Capco 青山發電有限公司
Castle Peak Power Co. Ltd.

Black Point Gas Supply Project

EIA Study (EIA Study Brief ESB-208/2009)

EIA Report (Rev 3)
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Section 8

Marine Ecology Assessment

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8 MARINE ECOLOGY ASSESSMENT

8.1 INTRODUCTION

This section of the EIA Report presents the findings of the marine ecological impact assessment associated with the construction and operation of the Gas Receiving Stations (GRSs) and submarine gas pipelines in the Black Point area. It summarises baseline information gathered from the literature review and ecological surveys on the marine ecological resources at Black Point. The methodologies and results of the literature review and baseline surveys are presented in *Annex 8A*.

8.2 RELEVANT LEGISLATION & ASSESSMENT CRITERIA

The criteria for evaluating marine ecological impacts are laid out in the *EIAO TM* and Study Brief (*ESB-208/2009*). *Annex 16* of the *EIAO TM* sets out the general approach and methodology for the assessment of impacts to marine ecological resources arising from a project or proposal. *Annex 8* of the *EIAO TM* recommends the criteria that can be used for evaluating such impacts.

Legislative requirements and evaluation criteria relevant to this Study for the protection of species and habitats of marine ecological importance are listed below. The details on each are presented in *Annex 8A*.

- *Marine Parks Ordinance (Cap 476)*;
- *Wild Animals Protection Ordinance (Cap 170)*;
- *Protection of Endangered Species of Animals and Plants Ordinance (Cap 586)*;
- *Town Planning Ordinance (Cap 131)*;
- *Hong Kong Planning Standards and Guidelines Chapter 10 (HKPSG)*;
- *Technical Memorandum on Environmental Impact Assessment Process* under the *Environmental Impact Assessment Ordinance (EIAO TM)*;
- *United Nations Convention on Biodiversity (1992)*;
- *Convention on Wetlands of International Importance Especially as Waterfowl Habitat (the Ramsar Convention)*;
- *PRC Regulations and Guidelines*.

8.3 SUMMARY OF BASELINE CONDITIONS

The site for the proposed GRS reclamation is adjacent to the existing BPPS near the northern reaches of the Urmston Road and on the outskirts of Deep Bay. The proposed submarine gas pipelines will traverse the Urmston Road to exit the Hong Kong Special Administrative Region (HKSAR) boundary (see *Figure 8A.1*). Black Point is located in the northwestern waters of Hong Kong. The surrounding waters are relatively shallow (~ – 5 – 8 mPD), apart from within the Urmston Road where the water depth can reach – 20 mPD. The reclamation will extend from the existing artificial shoreline to the north of the BPPS.

The marine ecological habitats in the immediate vicinity of the proposed GRS reclamation site of BPPS and pipeline route in Black Point have undergone anthropogenic disturbance through marine traffic via the Urmston Road, trawling activities and reclamation for the Black Point Power Station and CLP's Ash Lagoons. *Figure 8.1* presents representative photographs of habitats in the Study Area and presents a simplified habitat map.

Comprehensive literature review was conducted to examine the major habitats and species in the marine environment surrounding the Project Site and to identify potential information gaps for the baseline conditions of the habitats. Focussed field surveys and additional comprehensive data review were conducted to fill these information gaps. The findings of the literature review, field surveys, data review and an evaluation of the ecological importance of marine resources within the Study Area are summarised in the following section. The details are presented in full in *Annex 8A*.

The key finding of the literature review was the recorded presence of Indo-Pacific humpback dolphin *Sousa chinensis* in the waters of the Study Area. The review highlighted that the waters around Black Point did not report large numbers of sightings and are used as marginal habitat by dolphins in Hong Kong (see *Section 8A.3.7*, *Annex 8A*).

Field surveys were conducted in habitats within and surrounding the reclamation site and pipeline route in the dry and wet seasons of 2009 (*Table 8.1*), while the additional data review for marine mammals utilised data from January 2005 to June 2009. Details of the baseline surveys are presented in *Annex 8A*.

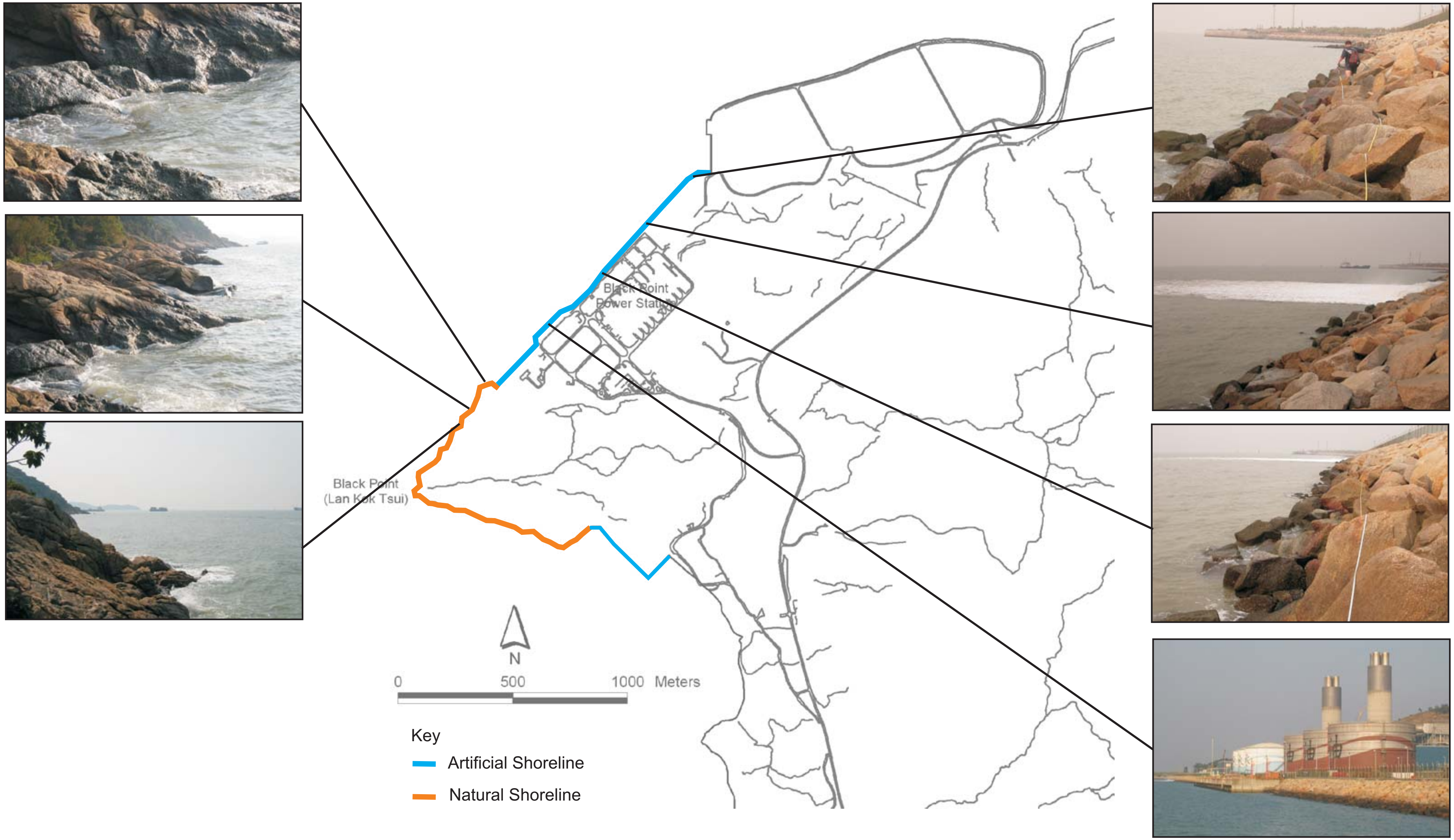

Figure 8.1

Intertidal Habitats Identified within the Study Area at Black Point

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Table 8.1 Marine Ecology Baseline Surveys

Survey Type	Methodology	Season & Date
Intertidal Assemblages at BPPS	Qualitative spot checks and quantitative surveys of three 100 m belt transects (at high, mid and low intertidal zones) at artificial seawall, covering both wet and dry seasons	Dry Season: 25 Mar 2009 Wet Season: 23 Jun 2009
Subtidal Benthic Assemblages	Quantitative grab sampling surveys at four sites (six stations at each site). Sites surveyed represented the reclamation site and pipeline alignment	Wet Season: 10 Jun 2009
Subtidal Hard Bottom Assemblages (Coral)	Spot dives within Study Area	30 Sept and 2 Oct 2009

Intertidal Hard Bottom Assemblages

Seasonal quantitative transect surveys were conducted on the artificial seawall of the Black Point Power Station. Rocky shore species at all survey transects were common and widespread and no species of note were recorded.

Subtidal Soft Bottom Assemblages – Benthos

Systematic grab sampling was conducted within and in proximity to the footprint of the reclamation site and pipeline alignment in the wet season 2009. Infaunal assemblages at the surveyed sites were dominated by polychaete worms, and the species recorded are common and widespread with no particular conservation concern. In comparison with the Hong Kong average reported in the literature, the abundance and biomass of infauna at these sites are considered as medium to high, while taxonomic richness of infauna at these sites is considered as low. The ecological importance of these assemblages is considered as low.

Subtidal Hard Bottom Assemblages – Coral

Spot dive surveys were conducted on the artificial seawall of the Black Point Power Station, within the proposed reclamation site and on hard substrate identified along the proposed pipeline route. No corals (hard, soft, gorgonians or whips) were recorded during the spot dives within survey area and thus the ecological importance of these habitats is considered as low.

Indo-Pacific Humpback Dolphins

A comprehensive data review was undertaken by the Hong Kong Cetacean Research Project (HKCRP) using the long-term dolphin monitoring data collected from Deep Bay and western Northwest Lantau from January 2005 to

June 2009. This review aimed to characterise the use of marine waters of the Project Site and its vicinity by the Indo-Pacific humpback dolphin.

Findings of the data review showed that humpback dolphins have been sighted along and adjacent to the proposed gas pipeline alignment, and also near the proposed reclamation site at BPPS. Dolphin densities (DPSE values) were considered as low to moderate for the proposed reclamation site and along the pipeline alignment.

8.3.2 *Ecological Importance*

The ecological importance of the habitats was determined through reference to the following:

- Literature review;
- Findings of the field surveys and additional data review;
- Comparison with other areas in Hong Kong; and
- *Annexes 8* and *16* of the *EIAO-TM*.

None of the marine ecological resources and habitats in the proposed Project Site is considered as of high ecological value. Key findings and outcomes of the evaluation of ecological importance are summarised in *Table 8.2* and presented in full in *Annex 8A*.

Table 8.2 Ecological Importance of the Marine Habitats

Habitat	Ecological Importance within Project Area
Intertidal Hard Bottom Habitat	Low
Subtidal Soft Bottom Habitats	Low
Subtidal Hard Bottom Habitat	Low
Marine Waters	Low to Moderate for the Indo-Pacific humpback dolphin *Sousa chinensis*

8.3.3 *Marine Ecological Sensitive Receivers*

Based on the review of available information on existing conditions in the Study Area and its immediate vicinity, marine ecological sensitive receivers have been identified in accordance with the *EIAO-TM* criteria, and are consistent with the ones identified in the *Water Quality Impact Assessment* (*Section 6*). These sensitive receivers and their distance from the project facilities are listed in *Table 8.3* and presented in *Figure 6.3*.

Table 8.3 Approximate Shortest Distance to Marine Ecological Sensitive Receivers (SRs) around the Proposed GRS Reclamation and Submarine Pipelines from Black Point

Sensitive Receiver	Name	Shortest Distance from SR to Proposed Project Facilities
Seagrass Beds	Ha Pak Nai	3.2 km
	Pak Nai	4.5 km
Marine Parks	Designated Sha Chau and Lung Kwu Chau	3 km
Intertidal Mudflats	Ha Pak Nai	2.5 km
Mangroves	Sheung Pak Nai	5 km
	Ngau Hom Shek	6 km
Horseshoe Crab Nursery Grounds	Ha Pak Nai	3 km
	Pak Nai	4.3 km
	Sheung Pak Nai	5 km
	Ngau Hom Shek	6 km

Findings of the literature review suggest that the natural shore at the Black Point headland, which is about 1 km from the Project Site, is comprised of common and widespread rocky shore species with no species of conservation interest (see *Annexes 8A* and *8B*). In comparison to records of other similar habitats in Hong Kong reported in the literature, the diversity of intertidal biota at this shore was considered to be low, and this habitat is regarded as of low ecological value. Consequently, the natural shore at the Black Point headland is not considered as a marine ecological sensitive receiver in this EIA Study.

8.4 ASSESSMENT METHODOLOGY

A desktop literature review and supporting field surveys and data review (summarised in *Section 8.3* and presented in detail in *Annex 8A*) were conducted in order to establish the ecological profile of the area within and surrounding the Project. The importance of potentially-impacted ecological resources identified within the Study Area was evaluated using the methodology defined in the *EIAO-TM*. Potential impacts to these resources due to the construction and operation of the GRSs and submarine gas pipelines were assessed (following the *EIAO-TM Annex 16* guidelines) and the impacts evaluated (based on the criteria in *EIAO-TM Annex 8*). Findings of water quality modelling (*Section 6*) are used, where appropriate, to assess potential impacts on the identified marine ecological resources.

It is noted that the construction of the first pipeline, and the construction of the second pipeline and the reclamation, will involve two phases. First Phase construction (Pipeline 1 and co-located GRS) is expected to commence in 2011 while Second Phase construction (Pipeline 2, reclamation and associated GRS) could commence within 24 months following commissioning of the First Phase. However in order to evaluate worse-case project-specific impacts, the assessment presented in the following sections has taken into consideration the overall impacts of the construction of both pipelines and the reclamation.

Potential impacts to marine ecological resources, and marine mammals, are discussed in *Sections 8.5* and *8.6* respectively.

8.5 POTENTIAL IMPACTS & IMPACT ASSESSMENT ON MARINE ECOLOGICAL RESOURCES

8.5.1 Construction Phase

Impacts associated with the proposed Project are divided into those occurring during:

- **Submarine gas pipeline installation**: the installation works will involve dredging, jetting and pipe-laying works.
- **Dredging and reclamation for the GRS**: along the line of the proposed seawalls the existing marine sediments will be dredged to provide suitable foundations. After completion of the seawalls, the reclamation area will be filled using sand and / or public fill. The proposed reclamation works are of relatively small scale (about 0.5 ha).

Potential impacts to marine ecological resources and sensitive receivers arising from these construction activities may be divided into those due to direct disturbance to the habitat and those due to perturbations to key water quality parameters. These potential impacts are summarised in *Table 8.4* and discussed in further detail in the following sections.

Table 8.4 Summary of Potential Construction Phase Impacts on Marine Ecological Resources

Nature of Impact	Marine Habitat Affected	Potential Impact
Dredging and Reclamation of the GRSs at BPPS		
Habitat Loss	Subtidal Soft Bottom Habitat at the proposed reclamation site	Permanent loss of approximately 0.5 ha of seabed with minor temporary loss at the seawall works footprint (about 0.85 ha)
	Subtidal and Intertidal Artificial Shores at the proposed reclamation site	Permanent loss of approximately 100 m of existing subtidal and intertidal artificial shores, replaced by 200 m of new artificial shore
Short-term Changes in Water Quality	Subtidal Soft Bottom Habitat	Potential burial of benthic organisms during dredging
	Subtidal and Intertidal Artificial/ Natural Shores	Potential water quality impacts on subtidal and intertidal organisms

Nature of Impact	Marine Habitat Affected	Potential Impact
Submarine Gas Pipeline Installation		
Temporary Habitat Loss	Subtidal Soft Bottom Habitat along the proposed pipeline corridor	Temporary loss of about 15.6 ha of seabed along the approximately 5 km route of the two pipelines (see *Table 3.2* for calculation)
Short-term Changes in Water Quality	Subtidal Soft Bottom Habitat	Potential deposition of sediment onto the seabed affecting benthic organisms
	Subtidal and Intertidal Artificial/ Natural Shores	Potential water quality impacts on subtidal and intertidal organisms

As discussed in *Section 6.7*, only minor water quality impacts will be expected due to discharges from hydrotesting and works vessels during construction and, therefore, impacts on marine ecology including marine mammals are not considered as a concern.

Permanent Habitat Loss

None of the marine ecological sensitive receivers presented in *Table 8.3* is found within the Project Site and thus direct, permanent habitat disturbance will not occur at these sensitive receivers.

<u>Subtidal Soft Bottom Habitats at the Reclamation Site</u>

Within the reclamation footprint at BPPS, impacts will be due to the burial of organisms during filling, or removal of organisms during dredging. Dredging would also directly affect the margins of seabed at the base of existing seawalls. These impacts are an unavoidable consequence of the Project and would occur during dredging and backfilling operations associated with the reclamation works for the GRS.

It is, therefore, important to determine whether the works areas contain unique or otherwise noteworthy benthic assemblages which will be lost. Findings from a literature review and field surveys indicate that the benthic assemblages in the vicinity of the reclamation were dominated by polychaetes and characterised by similar species diversity (for both seasons) and dry season biomass as found elsewhere in Hong Kong. The wet season biomass of the benthic assemblages at Black Point was comparatively higher than other areas in Hong Kong waters. However, all of the species recorded occur frequently in Hong Kong and no rare species were observed. As a result, the assemblages were regarded as being of low ecological value.

The scale of the reclamation and extent of works area have been reduced as far as practicable through modifications to the engineering layout. Although the proposed reclamation and dredging will result in permanent loss of about 0.5 ha of subtidal soft benthic habitats due to the reclamation, the severity of the impact is anticipated to be acceptable in terms of loss of benthic assemblages, as the seabed areas to be reclaimed and dredged are of low ecological value and support benthic species which are common in Hong Kong waters.

Subtidal & Intertidal Artificial Shores at the Reclamation Site

The proposed reclamation will result in the loss of subtidal and intertidal hard bottom assemblages along the ~ 100 m existing sloping artificial shores, via burial of organisms.

Coral communities were not found along this stretch of shoreline, and results from field surveys and literature review indicated that the intertidal assemblages recorded on the artificial shores are typical artificial shore species in Hong Kong with low species diversity. Both the subtidal and intertidal assemblages on the artificial shores are, therefore, regarded as of low ecological value.

Given that a relatively short stretch of artificial shores will be permanently lost (~ 100 m), the severity of the impact is anticipated to be acceptable in terms of the loss of low ecological value assemblages. This 100 m stretch of seawall will be replaced by about 200 m of new artificial vertical seawalls surrounding the GRS reclamation. It is anticipated that assemblages of intertidal and subtidal organisms will, over time, settle on and recolonise the newly constructed seawalls, as environmental conditions of that area would be similar to existing conditions that have allowed the growth of these organisms.

Temporary Habitat Loss

None of the marine ecological sensitive receivers presented in *Table 8.3* is found within the Project Site and thus direct, temporary habitat disturbance will not occur at these sensitive receivers.

Subtidal Soft Bottom Habitats along the Pipeline Corridor and at the Reclamation Seawall Trenches

No long-term direct impacts are expected to occur due to the installation of the gas pipelines. Short-term impacts on subtidal soft bottom assemblages are predicted to occur as a result of the dredging/ jetting operations associated with the burial of the pipelines.

The width of pipeline trenches has been reduced where practical. The width of the trenches is approximately 3 - 35 m wide, and about 15.6 ha of seabed is expected to be temporarily affected for the installation of two pipelines. The pipelines (approximately 32" – 42 " in diameter) will be laid in soft seabed habitats that are regarded to be of generally low ecological value. Once the installation operations have ceased, assemblages in the affected areas are expected to return due to the recolonisation of the seabed by benthic fauna.

Following installation, the pipelines will be protected by rock armour. Rock armour is necessary to achieve adequate protection against anchor drop and drag for the gas pipeline. The expected overall duration of rock armour placement on the gas pipelines is around four months.

Natural backfilling of marine sediment over the rock armour will occur and is expected to be quickly recolonised by benthic organisms. Water quality impacts from these works are not expected as the fines content of the armour rock material is low.

Short-term impacts on subtidal soft bottom assemblages are predicted to occur as a result of the dredging operations at the seawall trenches of the reclamation site. The benthic assemblages within this footprint are considered to be of low ecological value.

Overall, given the temporary nature of the potential impacts and the low ecological value of the associated benthic assemblages, the severity of the impact is anticipated to be acceptable and adverse impacts are not predicted.

Short-term Changes in Water Quality

All sensitive receivers presented in *Table 8.3* are considered to be of sufficient distance from the Project Site and marine works areas and are unlikely to be affected indirectly by the construction of the Project. This is supported by results of the water quality modelling which suggest that unacceptable water quality impacts are not predicted at these sensitive receivers (see *Section 6.7*).

<u>Suspended Solids (SS)</u>

Dredging/ Sand-filling of the Reclamation

Dredging of sediments within the reclamation site and along the line of the seawalls, and filling of the seawall trenches using sand and/ or public fill, will generate suspended solids (SS) within the water column and may result in increased sediment deposition in subtidal and intertidal assemblages in close proximity of the works areas. Computational modelling has been undertaken to analyse suspended sediment dispersion from dredging works (*Section 6.7.1*). Sediment may be deposited on the seabed and other subtidal hard substrates outside the reclamation sites during dredging and backfilling (through dispersion of sediment plumes) and post-placement (through erosion and wave-induced resuspension).

With reference to the water quality modelling results (*Section 6.7.1*), elevations in SS would be localised and confined to the works area. The area affected is expected to be small as sediment will be deposited within a short distance of the dredging and filling works (at a distance of ~ 1 km). It should be noted that backfilling for the reclamation area will take place behind completed seawalls which will prevent to a large degree the dispersion of SS. Therefore elevations in SS are not predicted to affect the marine ecological sensitive receivers at levels of concern (as defined by the WQO and tolerance criterion) given their separation distance from the reclamation works area. Consequently, unacceptable impacts on marine ecological sensitive receivers are not expected.

Whilst subtidal and intertidal assemblages immediately outside of the reclamation site and dredged areas are predicted to experience elevations in SS levels, these are expected to occur temporarily. These assemblages in proximity to the proposed reclamation are considered to be of low ecological value (*Section 8.3*). As the areas affected are often disturbed by demersal trawling and SS laden discharges from the Pearl River, the organisms present are thus assumed to be adapted to seabed disturbances and SS elevation. Based on the assumption that eventually the affected areas will be recolonised by fauna typical of the area, then the temporary loss of these low ecological value assemblages is deemed acceptable. Unacceptable impacts to subtidal and intertidal assemblages in the vicinity of the reclamation arising from elevated SS levels are not anticipated.

Dredging of Pipeline Trenches

Dredging of sediments along the proposed pipeline corridors is expected to generate SS within the water column and may result in increased sediment deposition on the seabed in close proximity to the works areas. Computational modelling has been undertaken to analyse suspended sediment dispersion from the dredging works (*Section 6.7.1*).

Impacts to subtidal benthic assemblages immediately outside of the pipeline trenches are expected to occur temporarily as the modelling results indicate that the pipeline dredging works would only result in short-term, localised elevations of SS in each particular location. The habitats affected along the route are expected to be small in size and generally confined to the works corridor since suspended sediments entering the water column will not be subject to a high degree of lateral dispersion (*Section 6.7.1*).

Subtidal assemblages in proximity to the proposed pipeline alignment are considered to be of low ecological value (*Section 8.3*). As the areas affected are often disturbed by demersal trawling and SS laden discharges from the Pearl River, the organisms present are thus assumed to be adapted to seabed disturbances and SS elevation. Based on the assumption that eventually the affected areas will be recolonised by fauna typical of the area, then the temporary loss of these low ecological value assemblages is not considered to be unacceptable. Unacceptable impacts to subtidal assemblages in the vicinity of the pipeline alignment arising from elevated SS levels are not anticipated.

As for potential impacts to the subtidal and intertidal assemblages from the dredging works, they are predicted to occur immediately outside of the dredged areas near the landing point only and are expected to occur temporarily. Also elevations in SS are not predicted to affect the marine ecological sensitive receivers at levels of concern (as defined by the WQO and tolerance criterion) given their separation distance from the works area and hence unacceptable impacts on these sensitive receivers are not expected (see *Section 6.7.1*).

Jetting of Pipeline Trenches

As discussed in *Section 3* of this EIA Report, jetting would be adopted as the chosen method for installing the gas pipelines along certain sections of the alignment in both Hong Kong and PRC waters. *Section 6* has analysed the potential water quality impacts of this method.

Jetting works will generate SS within the water column and result in the deposition of sediment onto the seabed affecting benthic organisms adjacent to the utility trenches. With reference to the water quality modelling results (*Section 6.7.1*), suspended sediments entering the water column due to jetting are predominantly confined to the bed layer and are not subject to a high degree of lateral dispersion. Impacts to the benthic organisms would be temporary and localised in extent. The area affected is expected to be small as sediment will be deposited within a short distance of the jetting works (at a distance of ~ 1 km).

For jetting works in Hong Kong waters, elevations in SS are not predicted to affect the marine ecological sensitive receivers at levels of concern (as defined by the WQO and tolerance criterion) given their separation distance from the jetting works area. Consequently, unacceptable impacts to marine ecological sensitive receivers are not expected.

Whilst subtidal and intertidal assemblages in the vicinity of the pipeline trenches are predicted to experience elevations in SS levels as a result of jetting in Hong Kong waters, these are expected to occur temporarily during the works period. These assemblages in proximity to the proposed reclamation are considered to be of low ecological value and are adapted to seabed disturbances and SS elevation. Unacceptable impacts to subtidal and intertidal assemblages in the vicinity of the jetting works areas arising from elevated SS levels are not anticipated.

At this stage it has been assumed that the installation of submarine gas pipelines in PRC waters will be conducted largely using jetting. This assumption is based on the feasibility study for the Mainland China segment of the pipeline route. For the purpose of this assessment potential impacts of jetting in PRC on marine ecological resources and sensitive receivers in Hong Kong waters have been evaluated and assessed for the PRC waters within about 2.5 km from the HKSAR boundary (see *Section 6.7*).

With reference to the water quality modelling results, jetting works in PRC waters are not predicted to result in SS elevations that would affect the marine ecological sensitive receivers at levels of concern (as defined by the WQO and tolerance criterion). Consequently, unacceptable impacts on marine ecological sensitive receivers are not expected.

Dissolved Oxygen (DO)

The relationships between SS and dissolved oxygen (DO) are complex, with increased SS in the water column combining with a number of other factors to reduce DO concentrations in the water column. Elevated SS (and turbidity) reduces light penetration, lowers the rate of photosynthesis by phytoplankton (primary productivity) and thus lowers the rate of oxygen production in the water column. This has a particularly adverse effect on the eggs and larvae of fish, as at these stages of development, high levels of oxygen in the water are required for growth due to their high metabolic rate. DO depletions are most likely to affect sessile organisms as they cannot move away from areas where DO is low (unlike mobile species such as fish).

With reference to the water quality modelling results (*Section 6.7.3*), the dredging/ jetting would only generate temporary and localised low level SS elevation and not significant depletions of DO. Depletions of DO as a result of the dredging/ jetting activities have been predicted to be undetectable and compliant with the relevant WQOs. It is thus expected that unacceptable impacts to the marine ecological assemblages and sensitive receivers present in the vicinity of the reclamation site and pipeline alignment are not expected to occur.

Nutrients

High levels of nutrients (total inorganic nitrogen - TIN and ammonia) released from dredged sediments to seawater may potentially cause rapid increases in phytoplankton to the point where an algal bloom may occur. An intense bloom of algae can lead to sharp increases in DO levels in surface water. However, at night and when these algae die there is usually a sharp decrease in the levels of dissolved oxygen in the water, as dead algae fall through the water column and decompose on the bottom. Anoxic conditions may result if DO concentrations are already low or are not replenished. This may result in mortality to marine organisms due to oxygen deprivation.

The water quality modelling results (*Section 6.7.4*) have indicated that dredging would generate low level SS elevation in a localised area close to the works. Consequently nutrient levels are not expected to increase appreciably from background conditions during the dredging operations. Algal blooms and unacceptable impacts to the sensitive receivers and marine ecological assemblages present in the vicinity of the reclamation area and pipeline route are not expected to arise due to the works.

8.5.2 *Operation Phase*

No impacts are expected to occur during the operation of the submarine pipelines. The pipelines are unlikely to be damaged as they will be buried to approximately 1 m - 3 m within the seabed. The pipelines are designed to be maintenance free but should it require inspection this will be done using a remotely operated intelligent pipe inspection gauge (PIG). This type of inspection device will be within the pipelines. Consequently, there will be no need to disturb the seabed during inspection and therefore marine ecology will not be affected.

Potential impacts associated with the operation phase are thus expected to be limited to potential changes to hydrodynamic regime due to the physical presence of the GRS reclamation. Secondary impacts on water quality may also arise from the reclamation in terms of limited dispersion of cooling water discharged from the BPPS.

Hydrodynamic Regime

The reclamation for the GRSs will create a minor change in the shape of the existing coastline. The effects of changes in coastal configuration on the current velocities have been assessed (*Section 6.8*). Owing to the small scale of the reclamation, no significant changes in the hydrodynamic regime and flushing capacity around the BPPS area were predicted. Significant sedimentation is also not predicted to occur along the new seawalls. Consequently, no operation phase impacts on marine ecological resources due to changes in the hydrodynamic regime are expected.

Secondary Water Quality Impacts

Cooling water will be discharged at the seawater outfall of the BPPS and the maximum allowable increase in temperature is 10 ºC above ambient. Results of the water quality modelling have shown that in the presence of the GRS reclamation, temperature of the cooling water is expected to dissipate rapidly upon discharge. Whilst no non-compliance with the WQO is predicted to occur at the marine ecological sensitive receivers in either the dry or wet season (*Section 6.8.4*), the predicted temperature differences are confined to the discharge location with a maximum of 2 °C difference from existing condition for a distance of < 1 km from the point of discharge. This is considered as a potential secondary impact on water quality as a result of this Project.

The temperature change is predicted to be confined to the surface layer with reduced impact to the bottom layer. Impacts are thus expected to mainly occur in the surface layer of the water column or in the shallower water of the intertidal zone. Impacts on the seabed will be less severe as temperature change is lower than the surface.

The potential impacts of this thermal discharge are principally related to the physiological effects on marine biota in a zone of elevated temperature near the point of discharge. Effects of ambient temperature elevation will depend largely on an organism's tolerance towards thermal stress and water movement. Marine ecological resources of the BPPS area are expected to be of low sensitivity as these tropical species are expected to be able to tolerate slight elevations in thermal stress. Thermal impacts to these organisms are hence expected to be of low severity and hence unacceptable impacts are not anticipated. No effects on ecological carrying capacity of the assemblages are expected since it is considered unlikely that population size of subtidal/ intertidal assemblages would be affected by the predicted temperature difference.

8.6 *POTENTIAL IMPACTS & IMPACT ASSESSMENT ON MARINE MAMMALS*

In this *Section*, the potential for impacts associated with various marine works and activities involved in the proposed Project are examined in detail to provide an assessment of the significance of potential effects on the Indo-Pacific humpback dolphin *Sousa chinensis*. The significance of a potential impact from works or activities on marine mammals can be determined by examining the consequences of the impact on the affected animals. This is related to the source, nature, magnitude and duration of the impact, the level of exposure to the impact in terms of the number (and age classes) of affected animals and their response to an impact.

The consequences of an impact on these marine mammals have the potential to range from behavioural changes of individual animals through to population-level effects (1) (2) (3). The potential consequences of impacts on marine mammals are as follows:

- **Behavioural changes**: Affected individual animals may change travelling speed, dive times, avoid areas, change travel direction to evade vessels, change vocalisation due to acoustic interference, reduce resting, socialising and mother-calf nursing. Provided that disturbances leading to behavioural changes are temporary, localised and outside areas of ecological importance to marine mammals, disturbances causing behavioural changes would generally not be considered significant (i.e. effects would be of short duration, normal activities will resume with no appreciable effect on fitness or vital rates).

(1) National Research Council (2005) *Marine Mammal Populations and Ocean Noise: Determining When Noise Causes Biologically Significant Effects*. National Academies Press, Washington DC

(2) Wursig B, Greene CR, Jefferson TA (2000) Development of an air bubble curtain to reduce underwater noise of percussive piling. *Marine Environmental Research* 40: 79-93

(3) Greene CR, Moore SE (1995) Man-made noise. In: *Marine Mammals and Noise* (Eds. Richardson WJ, Greene CR, Malme CI, Thomson DH). Academic Press, London

- **Life function immediately affected**: Avoidance of affected areas may diminish individual animals' feeding activity. Loss of a marine area to reclamation will permanently eliminate a habitat area. Similarly, disturbance/ loss of prey resources due to water quality impacts may diminish available feeding opportunities in the vicinity of works. Interference with echolocation through underwater noise could also affect feeding. Provided that disturbances are temporary and localised, or permanent losses of habitat represent a small portion of available habitat and are outside areas of ecological importance to marine mammals, impacts would generally not be considered to have a significant effect on marine mammals (i.e. effect would be short term and therefore have no appreciable effect on fitness or vital rates).

- **Fitness and Vital Rate Impacts**: If works cause widespread and prolonged adverse impacts, with limited or no alternative habitat available for animals to use, fitness and vital rates will be affected, including growth rates, reproduction rates and survival rates (life-stage specific). In the same way, any works or activity likely to result in injury or mortality of marine mammals would obviously affect survival rates. Activities causing impacts on fitness and vital rates would be considered significant (i.e. if effects are long-term or inescapable, they will diminish the health and survival of individuals).

- **Population effects**: Impacts on the fitness and survival of individuals have the potential to, for instance, affect population growth rates and population structure. Impacts resulting in population effects would be considered significant (i.e. if effects are long term and detrimental to the population as a whole).

8.6.1 Construction Phase

As discussed previously, works for the proposed Project will primarily involve the dredging and reclamation for the GRS and submarine gas pipeline installation. Potential impacts associated with these construction activities are summarised in *Table 8.5*. Effects on Indo-Pacific humpback dolphins have been assessed and are discussed in detail below.

Table 8.5 Summary of Potential Construction Phase Impacts on Marine Mammals

Nature of Impact	Potential Impact
Permanent Habitat Loss	Permanent loss of approximately 0.5 ha of marine waters as potential marine mammal habitat due to the reclamation site
Potential Disturbance from Submarine Pipeline Installation Works	Potential disturbance from submarine gas pipeline installation operations
Potential Disturbance from Marine Works Vessels	Increased marine traffic and elevations in underwater sound level due to marine construction activities
Short-term Changes in Water Quality	Potential water quality impacts associated with marine construction activities
Contaminant Release & Bioaccumulation	Potential bioaccumulation of contaminants released from dredging/ jetting operations

Permanent Habitat Loss at the Reclamation Site

The proposed reclamation of about 0.5 ha at the BPPS for the GRS would result in a permanent loss of sea area and hence the permanent loss of nearshore marine mammal habitat. The physical loss of habitat during and after reclamation works may potentially affect some individuals of Indo-Pacific humpback dolphin, *Sousa chinensis*, which utilise Black Point waters as a part of their home range.

Based on findings of the literature review and comprehensive data review (*Sections 8A.3.7* and *8A.5* of *Annex 8A*), waters off Black Point are at the periphery of most dolphins' ranges, and only 10 of the 99 identified dolphins have consistently utilized the marine waters in this area (at 50% UD ranges). The nearshore waters under the footprint of the proposed reclamation, which is adjacent to artificial shoreline, are expected to be an area of low dolphin density and abundance and have been evaluated to be of low to moderate ecological importance.

It is also considered that the area of nearshore waters to be lost is very small and represents only a very small portion of available habitat for this species. Photo-identification studies have shown Indo-Pacific humpback dolphins have extensive home ranges often extending over 100 km^2 and may forage and feed throughout (4) (5). In the context of the size of the home ranges which may encompass extensive areas across western Hong Kong waters and beyond, the ~ 0.5 ha of habitat would represent a very minor portion of an individual animal's home range.

(4) ERM (2006) *Liquefied Natural Gas (LNG) Receiving Terminal and Associated Facilities: EIA Study* (EIA Study Brief ESB-126/2005). Prepared for CAPCO

(5) Hung SK (2008) *Habitat Use of Indo-Pacific Humpback Dolphins (*Sousa chinensis*) in Hong Kong*. Unpublished PhD Thesis. The University of Hong Kong

It should be noted that the habitat loss is not likely to significantly impact the fitness or vital rates of affected individual animals that currently utilise these waters. The permanent loss of marine habitat due to reclamation is not predicted to adversely impact the fisheries resources that would be available in the waters surrounding the reclaimed area (the fish and marine invertebrates in the marine habitat serve as marine mammal's food prey), since existing fisheries production from the affected shoreline area is very low.

Given that the potential impacts constitute a permanent, irreversible loss of only a very small area of low-to-moderate ecological importance marine mammal habitat with little, if any, secondary impacts, the severity of the impact is anticipated to be acceptable and adverse impacts are unlikely to be significant.

Potential Disturbance from Submarine Pipeline Installation Works

Direct impacts due to gas pipeline installation on Indo-Pacific humpback dolphin habitats in Deep Bay are not expected to be severe, as the pipeline construction works would not cause any permanent loss of the marine habitats in the area.

The proposed submarine gas pipelines will be installed by a combination of grab dredging and jetting (consideration of pipeline installation methods is presented in *Section 2.3.4*). Dredging and jetting have been used extensively in Hong Kong and there is no prior evidence that dolphins have ever been injured by dredging or jetting activities.

Marine mammal researchers have observed humpback dolphins in Hong Kong around dredging activities a number of times, and there is no evidence to suggest that areas in which dredging occurs (such as the Contaminated Mud Pit areas at East of Sha Chau and around Lung Kwu Chau) have been permanently abandoned by dolphins, although short-term decline in dolphin abundance may occur. The observations by the researchers appear to suggest that the dolphins have short-term avoidance of the immediate works areas of dredging / jetting activities (on the order of movements of several hundreds or thousands of metres).

In Hong Kong, there is some previous experience of pipeline impact assessment and the present Project would be the seventh similar pipeline to be installed or permitted (*Table 8.6*). These projects have all been installed or permitted in areas of high ecological importance and this Project has adopted similar construction methodology and mitigation measures.

Table 8.6 Summary of Previous Pipeline Projects in Areas of High Ecological Importance of Hong Kong

Pipeline Project	Installation Method	Date	Length	Passes Through/ Close to Sensitive Habitat				
				Marine Reserve	Marine Park	Indo-Pacific Humpback Dolphin	Finless Porpoise	Corals
Towngas Shenzhen – Tai Po	Dredging & Jetting	2005	~ 45 km		Yes			Yes
Towngas Tai Lam – Lantau	Dredging	1996	~ 5 km			Yes		
HEC Shenzhen – Lamma	Dredging & Jetting	2005	~ 90 km	Yes	Yes		Yes	Yes
AAHK PAFF – Sha Chau	Dredging	2006/ 2007	~ 8 km		Yes	Yes		
AAHK Sha Chau – Airport	Dredging	1996	~ 10 km		Yes	Yes		
CLP Yacheng – Black Point	Dredging	1995	~ 75 km		Yes	Yes	Yes	

The nature of works for the proposed pipelines for this Project is similar to these previously-approved projects (6). It is envisaged that the severity of potential impacts associated with this Project is considerably lower than the above previously-approved pipeline projects, given the shorter length of pipelines for this Project and the low to moderate ecological importance of Deep Bay for Indo-Pacific humpback dolphins. There is also no evidence of significant residual impacts on marine mammals due to dredging/ jetting. With appropriate mitigation and EM&A requirements, potential impacts to marine mammals were deemed environmentally acceptable.

There is a consensus among the leading local marine mammal specialists that reducing the duration of marine works and the area of marine concurrent anthropogenic activity is a highly-effective approach to reduce impacts on marine mammals. It is, therefore, important to reduce the total duration of marine works to limit potential short-term behavioural disturbance and / or displacement of dolphins.

In order to reduce the duration of works in different works area, the following approach has been adopted:

(6) The use of jetting in Indo-Pacific humpback dolphin habitats in HKSAR waters has been approved for previous submarine cable installation projects. Also results of the water quality modelling (Section 6.7.1) suggest that jetting did not result in any exceedance of the WQOs at sensitive receivers and is considered as an environmentally acceptable method.

- Adopt optimal pipeline installation methods: jetting is a comparatively faster way to construct a pipeline trench than grab dredging, and is adopted for the majority of the pipeline alignment (i.e. along Sections 2 and 4 with a total length of about 3.15 km) to shorten the works programme (7) (8) (9).

- Operate a number of dredgers concurrently (see *Section 6.7*): it is assumed that for the installation of each pipeline, two dredgers will be used.

At present, pipeline trenching and installation works have been scheduled to take place within a period of about five months for each construction phase. With a shorter works programme, it is expected that marine mammals that have avoided the vicinity of the works areas can return to the area sooner.

The majority of the pipeline trenches will be excavated by dredgers/ jetting machine operating 12 hours per day. This scheduling measure has been adopted as part of a marine mammal exclusion zone that will be implemented during dredging/ jetting works along the gas pipeline route. Such exclusion zones are most effectively enforced during daylight hours and hence dredging/ jetting works along the pipeline route have been scheduled to take place for 12 hours during daylight.

For safety reasons, dredgers will operate 24 hours on the pipeline section that crosses the Urmston Road channel off Black Point. It is important to minimise the duration of works in these areas to prevent risk to vessels and high speed ferries in this busy channel. It is not expected that night time dredging along this short section of the route will have any significant impact on marine mammals, since the abundance of Indo-Pacific humpback dolphins may be influenced not only by diurnal patterns but also tidal state (10).

The submarine pipelines will be laid from barges into the trenches on the seabed, and therefore will not cause an underwater obstruction to marine mammals. It should also be noted that the duration of the various activities is short as pipe-laying would be expected to occur for only one month.

(7) The jetting method does not generate any dredged material and can offer enormous benefit in terms of waste management given that existing capacity for contaminated sediment disposal is very limited. The potential merit of the jetting method is thus considered as critical to the overall environmental acceptability of this Project.

(8) The use of jetting along the Urmston Road Crossing section of the pipeline alignment is not feasible since a jetted pipeline trench with armour rock protection reaching only the seabed level cannot offer sufficient level of protection from the risk of anchor drop/ drag.

(9) It is acknowledged that dredging by trailing suction hopper dredger (TSHD) can be undertaken at a rate faster than that of jetting and can offer greater schedule benefit. However along Sections 2 and 4 of the proposed pipeline alignment, the water depths are too shallow (sometimes as shallow as -3 mPD only) to utilise a TSHD which typically has a draft of at least 5 m. Therefore the use of TSHD is not feasible. Also dredging by TSHD does not offer any environmental merit in terms of dredged material management.

(10) Convention on Migratory species (CMS): *Sousa chinensis* <http://www.cms.int/reports/small_cetaceans/data/S_chinensis/s_chinensis.htm> Access on 7 Sept 2009

Similarly, vessels involved in armour protection placement will proceed along the pipelines in a specific area and their activities are not expected to impact marine mammals. The placement of rock armour is not expected to cause impacts to water quality or marine ecological resources, as the vessel will comply with the speed limitations and the backfill material will have a low fines content. As the armour rocks will be placed directly on top of the pipe which is located at the bottom of the dredged trench, it is not expected to pose a collision risk/ obstruction to dolphins.

It should be noted that many similar pipelines have been installed or permitted in Hong Kong with similar post-construction protection using armour rock, including HEC Shenzhen to Lamma pipeline, AAHK PAFF pipeline and Towngas Shenzhen to Tai Po pipeline, in which some of the pipeline sections pass through Indo-Pacific humpback dolphin habitats, i.e. the Sha Chau Lung Kwu Chau Marine Park. Consequently, placement of rock armour on the gas pipelines is not expected to cause significant impacts to marine mammals.

Potential Disturbance from Marine Works Vessels

Increased Marine Traffic

Construction of the proposed Project has the potential to result in an increase in marine traffic associated with the dredging/ jetting and reclamation works, which may affect Indo-Pacific humpback dolphin. There are two key ways increased vessel traffic has the potential to impact marine mammals. Firstly, vessel movements may potentially increase physical risks to dolphins. Secondly, the physical presence of works vessels due to construction may cause short-term avoidance of the area where works vessels are operating.

