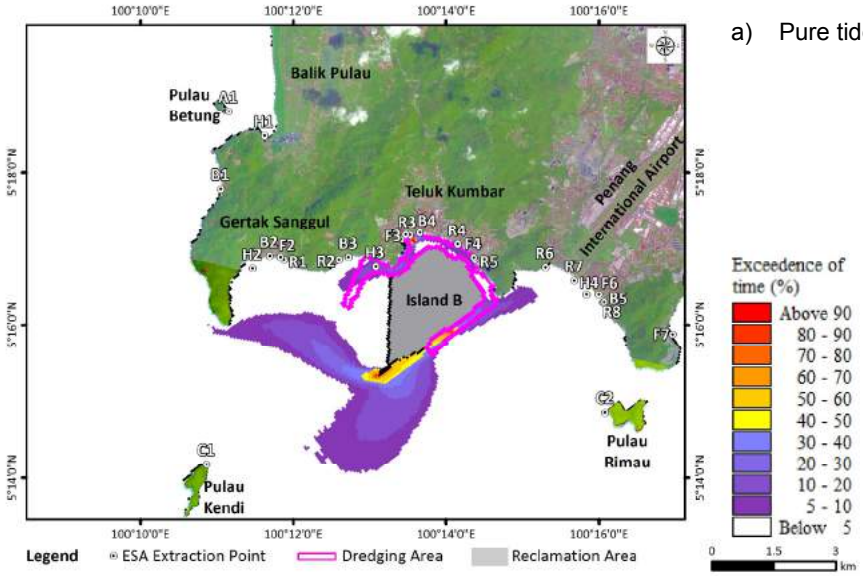
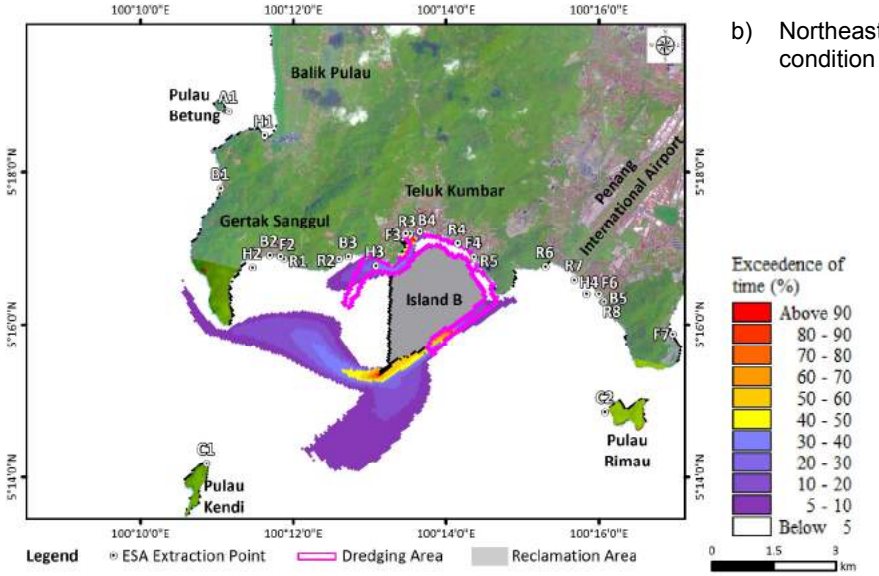
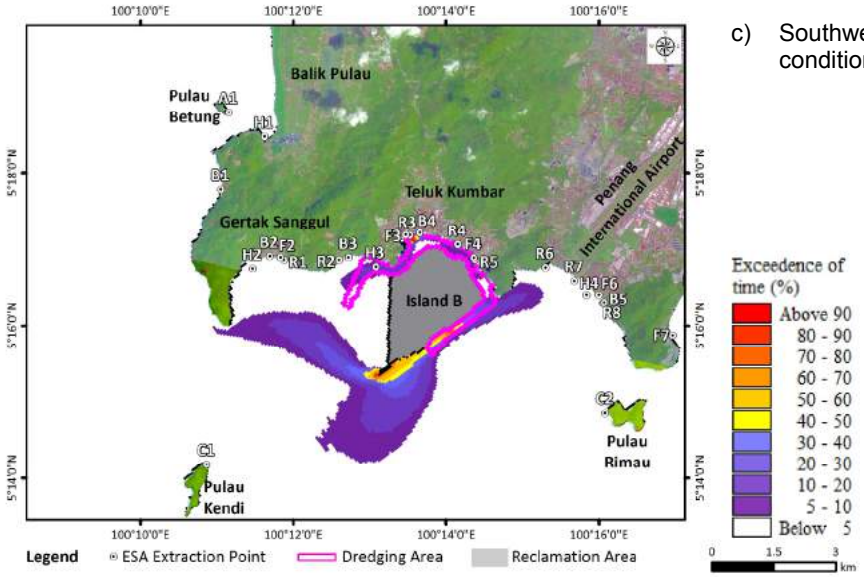


a) Pure tide condition



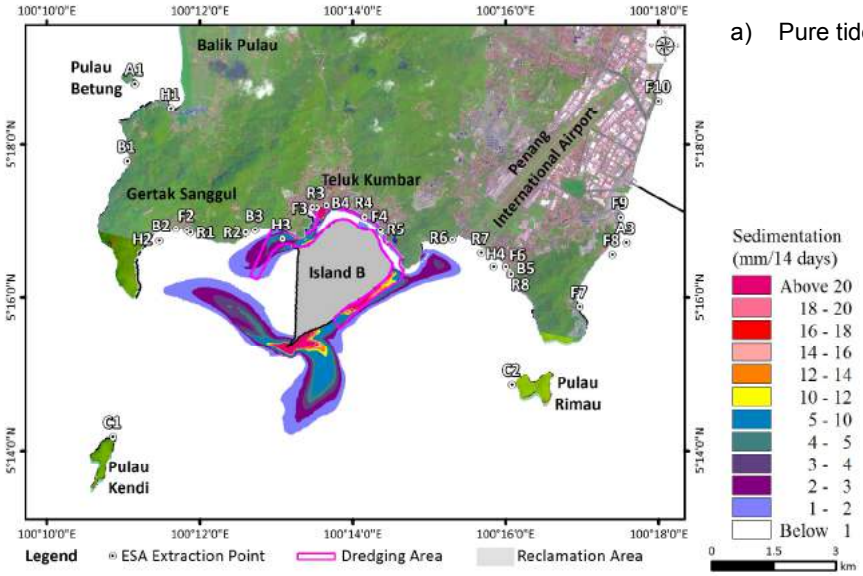
b) Northeast Monsoon condition



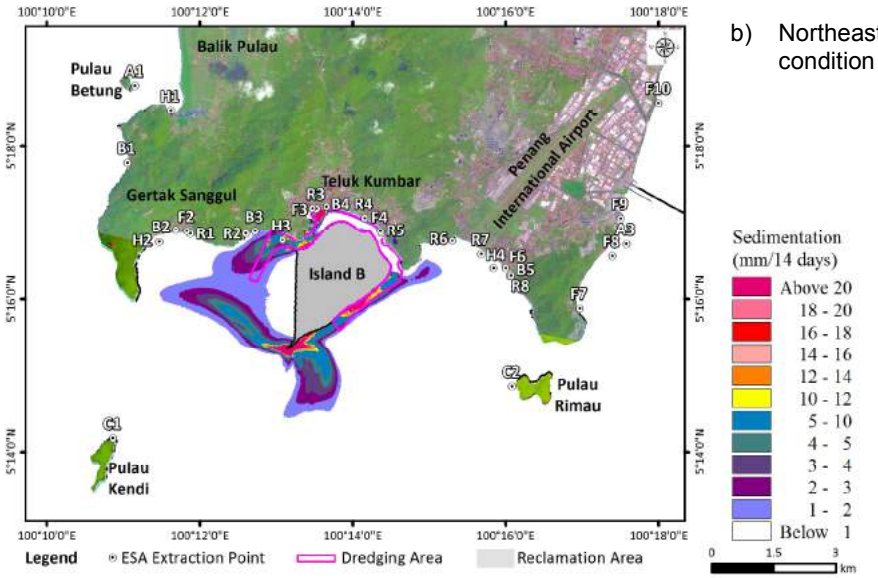
c) Southwest Monsoon condition

F7.55

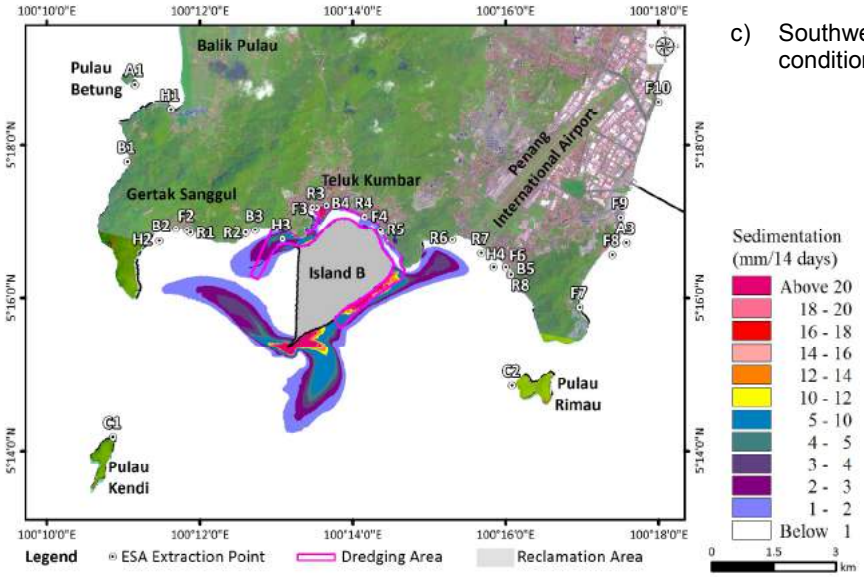
Percentage of time exceedance of suspended sediment concentration above 10 mg/L for Scenario 2, unmitigated condition



a) Pure tide condition



b) Northeast Monsoon condition



c) Southwest Monsoon condition

F7.56 Sedimentation of suspended sediment for Scenario 2, unmitigated condition

Mean and maximum excess suspended concentration levels were extracted at the ESAs points and tabulated together with locations where the peak concentration occur, which are presented in T7.35.

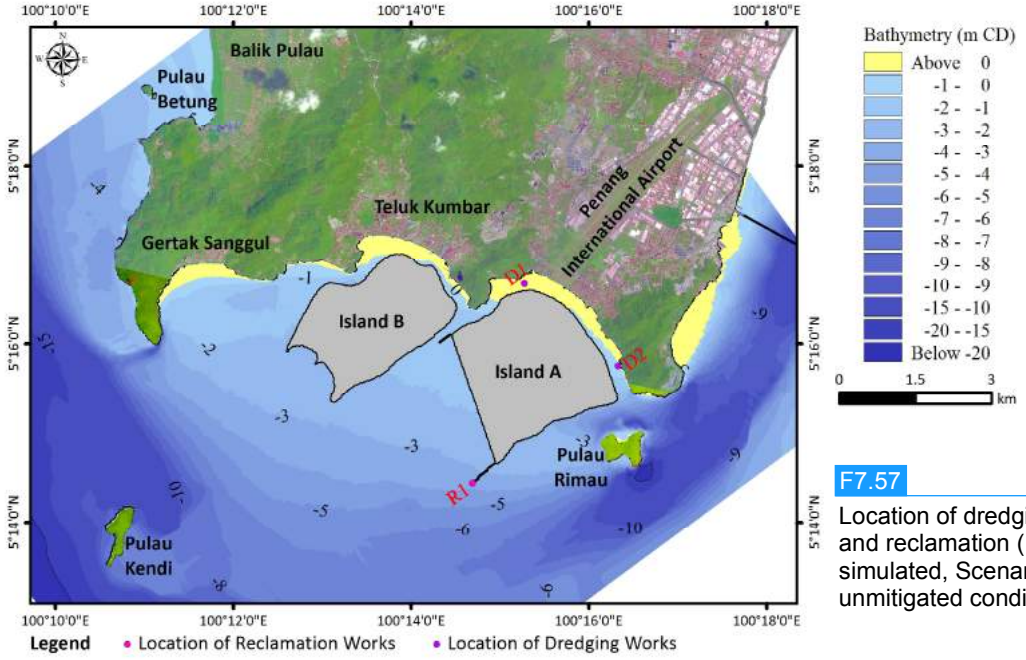
T7.35 Mean and maximum excess suspended concentration at the ESAs for Scenario 2

Point	Location	Excess Suspended Sediment Concentration (mg/L)		Remarks
		Mean	Max	
R1	Sungai Gertak Sanggul	0	2	Insignificant impact
R2	Sungai Gemuruh	1	13	Insignificant impact
R3	Sungai Teluk Kumbar	2	11	Insignificant impact
R4	Sungai Mati	2	28	Insignificant impact
R5	Sungai Batu	2	45	Insignificant impact
R6	Sungai Bayan Lepas	0	1	Insignificant impact
R7	Bayan Lepas Main Drain	0	0	Insignificant impact
R8	Sungai Ikan Mati	0	0	Insignificant impact
C1	Pulau Kendi	0	1	Insignificant impact
C2	Pulau Rimau	0	0	Insignificant impact
H1	Sungai Pulau Betung	0	0	Insignificant impact
H2	Gertak Sanggul	0	1	Insignificant impact
H3	Teluk Kumbar	0	117	High TSS level will affect the existing hatcheries' filtration system, thus mitigation measure is required
H4	Permatang Damar Laut	0	0	Insignificant impact
A1	Pulau Betung	0	2	Insignificant impact
A2	Sungai Pulau Betung	-	-	No data (upstream location)
A3	Batu Maung	0	0	Insignificant impact
F1	Sungai Pulau Betung	-	-	No data (upstream location)
F2	Gertak Sanggul	0	1	Insignificant impact
F3	Teluk Kumbar	4	19	Insignificant impact
F4	Sungai Batu	3	54	Insignificant impact
F5	Permatang Tepi Laut	-	-	No data (upstream location)
F6	Permatang Damar Laut	0	0	Insignificant impact
F7	Teluk Tempoyak Besar	0	0	Insignificant impact
F8	Teluk Tempoyak Kecil	0	0	Insignificant impact
F9	Batu Maung	0	0	Insignificant impact
F10	Sri Jerjak	0	0	Insignificant impact
-	Tanjung Gertak Sanggul	2	10	No sensitive receptor at this location, thus insignificant impact
-	Headland of Island B	11	132	Turbid water may cause aesthetic impact, but it will only be localised and temporary during Scenario 2. Thus, insignificant impact
-	Teluk Kumbar	4	102	Impact on hatchery operation nearby. Refer to ESA Point H3

c) Scenario 3

Findings from Scenario 2 have demonstrated that the reclamation works within the Project site do not result in significant level of excess suspended sediment concentrations at the ESAs. This is because the current speeds are lower at the inner ends of the reclaimed islands. It is therefore considered not necessary to simulate the reclamation works at the inner end of Island A in Scenario 3.

Instead, the sediment spill dispersion model for Scenario 3 simulates placement of the initial reclamation layer without containment at the outer-most end of Island A. At the same time, dredging works are carried out by two dredgers working simultaneously. One dredger is dredging between Island A and the existing foreshore and the other one is dredging the access channel near Tanjung Teluk Tempoyak at -2 m CD. F7.57 shows the locations of the dredging and reclamation activities for Scenario 3.

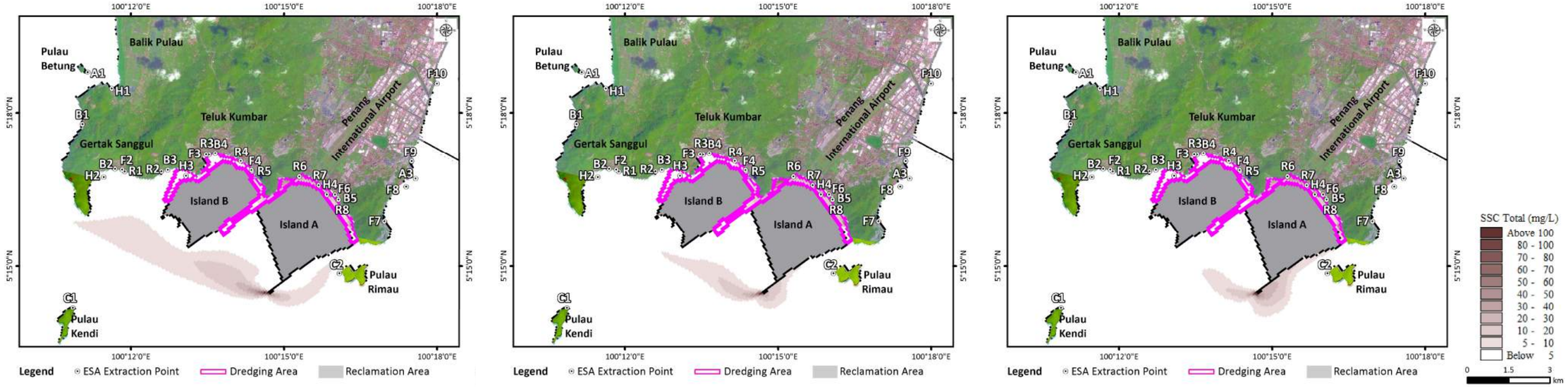


F7.57

Location of dredging (D) and reclamation (R) works simulated, Scenario 3 unmitigated condition

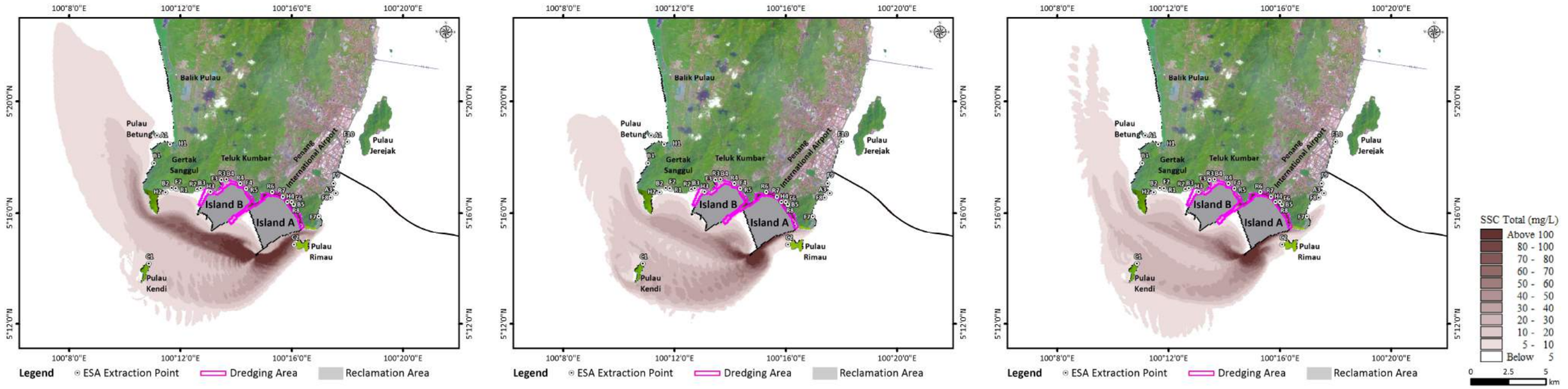
It is noted that although the reclamation works in Scenario 4 are planned to start while the dredging works in Scenario 3 are being carried out, the reclamation works in Scenario 4 will start from the inner end of Island C instead of the outer end. As such, the reclamation location considered for Island A is still considered the worst case as it is at the outer end of Island A where there are fast currents.

