6 Predicted Environmental Impacts and Mitigation Measures

Environmental impacts covering all aspects of the natural and human environment are discussed in this section. The various construction and operations stage impacts are discussed according to the affected environmental component and assessed in a structured manner in terms of the magnitude of the effect, the consequences, and the temporal and spatial scale of the effect according to the methodology outlined in Section 6.1.

An outline of the issues addressed in this Section is given in Table 6.1. For each impact, the recommended mitigation measures are discussed, followed by an evaluation of residual impact severity, which is the level of impact that remains after all mitigation measures are implemented. Each impact is scored based on the matrix outlined in Section 6.1. A summary of all impacts is also given at the end of this chapter in Section 6.23.

Table 6.1 Environmental impacts evaluated and chapter outline.

Section	Type of Environmental Impact
6.2	Coastal Hydraulics
6.3	Coastal Morphology
6.4	Water Quality
6.5	Hydrology And Drainage
6.6	Air Quality
6.7	Noise
6.8	Terrestrial Ecology
6.9	Mangrove
6.10	Avifauna
6.11	Macrobenthos
6.12	Plankton
6.13	Fish Fauna
6.14	Marine Megafauna
6.15	Seagrass
6.16	Coral
6.17	Socioeconomic Impacts
6.18	Quantitative Risk Assessment
6.19	Health Impact Assessment

Section	Type of Environmental Impact
6.20	Land Use Compatibility Assessment
6.20.4	Land Traffic Impacts
6.22	Marine Traffic And Navigation

6.1 Impact Assessment Framework

For each potential impact, the impact severity is evaluated based on the spatial importance, magnitude of impact, its permanence, its reversibility and whether or not the impact is cumulative. These considerations are addressed in a structure manner through the Rapid Impact Assessment Matrix (RIAM) as outlined below:

6.1.1 General Analysis Scope

The scope of this DEIA was carefully determined through in-depth consideration of the environmental characteristics of the project site and the project itself. As noted, the scoping undertaken to determine the impact assessment scope and methods were documented and endorsed in the approved TOR.

6.1.1.1 Spatial Scope

The spatial scope for the analysis of the potential impacts extended to the area in which the impact would be realised (including any potential cross-border effects). This ultimately entailed that all analyses considered the affected areas at the appropriate scale for the particular environmental parameter. For example, model boundaries were determined to ensure sufficient coverage of potential impacts areas. In general, however, the primary spatial scope of analysis was within approximately 10 km of the project site for the marine environment and approximately 5 km from the project for the land-based, primarily socioeconomic, components. Key sensitive environmental features considered were the mangrove areas in Sg. Pulai, fringing the Tg. Piai and Pulau Kukup (encompassing Ramsar sites), seagrass meadows around Merambong Shoal, Tg. Adang/ PTP and in Sg. Pulai, corals around Pulau Merambong and finally coastal settlements and coastal industries in area.

The scope of assessment also determined the depth of baseline investigations as described in Sections 1.4.4.2 and 5 and the use of appropriate impact analysis methodologies.

6.1.1.2 Impact Assessment Scenarios

Project Phases

As described in Section 3.3, the project development will be carried out in three phases, with the second phase including capital dredging for the eastern berth areas. The pre and post-development conditions for these phases are depicted in Figure 6.2.

The impact evaluation, primarily for the hydraulic and habitat impacts, considers the impacts of each of these phases separately. This addresses the potential impacts of project abandonment or in the event of long delays in the implementation of subsequent phases.

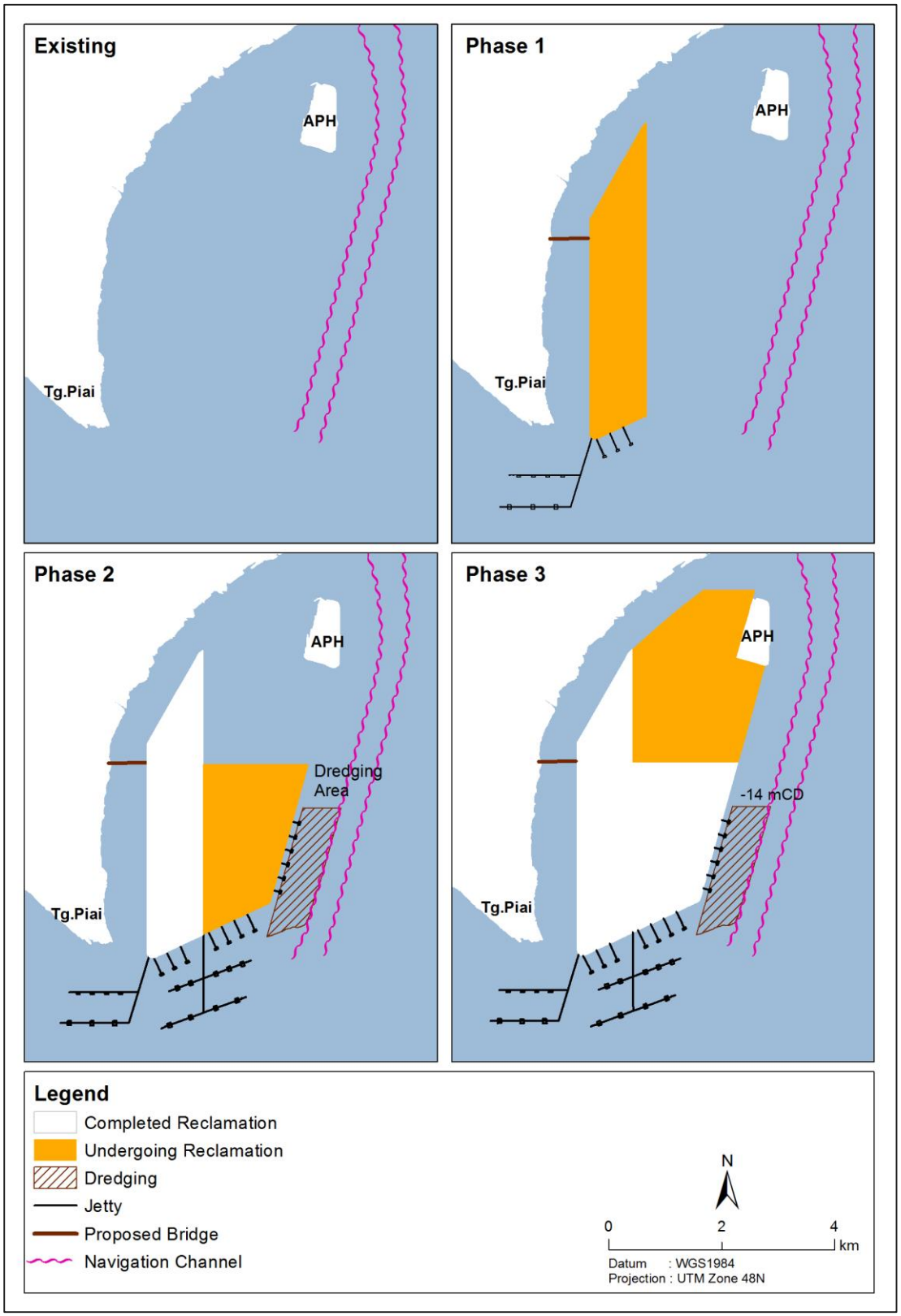

Figure 6.1 Reclamation phases considered in the impacts assessment.

Cumulative Impacts

The following future planned/ committed developments in the area have been considered:

- Port of Tg. Pelepas Phase IV (hydraulic assessment)
- Integrated Container Terminal (ICT) (land use compatibility assessment)

- Sg. Pulai Bridge (land use compatibility assessment)
- Tg. Bin Power Plant expansion (hydraulic assessment)
- DID Coastal Protection Scheme (hydraulic assessment)

These developments have been incorporated in the cumulative impacts assessments where relevant, namely for the hydraulic and flushing impacts as well as the land-use compatibility assessment.

6.1.1.3 Definitions

As outlined above, the impacts for each environmental component are assessed separately for the construction stage and the operations stage. In general, construction stage impacts are defined as all those that are related to the construction activities (temporary, process-based impacts), whereas operations stage impacts are all those related to the presence of the project footprint (permanent impacts) as well as related operational activities.

Hence for example, sediment plume impacts as a result of reclamation are a *construction stage* impact, whereas any permanent impacts arising from the reclamation footprint such as hydraulic impacts or the permanent loss of benthic habitat are discussed under the *operations stage* impacts (even though some of these impacts will be incurred during the construction phase).

Further to the above example, permanent impacts related to the footprint of the intermediate reclamation phases described in Section 6.1.1.2 are also assessed under *operations stage* impacts.

6.1.2 Rapid Impact Assessment Matrix (RIAM)

6.1.2.1 Evaluation Criteria

The RIAM framework structures the assessment on five criteria which are grouped into two categories as detailed below.

Group A Criteria

There are two criteria within Group A:

A1: **Importance** of the condition, which is assessed against the spatial boundaries, or human interests it will affect (Table 6.2) and

A2: **Magnitude**, which is defined as a measure of the scale or severity of benefits/dis-benefit of an impact (Table 6.3). At this scoping stage (i.e. prior to the impact prediction studies), the evaluation of impact magnitude/ severity has been based on the expert judgement of the consultants.

Table 6.2 Importance of the condition – scoring, generic and project-specific definitions.

Score	General Description	Project-specific Description
4	**Important to national/international interests**	**Malaysia as a whole and cross-border effects to Singapore**
3	Important to State / national interests	Johor and Peninsular Malaysia
2	Important to areas immediately outside the local condition	South Western Johor (Tanjung Piai, Sungai Pulai) and Johor Straits
1	Important only to the local condition	Tanjung Piai

Score	General Description	Project-specific Description
0	No importance	No importance/ not relevant

Table 6.3 Magnitude of the impact

Score	Definition
+3	Major positive benefit
+2	Significant improvement in status quo
+1	Improvement in status quo
0	No change/status quo
-1	Negative change to status quo
-2	Significant negative dis-benefit or change
-3	Major dis-benefit or change

Rating of Magnitude
With respect to biological – ecological impacts, the rating of impact magnitude has been guided by the general parameters listed in Table 6.4 below.

Table 6.4 Evaluation of magnitude of impact.

Category	Habitat	Protected species	Ecosystem functioning
Major	> 60% removed	Mortality may affect recruitment and capacity to increase	Measurable impact to functions, and some functions are missing/ declining/ increasing outside historical range and/or facilitate new species to appear.
Significant	30 – 60% removed	Mortality within some spp. Levels of impact at the maximum acceptable level.	Measurable changes to ecosystem components but no loss of functions or components.
Negative	<30% removed	Affected but no impact on local population status (e.g. stress or behavioural change to individuals).	Keystone species not affected, minor changes in relative abundance.
Beneficial	Habitat creation	Improvement in population status	N/A.

For social impacts, the impact significance evaluation has been guided by various considerations as outlined in Table 6.5.

Table 6.5 Significance criteria for social impact assessment.

Significance	Criteria: Social Impact
Major negative impact	Considerable adverse change to current amenity, lifestyle and everyday community activities and functioning. Displacement or relocation of houses or businesses Severance of many communities in the area from facilities and services. Permanent and total loss of formal and informal recreational facilities of regional importance, without opportunity for replacement / re-provisioning within the region. An 'unhealthy' demographic structure is created in a community. Permanent closure of one or more businesses. Significant impact to many tourist attractions / facilities. These impacts would be considered by society as constituting an important and usually long term- permanent change to the social environment.
Significant Adverse	Noticeable adverse change to current amenity, lifestyle and everyday community activities, but with scope for some mitigation. Relocation of a community and or recreational facility to a less socially appropriate location. Separation of a small number of residences from facilities and services. Impact to a number of tourist attractions / facilities. Adverse impact upon a large number of businesses, however their operations remain viable. The disruption of livelihood for a community. These impacts are real but not substantial, and would be viewed by society as constituting a fairly important and usually medium term change to the social environment
Minor Adverse	Localised or limited noticeable change to current amenity, lifestyle and everyday community activities, which can be largely mitigated. The functional usability of community and recreational (formal or informal) facilities affected. Localised or limited change to the operation of businesses or tourism facilities. Temporary access alterations to residential properties, businesses, community facilities and recreational areas during construction. The disruption of livelihood for a group of households. These impacts have little real effect, and would be viewed by society as constituting a fairly unimportant and usually short term change to the social environment

Group B Criteria

Group B criteria are:

- Permanence (B1)

This defines whether a condition is temporary or permanent and should be seen only as a measure of the temporal status of the condition.

- Reversibility (B2)

This defines whether the condition can be changed and is a measure of the control over the effect of the condition. It should not be confused or equated with permanence.

- Cumulativity (B3)

This is a measure of whether the effect will have a single direct impact or whether there will be a cumulative effect over time, or a synergistic effect with other conditions.

The scale of each Group B criterion is shown in Table 6.6 below.

Table 6.6 Scale for Group B criteria.

Score	Permanence (B1)	Reversibility (B2)	Cumulativity (B3)
1	No change/Not applicable		
2	Temporary	Reversible	Non-cumulative/Single
3	Permanent	Irreversible	Cumulative/Synergistic

6.1.2.2 Score and Range System

For each potential impact/ issue, an environmental score (ES) is calculated based on the following formula:

ES = A1*A2*(B1+B2+B3)

The ES scores are then banded together into ranges as detailed in Table 6.7. The range values span from major positive impact +E to major negative impacts -E.

Table 6.7 Range bands used for RIAM

RIAM Environmental Score (ES)	Range Value (RV)	Description of RV
72 to 108	E	Major positive impact
36 to 71	D	Significant positive impact
19 to 35	C	Moderate positive impact
10 to 18	B	Minor positive impact
1 to 9	A	Slight positive impact
0	N	No change/Status quo/Not applicable
-1 to -9	-A	Slight negative impact
-10 to -18	-B	Minor negative impact
-19 to -35	-C	Moderate negative impact
-36 to -71	-D	Significant negative impact
-72 to -108	-E	Major negative impact

6.2 Coastal Hydraulics

The behaviour of coastal environments is largely governed by the dynamics between tides, waves and winds. The implication is that planned reclamation and dredging works

associated with the Project may alter the existing hydrodynamic regimes (currents, water levels, tidal prism and waves) in the area that contribute to defining the coastal and marine characteristics of the Tg. Piai area, including morphology, water quality, and subsequently the ecology and drainage.

The likelihood and severity of such changes has been assessed using the numerical modelling described in Section 5 above and in greater detail in Appendix E. This section focuses on the hydraulic impacts, while consequent morphological impacts are discussed separately in Section 6.2.4.4.

6.2.1 Evaluation Framework

The predicted differences in currents, water levels and waves from existing conditions (the baseline) are used for this impact evaluation.

The methodologies and evaluation framework used to evaluate project-induced impacts to coastal dynamics are outlined in the following subsections. A detailed description of the model set-ups, bathymetries and the production periods can be found in Appendix E.

6.2.1.1 Impact Indicators

The framework used to determine whether project related changes to the hydraulic conditions at Tg. Piai are likely to lead to significant impacts are outlined below.

Currents

Flow conditions in the study area are primarily driven by tidal force but other effects as wind and pressure fields can also induce current flows. Changes to currents as a result of the Project are assessed through specific analysis of the following current characteristics:

Current fields

One of the most important assessments of changes in current conditions is the change in current fields. In particular, the generation of changes in the form of shear zones and eddies is a key indicator for potential negative change particularly in areas where navigation occurs. Although the presence of eddies or shear zones is a clear indicator of potential concern, the significance of any such changes remains specific to environmental receptors influenced.

Mean current speeds

Mean current speed is appropriate for determining overall changes to currents as a result of the Project. For assessment, this parameter is defined as the numerical depth-integrated mean of the current speed at each point in the model domain over a 14-day spring-neap tidal cycle. Changes in mean current speed less than 5% are typically considered as 'No Change.'

Maximum current speeds

This parameter is appropriate for assessing maximum/worst-case changes to the currents as a result of the Project. The maximum current conditions are defined as the numerical maximum of the depth-integrated current speed at each cell in the model domain over the 14-day modelled spring-neap tide period. Changes in maximum current speed less than 5% are typically considered as 'No Change.'

Water Levels

Changes to water levels as a result of the reclamation works are assessed based on the effect on rivers and streams in the Project area. Any increase in peak water levels can lead to increased flooding risk, and therefore any increase is a potentially negative impact. The water levels between the baseline (pre-development) condition and the post-development situation are compared for key areas, namely:

- Sg. Pulai river mouth

- Streams along the Piai coastline to the west of the proposed reclamation.

Waves

Effects of the reclamation work on the wave climate are based on the changes in frequency and direction as a result of the Project area, especially for the mangrove areas on the east coast where erosion is reported.

6.2.1.2 Scope

The reclamation will be carried out in three phases, with the second phase including capital dredging for the eastern berth areas (refer to Section 3.3 for further details). The scope for the hydraulic impact evaluation is to consider the impacts of each of these phases separately. The pre and post-development conditions for these phases are depicted in Figure 6.2.