In Hong Kong, there have been instances when dolphins have been killed or injured by vessel collisions [11] [12], and it is thought that this risk is mainly associated with high-speed vessels such as ferries. In terms of potential impacts arising from works vessel traffic of this Project, the risk of vessel collision is considered to be very small, as works vessels would be slow moving. Works vessels such as dredgers must necessarily move at slow speed as they perform works on the seabed. A number of other vessels, including tugs for the anchor lines, may be involved during the gas pipeline installation activities in addition to the works vessels, such as pipeline lay barge, dredging/ jetting plant and vessels for armour rock placement. These vessels would also be slow moving. Slow-moving vessels would not pose a significant risk to dolphins including young animals. To err on the side of caution, the risk of vessel strike will also be managed through a series of

(11) Parsons ECM, Jefferson TA (2000) Post-mortem investigations on stranded dolphins and porpoises from Hong Kong waters. *Journal of Wildlife Diseases* 36: 342-356

(12) Jefferson TA, Curry BE, Kinoshita R (2002) Mortality and morbidity of Hong Kong finless porpoises, with special emphasis on the role of environmental contaminants. *Raffles Bulletin of Zoology (Supplement)* 10: 161- 171

precautionary measures (*Section 8.8.2*). It should be noted that waters off Black Point have existing high levels of marine traffic using the Urmston Road channel. In this context, vessel traffic associated with the proposed Project would represent a minor increase in marine traffic in this area. The movements of all marine works vessels will be maintained to the specific works areas with the implementation of the rules for vessel operation,

The effect of the physical presence of work vessels and other vessels on dolphins would be limited to temporary behavioural disturbance of a number of animals, if and when encounters with vessels occur. It would be expected that these animals may avoid the vicinity of the works areas whilst works vessels are in operation. These disturbances would not be expected to have a biologically-significant impact on the affected animals. As discussed previously photo-identification of individual dolphins has shown these animals have extensive home ranges often of more than 100 km^2 and perform their main functions (feeding, socialising, breeding) throughout their home ranges. Therefore any works areas avoided would constitute a very small portion of the waters they inhabit.

This assumption that the presence of work vessels would not adversely impact marine mammals is consistent with other EIA and environmental monitoring studies in Hong Kong. Contaminated mud disposal facilities have been in operation in the East of Sha Chau area for over fifteen years. Data available on the use of the waters does not indicate that the operations of these facilities are resulting in long-term avoidance behaviour or displacement by the dolphins (13). In addition, dolphins have returned and are using the waters near the Chek Lap Kok airport (14). The construction of a blockwork jetty and dredging at Lung Kwu Chau inside Lung Kwu Chau and Sha Chau Marine Park in 2003 have not significantly affected dolphin utilisation in this area.

On the basis of the above, whole-scale changes to dolphin's behaviour are highly improbable during the pipeline installation works. Mothers and calves are in constant communication with each other, and it is extremely unlikely that there will be a separation between the two arising from the proposed works. Other individual (including life function [feeding, socialising and breeding] and fitness/ vital rate impacts) and population effects are also not anticipated due to the short-term nature of potential impacts.

Given that waters off Black Point are at the periphery of most dolphins' ranges and the inshore waters surrounding the proposed pipelines are expected to be

(13) ERM (2002) *Environmental Monitoring and audit for Contaminated Mud Pit IV at East Sha Chau*. Report for the Civil Engineering Department

(14) Jefferson TA (ed.) (2005) *Monitoring of Indo-Pacific humpback dolphins (*Sousa chinensis*) in Hong Kong waters – data analysis: final report*. Unpublished report submitted to the Hong Kong Agriculture, Fisheries and Conservation Department

an area of low dolphin density and abundance (*Sections 8A.3.7* and *8A.5*), unacceptable adverse impacts of increased marine traffic on Indo-Pacific humpback dolphin are not anticipated.

Underwater Sound

Marine construction activities can result in a short-term increase in underwater sound from marine vessels, which may potentially affect Indo-Pacific humpback dolphin.

Small cetaceans are acoustically sensitive at certain frequencies, and sound is important to their behavioural activities in terms of intraspecific communication. Most dolphins can hear within the range of 1 to 150 kHz, though the peak for a variety of species is between 8 and 90 kHz (15). Indo-Pacific humpback dolphins have been reported to use five categories of vocalisation associated with different activities (16). These animals use high-frequency broad-band clicks in the range of 8 kHz to > 22 kHz during foraging. During both foraging and socialising, burst pulse sounds of barks and quacks in the frequency range of 0.6 kHz to > 22 kHz are used. Low-frequency, narrow-band grunt vocalisations in the range of 0.5 kHz to 2.6 kHz are also used during socialising activity. Dolphins also have whistle vocalisations in a wide frequency from 0.9 kHz to 22 kHz (17).

Dredging/ jetting and large vessel traffic generally results in low-frequency noise, typically in the range of 0.02 to 1 kHz, which is below the peak range of 8 - 90 kHz reported for dolphins. For this reason, underwater sound generated by dredging/ jetting, pipe-laying operations and armour rock placement is not expected to acoustically interfere significantly with dolphins. Unacceptable adverse impacts of increased marine traffic on Indo-Pacific humpback dolphin are not anticipated.

Potential Water Quality Impacts

High SS levels do not appear to have a direct impact on dolphins since these animals are air breathing and therefore SS in the water column have no effect on their respiratory surfaces. Also Indo-Pacific humpback dolphins have evolved to inhabit areas near river mouths and are therefore well-adapted for hunting in turbid waters, owing to their use of echolocation, in addition to visual information.

With reference to the water quality modelling results (*Section 6.7*), fisheries resources are not predicted to be adversely affected, as the SS elevations are localized to the works areas. In addition, the level of fisheries production

(15) Richardson WJ, Greene CR, Malme CI, Thomson DH (1995) *Marine Mammals and Noise*. Academic Press

(16) Van Parijs SM, Corkeron PJ (2001) Vocalizations and behaviour of Pacific Humpback Dolphins *Sousa chinensis*. *Ethology* 107: 701-716

(17) It should be noted that Van Parijs & Corkeron (2001) only recorded up to a maximum of 22 kHz, and it is understood that many of these sounds may have components that go above 22 kHz.

from the works areas is known to be very low, suggesting that these areas are unlikely to be important feeding grounds for dolphins. The consequences of this are that impacts to marine mammals through loss of localised feeding habitat (fisheries resources) are not predicted to occur. It is thus expected that unacceptable impacts to marine mammals arising from elevated SS levels will not occur. It should be noted that the Indo-Pacific humpback dolphin and their prey species are naturally exposed to high levels of suspended solids in the Pearl River Estuary.

In terms of the potential impacts of jetting on marine mammal habitat inside the Sha Chau and Lung Kwu Chau Marine Park, results of the water quality modelling show that SS elevations as a result of jetting operations for pipeline installation in both the Hong Kong and PRC waters are predicted to be compliant with the water quality objectives for both seasons at the northern boundary of the Marine Park. These elevations will be short-term, since the jetting operations will only last for a short period of time (about 1 month).

With the implementation of effective mitigation measures, such as the optimisation of jetting rates and water quality monitoring, adverse impacts to marine mammal habitat within the Sha Chau and Lung Kwu Chau Marine Park are therefore not expected. It is important to note that jetting will not be undertaken concurrently with dredging operations and will only commence upon completion of dredging activities.

Other EIA studies that have addressed impacts due to elevated SS have drawn similar conclusions. For instance, a previously-approved EIA study for the Permanent Aviation Fuel Facility (PAFF) (EIA-077/2002) (18) stated that: "*There is no reason to assume that suspended solid releases during pipeline construction will have an impact on dolphins*". Based on the assessment above and other experience with the effects of suspended sediment on marine mammals, elevations in SS associated with the marine works for this Project are not anticipated to adversely impact dolphins.

Contaminant Release & Bioaccumulation

Another potential impact on marine mammals associated with disturbance of bottom sediment during dredging or jetting is the potential bioaccumulation of released contaminants. The potential for release of contaminants from sediments when disturbed has been reviewed in *Section 6*, whereas, a comprehensive set of data on the quality of marine sediment is provided in *Section 7*. Within these *Sections* it is concluded that some of the samples from the reclamation and dredging/ jetting area contained levels of arsenic in excess of the Lower Chemical Exceedance Level (LCEL), but below the Upper Chemical Exceedance Level (UCEL), i.e. Category M. It is highly likely that

(18) Mouchel Asia Limited (2002) *EIA for Permanent Aviation Fuel Facility for Hong Kong International Airport*. Prepared for Hong Kong Airport Authority

the elevated levels of arsenic are derived from natural sources, e.g. local geology, and are not present as a result of human activity [19].

In terms of the potential for impacts to occur to marine mammals, a recent EM&A conducted on the continuation of the disposal of highly-contaminated marine muds into dedicated mud pits in the East of Sha Chau area provides the best available information on bioaccumulation in marine mammals in Hong Kong [20]. The assessment, which was based on bio-concentration factors and metal concentrations in local fish and shellfish species, provided a comparison between the risks to dolphins in areas where Category H marine sediments would be dredged / disposed and those areas considered as being uncontaminated. Exposure pathways were assumed to be consumption of contaminated food by dolphins that utilise waters in the vicinity of the disposal ground, and in an area representative of background conditions. The result of this detailed risk assessment, which has been approved under the *EIAO*, concluded that elevated levels of arsenic in dredged marine sediments do not pose an adverse risk to the Indo-Pacific humpback dolphins of Hong Kong.

Concentrations of arsenic are low (compared to concentrations in potential prey) in liver and kidney of most cetaceans, including Indo-Pacific humpback dolphins. Concentrations of arsenic in cetacean tissues usually are lower than those in their prey [21] [22]. Most of the arsenic in dolphin prey is in organic forms, particularly arsenobetaine, which is excreted unmetabolized in the urine by most mammals and poses little threat to their livelihood.

The aforementioned assessment was based on highly-contaminated mud, i.e. Category H. The suite of analytes analysed for sediments collected off Black Point has included a range of organic compounds, including polychlorinated organic compound, specified in the relevant Technical Circular (*PNAP 252*). All samples reported concentrations of these substances below the reporting limits.

As the release of heavy metals and micro-organic pollutants from the sediment when disturbed are expected to be of short duration and at low levels, impacts on marine mammals due to bioaccumulation of released contaminants from dredged sediments are not expected to occur.

(19) EPD (2002) Marine Water Quality in Hong Kong in 2002

(20) ERM (2008) *Environmental Monitoring & Audit of the Contaminated Mud Pits at East of Sha Chau (2005-2008): Second Risk Assessment Report*. Prepared for Civil Engineering and Development Department

(21) Neff JM (1997) Ecotoxicology of arsenic in the marine environment. *Environmental Toxicology and Chemistry* 16: 917-927

(22) Parsons ECM (1999) Trace element concentrations in tissues of cetaceans from Hong Kong's territorial waters. *Environmental Conservation*: 26: 30-40

8.6.2 *Operation Phase*

No impacts are expected to occur during the operation of the submarine pipelines and the GRSs. In addition, unacceptable adverse impacts of changes in hydrodynamic regime and secondary water quality impacts on marine ecological resources are not anticipated (*Section 6.8*), hence potential secondary, indirect effects on Indo-Pacific humpback dolphins are not predicted to occur.

In the event of leakage or loss of containment in a submarine pipeline, given its low solubility in seawater, the natural gas will bubble to the sea surface. Unacceptable impacts on Indo-Pacific humpback dolphins are thus not expected to occur.

8.7 *IMPACT EVALUATION*

Based upon the information presented *in Sections 8.5* and *8.6*, the significance of the marine ecological impacts associated with the construction and operation of the proposed Project has been evaluated in accordance with the *EIAO-TM* (*Annex 8, Table 1*). The outcomes of this evaluation are summarised in *Table 8.7*.

This impact assessment indicates that no unacceptable impacts to marine ecology are expected to occur. Furthermore, any predicted changes to water quality, and hence surrounding marine habitats, are as a result of applying specific mitigation measures likely to be localised to the works area, to be of short duration, to be reversible and will occur within a limited and transient mixing zone.

Permanent loss of subtidal benthic assemblages under the reclamation footprint is anticipated; however, these assemblages are regarded as of low ecological value and given the small affected area, such loss is deemed acceptable. Although soft bottom habitat within the pipeline dredging / jetting works areas will also be temporarily lost, it has been demonstrated through long-term monitoring of previously dredged areas and existing Contaminated Mud Pits in the East of Sha Chau area that marine organisms have recolonised the areas following the completion of the works (23). As such, it is anticipated that subtidal assemblages influenced by dredging/ jetting will settle on and recolonise the seabed, returning it to the former conditions.

The loss of intertidal and subtidal assemblages on existing seawalls due to reclamation is expected to be compensated through the provision of seawalls that provide adequate surfaces for colonisation, once reclamation works have

(23) Qian PY, Qiu JW, Kennish R, Reid CA (2003) Recolonisation of benthic infauna subsequent to capping of contaminated dredged materials in East Sha Chau, Hong Kong. Estuarine, Coastal & Shelf Science 56: 819-831

been completed (200 m of concrete armour vertical seawalls). It is anticipated that intertidal and subtidal assemblages similar to those recorded in the field surveys, will settle on and recolonise the newly-constructed seawalls of the reclamation.

With appropriate mitigation measures, no biologically-significant impacts to marine mammals are expected to occur. The ~ 0.5 ha reclamation will cause permanent and irreversible loss of marine mammal habitat of low to moderate ecological importance. Dolphins that have short-term avoidance of the immediate works areas of marine construction activities are expected to return to the areas upon completion of the works. Consequently, whole-scale changes to dolphin's behaviour are highly improbable during the marine construction works, and other individual (including life function [feeding, socialising and breeding] and fitness/ vital rate impacts) and population effects are also not anticipated due to the short-term nature of potential impacts.

Potential impacts to marine ecological resources including the Indo-Pacific humpback dolphins, during operation of the facilities are not predicted to occur.

Table 8.7 Significance of Marine Ecological Impacts Associated with the Construction and Operation of the Proposed Project Evaluated in accordance with EIAO-TM

Criteria	Marine Ecological Resources	Marine Mammals
Habitat Quality	Impacts are predicted to occur only to the low ecological value coastal habitats (intertidal and subtidal) and benthic habitats within the reclamation site and along the pipeline alignment. The selection of the reclamation site and pipeline alignment has avoided natural shores, habitats of high ecological value and the Sha Chau and Lung Kwu Chau Marine Park. Potential water quality impacts and associated impacts to marine ecological resources and sensitive receivers have been shown to be compliant with the relevant assessment criteria.	The reclamation works will affect about 0.5 ha of marine waters off Black Point where low densities of Indo-Pacific humpback dolphins may occur. The submarine pipelines also pass through areas of low densities of dolphins. These waters, which are marine mammal habitat of low to moderate ecological importance, represent a very minor portion of extensive home ranges of affected animals. The marine waters at this location have been disturbed through reclamation in the past and are not considered to represent key habitat for dolphins. These waters are also affected by high volumes of vessel traffic.
Species	Based on literature and field surveys, no organisms of ecological interest were identified in proximity to Black Point. Marine ecological sensitive receivers including horseshoe crab, seagrass and mangrove habitats were situated at distant locations from the proposed works. No impacts are expected to these sensitive receivers.	Organisms of ecological interest reported from the literature include the Indo-Pacific humpback dolphin. Significant impacts are not predicted to occur to this species, due to the marine works, as water quality perturbations are predicted to be transient and compliant with the WQO. Only indirect, temporary disturbance to marine mammals due to disturbance and underwater sound from increased marine traffic are expected.
Size	The total size of the reclamation site is about 0.5 ha, including about 200 m of artificial shore. Low ecological value intertidal, subtidal hard surface and benthic assemblages within the GRS footprint will be directly impacted. The low ecological value benthic assemblages within the approximately 15.6 ha pipeline alignment (~ 5 km in HKSAR waters, trench wide is 3 - 35 m wide) will be lost during dredging/ jetting but are expected to become re-established within a year (see *Reversibility*). Low ecological value artificial shore assemblages are expected to recolonise.	The reclamation works will affect about 0.5 ha of marine waters where low levels of Indo-Pacific humpback dolphin density have been reported. The marine waters have been disturbed through reclamation in the past and are not considered to represent key habitat for dolphins. The loss of ~ 0.5 ha of marine waters would be an unavoidable consequence of the proposed Project, but the reclamation engineering required for the GRS has been reduced in size to the greatest extent practicable. The total length of the gas pipelines is about 5 km in HKSAR waters with the dredged trench width of 3 – 35 m. The nature and scale of pipeline installation works is comparable to other pipeline projects in Hong Kong that were deemed acceptable to construct in habitats of Indo-Pacific humpback dolphins inside the Sha Chau and Lung Kwu Chau Marine Park. Experience from these projects indicates that, with appropriate mitigation and monitoring, marine mammals are not likely to be adversely affected in the long term by such works.

Criteria	Marine Ecological Resources	Marine Mammals
Duration	The reclamation works are predicted to last for 6 - 7 months and the pipeline trenching and installation works for approximately 5 months. Increases in SS levels in the vicinity of sensitive receivers are expected to be low and temporary, and within environmentally acceptable limits as defined by the relevant assessment criteria.	The reclamation works are predicted to last for 6 - 7 months and the pipeline trenching and installation works for approximately 5 months. Increases in SS levels in the vicinity of sensitive receivers are expected to be low and temporary, and within environmentally-acceptable limits as defined by the WQO.
Reversibility	Impacts to the benthic assemblages inhabiting the soft bottom habitats along the pipeline alignment are expected to be relatively short-term and recolonisation of the sediments is expected to occur. Similarly, the low ecological value assemblages present on the artificial seawall can be expected to recolonise the seawall once it is reinstated.	The only permanent impacts at Black Point to dolphins are likely to be from the reclamation works, which will affect about 0.5 ha of marine waters where Indo-Pacific humpback dolphin have been recorded in low densities.
Magnitude	No unacceptable impacts to the ecologically sensitive habitats have been predicted to occur. Operation phase impacts are not expected to occur.	No unacceptable impacts to affected individual dolphins have been predicted to occur. Operation phase impacts are not expected to occur.

8.8 MITIGATION MEASURES

8.8.1 General

In accordance with the guidelines in the *EIAO-TM* on marine ecology impact assessment, the general policy for mitigating impacts to marine ecological resources, in order of priority, are:

- **Avoidance**: Potential impacts should be avoided to the maximum extent practicable by adopting suitable alternatives;
- **Minimisation**: Unavoidable impacts should be minimised by taking appropriate and practicable measures such as constraints on the intensity of works operations (e.g. dredging/ jetting rates) or timing of works operations; and
- **Compensation**: The loss of important species and habitats may be provided for elsewhere as compensation. Enhancement and other conservation measures should always be considered whenever possible.

To summarise, this initial assessment of impacts demonstrates that impacts will largely be avoided during the construction and operation of the proposed Project, particularly to the key ecological sensitive receivers (marine mammals), through the following measures:

- **Avoid Direct and Indirect Impacts to Ecologically Sensitive Habitats**: The site for the GRS reclamation has avoided the key habitats for Indo-Pacific humpback dolphin (including Sha Chau and Lung Kwu Chau Marine Park) and areas of high marine mammal sighting density. The location of the reclamation at BPPS has a low sighting density of marine mammals. Dispersion of sediment from dredging and sand filling does not affect the ecological receivers at levels of concern.
- **Pipeline Alignment**: The preferred alignment of the two submarine pipelines is at a sufficient distance from key ecological sensitive habitats, such as the Sha Chau and Lung Kwu Chau Marine Park, so that the transient [24] elevation of suspended sediment concentrations from the installation works does not affect the receivers at levels of concern.
- **Installation Equipment**: The installation of the pipelines has been shown to be environmentally acceptable and compliant with the water quality assessment criteria.

(24) Whilst installation works of the gas pipelines along the 5 km route would take about 6 months, works proceeding along individual sections of the route would give rise to short term, low level and transient impacts on habitats

- **Adoption of Acceptable Working Rates**: The modelling work has demonstrated that the selected working rates for dredging/ jetting will not cause unacceptable impacts to the receiving water quality (25). Consequently, unacceptable indirect impacts to marine ecological sensitive receivers and resources have been avoided.

8.8.2 *General Measures for Marine Ecological Resources*

The following measures to mitigate the impact of the construction and operation of the marine ecological resources, including marine mammals, are recommended:

- The vessel operators will be required to control and manage all effluent from vessels to prevent avoidable water quality impacts;

- A policy of no dumping of rubbish, food, oil, or chemicals will be strictly enforced. This will also be covered in the contractor briefings; and

- The effects of construction of the Project on the water quality of the area will be reduced as described in the *Water Quality Impact Assessment* (*Section 6*). These measures will serve to ensure water quality impacts are compliant with the relevant water quality standards, as set out in statutory Water Quality Objectives.

8.8.3 *Specific Measures for Marine Mammals*

Measures to mitigate the impact of the construction and operation of the Project have been developed in consultation with an internationally-recognised marine mammal expert. The following recommendations may be considered to reduce potential construction and operation impacts on Indo-Pacific humpback dolphins:

- All vessel operators working on the Project construction will be given a briefing, alerting them to the possible presence of dolphins in the marine works area, and the guidelines for safe vessel operation in the presence of cetaceans. If high-speed vessels are used in this Project, they will be required to slow to 10 knots when passing through the Project's marine works area. With implementation of this measure, the chance of boat strike resulting in physical injury or mortality of marine mammals will be extremely unlikely. Similarly, by observing the guidelines, vessels will be operated in an appropriate manner so that marine mammals will not be subject to undue disturbance or harassment; and

(25) Except for the pipeline section along Urmston Road, dredging/ jetting works shall be restricted to a daily maximum of 12 hours with daylight operations. Because of marine traffic constraints, dredgers may need to operate 24 hours on the pipeline section that crosses the Urmston Road channel off Black Point, enabling completion in the shortest possible time.

- The vessel operators of this Project will be required to use predefined and regular routes, as these will become known to dolphins using these waters. This measure will further serve to minimise disturbance to marine mammals due to vessel movements.

In line with current practice in areas where Indo-Pacific humpback dolphins are present in Hong Kong, the following measures will be adopted during marine dredging or jetting operations to assist in the protection of marine mammals:

- A marine mammal exclusion zone within a radius of 250 m from dredgers / jetting laybarge will be implemented during the construction phase. Qualified observer(s) will scan an exclusion zone of 250 m radius around the work area for at least 30 minutes prior to the start of dredging / jetting. If cetaceans are observed in the exclusion zone, dredging / jetting will be delayed until they have left the area. This measure will ensure the area in the vicinity of the dredging / jetting work is clear of marine mammals prior to the commencement of works and will serve to reduce any disturbance to marine mammals. As per previous practice in Hong Kong, should cetaceans move into the dredging / jetting area during dredging, it is considered that cetaceans will have acclimatised themselves to the works, therefore cessation of dredging / jetting is not required (26).

8.9 RESIDUAL ENVIRONMENTAL IMPACTS

Taking into consideration the ecological value of the habitats discussed in the previous sections and the resultant mitigation and precautionary measures, residual impacts occurring as a result of the proposed terminal have been determined and are as follows:

- The loss of approximately 100 m of artificial shoreline which is of low ecological value. The residual impact is considered to be acceptable, as the loss of these habitats will be compensated by the provision of approximately 200 m of vertical seawalls that are expected to become recolonised by intertidal and subtidal assemblages of a similar nature after construction;

- The loss of about 0.5 ha of subtidal soft bottom assemblages within the reclamation sites. The residual impact is considered to be acceptable as the habitat is of low ecological concern and very small in size in the context of surrounding similar habitat.

(26) This precautionary measure is consistent with conditions for grab dredging works inside the Sha Chau and Lung Kwu Chau Marine Park included in the issued Environmental Permit for the Permanent Aviation Fuel Facility for Hong Kong International Airport project

- The loss of about 0.5 ha of marine waters within the reclamation sites. Although the habitat loss would be an inevitable and adverse consequence of the Project, the residual impact is assessed to be acceptable after taking into consideration a number of factors. The loss of marine mammal habitat is very small in the context of the size of habitat available to dolphins. Taking account of the sizable home ranges and mobility of affected animals, it is expected that the loss would not give rise to biologically significant adverse impacts on individual dolphins or the dolphin population as a whole. Additionally, low densities of dolphins are expected to occur in these waters, and the habitat which would be lost would not be considered key marine mammal habitat in particular due to considerable disturbance by heavy marine traffic.

- Approximately 7.8 ha of benthic habitats (*Table 8.5*) along each pipeline route will be physically disturbed during dredging/ jetting, but similar subtidal benthos will recolonise over time. The residual impacts are considered to be acceptable as the habitats are of low ecological value and because infaunal organisms and epibenthic fauna are expected to recolonise the sediments after the pipelines have been laid.

- Given that the daylight operations have been specified for dredging/ jetting activities (except for 24-hour dredging across Urmston Road pipeline section) it is expected that potential disturbance and displacement of dolphins from the works area are expected to be temporary and of relatively short duration, making them acceptable.

8.10 CUMULATIVE IMPACTS

8.10.1 *Project-Specific Cumulative Impacts*

The assessment presented herein has already addressed the cumulative effects of different activities of this Project on marine ecological resources. The *Water Quality Assessment* (*Section 6*) was based on the worst-case scenario of concurrent construction of all Project facilities and thus has also incorporated the cumulative impacts of this specific Project. The cumulative impacts of the various project-specific construction activities have been demonstrated in *Section 6* as not causing unacceptable impacts to water quality. Consequently, unacceptable cumulative impacts to marine ecological resources are not predicted to occur.

8.10.2 *Cumulative Impacts with Other Developments*

As for the cumulative impacts with other developments in northwestern or western Hong Kong waters, information from publicly available sources suggested that the construction/ implementation programmes of the following major projects would coincide with the construction of this Project (27):

- Hong Kong Link Road (HKLR) of the Hong Kong – Zhuhai – Macao Bridge (HZMB), which is about 15 km south of the pipeline corridor;
- Hong Kong Boundary Crossing Facilities (HKBCF) of the HZMB, which is about 12 km south of the pipeline corridor;
- Tuen Mun – Chek Lap Kok Link (TMCLKL), which is about 10 km from the pipeline corridor; and
- Contaminated Mud Pits (CMPs) at East Sha Chau and South Brothers, which are at least 10 km from the pipeline corridor.

Results of water quality modelling undertaken as part of this EIA Study (see *Section 6* for details) showed that sediment plumes from the construction of this Project were limited to within about 3 km of the marine works areas. Sediment plumes of similar sizes were also reported in the EIA of the CMPs (28). Water quality modelling and assessment conducted as part of ARUP (2009a,b) (29) (30) suggested that the sediment plumes from the construction of the HKLR, HKBCF and TMCLKL were generally confined to within the sheltered East Tung Chung Bay and do not merge with sediment plumes from the other concurrent projects, although the plumes could, under certain tidal conditions, slightly mix with the plumes from the (unmitigated) Lantau Logistic Park. Since the water quality mixing zone of this Project is unlikely to overlap with those of other concurrent projects in this part of Hong Kong, it can, therefore, be concluded that cumulative impacts on water quality impacts and hence on marine ecological resources are not predicted to occur.

Project-specific adverse operation phase impacts on marine ecological resources are not expected to occur (*Sections 8.5.2* and *8.6.2*), thus operation phase cumulative impacts with other developments in and around Black Point are not predicted.

Indo-Pacific Humpback Dolphins

Impacts presented in *Section 8.6.1* were examined to evaluate potential cumulative impacts with other developments in northwestern or western Hong Kong waters. Outcomes of this evaluation are summarised as follows:

(27) Information from the Shenzhen Port Tonggu Channel Developing Office indicates that maintenance dredging of the Tonggu Waterway may take place annually. Updated information to determine if there is any overlap with the construction for this Project is not available and this will be reviewed at a later stage

(28) ERM (2005) *New Contaminated Mud Marine Disposal Facility at Airport East / East Sha Chau Area: EIA Report*. Prepared for CEDD

(29) ARUP (2009a) *Environmental Impact Assessment of the Hong Kong - Zhuhai - Macao Bridge Hong Kong Link Road*. Prepared for Highways Department

(30) ARUP (2009b) *Environmental Impact Assessment of the Hong Kong - Zhuhai - Macao Bridge Hong Kong Boundary Crossing Facilities*. Prepared for Highways Department

- Permanent Habitat Loss: Permanent habitat loss as a result of this Project is considered to be very small (0.5 ha), is focussed on a disturbed areas that was reclaimed in the past and is unlikely to exert an unacceptable cumulative effect. Major development projects in this part of Hong Kong are expected to result in a loss of about 487 ha of potential dolphin habitats in HKSAR waters and 80 ha in adjacent PRC waters, of which about 319 ha were considered as habitats regularly used by humpback dolphins [31] [32]. The severity of such cumulative habitat loss is expected to be significantly reduced to acceptable levels by mitigation measures proposed as part of the HKBCF EIA study.

- Underwater Sound: this Project does not involve any noisy construction methods such as underwater piling, hence it is not anticipated to aggravate potential underwater sound impacts arising from other projects in the vicinity. This Project is located at sufficient distance (> 10 km) from other projects, and given the similarity in underwater acoustic profiles generated by works vessels of this Project and other projects (by the use of large vessels generating low-frequency sound), cumulative effects of works vessels operational sound, if any, are anticipated to be negligible.

- Marine Traffic from Dredging Activities & Other Marine Works: this Project is located at sufficient distance (> 10 km) from other projects in the vicinity such that the cumulative effects of marine traffic disturbance and dolphin collision risk, if any, are anticipated to be negligible. It is expected that similar, slow-moving works vessels would be used in this Project and other projects, and similar mitigation measures, e.g. vessel speed limit and regular routes (*Section 8.8.3*) would be adopted in different project to minimise the magnitude of potential cumulative impacts.

On the basis of the above, cumulative impacts on Indo-Pacific humpback dolphins are not predicted to occur.

Intertidal & Subtidal Assemblages

Intertidal and subtidal assemblages within the Study Area are considered as of low ecological value. Given the small extent of this Project, temporary or permanent loss of these assemblages as a result of this Project are not anticipated to contribute to unacceptable cumulative impacts with other developments in northwestern and western Hong Kong waters.

(31) ARUP (2009a) *Op cit*

(32) ARUP (2009b) *Op cit*

8.11 ENVIRONMENTAL MONITORING & AUDIT

The following presents a summary of the Environmental Monitoring and Audit (EM&A) measures focussed on ecology during the construction and operation phases of the proposed Project.

8.11.1 *Construction Phase*

During the construction phase, the following EM&A measures will be undertaken to verify the predictions in the impact assessment and ensure the environmental acceptability of the construction works:

- Water quality impacts will be monitored and checked through the implementation of a Water Quality EM&A programme (refer to *Section 6* for details). The monitoring and control of water quality impacts will also serve to avoid unacceptable impacts to marine ecological resources.

- An exclusion zone will also be monitored for the presence of marine mammals around the dredging / jetting barges during construction of the GRS reclamation and submarine pipelines, as described in *Section 8.8.4*. Through implementation of the recommended EM&A measures, unacceptable impacts on marine mammals will likely be avoided. Details of the marine mammal exclusion zone monitoring components are presented in full in the EM&A Manual presented separately.

In addition, CAPCO will conduct additional monitoring of the distribution and abundance of dolphins during the pre-construction, construction and post-construction phases of the Project to document potential changes in the dolphin distribution pattern with regard to this Project and recovery of dolphin habitat use in the vicinity of the works area. Details of the monitoring programme will be developed at a later stage (e.g. during Environmental Monitoring & Audit).

8.11.2 *Operation Phase*

The assessment presented above has indicated that significant operational phase impacts are not expected to occur to marine ecological resources. Consequently, no marine ecology-specific operation phase EM&A measures are considered necessary.

8.12 SUMMARY & CONCLUSIONS

The present Project has selected a preferred location for the GRS reclamation and submarine pipelines alignment that avoids, to the extent practical, adverse impacts to habitats or species of high ecological value, e.g. intertidal mudflat and horseshoe crab nursery ground in Ha Pak Nai and the Sha Chau and Lung Kwu Chau Marine Park, both of which are located at least 3 km from the Project and are considered to be too remote to be affected. Marine ecological resources in close proximity to the proposed Project are regarded as of low to low-to-moderate ecological values (*Table 8.2*).

Although the permanent loss of about 0.5 ha of marine mammal habitat would be an inevitable consequence of the project, the residual impact is assessed to be acceptable after taking into consideration a number of factors. The loss of marine mammal habitat is very small in the context of the size of habitat available to dolphins. Taking account of the sizable home ranges and mobility of affected animals, it is expected that the loss would not give rise to biologically-significant impacts on individual dolphins or the dolphin population as a whole. Also, only low densities of dolphins are expected to occur in these waters, thus the habitat that would be lost would not be considered key marine mammal habitat.

Likewise, the loss of about 0.5 ha of subtidal soft-bottom habitats due to the reclamation is considered as environmentally acceptable since the area affected is relatively small in the context of the extent of similar habitat available in the vicinity and the low ecological value of the affected assemblages.

As impacts arising from the proposed dredging and jetting works are predicted to be largely confined to the specific works areas and the predicted elevations of suspended sediment, due to the Project, are not predicted to cause exceedances of the relevant assessment criteria, adverse impacts to water quality, and hence marine ecological resources or marine mammals, are not anticipated.

Measures designed to reduce impacts to the population of marine mammals that use the area include restrictions on vessel speed. The mitigation measures designed to reduce impacts to water quality to acceptable levels (compliance with WQOs) are also expected to mitigate impacts to marine ecological resources.

Specific measures have been identified for marine works taking place in areas where marine mammals are sighted and these include monitored-exclusion zones during marine dredging and jetting works.

Operation phase adverse impacts to marine ecological resources are not expected to occur.

Annex 8A

Baseline Marine Ecological Resources

CONTENTS

8A BASELINE MARINE ECOLOGICAL RESOURCES

8A.1 INTRODUCTION

This *Annex* describes the existing conditions of marine ecological resources within and in proximity to the proposed Project off Black Point. Marine ecological habitats and resources have been identified and the ecological value of the Study Area evaluated. The assessment has been based on a review of the available literature, as well as detailed field surveys to provide the most up-to-date information on existing conditions. The rationale for surveys is presented, followed by the methodologies employed, results obtained and a discussion of the results and comparison with other similar studies where appropriate. The findings enclosed within this *Annex* will form the basis of establishing the ecological importance of the different marine habitats within and around the proposed development areas.

8A.1.1 *Marine Ecological Study Area*

The Study Area for the marine ecological assessments has incorporated the footprint of the proposed reclamation at the Black Point Power Station (BPPS) and the broad alignment corridor for the submarine pipeline connection to the BPPS. It also covers an area of open water of north-western and western Hong Kong to ensure that potential marine ecological sensitivities that have been identified in the water quality impact assessment are considered (see *Section 6*). This relatively wide Study Area ensures that consideration is given to mobile species, in particular marine mammals that are present in the area. The Study Area is shown in *Figure 8A.1*.

8A.2 RELEVANT LEGISLATION & ASSESSMENT CRITERIA

Legislative requirements and evaluation criteria relevant to this Study for the protection of species and habitats of marine ecological importance are summarised below.

- *Marine Parks Ordinance (Cap 476)*;
- *Wild Animals Protection Ordinance (Cap 170)*;
- *Protection of Endangered Species of Animals and Plants Ordinance (Cap 586)*;
- *Town Planning Ordinance (Cap 131)*;
- *Hong Kong Planning Standards and Guidelines Chapter 10 (HKPSG)*;

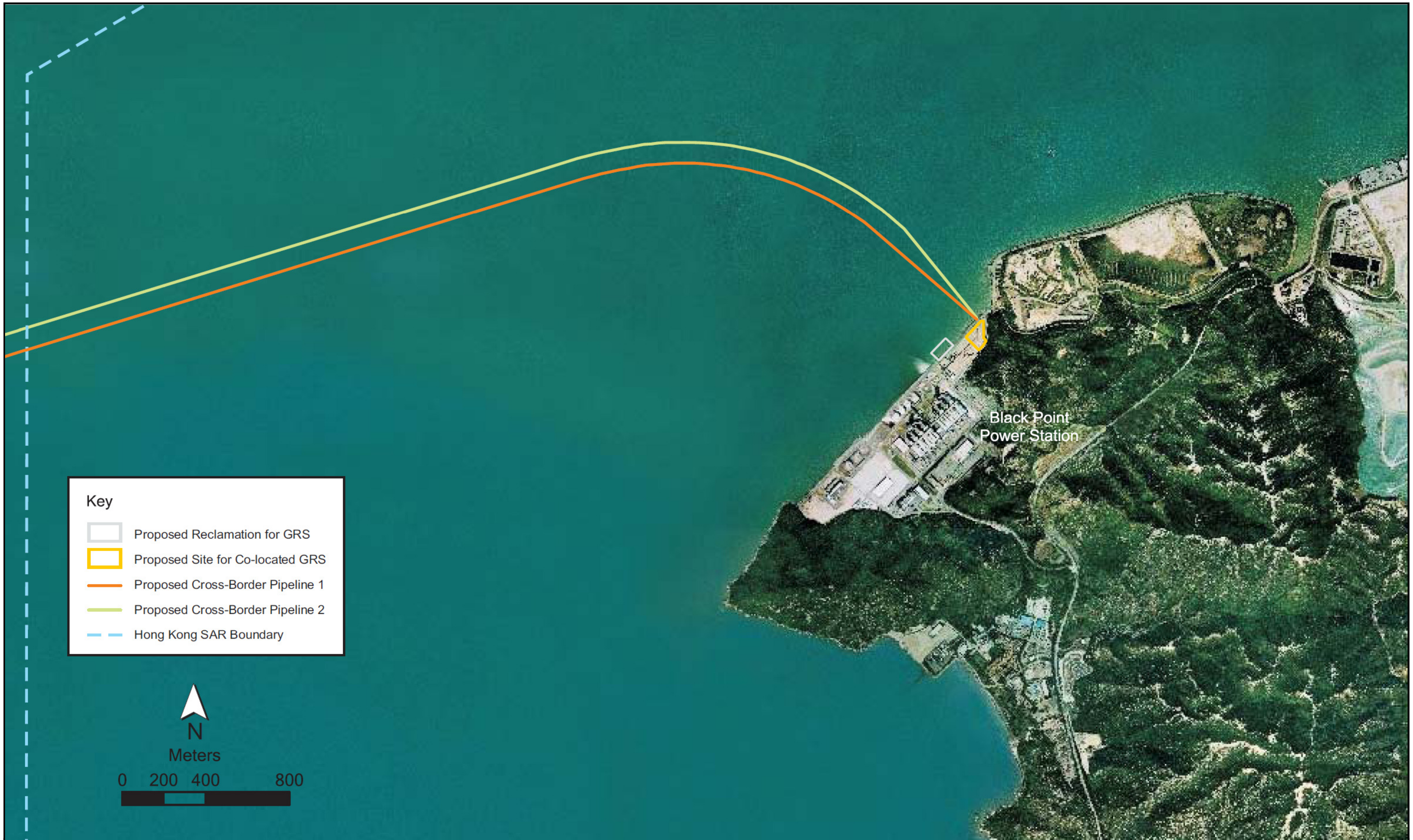

Figure 8A.1

Study Area for Marine Ecological Impact Assessment

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- *Technical Memorandum on Environmental Impact Assessment Process* under the *Environmental Impact Assessment Ordinance (EIAO TM)*;
- *United Nations Convention on Biodiversity (1992)*;
- *Convention on Wetlands of International Importance Especially as Waterfowl Habitat (the Ramsar Convention)*; and
- *PRC Regulations and Guidelines*.

Details on each of the above are presented below.

8A.2.1 Marine Parks Ordinance (Cap 476)

The *Marine Parks Ordinance* provides for the designation, control and management of marine parks and marine reserves. It also stipulates the Director of Agriculture, Fisheries and Conservation as the Country and Marine Parks Authority, which is advised by the Country and Marine Parks Board. The *Marine Parks and Marine Reserves Regulation* was enacted in July 1996 to provide for the prohibition and control of certain activities in marine parks or marine reserves.

8A.2.2 Wild Animals Protection Ordinance (Cap 170)

Under the *Wild Animals Protection Ordinance*, designated wild animals are protected from being hunted, whilst their nests and eggs are protected from destruction and removal. All birds and most mammals including all cetaceans are protected under this Ordinance, as well as certain reptiles (including all sea turtles), amphibians and invertebrates. The Second Schedule of the Ordinance that lists all the animals protected was last revised in June 1997.

8A.2.3 Protection of Endangered Species of Animals and Plants Ordinance (Cap 586)

The *Protection of Endangered Species of Animals and Plants Ordinance* was enacted to align Hong Kong's control regime with the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). With effect from 1 July 2006, it replaces the *Animals and Plants (Protection of Endangered Species) Ordinance (Cap 187)*. The purpose of the *Protection of Endangered Species of Animals and Plants Ordinance* is to restrict the import and export of species listed in CITES Appendices so as to protect wildlife from overexploitation or extinction. The Ordinance is primarily related to controlling trade in threatened and endangered species and restricting the local possession of them. Certain types of corals are CITES listed, including Blue coral (*Heliopora coerulea*), Organ pipe corals (family Tubiporidae), Black corals (order Antipatharia), Stony coral (order Scleractinia), Fire corals (family Milleporidae) and Lace corals (family Stylasteridae). The import, export and possession of listed species, no matter whether dead or living, is restricted.

8A.2.4 *Town Planning Ordinance (Cap 131)*

The *Town Planning Ordinance* provides for the designation of areas such as "Coastal Protection Areas", "Sites of Special Scientific Interest (SSSIs)", "Green Belt" and "Conservation Area" to promote conservation or protection or protect significant habitat.

8A.2.5 *Hong Kong Planning Standards and Guidelines Chapter 10 (HKPSG)*

Chapter 10 of the *HKPSG* covers planning considerations relevant to conservation. This chapter details the principles of conservation, the conservation of natural landscape and habitats, historic buildings, archaeological sites and other antiquities. It also addresses the issue of enforcement. The appendices list the legislation and administrative controls for conservation, other conservation-related measures in Hong Kong, and Government departments involved in conservation.

8A.2.6 *Technical Memorandum on Environmental Impact Assessment Process under the Environmental Impact Assessment Ordinance (EIAO TM)*

Annex 16 of the *EIAO TM* sets out the general approach and methodology for assessment of ecological impacts arising from a project or proposal, to allow a complete and objective identification, prediction and evaluation of the potential ecological impacts. *Annex 8* recommends the criteria that can be used for evaluating ecological impacts.

8A.2.7 *Other Relevant Legislation*

The Peoples' Republic of China (PRC) is a Contracting Party to the *United Nations Convention on Biological Diversity* of 1992. The Convention requires signatories to make active efforts to protect and manage their biodiversity resources. The Government of the Hong Kong Special Administrative Region (HKSAR) has stated that it will be "committed to meeting the environmental objectives" of the Convention (PELB 1996).

The *Convention on Wetlands of International Importance Especially as Waterfowl Habitat* (the Ramsar Convention) applies in the HKSAR. The Convention requires parties to conserve and make wise use of wetland areas, particularly those supporting waterfowl populations. Article 1 of the Convention defines wetlands as "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters." The Mai Po/ Inner Deep Bay wetland was declared a Wetland of International Importance ("*Ramsar Site*") under the Convention in 1995.

The PRC in 1988 ratified the *Wild Animal Protection Law* of the PRC, which lays down basic principles for protecting wild animals. The Law prohibits killing of protected animals, controls hunting, and protects the habitats of wild animals, both protected and non-protected. The Law also provides for the creation of lists of animals protected at the state level, under Class I and Class II. There are 96 animal taxa in Class I and 161 in Class II. Class I provides a higher level of protection for animals considered to be more threatened.

8A.3 MARINE ECOLOGICAL RESOURCES – EXISTING INFORMATION

8A.3.1 Introduction

This section describes the baseline conditions of the marine ecological resources at the Study Area from existing information in available literature. Baseline conditions have been assessed based on a review of the findings of past marine ecological surveys around the Black Point area and other relevant studies, and the collation of available information regarding the marine ecological resources of this part of Hong Kong.

Based on this review, an evaluation of the information collected was conducted to identify any gaps and to conduct an assessment of ecological importance of the marine habitats. Where information gaps were identified or where certain habitats or species were considered to warrant further attention, focussed field surveys and detailed data reviews have been conducted (see *Sections 8A.4* and *8A.5*).

8A.3.2 Site Description

The site for the proposed GRS reclamation is adjacent to the existing BPPS near the northern reaches of the Urmston Road and on the outskirts of Deep Bay, while the proposed submarine gas pipelines will traverse the Urmston Road to exit the Hong Kong Special Administrative Region (HKSAR) boundary (*Figure 8A.1*). Black Point is located in the northwestern waters of Hong Kong. The surrounding waters are relatively shallow (~ – 5 – 8 mPD), apart from within the Urmston Road where the water depth can reach – 20 mPD.

