to complete the works with no storage on the seabed. No additional vegetation clearance should be done to accommodate permanent or temporary storage facilities. No storage of diesel or petrol is

allowed on site at any time except within designated material storage area such as the barge or bund only and with appropriate secondary containment system. When refuelling of machinery is required, diesel or petrol cans are to be transported within secondary containment to the location of the machinery with caution. No pouring of diesel or petrol directly from cans is allowed during refuelling. The Contractor is required to use a rotary pump fitted with stop valve or equivalent during transfer of diesel or petrol from the cans to the machines. Spill kits are to be always available at the storage areas and refuelling locations.

6.3.9.4 Welfare Facilities

Rest areas, meal areas and adequate portable toilets shall be provided and indicated on the layout plan. If necessary, sanitary facilities (portable toilets) shall be located away from the intertidal zone (this includes the rocky shore and seagrass meadows). The Contractor shall make provision for the portable toilet(s) to be emptied regularly by a Licensed Waste Contractor. Rest areas where food and beverage are consumed must be enclosed and provided with wildlife-proof bins.

6.3.10 Environmental Incident Contingency Plan

The Contractor shall provide an Environmental Incident Contingency Plan to facilitate coordinated response actions by the Contractor and the Agencies to protect the environment from damaging effects of unauthorised and accidental release of pollutants.

The plan shall provide:

a) The assignment of duties and responsibilities among involved stakeholders in relation to the responsibilities of the party, or parties, responsible for the pollution incident.
b) A reporting system suitable for the rapid receipt of pollution reports and for notifying other jurisdiction as warranted.
c) The establishment of a focal point to provide coordination and direction for the implementation of this plan.
d) The identification of expertise and response resources that may be of assistance for the implementation of this Plan.
e) Policies with respect to emergency provisions applicable to the handling, treatment or disposal of certain pollutants.

In the event of an incident with minor to moderate significance, the Contractor shall identify the source of pollution, and notify SDC accordingly. Additional monitoring will be conducted to investigate the causes of exceedance and report the investigation results to SDC, and if exceedance is due to the construction works. The Contractor shall increase monitoring frequency until exceedance stops if exceedances are considered related to the Contractor's construction works and report the results.

In the event of an incident with risk of major significance, the Contractor shall stop work immediately and take immediate action to avoid further exceedance and rectify any unacceptable practice. He shall submit the mitigation plan and actions undertaken if the Environmental Team has indicated that exceedance is related to the construction works and amend the construction methodology if appropriate. The Contractor shall also ensure the handling of environmental complaints follows the established environmental complaint reporting channel as defined within the contingency plan.

During the grievance investigation work, the Contractor shall cooperate with SDC in providing all necessary information and assistance for completion of the investigation. If mitigation measures are identified in the investigation, the Contractor shall promptly carry out the mitigation works. SDC and Board's EMMP Specialists shall ensure that the measures have been carried out by the Contractor.

6.3.11 Wildlife Response Plan

The Wildlife Response Plan will be activated whenever a trapped/injured/dead/dangerous animal is encountered around or within the worksites. The objective of the Wildlife Response Plan is to minimise animal injury and mortality by responding appropriately to the different fauna encounter scenarios in **Figure 6-2**. This will be emphasized during the biodiversity awareness training (**Section 6.3.13**). All wildlife incidents shall be reported and documented in a Wildlife Incident Form (**Appendix N**).

The Contractor shall engage a Wildlife Management Company to carry out trapping, rescue, and/or relocation of trapped or injured fauna in accordance with S10 and S5 directives. The Wildlife Management Company shall be listed under NParks' public register of certified Wildlife Management Contractors.

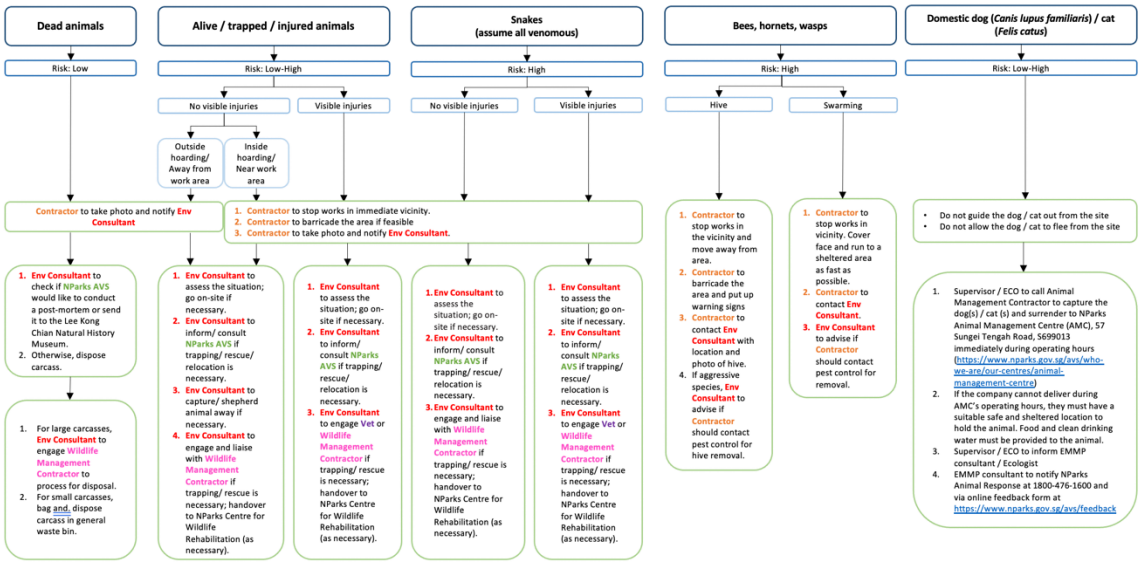


Figure 6-2 Flowchart of the Wildlife Response Plan

6.3.12 Emergency Preparedness

The Contractor shall ensure that all necessary precautions are taken for the safety and health of his working crew at all times.

The Contractor shall use fresh water for mitigating fire hazards rather than chemical suppressants.

The Environmental Manager shall be required to monitor the weather conditions. He shall inspect the work area after a heavy rainfall event or storm to ensure no major environmental incidents has occurred (e.g. siltation or erosion) from any of his work activities. He is to advise on the continuation of the

work activities or cease of all work activities if the weather conditions are not suitable to carry out the works.

An emergency preparedness plan shall be prepared to address all foreseeable emergency scenarios at the site and plan for appropriate response.

6.3.13 Biodiversity Awareness Training

The Contractor shall provide biodiversity awareness training to all staff and construction workers, including sub-Contractors prior to the commencement of their work activities, with mandatory refresher sessions at least every six months and regularly during daily toolbox briefings. Literature utilised for the briefing session shall be shared with the personnel involved. The briefing session shall provide details on various components in the CEMMP and shall minimally cover the following topics:

a) Sensitivities of the site surroundings.
b) Protection of biodiversity.
c) Preventing human-wildlife conflict (e.g., strictly no feeding of wildlife).
d) Preventing siltation and water pollution.
e) Housekeeping – litter prevention, vector control, etc.
f) F&B Control.

In addition, the relevant key messages on the above topics should be communicated to all visitors to the site in one briefing session (e.g., concurrent with Health and Safety on-site induction).

6.4 Biodiversity Monitoring Programme Requirement

The Contractor shall have in place monitoring and inspection regimes to check if the specified biodiversity and environmental mitigation measures are effective throughout the construction phase. He shall take note that strict compliance with the biodiversity and environmental requirements, including all necessary biodiversity and environmental mitigation measures, is his full responsibility.

Any specialist sub-contractor engaged by the Contractor to undertake the works under the EMMP shall be adequately experienced, with relevant certification or accreditation from local statutory bodies if required. Equipment and instrument used shall be maintained/ calibrated with manufacturer recommended frequencies. All the certifications, accreditation and quality assurance records shall be gathered and documented if and when required by SDC.

The final monitoring plan to be implemented over the course of the construction phase will be developed as part of the CEMMP by the Contractor, for submission to SDC.

6.4.1 Flora and Arboriculture

Flora and arboriculture management consists of managing matters related to the adequate and successful conservation of trees and vegetation within and adjacent to the worksite (up to 15-m from the worksite, **Figure 6-4**).

The flora and arboriculture monitoring aims to assess the impacts of construction to retained vegetation and habitat (i.e., adjacent forest), such as tree health, unauthorised vegetation removal, edge effects, habitat degradation from soil erosion, and rubbish dumping.

This includes the reviewing of tree felling and site clearance plans (**Section 6.4.1.1**), establishment of tree protection zones (**Section 6.4.1.2**), verification and reviewing of site works (**Section 6.4.1.3**), salvaging of species of conservation significance (**Section 6.4.1.4**) and site inspections (**Section 6.4.1.5 to 6.4.1.6**).

6.4.1.1 Review of Tree Felling and Site Clearance Plans

The Contractor's appointed Certified Arborist is to determine the trees to be retained or felled before the commencement of construction activities. This is to be carried with referenced to the arboriculture data from the Baseline Study, which includes the assessment of tree physiological health, vigour, and structural stability, photographs, as well as the geographic locations of each specimen. This should apply to trees within the development footprint, including working spaces, construction access roads, and hoarding boundaries.

Any horticultural waste resulting from vegetation clearance should be disposed of on the same day to reduce the likelihood of fauna seeking shelter among the horticultural waste.

6.4.1.2 Establishment of Tree Protection Zones (TPZs)

TPZs are to be erected for tree specimens recommended for retention by the Contractor's appointed Certified Arborist. These specimens could be within the development footprint and/or very close to but are outside the worksite boundary. In particular, there is recommendation in the EIA for retention of large *Xylocarpus rumphii* specimens (**Section 3.3.5.1**)—appropriate Tree Protection Zones (TPZs) should be established on site to ensure their continued preservation throughout the construction.

Proper TPZs with a designated access for monitoring purposes should be established by the Contractor according to guidelines provided in **Appendix L.** If there are design plans or site access issues, the Contractor's Arborist should propose measures to shield them from being damaged. This should be executed in consultation with the structural engineers and in accordance with the guidelines established by the NParks. Construction

works, such as tree felling and work in the 'no-go zone' for laying of trails (avoidance of tree roots), would require the Contractor's Arborist to oversee the works.

In the event of observed damage to flora and trees, the Contractor shall carry out the following steps:

1. Take immediate action to avoid further damage to the surrounding flora and trees;
2. Notify SDC / Board's EMMP Specialists for further assessment and determine the retention value of affected trees; and
3. Implement the proposed mitigation measures as recommended by SDC / Board's EMMP Specialists.