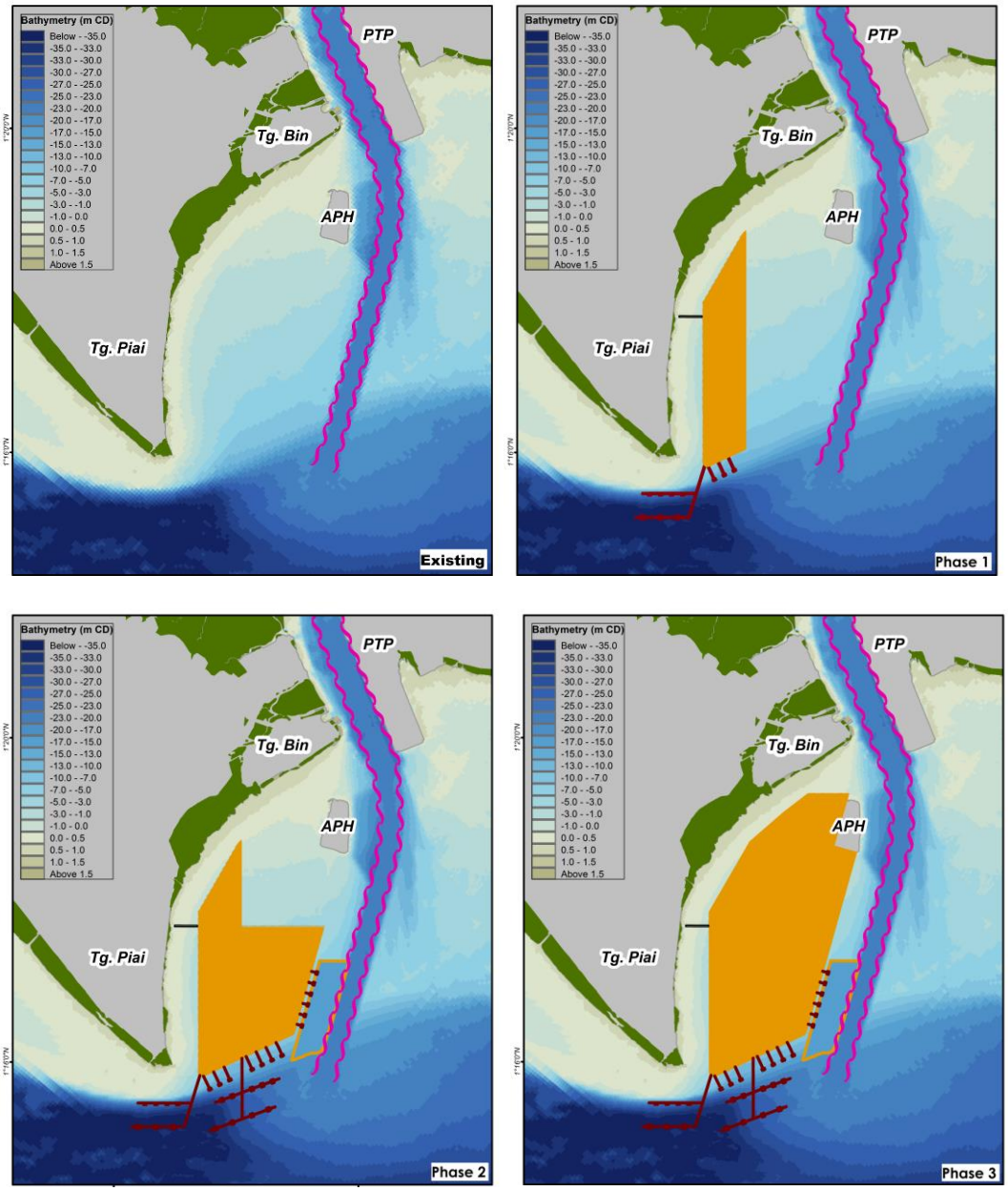

Figure 6.2 Reclamation phases considered in the construction stage hydraulic and morphological impacts assessment

6.2.2 Sensitive Receptors

Effects to the following sensitive receptors in the project area are used as the basis for the impact evaluation:

- Mangrove areas around Tg Piai, Sungai Pulai and Pulau Kukup;
- Intertidal mudflat areas;
- Relevant infrastructure: Pelabuhan Tanjung Pelepas (including the port and navigation channel), Tg Bin Power Station, Tg Bin Oil Terminal, etc.

6.2.3 Construction

6.2.3.1 Potential Impacts

There are no specific impacts on currents, water levels of waves created by the construction activities.

The presence of the reclamation, dredge pocket and jetties post-construction leads to an impact on currents, water levels and waves. As these impacts are permanent they are set out under Operational Impacts in Section 6.2.4.

6.2.4 Operation

Permanent impacts remain after the construction activities (reclamation and dredging) are completed. This includes changes from the reclamation works, the berthing jetty structures and the dredging of the seabed for navigations access on currents, water levels and wave climate. Potential permanent impacts on current flows, water levels and waves are explained in the sub-section below.

6.2.4.1 Potential Impacts

Currents

Potential impacts on current flow have been carried out for the three project phases of the development during NE, SW and inter monsoon. Since changes in current speed are similar for all climatic conditions, discussion on the impact assessment is focused on the NE monsoon conditions.

Phase 1

The predicted flows for existing and Phase 1 and the impacts of the development on the flow conditions are presented from Figure 6.3 through to Figure 6.6. The results show that changes are moderate and localised around the development, which is mainly related to the fact that the reclamation is built on shallow waters and mudflats that in their present condition impose a significant resistance on the flow. Pertinent findings shown in the below figures are:

- The most pronounced changes are found along the waters off the southern side of the reclamation where a jetty is proposed and a 5 km narrow corridor located in the shallow tidal flats between the reclamation and the mainland;
- The predicted reduction of the currents in the southern berthing areas is induced by the jetty piles that increase the flow resistance. A maximum current speeds reduction of up to 0.1-0.2 m/s is observed along a narrow (depth-contour aligned) corridor, radiating from the outer part of the F-shaped berths on the southern side of the reclamation, i.e. in the east-west direction;
- An increase in mean and maximum flow velocities is observed at localized areas on the west side of the reclamation (between the reclamation and the existing shoreline). Maximum mean increase near the reclamation area of 0.1 m/s is predicted and

maximum increase of maximum speed of 0.3 m/s. This may cause erosion in the mudflat areas that could impact negatively in mangroves;

- No significant changes in current speed are predicted along the main navigation channel;
- All predicted changes are within the project area, no significant regional impacts are predicted or other relevant areas as the navigation channel. Current speed changes are similar for the different climatic conditions.

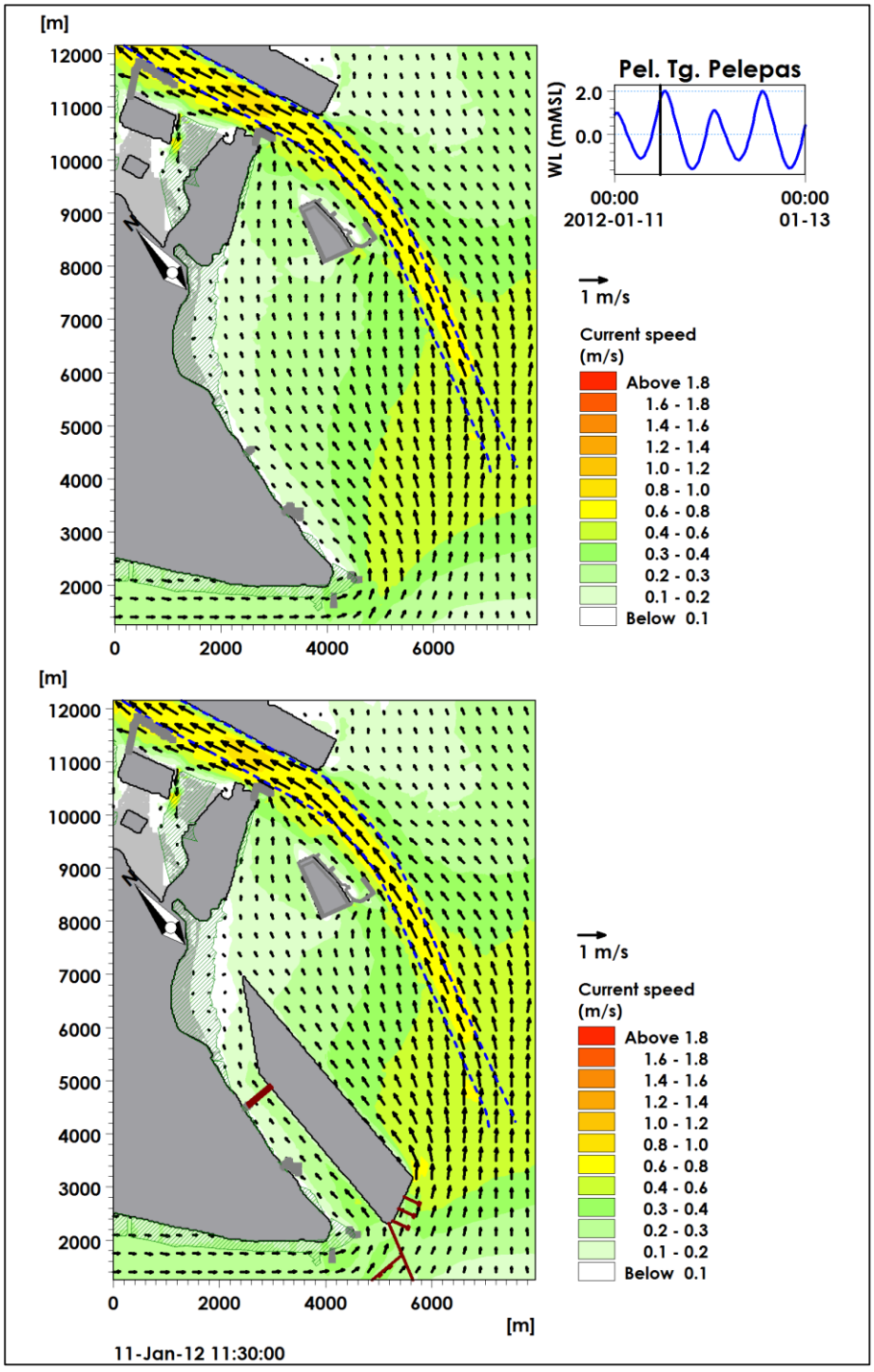

Figure 6.3 Typical spring flood tide current patterns, existing (top) and Phase 1 (bottom)

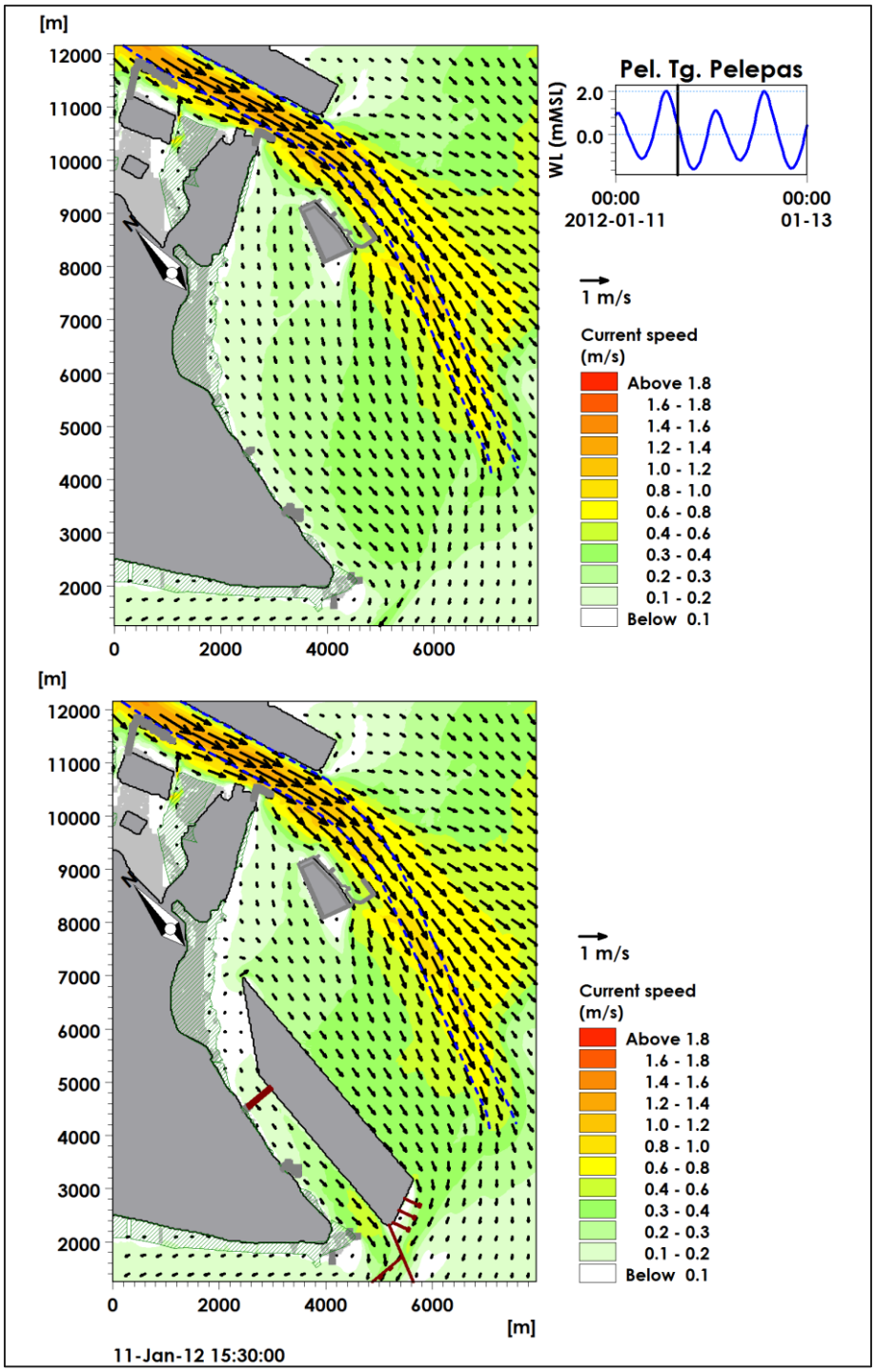

Figure 6.4 Typical spring ebb tide current patterns, existing (top) and Phase 1 (bottom)

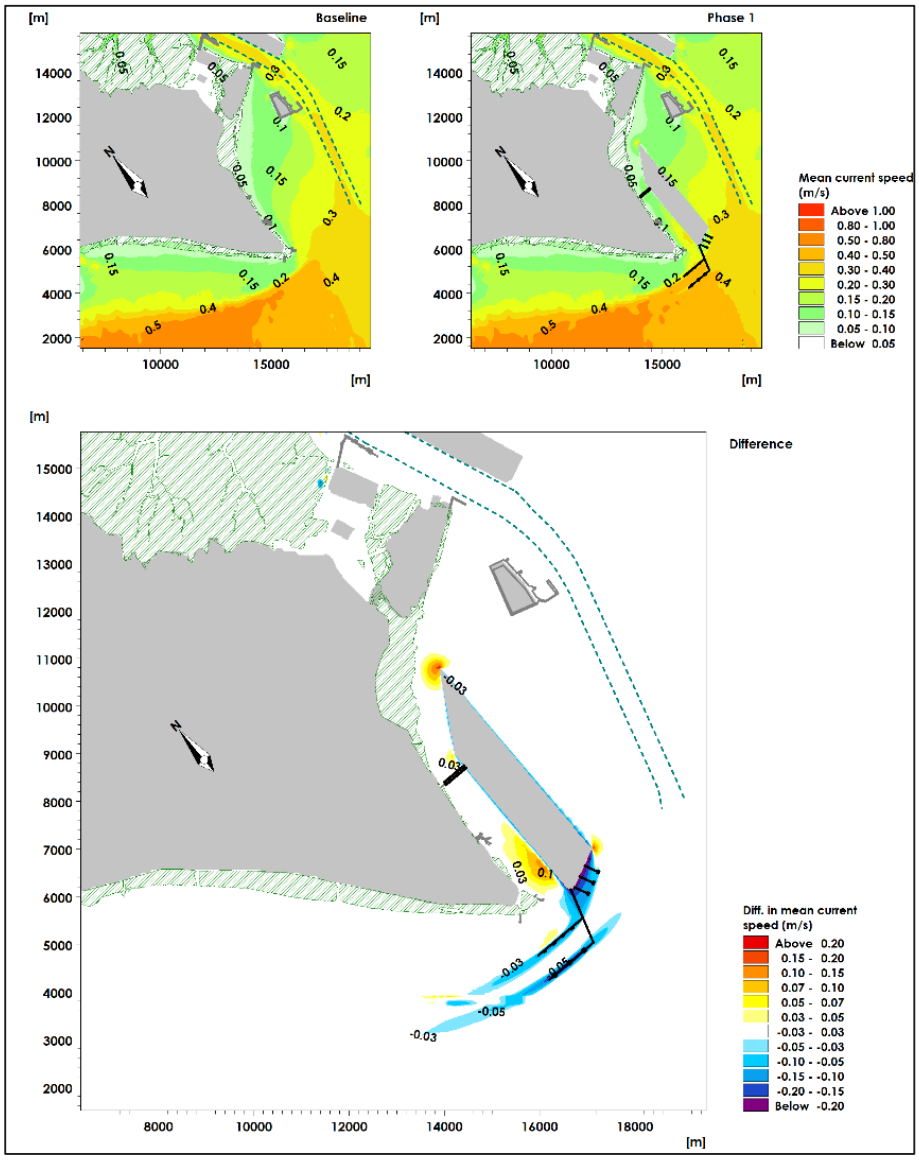

Figure 6.5 Mean current speed for baseline and phase 1 (top) and difference (bottom).