F7.58 and F7.59 show the mean and maximum excess suspended sediment concentrations for Scenario 3, unmitigated condition, for different climatic conditions respectively. The pure-tide condition appears to be the worst-case condition, in terms of the extent and level of suspended sediment concentration, especially near Pulau Rimau. From the figures, the excess suspended sediment concentration appears to be primarily arising from the reclamation activities as the dredging locations are relatively sheltered. The reclamation location is at a very fast current area. The peak suspended sediment concentration occurs along the headlands of Island A and Island B, before tapering off at Tanjung Gertak Sanggul and Tanjung Teluk Tempoyak.



a) Pure tide condition b) Northeast Monsoon condition c) Southwest Monsoon condition

F7.58 Mean excess suspended sediment concentration for Scenario 3, unmitigated condition



a) Pure tide condition b) Northeast Monsoon condition c) Southwest Monsoon condition

F7.59 Maximum excess suspended sediment concentration for Scenario 3, unmitigated condition

The results show that the maximum excess suspended sediment concentration at Pulau Betung is up to 10 mg/L and less than 5 mg/L at Batu Maung. There are therefore, no impacts to the aquaculture farms in these areas. Likewise, the water abstraction point for the hatchery near Sungai Pulau Betung is not affected. The maximum excess suspended sediment concentration at Pulau Kendi and Pulau Rimau appears high, especially at the latter. F7.60 and F7.61 show the percentage of time exceedance for 5 and 10 mg/L excess suspended sediment concentrations respectively. F7.62 shows the sedimentation rates of suspended sediment at Pulau Kendi are less than 1 mm over 14 days.

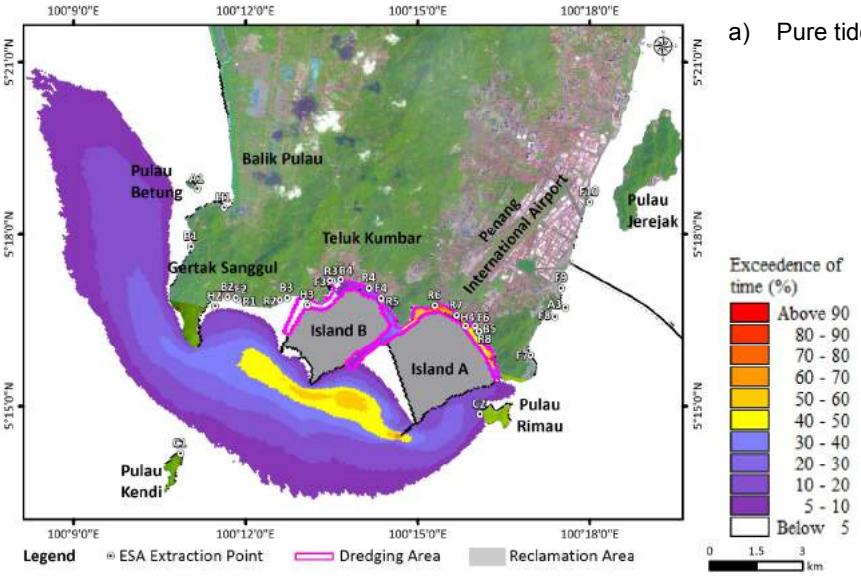
Mean and maximum excess suspended concentration levels were extracted at the ESAs points and tabulated together with locations where the peak concentration occur, as presented in T7.36.

T7.36 Mean and maximum excess suspended concentration at the ESAs for Scenario 3

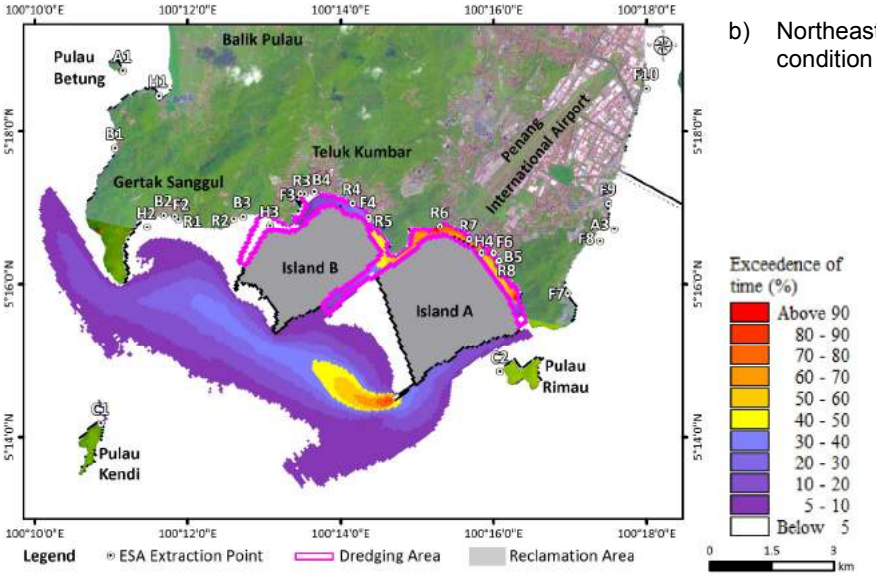
Point	Location	Excess Suspended Sediment Concentration (mg/L)		Remarks
		Mean	Max	
R1	Sungai Gertak Sanggul	0	3	Insignificant impact
R2	Sungai Gemuruh	0	1	Insignificant impact
R3	Sungai Teluk Kumbar	1	29	Insignificant impact
R4	Sungai Mati	1	12	Insignificant impact
R5	Sungai Batu	3	25	Insignificant impact
R6	Sungai Bayan Lepas	26	244	Turbid water may cause aesthetic impact, but it will only be localised and temporary during Scenario 3. Thus, insignificant impact
R7	Bayan Lepas Main Drain	26	315	Turbid water may cause aesthetic impact, but it will only be localised and temporary during Scenario 3. Thus, insignificant impact
R8	Sungai Ikan Mati	13	226	Turbid water may cause aesthetic impact, but it will only be localised and temporary during Scenario 3. Thus, insignificant impact
C1	Pulau Kendi	1	5	Insignificant impact
C2	Pulau Rimau	2	47	High TSS level may cause stress to the corals. Refer to *Section 7.5.1*.
H1	Sungai Pulau Betung	0	0	Insignificant impact
H2	Gertak Sanggul	0	1	Insignificant impact
H3	Teluk Kumbar	0	7	Insignificant impact
H4	Permatang Damar Laut	19	241	High TSS level will affect the existing hatcheries' filtration system, thus mitigation measure is required

T7.36 Mean and maximum excess suspended concentration at the ESAs for Scenario 3 (cont'd)

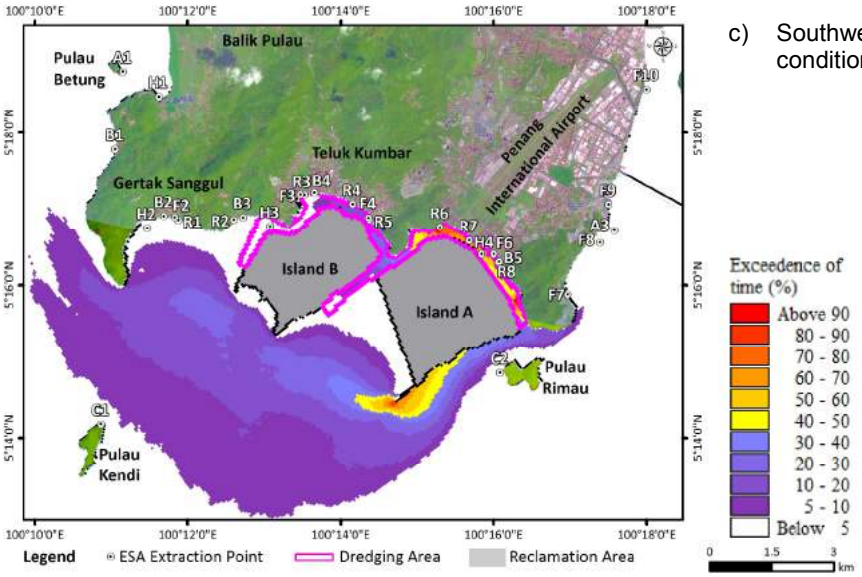
Point	Location	Excess Suspended Sediment Concentration (mg/L)		Remarks
		Mean	Max	
A1	Pulau Betung	0	4	Insignificant impact
A2	Sungai Pulau Betung	-	-	No data (upstream location)
A3	Batu Maung	0	0	Insignificant impact
F1	Sungai Pulau Betung	-	-	No data (upstream location)
F2	Gertak Sanggul	0	2	Insignificant impact
F3	Teluk Kumbar	0	2	Insignificant impact
F4	Sungai Batu	4	35	Insignificant impact
F5	Permatang Tepi Laut	-	-	No data (upstream location)
F6	Permatang Damar Laut	17	271	Turbid water may cause aesthetic impact, but it will only be localised and temporary during Scenario 3. Thus, insignificant impact
F7	Teluk Tempoyak Besar	0	1	Insignificant impact
F8	Teluk Tempoyak Kecil	0	0	Insignificant impact
F9	Batu Maung	0	0	Insignificant impact
F10	Sri Jerjak	0	0	Insignificant impact
-	Tanjung Gertak Sanggul	2	15	Turbid water may cause aesthetic impact, but it will only be localised and temporary during Scenario 3. Thus, insignificant impact
-	Headland of Island B	11	95	Turbid water may cause aesthetic impact, but it will only be localised and temporary during Scenario 3. Thus, insignificant impact
-	Headland of Island A	10	223	Turbid water may cause aesthetic impact, but it will only be localised and temporary during Scenario 3. Thus, insignificant impact
-	Tanjung Teluk Tempoyak	1	18	Turbid water may cause aesthetic impact, but it will only be localised and temporary during Scenario 3. Thus, insignificant impact



a) Pure tide condition



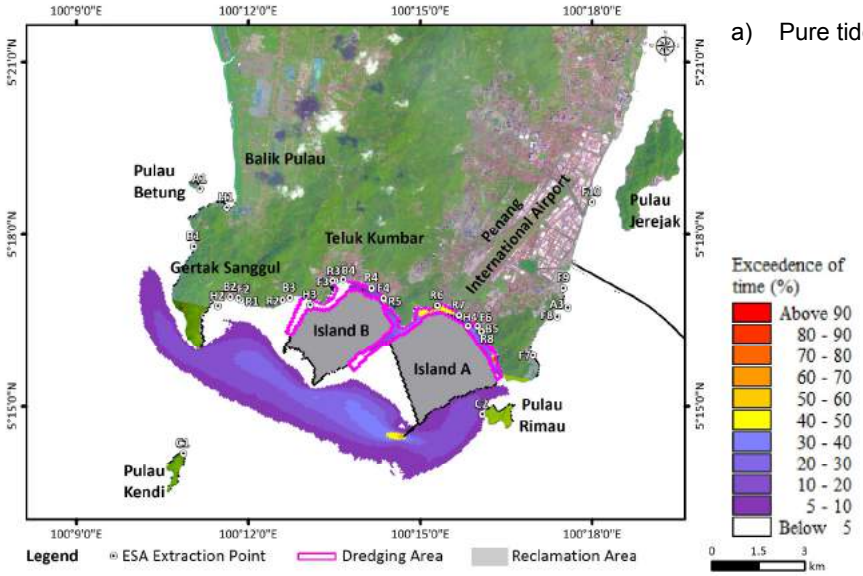
b) Northeast Monsoon condition



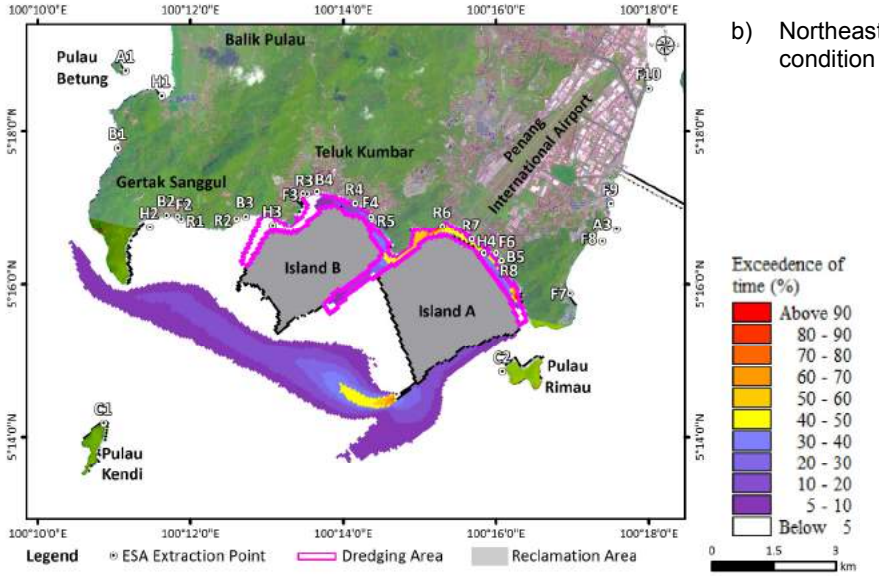
c) Southwest Monsoon condition

F7.60

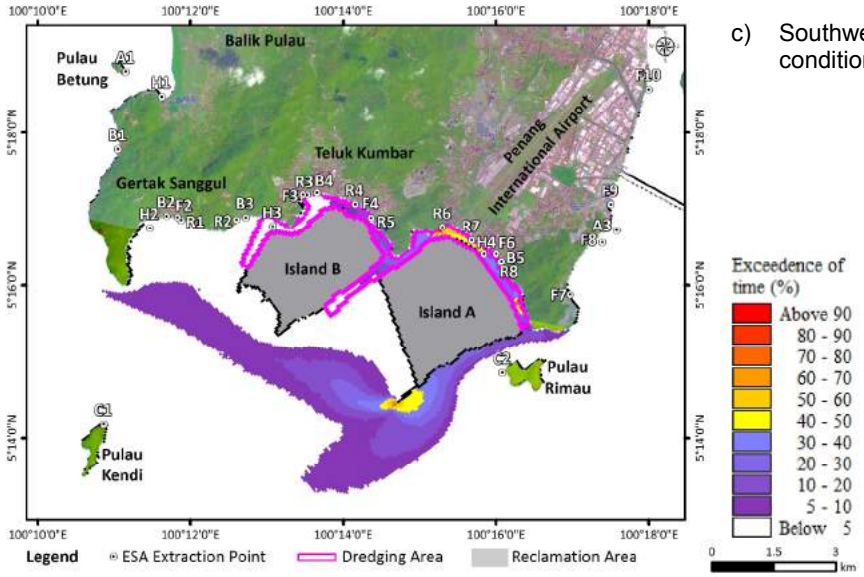
Percentage of time exceedance of suspended sediment concentration above 5 mg/L for Scenario 3, unmitigated condition



a) Pure tide condition



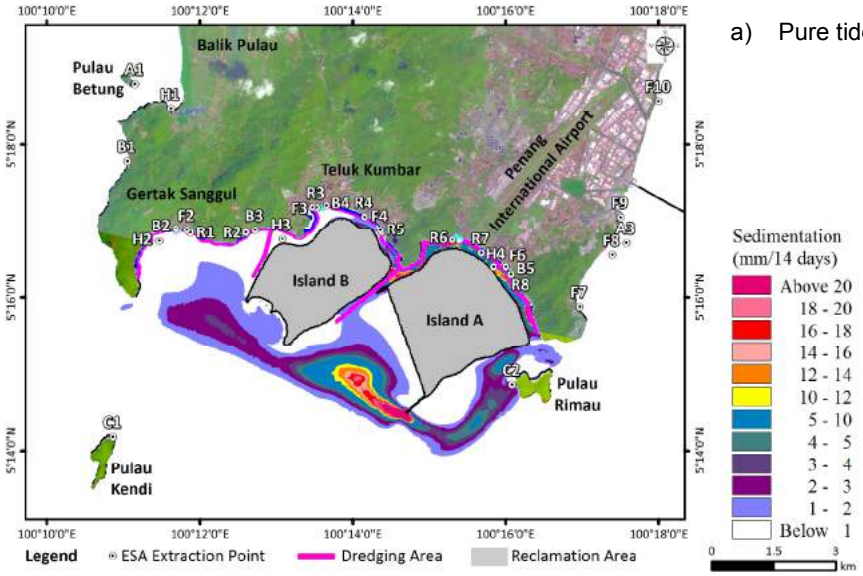
b) Northeast Monsoon condition



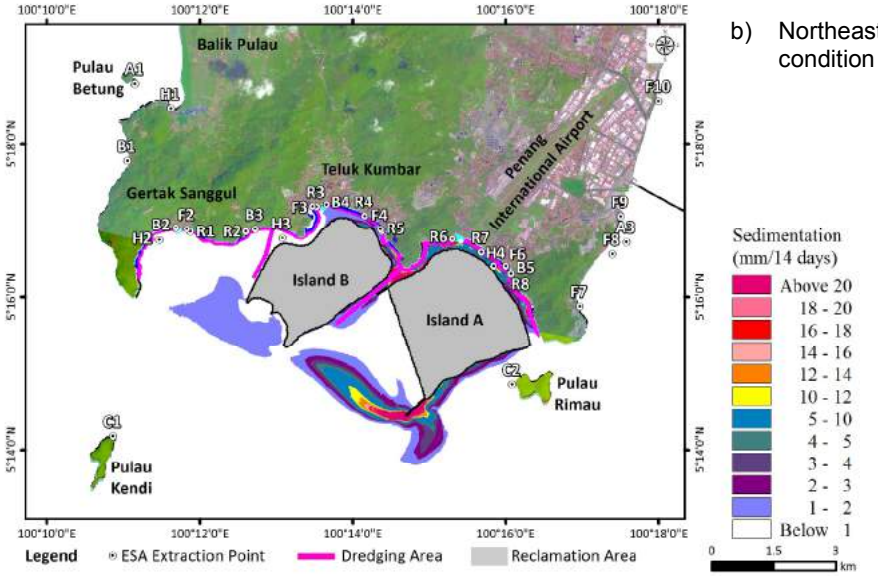
c) Southwest Monsoon condition

F7.61

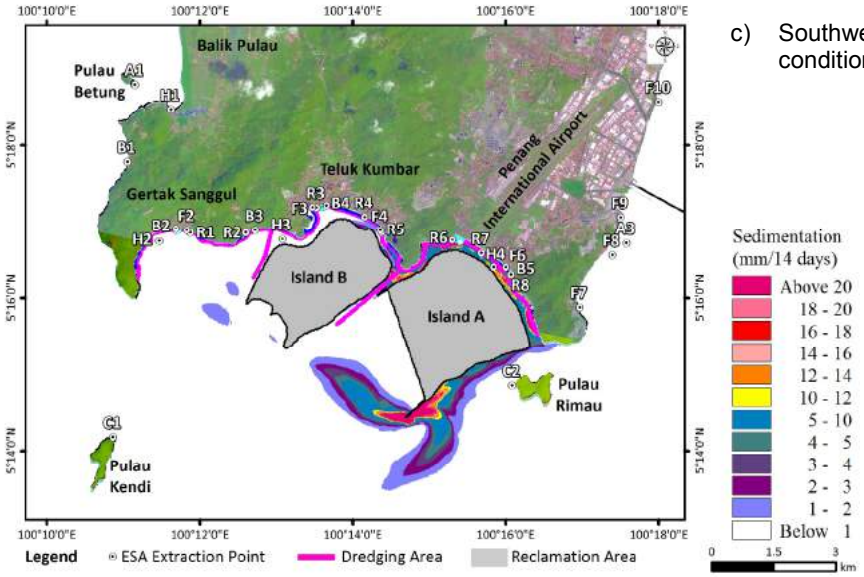
Percentage of time exceedance of suspended sediment concentration above 10 mg/L for Scenario 3, unmitigated condition



a) Pure tide condition



b) Northeast Monsoon condition



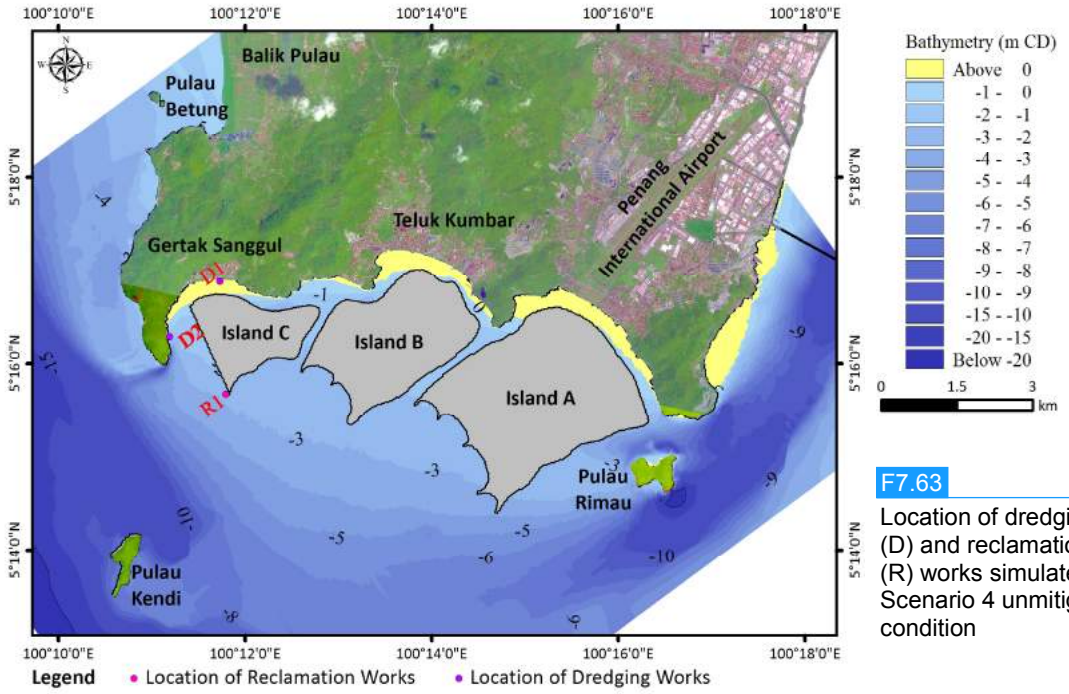
c) Southwest Monsoon condition

F7.62

Sedimentation of suspended sediment for Scenario 3, unmitigated condition

d) Scenario 4

Similar to Scenarios 2 and 3, the activities simulated in Scenario 4 are placement of an initial reclamation layer without containment at the outer-most end of Island C as well as two dredgers working at the same time. The simulated activities are shown in F7.63.