6.4.1.3 Verification and Review of Footprints for Worksite Boundaries and Access Pathways

Following the pegging of the worksite boundaries, as well as setting out for areas required for access pathways, material storage etc., the alignment and footprints are to be verified by the SDC's Flora Specialist via ground-truthing. This is to be carried out with the aid of a Global Positioning System (GPS) receiver and cross-checked with the development footprint drawings. The SDC's Flora Specialist should ensure there is no excessive vegetation and/or tree removal. The SDC's Flora Specialist should also review the proposed locations for access pathways, material storage etc., to ensure vegetation removal is kept minimal.

6.4.1.4 Salvaging of Plant Species of Conservation Significance

For affected plant species of conservation significance located within the working area, they should be salvaged prior to the start of hoarding installation and clearance works. Where plant specimens of conservation significance are located near the hoarding alignment, SDC's Flora Specialist should work with the Contractor to adjust the alignment to avoid direct or indirect impacts to plant specimens of conservation significance as much as possible. The final list of specimens to be salvaged should be carried out in consultation with NParks. Guidelines for sapling salvaging and harvesting is provided in **Appendix M**.

6.4.1.5 Monthly Arboriculture Inspection

The Contractor's appointed Certified Arborist is to carry out the following during the monthly arboriculture inspections:

1. Assess the conditions of retained trees as well as trees within 10 m along the new forest edges, i.e., physiological health, vigour, and structural stability, and recommended mitigation measures where necessary;
    a. Ensure they have not deteriorated and that there are no mechanical damages;
    b. Carry out rehabilitation and remediation measures of the trees exhibit signs of stress (e.g., implement a watering schedule to prevent plants from drying out);
    c. Implement long-term mitigation solutions or recommend additional tree removal where necessary;
2. Review method statements from builders for construction at proximity to trees;
3. Determine if more trees need to be removed after site clearance based on the construction activities happening in proximity to the retained trees and liaise with NParks for permission where necessary;
4. Ensure that there is no water ponding as a result of soil level changes and/or improper drainage within the designated TPZs;
5. Assess the site conditions and propose solutions if there are design changes, changes in working spaces, or TPZ dimensions, etc., to minimise conflicts with the original work protocols;
6. Inspect the integrity of the TPZs; and
7. Provide monthly report with recommendations of mitigating measure (s) if any, including photos of tree and conditions of TPZs; and
8. Ensure that works are carried in alignment with NParks' standards.

6.4.1.6 Monthly Flora Inspection

The Contractor's EMMP Specialist is to carry out the following during the monthly flora inspections:

1. Identify any unauthorised removal of vegetation beyond the agreed worksite boundaries;
2. Identify any habitat degradation (e.g., soil erosion, pollution, unauthorized dumping of waste material, construction debris, or oil/chemical leakage) to sensitive habitats as a result of construction activities;
3. Identify and monitor for forest edge effects and recommend appropriate mitigation measures, where applicable; and
4. Identify exotic fast-growing plants and provide recommendations for their removal, where applicable.
5. Monitor the health of transplant plants (if any).

6.4.2 Fauna

The fauna programme consists of managing of concerns related to fauna within and around all designated work areas (**Figure 6-4**). The objectives of fauna management plan are as follows:

- Minimise negative impacts to fauna, particularly to species of conservation interest
- Minimise fauna entrapment on site by inspecting features such as hoarding that may cause fauna entrapment as well as use of 100% biodegradable erosion control blankets (apart from those that are part of the slope stabilisation measures)
- Monitor presence of trapped/ injured/ dead fauna within working area
- Prevent human-wildlife conflicts

It includes pre-felling tree inspections for fauna (**Section 6.4.2.1**), as well as site inspections and monitoring (**Section 6.4.2.2** and **Section 6.4.2.36.4.2.4**).

6.4.2.1 Pre-felling Fauna Inspection

The Contractor's EMMP Specialist is to carry out the following for pre-felling fauna inspections if there is a need to remove any vegetation or fell trees. The pre-felling fauna inspection protocol is **Figure 6-3**.

1. Conduct pre-site clearance fauna inspections for trees and non-tree vegetation to be removed. The pre-site clearance fauna inspection includes the identification and reporting of the following:
    a. Active bird nests, including hollows, and other forms of nesting structures utilised by birds
    b. Active mammal nests/ burrows/ roosts
    c. Other less-mobile animals that are at risk of injury/ mortality during tree felling or vegetation removal (e.g., Sunda pangolin)
    d. Animals that may be implicated in human-wildlife conflict (e.g., snakes)
2. Check tree trunks, branches and canopy with binoculars from multiple angles and distances. Any cavities in tree trunks that may be utilised as nesting/ roosting structures are to be noted for closer inspection if deemed potentially active. If a nest is potentially identified and activity level is uncertain, the Ecologist will conduct or supervise the closer investigation of the nest site utilising elevating equipment where required
3. Produce a pre-felling fauna inspection report, indicating any relevant information collected during the inspection, including Tree Tag ID (and/ or flora location coordinates if not tagged), animal observations, recommended actions and photographic evidence
4. Pre-felling fauna inspection is valid for seven days, i.e., if the inspected trees or vegetation are not removed within seven days of the Ecologist's inspection, the inspection will be repeated
5. If animals or active nests are found, the Contractor shall:
    a. Not disturb the animal and allowed them to move away on their own before tree felling or vegetation removal, unless the Ecologist deems it necessary to relocate them
    b. Allow nesting birds to fledge and leave the nests on their own before tree felling or vegetation removal

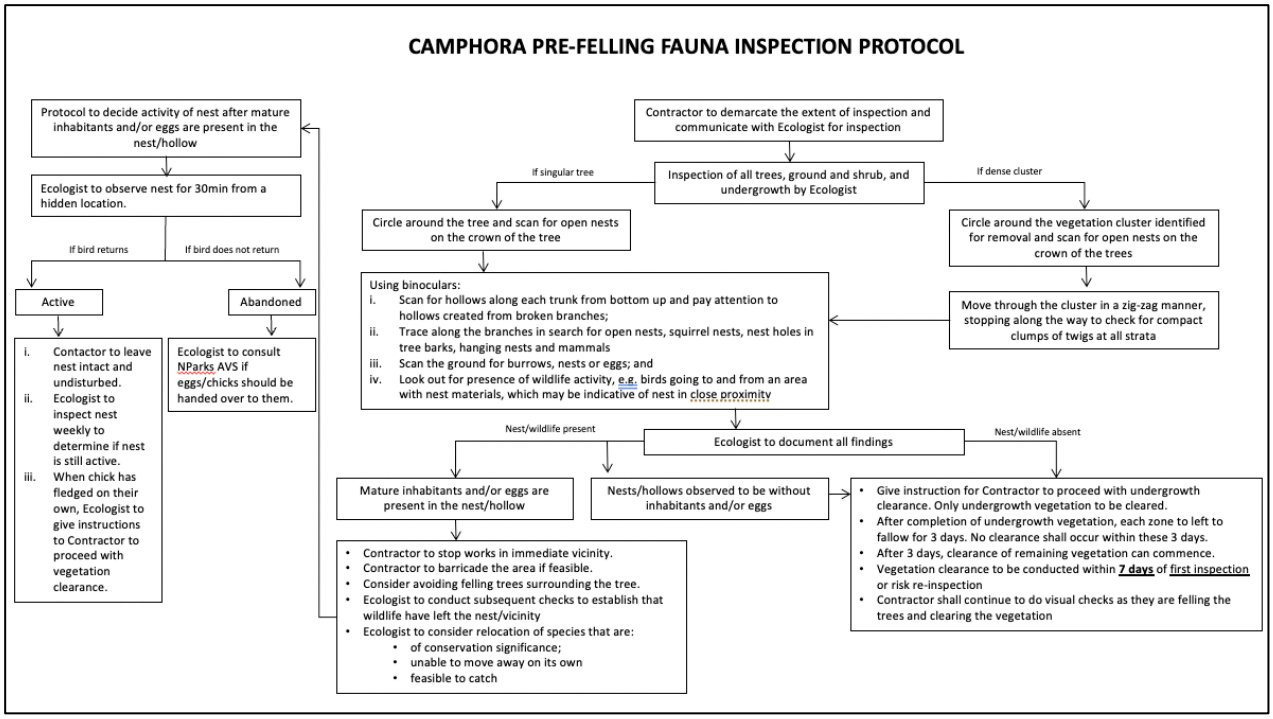


Figure 6-3 Pre-felling fauna inspection protocol

6.4.2.2 Daily Fauna Inspection

The Environmental Manager shall carry out routine biodiversity and environmental site inspections. These inspections should cover the biodiversity and environmental situation, pollution control and implementation of mitigation measures within the entire work site boundary, the intertidal zone and any off-site areas which are likely to be affected, directly or indirectly, by the site activities (**Figure 6-4**). The site inspection shall be carried out using standardised reporting methodologies, such as a Daily Checklist, including issues such as tree and biodiversity protection, storage of hazardous chemicals, waste reduction and management, pollution management, vector control, etc.

Inspection results and associated recommendations for improvements to the protection and pollution control shall be submitted to the Contractor's Site Supervisor within 24 hours for reference and for taking immediate action. The Contractor shall follow the procedures and timeframe stipulated in the biodiversity and environmental site inspection and the deficiency and action reporting system formulated by the Environmental Manager, and report on any remedial measures subsequent to the site inspections.

The Contractor’s Environmental Manager shall ensure that the following:

1. Visual inspections for integrity of silt fence to check for gaps;
2. Visual inspections of possible siltation events along Tanjong Rimau shores resulting from the works of this project;
3. Visual inspections for signs of any disturbances or other violations leading to impacts on wildlife. This includes, but is not limited to, signs of trapping of animals, roadkill, etc.; and
4. Carry out daily fauna inspection prior to the start of works. This includes a visual inspection for any dead or trapped wildlife, mass fish deaths, or dugong feeding trails along the coastal working area. Record the findings of the inspection in the Fauna Inspection Form. Implement Wildlife Response Plan (**Section 6.3.11**), where necessary; and record wildlife incidents on Fauna Incident Form (**Appendix N**).