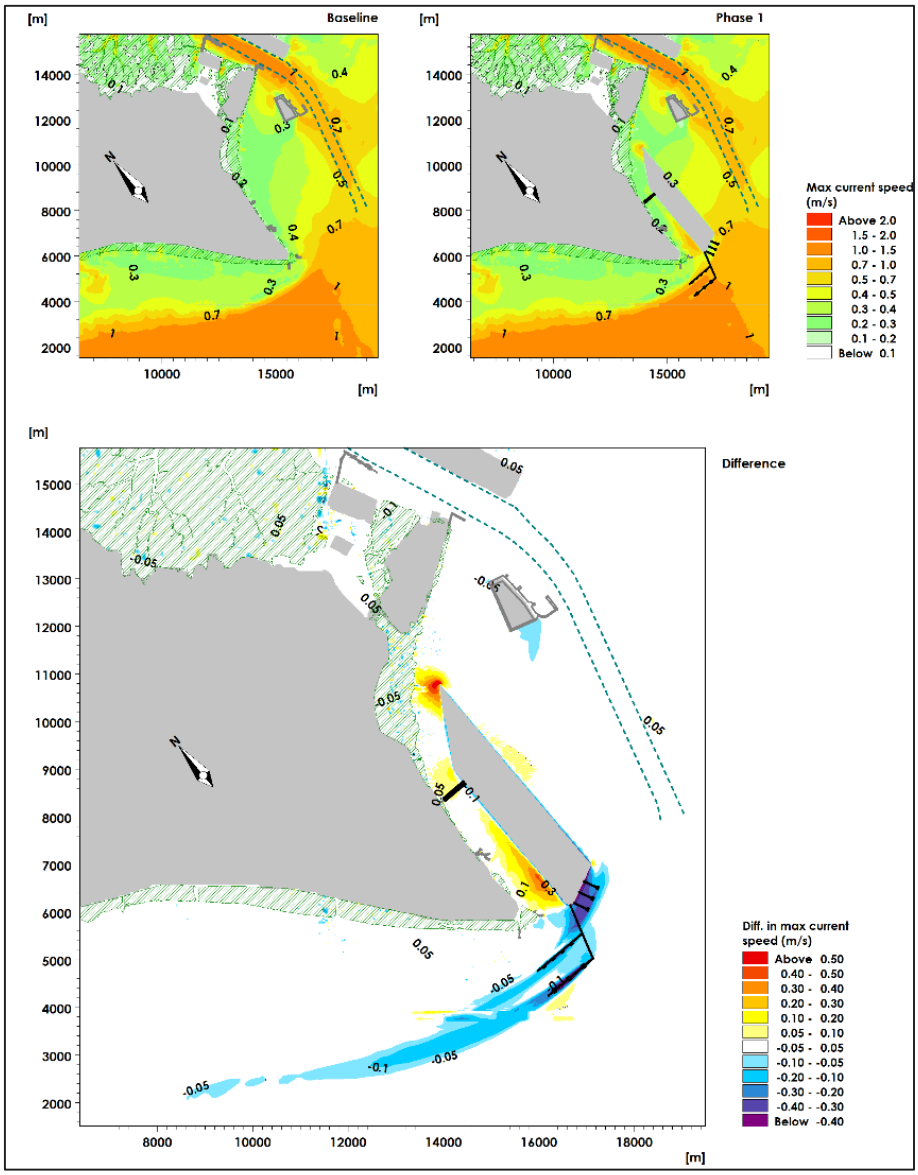

Figure 6.6 Maximum current speed for baseline and phase 1 (top) and difference (bottom).

Phase 2

Results of the simulations for Phase 2, are presented in Figure 6.7 through to Figure 6.10. The results show:

- Current speed changes are similar for the different climatic conditions.
- Mean and maximum changes in current speeds are generally localized around this phase development for all climatic scenarios;
- Mean and maximum flow velocities south of the reclamation (aligned with the reclamation frontage) induce a reduction of the flow; this is a further reduction compared to Phase 1 due to the construction of the additional piled jetty. A decrease of up to 0.4 m/s in maximum speeds is predicted. This reduction is due to the lee-zone created by additional resistance induced by the new berths.
- Current speeds remain mainly unchanged along most of the navigation channel east of the reclamation. However some changes in maximum current speeds are predicted in the southern end with predicted increases in maximum currents of up to 0.2 m/s and 0.03 m/s in mean currents. No significant changes in the current direction and no eddies or other complex flow pattern are generated by the development;

- A reduction in current flows is predicted, localised along the proposed eastern berthing area. The deepening of this area through dredging and the jetty construction will induce a reduction in current flows;
- Reduction in currents in the area north of the phase 2 development and the existing APH facility. The most significant reduction is predicted in the corner. Mean current speed reductions of 0.15 to 0.2 m/s are predicted;
- Predicted current speed changes along a narrow corridor west of the reclamation site remain similar to the Phase 1 predictions;
- No significant regional impacts are predicted. Neither changes in current speed and direction nor to other relevant areas such as the navigation channel.

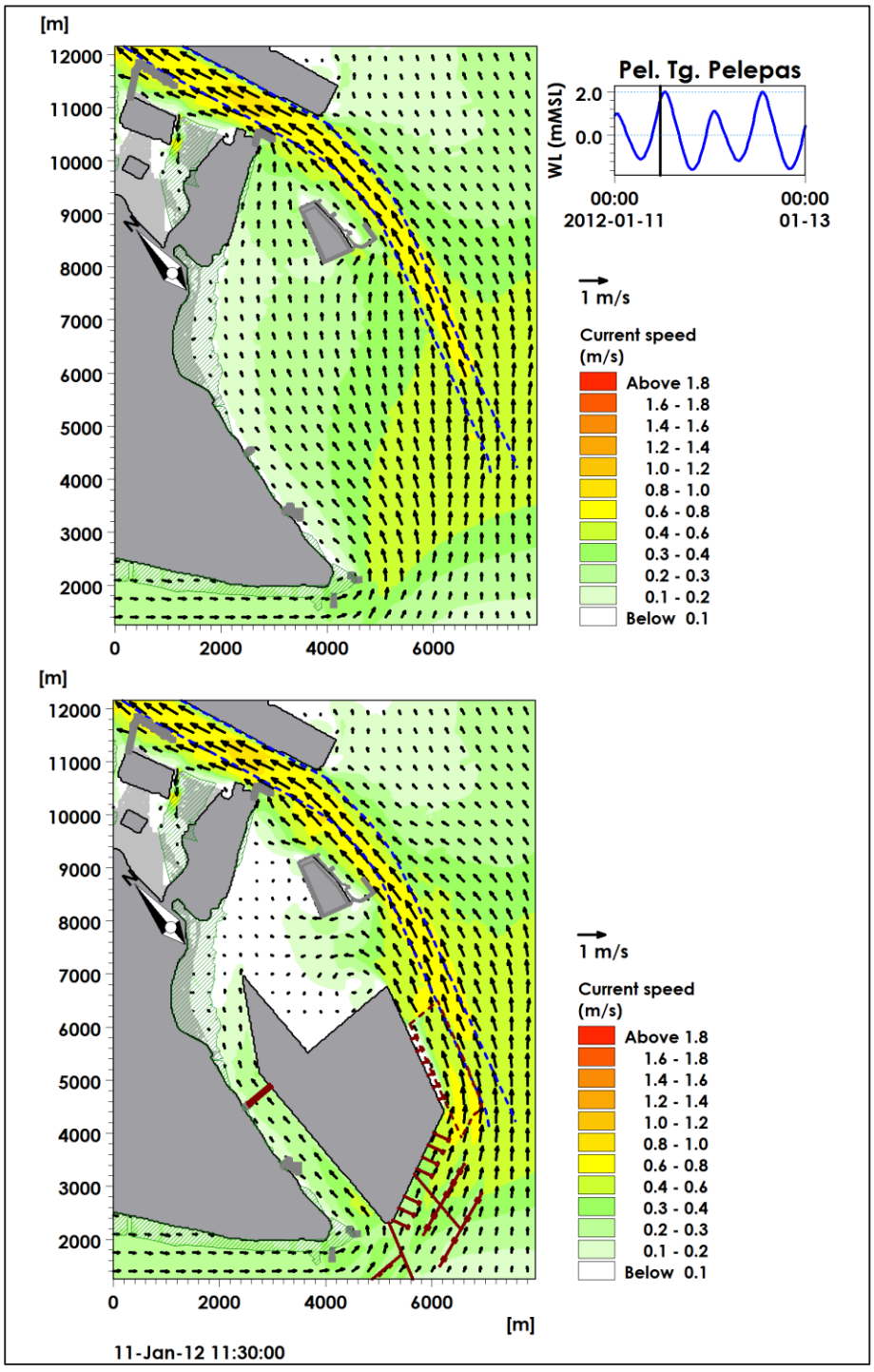

Figure 6.7 Typical spring flood tide current patterns, existing (top) and Phase 2 (bottom).

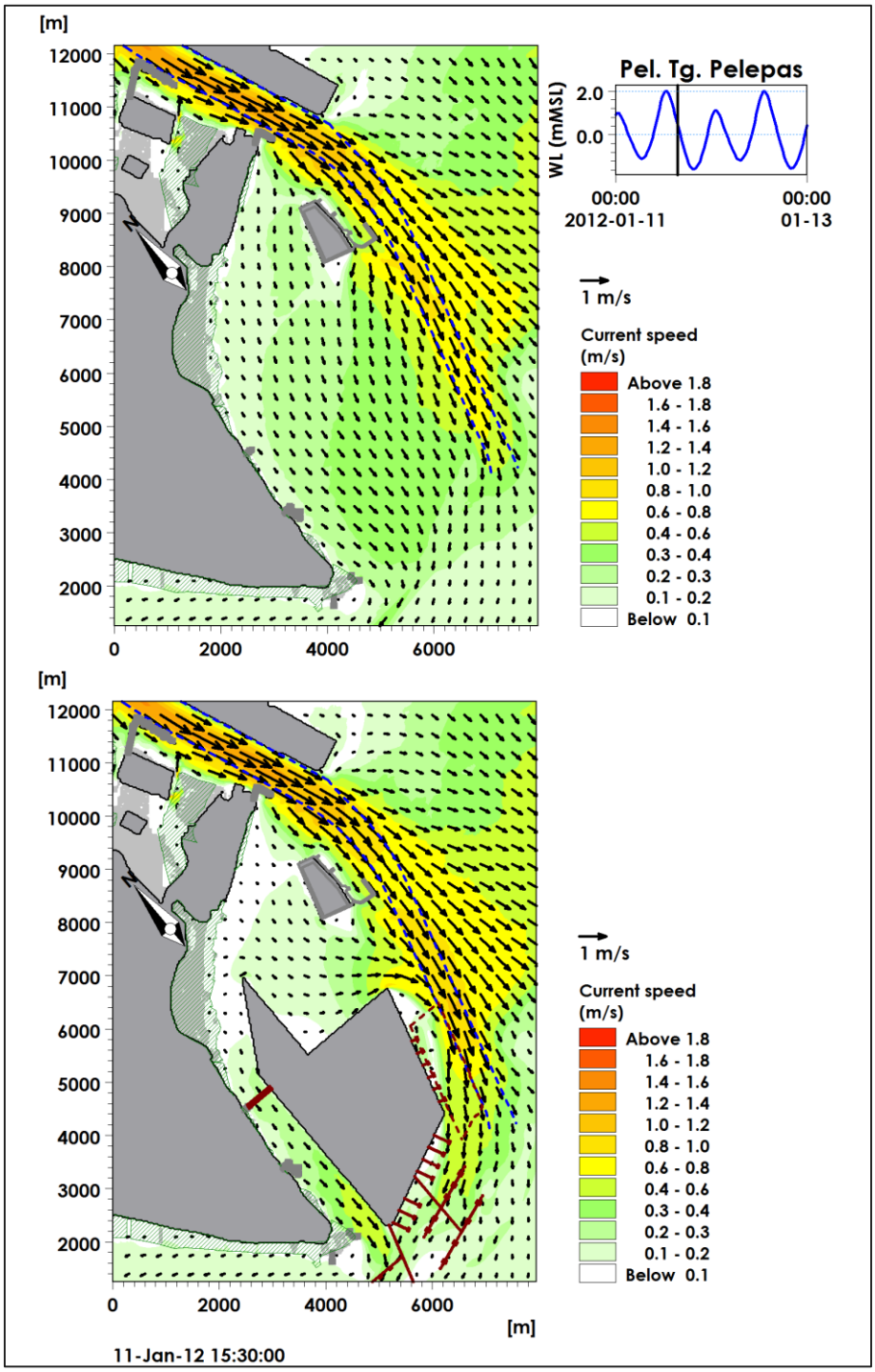

Figure 6.8 Typical spring ebb tide current patterns, existing (top) and Phase 2 (bottom).

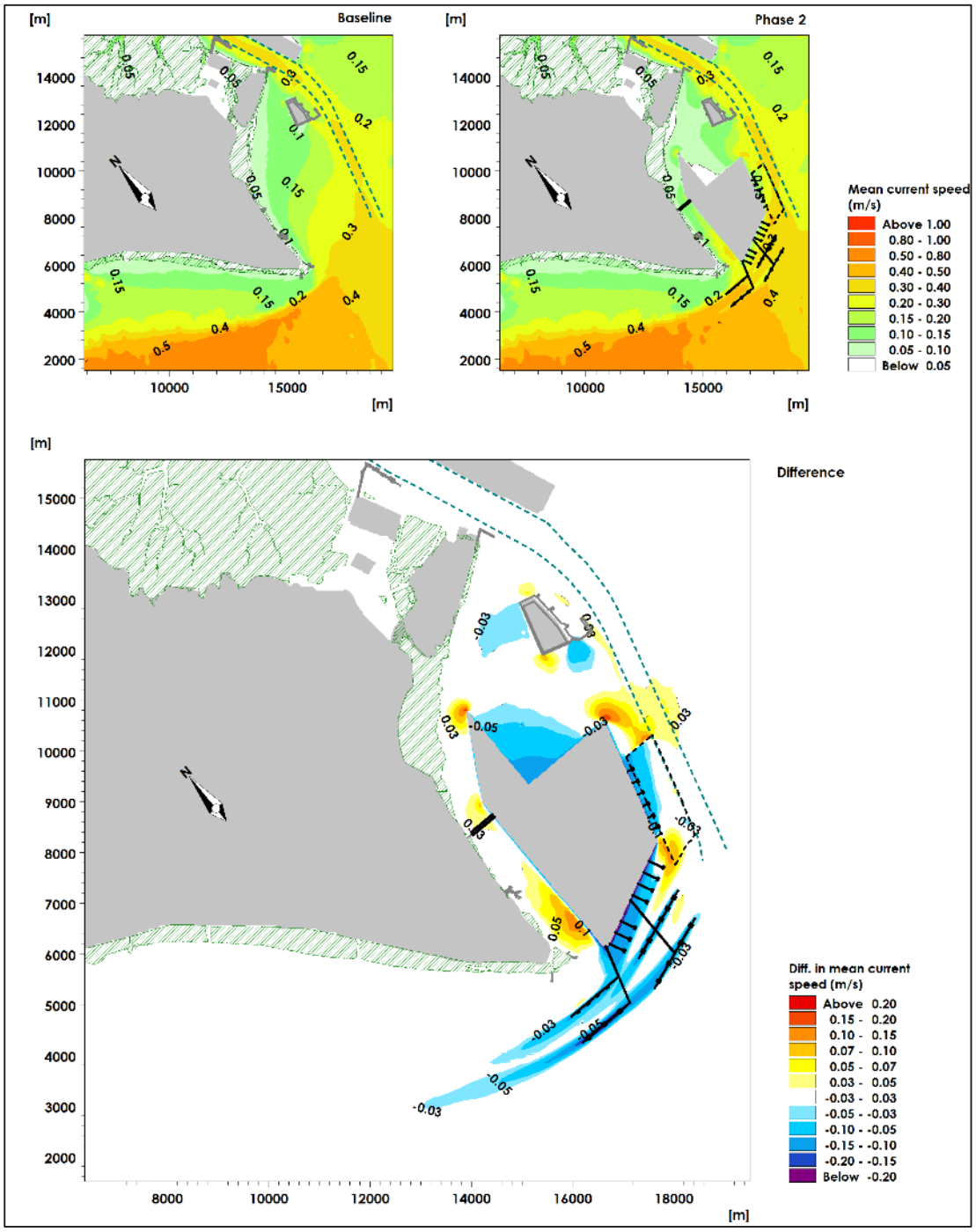

Figure 6.9 Mean current speed for baseline and phase 2 (top) and difference (bottom).

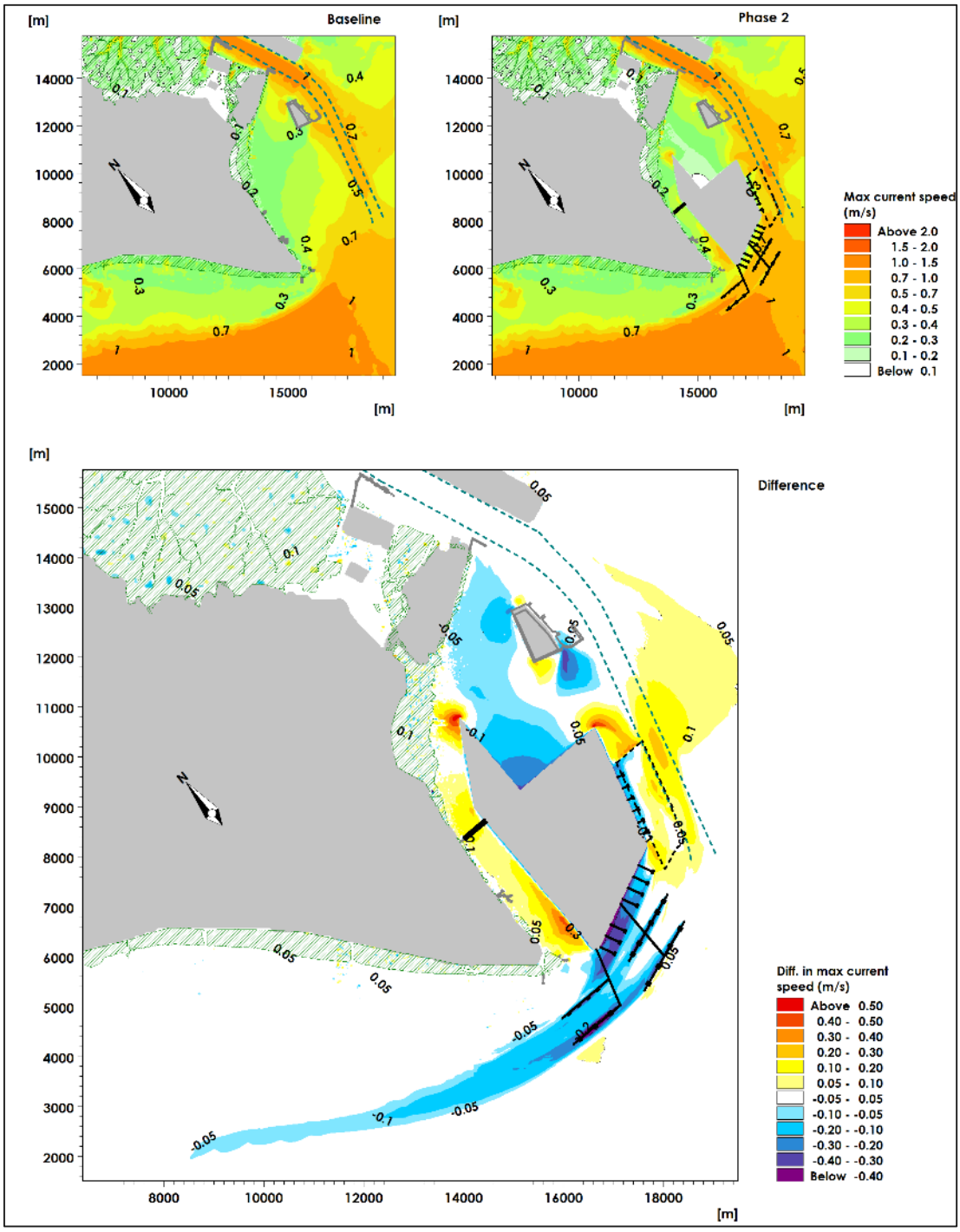

Figure 6.10 Maximum current speed for baseline and phase 2 (top) and difference (bottom).