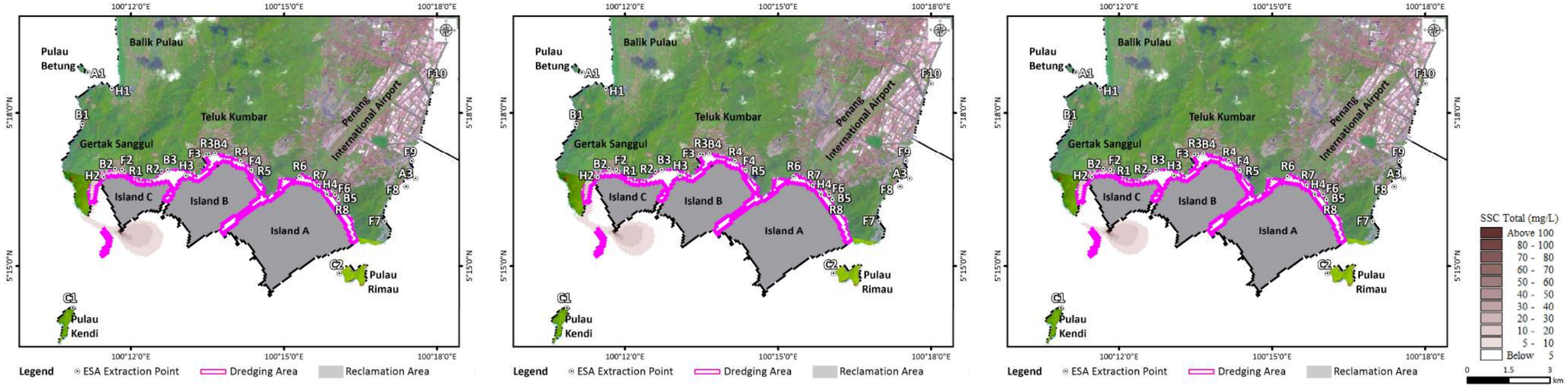
F7.63
Location of dredging (D) and reclamation (R) works simulated, Scenario 4 unmitigated condition

F7.64 and F7.65 show mean and maximum excess suspended sediment concentrations for Scenario 4, unmitigated condition for different climatic conditions respectively. The pure tide condition appears to be the worst-case condition, in terms of the extent and level of suspended sediment concentration. The extent of maximum excess suspended sediment concentration is similar to that of the dredging works near Tanjung Gertak Sanggul in Scenario 1, albeit slightly smaller. The peak concentration of suspended sediment is very localised, which occur at Island C marina and Tanjung Gertak Sanggul. The excess suspended sediment arising from the dredging and reclamation activities does not extend to the east of Island B.

F7.65 shows that the maximum suspended sediment concentration at Pulau Betung is less than 20 mg/L, thus lower than the tolerable limit of 80 mg/L for aquaculture. The maximum suspended sediment concentration at the water abstraction point near Pulau Betung is less than 5 mg/L.

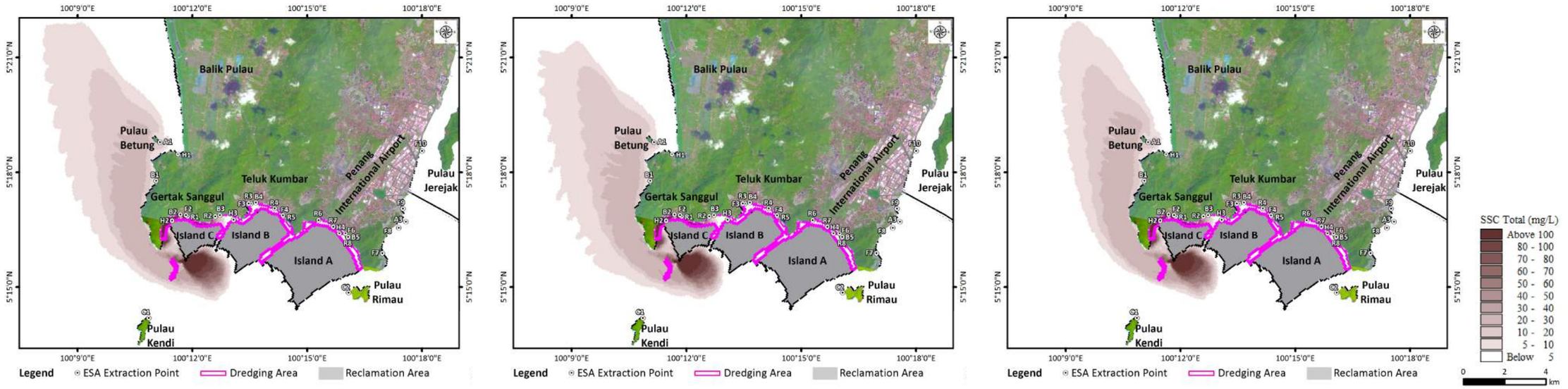
The percentage of time exceedance for 5 and 10 mg/L excess suspended sediment concentrations are presented in F7.66 and F7.67 respectively. These figures show that the tolerable limits for coral reefs are not exceeded at Pulau Kendi and Pulau Rimau. F7.68 shows the sedimentation rates of suspended sediment at Pulau Rimau and Pulau Kendi do not exceed 1 mm over 14 days.

Considering the results from the sediment spill dispersion modelling simulations for the dredging and reclamation activities in Scenario 4, there is no exceedance of tolerable limits of excess suspended sediment concentrations at the ESAs considered.



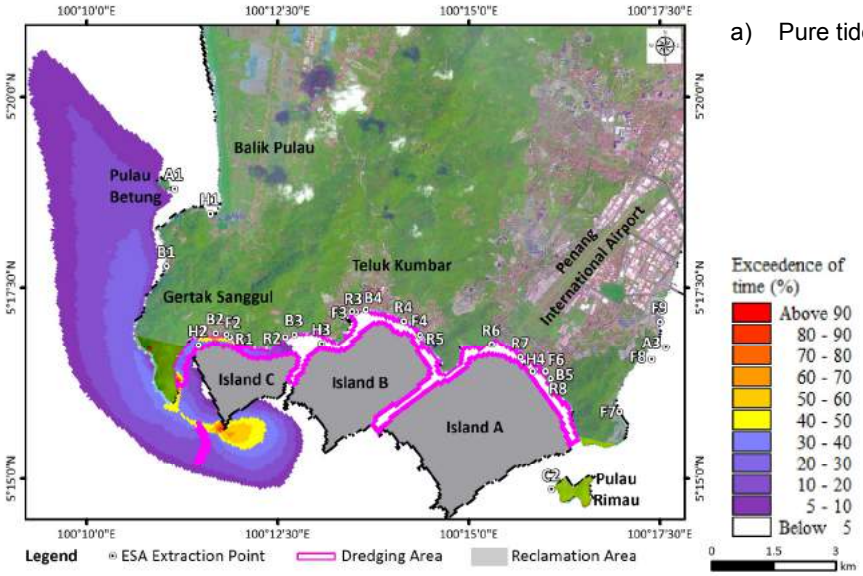
a) Pure tide condition b) Northeast Monsoon condition c) Southwest Monsoon condition

F7.64 Mean excess suspended sediment concentration for Scenario 4, unmitigated condition

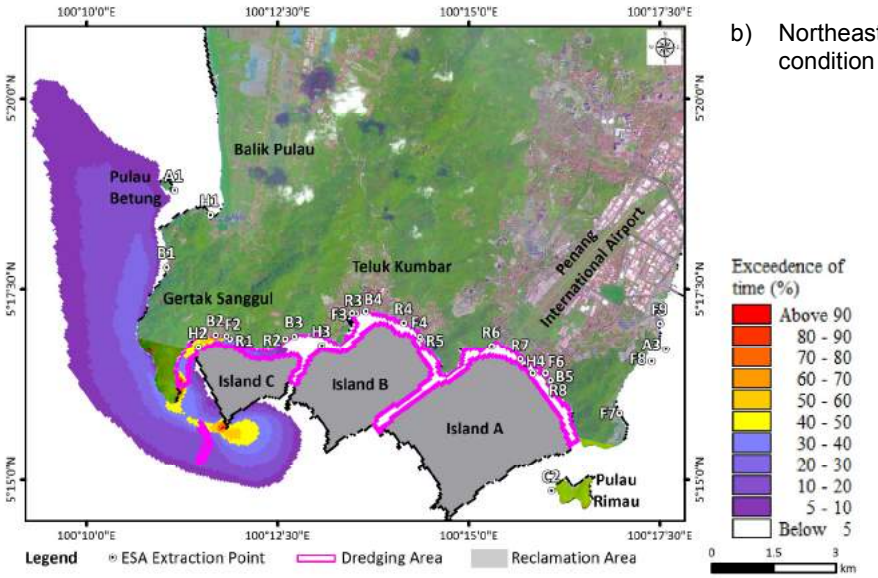


a) Pure tide condition b) Northeast Monsoon condition c) Southwest Monsoon condition

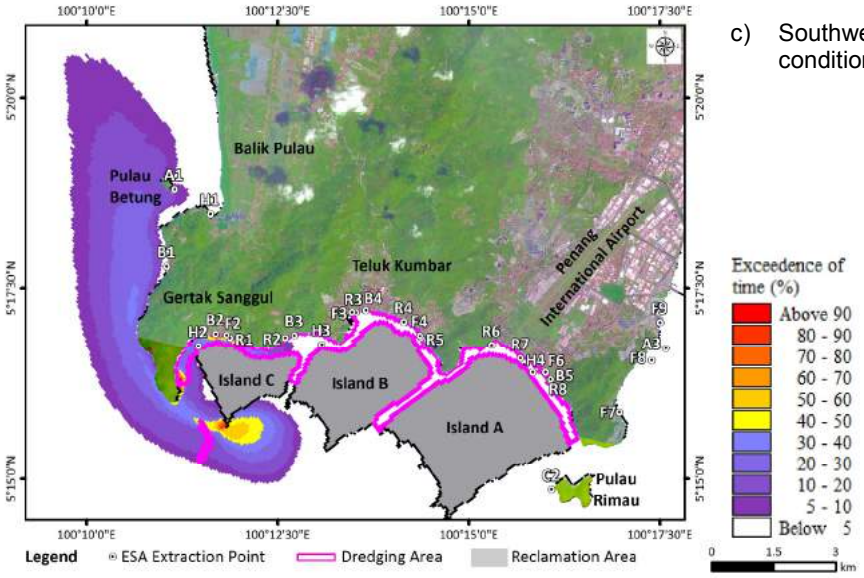
F7.65 Maximum excess suspended sediment concentration for Scenario 4, unmitigated condition



a) Pure tide condition



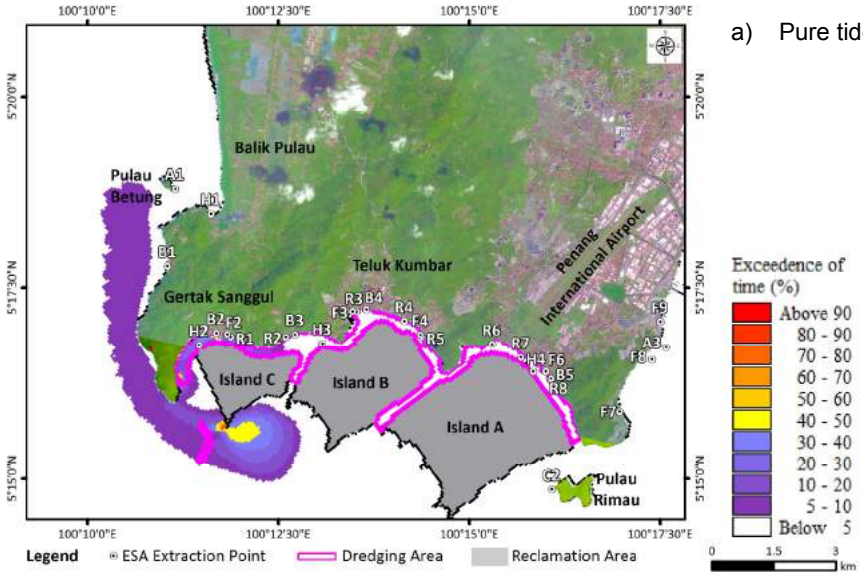
b) Northeast Monsoon condition



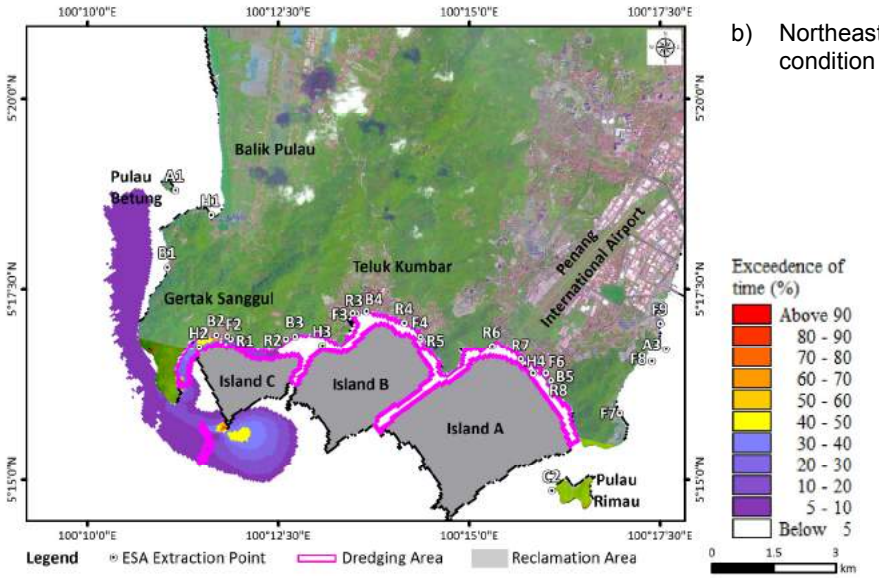
c) Southwest Monsoon condition

F7.66

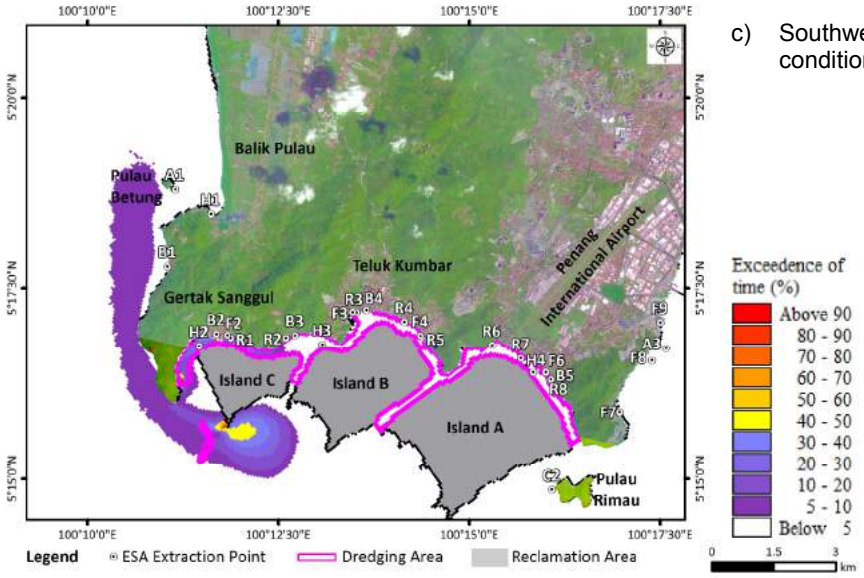
Percentage of time exceedance of suspended sediment concentration above 5 mg/L for Scenario 4, unmitigated condition