6.4.2.3 Monthly Fauna Site Inspection

Monthly fauna inspections will be conducted within the work area boundaries. The Contractor's EMMP Specialist Team shall ensure that the following:

- Presence of trapped/ injured/ dead fauna.
- Potential fauna entrapments (e.g., ECBs, TPZs, pits, drains, ponds, trenches, tanks). The Contractor shall ensure that 100% biodegradable erosion control blankets are used to prevent snake entrapment, except those that have been propose as part of the slope stabilisation works.
- Non-compliance of ECM measures.
- Improperly disposed/ stored food and food packaging.

If specimens (i.e. corals) are transplanted to adjacent areas outside the working zone, these transplanted specimens shall also be monitored monthly. A detailed monitoring regime shall be incorporated into the CEMMP for SDC's review and approval.

6.4.2.4 Fauna Monitoring

Fauna monitoring surveys will be conducted once every two months by the Contractor's EMMP Specialist Team. The monitoring surveys should focus on the intertidal and subtidal habitats. The sampling methods and locations shall closely correspond to those undertaken during the EIA. A comparison of species presence can be made with the EIA, where appropriate, to indicate any changes in fauna diversity. Details of the surveys will consider the construction phases, final construction working area, and final construction access alignment.

Intertidal and Subtidal Surveys

Intertidal and subtidal surveys should be conducted once before the start of any construction activities (including terrestrial works). During the construction period and for six months after construction, survey should be carried out once every two months. One intertidal and subtidal survey should be conducted within two weeks prior to the coral spawning season. If the scheduled survey does not align with this period, the next survey should be brought forward accordingly. No surveys should be undertaken during the coral spawning event. Coral spawning period will be stipulated by NParks.

Intertidal surveys should be carried out at low-tide to monitor the impact (if any) on seagrasses and intertidal fauna using two methods.

(1) Quadrat survey: Four intertidal survey points (Q01-Q04; **Figure 6-4**) will be established at locations adjacent to the construction boundary and within sensitive habits. The location of the survey point will be fixed, with permanent markers installed where feasible. At each location, four replicate quadrats of 50 cm by 50 cm will be placed in areas within seagrasses to monitor the percentage cover.

(2) Transect surveys: Ten intertidal transects (T01-T10; **Figure 6-4**), each measuring 20 m in length, will be established along the intertidal zone. The start and end location of the transect will be fixed, with permanent markers installed where feasible. Five quadrats will be randomly placed along each transect to be surveyed.

For both methods, all percentage cover of a predetermined categories of flora and fauna within the quadrat, including seagrass, algae, other major sessile invertebrates, and abiotic substrate, should be documented (**Table 6-2**). All species within the quadrat should be identified to the lowest taxonomic level possible. Important behavioural observations (e.g., displaying guarding and mating) should be recorded. Other incidental observation of highly mobile fauna, including terrestrial fauna, should be recorded and reported.

Subtidal surveys should be carried out by SCUBA diving at safe conditions to monitor the impact (if any) on corals and subtidal fauna community using three methods at S01, S02 and S03 (**Figure 6-4**).

(1) Line Intercept Transect (LIT): Five transects (S01-S02; **Figure 6-4**) and three transects (S03, **Figure 6-4)** each measuring 20 m in length, will be established along the subtidal zone, within the area where baseline surveys were conducted. If this is not feasible due to the construction footprint, a reduced number should be proposed to NParks as part of the CEMMP.

Benthic lifeforms occurring directly beneath the transect tape should be recorded, as described by English et al. (1997) [19]. The benthic lifeform categories used to characterise the benthic morphology of the sites are described in **Table 6-3**. Permanent underwater markers can be placed at the start, 5m intervals along the transect and at the end of the transect.

(2) Belt surveys for fish and invertebrates: Along the same transect as the LIT and using following methods as described in English et al. (1997) [19], where fish and mobile invertebrates within a 5 m wide belt are recorded together with their abundance.

(3) Coral health monitoring: Along the same transect as the LIT, five coral colonies of at least 25 cm should be selected for monitoring throughout the construction period. Monitoring should include the measurement of its size and using the Coral Health Chart [40] to monitor for coral bleaching.

To ensure the safety of the divers, no barge works (i.e. barge movement) should be carried out during the diving surveys. Similar to intertidal surveys, all species recorded should be identified to the lowest taxonomic level possible. Important behavioural observations (e.g., displaying guarding and mating) should also be recorded.

If corals are transplanted, regular coral health monitoring of the transplanted colonies should be incorporated into the intertidal or subtidal surveys, depending on the location of the transplantation. The exact locations intertidal and subtidal surveys should be determined and recorded in the CEMMP in consultation with SDC, Board's EMMP Specialist team and NParks.

Table 6-2 List of targeted taxon in the intertidal zone

Intertidal Targeted Taxon	Description
Scleractinia	Hard corals
Alcyonaceae	Soft Corals
Porifera	Sponges
Algae	Turf algae, coralline algae, macroalgae, algae assemblage (non-distinct mass of algae consisting of more than 1 species)
Seagrass	Tape seagrass, spoon seagrass, Sickle seagrass
Polychaeta	Segmented worms
Crustacea	Barnacles, shrimps, crabs etc.
Ophiuroidea	Brittle stars and basket stars
Holothuroidea	Sea cucumbers
Asteroidea	Sea stars
Echinodea	Sand dollars and sea urchins
Enteropneusta	Acorn worms, live in sand or silt bottoms
Bivalvia	Clams, oysters, mussels etc.
Gastropoda	Cowries, cone shells, nudibranch etc.
Anopla	Unsegmented, ribbon worms
Turbellaria	Flatworms

Sipunculidea	Peanut worms

Table 6-3 List of targeted taxon in the subtidal zone

Major Benthic Category	Individual Category	Remarks/Comments
Targeted taxon	Hard Coral	All hard corals from order Scleractinia and blue coral (Helipora sp.). This includes mushroom coral that are solitary and free-living coral
	Soft coral	Soft-bodied corals from the order Alcyonaceae
	Sponges	A group of mostly filter-feeding sessile marine invertebrates from the phylum Porifera
	Algae	Including turf algae, coralline algae, macroalgae, algae assemblage (non-distinct mass of algae consisting of more than 1 species)
	Seagrass	From families Hydrocharitaceae and Cymodoceaceae
Targeted abiotic	Rubble	Unconsolidated coral fragments
	Rock	Non-carbonate, e.g., Granite rock
	Silt	Particles with grain size <63 µm; settles slowly when disturbed
	Sand	Particles with grain size >63 µm; settles fast when disturbed
Others	Others sessile fauna	Ascidians, anemone, giant clams, zoanthids etc.

6.5 Marine Water Quality Monitoring Programme Requirement

This section sets out the requirements for the Marine Water Quality Monitoring Programme to be implemented under the Construction Environmental Monitoring and Management Plan (CEMMP). The programme applies to all works that may affect nearshore waters at Tanjong Rimau, including temporary bund construction and removal, revetment and XblocPlus placement, slope works close to the shoreline, and operation of marine vessels and barges.

The monitoring programme is designed so that results are directly comparable with the baseline survey and with the ASEAN marine water quality criteria (AMWQC).

6.5.1 Objectives

The objectives of the marine water quality monitoring programme are to:

1. Verify that construction activities do not cause unacceptable deterioration in marine water quality compared with:
    - the baseline conditions established at stations S1, S2 and S3; and
    - the relevant AMWQC for coastal waters.
2. Provide early warning of any deterioration in water quality so that corrective actions can be taken before significant impacts occur.
3. Confirm the effectiveness of sediment and pollution control measures taken by the Contractor.
4. Provide a transparent record of marine water quality conditions for reporting to SDC and the relevant authorities.

6.5.2 Monitoring locations

Monitoring shall be carried out at the same marine stations used for the baseline survey (**Table 6-4**), or at stations that are demonstrably equivalent in position and exposure. Monitoring should be carried out monthly during the construction phase and once during the operational phase:

Table 6-4 Monitoring locations for marine water quality

Station ID	Role in programme	General description	Relation to works
S1	Impact station	Nearshore waters on the northern side of Tanjong Rimau headland	Within the near field of construction works at Site A and a barge berthing area.
S2	Impact station	Nearshore waters on the western side of Tanjong Rimau headland	Within the near field of construction works at Site B and a barge berthing area.
S3	Impact station	Nearshore waters along the southern shoreline of Tanjong Rimau	Within the near field of construction works at Sites C1 and C2.

The exact coordinates of S1, S2 and S3 shall follow those used in the baseline survey. Any relocation of a station must be justified, documented and agreed with the SDC and the relevant authority before monitoring begins.

6.5.3 Parameters and analytical methods

The monitoring programme shall, as a minimum, cover the parameters listed below (**Table 6-5**). These match the baseline survey to allow direct comparison.

Table 6-5 Parameters and criteria for marine water quality

Parameter	Unit	ASEAN Marine Water Quality Criteria (AMWQC)
Temperature	°C	Increase not more than 2 °C above the maximum ambient temperature
Dissolved Oxygen	mg/L	>4
Specific Conductivity	µS/cm	-
pH		-
Turbidity	NTU	-
Salinity	PSU	-
Secchi Depth	m	-
Ammonia as NH_3-N	µg/L	70
Cadmium as Cd	µg/L	10
Chromium as Cr(VI)	µg/L	50
Copper as Cu	µg/L	8
Cyanide as CN	µg/L	7
Lead as Pb	µg/L	8.5
Mercury as Hg	µg/L	0.16
Nitrate as NO_3-N	µg/L	60
Nitrite as NO_2-N	µg/L	55
Oil and Grease	mg/L	0.14
Phenolic Compounds as Phenols	mg/L	0.12
Phosphate as PO_4-P	µg/L	15
Tributyltin	ng/L	10

Total Suspended Solids (TSS)	mg/L	10% increase maximum over seasonal average concentration
Faecal Coliform	cfu/100mL	100
Enterococci	cfu/100mL	35

All in-situ measurements shall be taken using calibrated meters following the manufacturer's instructions. All laboratory analyses shall be carried out by an SINGLAS accredited laboratory using recognised standard methods (for example, APHA Standard Methods, US EPA Method, or equivalent). Detection limits shall be low enough to demonstrate compliance with the AMWQC.

6.5.4 Monitoring frequency and duration

Monitoring shall cover three stages: baseline verification, construction phase impact monitoring and post-construction verification (**Table 6-6**). In-situ water quality monitoring should be carried out using a calibrated multi-parameter probe and at depth of 1 m. Ex-situ marine water sample should be collected by grab sampling technique at a depth of 1 m at each point using a horizontal Van Dorn water sampler. Water quality methods should reassemble EIA baseline (**Section 4.1.1**). One water quality survey should be conducted one month prior to the coral spawning season. If the scheduled survey does not align with this period, it should be brought forward accordingly. No surveys should be undertaken during the coral spawning event. The coral spawning season will be stipulated by NParks.