Phase 3

Results of the simulations for final layout are presented in Figure 6.11 to Figure 6.14:

- Mean and maximum changes in current speeds are localized around this phase of development;
- Mean and maximum flow velocities along the west/landward side of the reclamation increase further compared to phases 1 and 2. Maximum speeds are now seen to increase by 0.2 to 0.3 m/s (compared to baseline conditions) over a significant stretch of the new channel created between the existing mangrove forest fringe and the west reclamation frontage. This will most likely induce re-suspension of fine material from the

shallow mudflat areas that may lead to impacts on sediment transport and deposition patterns;

- A decrease of up to 0.4 m/s in maximum speeds is predicted south of the reclamation frontage in the berthing deeper waters. This reduction is due to the lee-zone created by additional resistance induced by the new berths. Predicted changes are very similar to those predicted for Phase 2.
- Limited changes on the flow conditions are observed along the existing navigation channel. The completion of the reclamation works allows a slight improvement of flow conditions as compared to the Phase 2. The predicted changes in maximum currents speed reach 0.05-0.1 m/s but no significant changes are observed in the current direction (see Figure 6.11 and Figure 6.12). For this final layout the flow along the navigation channel becomes slightly more aligned (smooth) as for phase 2 with the main orientation of the currents following the navigation channel (i.e. less cross-channel motion is observed);
- Overall changes are localised within the project area and no significant changes are predicted along the navigation channel or other relevant areas.

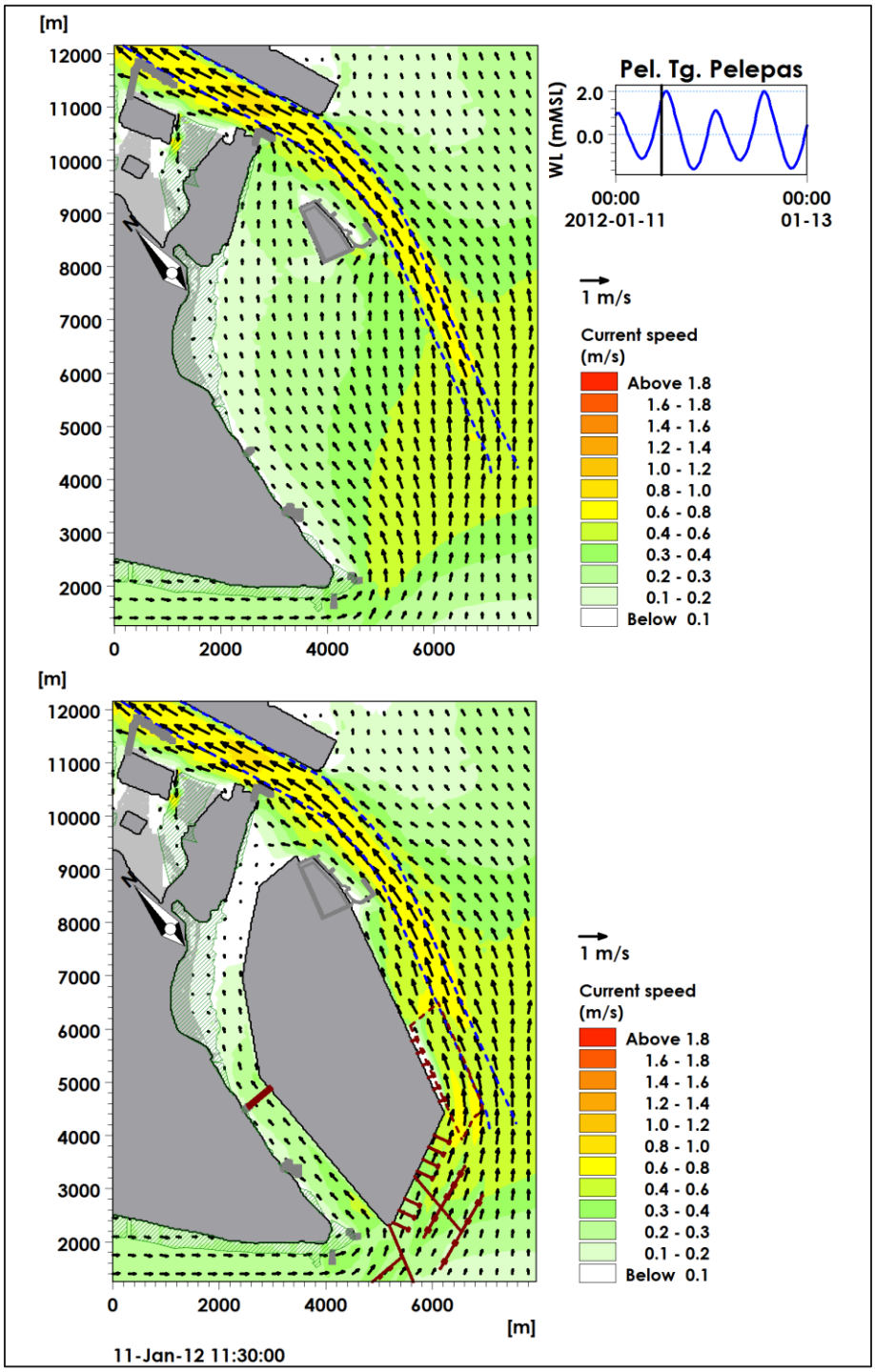

Figure 6.11 Typical spring flood tide current patterns, existing (top) and Phase 3 (bottom).

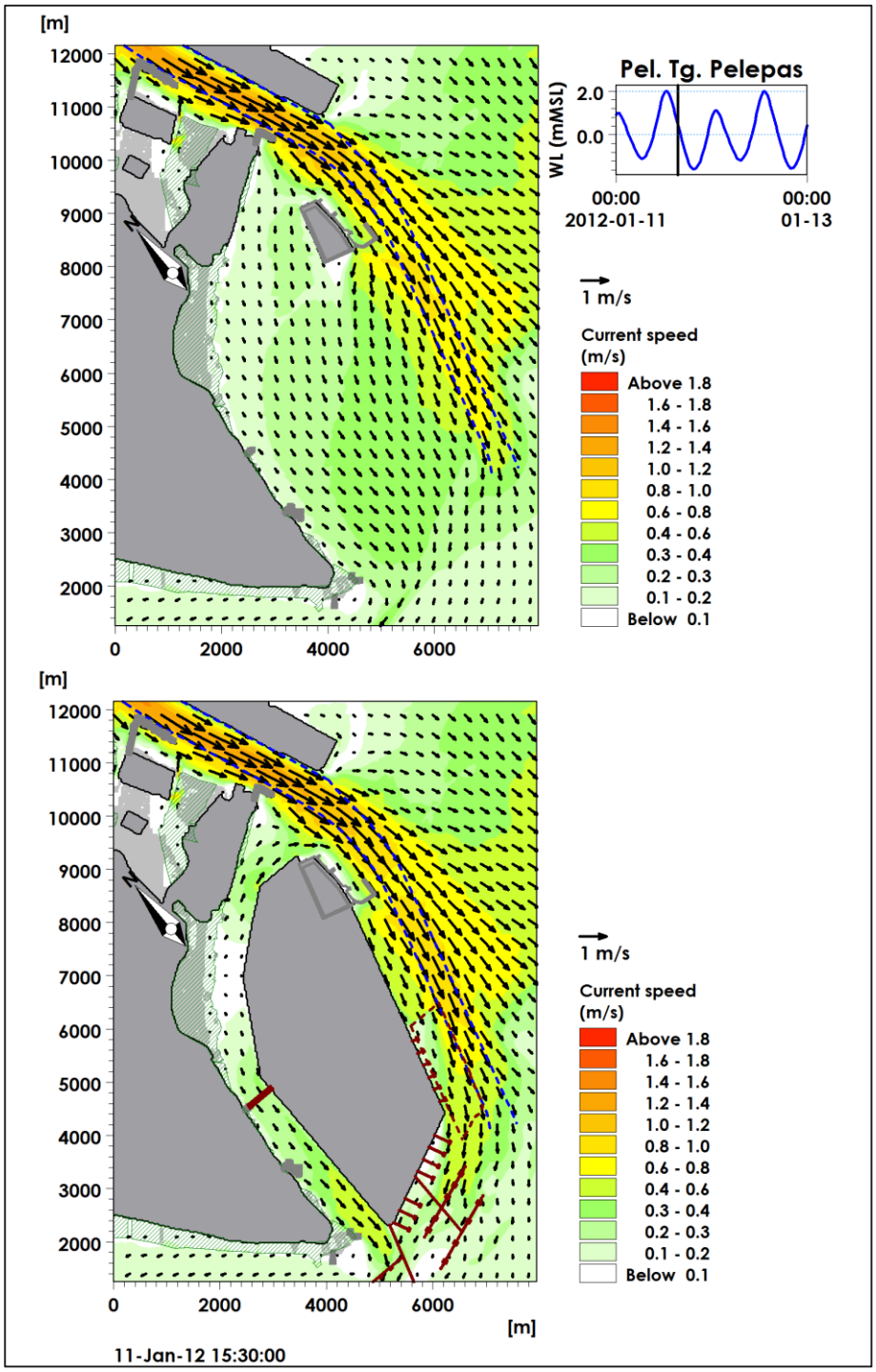

Figure 6.12 Typical spring ebb tide current patterns, existing (top) and Phase 3 (bottom)

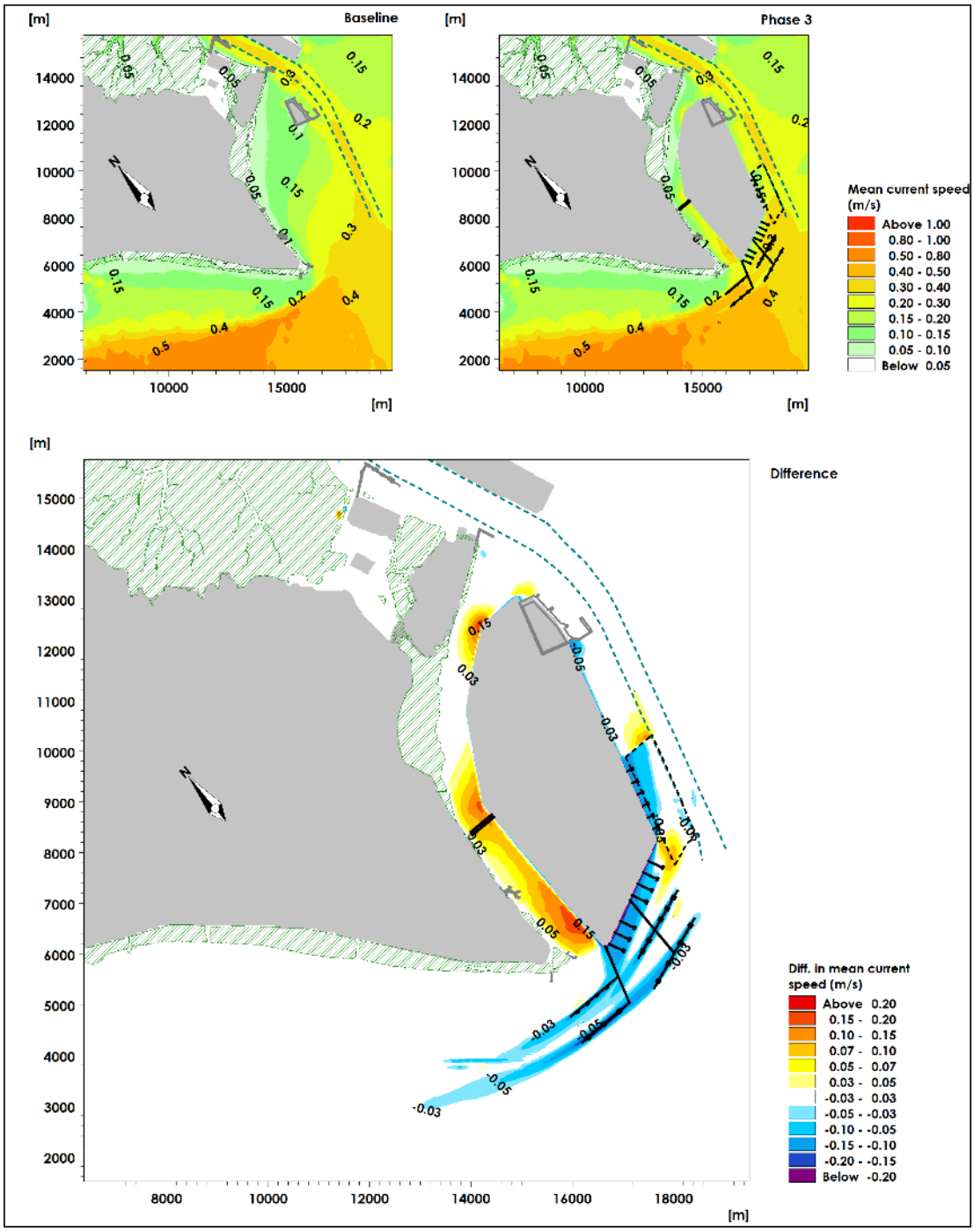

Figure 6.13 Mean current speed for baseline and phase 3 (top) and difference (bottom).

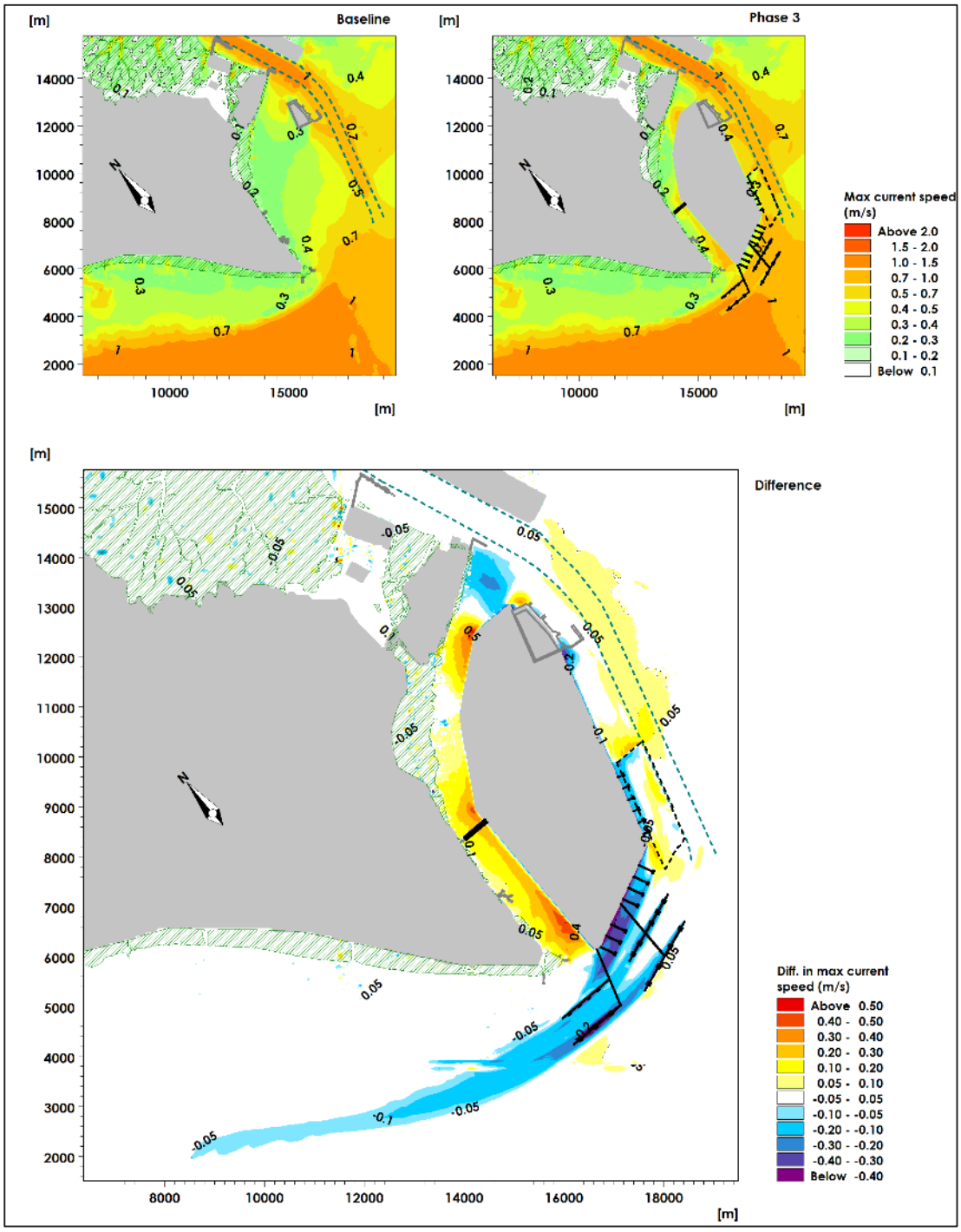

Figure 6.14 Maximum current speed for baseline and phase 3 (top) and difference (bottom).

Impact Evaluation

The key impact on currents is the increase that occurs along the western side of the reclamation. This has the potential to cause erosion that could negatively affect the mudflats and mangroves in this area. Based on the RIAM, the impact is considered to be **Moderate Negative**.

Criteria	Score	Description
Importance	1	Important only to the local condition
Magnitude	-3	Significant Negative change to status quo
Permanence	3	Permanent
Reversibility	3	Irreversible
Cumulativity	2	Non-cumulative/Single
Environmental Score	-24	
Description	**-C**	**Moderate negative impact**

Water Levels

Water levels have been extracted from the numerical models at a number of locations as shown in Figure 6.15. Changes in water levels (depicted in Figure 6.16) at most locations are not significant except at points P3 and P4 (located between the reclamation and the mainland) which occur during low water conditions, with no significant changes during high water levels.