In terms of water quality, the Study Area experiences relatively dynamic estuarine-influenced conditions. The waters are a mixture of flows from the waters in Deep Bay, which mainly come from the Pearl River Estuary and the Shenzhen River, and oceanic waters. The former two flows are freshwater and the latter is saline marine water, which mix together and result in wide variations of salinity with depth, location and time. During the wet season when river flows are at their highest, the surface salinity decreases to estuarine conditions, whereas during the dry season, typical oceanic salinity prevails throughout the water column.

The Project Site consists of coastal/ offshore waters and artificial shoreline of the BPPS. A very short stretch of natural shoreline (< 20 m) is present between BPPS seawalls and the Ash Lagoon seawalls.

Natural soft shores are only found at some distances from the Project Site. Soft shores at Ha Pak Nai are about 2.5 km north of the Project Site. These shores will not be directly impacted by the Project, and given their distance from the Project's marine works areas, indirect effects, if any, are anticipated to be negligible. They are thus not considered further here.

8A.3.3 Literature Review

A literature review was conducted to determine the existing marine ecological conditions within the Study Area to identify habitat resources and species of potential importance. The list of local literature reviewed is presented in *Annex 8A.8 References*.

Based on the literature review the following habitats and/or organisms of ecological interest have been identified within the Study Area:

- Intertidal hard bottom assemblages;
- Subtidal hard bottom assemblages;
- Subtidal soft bottom assemblages, including;
    - Epifaunal assemblages;
    - Infaunal assemblages; and
- Marine Mammal.

Existing conditions of each of the above marine resources based on available literature are presented in more detail in the following sections.

8A.3.4 Intertidal Hard Bottom Assemblages

Intertidal hard shores of Hong Kong display characteristic zonation patterns consisting of different algal and invertebrate species along the vertical gradient from terrestrial to marine environments.

The intertidal hard bottom habitat of the Project Site consists primarily of sheltered to moderately-exposed artificial sloping seawalls constructed in the 1990s. The most recent information regarding the ecology of this habitat is available from ERM (2006) (and references therein). Data extracted from this study provide a direct representation of the intertidal assemblages at the Study Area and its immediate vicinity.

Results of comprehensive seasonal intertidal surveys at the artificial sloping seawalls of BPPS in March and July 2004 indicated that this habitat comprised low abundances/ densities of common and widespread rocky shore species (1). A total of 12 and 15 species were recorded in the dry and wet season surveys respectively, and no species of conservation interest were recorded. In comparison to records of other similar habitats in Hong Kong reported in the literature, the diversity and abundance of intertidal biota at Black Point was considered to be low. Transect locations for the 2004 surveys are presented in *Figure 8A.2*.

Natural rocky shores at the Black Point headland are about 1 km south of the Project Site. Comprehensive seasonal intertidal surveys have been conducted on this stretch of shores as part of ERM (2006) and results indicated that this habitat is comprised of common and widespread rocky shore species (2). A total of 12 species were recorded in both the dry and wet season surveys, and no species of conservation interest were recorded (see *Table 1* of *Annex 8B*). In comparison to records of other similar habitats in Hong Kong reported in the literature, the diversity of intertidal biota at this shore was considered to be low. Transect locations for the surveys are presented in *Figure 8A.2*.

8A.3.5 Subtidal Hard Bottom Assemblages

Coral communities are commonly regarded as the most ecologically important and valuable subtidal hard bottom assemblages. The AFCD report that there are over 80 species of corals recorded in Hong Kong waters (Chan et al 2005). The general trend for coral communities in Hong Kong is one of increasing abundance and diversity from west to east with the greatest diversity and abundance generally found in the eastern waters of Hong Kong. It has been suggested that the distribution of corals is primarily controlled by hydrodynamic conditions, in particular salinity level, turbidity and light penetration.

The western waters of Hong Kong, including the Deep Bay and Black Point areas, are influenced by the Pearl River Estuary which reduces salinities, increases turbidity and therefore reduces light penetration. Due to the requirements for coral growth, the cumulative effect of these conditions results in sub-optimal conditions for coral recruitment and survival. Corals are therefore much less abundant and diverse in Hong Kong's western waters than eastern waters.

(1) Dominant species recorded in the 2004 surveys included the littorinid snails *Echinolittorina radiata*, *E. vidua* and *Littoraria articulata*, the common dogwhelk *Thais clavigera*, limpets *Nipponacmea concinna* and *Siphonaria japonica*, and snails *Monodonta labio* and *Planaxis sulcatus*, the rock oyster *Saccostrea cucullata*, barnacles *Capitulum mitella*, *Tetraclita japonica*, *T. squamosa* and *Balanus amphitrite*, and algae (*Ulva* sp. and encrusting algae).

(2) Species composition on the Black Point headland natural shores was similar to that recorded on BPPS artificial shores (see footnote above). The species recorded in the 2004 surveys are summarised in *Table 1* of *Annex 8B*.

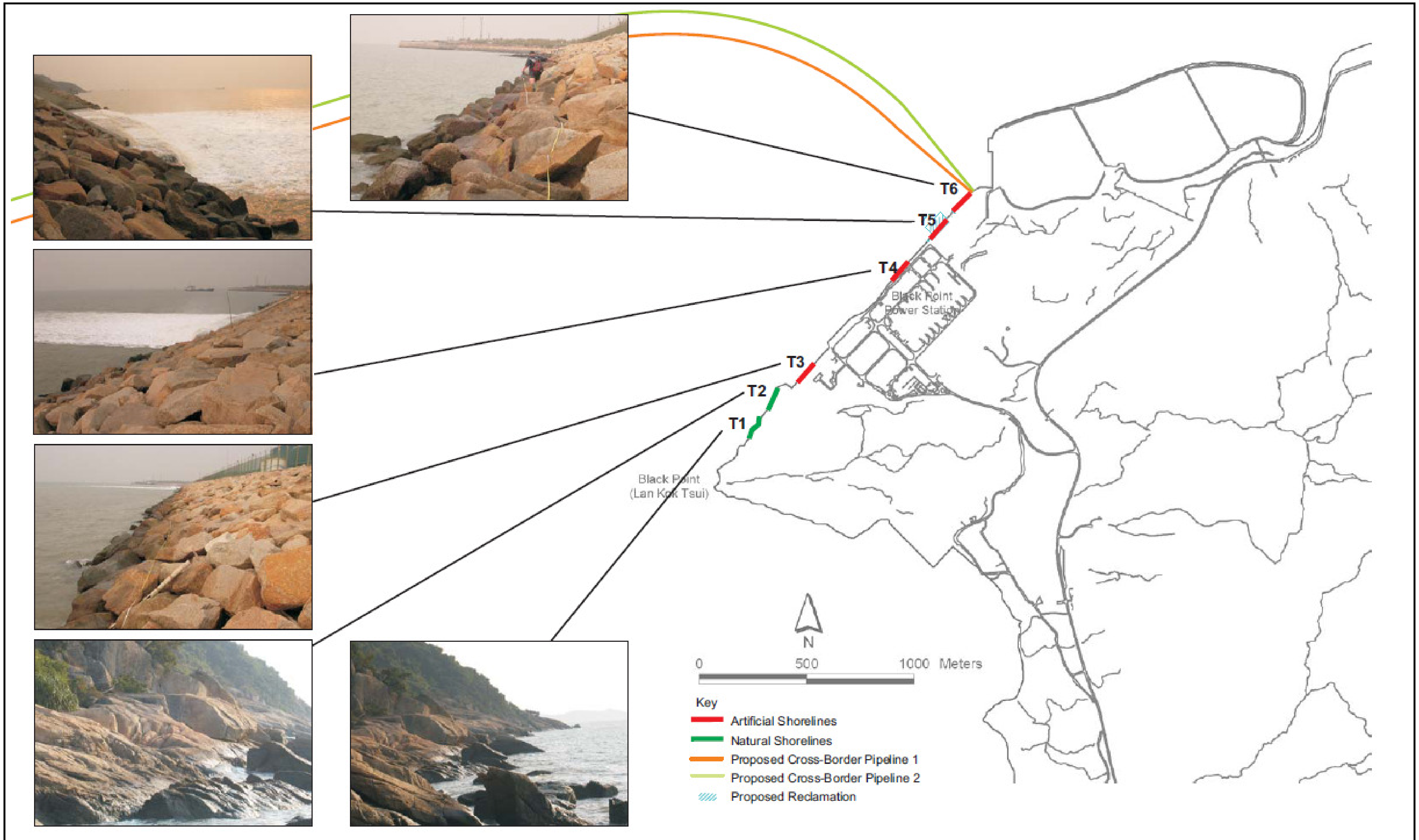

Figure 8A.2

Black Point Intertidal Sampling Transect Locations
(Reproduced from ERM (2006))

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Findings of the literature review suggest that there is no existing information on the subtidal hard bottom assemblages within the Study Area. Information on such assemblages in northwestern or western Hong Kong waters is limited to the findings reported in various EIA studies, which are summarised in *Table 8A.1*. These studies suggested that very low diversity and abundance of corals, predominantly octocorals and ahermatypic corals, were present in the survey areas in these waters.

Table 8A.1 Baseline Information on Subtidal Hard Bottom Assemblages in Western Hong Kong Water

Source	Location	Summary of Findings
ERM (1995)	Sha Chau	Only reported a few hermatypic hard corals (Family Faviidae) within the subtidal surveyed area
ERM (1997) Mouchel (2001)	East Sha Chau, Sham Tseng and Tsing Lung Tau	Solitary corals have been reported
Mouchel (2001) Maunsell (2002)	Sham Tseng, Tsing Lung Tau and Lung Kwu Chau	A number of ahermatypic cup corals (likely to be *Balanophyllia* or *Phyllangia* sp.), pale-blue gorgonian (*Euplexaura* sp.), soft coral *Dendronephthya* sp. colonies, isolated sea pens (*Virgularia* or *Pteroides* sp.) and one hermatypic coral *Oulastrea crispata* were recorded in June 2001 at Sham Tseng and Tsing Lung Tau. Similar results were also recorded in dive surveys at Lung Kwu Chau in November 2001
Mouchel (2004)	Sham Wat/ San Shek Wan	Recorded low abundance (< 5 % cover) of one hard ahermatypic cup coral *Balanophyllia* sp. on hard substrate to the west of Hong Kong International Airport (HKIA) at Sham Wat/ San Shek Wan and low abundance (< 5% cover) of the octocoral *Echinomuricea* sp at the eastern and southern sides of the HKIA in the October 2003 HZMB EBS survey. No hermatypic hard coral was recorded at any of the 27 dive sites
AFCD (2004a)	Intensive surveys in 2001-2002 to survey corals at 240 sites covering about 70 km of coastline in territorial waters	Hard corals were found in western waters of Hong Kong, but limited to southern Lantau waters (Tong Fuk, Soko Islands) and eastern (Cheung Chau, Hei Ling Chau) Lantau waters. Only sparse colonies or low-coverage communities composed of extremely tolerant and species were found
ARUP (2005)	Siu Ho Wan	Colonies of small-sized gorgonians (< 10 cm in length and < 1 % cover) were found on the boulders of the artificial seawalls near MTR depot at Siu Ho. No alive or dead hard corals were found

Source	Location	Summary of Findings
ARUP (2009a)	Sham Wat, Sha Lo Wan headland, Airport Channel, Airport Island, Tung Chung	No coral was found in the 2008 EVS survey within the Airport Channel. Only one genus of ahermatypic cup coral *Balanophyllia* and one genus of octocoral, *Echinomuricea* sp. were recorded from two and four of the seven survey sites respectively. Most hard substrates were dominated by barnacles, mussels and rock oysters
ARUP (2009b)	Northeast and southeast shores of Airport Island, and HKBCF reclamation site	Only 2 out of the 8 dive locations at southeast Airport Island had records of octocoral *Echinomuricea* sp. (< 1 % cover) in the 2009 MSS survey, and both sites are sloping boulder seawalls. Very low coverage of ahermatypic cup corals *Balanophyllia* sp. was found at the sloping seawall at northeast Airport Island. No hermatypic hard coral was recorded. No coral was found within the HKBCF reclamation site.
AECOM (2009)	Pillar Point, the Brothers and North Lantau near Tai Ho	Low coverage of populations of octocoral *Guaiagorgia* sp. (< 10%) and ahermatypic coral *Paracyathus rotundatus* (< 5%) were found along hard substrata

Ahermatypic cup corals and octocorals recorded in the northwestern/ western waters are less common in the oceanic eastern and southern waters of Hong Kong, as they appear to be adapted to the turbid and hyposaline conditions in western waters. The hard coral species recorded in the northwestern Hong Kong waters are very common in local waters (Scott 1984), although are more abundant in the eastern waters and the northwestern / western waters.

Although the surveys presented in *Table 8A.1* were conducted at some distance from Black Point, the results of these surveys may reflect the baseline condition in the artificial seawalls of BPPS due to similar environmental conditions. It is reasonable to expect that hard substrates are uncommon and very patchy in nature along the pipeline corridor given the heavy sedimentation of Pearl River Estuary and the presence of a homogeneous, silty/ muddy seabed in western Hong Kong waters. As such, coral communities of any ecological value or significance are not predicted to occur within the Study Area. Whilst it is possible that solitary gorgonians and sea pens may be present within the subtidal areas, large or important communities of hermatypic hard corals are not expected due to the unfavourable conditions imposed by the water quality.

8A.3.6 *Subtidal Soft Bottom Assemblages*

Epifaunal Assemblages

Subtidal epifauna are organisms (> 1 mm in size) living either on or within the surface sediments of the seabed. Due to the nature of the Hong Kong's fishery and the typical subtidal substratum in Hong Kong being soft bottom (sandy or silty) habitat, data on subtidal epifaunal assemblages in Hong Kong are primarily available from studies on benthic fisheries resources, collected by demersal trawling surveys.

Information on the epifaunal assemblages in proximity to the Study Area is available from a review of 15 years of data on fisheries resources collected from demersal trawls conducted as part of the ongoing marine monitoring of contaminated mud disposal at the East of Sha Chau Contaminated Mud Pits (ERM 2008). This review provides long-term data on epifaunal assemblages around Lung Kwu Chau. These data indicate that epifaunal assemblages at Lung Kwu Chau are dominated by gastropods (e.g. *Turritella terebra*), crabs (e.g. *Charybdis* spp.) and shrimps (e.g. *Metapenaeus* spp.), and are similar to other areas of Hong Kong. Abundance, biomass and Catch Per Unit Effort are, however, considered to be relatively low in comparison to other areas in Hong Kong. No species that were considered to be rare in Hong Kong were recorded.

Lung Kwu Chau is in relatively close proximity to the Study Area (about 3 km south), these data can be considered to be representative of the epifaunal assemblages in the Study Area.

<u>Horseshoe Crab</u>

Two species of horseshoe crab, *Tachypleus tridentatus* and *Carcinoscorpius rotundicauda*, have previously been recorded in AFCD surveys around Hong Kong waters (AFCD 2006) [(3)]. Juvenile horseshoe crabs can be found at mudflats at Ha Pak Nai/ Pak Nai in Deep Bay, and on intertidal sandy shores or mudflats at Tai Ho Bay, Tung Chung Bay, San Tau, Hau Hok Wan, Sha Lo Wan, Sham Wat Wan, Yi O and Shui Hau, Lantau Island (AFCD 2006, ARUP 2009a, b). Confirmed nursery sites for horseshoe crabs in recent years are Ha Pak Nai and Pak Nai in Deep Bay, San Tau near Tung Chung, Shui Hau at south Lantau and Tai Ho Bay in north Lantau (Chiu & Morton 1999, Fong 1999, Huang et al. 1999, Li 2008). Based on the abundance of juveniles, San Tau and Shui Hau are identified as the key nursery grounds for *C. rotundicauda* and *T. tridentatus* respectively (Li 2008).

Occurring in shallow to deep local waters, adult horseshoe crabs are occasionally fished by trawlers fishing from the subtidal mud in western Hong Kong waters, along the northwest coast of the Lantau Island including Tai O, Yi O, Sham Wat Wan, Sha Lo Wan and Tung Chung Bay (Huang et al. 1999).

Surveys conducted by Li (2008) in summer 2005 showed that both *Tachypleus tridentatus* and *Carcinoscorpius rotundicauda* were recorded in the survey areas

(3) A third species of horseshoe crab *Tachypleus gigas* was not recorded in Hong Kong since March 1995 and its local status is uncertain (Chiu & Morton 1999), likely to be locally extinct

of Pak Nai and Ha Pak Nai, with *C. rotundicauda* at very low abundance (only 1-2 individuals were recorded during the 5-month survey). Horseshoe crab nursery ground at Ha Pak Nai/ Pak Nai is located far away from the proposed GRS reclamation and proposed submarine gas pipelines (at least 2.5 km), and is considered to be too remote to be affected by the Project works.

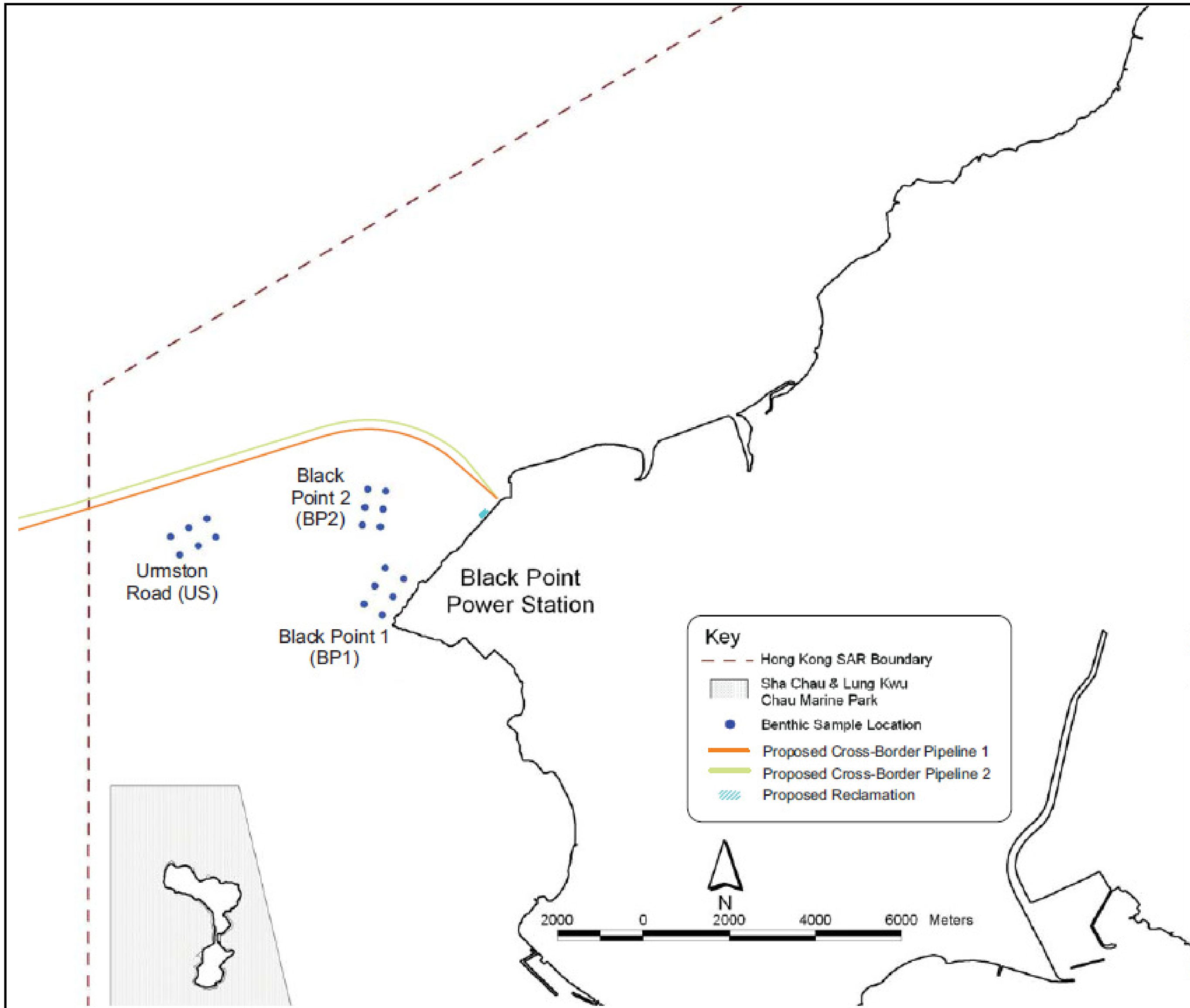
Infaunal Assemblages

Subtidal infauna are organisms (> 0.5 mm in size) living either on or within the surface sediments of the seabed. For the Deep Bay area, CityU Professional Services Limited (2002) reported that its infaunal assemblages were distinctive from those of the rest of Hong Kong waters, which was resulted from the influence of freshwater discharges from the Pearl River Estuary and the Shenzhen River. These conditions led to seasonal changes in the assemblages between the summer and winter months. The substratum of the Study Area and its vicinity is expected to be covered by very fine sand and/or silt, and the infaunal assemblages consisted mainly of soft, muddy bottom species dominated by opportunistic, pollution-tolerant species such as *Prionospio* spp. and *Mediomastus* spp. Whilst species diversity and abundance off Black Point were comparable with other locations in western Hong Kong waters, biomass of species recorded appeared to be higher than these locations especially in the wet season. Species diversity was, however, lower than that reported in South Lantau, Lamma and waters to the east of Hong Kong.

In addition to the above, ERM (2000) reported that the benthic infauna near Lung Kwu Tan has a generally mid-range total biomass and relatively high total number of individuals in comparison to other areas of Hong Kong. The fauna was found to be primarily polychaete worms, which is typical for Hong Kong. The species richness was high compared to other sites surveyed using the same techniques. Overall the site was found to exhibit similar ecological characteristics and patterns as other areas in the northwest New Territories and north Lantau.

Comprehensive seasonal data on the subtidal infaunal assemblages within and in the vicinity of the Study Area is available from ERM (2006) which provided an update from CityU Professional Services Limited (2002) and ERM (2000). Data from ERM (2006) therefore provide the best available data to represent the subtidal infauna assemblages within the Study Area

A comprehensive series of seasonal benthic surveys were conducted off Black Point in February and July 2004 (ERM 2006). Benthic sampling locations for the 2004 surveys are presented in *Figure 8A.3* and the results summarised below. Grab samples taken from three sites off the Black Point area in northwestern waters of Hong Kong indicate that in both seasons, infaunal assemblages off Black Point were dominated by polychaete worms (especially *Prionospio queenslandica*), except for the Urmston Road during the wet season where bivalves (especially the estuarine clam *Potamocorbula laevis*) had higher



Modified Van Veen grab as used to collect samples at Black Point and the Study Area

An example of a benthic grab sample before sieving.

Benthic sieving being carried out by an ERM Marine Scientist

Figure 8A.3

Black Point Subtidal Soft-Bottom Sampling Stations
(Reproduced from ERM (2006))

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numbers. No species of conservation interest or rare species have been recorded previously around the Black Point area.

In comparison to other subtidal infaunal assemblages of western and southwestern Hong Kong waters which were surveyed under the same survey programme, the abundance, biomass and taxonomic richness of infauna around Black Point are considered to be low to medium in both seasons, except for infaunal abundance and biomass in the wet season which are considered to be medium to high as contributed by high abundance of the estuarine clam (ERM 2006).

Biomass recorded during the 2004 survey at Black Point and Urmston Road was comparatively higher than other locations during the wet season, which was due to a generally higher proportion of bivalves recorded off Black Point. Whilst the biomass at Black Point was similar to or slightly lower than Western Lantau during the dry season, biomass at Urmston Road was similar to areas such as Lung Kwu Chau & Sha Chau, Peng Chau and Southwest of Po Toi during the dry season (*Figure 8A.4*).

In terms of species richness, infaunal assemblages at the Black Point and Urmston Road were considered to be similar to other locations reported in Hong Kong (CityU Professional Services Ltd 2002). The number of species of the benthic organisms in Black Point and Urmston Road recorded in the 2004 surveys were in the range of 26 to 31 species per 0.576 m^2 during wet season and 20 to 35 species per 0.576 m^2 during dry season, in which the mean number of species of the 120 stations reported in CityU Professional Services Ltd (2002) were 32.9 per 0.5 m^2 (wet season) and 33.7 per 0.5 m^2 (dry season) respectively.

8A.3.7 *Marine Mammals*

A total of 17 (and possibly up to 19) species of marine mammals (mostly cetaceans) have been recorded in Hong Kong waters (including one humpback whale sighted in 2009), two of which are considered residents: the Indo-Pacific humpback dolphin (*Sousa chinensis*, locally called Chinese white dolphins) and the finless porpoise (*Neophocaena phocaenoides*) (Jefferson & Hung 2007). Whilst the distribution of Indo-Pacific humpback dolphins is limited to the western waters of Hong Kong, which are influenced by freshwater input from the Pearl River (Parsons 1998, Jefferson 2000), finless porpoises are common in the waters of southern and eastern Hong Kong and do not occur in Hong Kong's northwestern waters (apart from very occasional strandings) (Jefferson & Hung 2007). Given the distinctive local distribution patterns of these two species, for the purpose of this review, only *Sousa chinensis* is discussed in this Study.

Owing to the high mobility of Indo-Pacific humpback dolphins, information available for not only the Study Area, but also waters of Deep Bay and

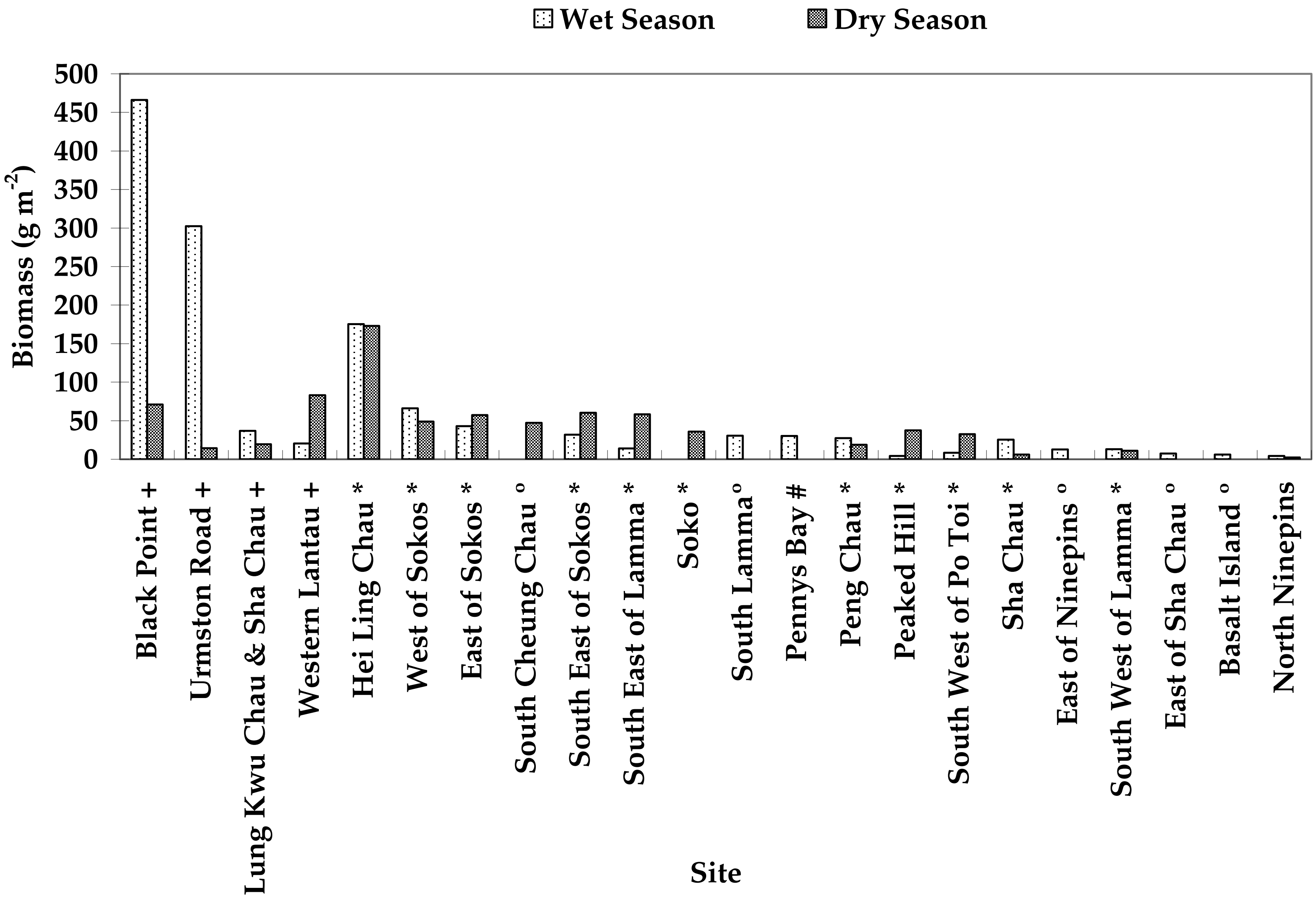

Figure 8A.4

Comparison of Mean Biomass of Subtidal Infaunal Assemblages around Hong Kong

(Reproduced from ERM (2006); +ERM (2006), *CityU Professional Services (2002), ºERM (1998) and #ERM (2000))

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western Northwest Lantau (including Black Point and Lung Kwu Chau & Sha Chau) have been the primary focus for this review to provide baseline conditions of a wider spatial coverage. Where available and appropriate, information on *Sousa chinensis* in waters of West and Southwest Lantau are also presented to provide additional useful information.

The Indo-Pacific humpback dolphin *Sousa chinensis* is a tropical/ sub-tropical cetacean widely distributed in the coastal and inshore waters of the Indian and western Pacific oceans (Hung 2008). It is protected locally by the *Wild Animals Protection Ordinance (Cap. 170)*, and is listed as "Near Threatened" in the 2008 IUCN Red List of Threatened Species (IUCN 2008). *Sousa chinensis* is also listed in CITES Appendix I (i.e. highest protection), and is listed as a "Grade I National Key Protected Species" in China. As such *Sousa chinensis* is considered a species of conservation interest/ concern, both locally in Hong Kong and regionally in China and across the Asia Pacific.

Studies on the distribution, abundance, habitat use, and life history of Indo-Pacific humpback dolphins within Hong Kong have been undertaken since September 1995 (Jefferson 2000, Jefferson et al 2002, Jefferson & Hung 2004). The AFCD reported that in 2006 at least 1,200 (4) individual dolphins were estimated to utilise the waters of the Pearl River Estuary and Hong Kong (5). A more recent estimate using 2004 to 2006 survey data indicates that the total population size of this species in these waters is considered to be about 1,300 to 1,500 individuals (Jefferson 2007). Of these individual dolphins, approximately 350 are thought to include waters within Hong Kong as part of their range.

Abundance of humpback dolphins in Hong Kong waters is the highest in the West Lantau and North Lantau (east of Lung Kwu Chau) areas *(*AFCD 2004, Hung 2008*)*. These areas are considered to be the major habitats for humpback dolphins in Hong Kong waters, where individuals of humpback dolphins have been consistently sighted throughout the year (Jefferson 2000, Jefferson & Hung 2004). Seasonal and spatial variation of abundance of humpback dolphins is usually observed; this is thought to be due to the increased input of freshwater from the discharge of the Pearl River Estuary and the subsequent movements of estuarine prey species into Hong Kong from PRC waters (Jefferson 2000, Barros et al 2004, Jefferson & Hung 2004, Hung 2008). The abundance of humpback dolphins in Hong Kong's waters, estimated using sighting effort data collected in Hong Kong between 2004 and 2006, ranged from 103 in spring to 193 in autumn (Jefferson 2007).

(4) This estimate did not include the individuals found in the western Estuary, southwest of Macau and Zhuhai, and therefore only represented a minimum.

(5) Agriculture, Fisheries and Conservation Department (AFCD): Chinese White Dolphin website <http://www.afcd.gov.hk/english/conservation/con_mar/con_mar_chi/con_mar_chi_chi/con_mar_chi_chi_abu_howmany.html> Accessed on 23 March 2009

Information on the utilisation of the waters around Black Point by humpback dolphins has been reviewed and the key finding is the recorded presence of this species in the waters in Deep Bay (and Northwest Lantau). From October 1995 to November 2004, there were 29 sightings of humpback dolphins (20 from vessels and 9 from helicopters) in Deep Bay (Dr TA Jefferson, pers comm). Deep Bay was found to be used by a small number of humpback dolphins (3-6 individuals) throughout the year, and dolphins occurred almost exclusively in the southern portion of Deep Bay, mostly near the Black Point headland. Average group size for humpback dolphins near Black Point was 2.9 ± 2.06 (range = 1 – 8, n = 29), which contained a smaller average group size than other areas in Hong Kong (Dr TA Jefferson, pers comm). This review highlighted that the waters around Black Point did not report large numbers of sightings, and are used as marginal habitat by dolphins in Hong Kong.

Recent studies on marine mammals in Hong Kong have attempted to conduct quantitative analysis of habitat use, by calculating the sighting densities and dolphin densities in terms of number of on-effort sightings/ dolphin abundance per km^2 with the survey area mapped using a 1 km by 1 km grid. These data are presented as Sightings Per Survey Effort (SPSE) and Density Per Survey Effort (DPSE) values. Results of AFCD's long-term monitoring suggest that the area around Black Point has a low density for dolphins, and the nearest high density area is along the east coast of Lung Kwu Chau (at least 3 km away).

Hung (2008) provided a detailed account of the Indo-Pacific humpback dolphin long-term monitoring data conducted in the Pearl River Estuary between 1996 and 2005. It supports previous findings that West Lantau is considered the most important area for dolphins in Hong Kong waters, followed by the area east of Lung Kwu Chau within the Sha Chau/ Lung Kwu Chau Marine Park. In contrast, humpback dolphins only used waters of Deep Bay infrequently (*Figure 8A.5*). The corrected sighting density (SPSE values) and dolphin density (DPSE values) (6) in Deep Bay were lower than those of other survey areas within Hong Kong (*Figures 8A.6* to *8A.8*).

Information regarding the abundance and distribution of Indo-Pacific humpback dolphins in waters within and in proximity to the Study Area is available from ERM (2006) which also included long-term data from AFCD (2004). Relevant data from ERM (2006) are thus extracted here to provide a

(6) For quantitative grid analysis of habitat use of dolphins, positions of on-effort sightings were plotted onto 1 km2 grids within the survey areas to calculate sighting density for each grid (number of on-effort sightings per km2). Sighting density grids were then normalized with the amount of survey effort conducted within each grid to provide a new, survey effort-corrected sighting density data, termed "SPSE", which represents the number of on-effort sightings per unit of survey effort. SPSE was further elaborated to look at actual dolphin densities (exact number of dolphins from on-effort sightings per km2). The new unit for this approach was termed "DPSE", which is the number of individual dolphins per unit of survey effort. Plotting the DPSE values of surveyed grid squares on maps allows areas where the most dense sightings of dolphins occur to be identified.

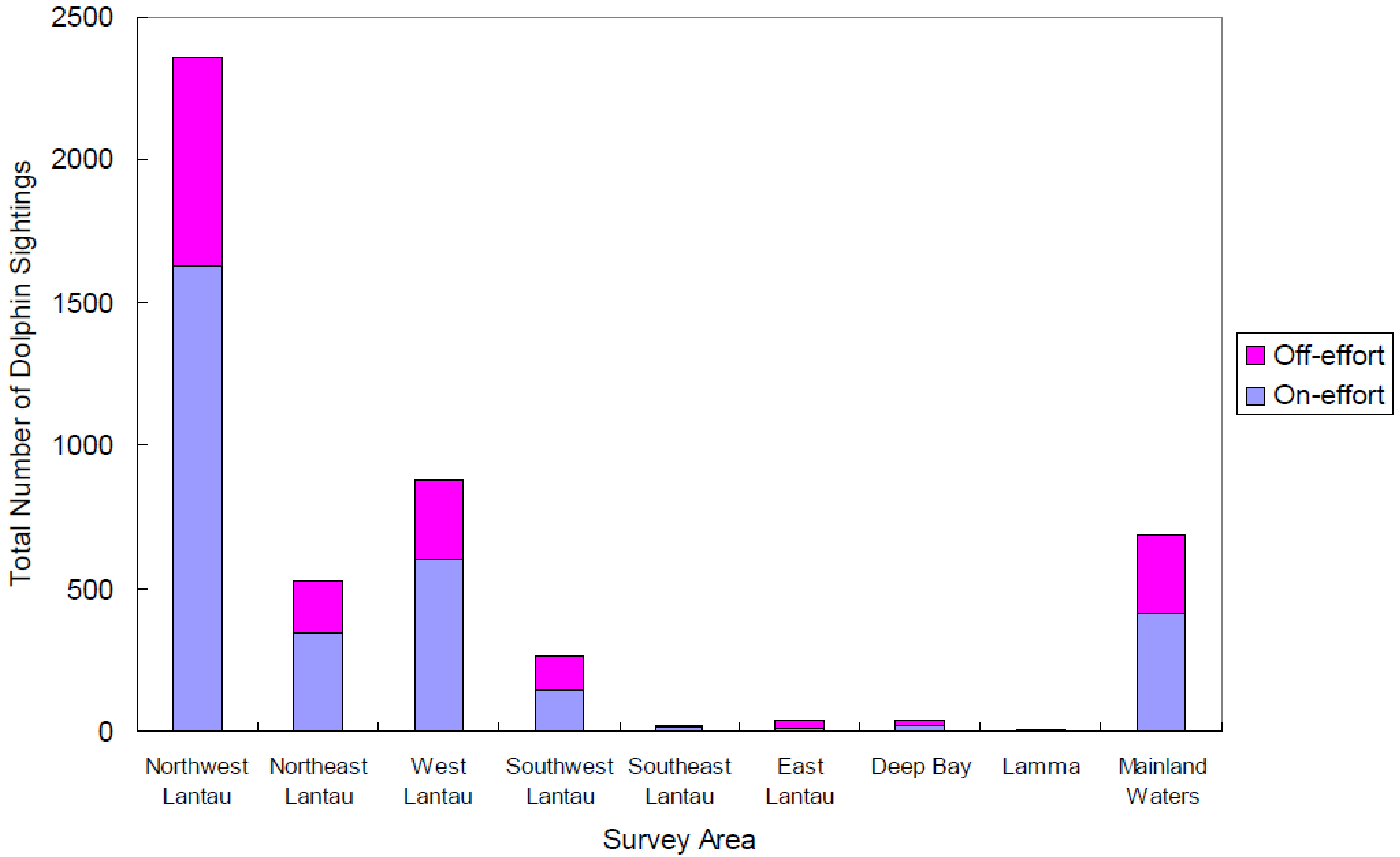

Figure 8A.5

Number of Indo-Pacific Humpback Dolphin Sightings in Different Survey Areas in Hong Kong and Mainland Chinese Territorial Waters during 1996-2005 (Reproduced from Hung (2008))

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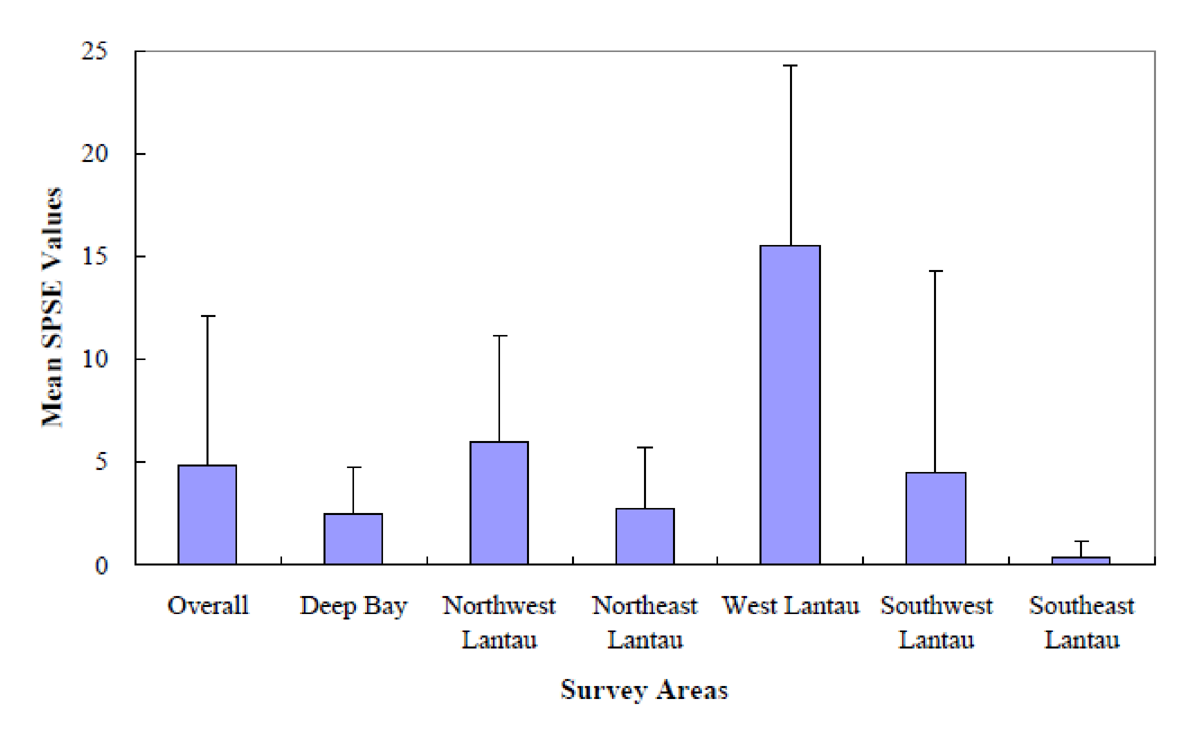