Table 6-6 Marine water quality monitoring frequency

Stage	Activity period	Stations	Minimum frequency	Key Notes
Baseline verification	Before start of any construction activity	S01, S02, S03	One in-situ and ex-situ monitoring event covering spring-ebb and neap-flood conditions	Confirms that conditions are consistent with original baseline or identifies any new background trends
Construction phase impact monitoring	Throughout the construction period	S01, S02, S03	Monthly, in-situ and ex-situ monitoring event covering spring-ebb and neap-flood conditions.	Weather to be recorded
Post-construction verification	After completion of construction works	S01, S02, S03	Once every two months, in-situ and ex-situ monitoring event covering spring-ebb and neap-flood conditions.	Confirms that water quality has returned to baseline or long-term conditions

If monitoring indicates that action levels (Table 6-7**)** are exceeded, the frequency shall be increased, at the discretion of the SDC and Board's EMMP Specialist, at the affected stations until marine water quality returns to within the alert level.

6.5.5 Field procedures and data quality assurance

The Contractor shall prepare a Marine Water Quality Monitoring Plan describing field and laboratory procedures in detail. As a minimum, the following requirements apply:

1. Calibrate field meters at the start of each monitoring day using appropriate standards. Record calibration results.
2. Collect surface and near bottom samples at each station where water depth permits.
3. Use clean, labelled sample bottles and preserve samples as required by the analytical method.
4. Complete a field record sheet for each station, recording date, time, tide, weather, sea state, current direction, construction activities in progress and any visible plumes or spills.
5. Submit samples to the SINGLAS accredited laboratory within the specified holding times.
6. Implement quality assurance and quality control procedures, including field duplicates, blanks and laboratory control samples at a minimum rate of ten percent of total samples.

7. Store and manage all data in a structured database to allow trend analysis and comparison with baseline and criteria.

6.5.6 Compliance, alert and action levels

For each monitored parameter, compliance will be assessed against both:

1. The **AMWQC** or other applicable regulatory criteria; and
2. The **baseline reference values** derived from the original baseline survey and the pre-construction verification monitoring at station S01, S02 and S03.

To guide management responses, two performance levels are defined for key impact parameters (particularly turbidity and total suspended solids, and oil and grease, **Table 6-7**):

Table 6-7 Action levels for water quality

Parameter group	Alert Level (Level 1)	Action Level (Level 2)	Required response
Turbidity and TSS	Value at an impact station (S01, S02 or S03) exceeds 20 percent (%) above corresponding baseline value at that station but is still within AMWQC or regulatory criterion.	Value at an impact station exceeds regulatory criterion.	**Level 1:** verify field measurements, inspect silt control measures, check for spills, adjust work methods. **Level 2:** immediately review and, if necessary, suspend relevant works, strengthen controls, notify SDC and relevant authority within 24 hours, and increase monitoring frequency
Oil and grease, visible sheen	Any detectable visible surface sheen attributable to site activities or oil and grease value at an impact station more than 20% above corresponding baseline value at that station but is still within AMWQC or regulatory criterion.	Persistent visible sheen or oil and grease value at an impact station exceeding AMWQC or regulatory criterion.	Same as above, with additional investigation of equipment and storage areas and prompt clean-up of any spills
Nutrients and other chemical parameters	Single measurement at an impact station more than 20% above corresponding baseline value at that station but is still within AMWQC or regulatory criterion.	Repeated exceedance of AMWQC or regulatory criterion or clear upward trend over three or more events linked to site activities.	Investigate sources, review housekeeping and wastewater management, and implement corrective measures.

6.5.7 Reporting and communication

The Contractor's EMMP Specialist Team shall provide:

1. Monthly marine water quality monitoring summary reports that include:
    - field datasheet, and laboratory results;
    - description of construction activities carried out during the reporting period;
    - tabulated and graphical presentation of monitoring results at all stations;
    - comparison with baseline values and applicable criteria;
    - identification of any alert level or action level exceedances;
    - description of investigations, corrective actions and outcomes; and
    - recommendations for any changes to the monitoring programme.
2. Immediate incident reports to SDC and relevant authorities within 24 hours of obtaining the data, whenever an action level is exceeded or a significant spill or pollution event occurs, describing the circumstances, initial findings and interim control measures.

Reports shall be copied to the SDC and the relevant authorities, as required by the project approvals.

6.5.8 Roles and responsibilities

Responsibilities for the marine water quality monitoring programme are summarised below (**Table 6-8**).

Table 6-8 Key responsibilities for marine water quality

Party	Key responsibilities
Contractor	Implement all minimum control stated in 5.3.3 including marine pollution and sediment control measures, facilitate access for monitoring, stop or modify works when instructed following an action level exceedance, maintain a site log of activities and incidents
EMMP Specialist Team	Plan and carry out sampling and measurements, ensure data quality, assess compliance against criteria and baseline, recommend and track corrective actions, prepare all monitoring reports
SDC and Board's EMMP Specialist	Review and approve the monitoring plan, review monitoring results, instruct the Contractor on required corrective actions, liaise with regulatory authorities as needed

This Marine Water Quality Monitoring Programme Requirement shall be read together with the detailed method statements and control measures in the CEMMP and shall be fully implemented for the duration of construction works that may affect marine water quality.

6.6 Ambient Air Quality Monitoring Programme Requirement

This section describes the Ambient Quality Monitoring Programme that will be implemented under the Construction Environmental Monitoring and Management Plan (CEMMP). The programme covers ambient air quality at Fort Siloso and Shangri La Rasa Sentosa Resort

The programme is designed so that data are directly comparable to the baseline surveys and to applicable regulatory criteria. It provides an objective basis to detect any deterioration linked to construction activities and to trigger timely corrective action.

6.6.1 Objectives

The objectives of the Ambient Quality Monitoring Programme are to:

1. Verify that construction activities do not cause unacceptable deterioration in ambient air quality at Fort Siloso and Shangri La Rasa Sentosa Resort compared with baseline conditions and relevant regulatory criteria.
2. Provide early warning of any significant deterioration so that work methods and controls can be adjusted promptly.
3. Demonstrate the effectiveness of air pollution and dust control measures implemented by the Contractor.
4. Provide a clear and traceable record for the project proponent, SDC, and the relevant authorities.

6.6.2 Monitoring locations

Ambient air quality monitoring shall be carried out at the following locations, similar to the baseline survey (**Table 6-9**, **Figure 6-4**) for 7 consecutive days before the start of construction, continuously during the construction phase and 7 consecutive days post- construction:

Table 6-9 Monitoring locations for ambient air quality

Station ID	Role in programme	General description	Relation to project activities
P01	Impact station	Fort Siloso monitoring point, within the Fort Siloso compound	Representative of visitors and staff at Fort Siloso and coastal trail users

P02	Impact station	Shangri La Rasa Sentosa Resort monitoring point, within resort grounds	Representative of resort guests and staff potentially affected by construction works along the shoreline

The precise coordinates and mounting heights shall follow those used for the baseline monitoring. Any relocation of a station must be justified, documented and agreed with the SDC and the relevant authority before monitoring begins.

6.6.3 Parameters, instruments and averaging periods

A continuous real time ambient air quality monitor that has been co-located and validated against US EPA reference instruments, shall be installed at each station. Using the derived gain and offset correction factors from this co-location, the Kunak Air Pro is considered suitable and fit for purpose for the ambient air quality baseline monitoring at Tanjong Rimau.

As a minimum, the following pollutants and averaging periods shall be monitored for assessment against the Singapore Ambient Air Quality Targets (SAAQT) (**Table 6-10**):

Table 6-10 Singapore ambient air quality targets

Pollutant	Assessment averaging period	Typical use in assessment
Particulate matter with aerodynamic diameter ≤ 10 micrometre (PM_{10})	24-hour mean	Dust and construction particulate impacts
Particulate matter with aerodynamic diameter ≤ 2.5 micrometre ($PM_{2.5}$)	24-hour mean	Fine particulate health exposure
Sulphur dioxide (SO_2)	24-hour mean	Regional combustion contributions and ship emissions
Nitrogen dioxide (NO_2)	1-hour mean	Short term exposure to traffic and equipment emissions
Ozone (O_3)	8-hour mean	Regional photochemical smog background
Carbon monoxide (CO)	1-hour mean and 8-hour mean	Short term and daily exposure to combustion emissions

Data shall be logged at hourly intervals or finer and automatically aggregated into the above averaging periods for assessment.

6.6.4 Monitoring frequency and duration

Ambient air quality monitoring at P01 and P02 shall be continuous for the duration of construction works that have the potential to affect air quality, including:

1. Drilling, scaling and trimming of slopes
2. Handling and placement of aggregates, armour rock and XblocPlus units
3. Significant movement of construction vehicles and equipment on access roads and working platforms
4. Marine activities involving tugboats and barges near the shoreline

The minimum monitoring requirement is listed in **Table 6-11**.

Table 6-11 Ambient air quality monitoring frequency and duration

Phase	Stations	Minimum duration	Data requirement
Pre-construction verification	**P01 & P02**	At least 7 consecutive days before commencement of major earthworks	Valid data capture for at least 90 percent (%) of hours in the period
Active construction	**P01 & P02**	Entire period of construction works	Continuous monitoring with valid data capture for at least 95% of hours each month

Post-construction verification	**P01 & P02**	At least 7 consecutive days after completion of all construction works	Valid data capture for at least 90% of hours in the period

Where data capture falls below the required percentage due to instrument downtime, the EMMP Specialist Team shall identify the cause, rectify it promptly and document the data gap.

6.6.5 Data quality assurance

The EMMP Specialist Team will prepare an Ambient Air Quality Monitoring Plan covering:

1. Routine calibration and zero or span checks in accordance with manufacturer recommendations.
2. Verification and application of co-location derived correction factors (gain and offset) where relevant.
3. Routine data validation, including identification and flagging of instrument faults, implausible readings and communication errors.
4. Maintenance and security procedures to ensure the monitors remain powered, weather protected and not tampered with.
5. A structured data storage and backup system to allow retrieval and auditing of all raw and processed data.

6.6.6 Performance criteria and response levels

Ambient air quality results shall be compared against:

1. The SAAQT values for each pollutant and averaging period.
2. The baseline ranges established for P01 and P02.

For practical management, two levels of response are defined in **Table 6-12**.