a) Pure tide condition



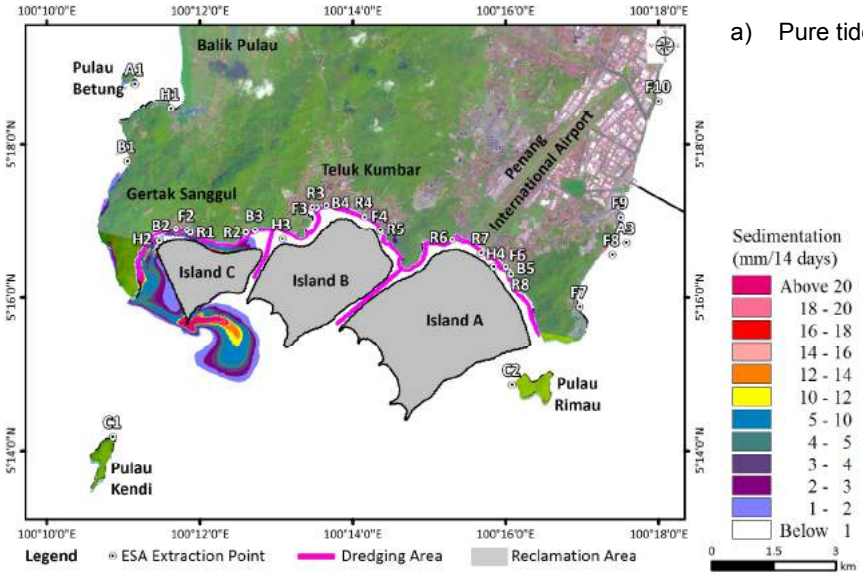
b) Northeast Monsoon condition

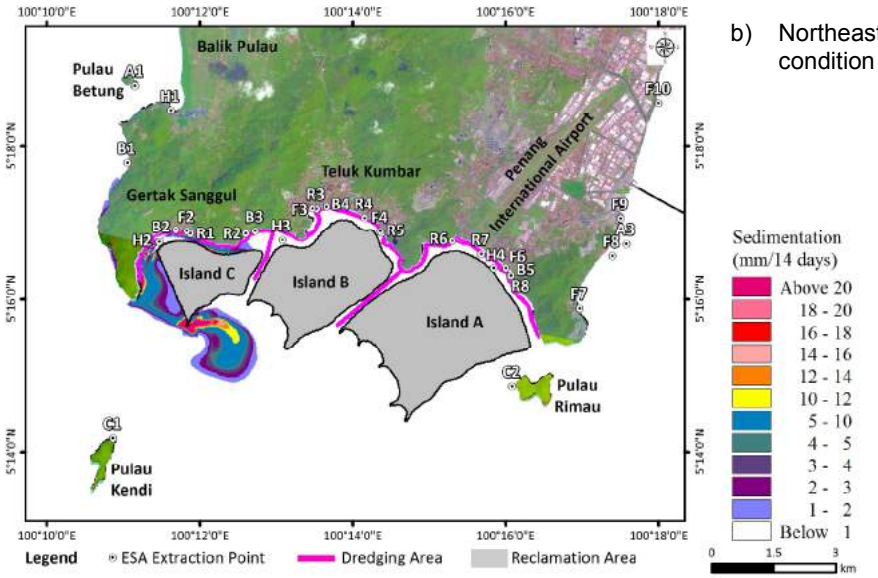


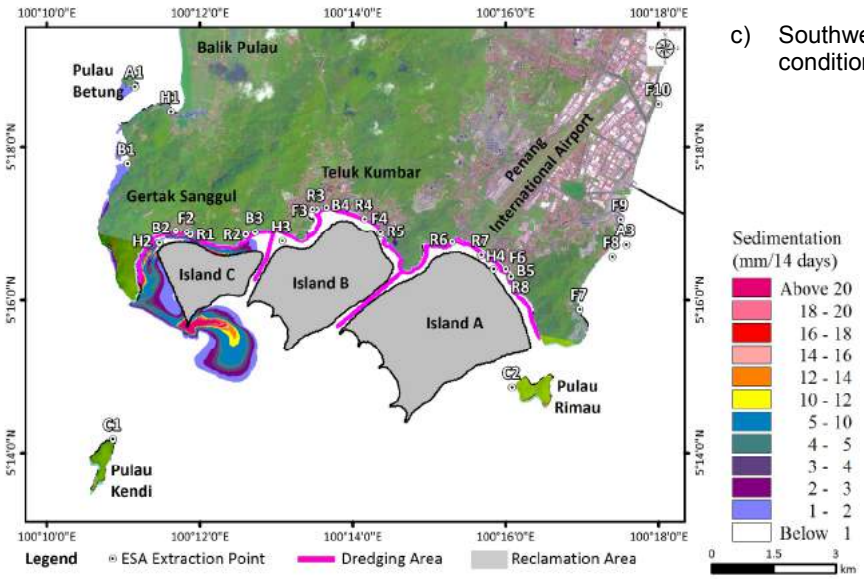
c) Southwest Monsoon condition

F7.67

Percentage of time exceedance of suspended sediment concentration above 10 mg/L for Scenario 4, unmitigated condition







F7.68

Sedimentation of suspended sediment for Scenario 4, unmitigated condition

Mean and maximum excess suspended concentration levels were extracted at the ESAs points and tabulated together with locations where the peak concentration occur, which are presented in T7.37.

T7.37 Mean and maximum excess suspended concentration at the ESAs for Scenario 4

Point	Location	Excess Suspended Sediment Concentration (mg/L)		Remarks
		Mean	Max	
R1	Sungai Gertak Sanggul	21	366	Turbid water may cause aesthetic impact, but it will only be localised and temporary during Scenario 4. Thus, insignificant impact
R2	Sungai Gemuruh	0	3	Insignificant impact
R3	Sungai Teluk Kumbar	0	0	Insignificant impact
R4	Sungai Mati	0	0	Insignificant impact
R5	Sungai Batu	0	0	Insignificant impact
R6	Sungai Bayan Lepas	0	0	Insignificant impact
R7	Bayan Lepas Main Drain	0	0	Insignificant impact
R8	Sungai Ikan Mati	0	0	Insignificant impact
C1	Pulau Kendi	0	0	Insignificant impact
C2	Pulau Rimau	0	0	Insignificant impact
H1	Sungai Pulau Betung	0	0	Insignificant Impact
H2	Gertak Sanggul	23	305	High TSS level will affect the existing hatcheries' filtration system, thus mitigation measure is required
H3	Teluk Kumbar	0	0	Insignificant impact
H4	Permatang Damar Laut	0	0	Insignificant impact
A1	Pulau Betung	1	9	Insignificant impact
A2	Sungai Pulau Betung	-	-	No data (upstream location)
A3	Batu Maung	0	0	Insignificant impact
F1	Sungai Pulau Betung	-	-	No data (upstream location)
F2	Gertak Sanggul	36	542	Turbid water may cause aesthetic impact, but it will only be localised and temporary during Scenario 4. Thus, insignificant impact
F3	Teluk Kumbar	0	0	Insignificant impact
F4	Sungai Batu	0	0	Insignificant impact
F5	Permatang Tepi Laut	-	-	No data (upstream location)
F6	Permatang Damar Laut	0	0	Insignificant impact
F7	Teluk Tempoyak Besar	0	0	Insignificant impact
F8	Teluk Tempoyak Kecil	0	0	Insignificant impact

T7.37 Mean and maximum excess suspended concentration at the ESAs for Scenario 4 (cont'd)

Point	Location	Excess Suspended Sediment Concentration (mg/L)		Remarks
		Mean	Max	
F9	Batu Maung	0	0	Insignificant impact
F10	Sri Jerjak	0	0	Insignificant impact
-	Tanjung Gertak Sanggul	6	24	Turbid water may cause aesthetic impact, but it will only be localised and temporary during Scenario 4. Thus, insignificant impact
-	Near Island C Marina	20	201	Turbid water may cause aesthetic impact, but it will only be localised and temporary during Scenario 4. Thus, insignificant impact

7.3.9.4 Overall Findings for Sediment Spill Dispersion

Sediment spill dispersion modelling simulations have been undertaken to assess the potential temporary impact on the ESAs within and in close proximity to the Project site, namely coral reefs at Pulau Rimau and Pulau Kendi, aquaculture farms in Batu Maung and Pulau Betung as well as water abstraction points of the hatcheries within the Project site and near Sungai Pulau Betung.

The model simulates the dredging and/or reclamation activities in all development scenarios. The worst case locations for the dredging and/or reclamation, in terms of high current speeds that would disperse the excess suspended sediment arising from these activities, have been used in the model simulations. The placement of a layer of sandy bedding material has been used to represent the reclamation works as it is considered the "worst case" for sediment spill dispersion.

The sediment spill dispersion modelling results show that the maximum excess suspended sediment concentration associated with the dredging and reclamation works in all development scenarios are below the tolerable limits at the aquaculture farms in Batu Maung and Pulau Betung, as well as the water abstraction point for the hatchery near Sungai Pulau Betung. The abstraction points for the hatcheries within the Project site will be affected in all scenarios, and thus an upgrade to the filtration systems of the hatcheries will be required.

The modelling results show that the dredging works for the dredged channels as well as the reclamation works of Islands B and C do not result in exceedance of tolerable limits of the excess suspended sediment concentrations at the coral reefs at Pulau Kendi and Pulau Rimau. The placement of the sandy bedding material for the rock bund along the southeastern edge of Island A in Scenario 3, however, is predicted to have an impact to the coral reefs at Pulau Rimau.

The sediment dispersion modelling forms part of the impact assessment on the coral reefs around Pulau Rimau. Based on the outcome of the hydraulic studies as well as the ecological assessment, it is recommended that the coral reefs along the western coastline of Pulau Rimau, i.e. those facing Island A, are to be fully traded off. The Project Proponent is committed to implement an offset programme that includes installation of artificial reefs and provision of grants of financial support for research related to coral reefs.

7.4 Impacts on Water Quality

One of the key issues that need to be handled delicately on this Project is the impact on water quality. Land reclamation and dredging can be very detrimental to water quality if they are not managed properly. Impacts arising from land reclamation and dredging can be considered as short-term impacts as these will cease once the reclamation and dredging works end after the development is completed.

However, the presence of newly-reclaimed islands will instigate a more serious problem as the impact will be extensive and permanent. For the proposed Project, the issue on water quality is very delicate as there are several rivers that can be classified as polluted discharging into the proposed development site.

7.4.1 Land Reclamation and Dredging

One of the major sources of impact to water quality by land reclamation and dredging activities is sediment plume which has been discussed extensively in *Section 7.3.5*. For land reclamation, sediment plume generation is mainly related to sand filling work. Activities that do not involve sand filling, such as construction of rock bund or revetment, will not generate significant level of sediment plume. It should be noted that the movement of vessels may also produce visible plume trailing in their wake, as illustrated in F7.69. This generally occurs at an area where the draft is relatively shallow and the seabed is made up of soft, muddy material. However, plume generated from the vessels' movement is mostly localised and does not significantly disperse over a large area.

F7.69 Sediment plume generated by vessel movement

As for dredging, the source for sediment dispersion may come from the material loosened by the cutter head which will be dispersed by the current over to the surrounding area. Meanwhile, the dredged material from the dredger will be filled into a barge via pipeline for disposal. During the filling process, significant sediment plume will be generated from the overflow.

a) Pre-dredging

The construction of workers' quarters and an access road will involve land-clearing works. The area to be cleared for the workers' quarters is approximately 4 acres while the access road is approximately 1 km in length. This activity will generate biomass that need to be managed and disposed properly. The exposed topsoil will cause surface erosion that will transport sediment to nearby waterbodies.

After the workers' quarters are completed, it is projected that a workers' base will be set up within or nearby the Project area. Workers residing within the base will generate significant amounts of solid waste, organic waste and wastewater. Sewage and greywater generated from the toilets and/or kitchen may cause elevated levels of BOD, *E. coli* and nutrients within the surrounding water if discharged untreated. Taking into account the existing water quality, these will further exacerbate the problem and may cause health problems not only to the workers but also to the neighbouring communities. Solid and organic waste, if not managed properly, may produce leachate that can lead to surface and groundwater pollution. Garbage and food waste will attract strays, pests and scavenger animals such as rats, crows, dogs and cats.

Normally, a stockpile and storage facilities will be constructed together with the workers' base. Spillage and runoff contamination from the stockpile and storage area will introduce pollutants to the surrounding water body.

b) Scenario 1

For this scenario, a total of 2.2 million m^3 of material will be dredged. As the location of the dredging is very near to the coastline, it is expected that the plume generated will affect the operation of hatcheries located at Gertak Sanggul, Teluk Kumbar and Permatang Damar Laut that source their water for operation via intake pipes located near the coastline, which is also located near the dredging area. A high level of TSS will cause operational problems to the hatcheries as the current filtration system utilised by the hatcheries functions according to the existing TSS level of around 10 to 20 mg/L. Details of the impact on hatchery operations will be further discussed in *Section 7.6.1 - Hatcheries*.

c) Scenario 2

Scenario 2 involves the creation of Island B and the dredging of channel surrounding Island B. As such, the main source of pollution on water quality will be the land reclamation and dredging activities that will cause high TSS level to the surrounding waters. A total of 93.8 million m^3 of sand will be used for Island B reclamation while the material to be dredged is approximately 1.6 million m^3.

Based on the sediment plume simulation, no sensitive receptors will be affected during this stage other than hatcheries at Teluk Kumbar. This is expected as the land reclamation and dredging activities will be conducted within the immediate vicinity of hatcheries at Teluk Kumbar. The maximum excess SSC level projected during this scenario is over 100 mg/L, which will render the marine water unsuitable for hatchery operation without additional treatment.

In addition to sediment plume, vessels deployed for the work is another potential source of water pollution. During this scenario, more vessels will be operating within the Project area as the actual reclamation work has commenced. Some vessels will store fuel, oil, grease and chemicals on board for operation and maintenance purposes. Spillage of these materials can happen, whether accidental or otherwise. Oil spill presents a significant contamination risk to the water surrounding the Project area. Depending on the currents and wind movement, the

oil slick may disperse over a large area as well as reaching Penang's southern coastline, impacting a myriad of receptors.

Some of the vessels will have toilet and kitchen facilities for the crew staying on board. Direct discharge of wastewater, greywater and other solid waste into the sea is detrimental to water quality if done in large quantity.

Ballast water and bilges generated from the vessels usually contain significant levels of pollutants, in which oil is the most common contaminant. According to Environmental Quality (Scheduled Waste) Regulation 2005, a mixture of water and oil such as ballast water is classified as Scheduled Waste. These contaminants will be introduced into the environment if the ballast water and bilges are not handled correctly as per the prevailing regulations.

It is expected that the number of workers residing at the quarters will increase. Correspondingly, the number of waste produced by the workers will also grow.

d) Scenario 3

The situation for this scenario will be similar with Scenario 2, where the land reclamation and dredging activities at Island A will cause high TSS level to the surrounding area while the vessels and machineries used will present a risk of pollution from oil, chemicals, wastewater, etc. The difference is that the impact will more prominently occur at the area of Permatang Damar Laut (Island A) instead of Teluk Kumbar (Island B). More importantly, the reclamation of Island A is located near to Pulau Rimau. As such, degradation of water quality during this period will affect the coral reefs at Pulau Rimau. Impact on water quality to corals at Pulau Rimau is further discussed in *Section 7.5.1 – Coral Reefs*.

e) Scenario 4

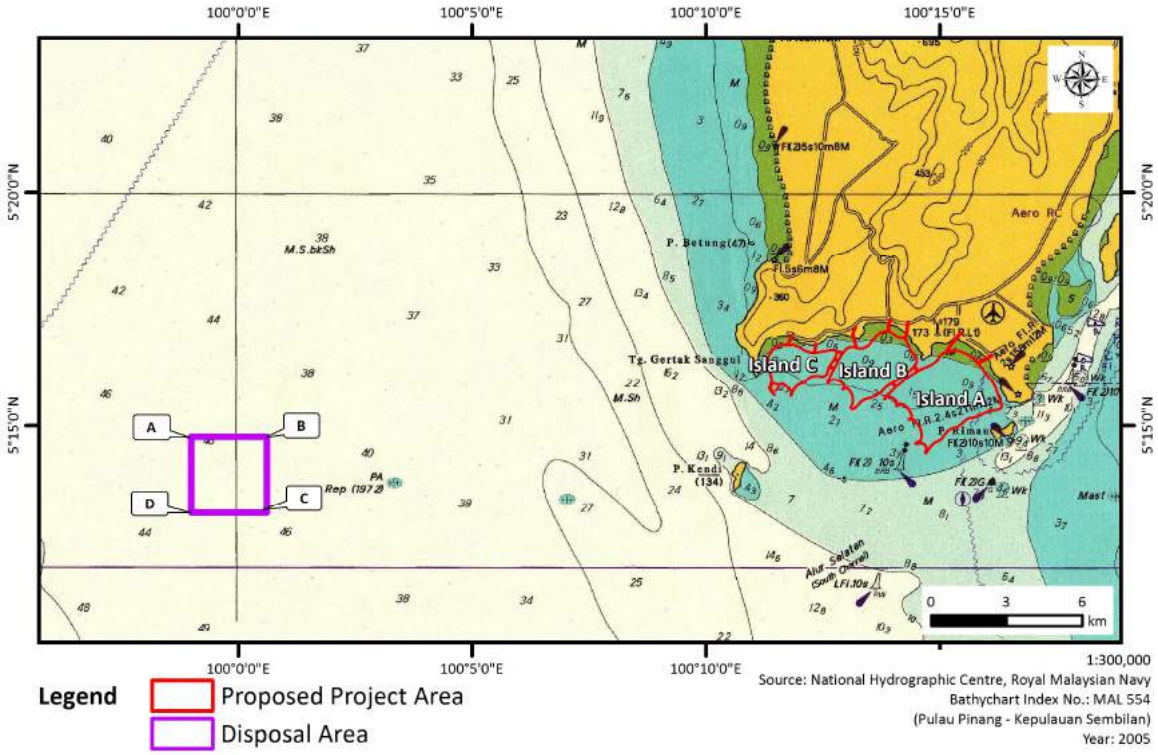
The situation for this scenario will be similar with the previous two scenarios, where the land reclamation and dredging activities will cause high TSS level to the surrounding area while the vessels and machineries used present a risk of pollution from oil, chemicals, wastewater, etc. However, the impact during this period will be more prominently felt at the western side of the study area, namely Gertak Sanggul and Pulau Betung. Correspondingly, the sensitive receptors that will be affected are those located at Gertak Sanggul i.e. hatcheries. The impact on hatcheries will be discussed in the following section as mentioned previously.

7.4.2 Disposal of Dredged Material

The material produced by the dredging activities will be disposed of at a designated disposal area as shown in F7.70 while the coordinates are as tabulated in T7.38. The disposal will be conducted by using hopper barges that will be pulled by tugboats to the disposal area located approximately 15 nautical miles (28 km) away from the Project area. Dredging activities will be conducted for all development scenarios. Thus the disposal of dredged material will occur over the whole period of the Project.

T7.38
Coordinates of the designated disposal area

Point	Longitude	Latitude
A	99° 58' 59.2"E	5° 14' 45.6"N
B	100° 00' 36.6"E	5° 14' 45.6"N
C	100° 00' 36.7"E	5° 13' 08.0"N
D	99° 58' 59.3"E	5° 13' 07.9"N



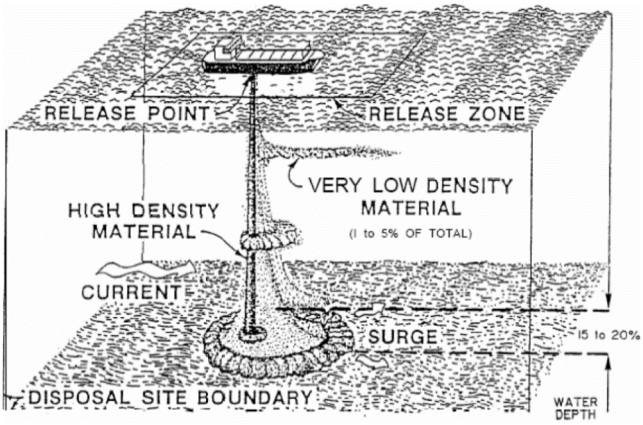
F7.70 Location of the designated disposal area

The process of dredged material disposal can be detrimental to the environment if done unsystematically and improperly. Careful consideration must be taken and proper procedures for disposal are to be followed at all times. In order to ensure the disposal process creates minimal impact on the environment, the recommended guidelines formulated by the Department of Environment (DOE) regarding the disposal site and method of disposing must be strictly followed, as listed in T7.39.