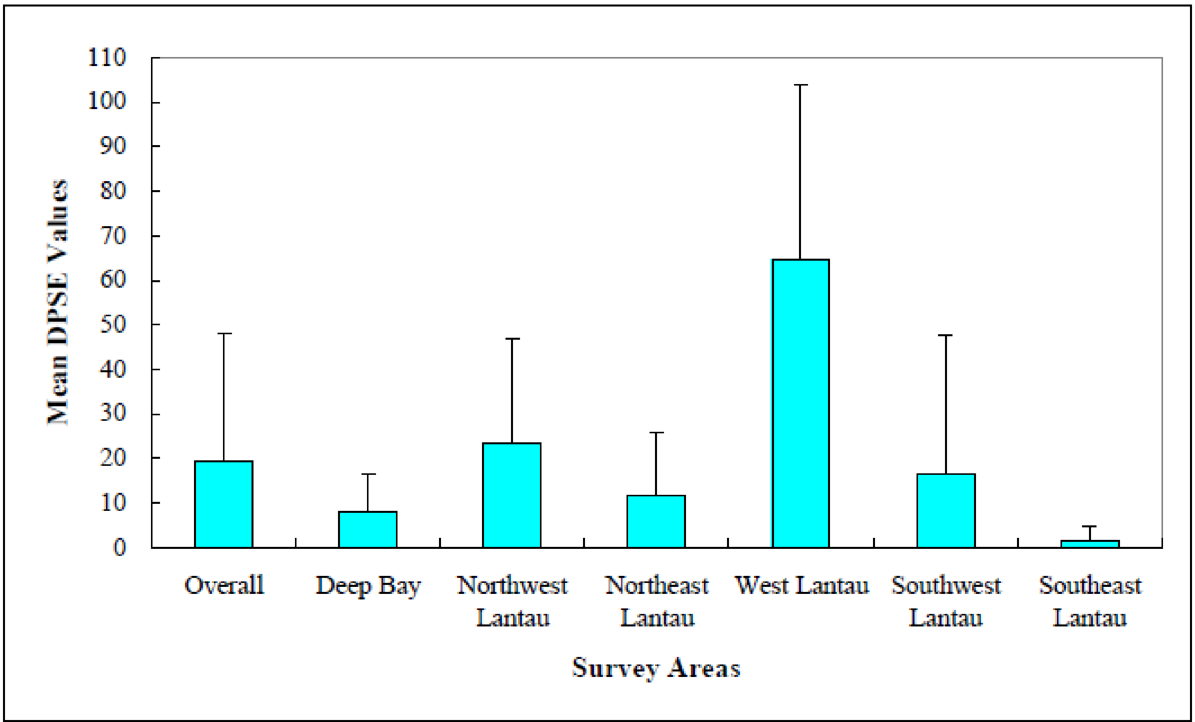

Figure 8A.6

Indo-Pacific Humpback Dolphin Sighting Densities (Mean SPSE ± SD; Top) and Dolphin Densities (mean DPSE ± SD; Bottom) among Six Survey Areas from1996-2005
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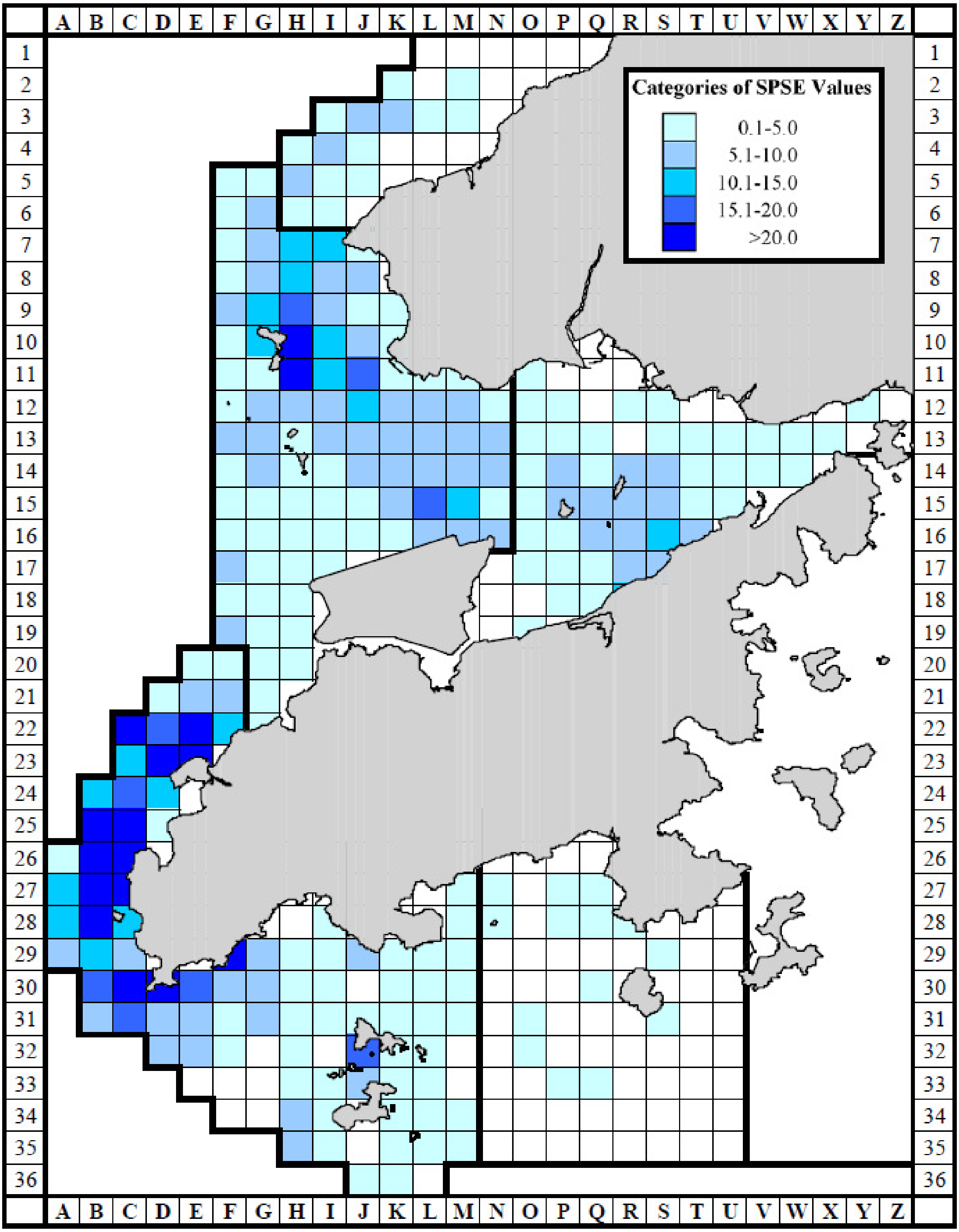

Figure 8A.7

Sighting Density of Indo-Pacific Humpback Dolphins Normalized by Survey Effort per km² in Waters around Lantau Island in 1996-2005 (SPSE = no. of on-effort dolphin sightings per 100 units of survey effort)
(Reproduced from Hung (2008))

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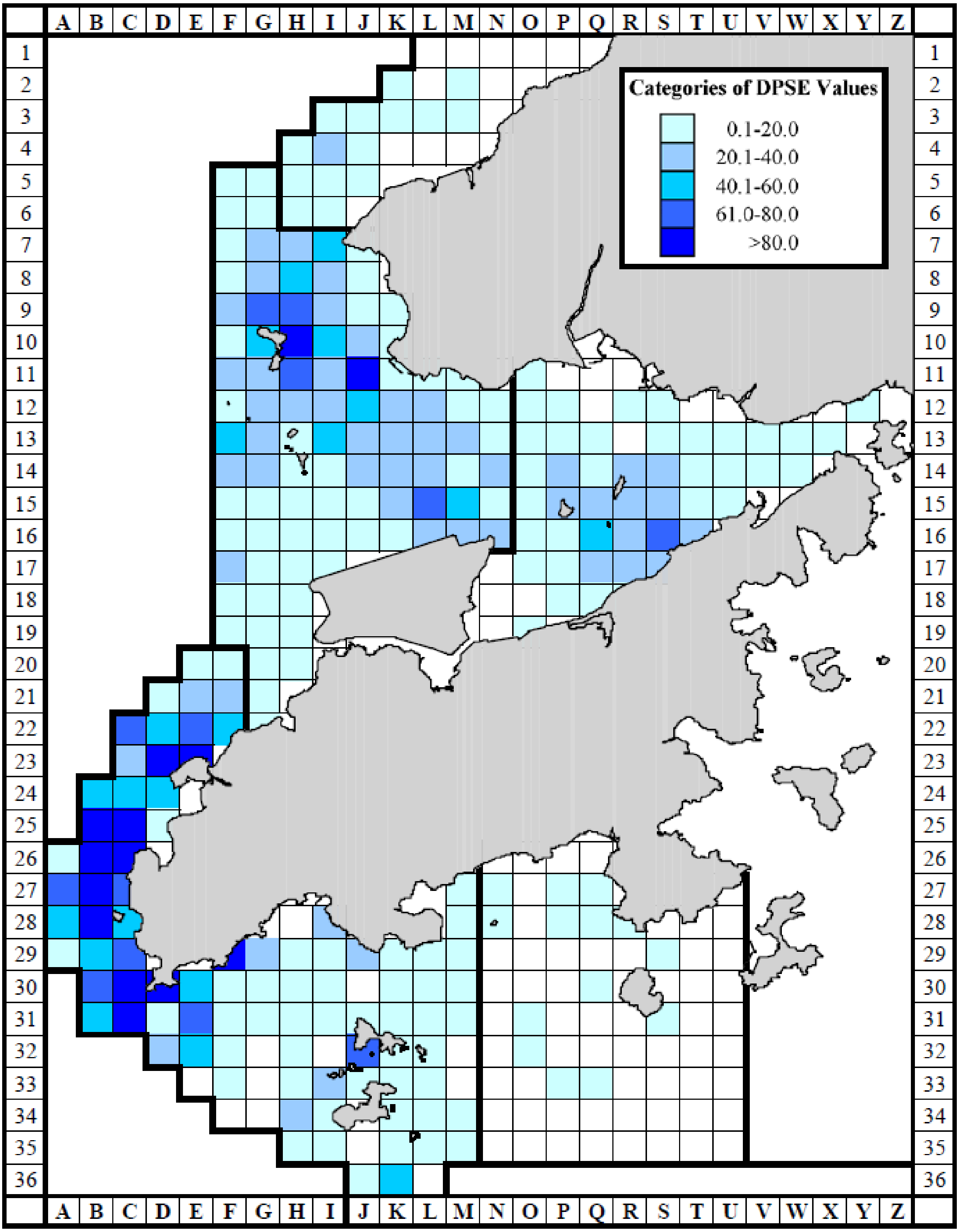

Figure 8A.8

Density of Indo-Pacific Humpback Dolphins Normalized by Survey Effort per km^2 in Waters around Lantau Island in 1996-2005 (DPSE = no. of dolphins per 100 units of survey effort) (Reproduced from Hung (2008))

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direct representation of the population ecology and habitat use of *Sousa chinensis* in this area.

An extensive programme of land- and vessel-based surveys for *Sousa chinensis* has been conducted off Black Point from February 2004 to May 2006 as part of ERM (2006) to supplement data available from AFCD's long-term monitoring (AFCD 2004). Monthly surveys were conducted to provide a detailed overview of dolphin utilisation of Hong Kong western waters, including the Northwest Lantau and Deep Bay areas (except for the northern part of Deep Bay). This survey programme was also undertaken in waters of West and Southwest Lantau.

Qualitative land-based dolphin surveys, conducted monthly from February 2004 to January 2005, recorded a total of 74 sightings of *S. chinensis* (a total of 141 individuals) within the 0.8 km-radius survey area, with no sighting records near the Black Point Power Station (ERM 2006; *Table 8A.2*). At Black Point, both the number of dolphin sightings and the number of individuals sighted were higher in winter and autumn than in spring and summer, with the majority of individuals recorded being adult-sized animals (109 out of 141 individuals sighted, ~ 77 %, *Table 8A.2*; ERM 2006).

Table 8A.2 *Summary of Results of Qualitative Land-Based Visual Survey of Indo-Pacific Humpback Dolphins at Black Point (Extracted from ERM (2006))*

Survey Detail	Qualitative land-based visual survey at Black Point
Duration	Monthly from February 2004 to January 2005
Survey Effort	360 hours (5 days per month and 6 hours per day for 12 months)
No. of Sightings	74 sightings • Winter: 31 sightings • Autumn: 23 sightings • Spring: 14 sightings • Summer: 6 sightings
No. of Individuals	141 individuals • Winter: 64 individuals • Autumn: 44 individuals • Spring & Summer: 33 individuals
Age Class	109 'Adult' (SA/ UA/ SP/ MO) 25 Juveniles (UJ) 7 Calves (UC)

As for the quantitative vessel-based surveys, which were conducted monthly from July 2005 to May 2006 in Deep Bay and Northwest Lantau, sighting records suggested that individuals of *Sousa chinensis* were sighted in waters off the Black Point Power Station and southern Deep Bay, but the fewest sightings took place in Deep Bay amongst the four areas surveyed. The majority of sightings were recorded along the West Lantau coastline, in

Southwest Lantau near Fan Lau, and in Northwest Lantau near the Sha Chau/ Lung Kwu Chau Marine Park (*Figure 8A.9*). Deep Bay also had relatively low densities (0.08 - 0.23 dolphins km^{-2}, depending on the season) and low estimates of abundance (< 10 dolphins in all seasons) within areas of western Hong Kong waters (*Table 8A.3*). In addition, dolphin average group size was the smallest for Deep Bay amongst the four areas surveyed (*Table 8A.3*).

Table 8A.3 ***Summary of Results of Quantitative Vessel-Based Line Transect Survey of Indo-Pacific Humpback Dolphins (Extracted from ERM (2006))***

	Quantitative vessel-based line transect survey			
Survey Area	Deep Bay	Northwest Lantau	West Lantau	Southwest Lantau
Duration	Monthly from July 2005 to May 2006			
Survey Effort (* useable transect distance)	906 km	385 km	396 km	2,409 km
No. of Sightings	25	62	109	79
+ Estimated individual density (D)	0.08 – 0.23 km^{-2}	0.57 – 0.94 km^{-2}	1.71 – 2.81 km^{-2}	0.10 – 0.44 km^{-2}
+ Estimated individual abundance (N)	2 – 7 individuals	49 – 82 individuals	47 – 78 individuals	6 – 29 individuals
Habitat Use (Average DPSE)	0.06 ± 0.12	0.44 ± 0.54	0.67 ± 0.51	0.09 ± 0.13
No. of grids with DPSE > 1	0 (out of 26 grids)	2 (out of 28 grids)	10 (out of 34 grids)	0 (out of 70 grid)
Proportion of Identified Dolphin Using the Survey Area as an Important Part of Their Home Range	5 out of 7 Identified Dolphins	12 out of 26 Identified Dolphins	11 out of 25 Identified Dolphins	4 out of 12 Identified Dolphins
Average Group Size	3.0 ± 2.37	3.7 ± 2.89	4.2 ± 3.8	3.6 ± 3.0

* Useable data were collected from surveys during relatively calm sea conditions of Beaufort 0-3

+ Individual density (D) represents an estimate of the number of individual dolphins in a 1 km^2 grid square area

Grid analysis of dolphin habitat-use data collected as part of ERM (2006) (estimated as Density Per Unit of Survey Effort [DPSE] [(7)]) showed that waters

(7) For quantitative grid analysis of habitat use of dolphins, positions of on-effort sightings were plotted onto 1 km2 grids within the survey areas to calculate sighting density for each grid (number of on-effort sightings per km2). Sighting density grids were then normalized with the amount of survey effort conducted within each grid to

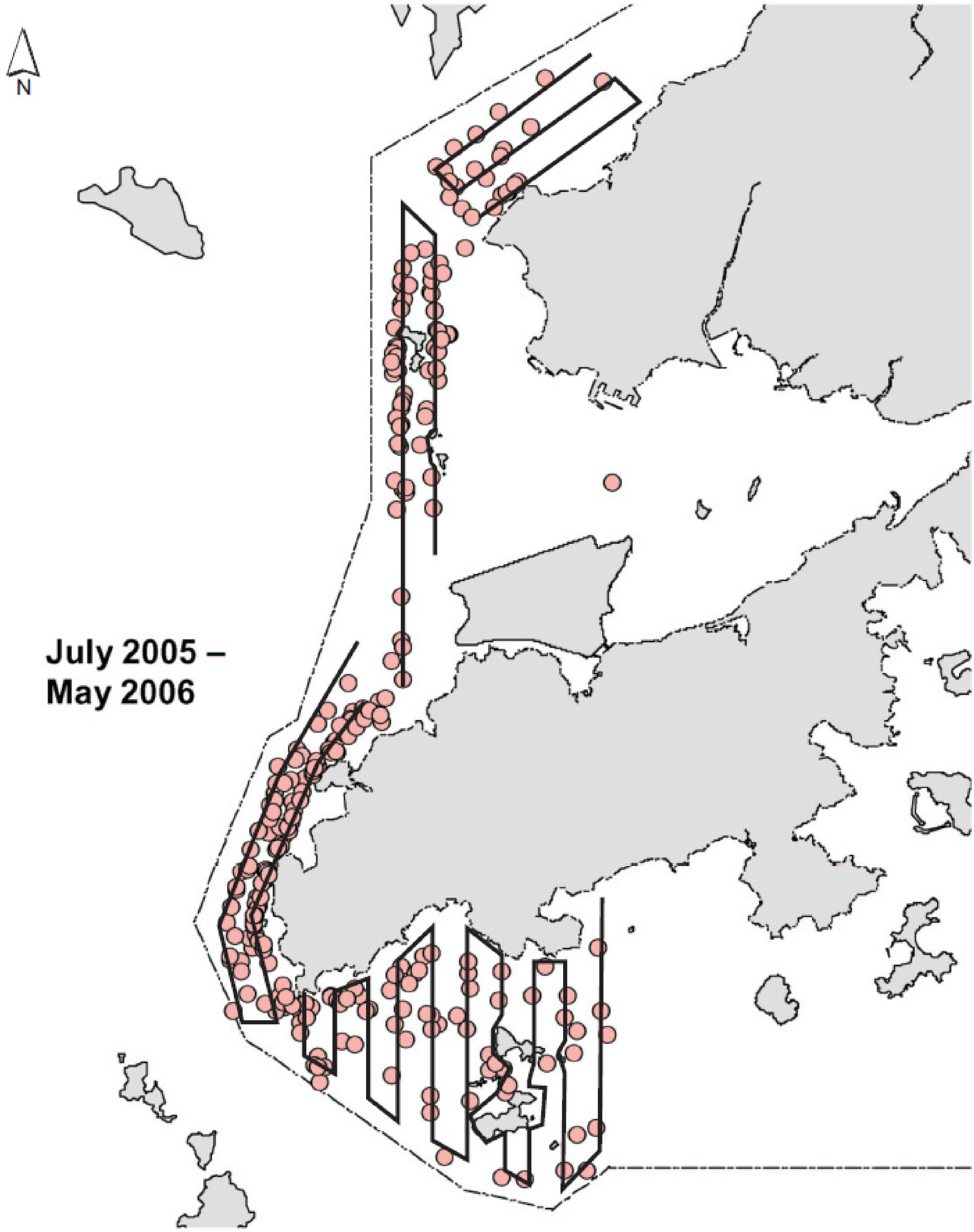

Figure 8A.9

Distribution of Indo-Pacific Humpback Dolphin Recorded during the 11 Months Survey (July 2005 – May 2006). Solid Line Indicates Transect Survey Line
(Reproduced from ERM (2006))

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of Deep Bay, even for the southwestern end of Deep Bay near the Black Point Power Station where DPSE values were the highest within the survey area, were only used to a small extent in comparison to high dolphin usage in the West Lantau (in waters between Sham Wat & Tai O and north to Peaked Hill) and western end of Northwest Lantau (*Table 8A.3*; *Figure 8A.10*).

As of 2006, a total of 398 Indo-Pacific humpback dolphins have been individually identified using photo identification as part of AFCD's long-term monitoring programme to track their movement patterns and habitat use within the Pearl River Estuary (ERM 2006). Seven of these identified dolphins were sighted in Deep Bay during the 2005-2006 survey, five of which appeared to use Deep Bay as a portion of their home range during the study period; such sighting records were much lower than those of Northwest Lantau (*Table 8A.3*). Of the 21 identified dolphins studied in the Ranging Pattern Study, only three were recorded in Deep Bay, 19 in Northwest Lantau, 5 in Southwest Lantau and 16 in West Lantau.

Overall, survey data gathered in 2005-2006 supported previous findings in the literature and indicated that dolphins use the mouth of Deep Bay at a low level throughout the year.

8A.3.8 Identification of Information Gaps

Based on the literature review presented in *Sections 8A.3.4 – 8A.3.7*, it was considered appropriate to conduct field surveys for the following marine ecological habitats of Black Point in order to provide the most up-to-date information on the baseline conditions of the resources that may potentially be affected directly by this Project:

- Intertidal survey;
- Subtidal coral survey; and
- Subtidal benthic survey.

As for marine mammals, long-term monitoring up to the period of June 2009 has been conducted by AFCD in the Deep Bay and Northwest Lantau areas. It was considered that data from this monitoring programme together with those collected as part of ERM (2006) are sufficient for providing the baseline conditions of marine mammals in the Study Area and thus additional field surveys are not necessary (Dr SK Hung, Dr TA Jefferson and Prof B Würsig, pers comm.). A comprehensive review of marine mammal data collected in the Study Area and vicinity from January 2005 to June 2009 was, however,

provide a new, survey effort-corrected sighting density data, termed "SPSE", which represents the number of on-effort sightings per unit of survey effort. SPSE was further elaborated to look at actual dolphin densities (exact number of dolphins from on-effort sightings per km2). The new unit for this approach was termed "DPSE", which is the number of individual dolphins per unit of survey effort. Plotting the DPSE values of surveyed grid squares on maps allows areas where the most dense sightings of dolphins occur to be identified.

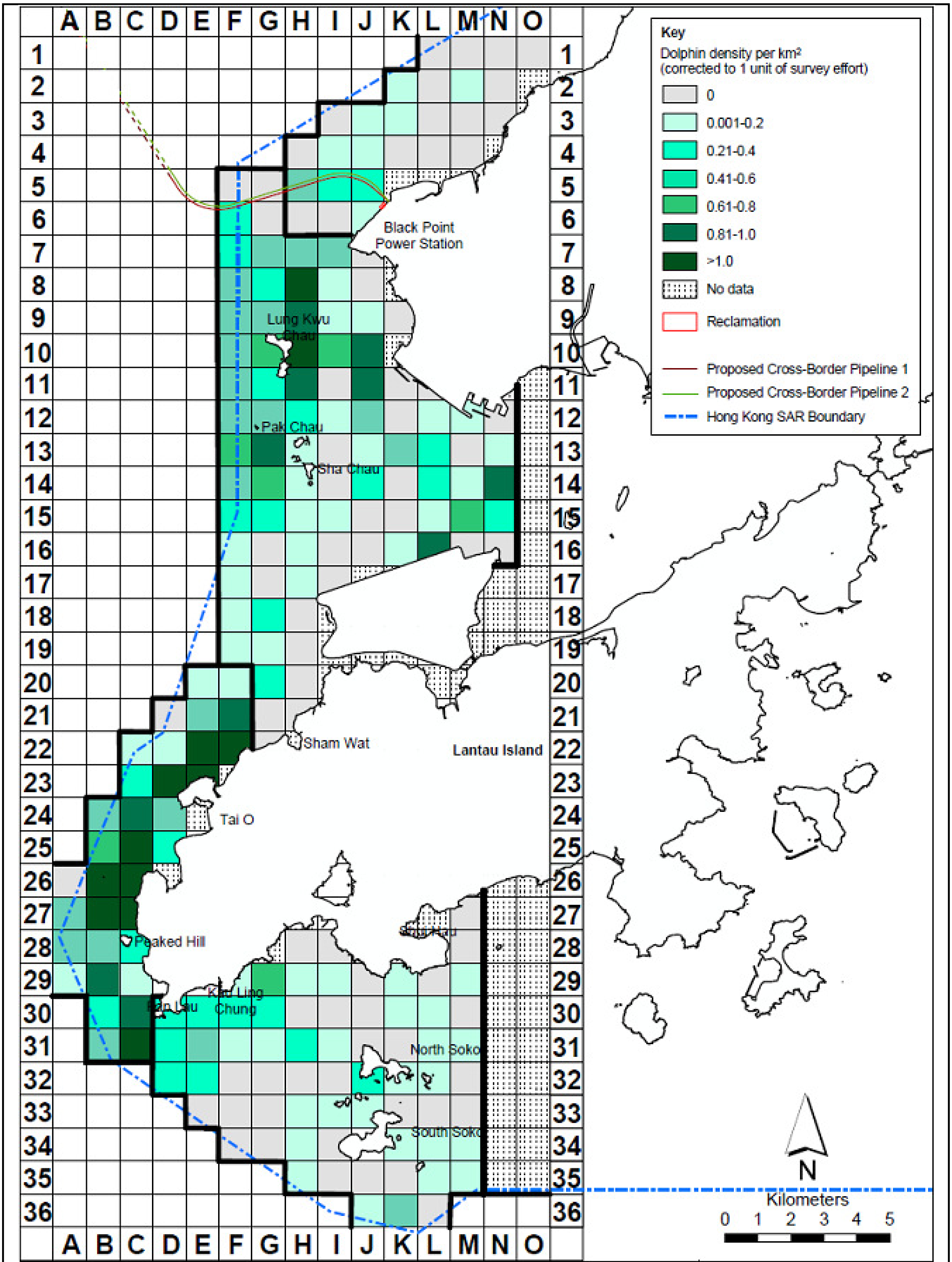

Figure 8A.10

Density of Indo-Pacific Humpback Dolphins with Corrected Survey Effort per km in Western Hong Kong Waters (Using data from ERM's July 2005-May 2006 survey combined with AFCD's monitoring data for the same period)
(Reproduced from ERM (2006))

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undertaken to provide the most up-to-date information on the baseline conditions of marine mammals.

8A.4 BASELINE MARINE ECOLOGICAL FIELD SURVEYS

Table 8A.4 summarises the field surveys undertaken in 2009 as part of this EIA.

Table 8A.4 Marine Ecology Baseline Surveys

Survey Type	Methodology	Season & Date
Intertidal Assemblages at BPPS	Qualitative spot checks and quantitative surveys of three 100 m belt transects (at high, mid and low intertidal zones) at artificial seawall, covering both wet and dry seasons	Dry Season: 25 Mar 2009 Wet Season: 23 Jun 2009
Subtidal Benthic Assemblages	Quantitative grab sampling surveys at four sites (six stations at each site). Sites surveyed represented the reclamation site and pipeline alignment	Wet Season: 10 Jun 2009
Subtidal Hard Bottom Assemblages (Coral)	Spot dives within Study Area	30 Sept and 2 Oct 2009

Survey methodologies have been selected to follow standard and accepted techniques for marine ecological surveys. In addition, each methodology has been previously conducted as part of other Environmental Impact Assessments (EIA) studies, accepted under the Hong Kong Environmental Protection Department *Environmental Impact Assessment Ordinance* (EIAO).

Survey schedules have been undertaken in accordance with the *Environmental Impact Assessment Ordinance, Cap.499 Guidance Note 7/2002 - Ecological Baseline Survey for Ecological Assessment*, specifically in terms of the following:

- Duration of Survey;
- Seasonality;
- Types of Survey Period; and
- Survey Effort.

The following sections present the methodology and results for each marine ecological survey undertaken as part of the assessment of marine ecological baseline conditions.

8A.4.1 *Intertidal Hard Bottom Assemblages*

Intertidal baseline surveys were carried out to characterise the existing ecological conditions of the intertidal assemblages within the Project Site. The surveys have been designed to provide an update of the physical and ecological attributes of the Study Area as presented in the ERM (2006).

Only one type of intertidal habitat, artificial shore, was identified in the Project Site. The artificial shore at the BPPS consists of steep sloping seawall of large boulders, and this habitat was examined for the intertidal surveys.

Survey Methodology

The intertidal surveys consisted of qualitative spot checks and quantitative transect surveys along the artificial sloping seawall within the Project Site. Whilst spot checks were conducted along accessible artificial sloping seawall, quantitative transect surveys for intertidal assemblages were conducted on locations previously surveyed in ERM (2006), namely T5 and T6 (*Table 8A.5*, *Figure 8A.11*). Intertidal surveys were conducted once in the dry season and once in the wet season. Local tide tables were used to assess tidal height at the site and times of surveys.

Table 8A.5 Description of the Survey Transects for Intertidal Hard Bottom Surveys at Black Point

Transect	Site Description
T5	Adjacent to the power stations cooling water outlet. Steep artificial seawall consisting of large boulders.
T6	Located on the artificial shoreline on northern shore of Black Point power station. Steep artificial seawall consisting of large boulders.

For qualitative spot checks, the accessible artificial seawall shorelines were surveyed. Organisms encountered were recorded and their relative abundance noted.

The sampling methodology adopted in ERM (2006) was applied to the quantitative surveys conducted in 2009. At each of the two survey locations (T5 and T6), three 100 m horizontal (belt) transects along the seawall were surveyed at each of the three shore heights: 2 m (high-shore), 1.5 m (mid-shore) and 1 m (low-shore) above Chart Datum (CD). On each transect, five quadrats (50 cm × 50 cm) were placed randomly to assess the abundance and diversity of flora and fauna (Σ n = 5 quadrats × 3 transects × 3 heights × 2 survey locations = 90). All organisms found in each quadrat were identified and recorded to the lowest possible taxonomic level to allow density per quadrat to be calculated. Sessile species, such as algae (encrusting, foliose and filamentous), barnacles and oysters, in each quadrat were also identified

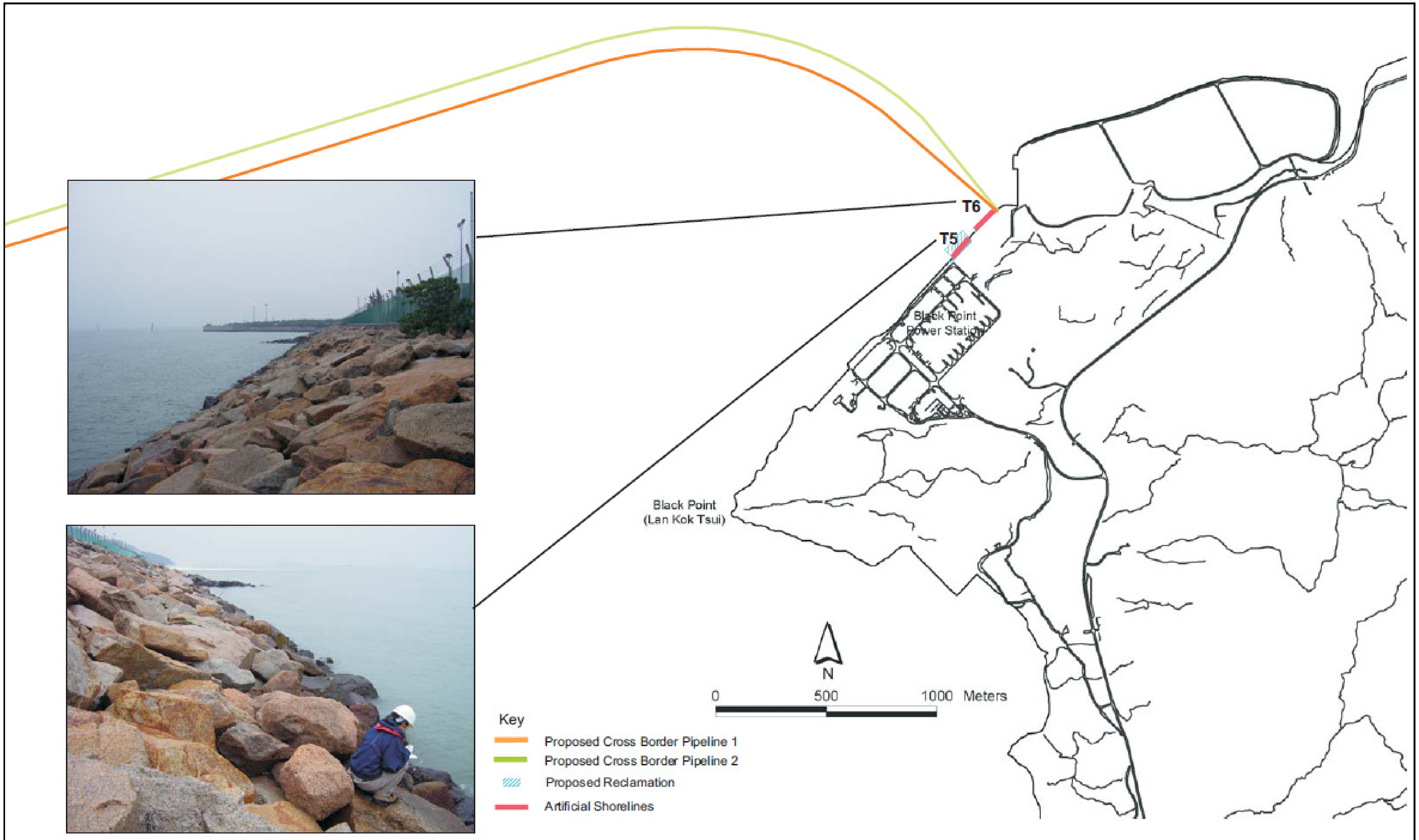

Figure 8A.11

Black Point Intertidal Sampling Transect Locations for Seasonal Surveys in 2009

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and estimated as percentage cover on the rock surface using a double-strung, 50 cm × 50 cm quadrat.

Results

Artificial sloping seawall of the Project Site exhibited a low diversity of species. A list of organisms encountered during the qualitative spot checks in the seasonal surveys and their relative abundances is provided in *Table 8A.6*. These species are all very common and widespread species on artificial shores of Hong Kong. Representative photos of the intertidal habitats within the Study Area are shown in *Figure 8A.11*.

A total of nine faunal groups were recorded in the dry season quantitative surveys in 2009. Dominant (in terms of abundance) organisms recorded included the littorinid snails *Echinolittorina radiata*, *E. trochoides* and *Littoraria articulata* in the high-shore, the nerite *Nerita albicilla* in the mid-shore, and the limpet *Nipponacmea concinna*, the common dogwhelk *Thais clavigera*, the rock oyster *Saccostrea cucullata* and the barnacles *Tetraclita* spp. in the low-shore (*Table 8A.7*). Both the abundance/ density of mobile species and percentage cover of sessile fauna were considered to be low (54.7 individuals m^{-2} and 59.7 % m^{-2} respectively). Only four species of algae were recorded in the survey.

As with the dry season survey, low diversity and abundance of intertidal biota were recorded during the wet season quantitative survey in 2009, and a total of nine faunal groups and one algal species were recorded on the sloping seawall. The species composition of the intertidal organisms was similar between seasons. Mean abundance of mobile species and sessile fauna recorded in the wet season survey were 34 individuals m^{-2} and 46 % m^{-2} respectively.

Overall, results of the seasonal surveys show that all species were common and widespread, and no notable species were recorded. Diversity and abundance of intertidal biota at the Study Area was similar to those recorded from other artificial shores in Hong Kong. Survey results are also largely similar to that reported in the intertidal surveys at Black Point (ERM 2006).

Table 8A.6 Relative Abundance of Intertidal Biota Recorded on Artificial Seawalls within the Study Area in the Dry Season (March 2009) and Wet Season (June 2009) Surveys

Group	Species	Dry Season (March 2009)			Wet Season (June 2009)		
		Seawall at Ash Lagoon	Seawall at Proposed Pipeline Landing Point	Seawall near BPPS Outfall	Seawall at Ash Lagoon	Seawall at Proposed Pipeline Landing Point	Seawall near BPPS Outfall
Snail	*Echinolittorina trochoides*	2	1	1	1	1	1
	Echinolittorina radiata	1	2	2	1	2	2
	Littoraria articulata	3	3	2	3	3	3
	Nerita albicilla	2	2	2	1	1	1
	Thais clavigera	0	1	1	0	1	1
Limpet	*Nipponacmea concinna*	1	1	1	0	1	1
Rock Oyster	*Saccostrea cucullata*	2	3	3	2	2	2
Barnacles	*Tetraclita* spp.	1	3	3	1	1	1
	Balanus amphitrite	1	1	0	2	2	2
	Capitulum mitella	1	1	1	0	1	1
Mobile crustaceans	*Ligia exotica*	2	1	0	3	3	3
	Hemigrapsus sanguineus	1	0	0	0	0	0
	Grapsus albolineatus	0	1	0	0	0	0
	Eriphia laevimana	0	1	0	0	0	0

Relative Abundance of species: 0 = Not Present; 1 = Rare within Transect; 2 = Common within Transect; 3 = Very Common within Transect

Table 8A.7 Mean Density (m-2) of Intertidal Fauna and Mean Percentage Cover (%) of Sessile Fauna and Flora recorded at Artificial Shoreline Transects T5 and T6 at Black Point during Dry Season (March 2009) and Wet Season (June 2009) Surveys

	Dry Season (March 2009)						Wet Season (June 2009)					
	High-Intertidal Zone		Mid-Intertidal Zone		Low-Intertidal Zone		High-Intertidal Zone		Mid-Intertidal Zone		Low-Intertidal Zone	
	T5	*T6*	*T5*	*T6*	*T5*	*T6*	*T5*	*T6*	*T5*	*T6*	*T5*	*T6*
Snail												
Echinolittorina trochoides	6.4	7.2	0	0	0	0	0	0	0	0	0	0
Echinolittorina radiata	26.4	26.4	0	0	0	0	20.0	39.2	0	0	0	0
Littoraria articulata	58.4	40.8	0	5.6	0	0	23.2	27.2	1.6	5.6	0	0
Nerita albicilla	0	0	23.2	12.8	1.6	8	0.8	0	8.8	16	0	1.6
Thais clavigera	0	0	0.8	0	6.4	8	0	0	1.6	0	0	0
Limpet												
Nipponacmea concinna	0	0	10.4	11.2	29.6	44.8	0	0	4.8	0	0	0
Patelloida pygmaea	0	0	0	0	0	0	0	0	12.8	32.0	2.4	5.6
Bivalves %												
Saccostrea cucullata	0	0	37	50.2	8.8	12.6	0	0	42	27	20	20
Barnacles %												
Tetraclita spp.	0	0	16.2	3	31	27.2	0	0	2.4	3.4	0	0
Balanus amphitrite	0	0	0	6	0	0	0	0	0	0	80	80
Algae %												
Ulva spp.	0	0	3	0	4	0	0	0	0	0	0	0
Hidenbrandia rubra	0	5	26.6	27	4	2	0	0	33	55	0	0
Cyanobacteria	3.2	12	0	0	0	0	0	0	0	0	0	0
Brown epiphytic algae	0	0	14	0	54.6	11	0	0	0	0	0	0

8A.4.2 *Subtidal Soft Bottom Assemblages*

Subtidal baseline surveys were carried out to characterise the existing ecological conditions of the seabed within the Study Area. The surveys have been designed to provide an update of the physical and ecological attributes of the Study Area as presented in the ERM (2006).

Field Survey Methodology

Benthic sediment samples were collected from four sites representative of the subtidal soft-bottom habitats of the submarine pipeline alignment and reclamation site. The numbers of sampling sites within the Study Area were considered sufficient given the relatively homogeneous nature of sediments at the sites. The locations of each survey site are shown in *Figure 8A.12*.

At each of the four survey sites, six stations approximately 100 m apart were established and one grab sample was collected from each station. Stations were sampled using a modified Van Veen grab sampler (960 cm^2 sampling area; 11,000 cm^3 capacity) with a supporting frame attached to a swivelling hydraulic winch cable.

Sediments from the grab samples were sieved on board the survey vessel. The sediments were washed onto a sieve stack (comprising 1 mm^2 and 500 μm^2 meshes) and gently rinsed with seawater to remove all fine material. Following rinsing any material remaining on the two screens was combined and carefully rinsed using a minimal volume of seawater into pre-labelled thick triple-bagged ziplock plastic bags. A 5% solution of borax-buffered formalin containing Rose Bengal in seawater was then added to the bag to ensure tissue preservation. Samples were sealed in plastic containers for transfer to the taxonomy laboratory for sorting and identification.

Laboratory Techniques

The benthic laboratory performed sample re-screening after the samples had been held in formalin for a minimum of 24 hours to ensure adequate fixation of the organisms. Individual samples from the 500 μm^2 and 1 mm^2 mesh sieves were gently rinsed with fresh water into a 250 μm^2 sieve to remove the formalin from the sediments. Sieves were partially filled while rinsing a specific sample to maximize washing efficiency and prevent loss of material. All material retained on the sieve was placed in a labelled plastic jar, covered with 70% ethanol, and lightly agitated to ensure complete mixing of the alcohol with the sediments. Original labels were retained with the re-screened sample material.

Standard and accepted techniques were used for sorting organisms from the sediments. Small fractions of a sample were placed in a petri dish under a 10-power magnification dissecting microscope and scanned systematically with

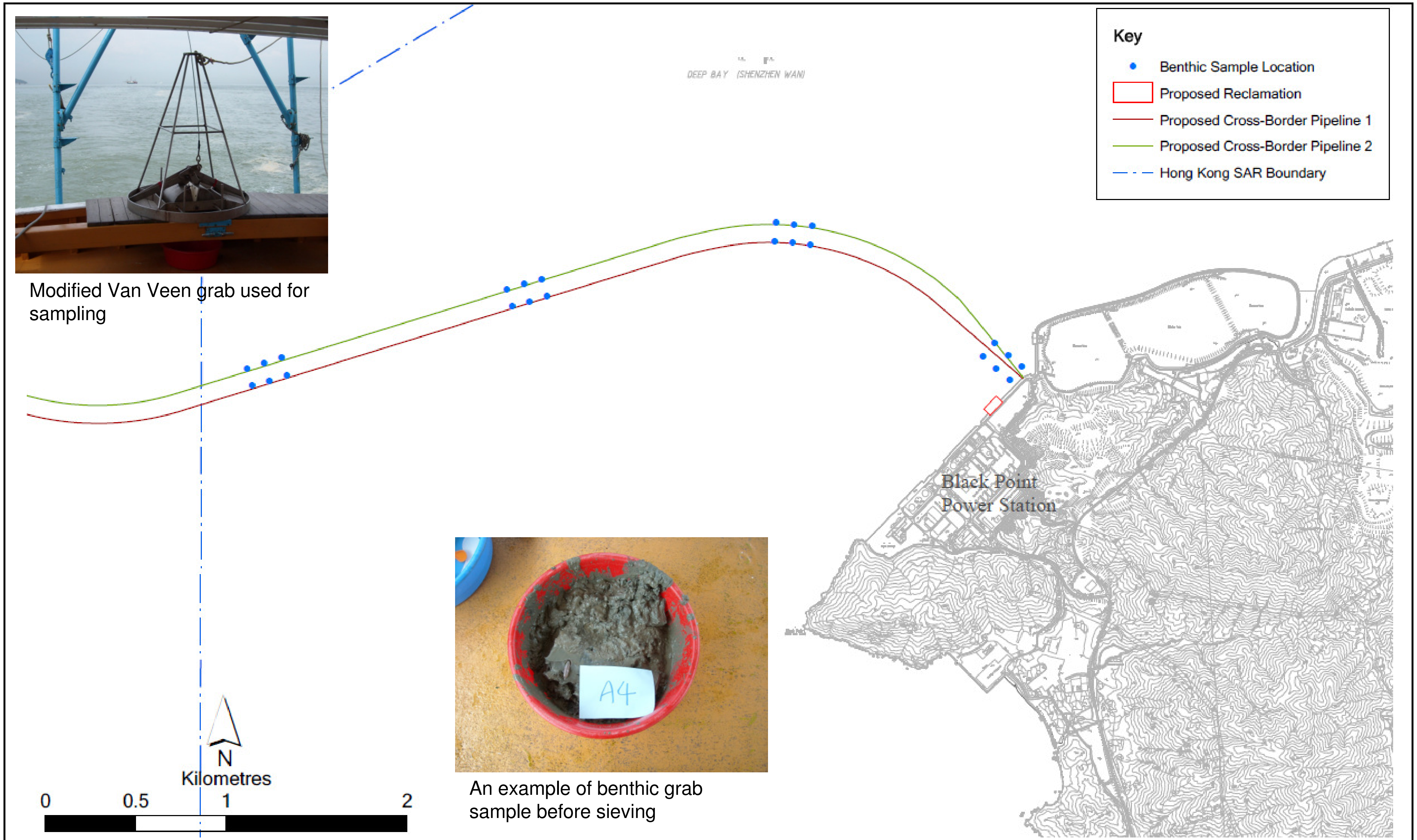

Figure 8A.12

Subtidal Soft-Bottom Sampling Stations for Wet Season Survey in 2009

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all animals and fragments removed using forceps. Each petri dish was sorted at least twice to ensure removal of all animals. Organisms representing major taxonomic groups, such as Polychaeta, Arthropoda, Mollusca, and miscellaneous taxa, were sorted into separate, labelled vials containing 70% ethanol.

Taxonomic identifications were performed by qualified and experienced specialist using stereo dissecting and high-power compound microscopes. These were generally to the species level except for unidentified taxa, which were identified to genera as far as practical. The careful sampling procedure employed minimizes fragmentation of organisms. If breakage of soft-bodied organisms occurred, only anterior portions of fragments were counted, although all fragments were retained and weighed for biomass determinations (wet weight).

Results

Grab samples were collected from all 24 sampling stations in the wet season survey on 10 June 2009. In general, conditions during surveys were fine with relatively calm sampling conditions throughout.