Table 6-12 Alert levels for ambient air quality

Level	Description	Typical trigger condition (example)	Required response
Level 1 Alert	Early warning of increasing concentrations	Any 24-hour PM_{10} or $PM_{2.5}$ average at P01 or P02 is 20% above the baseline value at the station but below the SAAQT value.	Verify data, inspect dust controls, check housekeeping on haul roads and stockpiles, and adjust work methods where practicable
Level 2 Action	Exceedance or strong indication that an exceedance may occur	Any pollutant average used for assessment (for example 24-hour PM_{10} or $PM_{2.5}$, 1-hour NO_2, 8-hour CO, 24-hour SO_2, 8-hour O_3) at P01 or P02 exceeds the applicable SAAQT value and can reasonably be linked to project activities	Immediately investigate, identify likely sources, strengthen control measures, modify or temporarily suspend relevant works, and notify the Engineer and relevant authorities as required. Increase monitoring and report on corrective actions and follow up results

6.6.7 Reporting and Communication

The Contractor's EMMP Specialist Team shall submit:

1. Weekly summary plots and tables for internal management during active construction.
2. Monthly reports consolidating all ambient air quality data, including:
    - description of construction activities during the month
    - data completeness statistics
    - graphical and tabulated comparison with SAAQT and baseline
    - identification of any Level 1 or Level 2 events and associated investigations and actions.

Reports shall be copied to the SDC and the relevant authorities, as required by the project approvals.

Any Level 2 Action event shall be reported to the SDC within 24 hours with a short incident report, followed by a more detailed account, including root cause analysis and recommended improvements.

6.6.8 Roles and responsibilities

The main responsibilities for the Ambient Quality Monitoring Programme are summarised in **Table 6-13**.

Table 6-13 Key responsibilities for ambient air quality

Party	Key responsibilities
Contractor	Implement and maintain dust, emission and noise control measures; cooperate with the monitoring consultant; adjust or suspend works when instructed following Action level events; maintain records of construction activities, complaints and responses
EMMP Specialist Team	Install, operate and maintain ambient air quality monitoring equipment; ensure data quality and completeness; interpret results against criteria and baseline; advise the Contractor on exceedances and required corrective actions; prepare all monitoring reports
SDC and Board EMMP Specialist	Review and approve the monitoring plan, review monitoring results, instruct the Contractor on required corrective actions, liaise with regulatory authorities as needed

This Ambient Quality Monitoring Programme Requirement shall be read together with the detailed method statements and control measures in the CEMMP and shall be fully implemented for the duration of relevant construction activities.

6.7 Ambient Noise Monitoring Programme Requirement

This section sets out the Ambient Noise Monitoring Programme that will be implemented as part of the Construction Environmental Monitoring and Management Plan (CEMMP) for the proposed slope stabilisation works at Tanjong Rimau, Sentosa Island, Singapore.

The programme is designed to ensure that construction related noise remains within the maximum permissible noise levels prescribed under the Environmental Protection and Management (Control of Noise at Construction Sites) Regulations administered by the NEA, and that noise sensitive receptors are appropriately protected.

6.7.1 Objectives

The key objectives of the Ambient Noise Monitoring Programme are to:

1. Verify that construction activities do not cause unacceptable increases in ambient noise at Fort Siloso and Shangri La Rasa Sentosa Resort compared with baseline conditions and applicable regulatory limits.
2. Provide early warning where noise levels approach or exceed the maximum permissible noise levels so that corrective actions can be taken promptly.
3. Demonstrate the effectiveness of the noise control measures specified in the EMMP and in the Contractor’s method statements.
4. Provide a clear, auditable record of noise conditions during construction for the project proponent, Sentosa Development Corporation and the relevant authorities.

6.7.2 Monitoring locations

Ambient noise monitoring will be carried out at the same locations used for the baseline survey (**Table 6-14**, **Figure 6-4**). Monitoring should be carried out for 7 consecutive days before the start of construction, continuously during the construction phase and 7 consecutive days post- construction.

Table 6-14 Monitoring locations for ambient noise

Station ID	Role in programme	General description	Relation to project activities

P01	Impact station	Fort Siloso monitoring point, within the Fort Siloso compound and oriented toward the coastal slope.	Representative of visitors and staff at Fort Siloso and users of the adjacent coastal trail.
P02	Impact station	Shangri La Rasa Sentosa Resort monitoring point, within resort grounds toward the slope and shoreline.	Representative of resort guests and staff, including sea facing rooms and outdoor amenities.

The precise coordinates and mounting heights shall follow those used for the baseline monitoring. Any relocation of a station must be justified, documented and agreed with SDC and the relevant authority before monitoring begins.

6.7.3 Parameters and equipment

Type 1 precision integrating sound level meters shall be used at both stations. The meters must be approved by NEA and be suitable for continuous unattended outdoor monitoring with appropriate weather proofing and windshields.

1. The following parameters will be measured and logged
    - A weighted equivalent continuous sound level over five-minute intervals, denoted as LAeq 5-minute
    - A weighted equivalent continuous sound level over one-hour intervals, denoted as LAeq 1-hour
    - A weighted equivalent continuous sound level over 12-hour daytime and evening periods, denoted as LAeq 12-hour

Assessment will be made for the following regulatory periods as defined in the Environmental Protection and Management (Control of Noise at Construction Sites) Regulations for “Other buildings” (see **Table 4-4**)

6.7.4 Monitoring frequency and duration

Ambient noise monitoring will be continuous at N1 and N2 for the duration of all noisy construction activities that may affect the receptors, including

- Drilling of soil nails and rock dowels
- Rock scaling, trimming and any breaking or compaction at the slope toe
- Operation of excavators, cranes and lifting equipment
- Marine related activities such as barge loading and unloading near the shoreline
- Construction traffic on access routes close to Fort Siloso and Shangri La Rasa Sentosa Resort

Minimum requirements are listed in **Table 6-15**.

Table 6-15 Ambient noise monitoring frequency and duration

Phase	Stations	Minimum duration	Data completeness requirement
Pre-construction verification	P01 & P02	At least seven consecutive days before construction works begin	At least 90% valid 5-minute intervals
Active construction	P01 & P02	Entire period of construction works	At least 95% valid 5-minute intervals each calendar month
Post-construction verification	P01 & P02	At least seven consecutive days after completion of all construction works	At least 90% valid 5-minute intervals

Where data capture falls below the required percentage due to instrument downtime, the EMMP Specialist Team shall identify the cause, rectify it promptly and document the data gap.

6.7.5 Data quality assurance

The EMMP Specialist Team will develop a Noise Monitoring Plan covering:

- Instrument calibration procedures including field checks and laboratory calibration at intervals recommended by the manufacturer.
- Routine inspection of microphones, windshields and mounting arrangements.
- Verification of time synchronisation across stations.
- Procedures for identification, flagging and exclusion of invalid data such as periods affected by tampering, instrument malfunction or extraneous non project noise events where clearly documented.
- Secure storage and regular backup of raw and processed data so that full histories can be retrieved for audit.

A logbook will be maintained that records calibration checks, maintenance activities, incidents, complaints and any changes in monitoring configuration.

6.7.6 Compliance criteria and response levels

Measured noise levels will be compared against

- The maximum permissible noise levels for "Other buildings" defined in the Environmental Protection and Management (Control of Noise at Construction Sites) Regulations for the relevant period and construction phase
- The baseline noise levels at P01 and P02 documented in the Environmental Impact Assessment.

For practical site management, two response levels will be implemented (**Table 6-16**).

Table 6-16 Alert levels for ambient noise

Level	Description	Typical trigger example	Required response
Level 1 Alert	Early warning that noise is approaching the applicable permissible limit	Rolling LAeq 5-minute at P01 or P02 within three decibels of the relevant limit for the current period, or a sustained upward trend while noisy works are in progress	Confirm data validity, review active equipment and work fronts, optimise work sequencing, reduce simultaneous operation of noisy plant where practicable and improve localised controls such as temporary barriers and enclosures
Level 2 Action	Exceedance or repeated near exceedance of the permissible limit attributable to project activities	Any LAeq 5-minute above the relevant permissible limit at P01 or P02 that can reasonably be linked to construction works, or repeated Level 1 Alert events over approximately one hour without improvement	Immediately review and adjust or temporarily stop the noisy activity, deploy additional mitigation measures such as mobile barriers, revise working method or plant selection, and notify the Engineer. Investigate the cause and implement corrective and preventive actions. Increase the frequency of internal review until levels are brought back under control

The relationship between the regulatory limits, the early warning Level 1 Alert and Level 2 Action are summarised below (**Table 6-17**).

Table 6-17 Ambient noise regulatory limit and associated actions

Indicator	Typical value relative to regulatory limit	Purpose
Regulatory limit	As stipulated in the Environmental Protection and Management (Control of Noise at Construction Sites) Regulations	Compliance requirement
Level 1 Alert threshold	Approximately three decibels below the limit	Early warning and proactive management
Level 2 Action threshold	At or above the limit	Trigger for immediate mitigation and possible work adjustment or suspension

These specific values can be refined in the CEMMP once construction methods and detailed plant lists are confirmed.

6.7.7 Reporting and Communication

The Contractor's EMMP Specialist Team will prepare:

1. Short weekly summaries for internal use that show time series plots of LAeq 5-minute at P01 and P02, annotated with major construction activities and any Level 1 or Level 2 events.
2. Formal monthly monitoring reports that include
    - a description of construction activities and work fronts during the reporting month
    - a summary of data completeness for each station
    - tables and charts comparing measured LAeq values with the applicable limits and baseline levels
    - details of all Level 1 Alert and Level 2 Action events, including causes, corrective measures taken and confirmation of follow up performance

Reports shall be copied to the SDC and the relevant authorities, as required by the project approvals.

Any Level 2 Action event shall be reported to the SDC within 24 hours with a short incident report, followed by a more detailed account, including root cause analysis and recommended improvements.

6.7.8 Roles and responsibilities

The key roles and responsibilities for implementing the Ambient Noise Monitoring Programme are summarised in **Table 6-18**.