T7.39 DOE guidelines for disposal of dredged material

Activity	Guidelines
On the disposal site	The depth shall be more than 20 m deep
	The location must be reasonably distant from sensitive areas
	The location must not be within fishing grounds, coral reefs and artificial reefs
On the method of disposing the dredged material	While disposing the dredged materials at the designated site, the vessel must be in continuous motion at the speed of 1 to 2 knots
	The materials being disposed should spread out within a reasonable distance of the designated area
	No point disposal is allowed
	Dispersion modelling should be carried out to indicate the vertical and horizontal movements of the materials being disposed

Disposal of the dredged material is not expected to generate significant plume. The reason for this is because the dumping of dredged material generally occurs underneath the transport vessel. During the dumping process, most of the material is caught within a vertical density current. Near the seabed, this current transforms into a horizontal one, influenced by the direction of the tidal current and the seabed slope (Malherbe 1991; Van Parijs *et al.*, 2002). Most of the dredged material will be deposited on the seabed whereby only the very low density material, which consists of less than 5% of the total material will be suspended in the water column and dispersed by currents. F7.71 illustrates the behaviour of dredged material during the dumping process.



F7.71
Behaviour of dredged material during dumping (Elsaeed 1991)

In addition, taking into account the location of the disposal site and its depth which is over 40 m, it is expected that sediment plume will not affect any sensitive receptors surrounding the area. As such, no mitigation measure is proposed for this activity.

On the other hand, leakage may occur to barges carrying dredged material to the disposal site. Sediment plume will be generated along the transportation route which causes the impact to be dispersed over a long stretch of area. Overfilling of barges also may cause spillage of dredged material along the way to the disposal site. Poorly-maintained barges and an incompetent crew may cause short dumping incidence to occur during transportation.

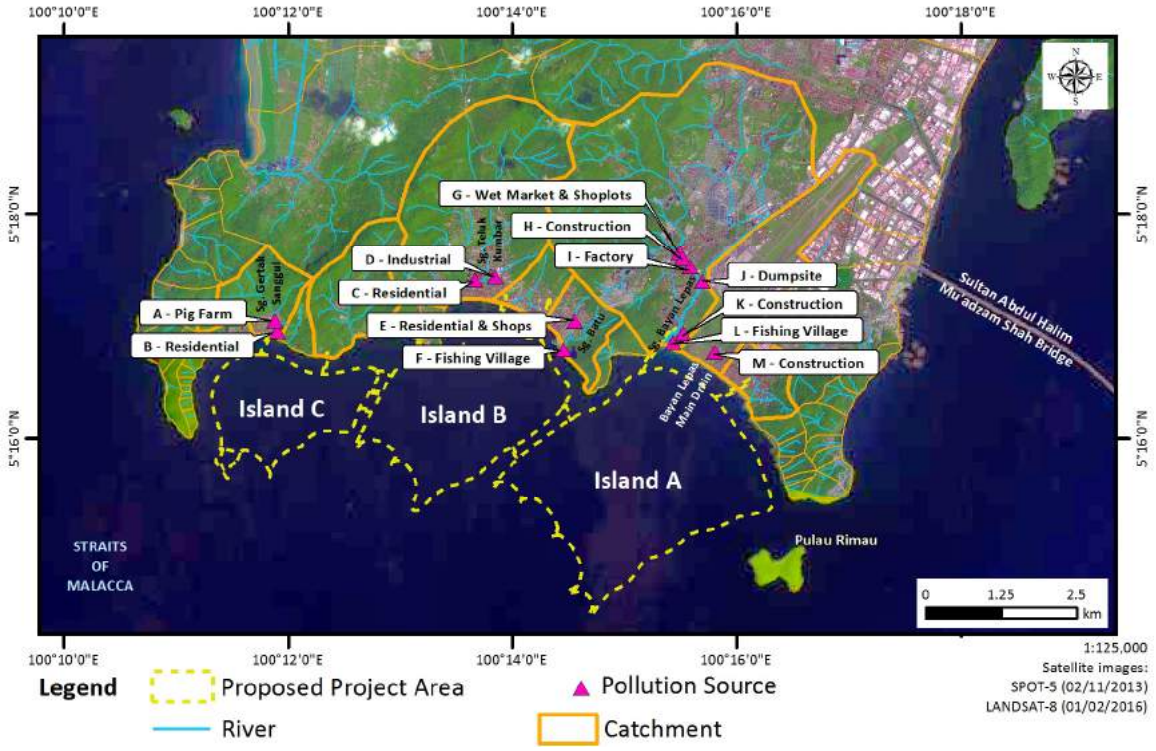
It should be noted that the disposal area proposed to be used for this Project is a new dumping area yet to be gazetted. As such, the Project Proponent is required to conduct a separate EIA study for approval.

7.4.3 Post-reclamation

The presence of new landmass in the form of the three islands is expected to significantly influence the flushing capacity of waters surrounding the Project site. Currently, there are eight main rivers and drains that discharge its water along Penang southern coastline. The river and marine water quality data collected during this study showed there was nutrient elevation (NH_3-N, NO_3-N and phosphate). While there is insufficient information in order to accurately determine the origin of the nutrients, it is undeniable the polluted rivers in the region remains a major contributor.

Based on the preliminary pollution source study, which is done concurrently with this EIA study, the major pollution sources (F7.72) and the current river conditions (T7.40) include the following:

a) Construction sites;
b) Factories;
c) Residential dwellings;
d) Shoplots;
e) Dumpsites;
f) Sewage treatment plants (IWK); and
g) Cottage industries (e.g. pig farms).



F7.72 Major pollution sources

T7.40 Summary of river conditions

River	Catchment Area (km^2)	Major Pollutant Sources	Debris	Water Quality
Bayan Lepas main drain	3.0	Construction sites	Minimal debris issue	Class III
Sungai Bayan Lepas	7.4	Construction sites; Shoplots; Factories; Dumpsite; Fishing village	Household debris along river bank; Construction waste	Class III
Sungai Batu	1.2	Residential; Fishing village	Vegetation; Household debris	Class III
Sungak Teluk Kumbar	7.1	Residential; Factories	Vegetation; Household debris (localised)	Class IV
Sungai Gertak Sanggul	1.3	Residential; Pig farms	Vegetation; Minimal debris issue	Class IV

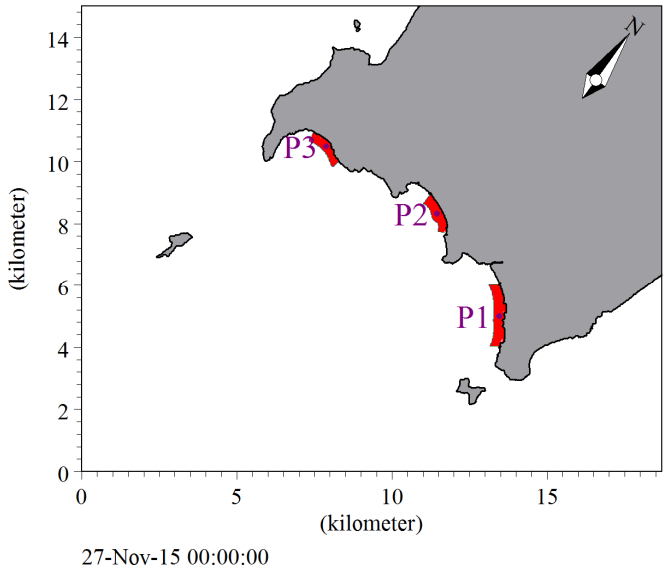
Note: Water quality for each river was classified based on DOE's water quality index (WQI) classification

This may be a cause for concern, as the flushing of pollutants could be disrupted by the presence of the islands. In fact, there is even potential for accumulation along the navigation channel if the water becomes stagnant (e.g. intertidal). Build-up of nutrients, such as NH_3-N, NO_3-N and phosphate presents the risk of algae blooms and even eutrophication (F7.73), with nitrogen species being the limiting nutrient for marine environments. This potential impact needs to be mitigated by ensuring the hydrodynamics of the region are not impeded due to the presence of the islands.

F7.73 Example of red tide occurrence in Benguela, Angola

The potential impact of the proposed development within the Project area with regard to water quality (flushing) has been assessed using MIKE 21 Advection-Dispersion (AD) module. The assessment has been undertaken by comparing the flushing capacities associated with the existing and "with Project" conditions. Generally, a good flushing capacity contributes to good water quality.

The flushing capacity has been assessed by determining the duration required to reduce the concentration of a tracer by half, known as the retention time (T_{50}). The assessment has been undertaken for spring and neap periods for pure tide, Northeast Monsoon and Southwest Monsoon conditions. As an indication, the T_{50} must not be more than two days to avoid severe water quality issues. It shall be kept to less than one day if the waterways are to be used for recreational purposes. The location of the tracers placed during the simulation for all scenarios are illustrated in F7.74. The corresponding rivers along the tracer point are shown in T7.41.



F7.74 Locations of tracers

T7.41

Tracer point and the corresponding river

Tracer Point	Corresponding River
P1	Bayan Lepas Main Drain
	Sungai Bayan Lepas
P2	Sungai Batu
	Sungai Teluk Kumbar
P3	Sungai Gertak Sanggul

T7.42 shows the time required to reduce tracer concentration by 50%, T_{50}, under the pure tide and monsoonal conditions in the existing condition and "with Project" scenarios. Meanwhile, the required T_{50} during the worst case scenario (neap period and pure tide) was presented spatially according to each corresponding river in F7.75.

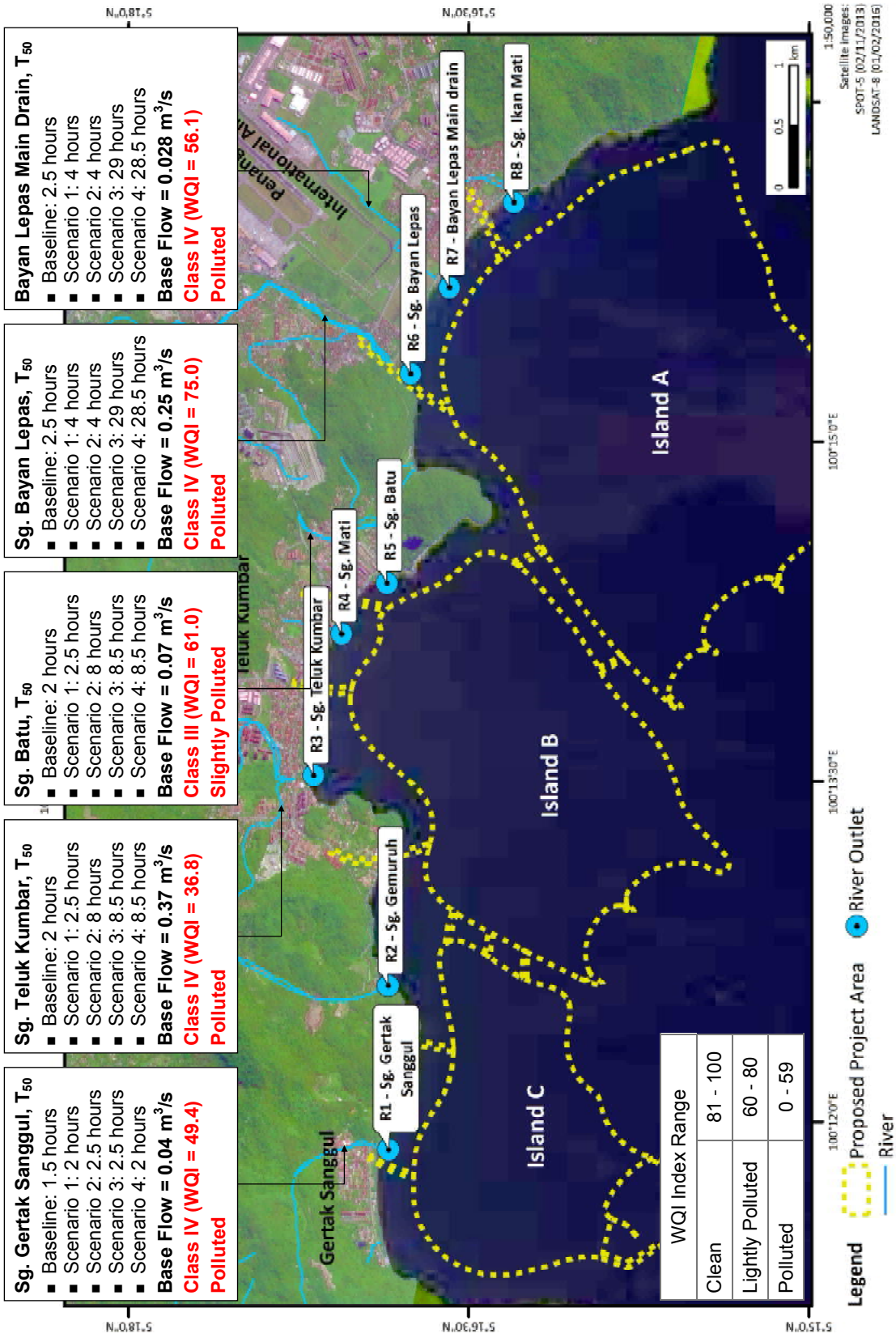
The results show that, in general, the T_{50} associated with the "with Project" scenarios are higher than the existing condition, but are less than 48 hours. This presents good flushing capacity if the existing water quality is clean.

It is noted that T_{50} is more than 24 hours at P1 (Sungai Bayan Lepas and Bayan Lepas Main Drain) for the pure tide condition during neap period in Scenarios 3 and 4. The T_{50} is 29 and 28.5 hours from the start of the simulation in Scenarios 3 and 4, respectively. Both are slightly over a day. The results also show that in Scenario 3 and 4, monsoonal winds will significantly reduce the T_{50} at P1 during neap tide.

Meanwhile, the retention time at P2 (Sungai Batu and Sungai Teluk Kumbar) will worsen from the existing 2 hours to 8 hours after the completion of Island A, and further worsen to 8.5 hours after the completion of Island B. While the retention time does not exceed 24 hours, the impact is still significant as the rivers that discharge into this area, namely Sungai Batu and Sungai Teluk Kumbar, are polluted and can be categorised as Class III and Class IV respectively.

T7.42 Summary of the T_{50} for pure tide, Northeast and Southwest Monsoon conditions

Scenarios		T_{50} (hours)					
		Spring			Neap		
		P1	P2	P3	P1	P2	P3
Pure tide condition	Existing condition	2.5	3.0	2.0	2.5	2.0	1.5
	Scenario 1	2.5	3.5	2.5	4.0	2.5	2.0
	Scenario 2	2.5	3.5	2.5	4.0	8.0	2.5
	Scenario 3	2.0	11.5	2.5	29.0	8.5	2.5
	Scenario 4	2.0	11.0	4.5	28.5	8.5	2.0
Northeast Monsoon condition	Existing condition	2.5	3.0	2.5	3.5	2.5	2.0
	Scenario 1	2.5	3.5	3.0	3.5	4.0	3.5
	Scenario 2	2.5	3.5	3.5	3.5	6.0	3.5
	Scenario 3	2.5	7.5	3.5	4.0	19.0	3.5
	Scenario 4	2.5	8.0	5.0	4.0	19.0	8.5
Southwest Monsoon condition	Existing condition	3.0	3.5	2.5	3.0	2.5	2.0
	Scenario 1	3.0	4.0	3.0	4.5	3.0	2.5
	Scenario 2	3.0	4.0	3.0	4.5	9.0	2.5
	Scenario 3	3.0	11.5	3.0	23.0	9.5	2.5
	Scenario 4	2.5	11.5	5.0	23.5	10.0	9.5



F7.75 Summary of T_{50} at each river outlet during worst-case scenario (neap period and pure tide)

It would have been preferable to conduct a dynamic water quality modelling exercise to ascertain the long-term impacts of the development towards water quality. However, due to large coverage area and lack of long-term hydrodynamic data, constructing a model with an acceptable level of confidence was not plausible at this juncture. Developing a model with minimal or no flushing on the other hand, would merely be an academic exercise which could not be substantiated.

Because of this, the focus was placed on mitigating the potential sources of the nutrient, which in this case, were the mainland sources that empty into the river as well as those of the coastline. This way, the risk of future nutrient elevation can be circumvented.

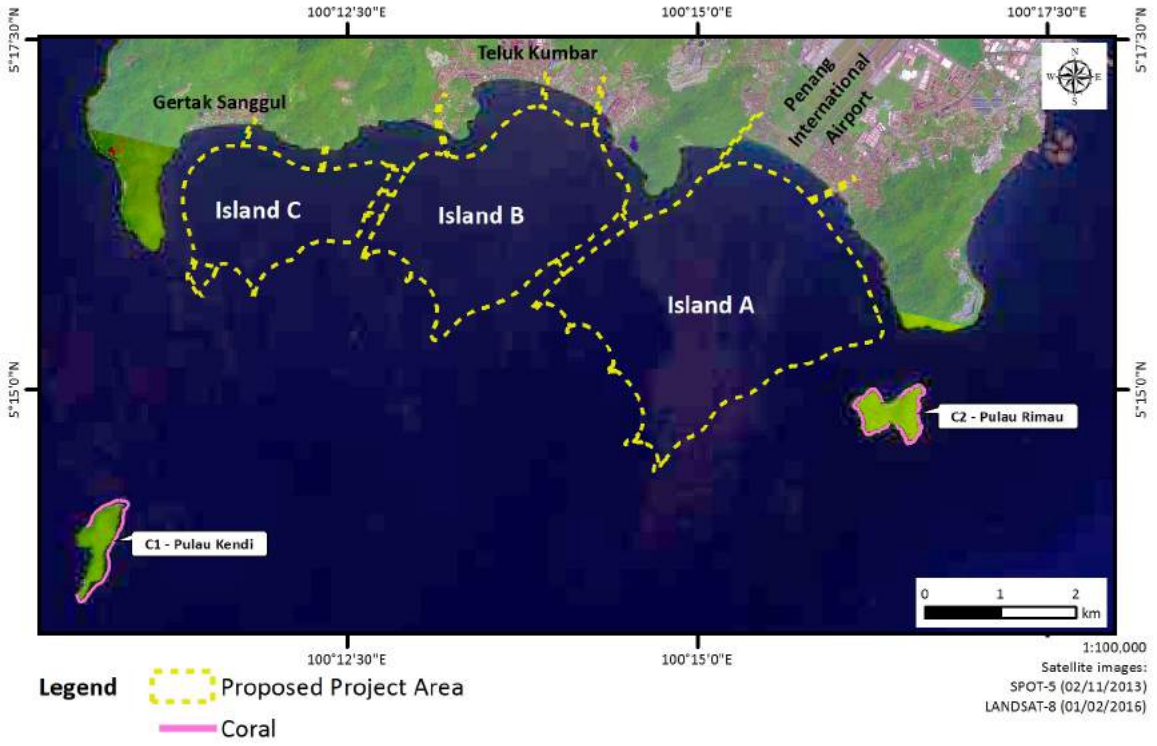
Another factor that contributes into the deterioration of water quality is the reduction in wave heights within the access channel. As discussed in *Section 7.3.7 – Waves*, some locations will experience a total deficit in wave heights after the reclamation is completed. Wave action is one of the factors that aides in the mixing and flushing of a water column and when this energy is removed, the flushing capacity will be affected.

7.5 Impacts on Environmentally Sensitive Areas

Each stage of the dredging and land reclamation works will cause changes to the environmental condition status quo. These changes may cause additional stress or pressure which then will materialise as negative impacts on the ESAs.

7.5.1 Coral Reefs

Pulau Rimau and Pulau Kendi hold an established network of coral reefs surrounding the rocky outcrops of these islands. Although both islands are located nearby to each other, the nature of coral reefs at Pulau Kendi and Pulau Rimau is different. At Pulau Kendi, the coral reefs are mostly hard coral reef, with some soft coral, whereas the coral reefs at Pulau Rimau are largely gorgonians. F7.76 shows the stretch where coral was observed at both islands.