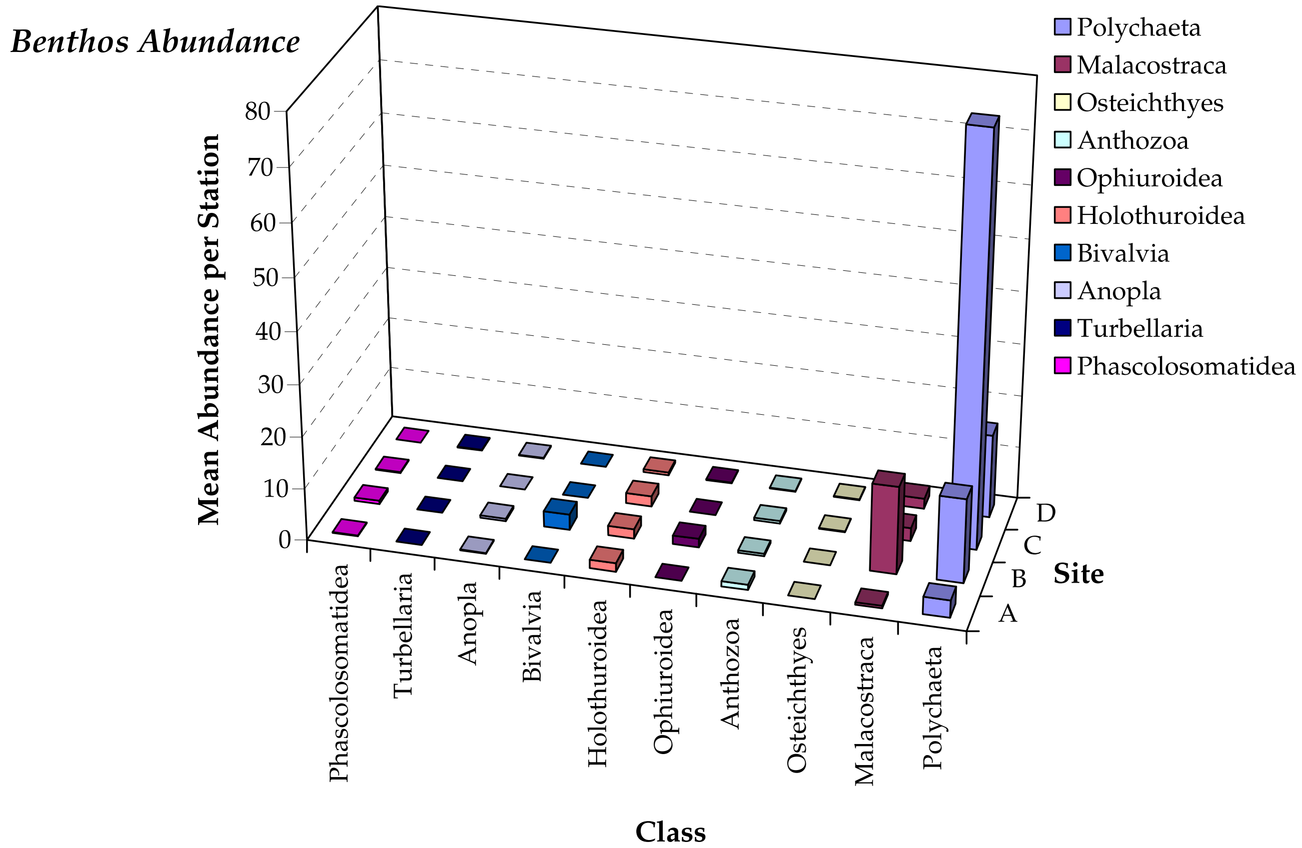
A total of 908 individual organisms were collected from the 24 grab sampling stations at the four survey sites. The specimens belong to nine Phyla with a total of 10 classes, 54 families and 69 species identified. *Table 8A.8* provides a summary on the abundance, biomass and taxonomic richness of infauna collected at each site. A complete set of raw data is presented in *Tables 2* and *3* of *Annex 8B.*

Results of the wet season benthic survey showed that, as with the findings of the 2004 surveys, infaunal abundance and biomass were considered to be medium to high at all sampling sites, while taxonomic richness (here represented by number of families and species of infaunal organisms) were low (*Table 8A.8*). There was some variation in infaunal abundance, biomass and taxonomic richness among sampling sites. Whilst the mean infaunal abundance per station and total biomass were higher at the Site C than other sites, taxonomic richness of infauna per station was higher at Site B than other sites (*Table 8A.8*). Variation within site (ie among sampling stations) was considered to be moderate, as can be seen from the standard deviation (SD) values (*Table 8A.8*).

In terms of infaunal abundance, the majority (75%) of organisms recorded in the wet season were from the Phylum Annelida, followed by Arthropoda (14%). Each of the other recorded phyla contributed to < 4 % of the number of individuals recorded. The polychaete worm *Prionospio queenslandica*, from the family Spionidae, was the most abundant species from the wet season survey (total abundance = 256 individuals), and it was present in all sampling sites. No rare or uncommon species were recorded in the wet season survey. The composition of infaunal assemblage at each site in terms of mean numerical abundance of organisms present (grouped by class) in the wet season survey is presented in *Figure 8A.13*.

In terms of infaunal biomass, organisms from the Phylum Echinodermata contributed 49% of the total biomass recorded, while organisms from Arthropoda, Annelida and Cnidaria also contributed significant biomasses (14%, 13% and 10% respectively). Each of the other recorded phyla contributed to < 5 % of the total infaunal biomass recorded. High biomass of echinoderms was contributed by individuals of the sea cucumber *Protankyra bidentata* at Sites A and C, and by individuals of the ball sea cucumber *Phyllophorus* sp. at Sites B and C. The composition of infaunal assemblage at each site in terms of mean biomass of organisms present (grouped by class) in the wet season survey is presented in *Figure 8A.13*.

Overall, results from the wet season surveys undertaken as part of this EIA suggested that infaunal assemblages of the surveyed sites consisted of common and widespread species typical of disturbed environment, i.e. numerical dominance of low biomass, stress-tolerant and short-lived polychaete species. As with the findings of ERM (2006), infaunal abundance and biomass in the wet season are considered to be medium to high as contributed by high abundance of echinoderms, while the taxonomic richness of infauna is low.



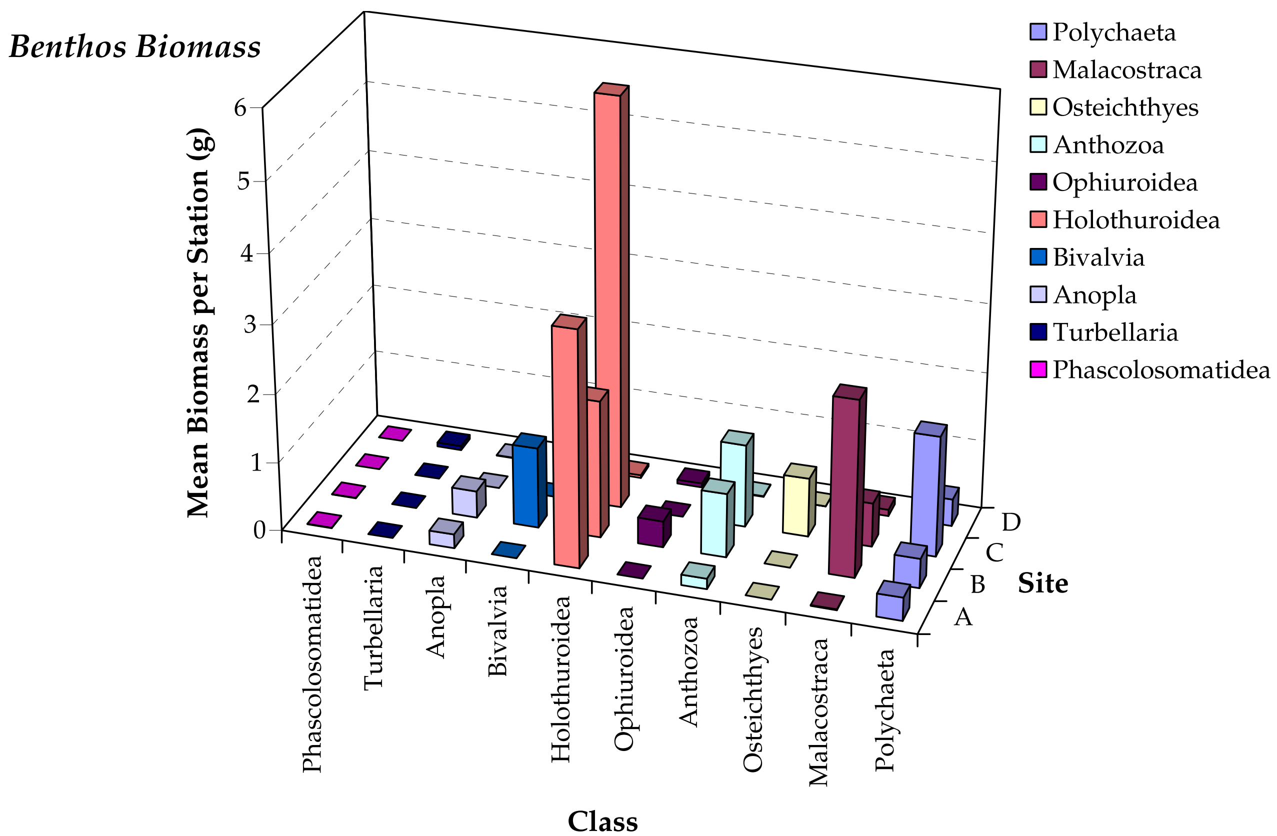


Figure 8A.13

Mean Numbers of Individuals and Biomass of Infaunal Organisms (Class level) per Stations from Grab Samples collected within the Study Area during the Wet Season Benthic Survey

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Table 8A.8 Composition of Infaunal Assemblages at the Sampling Sites for the Soft Bottom Habitat Surveys at the Black Point Study Area during the Wet Season Survey in June 2009

Site	Number of Stations Sampled	Total Number of Infaunal Individuals	Mean Number of Individuals per Station (± SD)	Mean Number of Individuals per m^2 (± SD)	Total Biomass (g wet weight)	Mean Taxonomic Richness (No. Families) per Station (± SD)	Mean Taxonomic Richness (No. Species) per Station (± SD)	Mean Biomass per Individual (g wet weight)
A	6	41	6.83 (± 1.72)	71.18 (± 17.94)	24.7817	5.50 (± 1.52)	5.50 (± 1.52)	0.6044
B	6	247	41.17 (± 27.48)	428.82 (± 286.29)	47.2071	13.17 (± 2.23)	13.83 (± 2.32)	0.1911
C	6	504	84.00 (± 54.00)	875.00 (± 562.46)	62.0628	9.83 (± 4.36)	10.17 (± 4.17)	0.1231
D	6	116	19.33 (± 14.19)	201.39 (± 147.85)	3.9987	7.00 (± 1.67)	7.17 (± 1.60)	0.0345

8A.4.3 *Subtidal Hard Bottom Assemblages*

Methodology

Subtidal dive surveys were undertaken at subtidal hard bottom habitats within the Study Area with a key focus at the proposed reclamation site and along the pipeline route where hard substrata were noted from the geophysical survey undertaken for this site (see *Section 11*). Survey locations are presented in *Figure 8A.14*.

Recent geophysical surveys identified a number of small patches of hard substrate along the pipeline route. These patches, identified as superficial dumped materials, occurred within the 500 m wide pipeline corridor and within approximately 10 m depth or less. The age of the patches is unknown.

Targeted spot dive checks were carried out at selected patches of dumped materials in close proximity to the proposed pipeline corridor to investigate if coral communities are present at these potential areas of hard substrate (*Figure 8A.14*). Ground-truthing of sessile assemblages at the selected hard substrate patches was thus used to characterise the biological nature of all patches of dumped material identified. Likewise, spot dive surveys were also undertaken along the artificial sloping seawall and seabed of the proposed reclamation site.

At each survey site, along 100 m transect, a spot dive reconnaissance check was conducted by commercial divers supervised by coral specialists to confirm the substrate type and associated sessile benthos, particularly the presence of coral communities (hard and soft corals). Representative photographs of the seabed and associated fauna were taken.

Survey Results

The dive surveys were conducted in September/ October 2009. The conditions during surveys were fine with calm conditions throughout. The visibility was generally < 0.2 m.

Results of dive surveys confirmed that at the selected patches of dumped materials and within the reclamation footprint, the seabed was composed of silt and mud with shell fragments. The subtidal zone of the seawall at the reclamation site was also covered with a layer of mud (depth = 0.2 – 0.8 m). The substrate of the survey transects showed no colonization of sessile taxa, and no corals, including hard corals, octocorals and black corals, were recorded. Representative photographs of the seabed at the survey transects are presented in *Figure 8A.15*.

Figure 8A.14

Subtidal Dive Survey Transects

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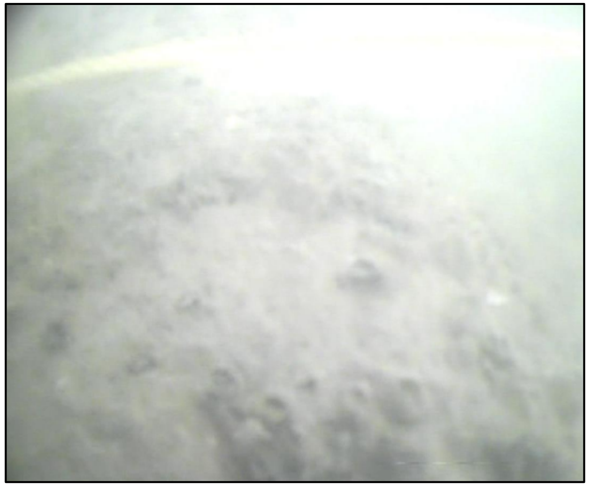
Dead barnacles


Silty/ Muddy seabed


Silty seabed with dead shell fragment


Silty seabed with dead shell fragment


Muddy seabed


Silty/ Muddy seabed

Figure 8A.15

Representative Photographic Records of the Seabed taken during the Subtidal Dive Survey

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8A.5 COMPREHENSIVE REVIEW OF MARINE MAMMAL BASELINE CONDITION

A comprehensive review of baseline marine mammal information in Deep Bay and western Northwest Lantau areas was conducted by Hong Kong Cetacean Research Project (HKCRP) as part of this EIA study to provide detailed, up-to-date baseline information on dolphin usage in the Study Area and its vicinity. The following sections describe the methodology and key findings for this data review.

8A.5.1 *Study Approach*

The HKCRP, through its research programmes with AFCD, environmental consultants and NGOs since 1995, has established several systematic, long-term databases for the study of population biology of Chinese white dolphins, *Sousa chinensis*, in Hong Kong waters. The present review study utilized the long-term monitoring data (e.g. line-transect survey data, dolphin sighting data, photo-identification catalogue of individual dolphins) collected from January 2005 to June 2009 in the Deep Bay and western Northwest Lantau areas to provide detailed baseline information on dolphin usage in the Study Area and its vicinity (*Figure 8A.16*). The ranging pattern analysis conducted as part of this review utilized all photo-identification data collected since 1995.

The seasons described in this review were defined as follows: winter (December-February), spring (March-May), summer (June-August) and autumn (September-November).

8A.5.2 *Data Analysis Methods*

Distribution Analysis

The line-transect survey data were integrated with Geographic Information System (GIS) in order to visualize and interpret seasonal and annual distribution of dolphins within the Deep Bay and western Northwest Lantau Survey Areas using dolphin sighting positions. Location data of dolphin groups from 2005 to 2009 were plotted on map layers of Hong Kong using a desktop GIS (ArcView© 3.1) to examine their distribution patterns in detail, and the dataset was also stratified into different subsets to examine distribution patterns of dolphin groups with different categories of group sizes, age classes and activities.

Encounter Rate Analysis

Since line-transect survey effort was uneven among different survey areas and across different years, the sighting rate (number of on-effort sightings per 100 km of survey effort) and dolphin encounter rate (number of dolphins sighted during on-effort per 100 km of survey effort) were calculated in each survey area in relation to the amount of survey effort conducted. Only line-transect data collected in Beaufort 3 or below condition were used in the encounter

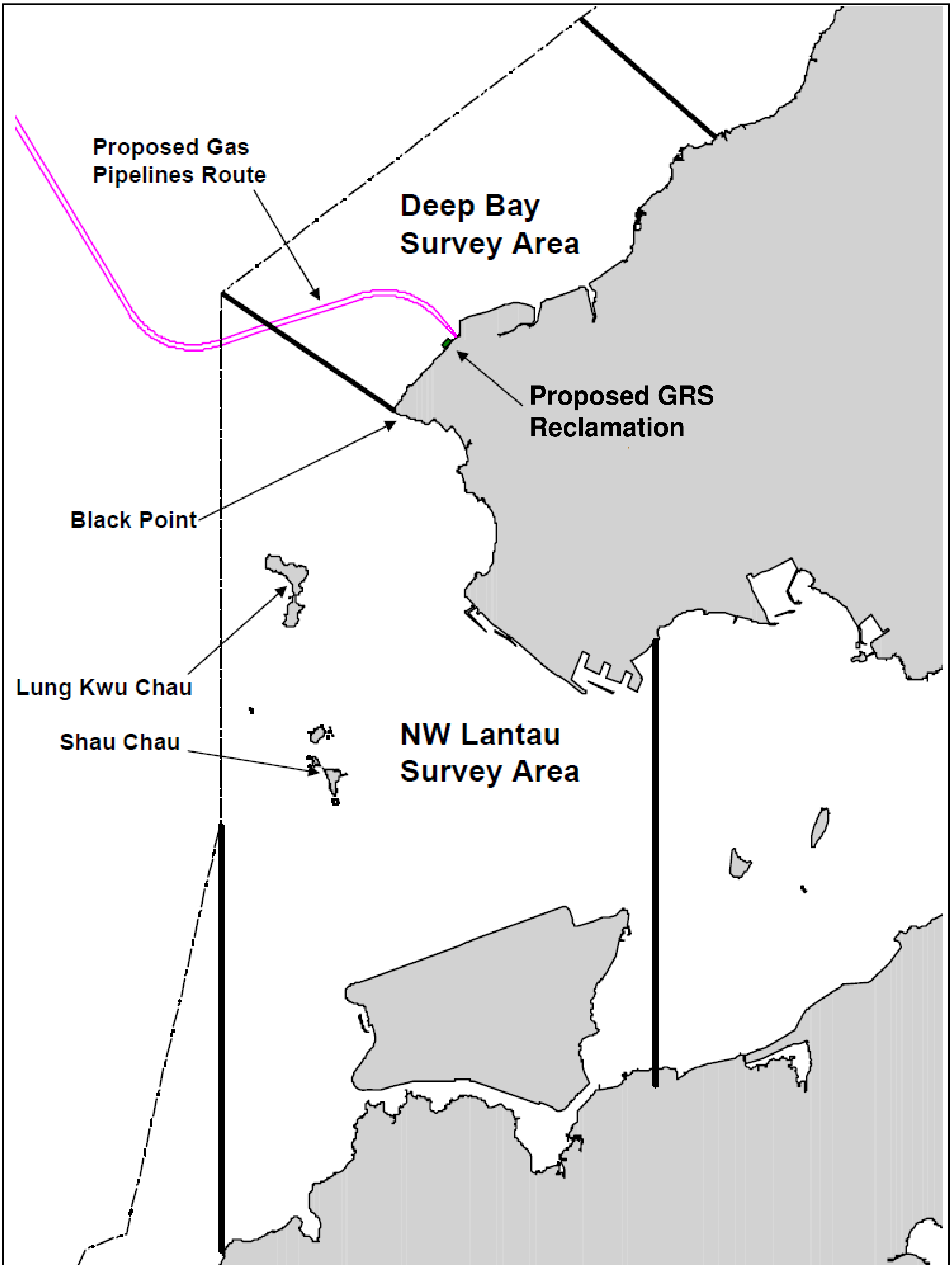

Figure 8A.16

Location of Proposed Gas Pipelines Route and GRS Reclamation between the Deep Bay and Northwest Lantau Survey Areas in Hong Kong

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rate analysis. The encounter rate could be used as an indicator to determine area of importance to dolphins among the survey areas.

Density & Abundance Analysis

This review study further analyzed the line-transect survey data from 2005 to 2009 to estimate dolphin density and abundance in Deep Bay, and reviewed previous estimates in other survey areas made in Jefferson (2007) to examine density and abundance of Chinese white dolphins in other areas overlapped with and adjacent to the Study Area.

To calculate dolphin density and abundance, one day's survey effort was used as the sample for analyses, and only surveys with at least 2.0 km of useable effort were included. Estimates were calculated from sighting and effort data collected during conditions of Beaufort 0-3 (see Jefferson & Leatherwood 1997, Jefferson 2000), using line-transect methods (Buckland et al. 2001). The estimates were made using the computer program DISTANCE Version 2.1 (Laake et al. 1994). The following formulae were used to estimate density, abundance, and their associated coefficient of variation:

$$\hat{D} = \frac{n\ \hat{f}(0)\ \hat{E}(s)}{2\ L\ \hat{g}(0)}$$

$$\hat{N} = \frac{n\ \hat{f}(0)\ \hat{E}(s)\ A}{2\ L\ \hat{g}(0)}$$

$$C\hat{V} = \sqrt{\frac{\hat{\text{var}}\ (n)}{n^2} + \frac{\hat{\text{var}}\,[\hat{f}(0)]}{[\hat{f}(0)]^2} + \frac{\hat{\text{var}}\,[\hat{E}(s)]}{[\hat{E}(s)]^2} + \frac{\hat{\text{var}}\,[\hat{g}(0)]}{[\hat{g}(0)]^2}}$$

where D = density (of individuals),

n = number of on-effort sightings,

f(0) = trackline probability density at zero distance,

E(s) = unbiased estimate of average group size,

L = length of transect lines surveyed on effort,

g(0) = trackline detection probability,

N = abundance,

A = size of the survey area,

CV = coefficient of variation, and

var = variance.

A strategy of selective pooling and stratification was used in order to minimize bias and maximize precision in making the estimates of density and abundance (Buckland et al. 2001). Different strategies were used for various line-transect components, which are described below:

Sighting rate [n/L] - Sighting rate varies strongly with season and area (see Jefferson 2000, Jefferson et al. 2002), and thus a fully-stratified analysis (full stratification by both season and survey area) was used. Clearly, sighting rate is one of the major parameters affecting density and abundance estimates, and although sample sizes were small for some strata ($n < 5$), pooling was not justified.

Trackline probability density [f(0)] - Because biases associated with small sample sizes can strongly affect the accuracy of density and abundance estimates, Buckland et al.'s (2001) guidelines regarding minimal sample sizes for estimation of the trackline probability density were followed. They suggested a minimum sample size of 60 sightings for modelling of this parameter.

Average group size [E(s)] - Because of indications that group size varies by geographic region (Jefferson 2000, Jefferson et al. 2002), data from more than one survey area were not pooled together. For those areas that had sample sizes of ≥ 10 for most seasons, a fully stratified analysis was used. DISTANCE computed both the arithmetic mean and a size-bias corrected mean; the lesser of these two values was used in the calculations (in order to avoid size-bias generally caused by missing smaller groups at large perpendicular distances).

Trackline detection probability [g(0)] - For Hong Kong Chinese white dolphins, Jefferson (2000) reported group dive time data and collected 71.8 hours of independent observer data, and from this estimated that the detection probability is unity for that study. The present analysis was an extension of Jefferson's (2000), with all survey techniques held constant. Therefore, the previously-estimated value of $g(0) = 1.0$ was used for all density and abundance calculations.

Coefficient of Variation [CV] – The variance component for the appropriate estimate of each component of the line-transect equation was used in calculating the overall CV of the estimated density and abundance. This resulted in more precise estimates for some areas and seasons than would have been the case with a fully-stratified analysis. However, this came at the expense of some slight potential for increase in bias.

Quantitative Grid Analysis of Fine-scale Habitat Use

Positions of on-effort sightings of Chinese white dolphins from 2005 to 2009 were retrieved from the long-term sighting database, and then plotted onto 1-km^2 grids among the survey areas around Deep Bay and Lantau Island on

GIS. Sighting densities (number of on-effort sightings per km^2) and dolphin densities (total number of dolphins from on-effort sightings per km^2) were then calculated for each 1-km^2 grid with the aid of GIS. Sighting density grids and dolphin density grids were then further normalized with the amount of survey effort conducted within each grid. The total amount of survey effort spent on each grid was calculated by examining the survey coverage on each line-transect survey to determine how many times the grid was surveyed during the study period. For example, when the survey boat traversed through a specific grid 50 times, 50 units of survey effort were counted for that grid. With the amount of survey effort calculated for each grid, the sighting density and dolphin density of each grid were then normalized by survey effort (i.e. divided by the unit of survey effort).

The newly-derived unit for sighting density was termed SPSE, representing the number of on-effort **s**ightings **p**er 100 units of **s**urvey **e**ffort. In addition, the derived unit for actual dolphin density was termed DPSE, representing the number of **d**olphins **p**er 100 units of **s**urvey **e**ffort. The following formulae were used to estimate SPSE and DPSE in each 1 km^2 grid within the study area:

$$SPSE = ((S / E) \times 100) / SA\%$$

$$DPSE = (D / E) \times 100 / SA\%$$

Where S = total number of on-effort sightings

D = total number of porpoise from on-effort sightings

E = total number of units of survey effort

SA% = percentage of sea area

The DPSE values of surveyed grid squares, plotted on maps, allows for identification and comparison of dolphin densities. Among the 1 km^2 grids that were partially covered by land, the percentage of sea area was calculated using GIS tools, and their SPSE and DPSE values were adjusted accordingly. Both SPSE and DPSE values were useful in examining dolphin usage within a 1-km^2 area.

Behavioural Data Analysis

When dolphins were sighted during line-transect vessel surveys, their activities were observed in detail. Different activities were categorized (i.e. feeding, socializing, travelling, milling/resting) and recorded on sighting datasheets. These data were then input to a separate database with sighting information, which can be used to determine the distribution of behavioural data with desktop GIS. Distribution of sightings of dolphins engaged in different activities would then be plotted on GIS and carefully examined to identify important areas for different activities. The behavioural data were also used in the quantitative grid analysis to identify important dolphin habitats for feeding and socializing activities.

Individual Ranging Pattern Analysis

Location data of individual dolphins with 10 or more re-sightings were obtained from the long-term dolphin sighting database and photo-identification catalogue with data collected up to June 2009. To deduce home ranges for individual dolphins using the fixed kernel method, the program Animal Movement Analyst Extension, created by the Alaska Biological Science Centre, USGS (Hooge & Eichenlaub 1997), loaded as an extension with ArcView© 3.1 along with another extension Spatial Analyst 2.0., was used. The program calculated kernel density estimates based on all sighting positions, and provided an active interface to display kernel density plots. The kernel estimator then calculated and displayed the overall ranging area at 95% UD (Utilization Distribution) level. The core areas of individuals with 10+ re-sightings at two different levels (50% and 25% UD) were also examined to investigate their core area use in detail. This analysis aimed to determine whether there were any overlaps of dolphin overall ranges (95% UD ranges) and core areas (50% and 25% UD ranges) with the proposed gas pipeline alignment and reclamation site.

8A.5.3 Results

Distribution

Due to differential survey effort in various survey areas, it is not possible to compare densities of dolphins by examining maps of distribution. The distribution maps are only useful for determining where animals occur and do not occur, and for comparing use of the area on a small scale (within a survey area). Comparisons of density or habitat use on a larger scale should make use of numerical density estimates or the results of the grid analyses (discussed below).

From January 2005 to June 2009, a total of 645 groups of 2,444 Chinese white dolphins were sighted during vessel and helicopter surveys in Northwest Lantau and Deep Bay Survey Areas. In the Deep Bay Survey Area alone, 35 groups of 107 Chinese white dolphins were sighted, with the majority of sightings during the 2005-06 surveys as part of ERM (2006).

In the western section of Northwest Lantau, distribution of dolphin sightings was mostly concentrated along the transect lines near Lung Kwu Chau, Sha Chau and Black Point headland (*Figure 8A.17*). Dolphin sightings were more scattered in the mouth of Deep Bay, and dolphins occurred occasionally in the inner part of Deep Bay. A number of dolphin sightings were made along and adjacent to the proposed gas pipeline alignment, and also near the proposed reclamation site at BPPS (*Figure 8A.17*).

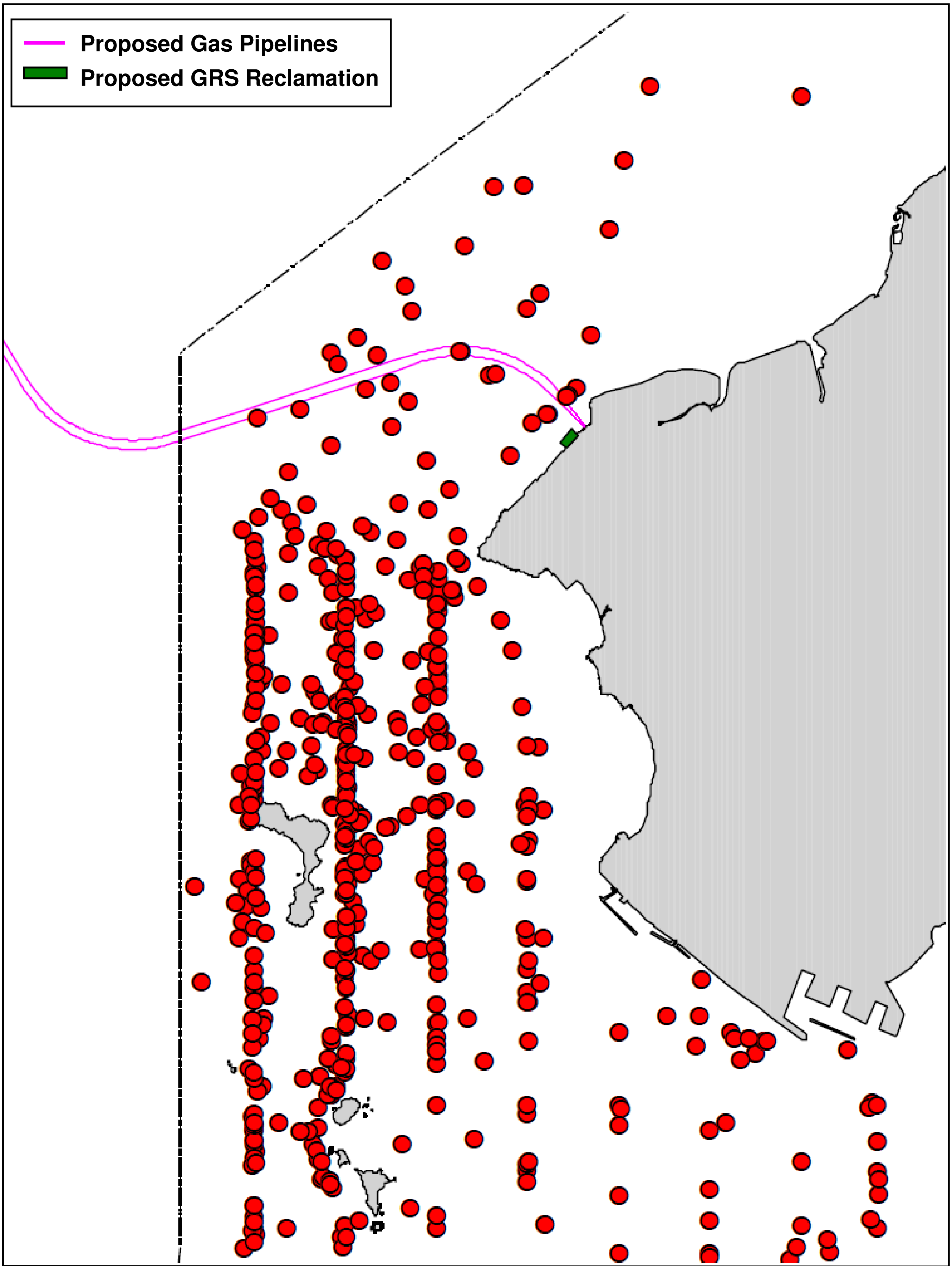

Figure 8A.17 **Distribution of Indo-Pacific Humpback Dolphin Sightings in the Deep Bay and Western Northwest Lantau Survey Areas from Jan 2005 – Jun 2009**

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Whilst dolphins occurred in Deep Bay and western Northwest Lantau throughout the year, seasonal variation in dolphin distribution at the mouth of Deep Bay was evident. Dolphin sightings within or adjacent to the Project Site were slightly higher in autumn and winter months than in spring and summer months (*Figure 8A.18*), and more dolphins were sighted at the inner part of Deep Bay in autumn and winter months than in spring and summer months (*Figure 8A.18*).

Encounter Rate

During 2005-09, the overall sighting rate and dolphin encounter rate among the five survey areas around Lantau were 7.5 and 28.2 respectively. Both sighting rate (8.0) and dolphin encounter rate (31.6) in Northwest Lantau were slightly higher than the overall, while the sighting rate (1.8) and dolphin encounter rate (6.3) in Deep Bay were the lowest among all five survey areas (*Figure 8A.19*) and were much lower than the overall. The sighting rates in Deep Bay were also lower than the other survey areas in all seasons except winter (*Figure 8A.19*).

Density & Abundance

During 2005-09, the abundance estimate of Chinese white dolphins in Deep Bay ranged from four dolphins in spring/summer to seven dolphins in autumn (*Table 8A.9*). Density estimates from the same area ranged from 13-24 individuals/100 km^2. In comparison, the abundance and density estimates of Chinese white dolphins in Northwest Lantau during 2004-06 ranged from 45-93 dolphins and 52-107 individuals/100 km^2 respectively, and those from Northeast Lantau ranged from 7-18 dolphins and 6-34 individuals/100 km^2 respectively (Jefferson 2007).

Dolphin density in Deep Bay was evidently much lower than the prime dolphin habitats in Northwest Lantau and West Lantau (*Figure 8A.20*). However, when compared to other survey areas that are at the periphery of the dolphin population range (i.e. Northeast Lantau and Southwest Lantau), dolphin densities in Deep Bay were slightly higher than these areas in winter and spring months (*Figure 8A.20*). Dolphin densities in Deep Bay were also relatively stable seasonally.

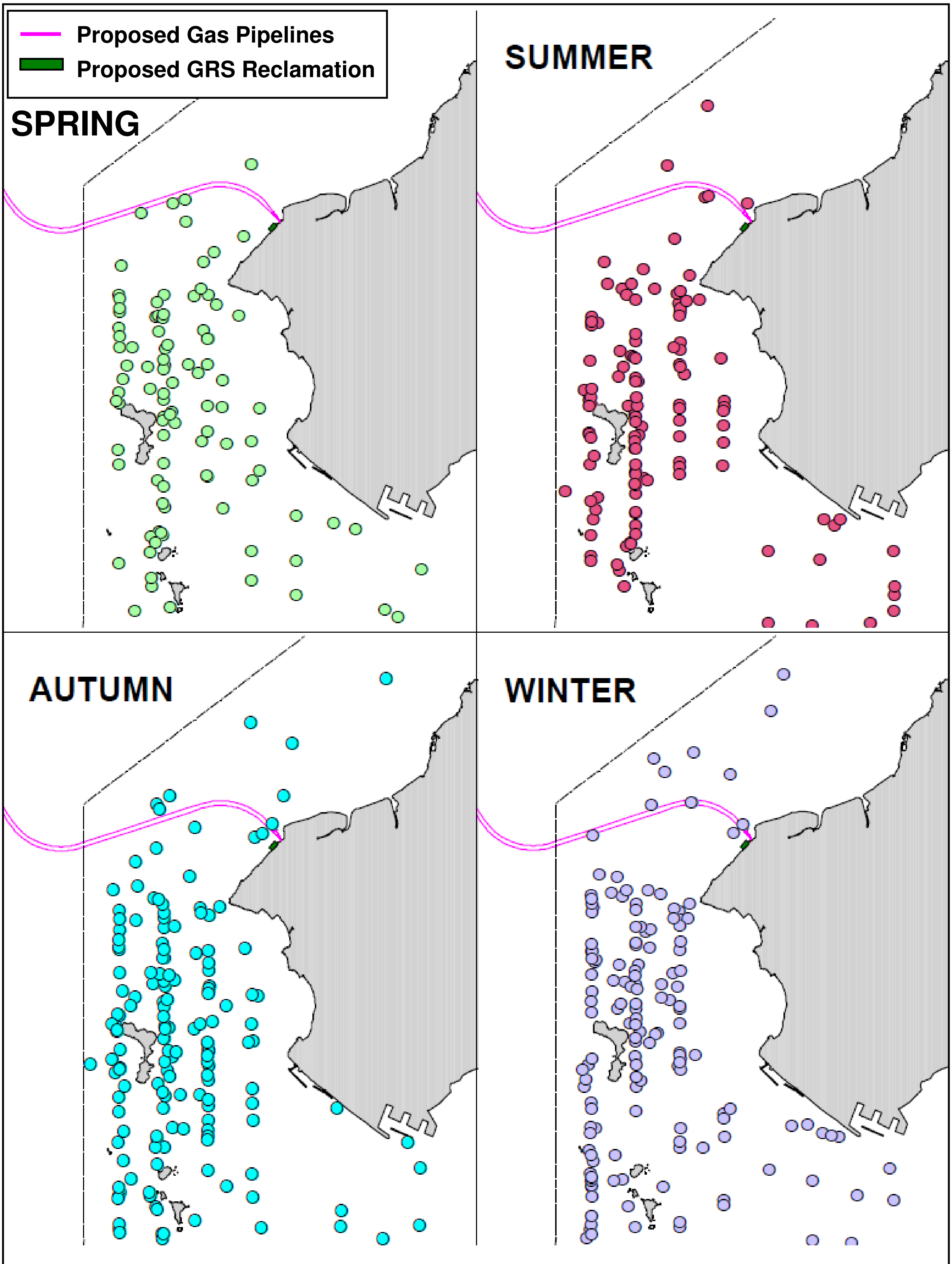

Figure 8A.18 **Seasonal Distribution of Indo-Pacific Humpback Dolphin Sightings in the Deep Bay and Western Northwest Lantau Survey Areas from Jan 2005 – Jun 2009**

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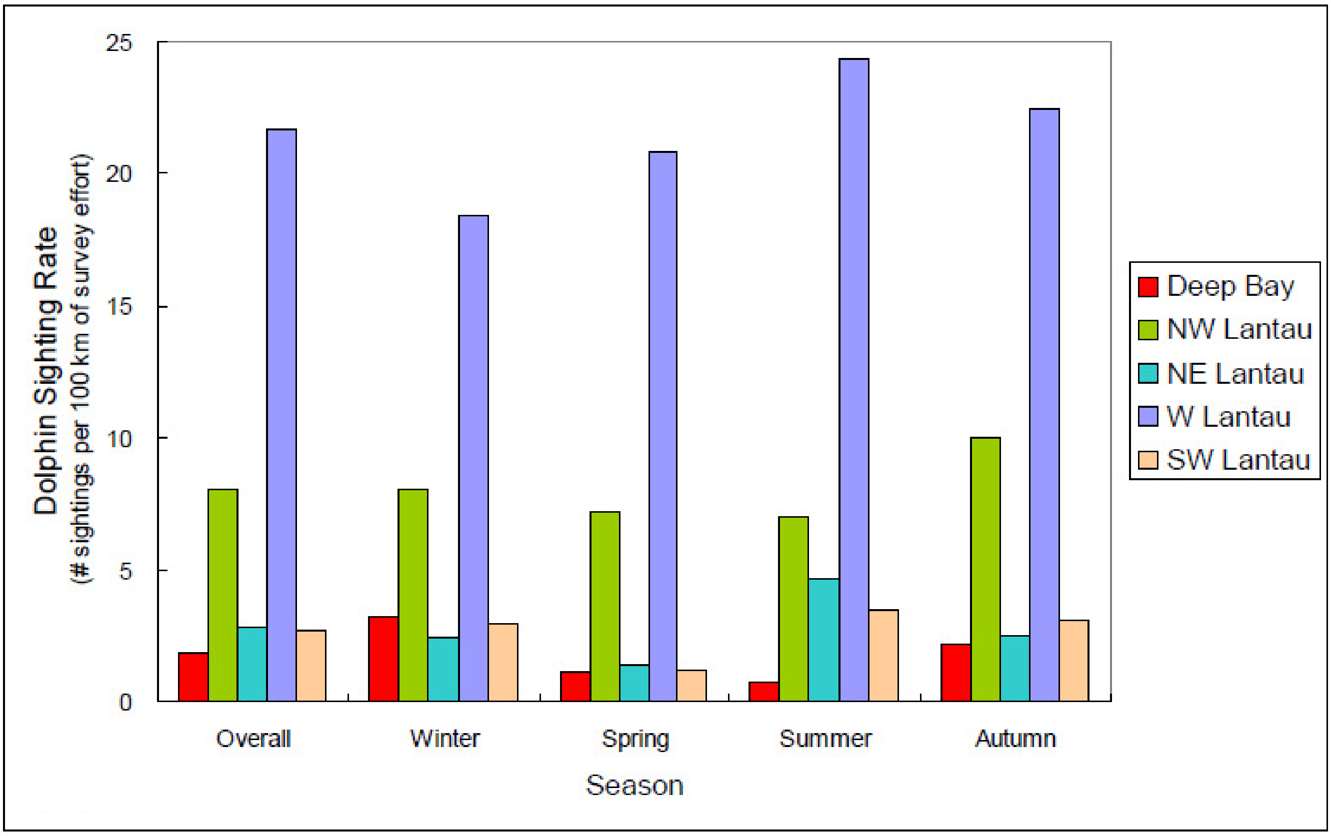

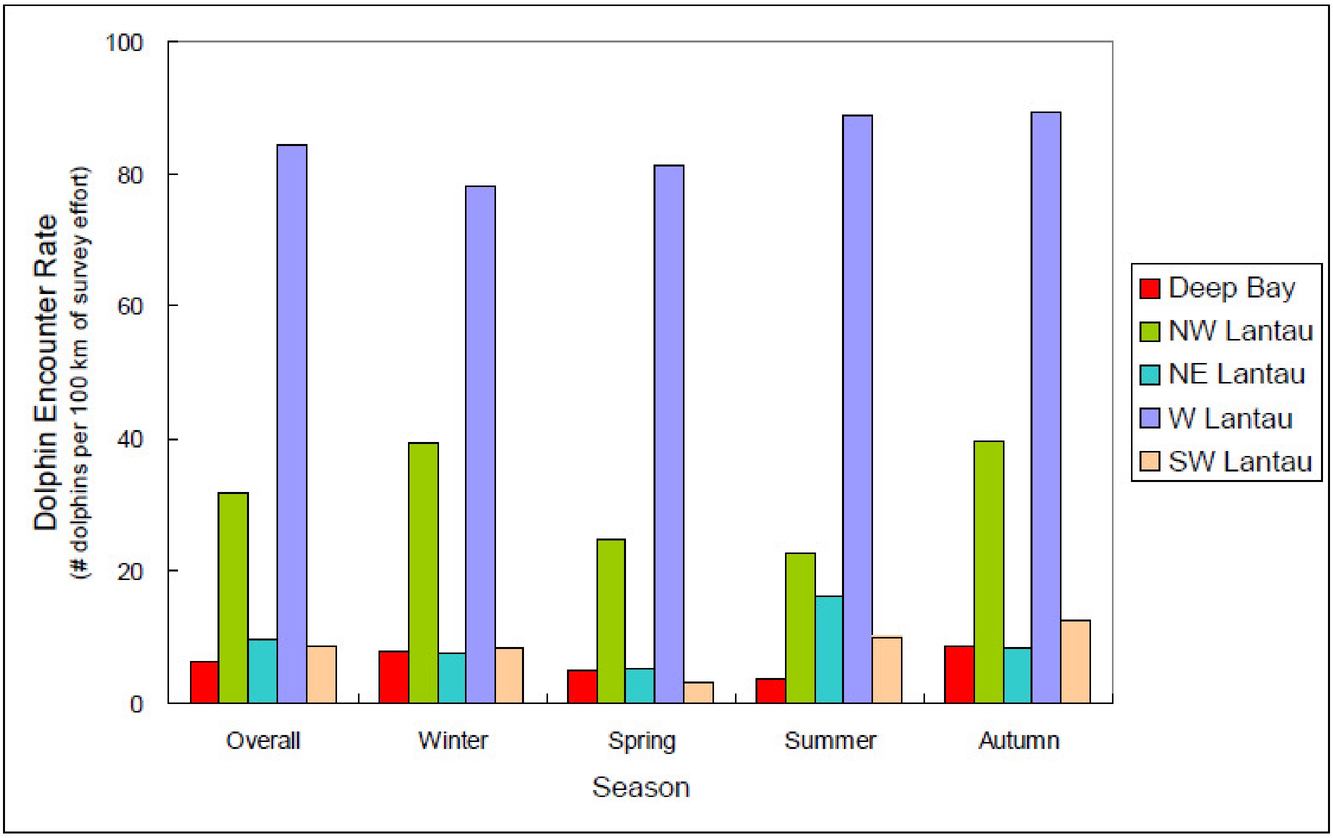

Figure 8A.19 **Sighting Rate and Dolphin Encounter Rate of Chinese White Dolphins among Different Survey Areas in Hong Kong (Data from Jan 2005 – Jun 2009)**

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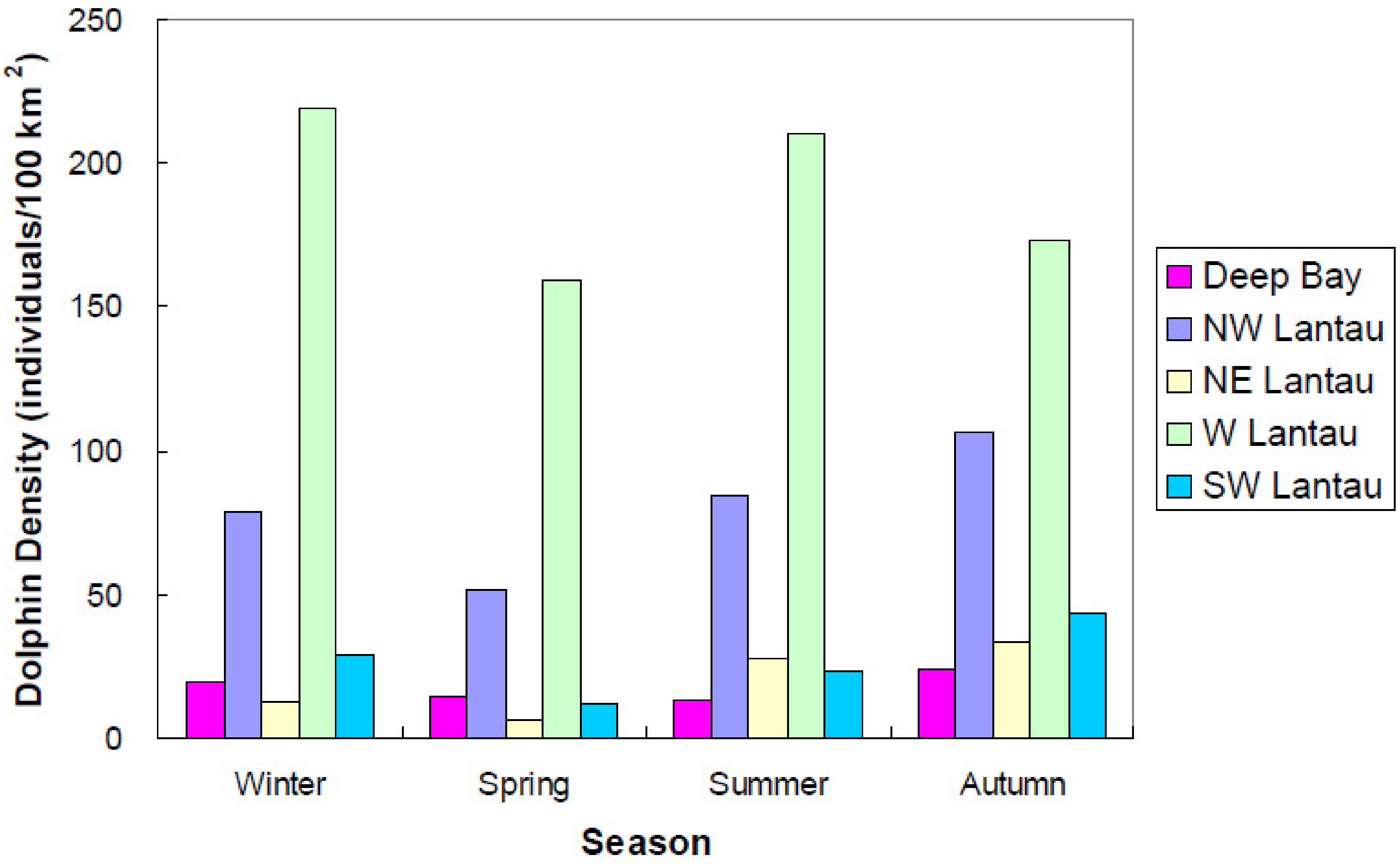

Figure 8A.20

Density Estimates of Chinese White Dolphins in Deep Bay (from 2005-09) and Other Survey Areas in Hong Kong (from 2004-06) among Different Seasons

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Table 8A.9 Estimates of Abundance and Associated Parameters for Chinese White Dolphins in Deep Bay during 2005-09

Survey Area	Survey Days	L (km)	n	f(0) (km^{-1})	E(s)	D (100 km^{-2})	N	CV (%)
Deep Bay								
Winter	27	450	13	5.4037	2.54	**19.80**	**6**	49.8
Spring	29	469	6	5.4037	4.33	**14.97**	**4**	58.2
Summer	32	539	7	5.4037	3.71	**13.03**	**4**	50.1
Autumn	27	498	11	5.4037	4.00	**23.87**	**7**	45.6

L: total length of transect surveyed; n: number of on-effort sightings; f(0): trackline probability density; E(s): unbiased mean group size; D: individual density; N: individual abundance; CV: coefficient of variation

Group Size

During 2005-09, most dolphin groups in Deep Bay and Northwest Lantau tended to be small, with 44% of the total composed of 1-2 animals, and only 4.5% of the groups composed of more than 10 animals. Within Deep Bay, most sightings were small dolphin groups with 1-4 animals, and only a few medium (5-9 animals) and large dolphin groups (≥ 10 animals) were sighted near the mouth of Deep Bay (*Figure 8A.21*). Within and adjacent to the proposed gas pipeline alignment, almost all sightings were small dolphin groups, and only two large dolphin groups were sighted just to the south of the proposed gas pipeline alignment (*Figure 8A.21*).