Table 6-18 Roles and responsibilities for ambient noise monitoring

Party	Key responsibilities
Contractor	Implement all noise control measures specified in the EMMP and method statements, cooperate fully with the EMMP Specialist Team, maintain a log of construction activities and any noise related complaints, and adjust or suspend works when instructed following Level 2 Action events.
EMMP Specialist Team	Install, operate and maintain the noise monitoring equipment, ensure data quality and completeness, interpret noise results, identify Level 1 and Level 2 events, recommend corrective actions and prepare all required monitoring reports.
SDC and Board EMMP Specialist	Review and approve the monitoring plan, review monitoring results, instruct the Contractor on required corrective actions, liaise with regulatory authorities as needed

This Ambient Noise Monitoring Programme Requirement shall be read together with the detailed method statements and control measures in the CEMMP and shall be fully implemented for the duration of relevant construction activities.

6.8 Ground Vibration Monitoring Programme Requirement

This section sets out the Ground Vibration Monitoring Programme to be implemented as part of the Construction Environmental Monitoring and Management Plan (CEMMP) for the proposed slope stabilisation works at Tanjong Rimau, Sentosa Island, Singapore.

The programme is designed to verify that construction related vibration remains within acceptable limits for both structural integrity and human comfort at vibration sensitive receptors, with specific reference to British Standard BS 5228 2:2009+A1:2014 "Code of practice for noise and vibration control on construction and open sites – Part 2: Vibration".

6.8.1 Objectives

The key objectives of the Ground Vibration Monitoring Programme are to:

1. Confirm that construction activities do not give rise to peak particle velocity levels that approach cosmetic damage guide values for sensitive buildings or cause unacceptable disturbance to occupants.

2. Provide early warning where vibration levels increase towards pre-defined project trigger thresholds so that corrective actions can be implemented promptly.
3. Demonstrate the effectiveness of the vibration control measures specified in the EMMP and in the Contractor's construction method statements.
4. Provide a transparent, auditable record of ground vibration conditions during construction for the project proponent, Sentosa Development Corporation and the relevant authorities.

6.8.2 Monitoring locations

Ground vibration monitoring will be carried out at the same locations used for the baseline survey and impact assessment (**Table 6-19**, **Figure 6-4**). Monitoring should be carried out for three consecutive days before the start of construction, continuously during high noise activities in the construction phase and three consecutive days post-construction.

Table 6-19 Monitoring locations for ground vibration

Station ID	Role in programme	General description	Relation to project activities
P01	Impact station	Fort Siloso vibration monitoring point located on firm ground close to heritage structures and oriented toward the coastal slope.	Representative of Fort Siloso heritage buildings and visitors using the fort and adjacent trails.
P02	Impact station	Shangri La Rasa Sentosa Resort vibration monitoring point located on firm ground within the resort, oriented toward the slope and shoreline.	Representative of resort buildings and occupants, including sea facing accommodations and common areas.

The precise coordinates and mounting heights shall follow those used for the baseline monitoring. Any relocation of a station must be justified, documented and agreed with the SDC and the relevant authority before monitoring begins.

6.8.3 Parameters and equipment

Ground vibration will be measured using permanent, triaxial vibration sensors (for example, geophones or accelerometers with appropriate converters) that are suitable for construction vibration monitoring and capable of logging continuous time histories and calculated metrics.

The primary assessment parameter is Peak Particle Velocity (PPV), measured in millimetres per second (mm/s), for each of the three orthogonal axes and as a resultant value.

Minimum equipment requirements are as follows:

1. Frequency range adequate to cover typical construction vibration (for example, approximately 2 hertz to 250 hertz or better).
2. Dynamic range sufficient to measure both low level background vibration and higher levels during drilling or other activities without clipping.
3. Secure and rigid coupling of the sensor to firm ground or a structural element representative of building foundations (for example, by bolting to a small concrete plinth or using approved mounting spikes where appropriate).
4. Data logger with accurate time synchronisation, continuous recording and sufficient memory for at least several weeks of data between downloads.
5. Capability to set and record exceedances of project specific PPV trigger and alarm thresholds.

A portable, calibrated field vibration source or a suitable functional test procedure will be used periodically to verify that each sensor and logging system is operating correctly.

6.8.4 Monitoring frequency and duration

Ground vibration monitoring will be focused on periods when vibration generating activities are underway and receptors could be affected. Typical sources include:

1. Drilling for soil nails and rock dowels.
2. Any localised rock breaking, trimming or compaction at the slope toe.
3. Movement of tracked or wheeled heavy plant on hard standing close to Fort Siloso and the resort.
4. Placement of armour rock and XblocPlus units and other marine operations close to the shoreline.

The minimum monitoring requirements are set out in **Table 6-20**.

Table 6-20 Ground vibration monitoring frequency and duration

Phase	Stations	Minimum monitoring requirement	Data completeness target
Pre-construction verification	P01 & P02	At least three consecutive days with representative existing activities but before major construction works begin	At least 90 percent valid PPV records for working hours
Active construction	P01 & P02	Continuous monitoring during all drilling, breaking, compaction and heavy plant operations that could affect receptors	At least 95 percent valid PPV records for each calendar month during working hours
Post-construction verification	P01 & P02	After completion of all construction works for 3 consecutive days	At least 90 percent valid PPV records for working hours

Where data capture falls below the required percentage due to instrument downtime, the EMMP Specialist Team shall identify the cause, rectify it promptly and document the data gap.

6.8.5 Data quality assurance

The Contractor's EMMP Specialist Team will develop and implement a Ground Vibration Monitoring Plan that includes clear procedures for:

1. Initial installation, including surface preparation, rigid mounting, orientation and verification of sensor coupling.
2. Instrument calibration, including manufacturer recommended laboratory calibration and regular field checks.
3. Verification of the accuracy of date and time stamps and synchronisation across stations.
4. Routine inspection of instrumentation after heavy rain, high tides or potential tampering.
5. Identification and flagging of suspect or invalid data, such as periods affected by instrument malfunction, disconnection or clearly unrelated extraordinary events, with justification recorded in the monitoring report.
6. Secure storage and regular backup of raw time histories and processed data so that complete records are available for audit if needed.

A dedicated log will be maintained for each station, recording installation details, calibration and maintenance activities, any incidents and any changes in configuration.

6.8.6 Compliance criteria and response levels

Measured ground vibration will be interpreted with reference to

1. British Standard BS 5228-2:2009+A1:2014 cosmetic damage guide values for buildings. For unreinforced or light framed structures such as residential or light commercial buildings, guide values are in the range of approximately 15 to 20 mm/s in the relevant frequency range. For reinforced or heavy structures, the guide value is 50 mm/s or above.

2. Human perception and comfort guidance from BS 5228-2. Vibration in the range of approximately 0.14 to 0.3 mm/s may be just perceptible, while sustained levels around 1 mm/s or more may lead to comment or complaint in quiet environments.

3. The baseline PPV ranges measured at Fort Siloso and Shangri La Rasa Sentosa, which are well below cosmetic damage thresholds but above perceptibility thresholds.

To provide a conservative margin of safety and to protect both structural and human receptors, project specific management thresholds will be adopted. These are not structural safety limits, but internal trigger levels intended to keep vibration comfortably below the BS 5228-2 cosmetic damage guide values and to manage human comfort proactively (**Table 6-21**).

Table 6-21 Project specific ground vibration criteria and response levels

Indicator	Typical threshold at P01 and P02	Basis and purpose	Required response
Cosmetic damage guide value (unreinforced or light framed buildings)	Approximately 15 to 20 mm/s (BS 5228-2)	International guidance for onset of cosmetic building damage	Used as an upper reference only; project management thresholds will be set well below this value
Project management target	5 mm/s PPV	Internal upper target for routine operations, based on impact assessment and human comfort considerations	Normal operations should be planned and controlled so that PPV at V1 and V2 generally remains at or below this level
Level 1 Alert threshold	3 mm/s PPV (single event or repeated occurrences over approximately 10 minutes)	Early warning that vibration is increasing above typical baseline values and approaching the project management target	Confirm data validity, identify active sources, review equipment settings and working methods, and implement practical reductions such as reduced drilling energy or increased separation distance where possible
Level 2 Action threshold	5 mm/s PPV (single event) or repeated events above 4 mm/s PPV within approximately 30 minutes	Action level set well below cosmetic damage criteria but at a level where human comfort could be affected if sustained	Immediately review and modify or temporarily suspend the high vibration activity, implement additional controls (for example, method change, alternative equipment, further separation), and notify the Engineer. Investigation and corrective measures will be documented and follow up checks carried out to confirm improvement

The specific numerical values may be refined in the detailed EMMP once final construction methods, equipment lists and updated baseline information are confirmed. Any change to these thresholds will be justified and recorded.

6.8.7 Reporting and Communication

The Contractor's EMMP Specialist Team will summarise vibration data in both short internal updates and formal reports.

1. Internal weekly summaries will include
    - Time history plots of PPV at P01 and P02 for key periods, annotated with major construction activities.
    - A list of all Level 1 Alert and Level 2 Action events, with times, sources where known and immediate responses.
2. Formal monthly reports will include at least
    - A description of construction activities and vibration sources during the reporting period.
    - Data completeness statistics for each station.
    - Summary tables of PPV statistics (for example, minimum, average, 95th percentile, maximum) for relevant work periods at P01 and P02.

- Comparison of measured PPV values against project management thresholds and BS 5228 2 guide values.
- Details of all Level 1 Alert and Level 2 Action events, including causes, corrective and preventive actions, and confirmation of subsequent performance.
- Any complaints or concerns raised by Fort Siloso or Shangri La Rasa Sentosa and the associated responses.

Any Level 2 Action event will be notified to the Engineer and project proponent within 24 hours through a brief incident note, followed by a more detailed note when the investigation is complete. A summary is listed in Table 6-21.

6.8.8 Roles and responsibilities

The key roles and responsibilities for implementing the Ground Vibration Monitoring Programme are summarised in **Table 6-22**.

Table 6-22 Roles and responsibilities for ground vibration monitoring

Party	Responsibilities
Contractor	Implement all vibration control measures specified in the EMMP and method statements; coordinate work sequencing to minimise high vibration activities near sensitive receptors; cooperate fully with the monitoring consultant; maintain a log of high vibration activities; and modify or suspend works when instructed following Level 2 Action events
EMMP Specialist Team	Design the Ground Vibration Monitoring Plan; install, operate and maintain vibration monitoring equipment at P01 and P02; ensure data quality; interpret vibration results; identify Level 1 and Level 2 events; recommend corrective actions; and prepare all required summaries and reports
SDC and Board EMMP Specialist	Approve the Ground Vibration Monitoring Plan and any revisions; review vibration monitoring reports and incident notes; agree on necessary changes to work methods and thresholds where justified; and coordinate communication with Sentosa Development Corporation and any regulatory authorities if required

This Ground Vibration Monitoring Programme Requirement will apply for the entire duration of relevant construction activities and shall be read together with the detailed method statements and control measures in the CEMMP and shall be fully implemented for the duration of relevant construction activities.