These changes are associated with the effect of the reclamation on the inflow of water during low water conditions - the current flow becomes parallel to the shore between the shore and reclamation rather than cross shore which increases flow resistance at low tide. This flow resistance becomes less pronounced during high water levels and therefore does not induce significant changes in water levels during high water conditions.

Climate change impact in the areas has been analysed based on a climate change impact study carried out by National Hydraulic Research Institute of Malaysia (NAHRIM). The sea level in the vicinity of Tg. Piai is predicted to rise to an average of 0.066 m in 2040 and an average of 0.253 m in 2100. In general, an estimate of global sea levels based on the Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report (AR5), the projection of sea level rise is about 0.55 m in 2100 (refer to Appendix E). Sea level rise will tend to increase the risk for flooding of low lying coastal areas. Sea level rise in itself will normally not cause flooding, but the raised sea level will increase the extreme water levels caused by storm surges. Based on this it is concluded that the reclamation shore protection should be designed for the predicted increase in sea level over its design life.

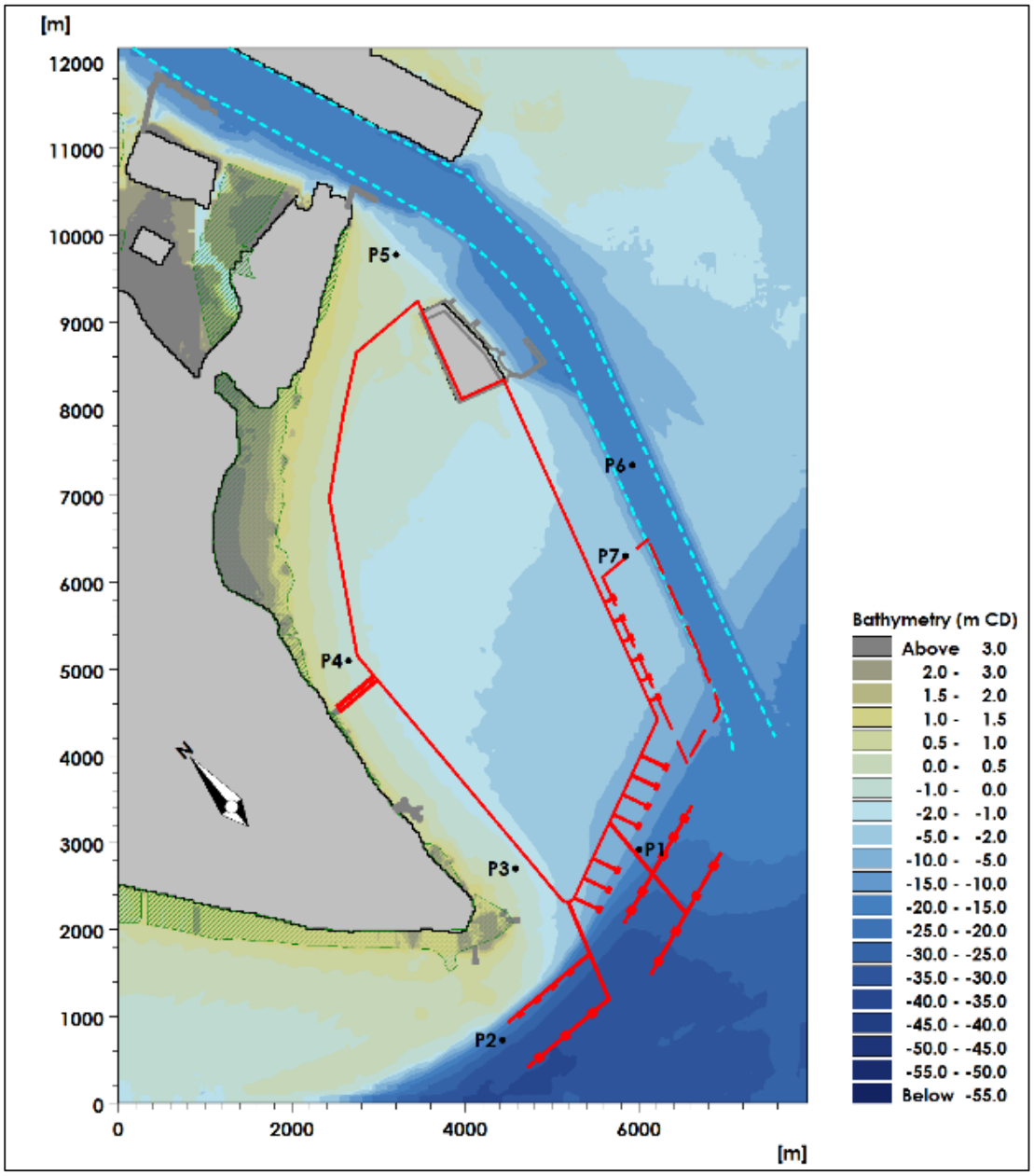

Figure 6.15 Location of water level extraction points

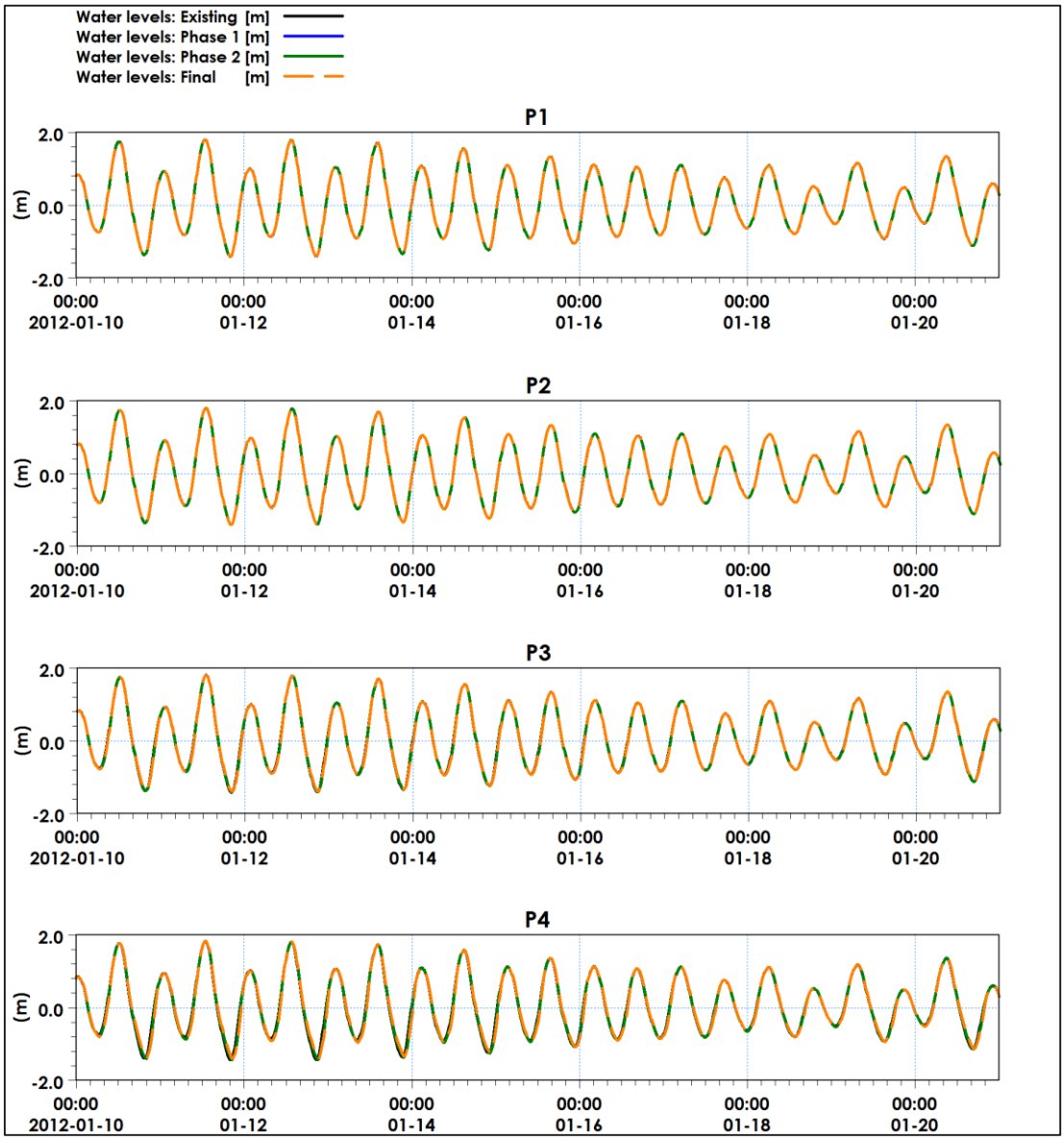

Figure 6.16 Water levels. Baseline and post construction.

Impact Evaluation

Based on the RIAM, the impact is considered to be **No Change**.

Criteria	Score	Description
Importance	2	Important to areas immediately outside the local condition
Magnitude	0	No Change
Permanence	3	Permanent
Reversibility	3	Irreversible
Cumulativity	3	Cumulative/Single
Environmental Score	0	

Criteria	Score	Description
Description	**N**	**No Change**

Tidal Prism

A tidal prism is the difference in the volume of water in an estuary or inlet between high and low tide. It is a key determinant of the residence time for a body of water, and as a result, may cause changes in ambient water quality should it be changed significantly. In this case there is potentially some level of impact on the tidal prism of the upstream areas mainly along Sg. Pulai and the Straits of Johor.

To evaluate potential changes in the volume of discharges across these areas, the water discharges have been extracted for the different development phases and climatic scenarios at two sites along Sg. Pulai (L1 and L2) and one in the Straits of Johor (L3) as shown in Figure 6.17. Simulations were carried out by applying the average and high (50 year design discharge) river flows to represent average and extreme discharges conditions in the study area.

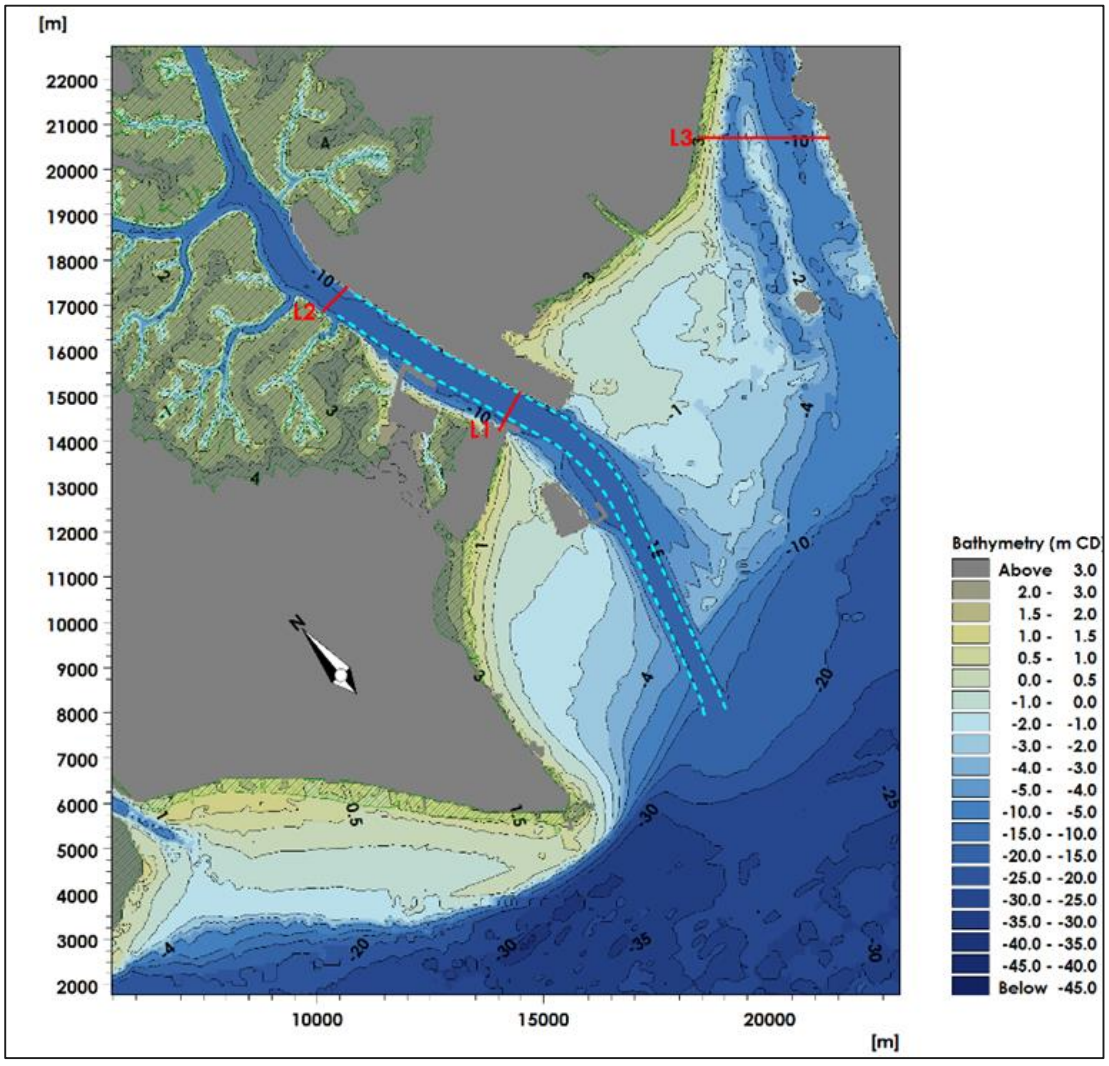

Figure 6.17 Location of discharge extraction lines L1, L2 and L3.

Comparing the discharge at these locations between the existing and post-development condition for the various phases show that all changes are significantly below 1% of the existing tidal prism.

Impact Evaluation
Based on the RIAM, the impact is considered to be **No Change**.

Criteria	Score	Description
Importance	2	Important to areas immediately outside the local condition
Magnitude	0	No Change
Permanence	3	Permanent
Reversibility	3	Irreversible
Cumulativity	3	Cumulative/Single
Environmental Score	0	
Description	**N**	**No Change**

Waves

An evaluation of the impact of the proposed structures in the wave climate has been carried out for all project phases. The results for the NE and SW Monsoon simulations are seen in Figure 6.18 to Figure 6.21, and show that:

- The predicted changes to wave conditions have similar characteristics for the three phases of the project;
- The predicted long term wave climate changes in the study area are as follows:
  - The area between the reclamation and the mainland is strongly sheltered from wave action. Wave action in this stretch of coast will be very limited due to the very short fetch (distance between the shoreline and the reclamation area)
  - The reclamation shelters the area the south of the reclamation site;
  - The area west of Tg. Piai along the Straits of Malacca will not have any significant changes in the wave conditions;
  - All predicted changes are localised around the proposed development and no regional effects are predicted
  - Most changes induced in the wave conditions are related to the reclamation footprint but the effect of the proposed jetties (south of the development) is predicted to induce some losses on the prevailing southern waves occurring during the SW monsoon. The wave losses induced by the southern jetties will further reduce the wave action around the Tg. Piai area between the development and the coast,
  - No significant changes in wave conditions are observed along the navigation channel.

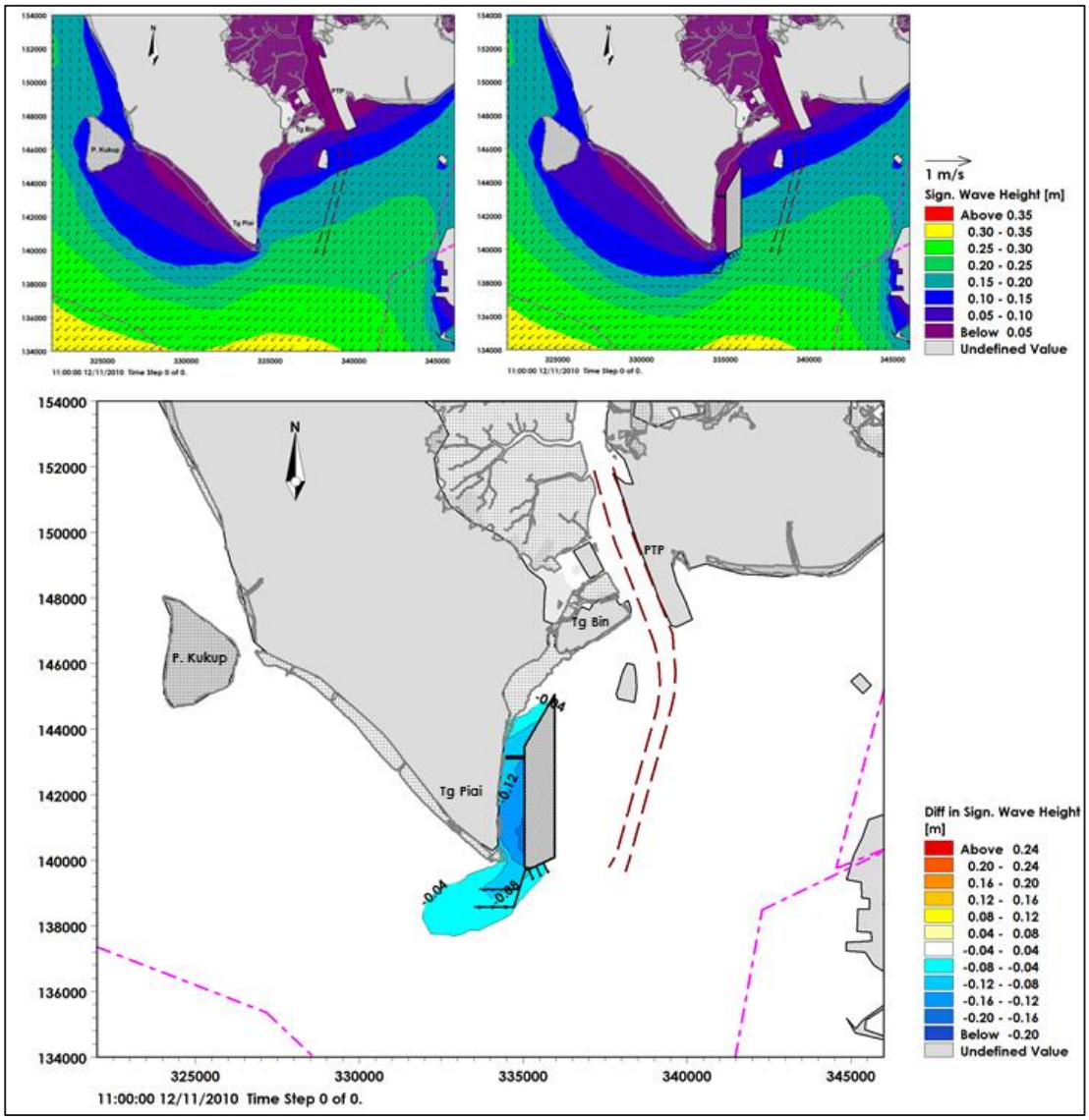

Figure 6.18 Waves condition during typical NE monsoon for existing (top left), Phase 1 (top right) and difference (below).