F7.76 Location of coral reefs at Pulau Kedi and Pulau Rimau

7.5.1.1 Land Reclamation and Dredging

The major impact arising from the reclamation process on the coral reefs would be turbidity and sedimentation. These two factors create shading caused by a decrease in ambient lighting as well as sediment cover on the coral's surface. Suspended sediments block sunlight from reaching the zooxanthellae, thus decreasing food availability and consequently leading to mortality (Bak, 1978; Miller, 1999; Masalu, 2000). The growth forms of many corals are focused on trapping light and thus are not optimised for sediment-shedding (Stafford-Smith, 1993; Sanders and Baron-Szabo, 2005). In addition, sedimentation also creates problem of costly energy spent by the corals due to mucus production, sediment clearance and also impaired feeding (Erftemeijer *et al*., 2012).

Though some corals can grow and survive in turbid waters, they however experience more stressful conditions compared to the clear water conditions. It has been demonstrated that increased turbidity and siltation in the coastal zone are potential causes of coral reef degradation (Terney Pradeep Kumara, 2010). High sedimentation does not necessarily lead to mortality, but it could still have sub-lethal effects i.e. reduced growth, lower calcification rates and reduced productivity, bleaching, increased susceptibility to disease, physical damage to coral tissue and reef structures (breaking and abrasion), and reduced regeneration from tissue damage (Erftemeijer *et al*., 2012). The coral re-colonisation is also expected to be restricted if high sedimentation occurs (Masalu, 2000; Miller, 1999; Delbeek and Sprung, 1994). Thus, this could lead to changes in reef community structure i.e. a decrease in density, diversity and coral cover, and will shift towards the dominances of non-coral species, such as sponges and algae.

The tolerance limit of the corals for the total suspended matter is widely ranged as it depends on the species, grain size, and geographic regions. The report by Erftemeijer *et al.* (2012) indicated that most soft corals and massive corals are relatively sensitive to turbidity. On the

other hand, laminar, plating and tabular corals as well as some morphologically variable corals are relatively tolerant. It is also indicated that the diameter of the coral's calyx is not correlated with their sensitivity towards turbidity. Some of the species that are well adapted to turbid waters include *Leptastrea*, Montipora, Pectinia, Porites (Dikou and Van Woesik, 2006), and *Turbinaria* (Stoddart and Stoddart, 2005) as well as the Gorgonians (Fabricius and Dommisse, 2000).

Grain size can also affect the tolerance limit of the corals, as fine sediments would only reduce the light penetration into the water bodies, whereas coarser particles may cause scouring and abrasion of coral tissue (PIANC, 2010). Geographic regions also play an important part in determining the tolerance limit of turbidity of the corals. For example, in the Great Barrier Reef of Australia, the threshold level of corals is 3.3 mg/L (Bell, 1990), as the area is not subject to any stresses from human activities. However, the threshold level is higher in marginal reefs in turbid near-shore area, such as in Magnetic Island (75 to 120 mg/L; Mapstone *et al*., 1989) and Cape Tribulation (100 to 260 mg/L; Hopley *et al*., 1993), both in Great Barrier Reef, Australia. Therefore, it is important to note that the threshold level for the reefs is a case-to-case basis, which will take into account the surrounding environment conditions as well as the severity of impact on the reefs. Currently only 10% of the coral species has been studied for their response towards the sediment disturbance, which still indicates poor understanding of the relationship between sediment stress and response of most corals.

For the purpose of this study, the tolerable limits of excess suspended sediment and sedimentation rate respectively established in PIANC Report No. 108-2010 "Dredging and port construction around coral reefs" has been used. Although the limits are related to hard coral reefs, they are adopted for both coral reefs as they are more conservative, in the absence of published tolerable limits for soft corals.

T7.43 and T7.44 show the tolerable limits of excess suspended sediment and sedimentation rate published in the PIANC report respectively. These tolerable limits for coral habitats constitute a conservative indicator of the potential stresses that can be added on other natural receptors. For the assessment of the sediment plume dispersion results, tolerable limits associated with the "Slight impact" category have been adopted.

Based on the sediment spill dispersion findings presented in *Section 7.3.9* above, the tolerable limits for the percentage of time exceedance for 5 and 10 mg/L excess suspended sediment concentrations are less than 5% at both Pulau Rimau and Pulau Kendi for Scenarios 1, 2 and 4, which mean that the tolerable limit are not exceeded. However, for Scenario 3, it is expected that limits will exceed up to 20% at Pulau Rimau once the reclamation works move closer to the island.

As for sedimentation caused by the dispersed sediment, the highest level recorded is at Pulau Rimau during Scenario 3, with a rate that exceed 3 mm over 14 days, which is over the tolerable limit for "Slight Impact".

Apart from sediment plume directly attributed to land reclamation and dredging activities, another potential impact arising from the reclamation Project on the coral reefs is the movement of boats and barges carrying materials into the reclamation site, particularly in the area of Pulau Rimau. The movement can potentially create wake that could affect the coral reefs, though currently there is no study on the impact of boat and barges wake onto the coral reefs. However, the wake is known to disturb the water circulation and alter tidal patterns that can disrupt the reef's nutrient supply (Asplund, 2000). The wake of the boats and barges are also known to induce turbidity, which is known to be detrimental to the corals.

T7.43 Impact severity categories for suspended sediment concentration

Category	Definition	Description
No impact	Excess suspended sediment concentration (SSC) > 5 mg/L for less than 1% of the time	Changes are significantly below physical detection level and below the reliability of numerical models, so that no change to the quality or functionality of the receptor will occur.
Slight impact	■ Excess SSC > 5 mg/L for less than 10% of the time ■ Excess SSC > 10 mg/L for less than 1% of the time	Changes can be resolved by numerical models, but are difficult to detect in the field as they are associated with changes that cause stress, not mortality, to marine ecosystems. Slight impacts may be recoverable once the stress factor has been removed.
Minor impact	■ Excess SSC > 5 mg/L for less than 20% of the time ■ Excess SSC > 10 mg/L for less than 5% of the time	Changes can be resolved by numerical models and are likely to be detected in the field as localised mortalities, but to spatial scale that is unlikely to have any secondary consequences.
Moderate impact	■ Excess SSC > 10 mg/L for less than 20% of the time ■ Excess SSC > 5 mg/L for more than 20% of the time	Changes can be resolved by numerical models and are detectable in the field. Moderate impacts are expected to be locally significant.
Major impact	■ Excess SSC > 25 mg/L for more than 5% of the time ■ Excess SSC > 10 mg/L for more than 20% of the time	Changes are detectable in the field and are likely to be related to complete habitat loss. Major impacts are likely to have secondary influences on other ecosystems.

T7.44 Impact severity categories for sedimentation

Category	Definition	Description
No impact	Sedimentation < 0.05 /m^2/day	<1.7 mm/14 days
Slight impact	Sedimentation < 0.1 kg/m^2/day	<3.5 mm/14 days
Minor impact	Sedimentation < 0.2 kg/m^2/day	<7 mm/14 days
Moderate impact	Sedimentation < 0.5 kg/m^2/day	<17.5 mm/14 days
Major impact	Sedimentation > 0.5 kg/m^2/day	>17.5 mm/14 days

In summary, the coral reef at Pulau Kendi is projected to be unaffected during the land reclamation and dredging works because the extent of sediment plume does not reach this location. However, the construction of perimeter bund at Island A will cause impact to coral reef at Pulau Rimau. It is assumed that only corals located at the west of Pulau Rimau will be greatly affected. Meanwhile, coral located at the east is expected to be sheltered. Thus, the loss of corals at Pulau Rimau is considered as partial trade-off.

7.5.1.2 Post-reclamation

Coral is known to be a very sensitive organism that can only survive within specific physical and biological environmental variables. Any changes in the status quo will cause stresses on the coral, which may lead to a bleaching event. Corals can survive and recover from a bleaching event if the stress is not severe and the environmental conditions return to normal quickly. However, if the algae loss is prolonged and the stress continues, coral eventually dies.

The presence of new landmass will change the existing coastal regime near the coral reefs of Pulau Kendi and Pulau Rimau. Based on the hydrodynamic findings discussed in *Section 7.3.5 - Currents*, there will be changes on current speed near Pulau Rimau and Pulau Kendi. For Pulau Kendi, the impacts are very small and can be considered as negligible (less than 3% change) due to the fact that the island is located some distant away from the proposed Project. However, massive current speed changes are projected to occur at Pulau Rimau after the completion of Island A (Scenario 3). The mean current speed is reduced by 0.1 m/s to the north and south of the island; increased by 0.15 m/s to the west of the island; and increased by 0.05 m/s to the east of the Pulau Rimau. The maximum current speed is reduced by up to 0.2 m/s to the north of the island and increased by 0.4 m/s to the west of the island. These changes are permanent. Correspondingly, the impacts on coral reefs caused by changes in other parameters only occur at Pulau Rimau and will started after the completion Island A (Scenario 3).

The variation in current speed is expected to cause alteration in the existing sedimentation and erosion rate. Generally, reduction in current speed will induce sedimentation and vice versa. Unlike sedimentation that is caused by settling sediment plume originating from the land reclamation and dredging activities, this is a long-term occurrence as one of the components of the overall coastal morphology. After Island A is completed, the changes in the eastern side of Pulau Rimau will experience erosion at a rate of 0.01 m/yr.

Another important parameter that determines the wellbeing of coral is wave action. Waves, along with tides, drive the water flow rate around the coral reefs. Sufficient exchange of water is vital in maintaining a healthy coral population. On the other hand, too much wave energy may cause heavy pounding that inflicts physical damage to the corals. The changes in wave condition at Pulau Rimau and Pulau Kendi have been discussed in *Section 7.3.7 - Waves*. In general, the protruding headland of Island A (Scenario 3) causes a reduction in wave height of up to 0.3 m at Pulau Rimau for the predominant wave direction (270^{o}N). This condition is expected to affect the water mixing surrounding the coral sites at Pulau Rimau. This impact can be further exacerbated because the marine water quality within the vicinity of the Project site may deteriorate after the completion of the Project.

As explained in *Section 7.4.3*, the newly-formed islands will affect the flushing capacity for waters surrounding the Project site. Currently, all main rivers that are discharging along the south coast of Penang Island can be categorised as “Slightly Polluted” to “Polluted” according to DOE’s WQI classification. The deterioration of water quality usually involves the buildup of nutrients such as BOD, nitrate and phosphate.

Nutrient enrichment can shift species composition of the coral community, where larger and slow-growing organisms that thrive in nutrient-poor waters are replaced by smaller and rapidly growing species (Bell, 1992; Done, 1992; Birkeland, 1988). The inclusion of significant additional levels of phosphate in the coral area would potentially affect the growth. High phosphate levels can lead to algal blooms, decreasing sunlight penetration that can reduce coral growth (Mohammed *et al*., 1995). Phosphate enrichment also contributes overgrowth by filamentous algae as well as inhibits precipitation of calcium carbonate from seawater (Kleypas *et al*., 1999).

The major changes in flushing capacity occur after the completion of Island A. It should be noted that the deterioration of water quality is expected to occur mainly in the flushing channel. Whether the extent of water pollution will reach the vicinity of Pulau Rimau and at what magnitude cannot be deduced at this moment without a more detailed simulation on water quality.

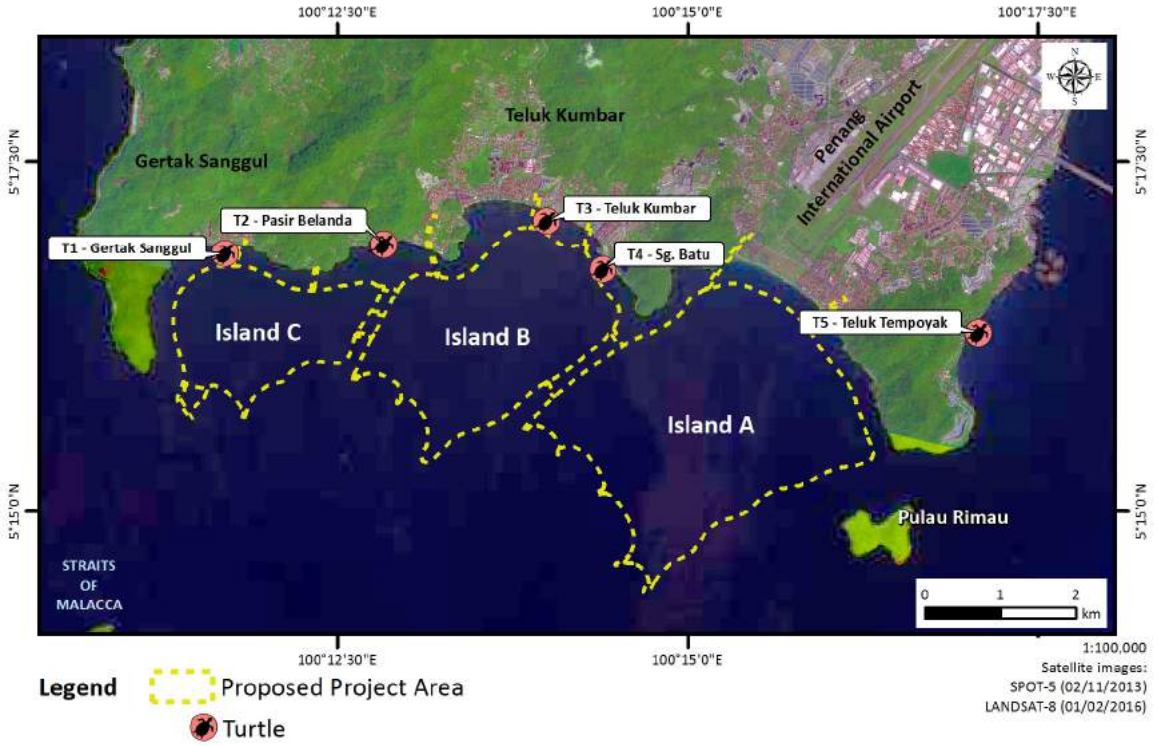
Nevertheless, it is deduced that once the reclamation of Island A is completed, there will be significant impact to the coral reefs at Pulau Rimau. Meanwhile, the coral reefs at Pulau Kendi is in general unaffected because of its distant location. These permanent impacts may hamper the recovery of coral reefs that would be affected during the reclamation of Island A. As such, the loss of coral reefs at Pulau Rimau is considered as partial trade-off.

7.5.2 Turtle Nesting Area

There are several turtle nesting sites identified along the south coast of Penang Island. T7.45 and F7.77 identify the stretch of beaches where turtle nestings have been recorded in the past. Two species have been reported to nest within the study area, namely Green Turtle and Olive Ridley Turtle. Artificial lightings from developments in Teluk Kumbar are known to discourage female turtles from nesting. Once the land reclamation and dredging works commence, disturbance by lights and noises from the vessels will worsen the situation and the south coast of Penang Island will become an unfavourable site for turtle landing.

T7.45 Turtle nesting sites

Point	Beach Name
T1	Gertak Sanggul
T2	Pasir Belanda
T3	Teluk Kumbar
T4	Sungai Batu (Pantai Medan)
T5	Teluk Tempoyak



F7.77 Turtle nesting sites at the south coast of Penang Island

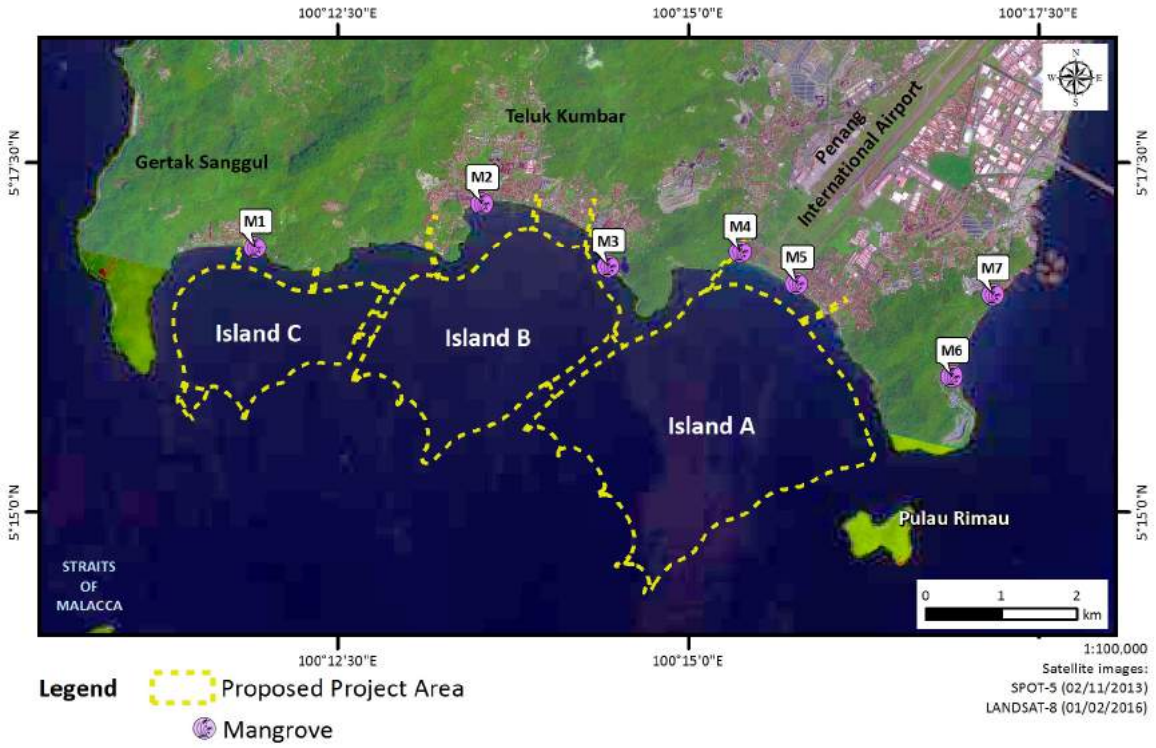
More pressingly, once the reclamation is completed, the new landmass will become a huge physical obstruction to the nesting beaches. Turtles are known to land only at the same stretch of beach for nesting. With these new obstacles in place, it is safe to assume that any turtles intending to nest at the south coast of Penang Island will not reach the landing site. As such, this ESA is considered as a trade-off.

7.5.3 Mangrove

While there are no significant mangrove forests found surrounding the Project area, some small patches of mangroves can still be observed mainly in the rivers nearby the Project site, as shown in T7.46 and F7.78. Although the mangroves appear to be less dense, taking into account the importance of mangroves in nearshore marine ecosystem, the impacts on mangroves is still evaluated and discussed in this subsection.

T7.46 Locations of mangrove patches

Point	Location of Mangrove
M1	Sungai Gertak Sanggul
M2	Sungai Teluk Kumbar
M3	Sungai Batu
M4	Sungai Bayan Lepas
M5	Bayan Lepas Main Drain
M6	Teluk Tempoyak Besar
M7	Teluk Tempoyak Kecil



F7.78 Mangroves observed nearby the Project site

7.5.3.1 Land Reclamation and Dredging

Mangroves are known to be very tolerant towards the range of suspended sediment loads that may be generated from dredging and reclamation activities (Doorn-Groen and Foster, 2007). According to Thampanya *et al*. (2002), the mangroves that are sensitive towards sedimentation are those with pneumatophore root (e.g. *Avicennia* sp.), though they are highly unlikely to be stressed, except when the sedimentation reach levels from 10 cm up to 30 cm for a prolonged period. The seedlings, however, are susceptible to sedimentation as the lenticels, which carry out the gas exchange may be blocked by sediment (Thampanya *et al*., 2002). On the other hand, erosion may cause destabilisation of the river bank, which in turn will uproot the mangroves trees.

Based on the hydraulic simulation results, no significant sedimentation and erosion is projected to occur at the mangroves area. As such, it is expected that the mangrove will not be affected during the course of Project implementation.