6.9 Sedimentation Monitoring Programme Requirement

Sediment traps act as measuring devices for sedimentation rates at the monitoring sites and provide feedback and validation for other monitoring parameters. At each station, three replicate traps, each made of three small cylindrical tubes attached together would be deployed along the reef crest (0 mCD), where coral cover is typically highest in Singapore. Replicates would be spaced approximately 2–5 m apart to capture local spatial variability, following the methods in the Survey Manual for Tropical Marine Resources [19]. Each replicate set would be collected monthly and sent to a laboratory for dry-weight analysis to derive sedimentation rates in kg/m²/day. The traps would be coated with non-toxic anti-fouling paint to reduce bio-fouling.

To establish baseline sedimentation rates, monitoring should begin at least one month before construction starts. Surveys would continue monthly throughout construction, and monthly for six months post-construction. One sedimentation survey should be conducted one month prior to the coral spawning season. If the scheduled survey does not align with this period, it should be brought forward accordingly. No surveys should be undertaken during the coral spawning event. Coral spawning period will be stipulated by NParks.

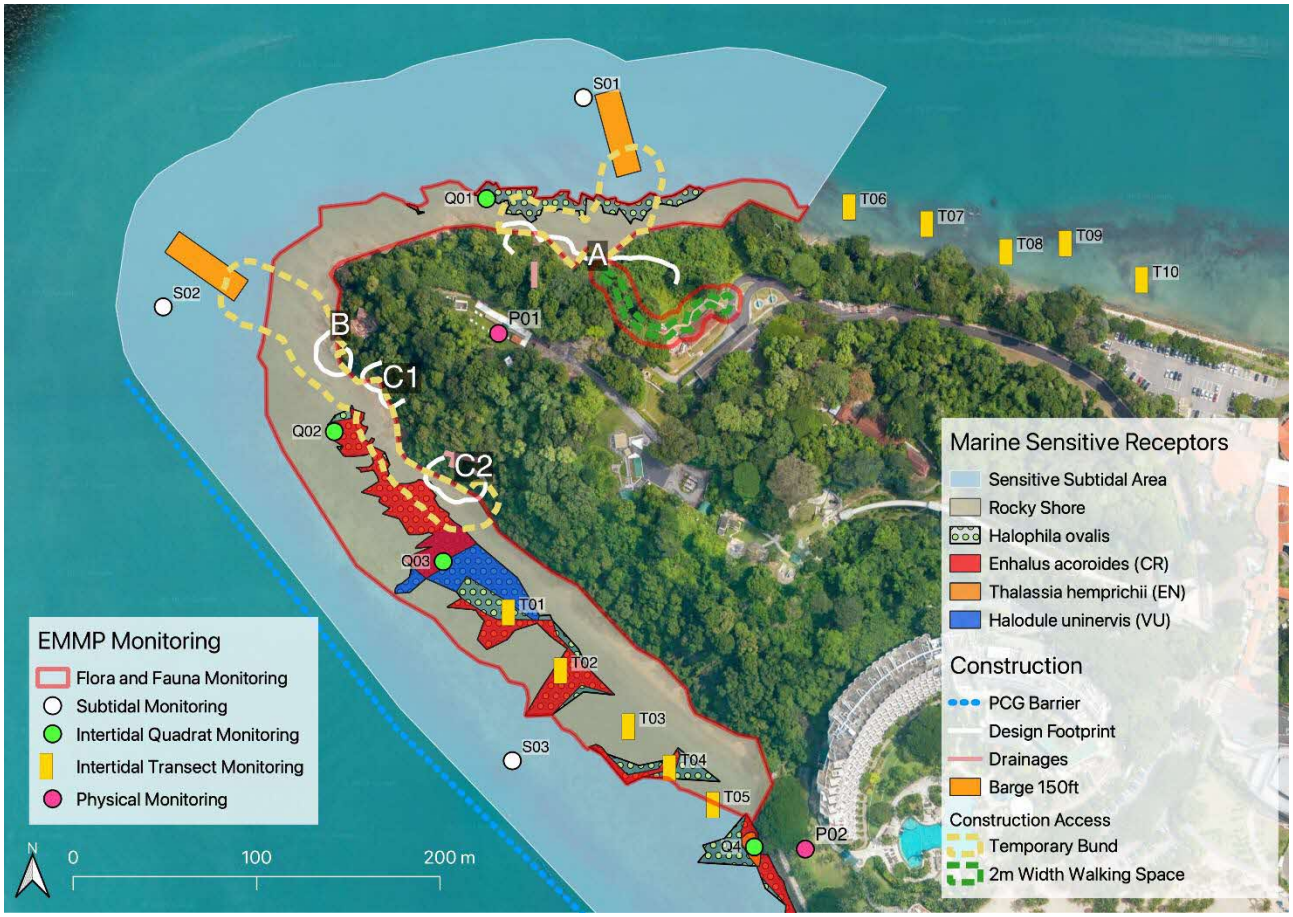


Figure 6-4 EMMP Monitoring locations

6.10 Post-construction Biodiversity Monitoring Requirements

The site should be fully cleared to restore its natural rocky shore appearance. The EMMP Specialist Team is to continue the supervision of the EMMP implementation by the Contractor after construction for a period of 6 months after completion of construction. Surveys shall be conducted at different frequency, some requiring surveys once every two months (i.e. immediately after the end of construction, the 2nd, 4th, and 6th month after construction). Post- construction monitoring is similar to the construction phase which includes both intertidal and subtidal surveys. There should be no need for inspection of work area. Similarly, transplanted specimens if any (terrestrial plants, and corals), should still be monitored closely. Adjustments should be made for marine surveys (intertidal, subtidal, water quality and sedimentation monitoring) during the coral spawning season, these surveys should be carried out before the actual spawning event. A summary of all the post-constriction monitoring is at **Table 6-23.**

The sampling methods and locations shall closely correspond to those undertaken during the construction monitoring. A comparison of species presence can be made with the EIA and construction monitoring, where appropriate, to indicate any changes in fauna diversity.

Table 6-23 Summary of monitoring requirements at the post-construction phase

Monitoring Type	Scope / Description	Locations (Figure 6-4)	Post-construction	Actioned By
Daily Site Inspection	Routine inspections of pollution control and ECM compliance. Check for trapped/injured fauna; assess entrapment risks (ECBs, pits, drains, TPZs)	Entire worksite boundary and	NA	Contractor's Environmental Manager

		intertidal areas		
Fauna Site Inspection	Entrapment risks, food waste issues, ECM non-compliance	Entire worksite boundary and intertidal areas	NA	Contractor's EMMP Specialist Team
Intertidal Survey[1]	Monitor for changes in intertidal biodiversity due to the construction using intertidal Transect and Quadrat method and monitoring of transplanted coral specimens (if any).	T01-T10	Once every two months	Contractor's EMMP Marine Specialist
Subtidal Survey[1]	Monitor for changes in subtidal biodiversity due to the construction using and monitoring of transplanted coral specimens (if any)	S01- S03	Once every two months	Contractor's EMMP Marine Specialist
Sedimentation[1]	Measures sedimentation rate using sedimentation traps.	S01- S03	Monthly	Contractor's EMMP Marine Specialist
Arboriculture Inspection	Monitor the health of retained trees, TPZ compliance and forest-edge condition. Monitor the health and survival of any terrestrial tree that is transplanted within the worksite boundary.	Retained trees; forest edge (10 m zone)	Once every two months	Contractor's Arborist
Flora Inspection	Monitor for unauthorised clearance, invasive species and habitat degradation. Monitor the health and survival of any terrestrial flora that is transplanted within the worksite boundary.	Flora monitoring boundary	Once every two months	Contractor's EMMP Flora Specialist
Marine Water Quality[1]	Monitor for changes in water quality due to the construction activity and to ensure that water quality levels are back to baseline values after construction. One in-situ and ex-situ monitoring event covering spring and neap tides, both flood and ebb conditions	S01- S03	Once every two months	Contractor's EMMP Marine Specialist
Ambient Air Quality	Continuous PM and gas monitoring ($PM_{2.5}$, PM_{10}, NO_2, SO_2, CO, O_3) to monitor for construction impact and to ensure that air quality levels are back to baseline values after construction.	P01 & P02	7 consecutive days	Contractor's EMMP Specialist
Ambient Noise	Continuous LAeq monitoring to ensure that vibration levels are within the limit	P01 & P02	7 consecutive days	Contractor's EMMP Specialist
Ground Vibration	Establish PPV baseline and regular monitoring to ensure that vibration levels are within limit	P01 & P02	3 consecutive days	Contractor's EMMP Specialist

[1]Surveys should follow the prescribed monitoring frequency (e.g. intertidal surveys once every two months during construction and post-construction phases). If scheduled surveys do not coincide with the coral spawning season, the dates should be adjusted such that intertidal and subtidal surveys are conducted within two weeks prior, and water quality and sedimentation surveys within one month prior to the spawning season. These surveys should not be conducted during the coral spawning event.

6.11 Biodiversity and Environmental Reporting

6.11.1 Reporting Requirements

6.11.1.1 Weekly Reporting

The Contractor and Environmental Manager shall maintain a weekly written report documenting the compliance of the Construction Works against EMMP requirements and this document shall be made available to SDC when requested.

6.11.1.2 Monthly Reporting

The Contractor shall prepare and submit monthly EMMP Reports within the first week of each month, to report on different aspects of the EMMP implementation in the preceding month for the whole construction phase. Non-conformities shall be highlighted in the reports.

The contents of the EMMP Monthly Reports shall include but is not limited to the following:

a) Types of relevant mitigation and management works implemented, corresponding to the specific project stage/activities;
b) Performance of the mitigation and management works;
c) Biodiversity and environmental monitoring results and findings, corresponding to the specific project stage/activities;
d) Incidents on site including incident investigation, root cause and corrective actions;
e) Exceedances (if any) on site including investigation, root cause and corrective actions;
f) Assessment of results against environmental standards; and
g) Further recommendations and corrective measures, if any.

The frequency of the EMMP Monthly Report may be adjusted to the corresponding construction stage or post-construction monitoring scopes required in the CEMMP measures.