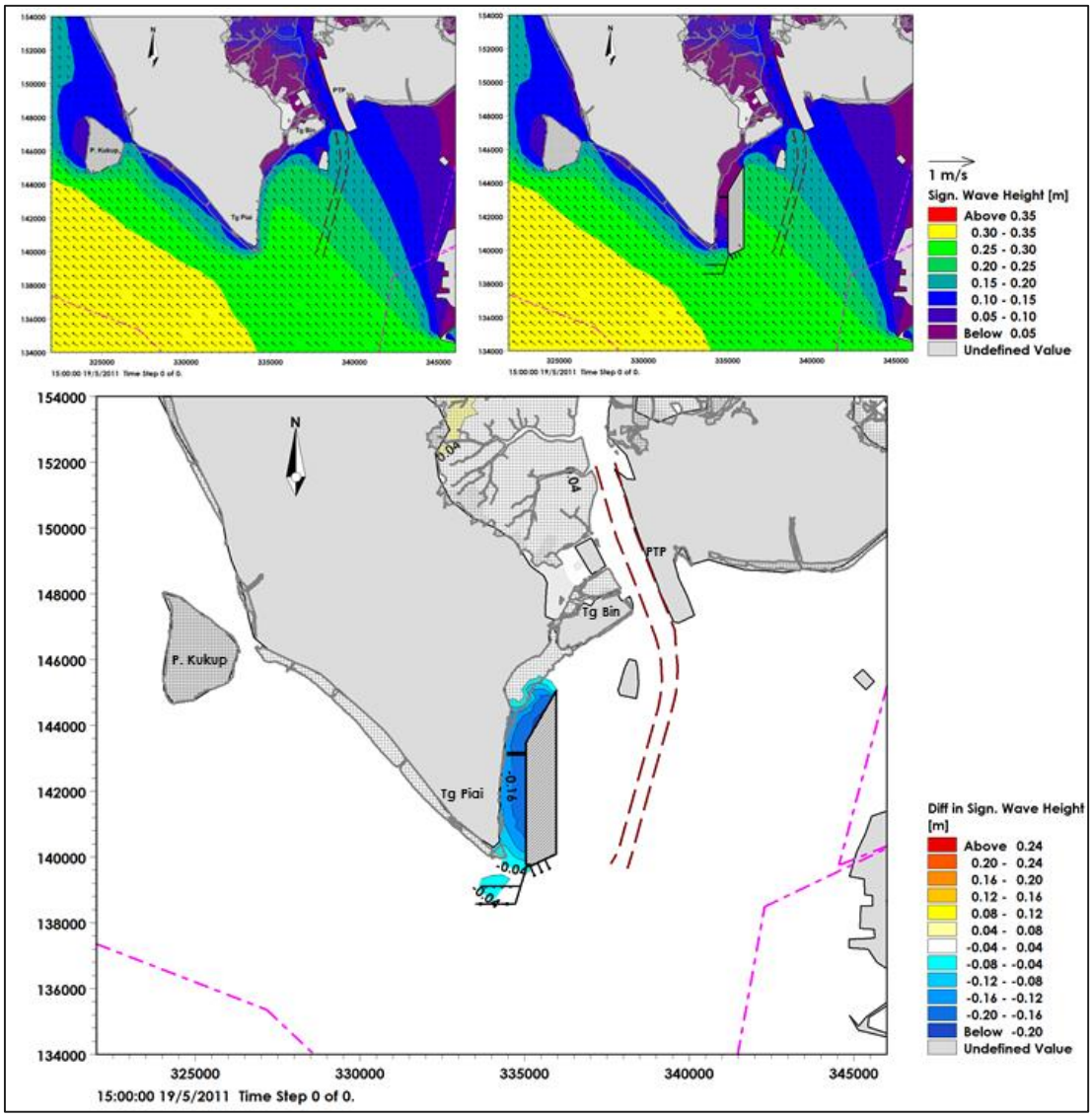

Figure 6.19 Waves condition during typical SW monsoon for existing (top left), Phase 1 (top right) and difference (below).

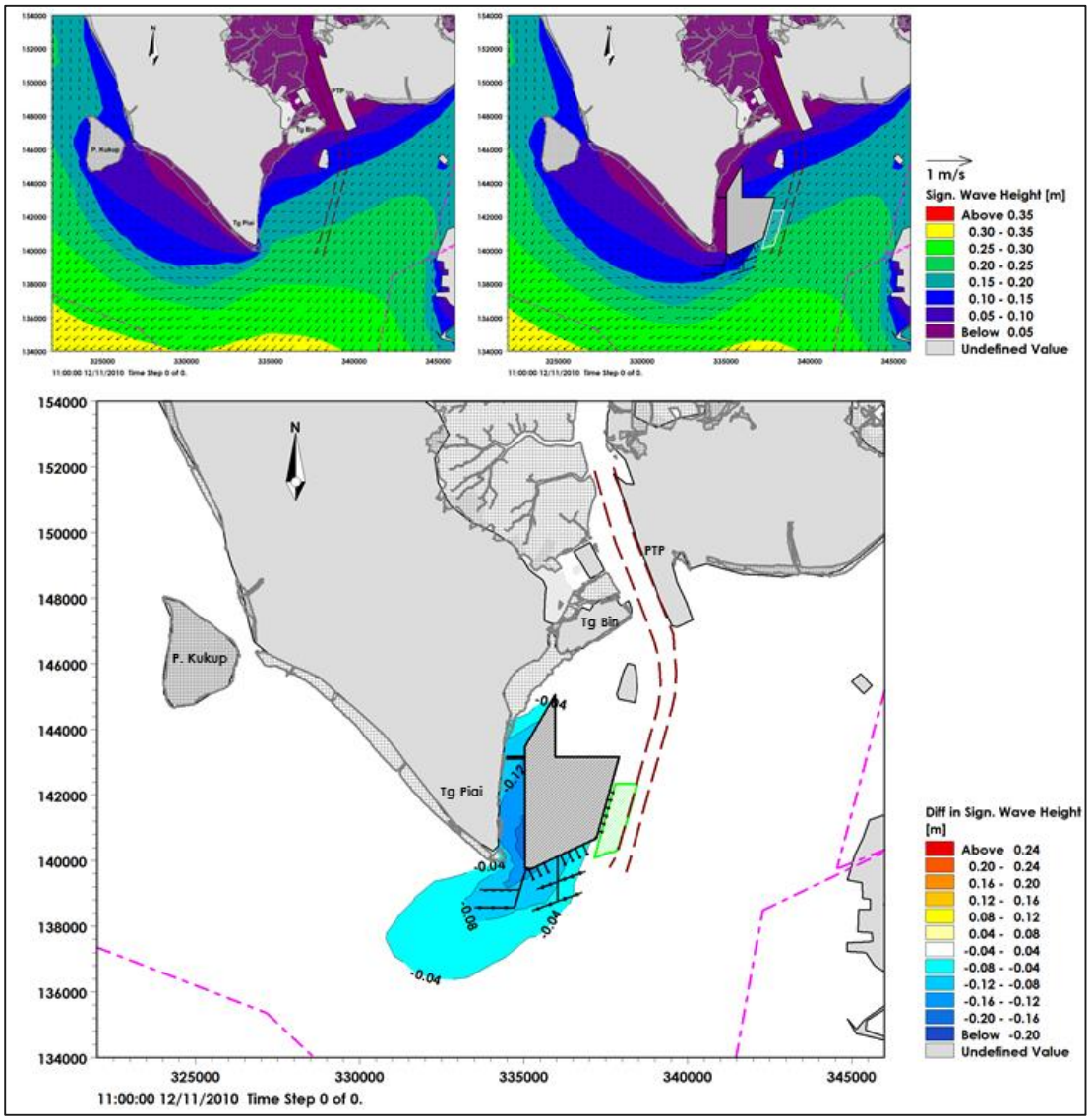

Figure 6.20 Waves condition during typical NE monsoon for existing (top left), Phase 2 (top right) and difference (below).

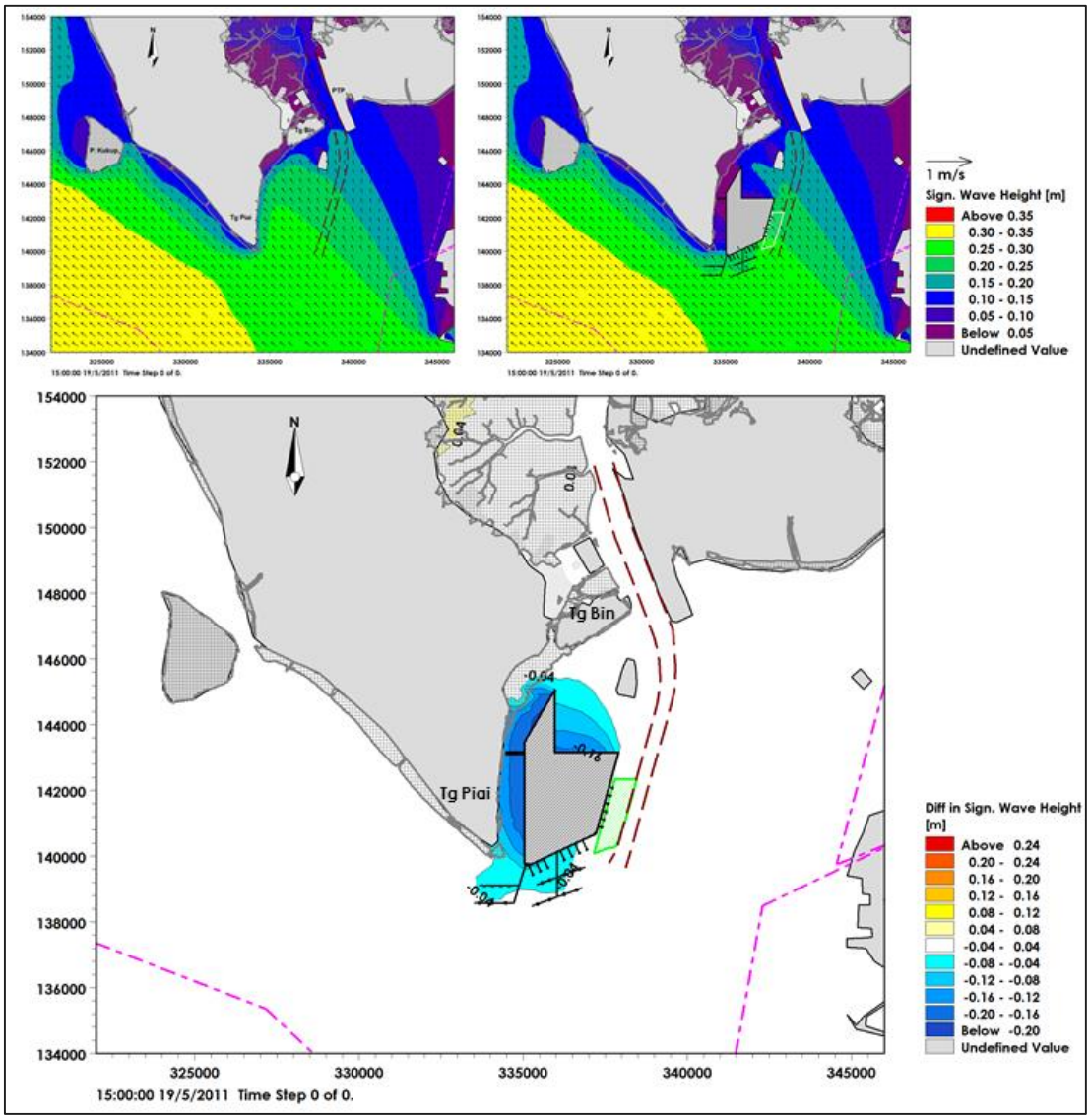

Figure 6.21 Waves condition during typical SW monsoon for existing (top left), Phase 2 (top right) and difference (below).

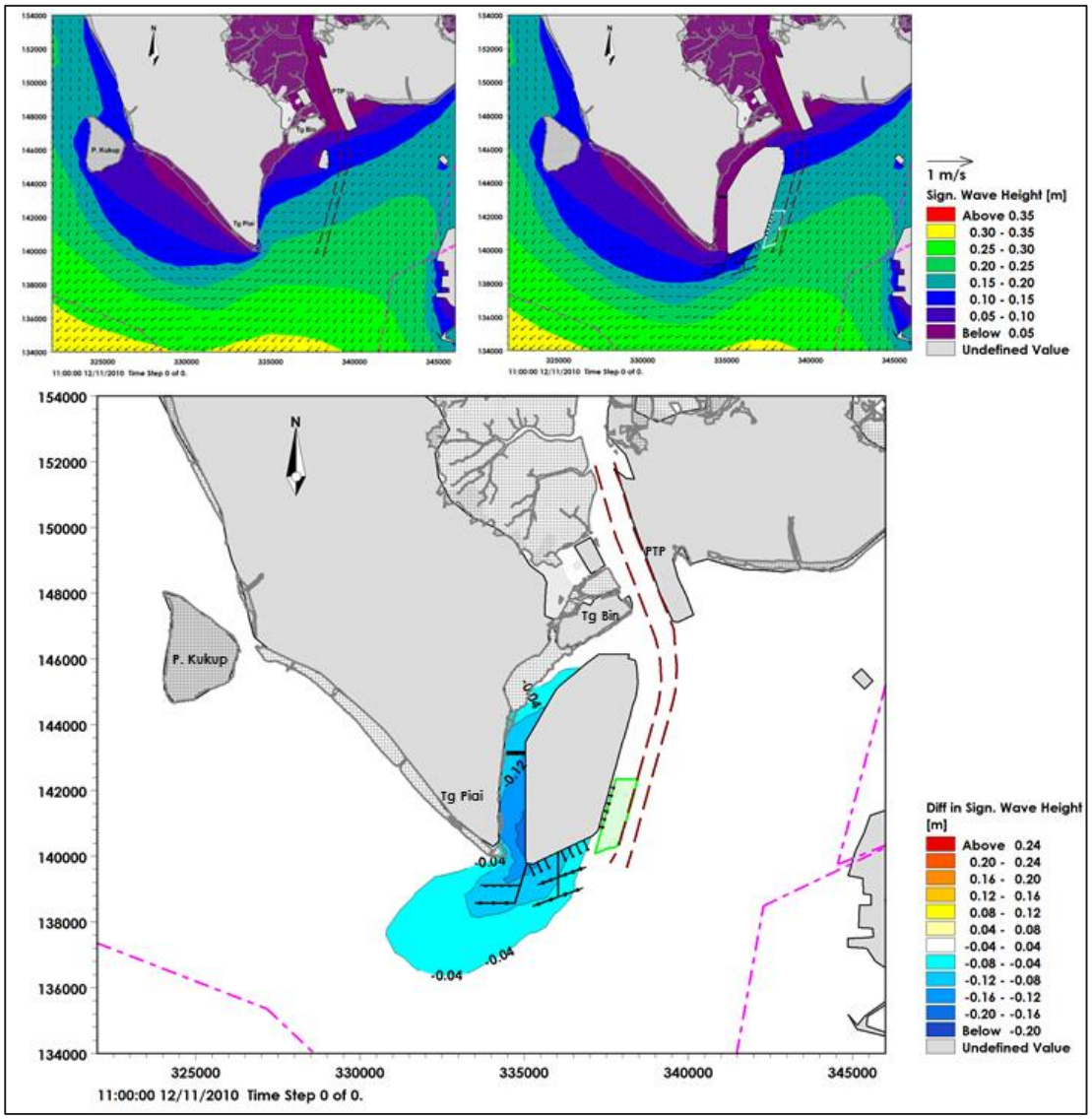

Figure 6.22 Waves condition during typical NE monsoon for existing (top left), Phase 3 (top right) and difference (below).