In contrast, medium and large dolphin groups were frequently sighted in the western Northwest Lantau area, along the Urmston Road (i.e. between Lung Kwu Chau and Black Point) and especially to the north and east of Lung Kwu Chau (*Figure 8A.21*).

Quantitative Grid Analysis of Fine-scale Habitat Use

For the present data review, SPSE and DPSE values (standardised per 100 units of survey effort) were calculated for all 356 1-km^2 grids in Deep Bay, Northwest, Northeast, West, Southwest and Southeast Lantau Survey Areas. The SPSE/DPSE values among the six grids that overlapped with the proposed gas pipeline alignment and reclamation site (i.e. Grids G5-6, H5, I5, and J5-6) were compared to the 356 grids in the six Survey Areas, the 96 grids in Northwest Lantau, and the 26 grids in Deep Bay. This quantitative analysis provides the best way to compare dolphin use of specific areas, especially on a small scale. Because the data are standardized for differential survey effort, it is possible to make direct comparison of density of two grids for interpretation.

During 2005-09, dolphins were recorded in five of the six grids that overlapped with the Project Site. The mean SPSE and DPSE (standardised per 100 units of survey effort) of these six grids were 4.9 ± 3.49 and 15.0 ±

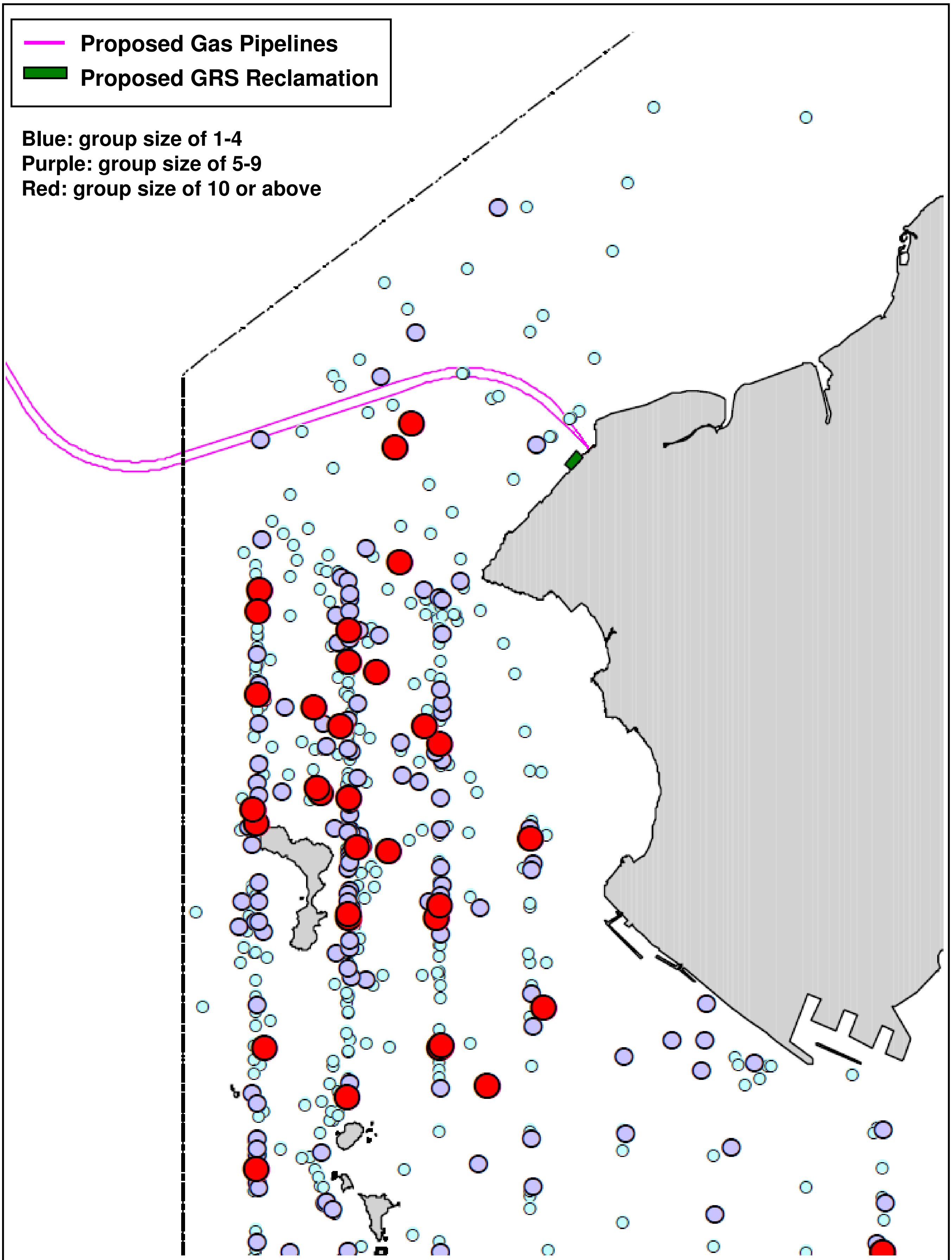

Figure 8A.21

Distribution of Chinese White Dolphin Sightings with Different Group Sizes in Western Northwest Lantau and Deep Bay from Jan 2005 – Jun 2009

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13.50 respectively and were considered as low (< 5 and < 20 respectively). Whilst the values mean SPSE and DPSE of these six grids were higher than the overall mean and the mean values of Deep Bay, they were lower than the mean values of Northwest Lantau (*Figure 8A.22*).

Habitat use of dolphins was also very uneven among the 1 km^2 grids of the Survey Areas. Grids with high sighting density and dolphin density were generally found to the north and east of Lung Kwu Chau, approximately 3 – 4 km south of the proposed gas pipelines (*Figure 8A.23*). The SPSE and DPSE values of the six grids that overlapped with the Project Site were considered as low to low-moderate, and none of these six grids that overlapped with the Project Site recorded moderate or high sighting density or dolphin density (*Figure 8A.23*). The area of proposed gas pipeline alignment and reclamation site was thus considered to be utilized by Chinese white dolphins at a low to low-moderate extent.

Calves

During 2005-09, a total of 30 unspotted calves (UCs) and 117 unspotted juveniles (UJs) (8) were sighted during on-effort surveys in Northwest Lantau and Deep Bay. Only a few UCs were sighted at the mouth of Deep Bay near the Black Point headland, and none of them were sighted in the vicinity of the proposed gas pipeline alignment or within the Deep Bay area (*Figure 8A.24*). In the western Northwest Lantau area, most sightings of UCs were made around Lung Kwu Chau (*Figure 8A.24*). A few UJs were sighted along the proposed gas pipeline alignment and in the inner part of Deep Bay, and as with the UCs, most UJs were sighted along the Urmston Road and around Lung Kwu Chau to the south of the proposed gas pipeline alignment (*Figure 8A.24*).

The on-effort data on UCs and UJs from 2005-09 were used to calculate the DPSE (standardised per 100 units of **s**urvey **e**ffort) of UCs and UJs for each grid in western Northwest Lantau and Deep Bay. UJs were recorded in two of the six grids that overlapped with the Project Site (*Figure 8A.25*), and the mean DPSE value of UJs for these six grids was 0.6 ± 0.67, which was lower than the overall mean (0.7 ± 1.72) and the mean value in Northwest Lantau (1.0 ± 2.14) but higher than that in Deep Bay (0.4 ± 0.90) (*Figure 8A.26*). During 2005-09, no UC was sighted in Deep Bay or within the proposed Project Site (*Figure 8A.25*). The areas of proposed gas pipelines and reclamation site were, therefore, only utilized by young dolphin calves to a low to low-moderate extent.

(8) Chinese white dolphins in Hong Kong have been classified into six age classes in relation to their colour pattern development, but the sequence of this development has yet to be confirmed with the exception of young calves (Jefferson 2000). The calves of Chinese white dolphins in Hong Kong are categorized into unspotted calves (UCs; newborn calves up to six months old that have not been weaned and are dependent on their mother) and unspotted juveniles (UJs; older calves up to 1-2 years old but still dependent on their mothers).

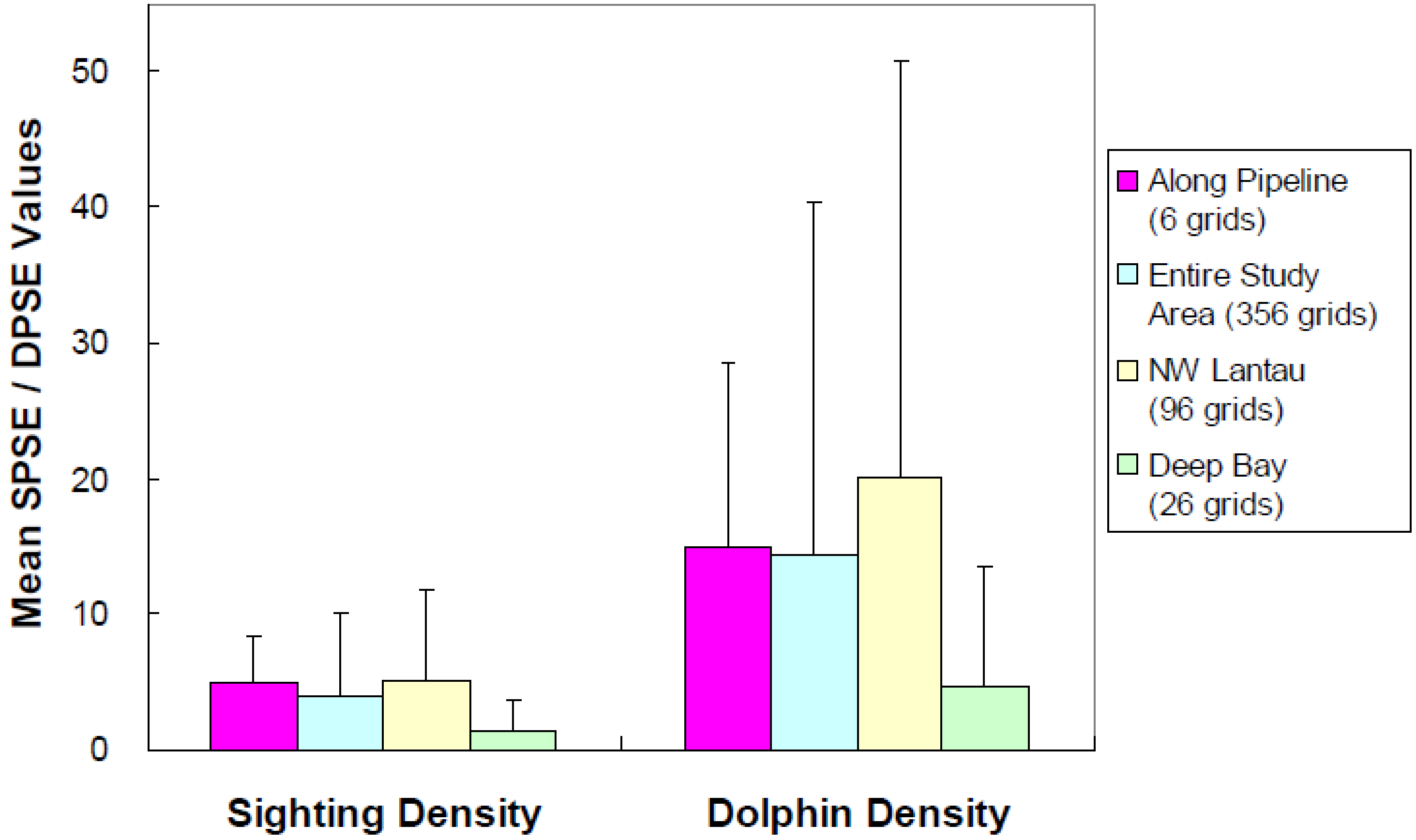

Figure 8A.22

Comparison of Sighting Density (Mean SPSE) and Dolphin Density (Mean DPSE) along the Proposed Gas Pipeline Alignment, the Entire Study Area, Northwest Lantau and Deep Bay Survey Areas

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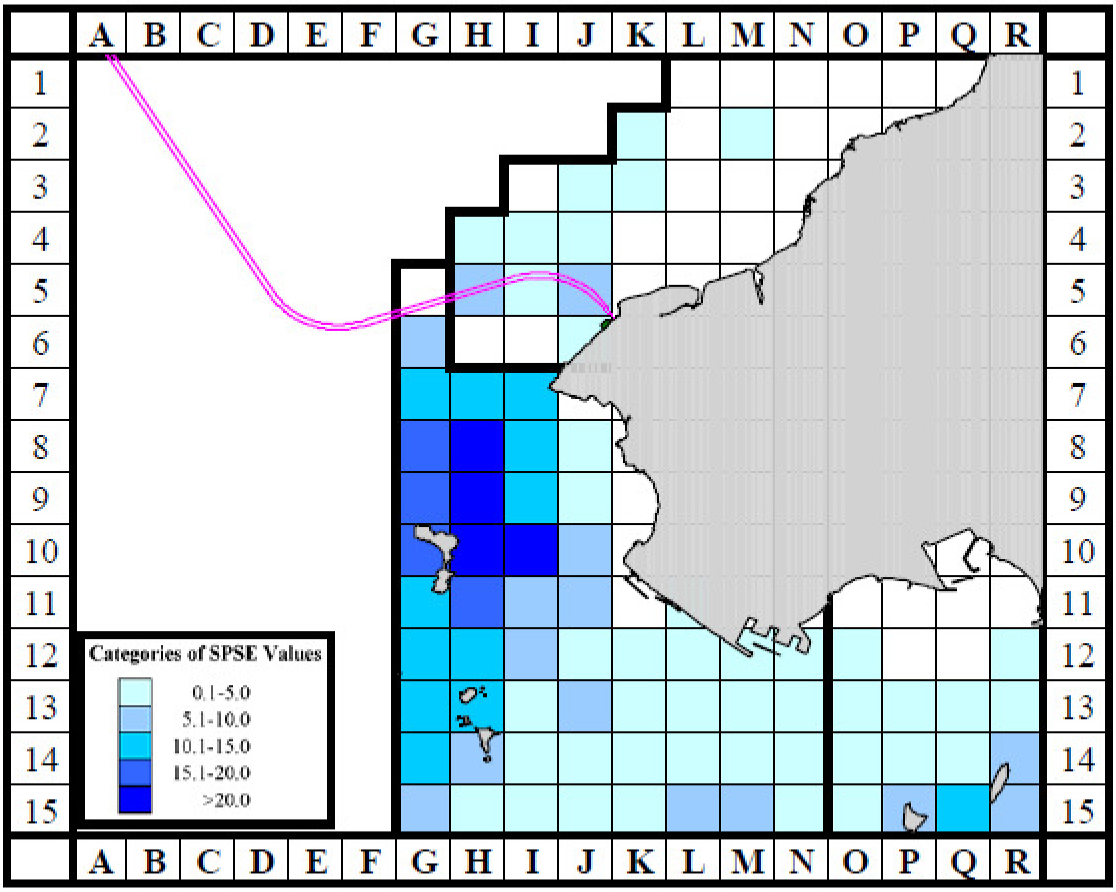

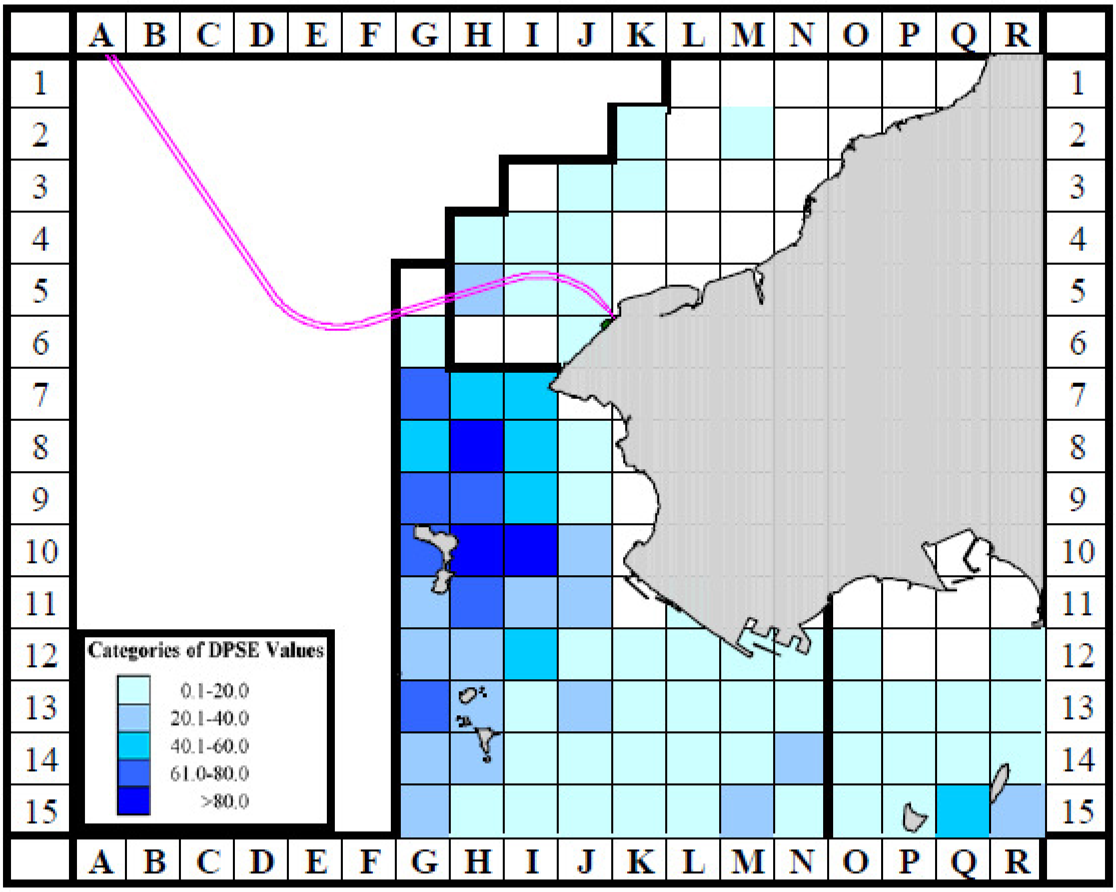

Figure 8A.23

Sighting Density (SPSE) and Density (DPSE) of Chinese White Dolphins with Corrected Survey Effort per km² in Western Northwest Lantau and Deep Bay, using Data from Jan 2005 – Jun 2009

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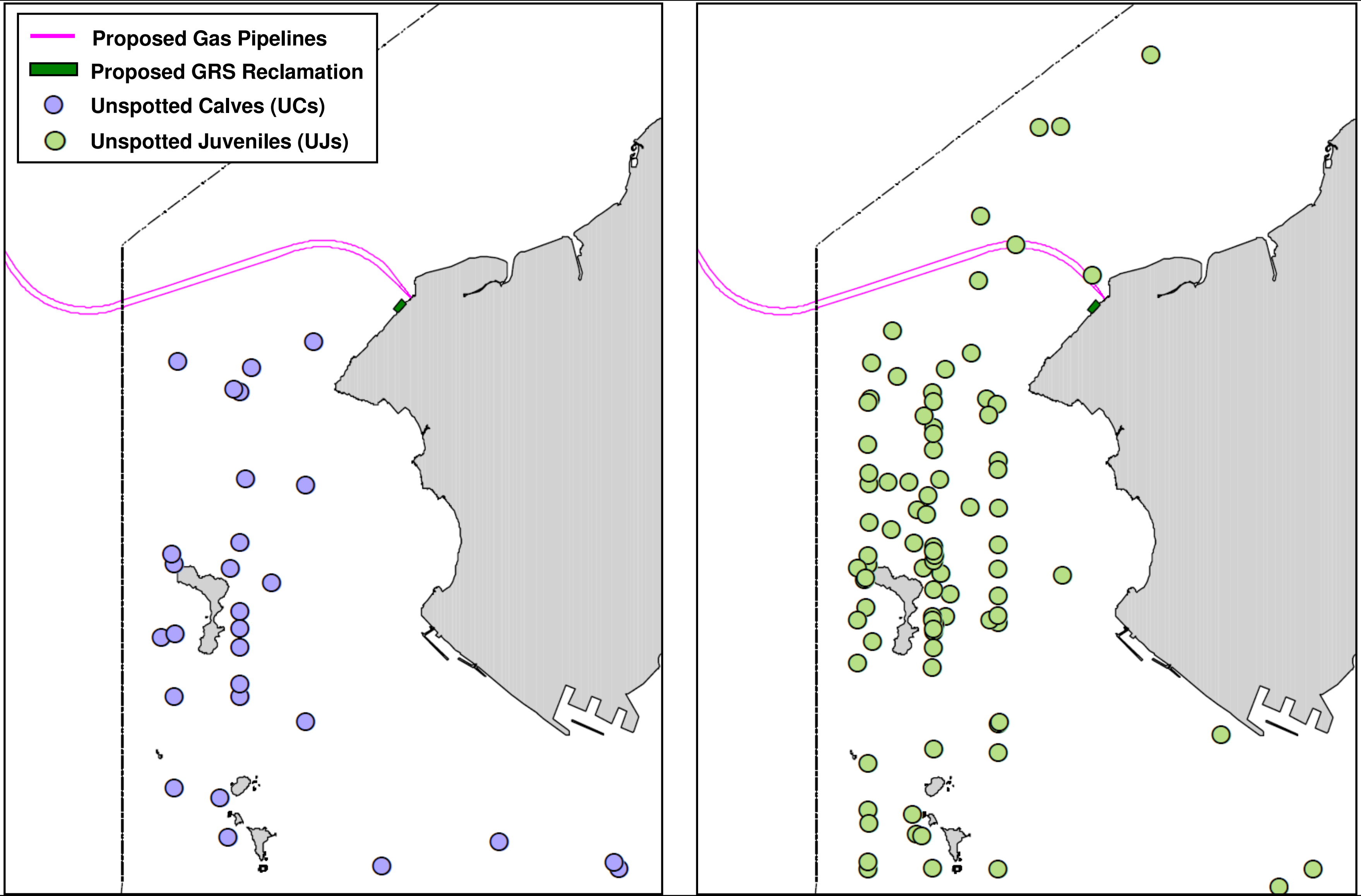

Figure 8A.24

Distribution of Unspotted Calves (UCs) and Unspotted Juveniles (UJs) in Western Northwest Lantau and Deep Bay from Jan 2005 – Jun 2009

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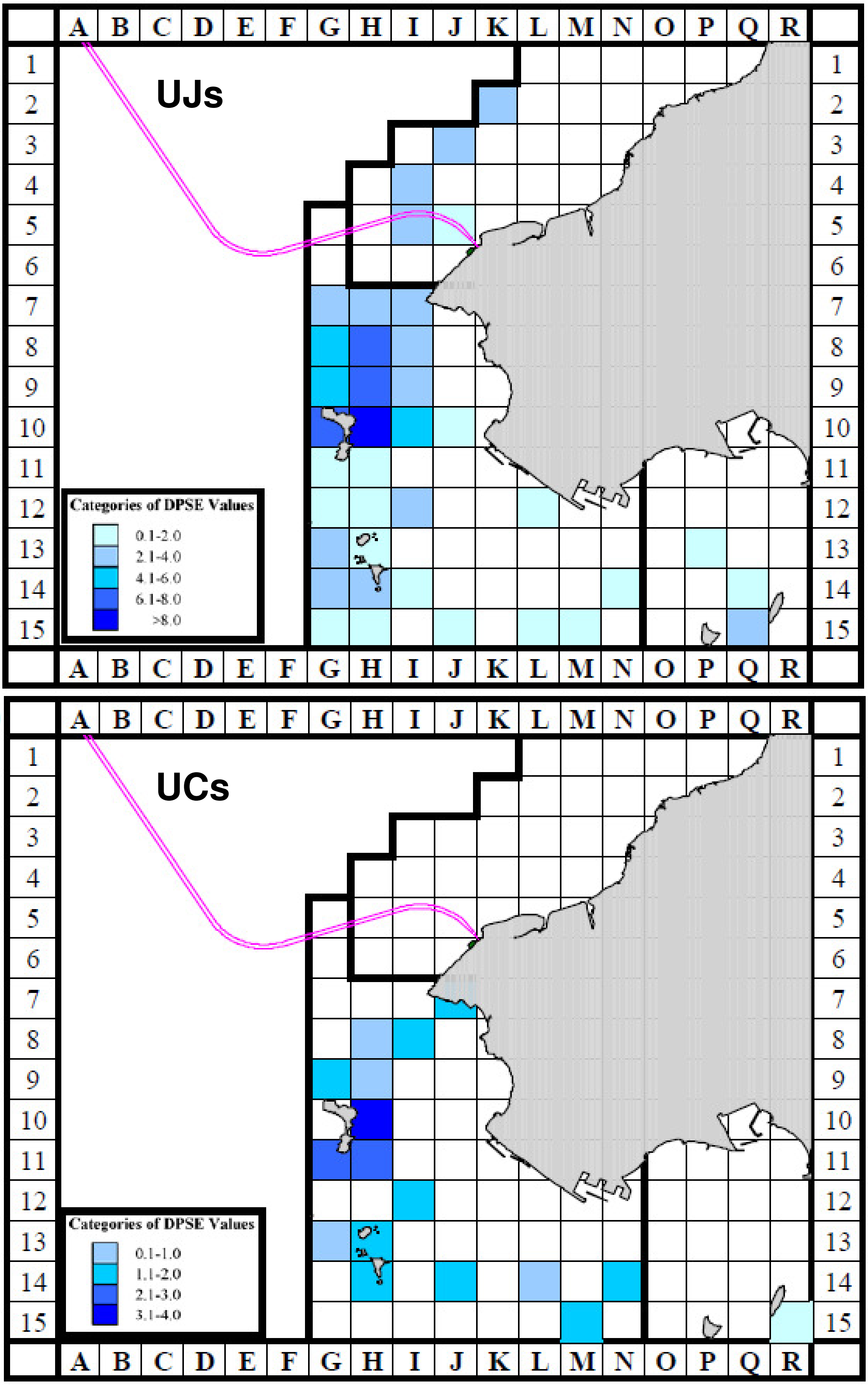

Figure 8A.25 **Density (DPSE) of Unspotted Juveniles (UJs) and Unspotted Calves (UCs) with Corrected Survey Effort per km^2 in Western Northwest Lantau and Deep Bay, using Data from Jan 2005 – Jun 2009**

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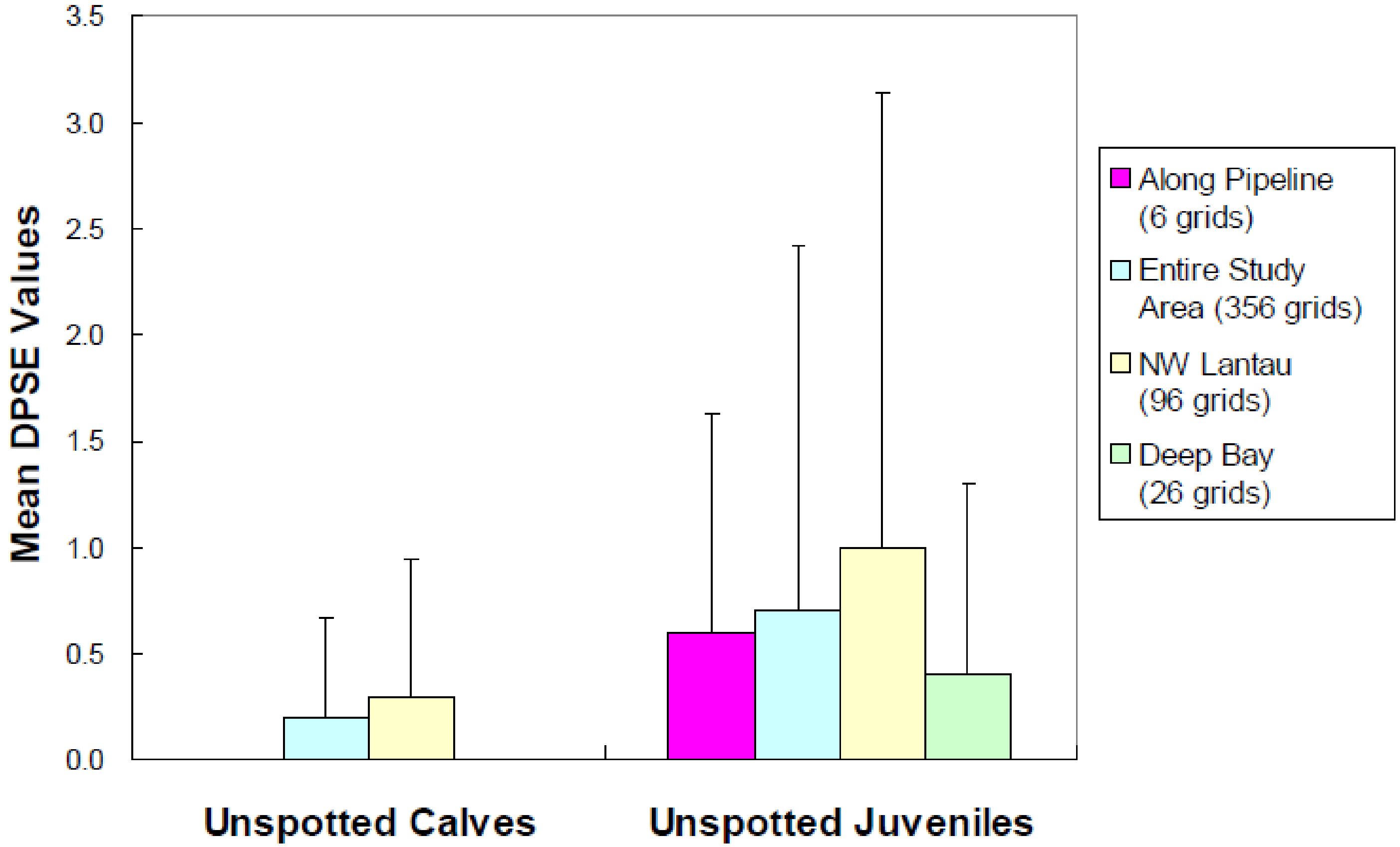

Figure 8A.26

Densities (Mean DPSE) of Unspotted Calves (UCs) and Unspotted Juveniles (UJs) along the Proposed Gas Pipeline Alignment, the Entire Study Area, Northwest Lantau and Deep Bay Survey Areas

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Behavioural Activities

Feeding and socialising activities are regarded as the two predominant daytime activities of Chinese white dolphins in Hong Kong (Hung 2008). During 2005-09, a total of 95 and 67 sightings were associated with feeding and socialising activities, respectively, in Northwest Lantau and Deep Bay. Dolphins rarely engaged in travelling and milling/resting activities in the two areas, with only 13 sightings associated with these two activities combined.

Several dolphin sightings associated with feeding and socialising activities were made near the proposed gas pipeline alignment, and these activities rarely occurred in the inner part of Deep Bay (*Figure 8A.27*). In the western Northwest Lantau area, whilst most of the feeding activities can be found along the Urmston Road and around Lung Kwu Chau, most of the socialising activities mainly occurred between Black Point headland and Lung Kwu Chau (*Figure 8A.27*).

To identify potential important habitats for feeding and socialising activities, the subset of on-effort dolphin sightings engaged in these two activities during 2005-09 were used to calculate the SPSE values (standardised per 100 units of **s**urvey **e**ffort) for grids in western Northwest Lantau and Deep Bay. Dolphins with feeding activities were recorded in three of the six grids that overlapped with the Project Site (*Figure 8A.28*), and the mean SPSE of these activities for these six grids 0.6 ± 0.67, was lower than the overall mean (0.7 ± 1.57) and the mean value in Northwest Lantau (0.8 ± 1.54) but higher than that in Deep Bay (0.2 ± 0.50) (*Figure 8A.29*). Likewise, dolphins with socialising activities were recorded in two of the six grids that overlapped with the Project Site (*Figure 8A.28*), and the mean SPSE of these activities for these six grids was 0.8 ± 1.27, which was higher than the overall mean (0.3 ± 0.80), the mean value in Northwest Lantau (0.5 ± 0.92) and the mean value in Deep Bay (0.3 ± 0.72) (*Figure 8A.29*). The areas of proposed gas pipelines and reclamation site were, therefore, utilized by dolphins for feeding activities and socializing activities at a low-moderate to moderate extent respectively.

Individual Ranging Pattern

Currently, the photo-identification catalogue of the Pearl River Estuary Chinese white dolphin population contains information of over 650 individuals identified in Hong Kong and the rest of the Pearl River Estuary, with 347 dolphins being first identified within Hong Kong territorial waters. A total of 99 individual dolphins from the photo-identification catalogue were seen 10 times or more and were examined in the ranging pattern analysis.

The ranging patterns of the 99 individual dolphins indicated that the majority of them only used the mouth of Deep Bay to a small extent, and the proposed gas pipelines route was located at the periphery of most of these individuals' ranges. The core area use patterns of individual dolphins revealed that the proposed gas pipeline alignment was situated within or adjacent to the 50%

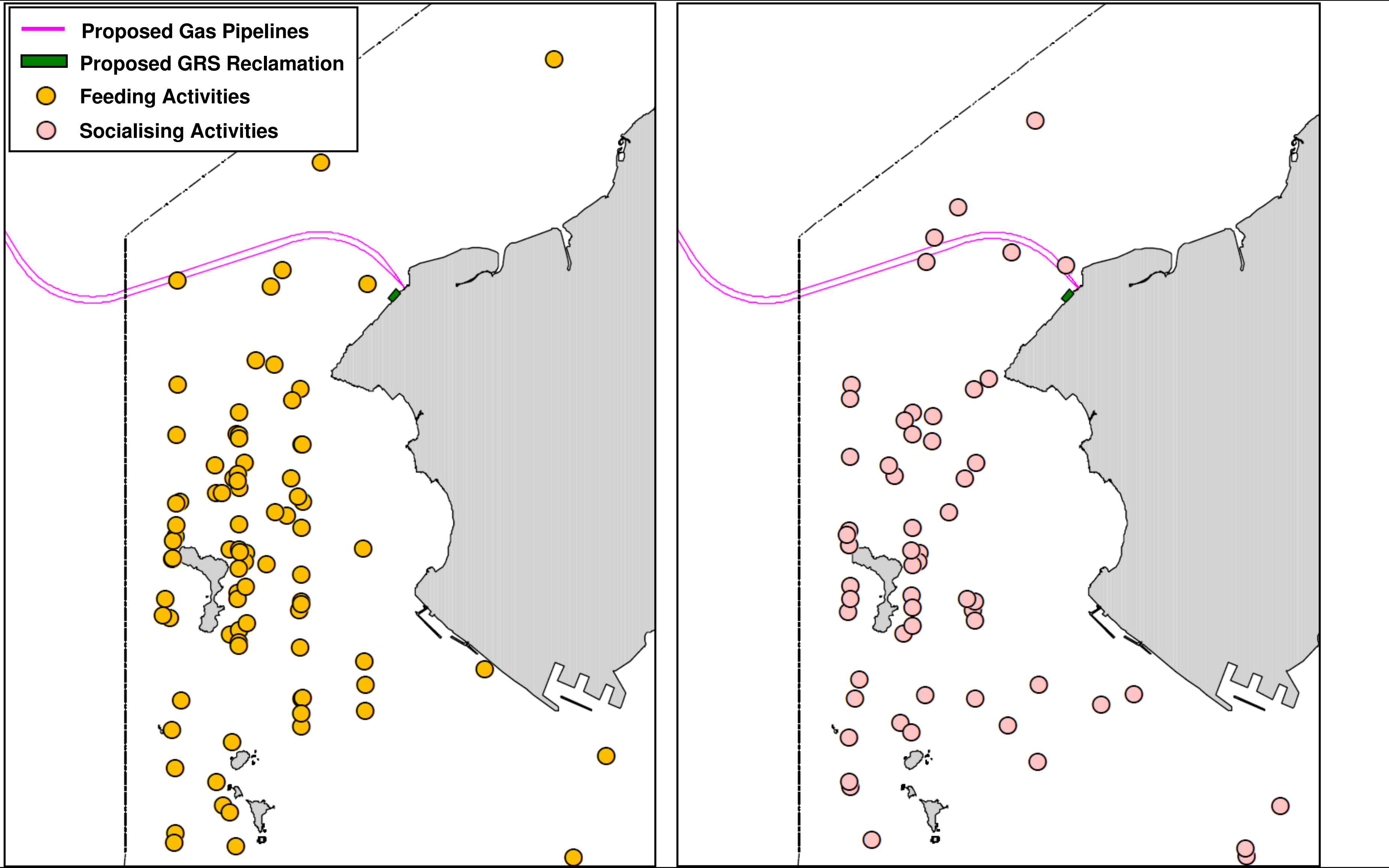

Figure 8A.27

Distribution of Dolphin Sightings Associated with Feeding and Socialising Activities in Western Northwest Lantau and Deep Bay from Jan 2005 – Jun 2009

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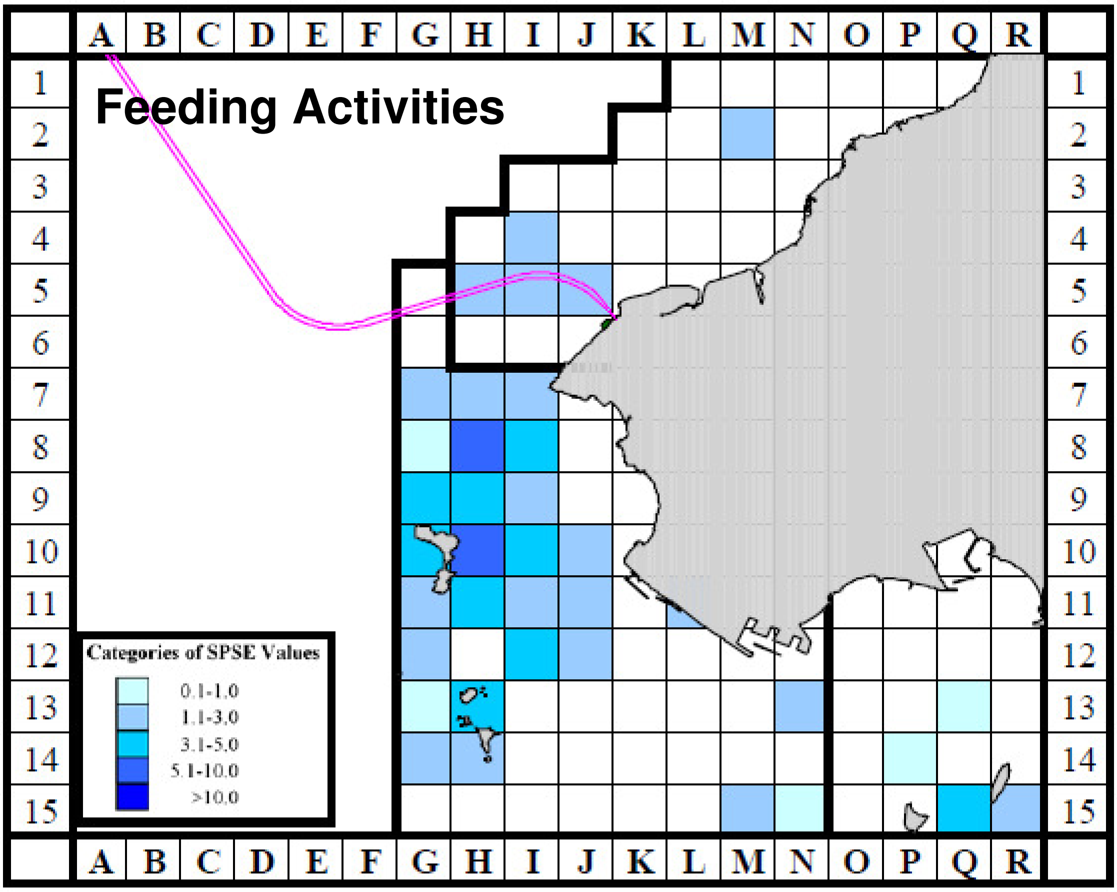