7.5.3.2 Post-reclamation

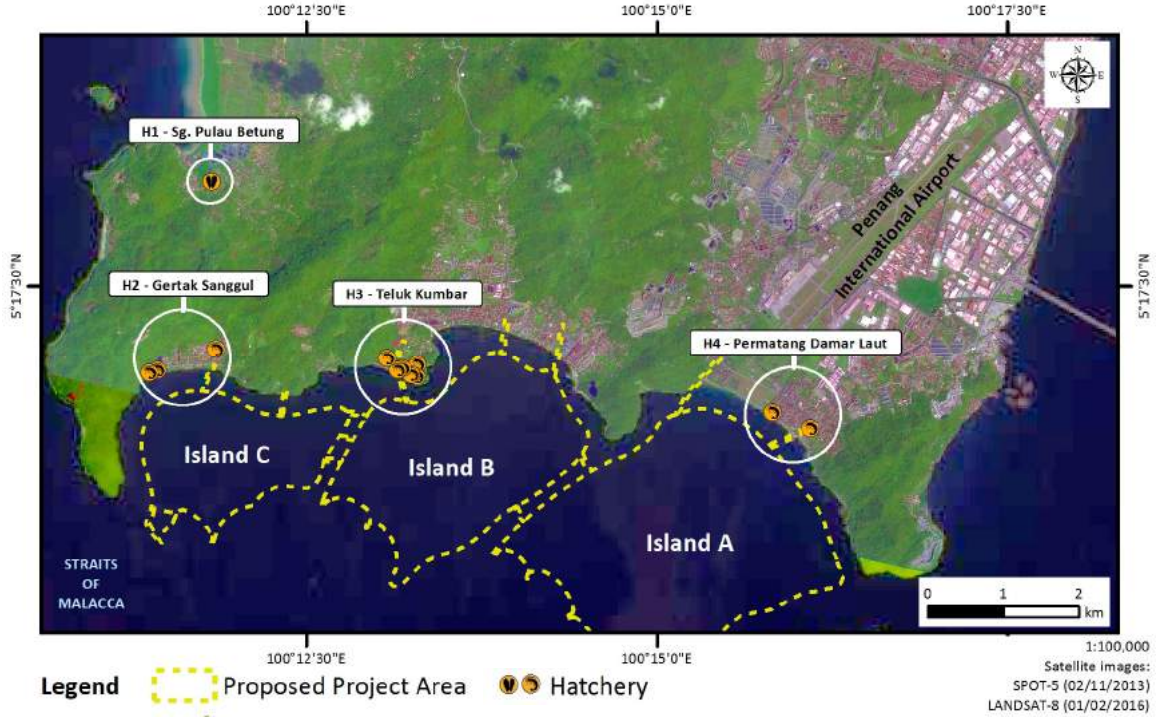
The proposed Project does not directly affect the mangroves due to its location. Nonetheless, the presence of three newly-reclaimed islands is expected to change the current flow at the study area. The increase in current flow may affect the mangrove negatively if erosion occurs along the riverbank populated by the mangroves. However, the hydraulic simulation results show that there will be no change in sedimentation and erosion rate at the mangrove area. Thus no impact is expected to occur.

7.6 Impacts on Fishing Industry

The proposed Project is situated in an area that has an active fishing industry, substantiated by clusters of hatchery and aquaculture operations as well as various fishing villages and jetties dotting along the coastline. The hatchery and aquaculture operations are especially noted to be significant in sizes and value. The produce are sold in local market as well as exported to Singapore and Hong Kong. As for fishermen within the study area, although they are mostly made up of small-scale, artisanal fishermen, it is still a vital source of livelihood for some of the local population.

7.6.1 Hatcheries

At the moment, there are four main clusters of hatchery operations located adjacent to the proposed Project site, as shown in F7.79. Hatcheries operations are very much dependent on the quality of sea water obtained via the intake. As different hatcheries operator adopt different types of treatment systems, the existing treatment system of all the hatcheries will be assessed and discuss with respective hatcheries operator to determine forms of upgrade preferred. The hatcheries' current treatment systems work on a baseline value of 10 to 15 mg/L of suspended solid during the high tides. An increase in sediment levels at the water intake points means there will be a need to upgrade the filtration systems of the hatcheries.



F7.79 Locations of hatchery operations

7.6.1.1 Land Reclamation and Dredging

As the water intake points of the hatcheries are located about 5 to 100 m from the shoreline, it is considered for the intake to be affected, especially during dredging activities. Dredging activities will be conducted for all development scenarios. Impacts to the hatcheries during the Project implementation stage can be gauged using extracted data from the sediment spill dispersion simulation.

a) Scenario 1

As detailed out in T7.47, the extracted data shows that all hatcheries will not be significantly affected during Scenario 1. However, this is not entirely accurate as dredging will be carried out directly at the location of water intake points for hatcheries at Gertak Sanggul, Teluk Kumbar and Permatang Damar Laut. Logically, these hatcheries may be impacted from the sediment plume dispersion. This situation was not reflected in the simulation because of model limitation i.e. the location of dredgers established in the model.

T7.47 Excess suspended sediment concentration level at the hatcheries for Scenario 1

Point	Location	Excess Suspended Sediment Concentration		Remarks
		Mean	Max	
H1	Near Sungai Pulau Betung	0	0	Insignificant impact
H2	Gertak Sanggul	1	3	Insignificant impact
H3	Teluk Kumbar	0	1	Insignificant impact
H4	Permatang Damar Laut	1	9	Insignificant impact

Nevertheless, it is reasonable to assume that the hatcheries at these locations may be impacted during this scenario. The high TSS level introduced by the dredging activities may cause additional loading to the current filtration system used by the hatcheries.

b) Scenario 2

The activities during this Scenario is conducted adjacent to Teluk Kumbar. Thus, the impact will be primarily felt by hatcheries located at Teluk Kumbar. This is reflected in the simulation model whereby there will be a significant increase in TSS level as shown in T7.48.

T7.48 Excess suspended sediment concentration level at the hatcheries for Scenario 2

Point	Location	Excess Suspended Sediment Concentration		Remarks
		Mean	Max	
H1	Near Sungai Pulau Betung	0	0	Insignificant impact
H2	Gertak Sanggul	0	1	Insignificant impact
H3	Teluk Kumbar	0	117	High TSS level will affect the existing filtration system, thus mitigation measure is required
H4	Permatang Damar Laut	0	0	Insignificant impact

After Island B is completed, the flushing capacity at Teluk Kumbar will increase from the existing 2 hours to 8 hours. Conservatively, it can be assumed that the water quality within the access channel of Island B where the intake pipe is currently located will deteriorate. The increase in nutrient and other pollutants in the marine water may render it to be unsuitable for hatcheries operation without extensive treatment.

Other hatcheries are expected not to be significantly affected during this scenario.

c) Scenario 3

During this scenario, the excess suspended sediment concentration does not increase significantly at all water intake locations as shown in T7.49. Nevertheless, the presence of Islands A and B will significantly alter the flushing capacity at Teluk Kumbar and Permatang Damar Laut area in which the retention time has increased to 8.5 and 29 hours respectively. This condition is expected to cause deterioration in water quality, especially at Permatang Damar Laut area, that may affect the hatchery operations.

T7.49 Excess suspended sediment concentration level at the hatcheries for Scenario 3

Point	Location	Excess Suspended Sediment Concentration		Remarks
		Mean	Max	
H1	Near Sungai Pulau Betung	0	0	Insignificant impact
H2	Gertak Sanggul	0	1	Insignificant impact
H3	Teluk Kumbar	0	7	Insignificant impact
H4	Permatang Damar Laut	19	241	High TSS level will affect the existing filtration system, thus mitigation measure is required

d) Scenario 4

For this scenario, the excess suspended sediment concentration recorded is very low at all locations as tabulated in T7.50. Thus the impact is deemed insignificant. However, there is a slight increase in retention time at Gertak Sanggul, from 1.5 to 2 hours. It is expected that this slight increase will not significantly alter the existing water quality at Gertak Sanggul, and thus, no impact to the hatcheries located within this area.

T7.50 Excess suspended sediment concentration level at the hatcheries for Scenario 4

Point	Location	Excess Suspended Sediment Concentration		Remarks
		Mean	Max	
H1	Near Sungai Pulau Betung	0	0	Insignificant impact
H2	Gertak Sanggul	23	305	High TSS level will affect the existing filtration system, thus mitigation measure is required
H3	Teluk Kumbar	0	0	Insignificant impact
H4	Permatang Damar Laut	0	0	Insignificant impact

7.6.1.2 Post-reclamation

After the reclamation is completed, it is expected that the level of TSS in the marine water will return within the normal range of baseline condition. However, the presence of three adjacent new islands will affect the flushing capacity, which in turn will cause significant degradation of water quality within the access channel, notably at Permatang Damar Laut and Teluk Kumbar area. At the moment, the locations of water intake point for all the hatcheries are located in the proposed access channel. As such, the water available for intake is of lower quality and may require further treatment.

7.6.2 Cage Cultures

There are significant numbers of marine fish cage culture operations at Batu Maung and Pulau Betung that could potentially be affected by the proposed Project. The main impact on aquaculture would come from potential deterioration of water quality. An increase in TSS and turbidity levels will cause additional stress on fishes reared in the aquaculture farms.

Theoretically, the response of cultured fish to adverse environmental conditions would be the same as that of wild fish. The initial response of fish would be to move away from the area of adverse environmental conditions. However, caged fish are not in a position to migrate from their culture site, irrespective of the environmental conditions, and are forced to put up with such adverse conditions. Generally, a greater incidence of disease infestation and/or slower growth could be expected. Known occurrences of mass fish mortality in cage aquacultures caused by high level of TSS have been reported in Malaysia. For cage cultures, the tolerable limit for TSS adopted is 80 mg/L. This is in line with the recommended in Water Quality Standards for Aquaculture in Malaysia (Liong, 1984).

The larvae and eggs are more vulnerable to lower concentrations of TSS as compared to juveniles and adults (Engell-Sørensen and Skyt, 2002), particularly in larvae where their gills are sensitive to clogging. In addition, the duration of exposure is also more critical when the fishes are persistently exposed to the TSS for prolonged period compared to being exposed to high level of suspended sediments for a short time (Berry *et al.*, 2003). Being exposed for longer periods would cause sub-lethal effects i.e. increased respiration rate due to the gills being clogged, hence depleting oxygen, as well as reduced feeding rates which indirectly lead to slower growth. Mortality would likely occur afterwards.

Higher concentration could cause the solids to deposit on the nets, thus becoming substrates for the growth of fouling organisms that would prevent proper water circulation. Higher concentrations could cause the solids to deposit on the nets, thus becoming substrates for the growth of fouling organisms that would prevent proper water circulation. The presence of suspended solids could also be related to disease such as “fin-rot” that is caused by Mycobacteria (Herbert and Merkens, 1961, Herbert and Richards, 1963).

T7.51 shows the projected mean and maximum excess SSC brought about by the proposed Project at the aquaculture farms for all development scenarios. Based on the table, the increase in mean excess SSC is negligible while the highest increase in maximum excess SSC is recorded at Batu Maung for Scenario 1 (14 mg/L). With these minimal changes, it is deduced that the impact to aquaculture operations caused by the proposed development is insignificant.

T7.51 Excess SSC level at the hatcheries for Scenario 1

Point	Location	Excess Suspended Sediment Concentration (mg/L)								Remarks
		Scenario 1		Scenario 2		Scenario 3		Scenario 4		
		Mean	Max	Mean	Max	Mean	Max	Mean	Max	
A1	Pulau Betung	1	7	0	2	0	4	1	9	Insignificant impact
A2	Sungai Pulau Betung	-	-	-	-	-	-	-	-	No data (upstream location)
A3	Batu Maung	1	14	0	0	0	0	0	0	Insignificant impact

7.6.3 Marine Capture Fisheries

The impact brought about by the proposed Project would be most felt by artisanal fishermen operating from the various landing points fronting the Project area. As for commercial fishing vessels, such as trawlers and Tuna Long-lines, particularly at Batu Maung, the loss of fishing grounds at the proposed Project site is not expected to affect their operation and catch since they fish further ashore. Therefore, the focus of this section is on the coastal fishermen.

It should be noted that the impact on fishermen and fisheries is relatively similar during the Project implementation phase and after the reclamation is completed (post-reclamation). As such, the impact components for both setting are discussed together under each section.

7.6.3.1 Loss of Fishing Ground

Fishing activities are undertaken within the mudflat area that is the target of the proposed reclamation. The area is a fishing ground for the fishermen from Sungai Batu, Permatang Damar Laut, Permatang Tepi Laut, Teluk Kumbar and Gertak Sanggul, which front the proposed reclamation site. Artisanal fishermen largely fish for crab (300 to 500 m) and shrimp (500 m and beyond) in the foreshore and near shore areas that are to be reclaimed.

During the Project implementation stage, this fishery is expected to be affected and, to some extent will be lost, with the implementation of the Project. This can potentially lead to decrease in fish landings and directly affect the income and livelihood of fishermen fishing in the area. The marine capture fishery is thus expected to be affected and this can potentially lead to overall decrease in fish landings.

After the reclamation is completed, the fishermen that are involved in crab and shrimp fishing will permanently lose a stretch of their fishing grounds at the reclamation footprint. Therefore, the fishing activities are likely to be shifted and concentrated at other areas such as off Pulau Kendi and Berting or other further area including Sri Jerjak, Batu Maung, Teluk Tempoyak Kechil and Besar as well as Pulau Betung, whereby fishermen from other fish landing points already been fishing at these areas. This would lead to increase the intensity of the fishing activities in these adjacent grounds.

The impact of the loss on the fishing economy in particular is difficult to assess on a quantitative basis. Fishermen are, by nature, opportunistic and will seek out other grounds to sustain their catch. Without accurate resource data, however, it is not possible to establish the extent to which these grounds would compensate for the loss in catch that will accompany the reduction in fishing area. What is clear, however, is the fishermen would have to move further out to fish, leading to increased operational cost, particularly fuel, which in turn will affect their productivity.

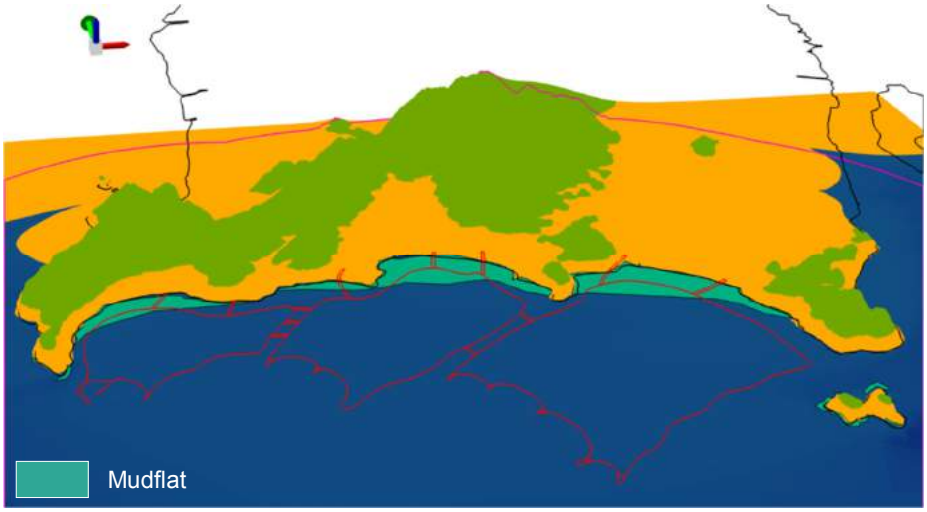
7.6.3.2 Loss of Fish Nursery Ground

Mudflats are highly productive areas and although may be relatively low in biological diversity, they support a high biomass of micro and infaunal organisms and support large fin and shellfish stocks due to the sediment being rich in organic content. Some footprints of the reclamation area cover intertidal mudflat area, as illustrated in F7.80, which can be considered as resulting in total loss.

It is pertinent to note that coastal shallows and intertidal zones are where the land and the sea meet. When artificially separated, nutrients from the land can no longer flow into coastal waters, threatening crabs, shrimp, clams and other organisms, which rely on this source of food. This has an impact on the ocean food chain and the fishing industry.

To be concise, collectively the intertidal/mudflat habitat is of great importance to large numbers of invertebrates and fish, supporting complex estuarine food webs and provide nursery and feeding grounds to large numbers of fish species. Hence, they are important to the local fishery economy.

These services are likely to be compromised to an extent by the proposed reclamation. Again, the extent to which this is likely to occur would depend on scope of the reclamation that is to be carried out. It should be noted that once the reclamation has taken place, the mudflats that are reclaimed and dredged would be lost.



F7.80
Mudflat area covered by the reclamation footprint

7.6.3.3 Fish Landing Points

Typical of an area where there is a substantial fishing industry, there are numerous fishermen jetties and facilities located along the coastline. Fishermen's jetty is an important structure normally used by these fishermen to unload their catch as well as providing a space to berth their boats. Ten landing points were identified that are susceptible to the impacts caused by the proposed Project, as illustrated in F7.81. Considerable increase in wave heights and/or current speeds may affect manoeuvring of the boats while sedimentation occurrence may cause the water depth to be shallow, thus requiring regular maintenance dredging.

a) Current Speed

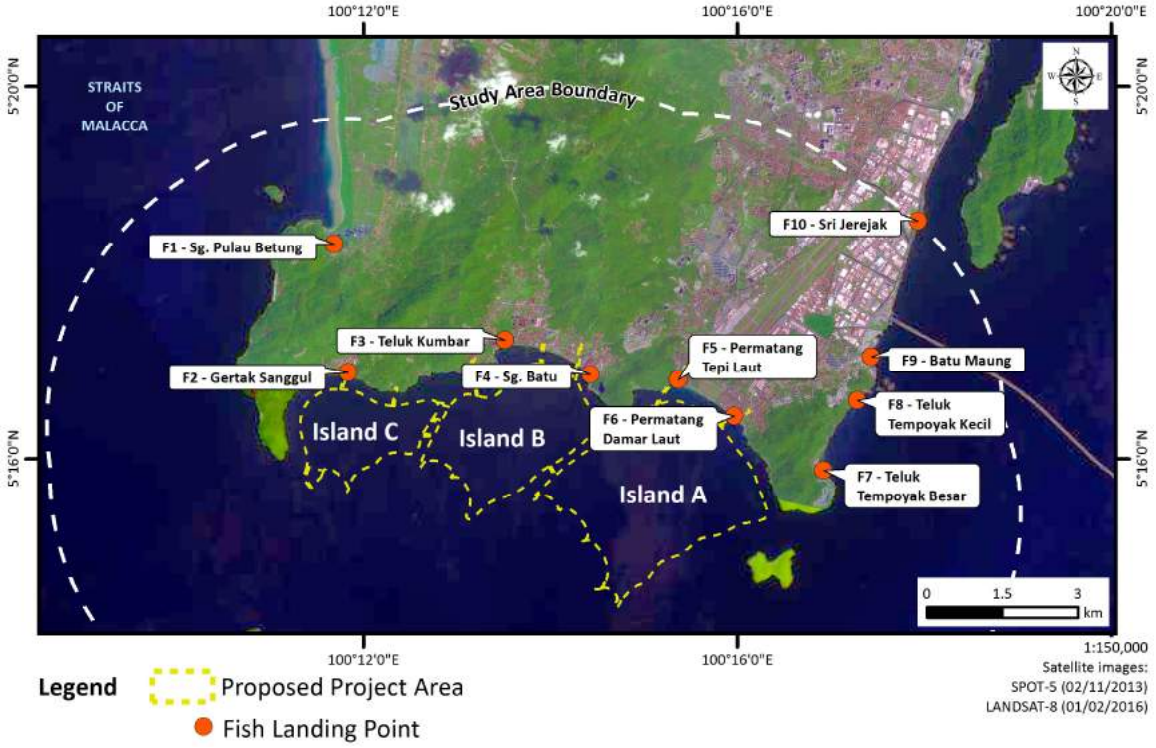
Hydraulic simulation for current speed is discussed extensively in *Section 7.3.5*. The result shows that there will be a considerable increase in current speed for the fish-landing point at Permatang Damar Laut and Sungai Batu. It is expected that manoeuvring of the boats will be slightly difficult because of this condition, especially for boats equipped with low-powered engines (less than 19 horsepower). Based on the survey conducted with local fishermen within the study area, boats with less than 19 horsepower engine made up approximately 3% of the total boats commonly used, mainly found at Batu Maung, Gertak Sanggul and Pulau Betung. As such, the increase in current speed at fish landing points is expected not to cause any significant impact to the fishermen.

b) Wave

Based on the result of wave heights simulation discussed extensively in *Section 7.3.7*, there is no significant increase in wave heights at all fish-landing points. Thus, it is deduced that the impact of wave height difference brought by the proposed Project will be insignificant.

c) Sedimentation and Erosion

T7.52 shows the rate of sedimentation or erosion that is expected to occur at the fish landing points. Based on the result, all locations will not be affected except for Gertak Sanggul and Sungai Batu whereby significant sedimentation is expected to occur. If unmitigated, water depth at these landing points will become shallower, which in turn will cause access difficulties for fishing boats.