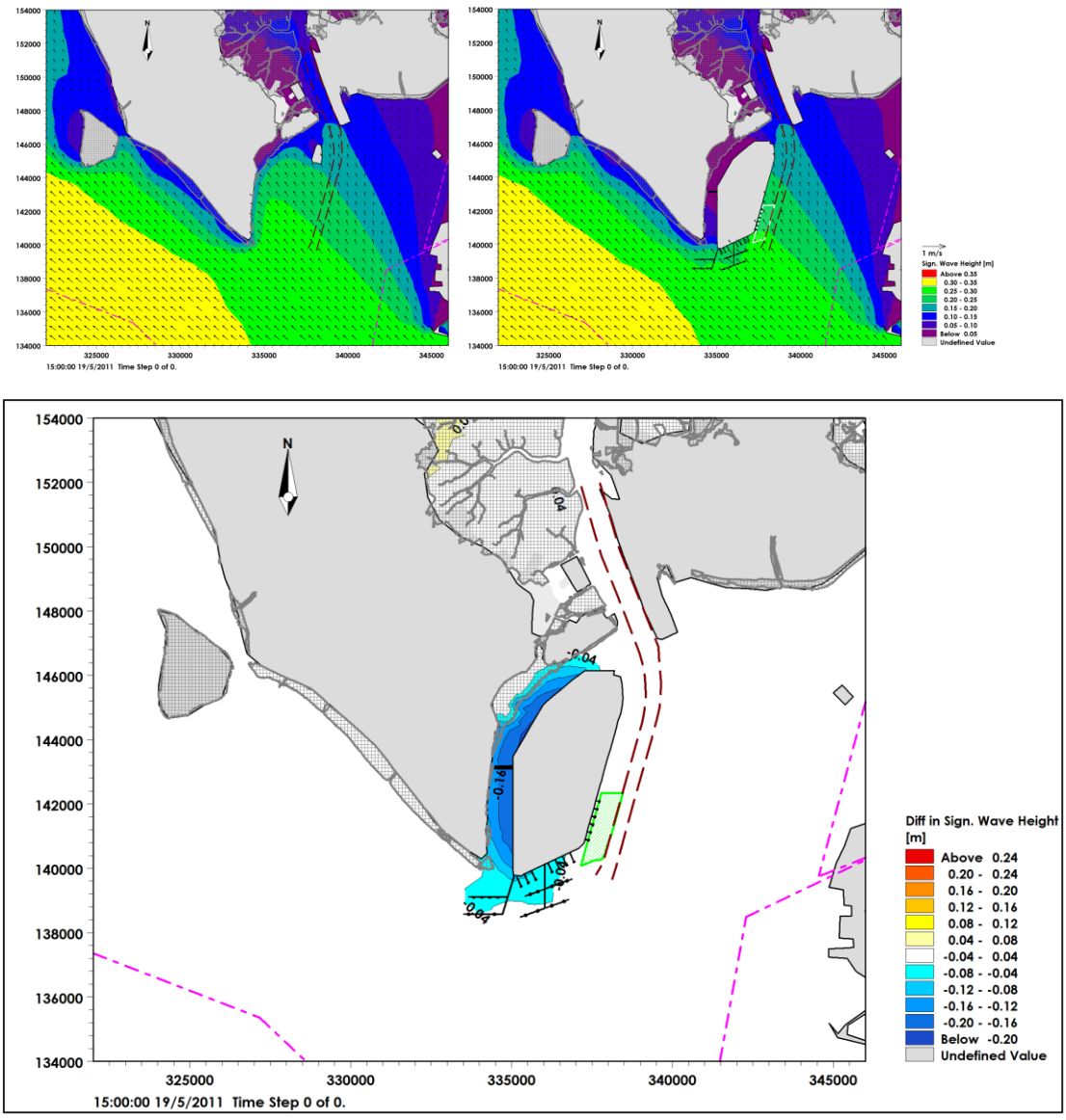

Figure 6.23 Waves condition during typical SW monsoon for existing (top left), phase 3 (top right) and difference (below).

Impact Evaluation

The principal impact of the development is the reduction of waves to the west of the development and the coastline. With a present regime of active coastal erosion thought to be strongly influenced by a change in wave energy resulting from the increasing numbers of vessels anchored to the southwest of Tg. Piai, this wave 'Shadow" may lead to a diminishing, if not a reversal, of this erosion. It should be noted however that an increase in current speeds is also predicted and the combined effect of these two processes is addressed below in Section 6.3.

In terms of the present impact evaluation it is appropriate to make the assessment at two scales, one being the regional changes and the other for the area to the west of the development and the coastline.

Impact Evaluation – Regional Impacts
Based on the RIAM, the impacts are considered to be **No Change**.

Criteria	Score	Description
Importance	2	Important to areas immediately outside the local condition
Magnitude	0	No Change
Permanence	3	Permanent
Reversibility	3	Irreversible
Cumulativity	3	Cumulative/Single
Environmental Score	0	
Description	**N**	**No Change**

Impact Evaluation – Eastern Tg Piai Coastline
Based on the RIAM, the impacts are considered to be **Minor Positive**.

Criteria	Score	Description
Importance	1	Important to local conditions only
Magnitude	+2	Significant improvement in status quo
Permanence	3	Permanent
Reversibility	3	Irreversible
Cumulativity	3	Cumulative
Environmental Score	+18	
Description	**B**	**Minor positive impact**

6.2.4.2 Mitigation Measures

A range of mitigation measures are available to address the environmental risks associated with the predicted hydraulic changes created by the proposed development.

Currents

The most significant risk (negative impact) that has been predicted in the study area that will lead to permanent change is the increase of current speeds in the narrow area between the proposed west frontage of the reclamation and the mainland. This could potentially induce re-suspension of fine material that could lead to the exacerbation of the present erosion of the inner mudflat areas and the mangrove fringe.

Mitigation measures are proposed to minimise the impact of currents in this area, using environmentally engineered control structures that include:

Drainage Channel
A drainage channel aligned immediately at the toe of the western side of the reclamation frontage as shown in Figure 6.24. This is designed to reduce current speeds in the area

between the reclamation and the existing shoreline which reduces any impacts on water levels in this area and reduces the risk of erosion occurring. The channel shall be built with the basic dimensions set out below. Typical cross sections through the channel are shown in Figure 6.25.

- North west part of the channel is 50m wide, with invert level at -1m CD (Figure 6.25);
- South west part is 75m wide, with invert level at -2m CD.

Coastal Structures
Three short structures (+1 m MSL top level) to control the flow rate in the area just off Tg Piai National Park are recommended. The objective is to force the main current flow to the area close to the reclamation frontage where the drainage channel is located. This will reduce the current speeds on the upper areas of the mudflats to values similar to or lower than the existing speeds thus ensuring that no erosion will occur along the mangrove frontage.

The proposed structures are shown in red in Figure 6.24 and briefly described below:

- South low crested groyne. This is constructed on the mudflats at the southern tip of Tg Piai.
- Middle control structure. This is a "U" shaped low crested structure constructed midway between the southern groyne and the access bridge to the reclamation.
- The access road to the reclamation constructed as a causeway for part of the length on the western side, with a bridge across the channel near the reclamation but allowing flows on the eastern side.

With these structures in place the tidal prism will remain mainly unchanged and a sub-tidal hydraulic connection retained with the offshore habitats allowing the passage of fish and other species between the mangroves and these habitats.

The effectiveness of the proposed mitigation measures has been modelled for the complete reclamation (Phase 3). This has been selected to include the maximum impacts from the reclamation, however the impacts for Phases 1 and 2 are similar as it is the Phase 1 reclamation that has the major impact. Figure 6.26 and Figure 6.27 show mean and maximum currents in the area between the reclamation and the shoreline with and without the proposed mitigation measures. These show that with the mitigation measures in place:

- The maximum currents speeds in the area are significantly reduced.
- Maximum current speeds on the upper mudflat areas are below 0.03 m/sec.

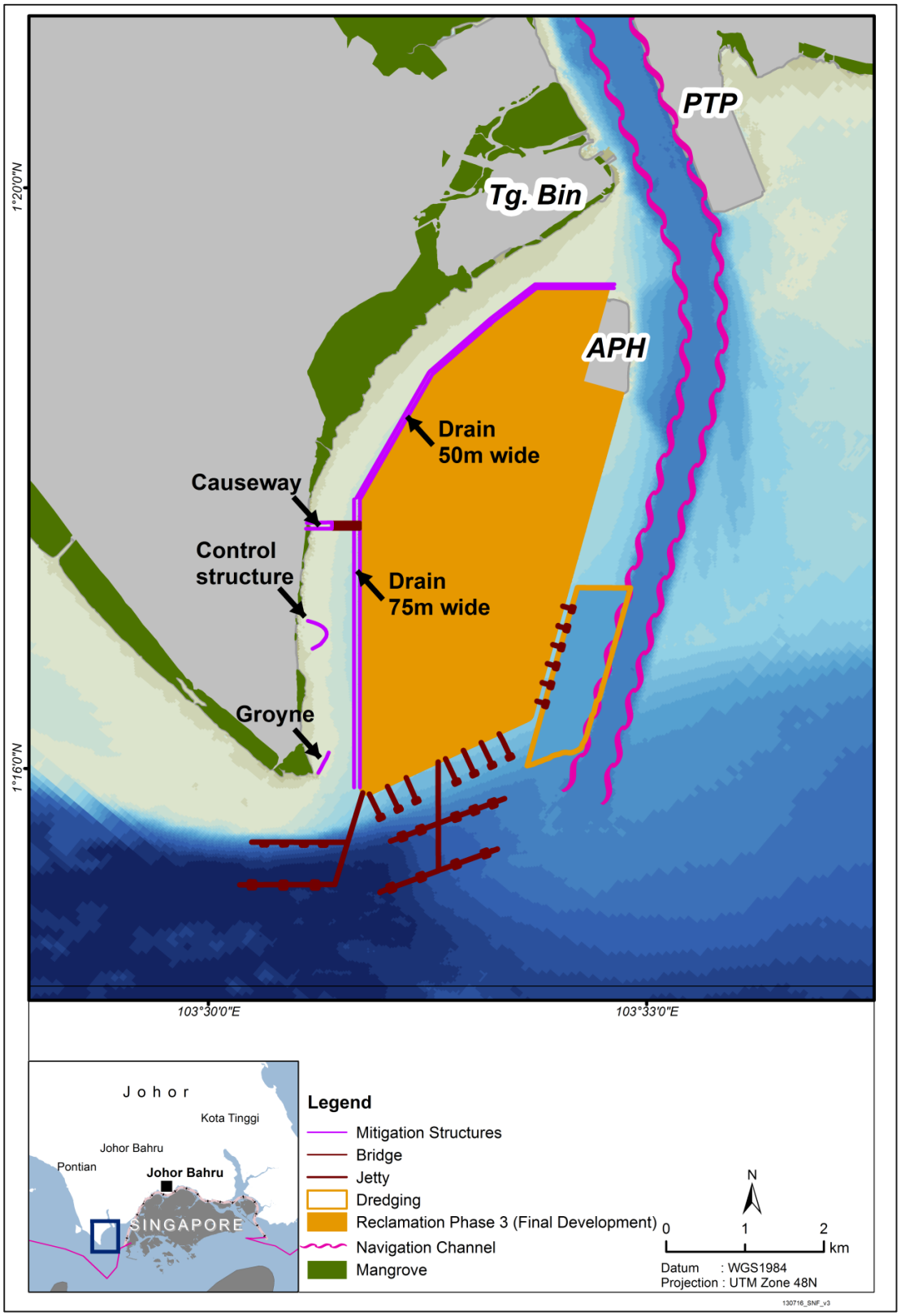

Figure 6.24 Bathymetry, proposed control structure and drainage channel).See also cross sections of the drainage channel in Figure 6.25.

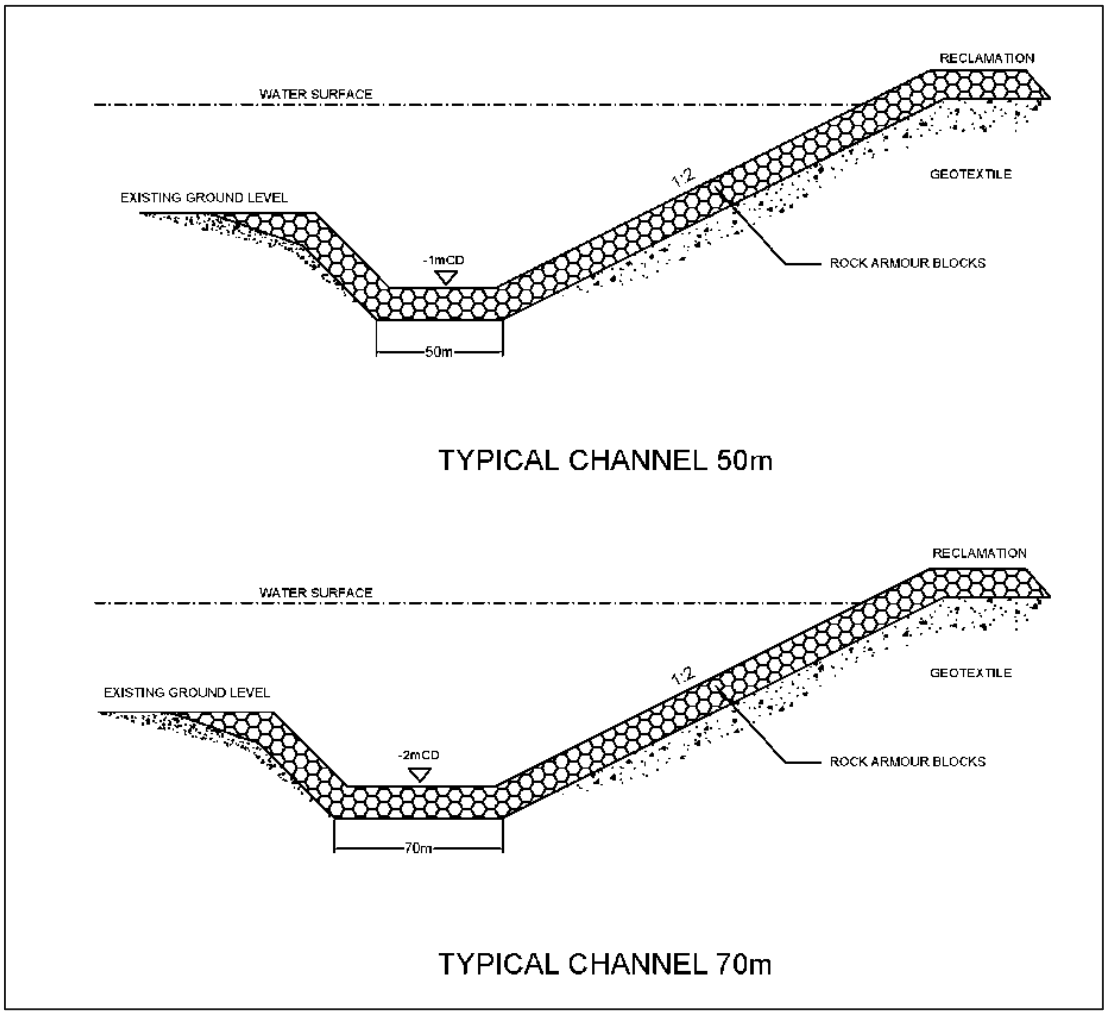

Figure 6.25 Cross section of proposed channel along the western perimeter of the reclamation.

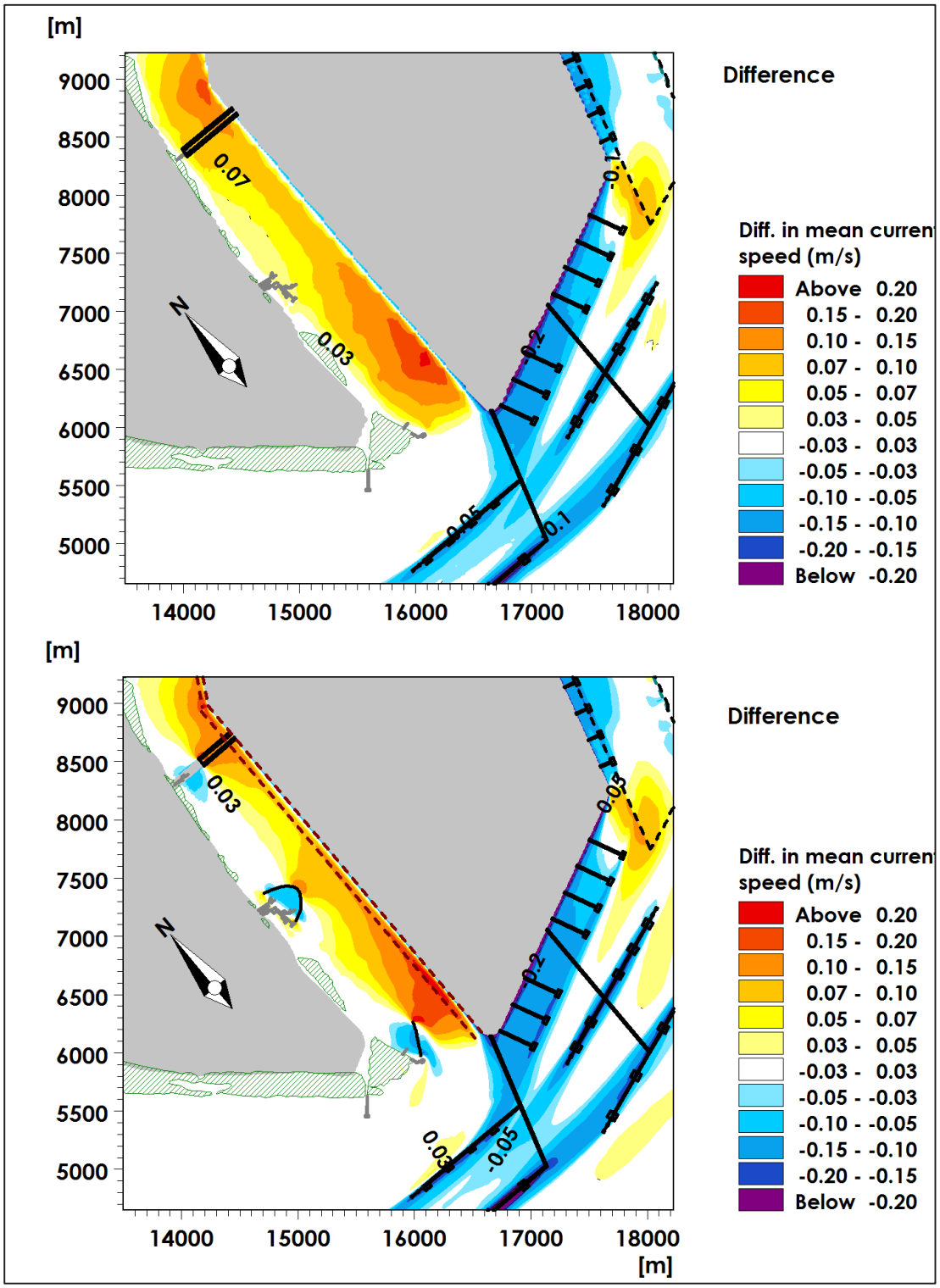

Figure 6.26 Zoom of the differences in mean current speed from the existing condition without mitigation (top) and with mitigation (bottom).