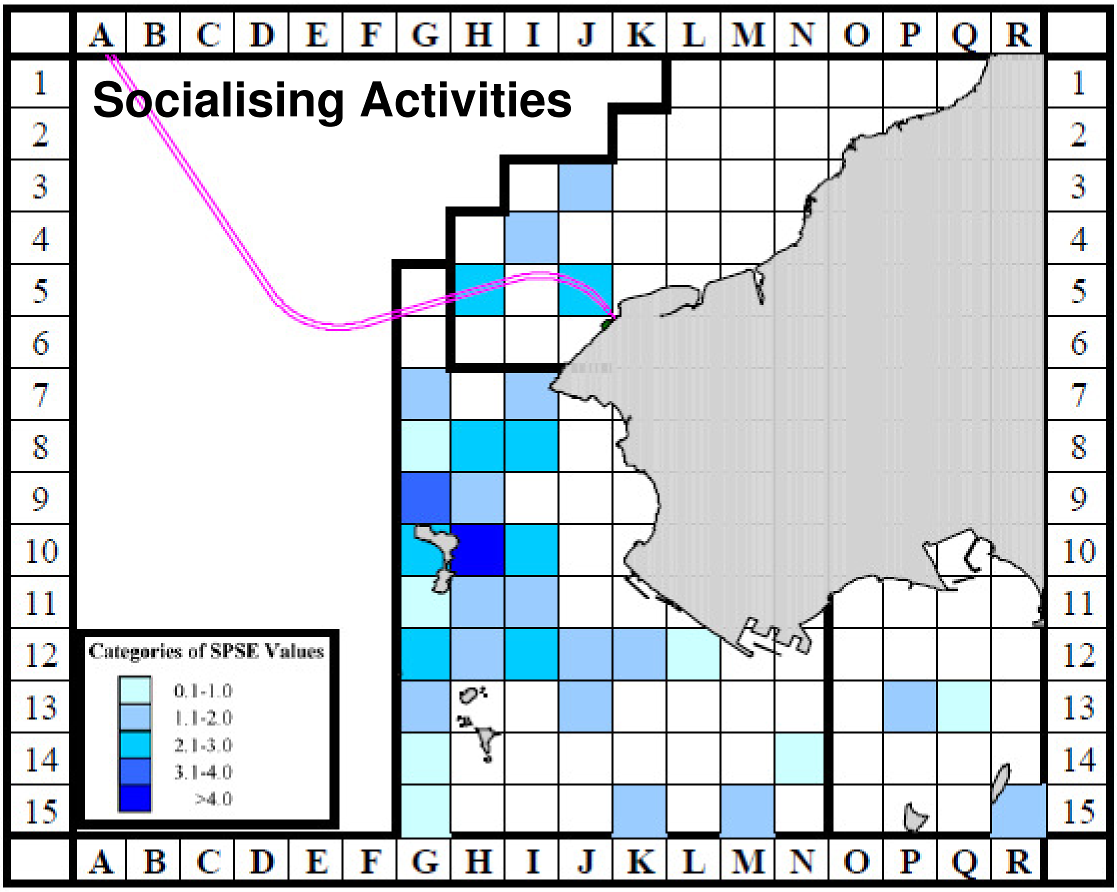

Figure 8A.28

Sighting Density (SPSE) of Feeding and Socialising Activities with Corrected Survey Effort per km² in Western Northwest Lantau and Deep Bay, using Data from Jan 2005 – Jun 2009

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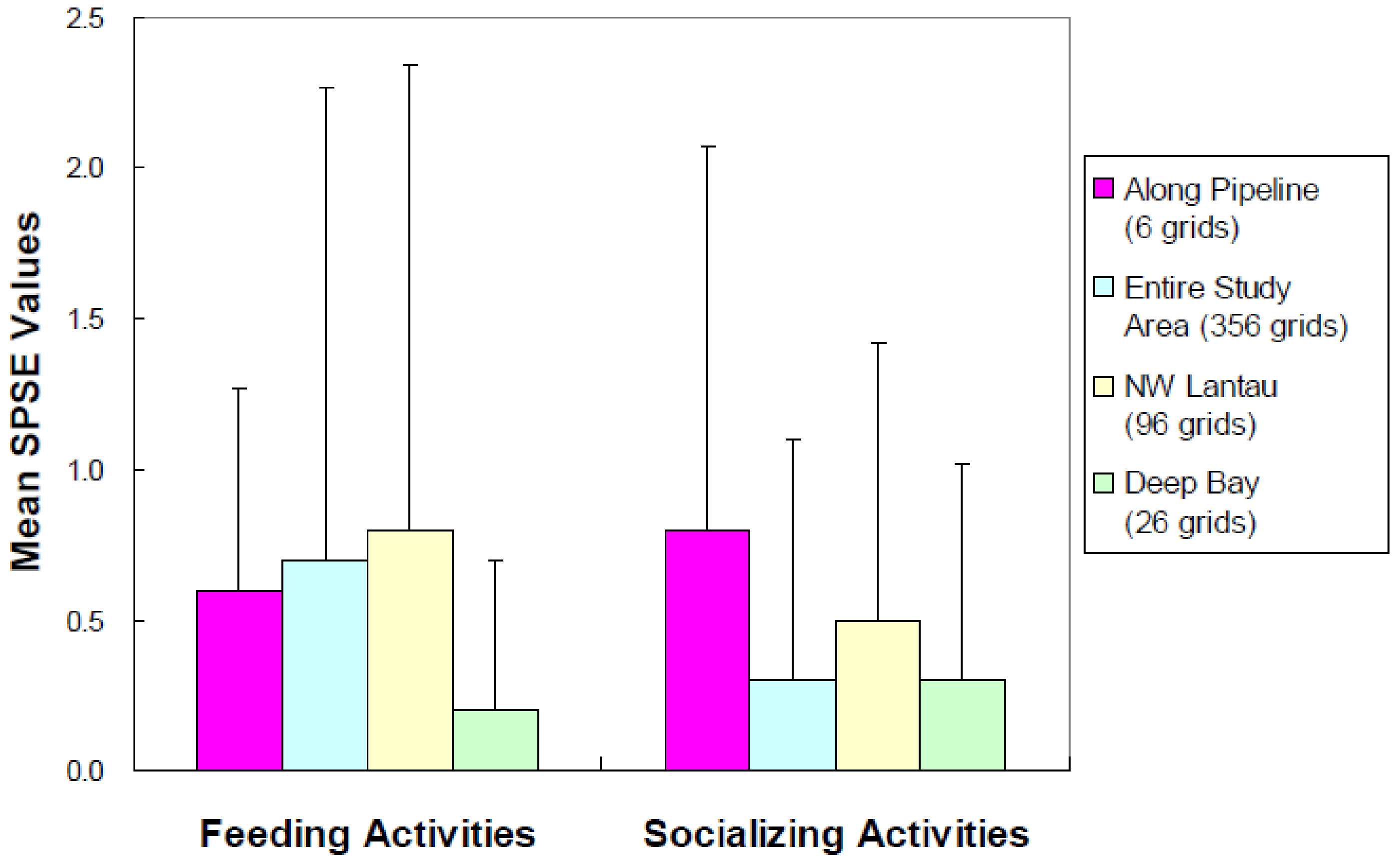

Figure 8A.29 **Sighting Densities (Mean SPSE) of Feeding and Socializing Activities along the Proposed Gas Pipelines Alignment, the Entire Study Area, Northwest Lantau and Deep Bay Survey Areas**

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UD ranges of only ten animals and the 25% UD ranges of only three animals (*Figure 8A.30*). This indicated that only a small proportion of identified dolphins have consistently utilized the area where the proposed gas pipelines are located. A total of 42 of the 99 individuals had their 95% UD ranges overlap with or adjacent to the proposed gas pipeline route, and three other individuals that were sighted 5-9 times (i.e. NL189, SL42 & SL30) also had their ranges overlap with the proposed gas pipeline route (*Annex 8C*).

8A.6 *EVALUATION OF ECOLOGICAL IMPORTANCE*

The existing conditions of the marine ecological habitats and resources within the Study Area have been assessed. These baseline conditions have been based on available literature and, where considered necessary, focussed field surveys and data review to update and supplement the data. Based on this information (presented in *Sections 8A.3 – 8A.5*), the ecological importance of each habitat has been determined according to the *EIAO-TM Annex 8* criteria, as follows:

- Naturalness
- Size
- Diversity
- Rarity
- Re-creatability
- Fragmentation
- Ecological Linkage
- Potential Value
- Nursery Ground
- Age
- Abundance

Within the Study Area of this EIA, which covers quite a large areal extent, variations in the ecological characteristics of habitats across different locations (which are kilometres apart) are likely to be present. To provide information of key relevance to the marine ecological assessment, the ecological importance of habitats presented in this baseline is therefore primarily focussed on the vicinity of the works areas of the proposed project.

Outcomes of the evaluation of ecological importance of the marine habitats and species within the Study Area are presented in *Tables 8A.10* to *8A.13*. The

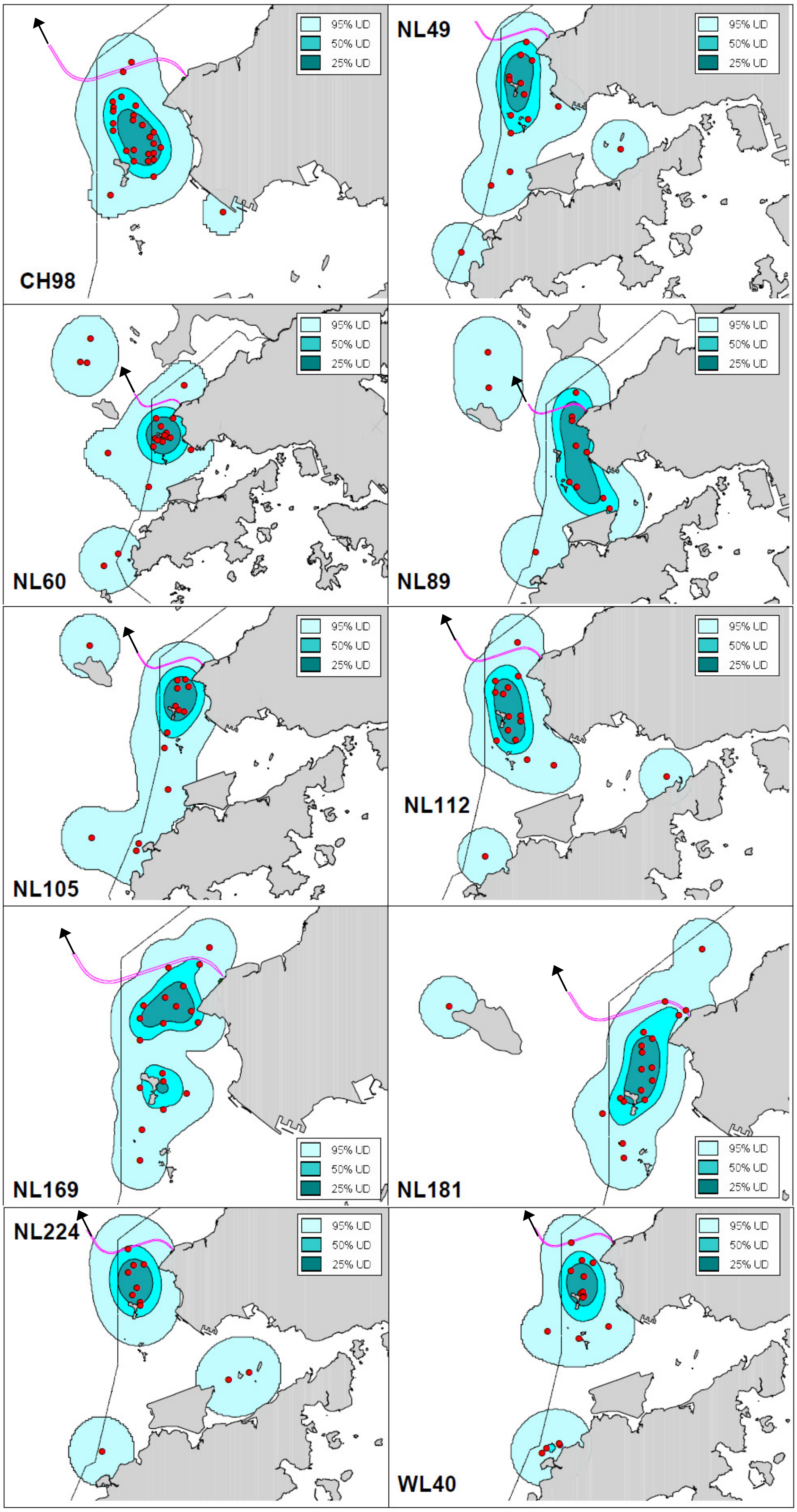

Figure 8A.30

Ranging Patterns of Ten Individual Dolphins at 95%, 50% and 25% UD Levels using Kernel Estimator

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application of the *EIAO-TM Annex 8* criteria has led to the following conclusions:

- The intertidal artificial seawall at the Black Point Power Station and the natural shores at the Black Point headland to be classified as low ecological importance;
- The subtidal artificial seawall at the Black Point Power Station and the hard bottom assemblages within the Project's footprint to be classified as low ecological importance;
- The subtidal soft benthos assemblages within the Project's footprint to be classified as low ecological importance; and
- The marine waters off the Black Point Power Station and along the corridor of the proposed submarine gas pipelines to be classified as of low-moderate ecological importance on the use of the area by Indo-Pacific humpback dolphins.

Table 8A.10 Ecological Importance of Intertidal Habitats at Black Point Power Station

Criteria	Intertidal Artificial Shorelines	Natural Rocky Shore at Black Point Headland
Naturalness	Artificial, constructed habitat.	Largely undisturbed.
Size	Large. The artificial shore adjacent to the Project Site is approximately 1 km in length and is the predominant habitat of the Black Point Power Station.	Medium. About 590 m of rocky shore habitat is found on the northern portion of the Black Point headland.
Diversity	Low. The intertidal assemblages of the sloping artificial shores comprise typical biota of sheltered to moderately-exposed rocky shores in Hong Kong, but with low diversity.	Low. The intertidal assemblages are composed of typical biota of moderately-exposed rocky shores in Hong Kong, but with low diversity.
Rarity	No species recorded are considered rare or of recognised conservation interest.	No species recorded are considered rare or of recognised conservation interest.
Re-creatability	Hard bottom substrata may be re-colonised by subtidal organisms.	Hard bottom substrata may be re-colonised by subtidal organisms.
Fragmentation	Low. The surrounding coastlines primarily comprise artificial intertidal shores.	Low. The shoreline is interspersed with areas of artificial seawall.
Ecological Linkage	The habitat is not functionally linked to any high value habitat in a significant way.	The habitat is not functionally linked to any high value habitat in a significant way.
Potential Value	Unlikely to become an area of conservation value.	Unlikely to become an area of conservation value.
Nursery Area	No significant records identified during the literature review or field surveys.	No significant records identified during the literature review or field surveys.

Criteria	Intertidal Artificial Shorelines	Natural Rocky Shore at Black Point Headland
Age	The artificial seawall has been in place since the site access of Black Point Power Station was obtained in March 1993.	n/a for these assemblages but the life cycle of the fauna and flora is very short.
Abundance	Lower abundance than natural rocky shore habitat.	Typical of other moderately-exposed shores in Hong Kong.
Summary	Intertidal assemblages of the artificial shores are reported to support a lower diversity and abundance of intertidal organisms as natural shores. **Ecological Importance - Low.**	The fauna of the intertidal region appears to be typical of moderately-exposed shores in Hong Kong, but with low diversity. The sites appear to have suffered some human disturbance. **Ecological Importance - Low.**

Table 8A.11 Ecological Importance of Subtidal Hard-Bottom Habitats at Black Point Power Station and within the Project Footprint

Criteria	Subtidal Artificial Shorelines & Other Hard Substrates
Naturalness	Artificial, constructed habitat.
Size	Large. The subtidal artificial shore in the Study Area is approximately 1 km in length which is found along a narrow band at depths of 3-4 m.
Diversity	Very low in comparison to other similar man-made habitats of Hong Kong.
Rarity	No sessile species was recorded.
Re-creatability	Hard bottom substrata may be re-colonised by subtidal organisms including corals
Fragmentation	Low. The surrounding coastlines primarily comprise artificial intertidal shores.
Ecological Linkage	The habitat is not functionally linked to any high value habitat in a significant way.
Potential Value	Very low since conditions are not highly suited for coral growth. High turbidity and high rates of sedimentation mean that the area is unlikely to become an area of coral conservation.
Nursery Area	No significant records identified during the literature review.
Age	The artificial seawall has been in place since the site access of Black Point Power Station was obtained in March 1993.
Abundance	Supported no live coral coverage in the Study Area.
Summary	No live coral cover is present. **Ecological Importance - Low.**

Table 8A.12 Ecological Importance of Subtidal Soft Benthos Assemblages at the Proposed GRS Reclamation and along the Corridor of the Proposed Submarine Gas Pipelines

Criteria	Subtidal Soft Benthos
Naturalness	Habitat disturbed to some extent by fisheries vessel trawling activities and is influenced by discharges from the Pearl River.
Size	Habitat is large in extent. Pipeline alignment is approximately 5 km in HKSAR waters.
Diversity	The assemblages are of similar diversity to other areas in the Hong Kong waters.
Rarity	No species recorded are considered rare or of recognised conservation interest.
Re-creatability	Benthic organisms may recolonise disturbed seabed areas.
Fragmentation	The habitat is not fragmented.
Ecological Linkage	The habitat is not functionally linked to any high value habitat in a significant way.
Potential Value	It is unlikely that the habitat could develop conservation interest.
Nursery Area	No significant records identified during the literature review.
Age	The fauna appear to be typical of those present in Hong Kong's soft benthos. The sediments in the habitat are constantly accreting and eroding and the fauna present there are typically short lived.
Abundance	In comparison to other parts of the western waters the assemblages are of medium to high abundance and biomass.
Summary	The sediments support low diversity but average abundance/ biomass of benthic organisms that are typical of Hong Kong's benthos. **Ecological Importance – Low.**

Table 8A.13 Ecological Importance of Marine Waters off the Black Point Power Station and along the Corridor of the Proposed Submarine Gas Pipelines

Criteria	Marine Mammal Habitat
Naturalness	In close proximity to artificial shorelines and the pipeline route traverses marine traffic lane of Hong Kong.
Size	Habitat is large in extent. Pipeline alignment is approximately 5 km in HKSAR waters.
Diversity	N/A.
Rarity	Indo-Pacific humpback dolphin *Sousa chinensis* has been recorded in the waters off Black Point.
Re-creatability	N/A.
Fragmentation	The habitat is not fragmented.
Ecological Linkage	Proposed pipeline route lies in waters that are utilised by humpback dolphins as part of their larger habitat. These waters are not regarded as major habitats for humpback dolphins.
Potential Value	Waters off Black Point are at the periphery of most dolphins' ranges, and only 10 of the 99 identified dolphins have consistently utilized this area (at 50% UD ranges).

Criteria	Marine Mammal Habitat
Nursery Area	Review of baseline conditions indicated lower sightings of young animals or mothers with calves off Black Point or in proximity to the pipeline route than in other waters of Hong Kong
Age	N/A
Abundance	Dolphin density and abundance are low in comparison to other waters of Hong Kong.
Summary	Route passes through waters where humpback dolphins have been sighted, but dolphin abundance was considered to be low. **Ecological Importance –Low to Moderate.**

8A.6.1 *Species of Conservation Interest*

In accordance with *EIAO-TM Annex 8* criteria, an evaluation of species of conservation value recorded from the Study Area is presented in *Table 8A.14.*

Table 8A.14 Species of Conservation Interest within the Study Area

Common Name	Scientific Name	Protection Status	Distribution, Rarity and other Notes
Indo-Pacific Humpback dolphin (locally known as Chinese White Dolphin)	*Sousa chinensis*	• Wild Animals Protection Ordinance • Protection of Endangered Species of Animals and Plants Ordinance (CITES Appendix I species [i.e. highest protection]) • Listed as "Endangered" in the China Species Red List • Listed as "Grade I National Key Protected Species" in China • Listed as "Near Threatened" in the 2009 IUCN Red List of Threatened Species	Range across Pearl River Estuary and across Hong Kong western and southern waters from Deep Bay to Lamma.

8A.7 SUMMARY

The findings from the literature review, field surveys and additional data review on marine ecological conditions of the Study Area off Black Point are detailed above and are summarized as follows.

The marine ecological habitats in the immediate vicinity of the proposed GRS reclamation site of BPPS and pipeline route in Black Point have undergone some degree of anthropogenic disturbance through marine traffic via the Urmston Road, trawling activities and reclamation for the Black Point Power Station and CLP's Ash Lagoons.

The key finding of the literature review was the recorded presence of Indo-Pacific humpback dolphin *Sousa chinensis* in the waters of the Study Area. The review highlighted that humpback dolphins have been sighted in Deep

Bay and western Northwest Lantau within the areas of the proposed reclamation and pipeline alignment.

To provide the most up-to-date baseline information for some components of the marine environment, focussed field surveys and additional data review were undertaken. Field surveys were conducted in habitats within and surrounding the reclamation site and pipeline route in the dry and wet seasons of 2009, while the additional data review for marine mammals utilised data from January 2005 to June 2009. The details of the baseline surveys are summarized in *Table 8A.4.*

The ecological importance of the habitats was determined through reference to the following:

- Literature review;
- Findings of the field surveys and additional data review;
- Comparison with other areas in Hong Kong; and
- *Annexes 8* and *16* of the *EIAO TM*.

None of the marine ecological resources and habitats in the proposed Project Site is considered as of high ecological value. Key findings and outcomes of the evaluation of ecological importance are summarised below.

Intertidal Hard Bottom Assemblages

Seasonal quantitative transect surveys were conducted on the artificial seawall of the Black Point Power Station. Rocky shore species at all survey transects were common and widespread and no species of high conservation importance were recorded. The assemblages recorded are considered to be of low diversity and low ecological importance.

Subtidal Soft Bottom Assemblages – Benthos

Systematic grab sampling was conducted within and in proximity to the footprint of the reclamation site and pipeline alignment in the wet season 2009. Infaunal assemblages at the surveyed sites were dominated by polychaete worms, and the species recorded are common and widespread species with no particular conservation concern. In comparison with the Hong Kong average reported in the literature, the abundance and biomass of infauna at these sites are considered as medium to high, while taxonomic richness of infauna at these sites are considered as low. The ecological importance of these assemblages is considered as low.

Subtidal Hard Bottom Assemblages – Coral

Spot dive surveys were conducted on the artificial seawall of the Black Point Power Station, within the proposed reclamation site and on hard substrate identified along the proposed pipeline route. No corals (hard, soft, gorgonians or whips) were recorded during the survey and thus the ecological importance of these habitats is considered as low.

Indo-Pacific Humpback Dolphins

A comprehensive data review was undertaken by the Hong Kong Cetacean Research Project (HKCRP) using the long-term dolphin monitoring data collected from Deep Bay and western Northwest Lantau from January 2005 to June 2009. This review aimed to characterise the use of marine waters of the Project Site and its vicinity by the Indo-Pacific humpback dolphin.

Findings of the data review showed that humpback dolphins have been sighted along and adjacent to the proposed gas pipeline alignment, and also near the proposed reclamation site at BPPS. Dolphin densities (DPSE values) were considered as low to moderate for the proposed reclamation site and along the pipeline alignment. The ecological importance of the Study Area is considered as low-to-moderate.

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Annex 8B

Data of Marine Ecological Resources

Table 1 Mean Density (m $^{-2}$) of Intertidal Fauna and Mean Percentage Cover (%) of Sessile Fauna and Flora recorded Natural Rocky Shore Transects T1 and T2 at Black Point during Dry and Wet Season 2004 Surveys

	Dry Season (2004)						**Wet Season (2004)**					
	High-Intertidal Zone		**Mid-Intertidal Zone**		**Low-Intertidal Zone**		**High-Intertidal Zone**		**Mid-Intertidal Zone**		**Low-Intertidal Zone**	
	T1	***T2***	***T1***	***T2***	***T1***	***T2***	***T1***	***T2***	***T1***	***T2***	***T1***	***T2***
Snail												
Echinolittorina trochoides	0	0	0	0	0	0	0	0.80 ± 2.53	0	0	0	0
Echinolittorina radiata	61.6 ± 170	3.60 ± 5.15	2.40 ± 5.06	3.60 ± 5.80	0	0	9.20 ± 21.2	9.60 ± 16.9	0	0	0	0
Littoraria articulata	173 ± 207	93.2 ± 102	74.0 ± 101	140 ± 140	0	0	27.2 ± 38.6	31.2 ± 44.9	2.40 ± 7.59	0	0	0
Monodonta labio	0	0	0.40 ± 1.26	0.80 ± 2.53	0.40 ± 1.26	0.80 ± 2.53	0	1.20 ± 3.79	0	0	0	0
Nerita albicilla	0	0	4.00 ± 7.54	7.60 ± 11.8	0	1.20 ± 2.70	0	0.40 ± 1.26	2.40 ± 3.86	34.4 ± 55.5	0	1.60 ± 2.80
Thais clavigera	0	0	0	0	1.20 ± 3.79	0	0	0	0	0	0.40 ± 1.26	1.60 ± 5.06
Limpet												
Siphonaria japonica	0	0	0	3.20 ± 7.73	0	13.6 ± 11.2	0	0	1.20 ± 2.70	4.80 ± 10.3	0	0
Nipponacmea concinna	0	0	0	0	0	2.00 ± 3.40	0	0	0	0	0	0
Cellana toreuma	0	0	0	0	0	0	0	0	3.20 ± 10.1	2.00 ± 4.32	0	0
Bivalves %												
Saccostrea cucullata	0	0	1.00 ± 2.11	0.90 ± 1.52	21.1 ± 26.3	4.30 ± 3.71	0	0.10 ± 0.32	12.1 ± 18.4	10.8 ± 12.7	1.00 ± 3.16	4.00 ± 9.66
Barnacles %												
Tetraclita japonica	0	0	1.60 ± 3.34	3.80 ± 3.74	16.2 ± 21.9	12.2 ± 11.9	0	0.10 ± 0.32	12.3 ± 16.1	18.8 ± 21.5	66.0 ± 17.1	44.0 ± 31.7
Balanus amphitrite	0.50 ± 1.58	0	0.60 ± 1.58	1.90 ± 2.85	9.60 ± 12.7	27.5 ± 19.3	0	0	0	0	0	0
Algae %												
Epiphytic algae	0	0	6.50 ± 12.5	0	17.0 ± 18.7	25.5 ± 29.9	0	0	0	0	27.4 ± 17.7	50.0 ± 29.1
Cyanobacteria	0	0	4.00 ± 9.37	5.00 ± 7.07	0.50 ± 1.58	11.0 ± 12.0	40.0 ± 33.7	18.0 ± 29.0	21.0 ± 23.3	9.00 ± 17.3	0	0

Table 2 Benthic Grab Survey Raw Data - Wet Season Abundance

Phylum	Class	Order	Family	Species	A1	A2	A3	A4	A5	A6
Annelida	Polychaeta	Terebellida	Ampharetidae	*Isolda pulchella*	0	1	0	0	0	0
Annelida	Polychaeta	Terebellida	Ampharetidae	*Samytha besslei*	0	0	0	0	0	0
Annelida	Polychaeta	Capitellida	Capitellidae	*Mediomastus californiensis*	0	0	1	0	2	3
Annelida	Polychaeta	Capitellida	Capitellidae	*Notomastus latericeus*	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Cirratulidae	*Cirratulus filiformis*	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Cirratulidae	*Tharyx* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Eunicida	Eunicidae	*Eunice indica*	0	0	0	0	0	0
Annelida	Polychaeta	Eunicida	Eunicidae	*Marphysa stragulum*	0	0	0	0	0	0
Annelida	Polychaeta	Flabelligerida	Flabelligeridae	*Pherusa parmata*	0	0	0	0	0	0
Annelida	Polychaeta	Flabelligerida	Flabelligeridae	*Pherusa plusoma*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Glyceridae	*Glycera onomichiensis*	1	0	1	0	0	0
Annelida	Polychaeta	Phyllodocida	Goniadidae	*Glycinde gurjanovae*	0	0	0	1	0	0
Annelida	Polychaeta	Phyllodocida	Goniadidae	*Goniada eremita*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Hesionidae	*Micropodarke dubia*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Hesionidae	*Ophiodromus angustifrons*	0	0	0	0	0	0
Annelida	Polychaeta	Eunicida	Lumbrineridae	*Lumbrineris* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Magelonidae	*Magelona pacifica*	0	0	0	0	0	0
Annelida	Polychaeta	Capitellida	Maldanidae	*Euclymene* sp.	0	0	0	0	1	0
Annelida	Polychaeta	Phyllodocida	Nephtyidae	*Aglaophamus dibranchis*	1	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Nereidae	*Nereis* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Eunicida	Onuphidae	*Diopatra* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Eunicida	Onuphidae	*Onuphis eremita*	1	0	0	0	0	0
Annelida	Polychaeta	Orbiniida	Orbiniidae	*Scoloplos* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Terebellida	Pectinariidae	*Pectinaria papillosa*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Phyllodocidae	*Phyllodoce papillosa*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Pilargiidae	*Sigambra hanaokai*	0	0	1	0	0	0
Annelida	Polychaeta	Spionida	Poecilochaetidae	*Poecilochaetus serpens*	0	0	0	0	1	0
Annelida	Polychaeta	Phyllodocida	Polynoidae	*Gattyana* sp.	0	0	0	1	0	0
Annelida	Polychaeta	Phyllodocida	Polynoidae	*Lepidonotus* sp.	0	0	0	0	1	0
Annelida	Polychaeta	Sabellida	Sabellidae	*Potamilla* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Spionidae	*Laonice cirrata*	0	0	0	0	1	0
Annelida	Polychaeta	Spionida	Spionidae	*Prionospio queenslandica*	0	1	0	0	0	0
Annelida	Polychaeta	Spionida	Spionidae	*Scolelepis squamata*	0	0	0	0	0	0
Annelida	Polychaeta	Terebellida	Terebellidae	*Loimia medusa*	1	0	0	0	0	0

Table 2 Benthic Grab Survey Raw Data - Wet Season Abundance

Phylum	Class	Order	Family	Species	A1	A2	A3	A4	A5	A6
Annelida	Polychaeta	Terebellida	Terebellidae	*Lysilla pacifica*	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Alpheidae	*Alpheus* sp.	0	0	0	0	0	0
Arthropoda	Malacostraca	Amphipoda	Ampeliscidae	*Byblis* sp.	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Callianassidae	*Callianassa* sp.	0	0	0	0	0	0
Arthropoda	Malacostraca	Isopoda	Paranthuridae	*Paranthura* sp.	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Penaeidae	*Metapenaeus ensis*	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Goneplacidae	*Typhlocarcinus nudus*	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Pinnotheridae	*Neoxenophthalmus obscurus*	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Porcellanidae	*Raphidopus ciliatus*	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Portunidae	*Charybdis variegata*	0	0	0	0	0	0
Arthropoda	Malacostraca	Stomatopoda	Squillidae	*Anchisquilla fasciata*	0	1	1	1	0	0
Arthropoda	Malacostraca	Stomatopoda	Squillidae	*Clorida latreillei*	0	0	0	0	0	0
Arthropoda	Malacostraca	Stomatopoda	Squillidae	*Oratosquilla oratoria*	0	0	0	0	0	0
Chordata	Osteichthyes	Perciformes	Taenioididae	*Trypauchen vagina*	0	0	0	0	0	0
Cnidaria	Anthozoa	Actiniaria	Actiniidae	*Actinia* sp.	0	0	0	0	0	0
Cnidaria	Anthozoa	Ceriantharia	Cerianthidae	*Cerianthus* sp.	1	1	0	0	1	1
Cnidaria	Anthozoa	Pennatulacea	Veretillidae	*Cavernularia obesa*	0	0	0	0	0	0
Cnidaria	Anthozoa	Pennatulacea	Virgulariidae	*Virgularia gustaviana*	1	0	0	1	0	0
Echinodermata	Ophiuroidea	Gnathophiurida	Amphiuridae	*Amphioplus laevis*	0	0	0	0	0	0
Echinodermata	Holothuroidea	Molpadiida	Caudinidae	*Acaudina molpadioides*	0	0	0	0	0	0
Echinodermata	Holothuroidea	Dendrochirotida	Phyllophoridae	*Phyllophorus* sp.	0	0	0	0	0	0
Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae	*Thyone* sp.	0	0	0	0	0	0
Echinodermata	Holothuroidea	Molpadiida	Molpadiidae	*Molpadia* sp.	0	0	0	0	0	0
Echinodermata	Holothuroidea	Apodida	Synaptidae	*Protankyra bidentata*	0	1	2	1	2	4
Mollusca	Bivalvia	Myoida	Pholadidae	*Martesia yoshimurai*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Cultellidae	*Cultellus attenuatus*	0	0	0	0	0	0
Mollusca	Bivalvia	Nuculoida	Nuculanidae	*Saccella parmata*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Psammobiidae	*Psammobia radiata*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Solenidae	*Solen gordonis*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Solenidae	*Solen grandis*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Tellinidae	*Moerella iridescens*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Veneridae	*Paphia undulata*	0	0	0	0	0	0
Nemertinea	Anopla	Heteronemertea	Cerebratulidae	*Cerebratulina* sp.	0	0	1	0	0	0
Plathyhelminthes	Turbellaria	Polycladida	Leptoplanidae	*Leptoplana* sp.	0	0	0	0	0	0
Sipuncula	Phascolosomatidea	Phascolosomaliformes	Phascolosomatidae	*Apionsoma trichocephalus*	0	0	1	0	0	0

Table 2 Benthic Grab Survey Raw Data - Wet Season Abundance

Phylum	Class	Order	Family	Species	B1	B2	B3	B4	B5	B6
Annelida	Polychaeta	Terebellida	Ampharetidae	*Isolda pulchella*	7	0	0	19	3	3
Annelida	Polychaeta	Terebellida	Ampharetidae	*Samytha besslei*	0	0	0	0	1	0
Annelida	Polychaeta	Capitellida	Capitellidae	*Mediomastus californiensis*	1	0	1	0	2	5
Annelida	Polychaeta	Capitellida	Capitellidae	*Notomastus latericeus*	1	1	1	0	0	0
Annelida	Polychaeta	Spionida	Cirratulidae	*Cirratulus filiformis*	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Cirratulidae	*Tharyx* sp.	0	2	0	0	0	0
Annelida	Polychaeta	Eunicida	Eunicidae	*Eunice indica*	0	1	0	0	1	0
Annelida	Polychaeta	Eunicida	Eunicidae	*Marphysa stragulum*	0	0	0	0	0	0
Annelida	Polychaeta	Flabelligerida	Flabelligeridae	*Pherusa parmata*	0	0	0	1	0	0
Annelida	Polychaeta	Flabelligerida	Flabelligeridae	*Pherusa plusoma*	0	0	2	0	0	1
Annelida	Polychaeta	Phyllodocida	Glyceridae	*Glycera onomichiensis*	2	0	0	4	2	1
Annelida	Polychaeta	Phyllodocida	Goniadidae	*Glycinde gurjanovae*	1	0	0	0	0	3
Annelida	Polychaeta	Phyllodocida	Goniadidae	*Goniada eremita*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Hesionidae	*Micropodarke dubia*	0	0	0	0	0	2
Annelida	Polychaeta	Phyllodocida	Hesionidae	*Ophiodromus angustifrons*	0	1	0	0	0	0
Annelida	Polychaeta	Eunicida	Lumbrineridae	*Lumbrineris* sp.	0	0	1	0	0	1
Annelida	Polychaeta	Spionida	Magelonidae	*Magelona pacifica*	0	0	0	0	0	0
Annelida	Polychaeta	Capitellida	Maldanidae	*Euclymene* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Nephtyidae	*Aglaophamus dibranchis*	0	0	0	0	1	1
Annelida	Polychaeta	Phyllodocida	Nereidae	*Nereis* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Eunicida	Onuphidae	*Diopatra* sp.	1	0	0	1	0	1
Annelida	Polychaeta	Eunicida	Onuphidae	*Onuphis eremita*	0	0	0	0	0	0
Annelida	Polychaeta	Orbiniida	Orbiniidae	*Scoloplos* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Terebellida	Pectinariidae	*Pectinaria papillosa*	1	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Phyllodocidae	*Phyllodoce papillosa*	0	0	0	1	1	0
Annelida	Polychaeta	Phyllodocida	Pilargiidae	*Sigambra hanaokai*	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Poecilochaetidae	*Poecilochaetus serpens*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Polynoidae	*Gattyana* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Polynoidae	*Lepidonotus* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Sabellida	Sabellidae	*Potamilla* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Spionidae	*Laonice cirrata*	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Spionidae	*Prionospio queenslandica*	1	1	2	0	6	8
Annelida	Polychaeta	Spionida	Spionidae	*Scolelepis squamata*	0	0	0	0	0	0
Annelida	Polychaeta	Terebellida	Terebellidae	*Loimia medusa*	0	0	0	0	0	0

Table 2 Benthic Grab Survey Raw Data - Wet Season Abundance

Phylum	Class	Order	Family	Species	B1	B2	B3	B4	B5	B6
Annelida	Polychaeta	Terebellida	Terebellidae	*Lysilla pacifica*	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Alpheidae	*Alpheus* sp.	0	0	0	0	0	0
Arthropoda	Malacostraca	Amphipoda	Ampeliscidae	*Byblis* sp.	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Callianassidae	*Callianassa* sp.	0	0	0	1	0	0
Arthropoda	Malacostraca	Isopoda	Paranthuridae	*Paranthura* sp.	1	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Penaeidae	*Metapenaeus ensis*	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Goneplacidae	*Typhlocarcinus nudus*	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Pinnotheridae	*Neoxenophthalmus obscurus*	30	5	1	48	13	2
Arthropoda	Malacostraca	Decapoda	Porcellanidae	*Raphidopus ciliatus*	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Portunidae	*Charybdis variegata*	0	0	0	0	0	0
Arthropoda	Malacostraca	Stomatopoda	Squillidae	*Anchisquilla fasciata*	0	0	0	0	0	0
Arthropoda	Malacostraca	Stomatopoda	Squillidae	*Clorida latreillei*	0	0	0	0	0	0
Arthropoda	Malacostraca	Stomatopoda	Squillidae	*Oratosquilla oratoria*	0	0	0	0	0	0
Chordata	Osteichthyes	Perciformes	Taenioididae	*Trypauchen vagina*	0	0	0	0	0	0
Cnidaria	Anthozoa	Actiniaria	Actiniidae	*Actinia* sp.	0	0	0	0	0	0
Cnidaria	Anthozoa	Ceriantharia	Cerianthidae	*Cerianthus* sp.	0	0	1	0	1	0
Cnidaria	Anthozoa	Pennatulacea	Veretillidae	*Cavernularia obesa*	0	0	0	1	0	0
Cnidaria	Anthozoa	Pennatulacea	Virgulariidae	*Virgularia gustaviana*	0	0	0	0	0	0
Echinodermata	Ophiuroidea	Gnathophiurida	Amphiuridae	*Amphioplus laevis*	3	1	2	3	0	1
Echinodermata	Holothuroidea	Molpadiida	Caudinidae	*Acaudina molpadioides*	1	0	0	0	0	0
Echinodermata	Holothuroidea	Dendrochirotida	Phyllophoridae	*Phyllophorus* sp.	5	0	2	0	2	0
Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae	*Thyone* sp.	0	0	1	0	0	0
Echinodermata	Holothuroidea	Molpadiida	Molpadiidae	*Molpadia* sp.	0	0	0	0	0	0
Echinodermata	Holothuroidea	Apodida	Synaptidae	*Protankyra bidentata*	0	0	0	0	0	0
Mollusca	Bivalvia	Myoida	Pholadidae	*Martesia yoshimurai*	2	0	0	0	1	0
Mollusca	Bivalvia	Veneroida	Cultellidae	*Cultellus attenuatus*	0	0	1	0	0	0
Mollusca	Bivalvia	Nuculoida	Nuculanidae	*Saccella parmata*	0	0	0	1	0	0
Mollusca	Bivalvia	Veneroida	Psammobiidae	*Psammobia radiata*	0	0	0	1	0	1
Mollusca	Bivalvia	Veneroida	Solenidae	*Solen gordonis*	0	0	1	1	0	0
Mollusca	Bivalvia	Veneroida	Solenidae	*Solen grandis*	0	0	0	1	0	0
Mollusca	Bivalvia	Veneroida	Tellinidae	*Moerella iridescens*	3	0	0	2	1	0
Mollusca	Bivalvia	Veneroida	Veneridae	*Paphia undulata*	0	1	0	0	0	1
Nemertinea	Anopla	Heteronemertea	Cerebratulidae	*Cerebratulina* sp.	0	1	0	1	0	1
Plathyhelminthes	Turbellaria	Polycladida	Leptoplanidae	*Leptoplana* sp.	0	0	0	0	0	0
Sipuncula	Phascolosomatidea	Phascolosomaliformes	Phascolosomatidae	*Apionsoma trichocephalus*	1	1	1	0	0	1

Table 2 Benthic Grab Survey Raw Data - Wet Season Abundance

Phylum	Class	Order	Family	Species	C1	C2	C3	C4	C5	C6
Annelida	Polychaeta	Terebellida	Ampharetidae	*Isolda pulchella*	0	0	0	0	1	0
Annelida	Polychaeta	Terebellida	Ampharetidae	*Samytha besslei*	0	0	0	0	0	2
Annelida	Polychaeta	Capitellida	Capitellidae	*Mediomastus californiensis*	10	34	11	43	59	42
Annelida	Polychaeta	Capitellida	Capitellidae	*Notomastus latericeus*	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Cirratulidae	*Cirratulus filiformis*	0	1	0	0	0	1
Annelida	Polychaeta	Spionida	Cirratulidae	*Tharyx* sp.	0	0	0	1	1	0
Annelida	Polychaeta	Eunicida	Eunicidae	*Eunice indica*	0	0	0	1	0	0
Annelida	Polychaeta	Eunicida	Eunicidae	*Marphysa stragulum*	1	0	1	0	0	0
Annelida	Polychaeta	Flabelligerida	Flabelligeridae	*Pherusa parmata*	0	0	0	0	0	0
Annelida	Polychaeta	Flabelligerida	Flabelligeridae	*Pherusa plusoma*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Glyceridae	*Glycera onomichiensis*	2	4	0	4	3	3
Annelida	Polychaeta	Phyllodocida	Goniadidae	*Glycinde gurjanovae*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Goniadidae	*Goniada eremita*	1	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Hesionidae	*Micropodarke dubia*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Hesionidae	*Ophiodromus angustifrons*	0	0	0	0	0	0
Annelida	Polychaeta	Eunicida	Lumbrineridae	*Lumbrineris* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Magelonidae	*Magelona pacifica*	0	0	0	0	0	0
Annelida	Polychaeta	Capitellida	Maldanidae	*Euclymene* sp.	0	1	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Nephtyidae	*Aglaophamus dibranchis*	0	1	0	0	2	8
Annelida	Polychaeta	Phyllodocida	Nereidae	*Nereis* sp.	0	0	0	0	0	1
Annelida	Polychaeta	Eunicida	Onuphidae	*Diopatra* sp.	0	0	0	0	0	1
Annelida	Polychaeta	Eunicida	Onuphidae	*Onuphis eremita*	0	0	0	0	0	0
Annelida	Polychaeta	Orbiniida	Orbiniidae	*Scoloplos* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Terebellida	Pectinariidae	*Pectinaria papillosa*	0	0	0	0	0	1
Annelida	Polychaeta	Phyllodocida	Phyllodocidae	*Phyllodoce papillosa*	0	0	0	0	0	1
Annelida	Polychaeta	Phyllodocida	Pilargiidae	*Sigambra hanaokai*	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Poecilochaetidae	*Poecilochaetus serpens*	0	0	0	0	0	2
Annelida	Polychaeta	Phyllodocida	Polynoidae	*Gattyana* sp.	0	0	1	0	0	1
Annelida	Polychaeta	Phyllodocida	Polynoidae	*Lepidonotus* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Sabellida	Sabellidae	*Potamilla* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Spionidae	*Laonice cirrata*	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Spionidae	*Prionospio queenslandica*	2	48	9	16	60	86
Annelida	Polychaeta	Spionida	Spionidae	*Scolelepis squamata*	0	0	0	1	0	0
Annelida	Polychaeta	Terebellida	Terebellidae	*Loimia medusa*	0	0	1	0	0	0