F7.81 Fish landing points within the study area

T7.52 Sedimentation rate at fish landing points for all scenarios

Point	Location	Average Sedimentation Rate (m/year)				Remarks
		Scenario 1	Scenario 2	Scenario 3	Scenario 4	
F1	Sungai Pulau Betung	-	-	-	-	No data (upstream location)
F2	Gertak Sanggul	0.01	0.01	0.01	0.14	Significant sedimentation, thus mitigation measure is required
F3	Teluk Kumbar	0.00	0.00	0.00	0.00	Insignificant impact
F4	Sungai Batu	0.01	0.14	0.10	0.04	Significant sedimentation, thus mitigation measure is required.
F5	Permatang Tepi Laut	-	-	-	-	No data (upstream location)
F6	Permatang Damar Laut	0.00	0.00	0.00	0.00	Insignificant impact
F7	Teluk Tempoyak Besar	0.00	0.00	0.00	0.00	Insignificant impact
F8	Teluk Tempoyak Kecil	0.00	0.00	0.00	0.00	Insignificant impact
F9	Batu Maung	0.00	0.00	0.00	0.00	Insignificant impact
F10	Sri Jerjak	0.00	0.00	0.00	0.00	Insignificant impact

7.7 Impacts on Marine Biology

Marine biology is an important component that is interconnected with the fishing industry. The study area comprises ecologically important habitats, namely mudflat, coral reefs, mangrove and coastal waters which support important marine fauna such as fish, macrobenthos and plankton. Therefore, should any component of the complex marine ecosystems be disturbed by the implementation of the proposed Project, the fishing industry may be affected.

7.7.1 Land Reclamation and Dredging

The various activities associated with the proposed island reclamation at the Project site will invariably bring about environmental impacts on different aspects of the marine environment and consequently on the immediate coastal environment as well as fisheries and aquaculture activities. The nature and intensity of these impacts would depend on the extent, intensity and timing of the activities and can be of a short or long-term nature.

7.7.1.1 Loss of Foreshore Area and Mudflat

The nature of reclamation is such that it is expected to lead to an irreversible change in the area to be reclaimed. The original physical, biological resources and productivity of the reclamation footprint would be lost permanently, particularly the coastal mudflats and its associated flora and fauna. The loss can be significant if the area to be reclaimed provide a significant level of ecosystem services. Though there is a buffer zone between the mainland and reclaimed area, it would not be able to compensate for a much larger portion of the foreshore area that will be reclaimed.

Impacts to biological resources can also come from physical and chemical environmental alterations associated with dredging activities. These physical and chemical changes can come from increases in suspended sediments, sedimentation, release of biogenic chemicals and reduction in dissolved oxygen. The biological impacts of dredging would be the disturbance and removal of benthic infauna and epifauna and alteration of the substrate upon which colonisation depends. This, in turn, can affect its stability as a fish, crustacean and shellfish habitat.

Where the remnant substrate is identical to the original sediment, disturbance is unlikely to be permanent and the extraction area can be re-colonised, although the time scale would vary depending on the nature and location of the sediment communities currently there. While the dredging vessel is to be anchored 4 nautical miles from the site, there is a possibility that the discharge from these vessels ends up contaminating the fishing grounds around them if proper control measures is not taken.

Department of Fisheries (DOF) said in a meeting on 15th February 2019 and 15th March 2019 that the loss of mudflats at the study area would adversely affect the nursery ground, feeding ground and migration corridor of the greasyback shrimp (*Metapenaeus ensis)* which is a deep water species. Landings in Kedah, Penang and Selangor could be affected with the loss of the mudflats at the study area. However, this species are not caught within the study area, where only shallow water species such as *Penaeus meguiensis* currently prevail in the catch. Though the *Metapenaeus ensis* may be harvested in deeper area by trawlers, its loss will not impact on local communities that do not depend on its capture.

The *Metapenaeus ensis* fishery is no doubt important, but its presence in deeper waters suggest that it would not be impacted by the proposed reclamation, which is largely in shallower waters. A major constraint is that there is no published data on the detailed migration patterns of the *Metapenaeus ensis* in relation to the study area. No study on the mudflat as nursery ground for the *Metapenaeus ensis* has ever been carried out.

7.7.1.3 Plankton

Primary and secondary productivity are important indicators of the available forage base for marine planktivorous organisms. These organisms, in turn, play an important part in the marine food web (Chong *et al*., 1990). Many commercially important pelagic fish species are, in fact, directly dependent on primary and secondary producers. The impacts of plankton populations are not restricted to a specific area and relate closely with primary and secondary productivity along the entire coastline.

The extent of primary and secondary productivity in a given environment is dependent on a number of factors including light levels, nutrient levels, temperature and favourable hydrographic conditions (Alongi and Cristoffersen, 1992). Under local conditions, where light intensity and duration are constant throughout the country, nutrient levels primarily mediate plankton densities.

Turbidity is a major factor mediating primary productivity in marine waters (Pequegnat, 1978). A significant increase in turbidity levels would therefore retard primary production and, by extension, the rest of the marine food web. Decreasing availability of food due to reduced photosynthesis (Pequegnat, 1978) would likely induce migration of herbivorous organisms out of the area to search for food. Hence, the action will continue to disrupt the food-web in the area by depriving food for the higher trophic, causing imbalance to the community there.

7.7.1.4 Macrobenthos

Sediment communities have been found to play a critical role in the food chain for the marine organism (Chong *et al*., 1990). Benthic macrofauna are also one of the most important food sources for marine demersal fish (Sasekumar, 1984; Sasekumar *et al*., 1984; Erfetemeyer *et al*., 1989). Thus, the loss of macrobenthic fauna at and adjacent to the site would clearly impact on fish fauna currently found there. Sediment communities relate closely with primary and secondary productivity along the entire coastline. Therefore, direct effects of constructions works on these organisms and disturbance to the seabed communities can also deleteriously affect organisms on higher trophic levels in adjacent areas by depriving them of food.

Crustaceans such as shrimps and molluscs (gastropod and bivalves), which have limited mobility and are largely dependent upon for food and shelter on the foreshore area, would be seriously affected due to reclamation and dredging activities. This, in turn, would reduce the abundance of these organisms. In addition, a study by Ingle (1952), recorded that high levels of suspended sediments have been shown to kill bivalves. Other impacts arise from the disturbance of seabed are the destruction of spawning areas and smothering or suffocation of sessile organisms in the area (Pennekamp and Quaak, 1990).

7.7.2 Transportation and Disposal of Dredged Material

Constant marine traffic movement (tug boats and barges) transporting fill material may disturb the aquatic communities along the transportation route. Oil discharge or leakages from the vessels may pollute the pelagic and benthic ecosystems. It could also increase the possibility of accidents at sea with further adverse consequences to the marine life. Spillage of fill material could result in increased water turbidity.

Settlement of sediment from the disposed materials will have a serious impact on the habitat of the benthic communities as the sediments will smother the communities at the sea bottom. However, this is a short-term impact. The benthic communities will eventually recover and recolonise the area.

7.7.3 Post-reclamation

7.7.3.1 Loss of Mudflat Area

The nature of reclamation is such that it is expected to lead to an irreversible change in the area to be developed. The original physical, biological resources and productivity prevailing at the proposed Project area would largely be lost permanently, particularly the coastal mudflats and its associated flora and fauna. Losses of such magnitude are likely to be key drivers of declines in biodiversity and ecosystem services in the intertidal zone of the region. Though there is a buffer zone (approximately 250 m of access channel) between the mainland and reclaimed area, it would not be able to compensate for a much larger portion of the foreshore area (4,500 acres) that is expected to be totally eliminated.

7.8 Impacts on Marine Traffic and Navigation

Land reclamation and dredging activities for this Project will involve a big number of vessels ranging from dredgers, barges, tug boats and pontoons. These vessels will operate within an area where there is a high concentration of fishermen boats as the coastline adjacent to the Project site housed a number of fishing villages and bases. In addition, there are also several boat operators catering for the recreational fishing trip. These operators were located at Pantai Sri Jerjak, Batu Maung, and Pulau Betung. It is projected that the fishermen, as the prominent marine user of the area, will be the most affected group in terms of marine traffic and navigation.

7.8.1 Land Reclamation and Dredging

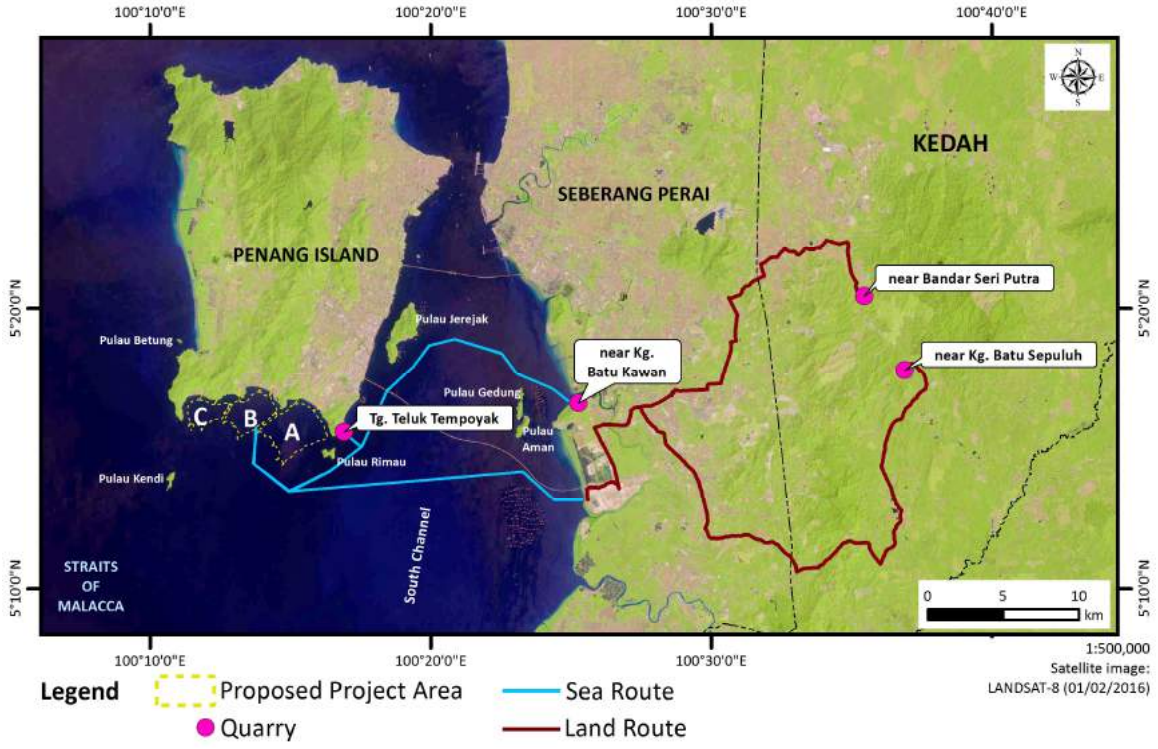
The proposed Project will cause a considerable increase in marine traffic within the vicinity of the Project site. Furthermore, vessels involved in the Project such as tugboats, barges and TSHDs are significantly larger in size compared to the existing marine traffic users which are mostly made up of fishermen and rental boats.

The movement of the fishing vessels will be restricted during the land reclamation and dredging periods. It is expected that lighted buoys will be deployed around the Project site to mark the designated working area. For safety reasons, this area is considered off-limit to the fishermen boats. If possible, the fishermen shall be requested to use assigned routes for travelling in and out of their villages/bases. However, by doing so, the daily commute of these fishermen will become longer, thus incurring additional fuel costs. On the other hand, the risk of collision between the fishermen and the working vessels will be greatly reduced.

The Project area is located within an area where fishermen looking for prawns regularly cast their net. If they continue to do so during the implementation of the Project, their nets may be entangled with the work vessels. During the process of casting their net, the mobility of the fishermen boats is limited. This situation presents a significant risk of collision between the work vessels and these boats.

Once dredging and land reclamation start, the Project site will be interspersed with fixed and movable structures such as pipelines, silt curtains and rock bunds. These structures present a safety risk for fishermen and other marine users, especially at night.

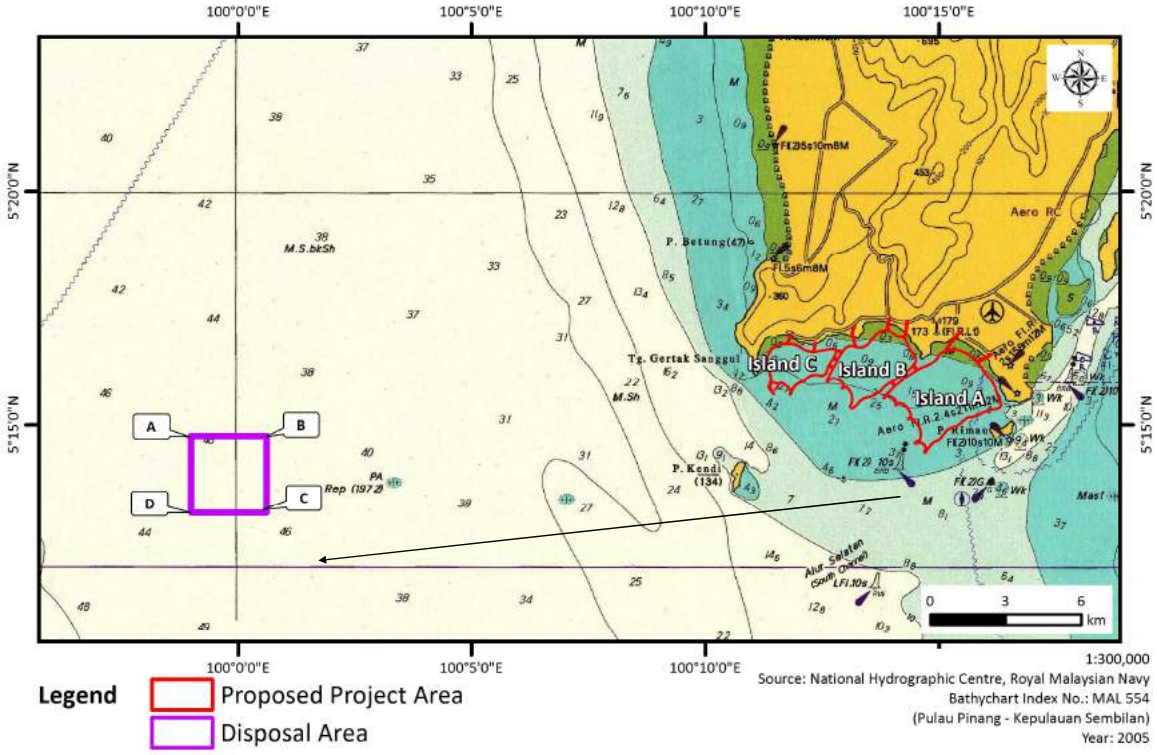
The Project location is also situated adjacent to the South Channel of the Penang Port. Based on the location of the proposed disposal ground and sand source, it is expected that the additional traffic caused by the land reclamation and dredging activities will not affect the marine navigation within South Channel. Transportation of rocks from the quarry in Juru will directly cross the South Channel, as illustrated in F7.82. But looking into the low traffic volume for the South Channel (approximately 20 to 30 vessel calls per year), it can be deduced that the impact will be insignificant.



F7.82 Rock barges route to the Project site

7.8.2 Transportation and Disposal of Dredged Material

The movement of barges carrying dredged material to the designated disposal area will travel along the route as shown in F7.83. The route to the dumping area will go nearby Pulau Kendi, which is a popular ground for fishermen and recreational fishing activities. The constant movement of barges will present collision risk between the work vessels and fishermen/angler boats, especially at night.



F7.83 Transportation route to the designated dumping area

7.8.3 Post-reclamation

As mentioned previously, post-reclamation refers to a stage when the reclamation and dredging are completed, but no topside development is undertaken yet. As such, no discernible impact to marine traffic and navigation is expected during this stage.

Later, once the topside development commences, a marina will be built on Island C. The presence of marina will bring about additional marine traffic into the Project area. In order to accurately assess the impacts from this additional traffic, it is advisable for a Marine Risk Assessment (MRA) to be conducted. Findings from the MRA study can be included in the EIA to be conducted during the topside development stage.

7.9 Traffic Impact Assessment (TIA)

Although this EIA study primarily focuses on the dredging and land reclamation related activities, some aspects that are related with topside development stage also need to be taken into account in order to get a better understanding on the overall impact of the proposed development to the surroundings. Land traffic is one of the relevant component of said aspects, thus an impact assessment study on land traffic was conducted whereby the findings will be discussed in the following sections.

7.9.1 Penang South Reclamation Transport Network

The development is proposed to be served by an extension to the proposed Bayan Lepas LRT line and an internal tram system. There will be three main highway connections from the development (shown in light blue in the diagram on the left below), providing grade-separated access to the wider expressway network, namely: Pan Island Link 2 (PIL 2), PIL 2A and Jalan Tun Dr. Awang Link (JTDA). In addition, there will be six secondary accesses and upgrading to the existing roads (Jalan Teluk Kumbar, Jalan Permatang Damar Laut and Jalan Gertak Sanggul). The proposed transport network for PSR is shown in F7.84.

7.9.2 Methodology

7.9.2.1 Passenger Car Unit (PCU) Conversion Factors

For the purposes of assessing the capacity of the road network, each vehicle classification is converted into PCUs to reflect the amount of road capacity they use in relation to a standard car. The conversion unit from vehicles to PCUs for the observed classes of vehicles were based on the values provided by REAM which are summarised in T6.26 in *Chapter 6: Existing Environment*.

7.9.2.2 Definition of Peak Period

The peak hour periods were determined by analysing the hourly traffic flows at all junctions within the study area. Based on analysis of the traffic flow data collected, the peak hours are found to occur during the following periods:

a) AM peak: 0730 – 0830 hours; and
b) PM peak: 1730 – 1830 hours.

7.9.2.3 Forecast of Future Traffic

Travel demand forecasting for the study is estimated by taking into consideration of the proposed development up to the future horizon when PSR development is fully matured. This involves making estimation of future growth in traffic demand due to socioeconomic indicators as well as land use changes. Estimation of development traffic uses the Highway Planning Unit Trip Generation Manual (2010).

The trips during the AM and PM peak periods are derived based on the land use in each of the parcels within the islands. The demand is distributed to areas both within the PSR development and to areas on Penang Island and the mainland based on a calibrated gravity model. The estimated trip generation for the proposed development is shown in T7.53.