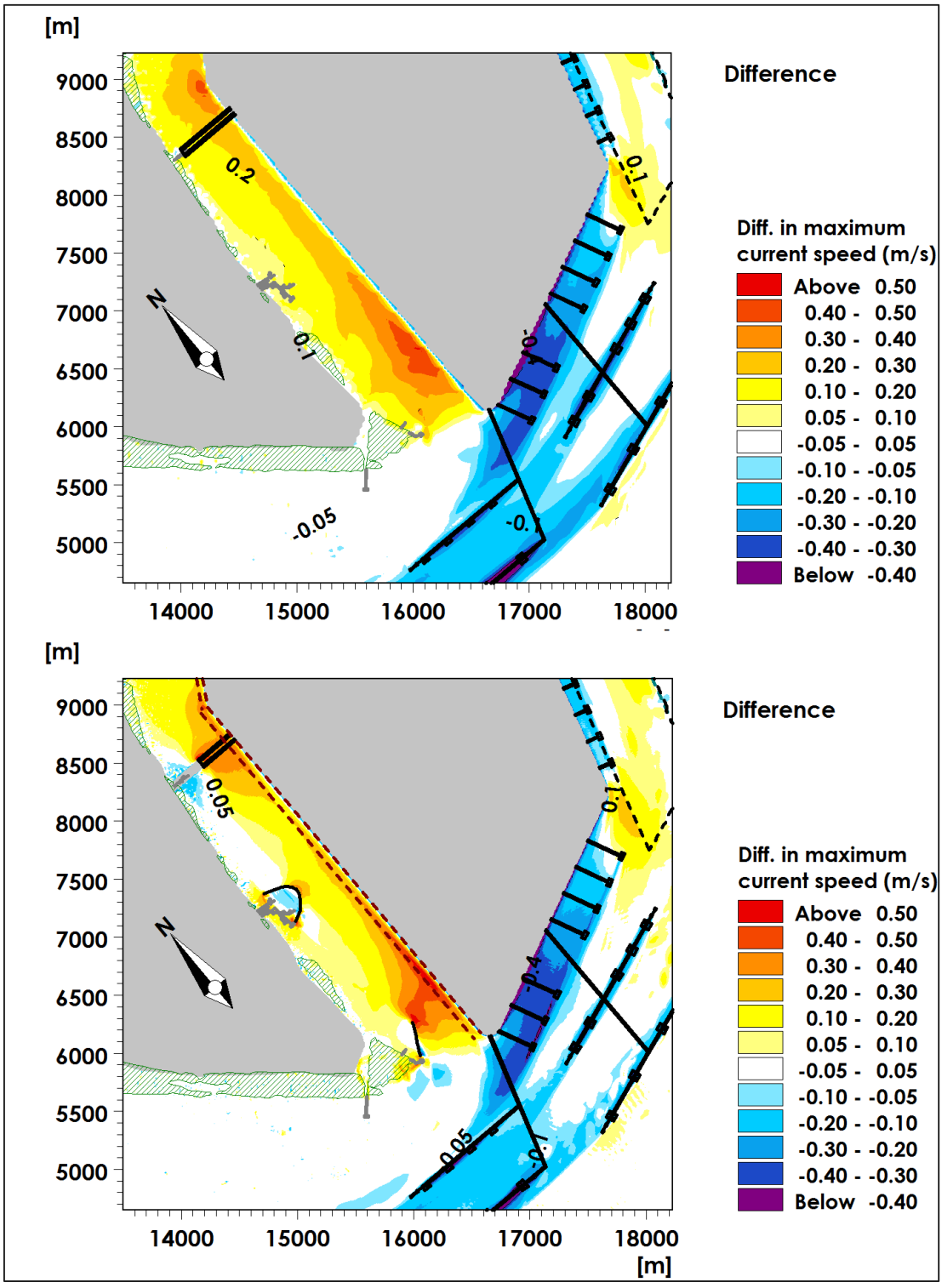

Figure 6.27 Zoom of the differences in maximum current speed from the existing condition without mitigation (top) and with mitigation (bottom).

Water Levels

No impacts predicted so no mitigation measures are proposed.

Tidal Prism

No impacts predicted so no mitigation measures proposed.

Waves

At a regional scale no impacts are predicted so no mitigation measures proposed.

At the local scale, i.e. the eastern Tg Piai coastline, a strong positive change is predicted with respect to the erosional processes currently experience in this area. These impacts are described further in Section 6.2.4.4 below.

6.2.4.3 Residual Impacts

Currents

Control structures do not always perform 100% to design objectives so there is still some possibility that there may be mild current impacts along parts of the coastline. Accordingly the Magnitude of impact has been scored as -1.

Impact Evaluation
Based on the RIAM, the impact is classified as a **Slight Negative**.

Criteria	Score	Description
Importance	1	Important only to the local condition
Magnitude	-1	No change to status quo
Permanence	3	Permanent
Reversibility	3	Irreversible
Cumulativity	2	Non-cumulative/Single
Environmental Score	-8	
Description	**-A**	**Slight Negative Impact**

Water Levels

No change in impact.

Tidal Prism

No change in impacts.

Waves

No change in impacts.

6.2.4.4 Cumulative Effects

The cumulative impact of the Project with other approved projects in the area is also included in the modelling. The cumulative layout includes reclamation (phase 3) with other projects listed below along with mitigation measures proposed in Section 6.2.4.2:

- Pelabuhan Tg. Pelepas Phase 3 Expansion. This includes the land reclamation works to extend the existing berthing area, widening and deepening of the navigation channel to -18.5 mCD. See Figure 6.28;
- JPS has proposed a coastal protection scheme in the area south of Tg. Piai that includes rubble mound parallel breakwaters. The drawings describing the proposed coastal protection layout have been provided by DID and the layout is shown in Figure 6.28.

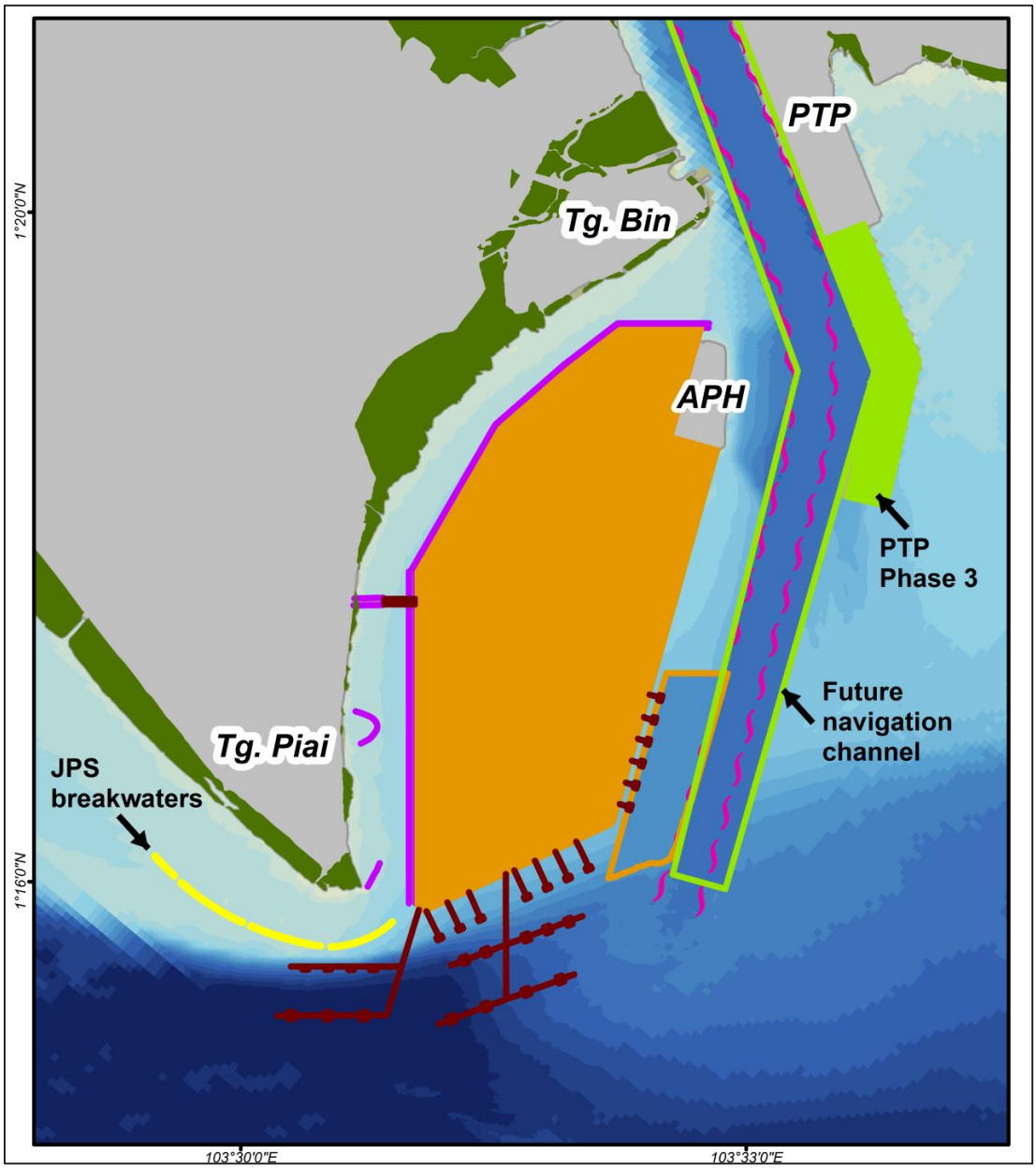

Figure 6.28 Reclamation of Phase 3 with cumulative conditions and mitigation structures.

Currents

Predicted changes in mean and maximum current flows relative to other approve developments in the have been considered and shown in Figure 6.29 and Figure 6.30. It can be concluded that:

- The cumulative changes in mean and maximum currents are localised around the proposed developments and similar to those predicted without the PTP and JPS developments in place;
- Some differences are predicted as follows, these are described below:
  - A small reduction in mean and maximum currents around the Tg Piai area and a small increase in currents along the nearshore areas between the west frontage of the reclamation and the mainland, these changes are however smaller than the one predicted for the project alone. The proposed mitigation measures help to reduce current close to the mangrove forest off Tg Piai National Park;
  - Increase in mean and maximum current speeds along the navigation channel, especially around the southern tip of the PTP phase 3 reclamation area;

- Reduction of currents speeds east and north of the PTP phase 3 reclamation area. This is due to the effect of the PTP extension that tends to produce a re-distribution of the current flows; and
- No regional changes are predicted.

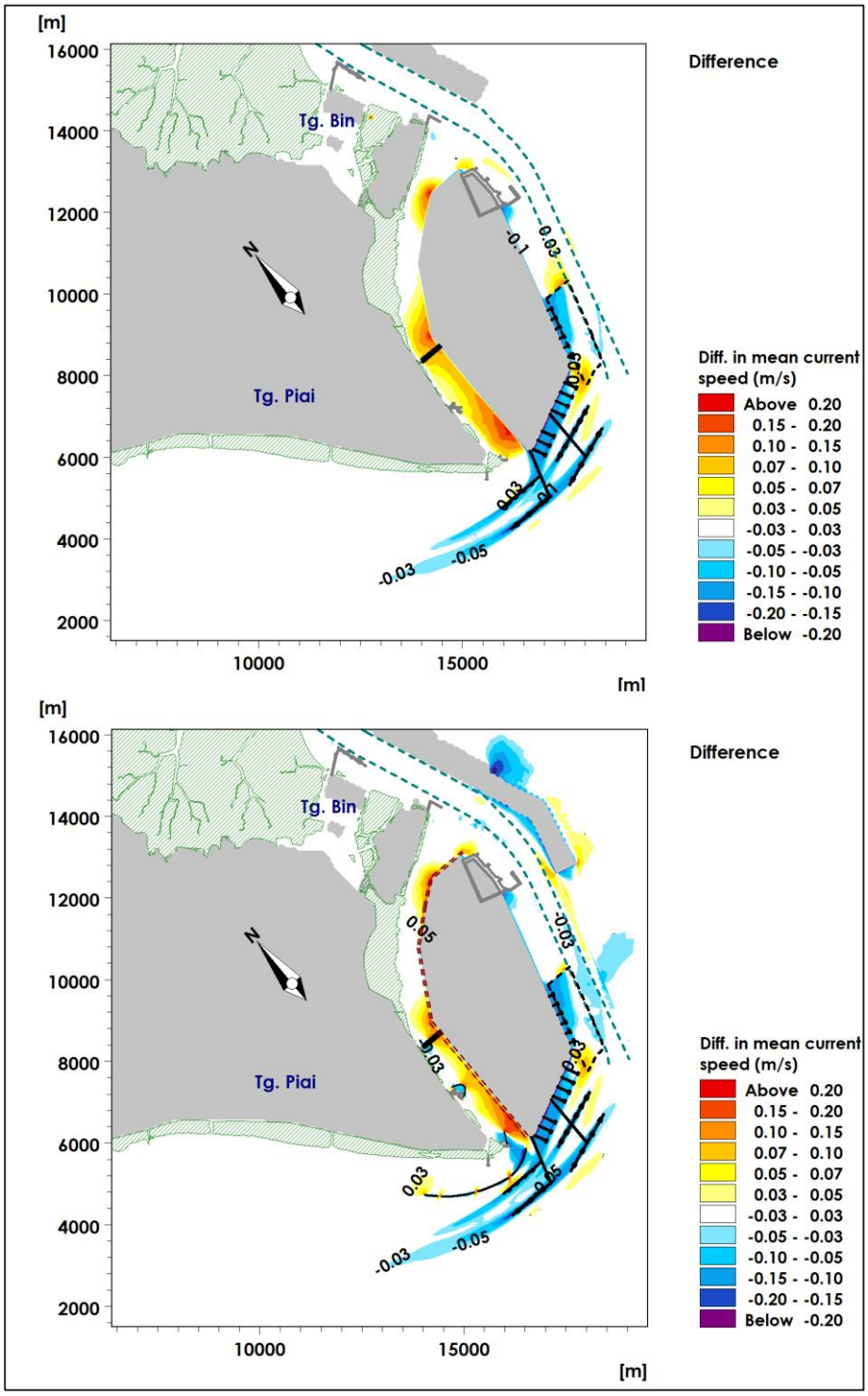

Figure 6.29 Differences in mean current speed from the existing condition for Phase 3 (top) and cumulative (bottom).

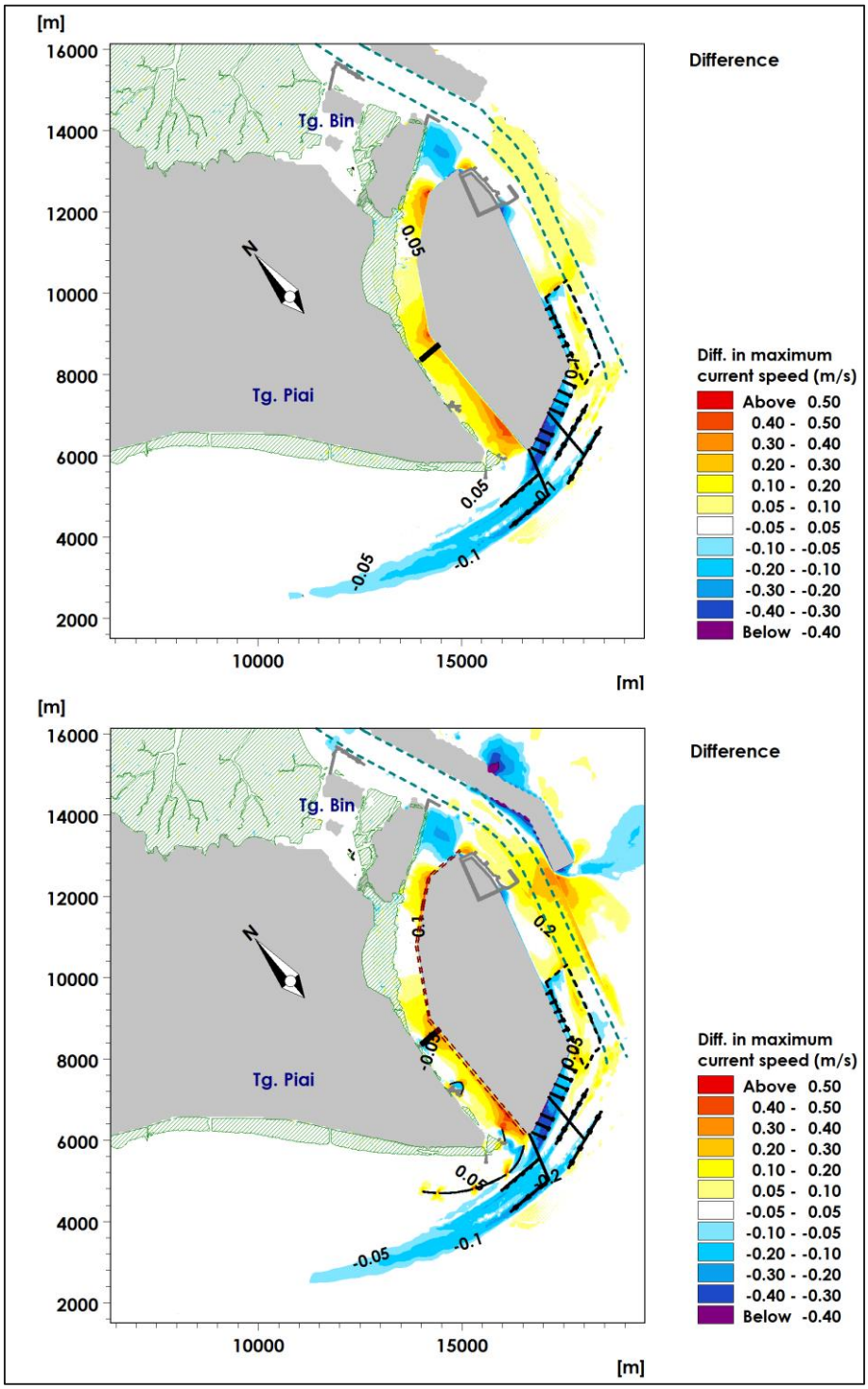

Figure 6.30 Differences in maximum current speed from the existing condition for Phase 3 (top) and cumulative (bottom).

Water Levels

No change in impacts.

Tidal Prism

No change in impacts.

Impact Evaluation

No changes predicted from Residual Impact evaluation.