The Environmental Manager is required to attend regular construction progress meetings between the Contractor and the Board (at least once a month) to present the monitoring results and observations, as well as recommendations where necessary.

6.11.1.3 Incident Reporting

Should the monitoring activities identify actual and/or potential non-conformities, the Environmental Manager shall implement or ensure implementation of corrective and preventive actions to deal with the identified non-conformities. This shall include and shall not be limited to the following:

a) Identifying and investigating non-conformities to determine their cause(s);
b) Correcting non-conformities and taking measures to mitigate their biodiversity and environmental impacts as appropriate;
c) Evaluating the needs for action(s) to prevent non-conformities and implementing appropriate actions designed to avoid their recurrence;
d) Recording the results of corrective actions, preventative actions and any decisions made on the EMMP; and
e) Reviewing the effectiveness of actions and decisions.

Any environmental incidents / non-conformances shall be reported to the SDC and the Board's EMMP Specialist.

6.11.2 Submission of Monitoring Reports

The following **Table 6-24** lists the submissions requirements for the Monitoring Reports. The Contractor shall ensure that all reports and documentation are prepared in a concise, accurate and professional manner with supporting diagrams, illustrations and drawings.

Table 6-24 Submissions Requirements for EMMP Monitoring Reports

S/N	Type of Report	Schedule of Delivery	Submission Requirements
1.	Submission of CEMMP	Three months within Contract award	1 soft copy + 1 hard copy
2.	Pre-construction Baseline Monitoring Report	Within one month of the last survey	1 soft copy + 2 hard copies
3.	Monthly Progress Reports	First week of each month, for monitoring done in the preceding month	1 soft copy + 2 hard copies
4.	Incident Compliance Reports	Within 24-hours of each incident	1 soft copy
5.	Other reports (Final approved copy)	As required	1 soft copy + 2 hard copies

Note:

Softcopy - Digital format in email or CD; and

Hardcopy - Coloured printed and bound.

7. Summary

7.1 Baseline and Environmental Impact Assessment

Sentosa Development Corporation (SDC) has appointed Camphora Pte Ltd (Camphora) to undertake an Environmental Impact Assessment (EIA) to comprehensively evaluated the potential environmental impacts of the proposed slope stabilisation construction at Tanjong Rimau.

Slope stabilisation works will be carried out at four locations (Sites A, B, C1, and C2) along Tanjong Rimau. At all sites, construction will begin with clearing loose soil, rocks, damaged structures, and vegetation, followed by the installation of temporary staging to facilitate safe access. At Site A, the slope will be reinforced with soil nails and grid beams, complemented by a XblocPlus and conventional armour rock revetment to reduce erosion. Stabilisation at Site B will involve the installation of rock dowels and rock netting. Sites C1 and C2 will be treated with erosion control blankets and further protected through the construction of the XblocPlus and conventional armour rock revetment. Construction access will rely primarily on marine transport, with barges delivering materials and excavators to a temporary rock bund that will serve as the working platform for all sites; terrestrial access will be required only at Site A to allow workers to reach the cliff-top area with minimal vegetation clearance along a 2 m wide path.

A summary of the potential residual impact significance of the assessed environmental aspects is summarised in table below (**Table 7-1**):

Table 7-1 Summary of Impact Significance

Environmental Aspect	Impact Significance (Unmitigated)	Residual Impact Significance (Post-mitigated)
Construction Phase		
Habitat	Negligible to Moderate	Negligible to Moderate
Flora	Negligible to Major	Negligible to Moderate
Fauna	Negligible to Moderate	Negligible to Moderate
Marine water quality	Minor to Moderate	Negligible to Minor
Ambient air quality	Negligible to Moderate	Negligible to Minor
Ambient noise	Minor to Moderate	Minor
Ground vibration	Minor to Moderate	Negligible to Minor
Operations Phase		
Habitat	Negligible	N/A
Fauna	Negligible	
Marine water quality	Minor	
Ambient air quality	Negligible	
Ambient noise	Negligible	
Ground vibration	Negligible	

Note:
N/A – where the impact significance with minimum controls is scored Negligible to Minor, no mitigation measures were proposed and hence, did not warrant for further assessment.

The EIA findings indicate that the anticipated adverse environmental impacts during construction can be effectively mitigated and reduced to within regulatory limits and acceptable residual levels. The recommended mitigation measures are designed to avoid, minimise, and control potential impacts.

To ensure these measures are properly implemented, an Environmental Monitoring and Management Plan (EMMP) should be developed. Upon commencement of works, the Contractor must ensure that all environmental control measures are adequate, actively minimise impacts, and validate any necessary adjustments to the recommended mitigation actions. The proposed mitigation, monitoring, and management measures have been detailed and assessed, and they are considered sufficient to ensure robust environmental management throughout the construction phase at Tanjong Rimau.

7.2 Biodiversity Monitoring Programme Requirement

The Environmental Management and Monitoring Plan (EMMP) sets out the framework for managing and monitoring biodiversity and environmental impacts arising from the Project's construction and operational

phases. It translates the mitigation measures identified in the EIA into an implementable set of requirements, performance standards, monitoring protocols and reporting responsibilities. The EMMP also provides the basis for the Contractor to develop a contract-specific Construction EMMP (CEMMP), which must be detailed, action-oriented and responsive to evolving site conditions.

The EMMP defines the objectives of the CEMMP and outlines the roles and responsibilities of the Contractor and its appointed Environmental Manager, Arborist and EMMP Specialist Team. It specifies the minimum biodiversity, environmental and operational requirements to be implemented throughout the Project, including measures relating to biodiversity protection, marine water quality, ambient air and noise control, vibration management, waste and vector control, site layout and housekeeping. Procedures for incident response, emergency preparedness and wildlife management are also prescribed in accordance with local regulatory requirements and NParks/NEA/PUB guidelines.

A comprehensive monitoring regime supports the implementation of the EMMP, ensuring the early detection of adverse impacts and enabling timely corrective actions. The monitoring framework covers weekly and ad hoc environmental inspections, flora and fauna monitoring, arboriculture inspections, intertidal and subtidal surveys, marine water quality monitoring, ambient air quality, noise and vibration monitoring, and post-construction for six months. Clear thresholds and action levels guide the Contractor's response to exceedances or non-compliances.

Table 7-2 provides a consolidated overview of all monitoring requirements, including their frequency, locations and the project phase during which each activity is to be undertaken.

Table 7-2 Summary of monitoring during EMMP phase (baseline, construction and post-construction phase)

Monitoring Type	Scope / Description	Locations (Figure 6-4)	Baseline	Construction Phase	Post-construction	Actioned By
Daily Site Inspection	Routine inspections of pollution control and ECM compliance. Check for trapped/injured fauna; assess entrapment risks (ECBs, pits, drains, TPZs)	Entire worksite boundary and intertidal areas	NA	Daily	NA	Contractor's Environmental Manager
Fauna Site Inspection	Entrapment risks, food waste issues, ECM non-compliance	Entire worksite boundary and intertidal areas	NA	Monthly	NA	Contractor's EMMP Specialist Team
Intertidal Survey[1]	Monitor for changes in intertidal biodiversity due to the construction using intertidal Transect and Quadrat method and monitoring of transplanted coral specimens (if any).	T01-T10	Once	Once every two months	Once every two months	Contractor's EMMP Marine Specialist
Subtidal Survey[1]	Monitor for changes in subtidal biodiversity due to the construction using and monitoring of transplanted coral specimens (if any)	S01- S03	Once	Once every two months	Once every two months	Contractor's EMMP Marine Specialist
Sedimentation[1]	Measures sedimentation rate using sedimentation traps.	S01- S03	Once one month before construction	Monthly	Monthly	Contractor's EMMP Marine Specialist
Arboriculture Inspection	Monitor the health of retained trees, TPZ compliance and forest-edge condition. Monitor the health and survival of any terrestrial tree that is transplanted within the worksite boundary.	Retained trees; forest edge (10 m zone)	When needed	Monthly	Once every two months	Contractor's Arborist
Flora Inspection	Monitor for unauthorised clearance, invasive species and habitat degradation. Monitor the health and survival of any terrestrial flora that is transplanted within the worksite boundary.	Flora monitoring boundary	Once	Monthly	Once every two months	Contractor's EMMP Flora Specialist

Marine Water Quality[1]	Monitor for changes in water quality due to the construction activity and to ensure that water quality levels are back to baseline values after construction. One in-situ and ex-situ monitoring event covering spring and neap tides, both flood and ebb conditions	S01- S03	Once	Monthly	Once every two months	Contractor's EMMP Marine Specialist
Ambient Air Quality	Continuous PM and gas monitoring ($PM_{2.5}$, PM_{10}, NO_2, SO_2, CO, O_3) to monitor for construction impact and to ensure that air quality levels are back to baseline values after construction.	P01 & P02	7 consecutive days	Continuous (≥95% uptime/month)	7 consecutive days	Contractor's EMMP Specialist
Ambient Noise	Continuous LAeq monitoring to ensure that vibration levels are within the limit	P01 & P02	7 consecutive days	Continuous (≥95% uptime/month)	7 consecutive days	Contractor's EMMP Specialist
Ground Vibration	Establish PPV baseline and regular monitoring to ensure that vibration levels are within limit	P01 & P02	3 consecutive days	Continuous, during high noise activity	3 consecutive days	Contractor's EMMP Specialist

[1]Surveys should follow the prescribed monitoring frequency (e.g. intertidal surveys once every two months during construction and post-construction phases). If scheduled surveys do not coincide with the coral spawning season, the dates should be adjusted such that intertidal and subtidal surveys are conducted within two weeks prior, and water quality and sedimentation surveys within one month prior to the spawning season. These surveys should not be conducted during the coral spawning event.

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Appendix A

Tanjong Rimau Lit Review Species List

Appendix B

Flora Datasheet

Appendix C

Arboriculture Tree Data

Appendix D

Intertidal and Subtidal Survey Data

Appendix E

Habitat Impact Assessment

Appendix F

Flora Impact Assessment

Appendix G

Fauna Impact Assessment

Appendix H

Marine Water Quality Test Report

Appendix I

Ambient Air Quality Test Report

Appendix J

MLS technical memorandum

Appendix K

Ground Vibration Test Report

Appendix L

Tree Protection and Conservation Guidelines

Appendix M

Guidelines for Sapling Harvesting, Tree Transplantation and Tree Maintenance

Appendix N

Wildlife Incident Form

Appendix O

Light Management in Night Works (NParks BIA Guidelines Technical Notes)