Table 2 Benthic Grab Survey Raw Data - Wet Season Abundance

Phylum	Class	Order	Family	Species	C1	C2	C3	C4	C5	C6
Annelida	Polychaeta	Terebellida	Terebellidae	*Lysilla pacifica*	0	0	2	1	0	0
Arthropoda	Malacostraca	Decapoda	Alpheidae	*Alpheus* sp.	0	0	0	0	0	1
Arthropoda	Malacostraca	Amphipoda	Ampeliscidae	*Byblis* sp.	0	0	0	0	1	1
Arthropoda	Malacostraca	Decapoda	Callianassidae	*Callianassa* sp.	0	0	0	0	0	0
Arthropoda	Malacostraca	Isopoda	Paranthuridae	*Paranthura* sp.	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Penaeidae	*Metapenaeus ensis*	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Goneplacidae	*Typhlocarcinus nudus*	0	0	0	0	1	0
Arthropoda	Malacostraca	Decapoda	Pinnotheridae	*Neoxenophthalmus obscurus*	0	4	0	2	0	1
Arthropoda	Malacostraca	Decapoda	Porcellanidae	*Raphidopus ciliatus*	0	1	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Portunidae	*Charybdis variegata*	0	0	0	0	0	0
Arthropoda	Malacostraca	Stomatopoda	Squillidae	*Anchisquilla fasciata*	0	0	0	0	0	0
Arthropoda	Malacostraca	Stomatopoda	Squillidae	*Clorida latreillei*	0	0	0	0	0	0
Arthropoda	Malacostraca	Stomatopoda	Squillidae	*Oratosquilla oratoria*	0	3	0	0	0	0
Chordata	Osteichthyes	Perciformes	Taenioididae	*Trypauchen vagina*	0	0	0	1	0	0
Cnidaria	Anthozoa	Actiniaria	Actiniidae	*Actinia* sp.	0	0	0	0	0	0
Cnidaria	Anthozoa	Ceriantharia	Cerianthidae	*Cerianthus* sp.	0	0	0	0	0	1
Cnidaria	Anthozoa	Pennatulacea	Veretillidae	*Cavernularia obesa*	0	0	2	0	0	0
Cnidaria	Anthozoa	Pennatulacea	Virgulariidae	*Virgularia gustaviana*	0	0	0	0	0	0
Echinodermata	Ophiuroidea	Gnathophiurida	Amphiuridae	*Amphioplus laevis*	0	0	0	0	0	0
Echinodermata	Holothuroidea	Molpadiida	Caudinidae	*Acaudina molpadioides*	0	0	0	0	0	0
Echinodermata	Holothuroidea	Dendrochirotida	Phyllophoridae	*Phyllophorus* sp.	0	2	0	0	1	0
Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae	*Thyone* sp.	0	0	0	0	0	0
Echinodermata	Holothuroidea	Molpadiida	Molpadiidae	*Molpadia* sp.	0	0	0	0	0	1
Echinodermata	Holothuroidea	Apodida	Synaptidae	*Protankyra bidentata*	2	1	5	0	0	0
Mollusca	Bivalvia	Myoida	Pholadidae	*Martesia yoshimurai*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Cultellidae	*Cultellus attenuatus*	0	0	0	0	0	0
Mollusca	Bivalvia	Nuculoida	Nuculanidae	*Saccella parmata*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Psammobiidae	*Psammobia radiata*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Solenidae	*Solen gordonis*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Solenidae	*Solen grandis*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Tellinidae	*Moerella iridescens*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Veneridae	*Paphia undulata*	0	0	0	0	0	0
Nemertinea	Anopla	Heteronemertea	Cerebratulidae	*Cerebratulina* sp.	0	0	0	0	0	0
Plathyhelminthes	Turbellaria	Polycladida	Leptoplanidae	*Leptoplana* sp.	0	0	0	0	0	0
Sipuncula	Phascolosomatidea	Phascolosomaliformes	Phascolosomatidae	*Apionsoma trichocephalus*	0	0	0	0	0	1

Table 2 Benthic Grab Survey Raw Data - Wet Season Abundance

Phylum	Class	Order	Family	Species	D1	D2	D3	D4	D5	D6
Annelida	Polychaeta	Terebellida	Ampharetidae	*Isolda pulchella*	0	0	2	21	0	1
Annelida	Polychaeta	Terebellida	Ampharetidae	*Samytha besslei*	0	0	0	0	0	0
Annelida	Polychaeta	Capitellida	Capitellidae	*Mediomastus californiensis*	0	0	0	1	4	4
Annelida	Polychaeta	Capitellida	Capitellidae	*Notomastus latericeus*	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Cirratulidae	*Cirratulus filiformis*	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Cirratulidae	*Tharyx* sp.	0	0	0	2	0	0
Annelida	Polychaeta	Eunicida	Eunicidae	*Eunice indica*	0	0	0	0	0	0
Annelida	Polychaeta	Eunicida	Eunicidae	*Marphysa stragulum*	0	0	0	0	0	0
Annelida	Polychaeta	Flabelligerida	Flabelligeridae	*Pherusa parmata*	0	0	0	0	0	0
Annelida	Polychaeta	Flabelligerida	Flabelligeridae	*Pherusa plusoma*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Glyceridae	*Glycera onomichiensis*	6	4	5	7	4	0
Annelida	Polychaeta	Phyllodocida	Goniadidae	*Glycinde gurjanovae*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Goniadidae	*Goniada eremita*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Hesionidae	*Micropodarke dubia*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Hesionidae	*Ophiodromus angustifrons*	0	0	0	0	0	0
Annelida	Polychaeta	Eunicida	Lumbrineridae	*Lumbrineris* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Magelonidae	*Magelona pacifica*	0	0	0	0	0	1
Annelida	Polychaeta	Capitellida	Maldanidae	*Euclymene* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Nephtyidae	*Aglaophamus dibranchis*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Nereidae	*Nereis* sp.	4	1	0	0	0	0
Annelida	Polychaeta	Eunicida	Onuphidae	*Diopatra* sp.	0	1	1	1	0	0
Annelida	Polychaeta	Eunicida	Onuphidae	*Onuphis eremita*	0	0	0	0	0	0
Annelida	Polychaeta	Orbiniida	Orbiniidae	*Scoloplos* sp.	0	0	0	5	0	0
Annelida	Polychaeta	Terebellida	Pectinariidae	*Pectinaria papillosa*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Phyllodocidae	*Phyllodoce papillosa*	0	0	0	0	1	0
Annelida	Polychaeta	Phyllodocida	Pilargiidae	*Sigambra hanaokai*	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Poecilochaetidae	*Poecilochaetus serpens*	0	0	0	0	0	1
Annelida	Polychaeta	Phyllodocida	Polynoidae	*Gattyana* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Polynoidae	*Lepidonotus* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Sabellida	Sabellidae	*Potamilla* sp.	0	1	0	0	0	0
Annelida	Polychaeta	Spionida	Spionidae	*Laonice cirrata*	0	0	0	0	0	1
Annelida	Polychaeta	Spionida	Spionidae	*Prionospio queenslandica*	0	0	0	8	4	4
Annelida	Polychaeta	Spionida	Spionidae	*Scolelepis squamata*	0	0	0	0	0	0
Annelida	Polychaeta	Terebellida	Terebellidae	*Loimia medusa*	0	0	0	1	0	0

Table 2 Benthic Grab Survey Raw Data - Wet Season Abundance

Phylum	Class	Order	Family	Species	D1	D2	D3	D4	D5	D6
Annelida	Polychaeta	Terebellida	Terebellidae	*Lysilla pacifica*	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Alpheidae	*Alpheus* sp.	2	0	0	0	0	0
Arthropoda	Malacostraca	Amphipoda	Ampeliscidae	*Byblis* sp.	0	0	0	1	0	0
Arthropoda	Malacostraca	Decapoda	Callianassidae	*Callianassa* sp.	0	0	0	0	0	0
Arthropoda	Malacostraca	Isopoda	Paranthuridae	*Paranthura* sp.	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Penaeidae	*Metapenaeus ensis*	0	0	0	0	1	0
Arthropoda	Malacostraca	Decapoda	Goneplacidae	*Typhlocarcinus nudus*	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Pinnotheridae	*Neoxenophthalmus obscurus*	1	0	2	0	0	0
Arthropoda	Malacostraca	Decapoda	Porcellanidae	*Raphidopus ciliatus*	0	1	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Portunidae	*Charybdis variegata*	0	0	2	0	0	0
Arthropoda	Malacostraca	Stomatopoda	Squillidae	*Anchisquilla fasciata*	0	0	0	0	0	0
Arthropoda	Malacostraca	Stomatopoda	Squillidae	*Clorida latreillei*	0	1	1	0	0	0
Arthropoda	Malacostraca	Stomatopoda	Squillidae	*Oratosquilla oratoria*	0	0	0	0	0	0
Chordata	Osteichthyes	Perciformes	Taenioididae	*Trypauchen vagina*	1	0	0	0	0	0
Cnidaria	Anthozoa	Actiniaria	Actiniidae	*Actinia* sp.	0	0	0	0	0	1
Cnidaria	Anthozoa	Ceriantharia	Cerianthidae	*Cerianthus* sp.	0	0	0	0	0	0
Cnidaria	Anthozoa	Pennatulacea	Veretillidae	*Cavernularia obesa*	0	0	0	0	0	0
Cnidaria	Anthozoa	Pennatulacea	Virgulariidae	*Virgularia gustaviana*	0	0	0	0	0	0
Echinodermata	Ophiuroidea	Gnathophiurida	Amphiuridae	*Amphioplus laevis*	0	1	0	0	0	0
Echinodermata	Holothuroidea	Molpadiida	Caudinidae	*Acaudina molpadioides*	0	0	0	0	0	0
Echinodermata	Holothuroidea	Dendrochirotida	Phyllophoridae	*Phyllophorus* sp.	0	0	0	0	0	0
Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae	*Thyone* sp.	0	0	0	0	0	0
Echinodermata	Holothuroidea	Molpadiida	Molpadiidae	*Molpadia* sp.	0	0	2	0	1	0
Echinodermata	Holothuroidea	Apodida	Synaptidae	*Protankyra bidentata*	0	0	0	0	0	0
Mollusca	Bivalvia	Myoida	Pholadidae	*Martesia yoshimurai*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Cultellidae	*Cultellus attenuatus*	0	0	0	0	0	0
Mollusca	Bivalvia	Nuculoida	Nuculanidae	*Saccella parmata*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Psammobiidae	*Psammobia radiata*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Solenidae	*Solen gordonis*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Solenidae	*Solen grandis*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Tellinidae	*Moerella iridescens*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Veneridae	*Paphia undulata*	0	0	0	0	0	0
Nemertinea	Anopla	Heteronemertea	Cerebratulidae	*Cerebratulina* sp.	0	0	0	1	0	0
Plathyhelminthes	Turbellaria	Polycladida	Leptoplanidae	*Leptoplana* sp.	0	0	0	0	1	0
Sipuncula	Phascolosomatidea	Phascolosomaliformes	Phascolosomatidae	*Apionsoma trichocephalus*	0	0	0	0	0	0

Table 3 Benthic Grab Survey Raw Data - Wet Season Biomass (in g)

Phylum	Class	Order	Family	Species	A1	A2	A3	A4	A5	A6
Annelida	Polychaeta	Terebellida	Ampharetidae	*Isolda pulchella*	0	0.0108	0	0	0	0
Annelida	Polychaeta	Terebellida	Ampharetidae	*Samytha besslei*	0	0	0	0	0	0
Annelida	Polychaeta	Capitellida	Capitellidae	*Mediomastus californiensis*	0	0	0.0041	0	0.0674	0.0427
Annelida	Polychaeta	Capitellida	Capitellidae	*Notomastus latericeus*	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Cirratulidae	*Cirratulus filiformis*	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Cirratulidae	*Tharyx* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Eunicida	Eunicidae	*Eunice indica*	0	0	0	0	0	0
Annelida	Polychaeta	Eunicida	Eunicidae	*Marphysa stragulum*	0	0	0	0	0	0
Annelida	Polychaeta	Flabelligerida	Flabelligeridae	*Pherusa parmata*	0	0	0	0	0	0
Annelida	Polychaeta	Flabelligerida	Flabelligeridae	*Pherusa plusoma*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Glyceridae	*Glycera onomichiensis*	0.1145	0	0.1017	0	0	0
Annelida	Polychaeta	Phyllodocida	Goniadidae	*Glycinde gurjanovae*	0	0	0	0.0155	0	0
Annelida	Polychaeta	Phyllodocida	Goniadidae	*Goniada eremita*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Hesionidae	*Micropodarke dubia*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Hesionidae	*Ophiodromus angustifrons*	0	0	0	0	0	0
Annelida	Polychaeta	Eunicida	Lumbrineridae	*Lumbrineris* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Magelonidae	*Magelona pacifica*	0	0	0	0	0	0
Annelida	Polychaeta	Capitellida	Maldanidae	*Euclymene* sp.	0	0	0	0	0.0282	0
Annelida	Polychaeta	Phyllodocida	Nephtyidae	*Aglaophamus dibranchis*	0.0062	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Nereidae	*Nereis* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Eunicida	Onuphidae	*Diopatra* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Eunicida	Onuphidae	*Onuphis eremita*	0.1179	0	0	0	0	0
Annelida	Polychaeta	Orbiniida	Orbiniidae	*Scoloplos* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Terebellida	Pectinariidae	*Pectinaria papillosa*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Phyllodocidae	*Phyllodoce papillosa*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Pilargiidae	*Sigambra hanaokai*	0	0	0.0008	0	0	0
Annelida	Polychaeta	Spionida	Poecilochaetidae	*Poecilochaetus serpens*	0	0	0	0	0.0237	0
Annelida	Polychaeta	Phyllodocida	Polynoidae	*Gattyana* sp.	0	0	0	0.0208	0	0
Annelida	Polychaeta	Phyllodocida	Polynoidae	*Lepidonotus* sp.	0	0	0	0	0.032	0
Annelida	Polychaeta	Sabellida	Sabellidae	*Potamilla* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Spionidae	*Laonice cirrata*	0	0	0	0	0.0216	0
Annelida	Polychaeta	Spionida	Spionidae	*Prionospio queenslandica*	0	0.0252	0	0	0	0
Annelida	Polychaeta	Spionida	Spionidae	*Scolelepis squamata*	0	0	0	0	0	0
Annelida	Polychaeta	Terebellida	Terebellidae	*Loimia medusa*	1.3735	0	0	0	0	0

Table 3 Benthic Grab Survey Raw Data - Wet Season Biomass (in g)

Phylum	Class	Order	Family	Species	A1	A2	A3	A4	A5	A6
Annelida	Polychaeta	Terebellida	Terebellidae	*Lysilla pacifica*	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Alpheidae	*Alpheus* sp.	0	0	0	0	0	0
Arthropoda	Malacostraca	Amphipoda	Ampeliscidae	*Byblis* sp.	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Callianassidae	*Callianassa* sp.	0	0	0	0	0	0
Arthropoda	Malacostraca	Isopoda	Paranthuridae	*Paranthura* sp.	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Penaeidae	*Metapenaeus ensis*	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Goneplacidae	*Typhlocarcinus nudus*	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Pinnotheridae	*Neoxenophthalmus obscurus*	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Porcellanidae	*Raphidopus ciliatus*	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Portunidae	*Charybdis variegata*	0	0	0	0	0	0
Arthropoda	Malacostraca	Stomatopoda	Squillidae	*Anchisquilla fasciata*	0	0.0498	0.0107	0.0172	0	0
Arthropoda	Malacostraca	Stomatopoda	Squillidae	*Clorida latreillei*	0	0	0	0	0	0
Arthropoda	Malacostraca	Stomatopoda	Squillidae	*Oratosquilla oratoria*	0	0	0	0	0	0
Chordata	Osteichthyes	Perciformes	Taenioididae	*Trypauchen vagina*	0	0	0	0	0	0
Cnidaria	Anthozoa	Actiniaria	Actiniidae	*Actinia* sp.	0	0	0	0	0	0
Cnidaria	Anthozoa	Ceriantharia	Cerianthidae	*Cerianthus* sp.	0.3129	0.0125	0	0	0.3476	0.0841
Cnidaria	Anthozoa	Pennatulacea	Veretillidae	*Cavernularia obesa*	0	0	0	0	0	0
Cnidaria	Anthozoa	Pennatulacea	Virgulariidae	*Virgularia gustaviana*	0.0281	0	0	0.1081	0	0
Echinodermata	Ophiuroidea	Gnathophiurida	Amphiuridae	*Amphioplus laevis*	0	0	0	0	0	0
Echinodermata	Holothuroidea	Molpadiida	Caudinidae	*Acaudina molpadioides*	0	0	0	0	0	0
Echinodermata	Holothuroidea	Dendrochirotida	Phyllophoridae	*Phyllophorus* sp.	0	0	0	0	0	0
Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae	*Thyone* sp.	0	0	0	0	0	0
Echinodermata	Holothuroidea	Molpadiida	Molpadiidae	*Molpadia* sp.	0	0	0	0	0	0
Echinodermata	Holothuroidea	Apodida	Synaptidae	*Protankyra bidentata*	0	1.8982	2.3495	3.385	3.9709	8.9567
Mollusca	Bivalvia	Myoida	Pholadidae	*Martesia yoshimurai*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Cultellidae	*Cultellus attenuatus*	0	0	0	0	0	0
Mollusca	Bivalvia	Nuculoida	Nuculanidae	*Saccella parmata*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Psammobiidae	*Psammobia radiata*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Solenidae	*Solen gordonis*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Solenidae	*Solen grandis*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Tellinidae	*Moerella iridescens*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Veneridae	*Paphia undulata*	0	0	0	0	0	0
Nemertinea	Anopla	Heteronemertea	Cerebratulidae	*Cerebratulina* sp.	0	0	1.2095	0	0	0
Plathyhelminthes	Turbellaria	Polycladida	Leptoplanidae	*Leptoplana* sp.	0	0	0	0	0	0
Sipuncula	Phascolosomatidea	Phascolosomaliformes	Phascolosomatidae	*Apionsoma trichocephalus*	0	0	0.0343	0	0	0

Table 3 Benthic Grab Survey Raw Data - Wet Season Biomass (in g)

Phylum	Class	Order	Family	Species	B1	B2	B3	B4	B5	B6
Annelida	Polychaeta	Terebellida	Ampharetidae	*Isolda pulchella*	0.0538	0	0	0.1426	0.026	0.0138
Annelida	Polychaeta	Terebellida	Ampharetidae	*Samytha besslei*	0	0	0	0	0.0295	0
Annelida	Polychaeta	Capitellida	Capitellidae	*Mediomastus californiensis*	0.0011	0	0.0034	0	0.014	0.0711
Annelida	Polychaeta	Capitellida	Capitellidae	*Notomastus latericeus*	0.0427	0.0206	0.0608	0	0	0
Annelida	Polychaeta	Spionida	Cirratulidae	*Cirratulus filiformis*	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Cirratulidae	*Tharyx* sp.	0	0.0023	0	0	0	0
Annelida	Polychaeta	Eunicida	Eunicidae	*Eunice indica*	0	0.057	0	0	0.0158	0
Annelida	Polychaeta	Eunicida	Eunicidae	*Marphysa stragulum*	0	0	0	0	0	0
Annelida	Polychaeta	Flabelligerida	Flabelligeridae	*Pherusa parmata*	0	0	0	0.314	0	0
Annelida	Polychaeta	Flabelligerida	Flabelligeridae	*Pherusa plusoma*	0	0	0.3023	0	0	0.0027
Annelida	Polychaeta	Phyllodocida	Glyceridae	*Glycera onomichiensis*	0.0345	0	0	0.0947	0.2019	0.0571
Annelida	Polychaeta	Phyllodocida	Goniadidae	*Glycinde gurjanovae*	0.0071	0	0	0	0	0.0318
Annelida	Polychaeta	Phyllodocida	Goniadidae	*Goniada eremita*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Hesionidae	*Micropodarke dubia*	0	0	0	0	0	0.0342
Annelida	Polychaeta	Phyllodocida	Hesionidae	*Ophiodromus angustifrons*	0	0.0066	0	0	0	0
Annelida	Polychaeta	Eunicida	Lumbrineridae	*Lumbrineris* sp.	0	0	0.0074	0	0	0.0122
Annelida	Polychaeta	Spionida	Magelonidae	*Magelona pacifica*	0	0	0	0	0	0
Annelida	Polychaeta	Capitellida	Maldanidae	*Euclymene* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Nephtyidae	*Aglaophamus dibranchis*	0	0	0	0	0.0021	0.0023
Annelida	Polychaeta	Phyllodocida	Nereidae	*Nereis* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Eunicida	Onuphidae	*Diopatra* sp.	0.3349	0	0	0.0853	0	0.1401
Annelida	Polychaeta	Eunicida	Onuphidae	*Onuphis eremita*	0	0	0	0	0	0
Annelida	Polychaeta	Orbiniida	Orbiniidae	*Scoloplos* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Terebellida	Pectinariidae	*Pectinaria papillosa*	0.0558	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Phyllodocidae	*Phyllodoce papillosa*	0	0	0	0.0043	0.0335	0
Annelida	Polychaeta	Phyllodocida	Pilargiidae	*Sigambra hanaokai*	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Poecilochaetidae	*Poecilochaetus serpens*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Polynoidae	*Gattyana* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Polynoidae	*Lepidonotus* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Sabellida	Sabellidae	*Potamilla* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Spionidae	*Laonice cirrata*	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Spionidae	*Prionospio queenslandica*	0.0066	0.0012	0.0214	0	0.0843	0.1502
Annelida	Polychaeta	Spionida	Spionidae	*Scolelepis squamata*	0	0	0	0	0	0
Annelida	Polychaeta	Terebellida	Terebellidae	*Loimia medusa*	0	0	0	0	0	0

Table 3 Benthic Grab Survey Raw Data - Wet Season Biomass (in g)

Phylum	Class	Order	Family	Species	B1	B2	B3	B4	B5	B6
Annelida	Polychaeta	Terebellida	Terebellidae	*Lysilla pacifica*	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Alpheidae	*Alpheus* sp.	0	0	0	0	0	0
Arthropoda	Malacostraca	Amphipoda	Ampeliscidae	*Byblis* sp.	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Callianassidae	*Callianassa* sp.	0	0	0	0.0837	0	0
Arthropoda	Malacostraca	Isopoda	Paranthuridae	*Paranthura* sp.	0.0008	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Penaeidae	*Metapenaeus ensis*	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Goneplacidae	*Typhlocarcinus nudus*	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Pinnotheridae	*Neoxenophthalmus obscurus*	3.0724	3.0164	0.2766	5.6451	1.4113	1.8786
Arthropoda	Malacostraca	Decapoda	Porcellanidae	*Raphidopus ciliatus*	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Portunidae	*Charybdis variegata*	0	0	0	0	0	0
Arthropoda	Malacostraca	Stomatopoda	Squillidae	*Anchisquilla fasciata*	0	0	0	0	0	0
Arthropoda	Malacostraca	Stomatopoda	Squillidae	*Clorida latreillei*	0	0	0	0	0	0
Arthropoda	Malacostraca	Stomatopoda	Squillidae	*Oratosquilla oratoria*	0	0	0	0	0	0
Chordata	Osteichthyes	Perciformes	Taenioididae	*Trypauchen vagina*	0	0	0	0	0	0
Cnidaria	Anthozoa	Actiniaria	Actiniidae	*Actinia* sp.	0	0	0	0	0	0
Cnidaria	Anthozoa	Ceriantharia	Cerianthidae	*Cerianthus* sp.	0	0	0.082	0	0.2716	0
Cnidaria	Anthozoa	Pennatulacea	Veretillidae	*Cavernularia obesa*	0	0	0	5.2272	0	0
Cnidaria	Anthozoa	Pennatulacea	Virgulariidae	*Virgularia gustaviana*	0	0	0	0	0	0
Echinodermata	Ophiuroidea	Gnathophiurida	Amphiuridae	*Amphioplus laevis*	0.8567	0.1593	0.4881	0.6874	0	0.1103
Echinodermata	Holothuroidea	Molpadiida	Caudinidae	*Acaudina molpadioides*	0.2191	0	0	0	0	0
Echinodermata	Holothuroidea	Dendrochirotida	Phyllophoridae	*Phyllophorus* sp.	4.7056	0	2.102	0	1.0431	0
Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae	*Thyone* sp.	0	0	3.8848	0	0	0
Echinodermata	Holothuroidea	Molpadiida	Molpadiidae	*Molpadia* sp.	0	0	0	0	0	0
Echinodermata	Holothuroidea	Apodida	Synaptidae	*Protankyra bidentata*	0	0	0	0	0	0
Mollusca	Bivalvia	Myoida	Pholadidae	*Martesia yoshimurai*	0.1632	0	0	0	0.0346	0
Mollusca	Bivalvia	Veneroida	Cultellidae	*Cultellus attenuatus*	0	0	0.2789	0	0	0
Mollusca	Bivalvia	Nuculoida	Nuculanidae	*Saccella parmata*	0	0	0	0.0449	0	0
Mollusca	Bivalvia	Veneroida	Psammobiidae	*Psammobia radiata*	0	0	0	0.4922	0	0.0705
Mollusca	Bivalvia	Veneroida	Solenidae	*Solen gordonis*	0	0	0.1083	1.0743	0	0
Mollusca	Bivalvia	Veneroida	Solenidae	*Solen grandis*	0	0	0	0.1138	0	0
Mollusca	Bivalvia	Veneroida	Tellinidae	*Moerella iridescens*	0.3396	0	0	0.0761	0.069	0
Mollusca	Bivalvia	Veneroida	Veneridae	*Paphia undulata*	0	4.0251	0	0	0	0.1331
Nemertinea	Anopla	Heteronemertea	Cerebratulidae	*Cerebratulina* sp.	0	1.4097	0	0.8907	0	0.045
Plathyhelminthes	Turbellaria	Polycladida	Leptoplanidae	*Leptoplana* sp.	0	0	0	0	0	0
Sipuncula	Phascolosomatidea	Phascolosomaliformes	Phascolosomatidae	*Apionsoma trichocephalus*	0.0045	0.0036	0.0094	0	0	0.0155

Table 3 Benthic Grab Survey Raw Data - Wet Season Biomass (in g)

Phylum	Class	Order	Family	Species	C1	C2	C3	C4	C5	C6
Annelida	Polychaeta	Terebellida	Ampharetidae	*Isolda pulchella*	0	0	0	0	0.0033	0
Annelida	Polychaeta	Terebellida	Ampharetidae	*Samytha besslei*	0	0	0	0	0	0.0138
Annelida	Polychaeta	Capitellida	Capitellidae	*Mediomastus californiensis*	0.0963	0.4411	0.1087	0.5704	0.9754	0.4582
Annelida	Polychaeta	Capitellida	Capitellidae	*Notomastus latericeus*	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Cirratulidae	*Cirratulus filiformis*	0	0.0456	0	0	0	0.0192
Annelida	Polychaeta	Spionida	Cirratulidae	*Tharyx* sp.	0	0	0	0.0012	0.0019	0
Annelida	Polychaeta	Eunicida	Eunicidae	*Eunice indica*	0	0	0	0.0162	0	0
Annelida	Polychaeta	Eunicida	Eunicidae	*Marphysa stragulum*	0.2122	0	0.8905	0	0	0
Annelida	Polychaeta	Flabelligerida	Flabelligeridae	*Pherusa parmata*	0	0	0	0	0	0
Annelida	Polychaeta	Flabelligerida	Flabelligeridae	*Pherusa plusoma*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Glyceridae	*Glycera onomichiensis*	0.3681	0.6525	0	0.4016	0.5934	0.0897
Annelida	Polychaeta	Phyllodocida	Goniadidae	*Glycinde gurjanovae*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Goniadidae	*Goniada eremita*	0.1186	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Hesionidae	*Micropodarke dubia*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Hesionidae	*Ophiodromus angustifrons*	0	0	0	0	0	0
Annelida	Polychaeta	Eunicida	Lumbrineridae	*Lumbrineris* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Magelonidae	*Magelona pacifica*	0	0	0	0	0	0
Annelida	Polychaeta	Capitellida	Maldanidae	*Euclymene* sp.	0	0.0227	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Nephtyidae	*Aglaophamus dibranchis*	0	0.0014	0	0	0.0049	0.0143
Annelida	Polychaeta	Phyllodocida	Nereidae	*Nereis* sp.	0	0	0	0	0	0.0013
Annelida	Polychaeta	Eunicida	Onuphidae	*Diopatra* sp.	0	0	0	0	0	0.0535
Annelida	Polychaeta	Eunicida	Onuphidae	*Onuphis eremita*	0	0	0	0	0	0
Annelida	Polychaeta	Orbiniida	Orbiniidae	*Scoloplos* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Terebellida	Pectinariidae	*Pectinaria papillosa*	0	0	0	0	0	0.3469
Annelida	Polychaeta	Phyllodocida	Phyllodocidae	*Phyllodoce papillosa*	0	0	0	0	0	0.008
Annelida	Polychaeta	Phyllodocida	Pilargiidae	*Sigambra hanaokai*	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Poecilochaetidae	*Poecilochaetus serpens*	0	0	0	0	0	0.0047
Annelida	Polychaeta	Phyllodocida	Polynoidae	*Gattyana* sp.	0	0	0.0444	0	0	0.002
Annelida	Polychaeta	Phyllodocida	Polynoidae	*Lepidonotus* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Sabellida	Sabellidae	*Potamilla* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Spionidae	*Laonice cirrata*	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Spionidae	*Prionospio queenslandica*	0.0124	0.4494	0.0437	0.0642	0.615	0.5812
Annelida	Polychaeta	Spionida	Spionidae	*Scolelepis squamata*	0	0	0	0.0047	0	0
Annelida	Polychaeta	Terebellida	Terebellidae	*Loimia medusa*	0	0	2.0324	0	0	0

Table 3 Benthic Grab Survey Raw Data - Wet Season Biomass (in g)

Phylum	Class	Order	Family	Species	C1	C2	C3	C4	C5	C6
Annelida	Polychaeta	Terebellida	Terebellidae	*Lysilla pacifica*	0	0	0.1179	0.0016	0	0
Arthropoda	Malacostraca	Decapoda	Alpheidae	*Alpheus* sp.	0	0	0	0	0	1.2161
Arthropoda	Malacostraca	Amphipoda	Ampeliscidae	*Byblis* sp.	0	0	0	0	0.0012	0.001
Arthropoda	Malacostraca	Decapoda	Callianassidae	*Callianassa* sp.	0	0	0	0	0	0
Arthropoda	Malacostraca	Isopoda	Paranthuridae	*Paranthura* sp.	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Penaeidae	*Metapenaeus ensis*	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Goneplacidae	*Typhlocarcinus nudus*	0	0	0	0	0.1001	0
Arthropoda	Malacostraca	Decapoda	Pinnotheridae	*Neoxenophthalmus obscurus*	0	0.9949	0	0.7721	0	0.1346
Arthropoda	Malacostraca	Decapoda	Porcellanidae	*Raphidopus ciliatus*	0	0.0451	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Portunidae	*Charybdis variegata*	0	0	0	0	0	0
Arthropoda	Malacostraca	Stomatopoda	Squillidae	*Anchisquilla fasciata*	0	0	0	0	0	0
Arthropoda	Malacostraca	Stomatopoda	Squillidae	*Clorida latreillei*	0	0	0	0	0	0
Arthropoda	Malacostraca	Stomatopoda	Squillidae	*Oratosquilla oratoria*	0	0.5539	0	0	0	0
Chordata	Osteichthyes	Perciformes	Taenioididae	*Trypauchen vagina*	0	0	0	5.1341	0	0
Cnidaria	Anthozoa	Actiniaria	Actiniidae	*Actinia* sp.	0	0	0	0	0	0
Cnidaria	Anthozoa	Ceriantharia	Cerianthidae	*Cerianthus* sp.	0	0	0	0	0	0.0706
Cnidaria	Anthozoa	Pennatulacea	Veretillidae	*Cavernularia obesa*	0	0	7.1496	0	0	0
Cnidaria	Anthozoa	Pennatulacea	Virgulariidae	*Virgularia gustaviana*	0	0	0	0	0	0
Echinodermata	Ophiuroidea	Gnathophiurida	Amphiuridae	*Amphioplus laevis*	0	0	0	0	0	0
Echinodermata	Holothuroidea	Molpadiida	Caudinidae	*Acaudina molpadioides*	0	0	0	0	0	0
Echinodermata	Holothuroidea	Dendrochirotida	Phyllophoridae	*Phyllophorus* sp.	0	0.119	0	0	0.0972	0
Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae	*Thyone* sp.	0	0	0	0	0	0
Echinodermata	Holothuroidea	Molpadiida	Molpadiidae	*Molpadia* sp.	0	0	0	0	0	0.0778
Echinodermata	Holothuroidea	Apodida	Synaptidae	*Protankyra bidentata*	14.7483	2.0798	18.2547	0	0	0
Mollusca	Bivalvia	Myoida	Pholadidae	*Martesia yoshimurai*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Cultellidae	*Cultellus attenuatus*	0	0	0	0	0	0
Mollusca	Bivalvia	Nuculoida	Nuculanidae	*Saccella parmata*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Psammobiidae	*Psammobia radiata*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Solenidae	*Solen gordonis*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Solenidae	*Solen grandis*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Tellinidae	*Moerella iridescens*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Veneridae	*Paphia undulata*	0	0	0	0	0	0
Nemertinea	Anopla	Heteronemertea	Cerebratulidae	*Cerebratulina* sp.	0	0	0	0	0	0
Plathyhelminthes	Turbellaria	Polycladida	Leptoplanidae	*Leptoplana* sp.	0	0	0	0	0	0
Sipuncula	Phascolosomatidea	Phascolosomaliformes	Phascolosomatidae	*Apionsoma trichocephalus*	0	0	0	0	0	0.0082

Table 3 Benthic Grab Survey Raw Data - Wet Season Biomass (in g)

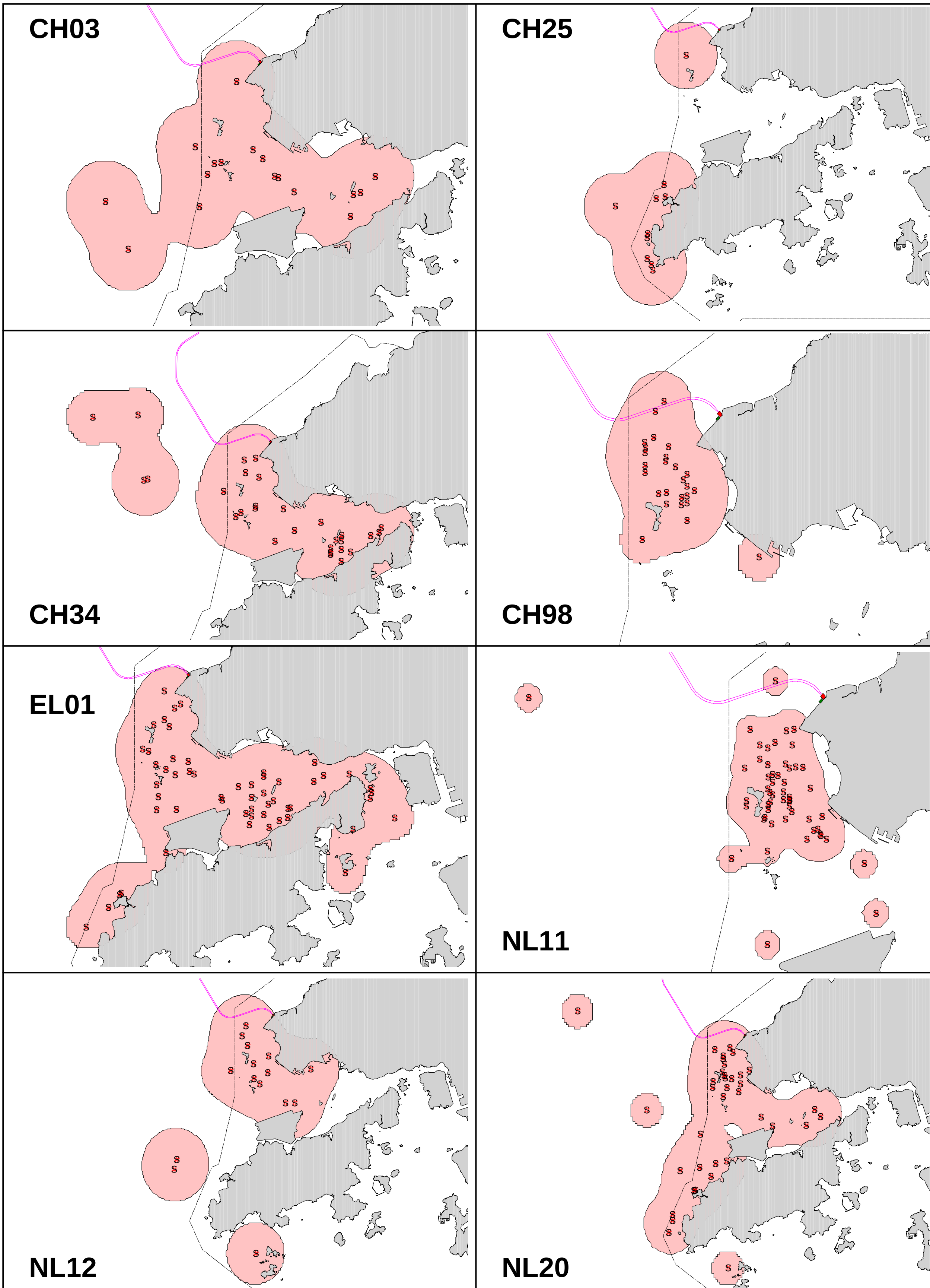
Phylum	Class	Order	Family	Species	D1	D2	D3	D4	D5	D6
Annelida	Polychaeta	Terebellida	Ampharetidae	*Isolda pulchella*	0	0	0.0066	0.1626	0	0.0051
Annelida	Polychaeta	Terebellida	Ampharetidae	*Samytha besslei*	0	0	0	0	0	0
Annelida	Polychaeta	Capitellida	Capitellidae	*Mediomastus californiensis*	0	0	0	0.0082	0.1109	0.075
Annelida	Polychaeta	Capitellida	Capitellidae	*Notomastus latericeus*	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Cirratulidae	*Cirratulus filiformis*	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Cirratulidae	*Tharyx* sp.	0	0	0	0.0062	0	0
Annelida	Polychaeta	Eunicida	Eunicidae	*Eunice indica*	0	0	0	0	0	0
Annelida	Polychaeta	Eunicida	Eunicidae	*Marphysa stragulum*	0	0	0	0	0	0
Annelida	Polychaeta	Flabelligerida	Flabelligeridae	*Pherusa parmata*	0	0	0	0	0	0
Annelida	Polychaeta	Flabelligerida	Flabelligeridae	*Pherusa plusoma*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Glyceridae	*Glycera onomichiensis*	0.4573	0.3349	0.1469	0.2796	0.4222	0
Annelida	Polychaeta	Phyllodocida	Goniadidae	*Glycinde gurjanovae*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Goniadidae	*Goniada eremita*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Hesionidae	*Micropodarke dubia*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Hesionidae	*Ophiodromus angustifrons*	0	0	0	0	0	0
Annelida	Polychaeta	Eunicida	Lumbrineridae	*Lumbrineris* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Magelonidae	*Magelona pacifica*	0	0	0	0	0	0.0034
Annelida	Polychaeta	Capitellida	Maldanidae	*Euclymene* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Nephtyidae	*Aglaophamus dibranchis*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Nereidae	*Nereis* sp.	0.0385	0.0048	0	0	0	0
Annelida	Polychaeta	Eunicida	Onuphidae	*Diopatra* sp.	0	0.0575	0.1281	0.001	0	0
Annelida	Polychaeta	Eunicida	Onuphidae	*Onuphis eremita*	0	0	0	0	0	0
Annelida	Polychaeta	Orbiniida	Orbiniidae	*Scoloplos* sp.	0	0	0	0.0149	0	0
Annelida	Polychaeta	Terebellida	Pectinariidae	*Pectinaria papillosa*	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Phyllodocidae	*Phyllodoce papillosa*	0	0	0	0	0.0032	0
Annelida	Polychaeta	Phyllodocida	Pilargiidae	*Sigambra hanaokai*	0	0	0	0	0	0
Annelida	Polychaeta	Spionida	Poecilochaetidae	*Poecilochaetus serpens*	0	0	0	0	0	0.0113
Annelida	Polychaeta	Phyllodocida	Polynoidae	*Gattyana* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Phyllodocida	Polynoidae	*Lepidonotus* sp.	0	0	0	0	0	0
Annelida	Polychaeta	Sabellida	Sabellidae	*Potamilla* sp.	0	0.0018	0	0	0	0
Annelida	Polychaeta	Spionida	Spionidae	*Laonice cirrata*	0	0	0	0	0	0.0032
Annelida	Polychaeta	Spionida	Spionidae	*Prionospio queenslandica*	0	0	0	0.0272	0.0182	0.0145
Annelida	Polychaeta	Spionida	Spionidae	*Scolelepis squamata*	0	0	0	0	0	0
Annelida	Polychaeta	Terebellida	Terebellidae	*Loimia medusa*	0	0	0	0.0108	0	0

Table 3 Benthic Grab Survey Raw Data - Wet Season Biomass (in g)

Phylum	Class	Order	Family	Species	D1	D2	D3	D4	D5	D6
Annelida	Polychaeta	Terebellida	Terebellidae	*Lysilla pacifica*	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Alpheidae	*Alpheus* sp.	0.0789	0	0	0	0	0
Arthropoda	Malacostraca	Amphipoda	Ampeliscidae	*Byblis* sp.	0	0	0	0.0019	0	0
Arthropoda	Malacostraca	Decapoda	Callianassidae	*Callianassa* sp.	0	0	0	0	0	0
Arthropoda	Malacostraca	Isopoda	Paranthuridae	*Paranthura* sp.	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Penaeidae	*Metapenaeus ensis*	0	0	0	0	0.2127	0
Arthropoda	Malacostraca	Decapoda	Goneplacidae	*Typhlocarcinus nudus*	0	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Pinnotheridae	*Neoxenophthalmus obscurus*	0.0525	0	0.0234	0	0	0
Arthropoda	Malacostraca	Decapoda	Porcellanidae	*Raphidopus ciliatus*	0	0.0546	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Portunidae	*Charybdis variegata*	0	0	0.1129	0	0	0
Arthropoda	Malacostraca	Stomatopoda	Squillidae	*Anchisquilla fasciata*	0	0	0	0	0	0
Arthropoda	Malacostraca	Stomatopoda	Squillidae	*Clorida latreillei*	0	0.0225	0.0119	0	0	0
Arthropoda	Malacostraca	Stomatopoda	Squillidae	*Oratosquilla oratoria*	0	0	0	0	0	0
Chordata	Osteichthyes	Perciformes	Taenioididae	*Trypauchen vagina*	0.0231	0	0	0	0	0
Cnidaria	Anthozoa	Actiniaria	Actiniidae	*Actinia* sp.	0	0	0	0	0	0.0614
Cnidaria	Anthozoa	Ceriantharia	Cerianthidae	*Cerianthus* sp.	0	0	0	0	0	0
Cnidaria	Anthozoa	Pennatulacea	Veretillidae	*Cavernularia obesa*	0	0	0	0	0	0
Cnidaria	Anthozoa	Pennatulacea	Virgulariidae	*Virgularia gustaviana*	0	0	0	0	0	0
Echinodermata	Ophiuroidea	Gnathophiurida	Amphiuridae	*Amphioplus laevis*	0	0.3459	0	0	0	0
Echinodermata	Holothuroidea	Molpadiida	Caudinidae	*Acaudina molpadioides*	0	0	0	0	0	0
Echinodermata	Holothuroidea	Dendrochirotida	Phyllophoridae	*Phyllophorus* sp.	0	0	0	0	0	0
Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae	*Thyone* sp.	0	0	0	0	0	0
Echinodermata	Holothuroidea	Molpadiida	Molpadiidae	*Molpadia* sp.	0	0	0.1888	0	0.0507	0
Echinodermata	Holothuroidea	Apodida	Synaptidae	*Protankyra bidentata*	0	0	0	0	0	0
Mollusca	Bivalvia	Myoida	Pholadidae	*Martesia yoshimurai*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Cultellidae	*Cultellus attenuatus*	0	0	0	0	0	0
Mollusca	Bivalvia	Nuculoida	Nuculanidae	*Saccella parmata*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Psammobiidae	*Psammobia radiata*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Solenidae	*Solen gordonis*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Solenidae	*Solen grandis*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Tellinidae	*Moerella iridescens*	0	0	0	0	0	0
Mollusca	Bivalvia	Veneroida	Veneridae	*Paphia undulata*	0	0	0	0	0	0
Nemertinea	Anopla	Heteronemertea	Cerebratulidae	*Cerebratulina* sp.	0	0	0	0.04	0	0
Plathyhelminthes	Turbellaria	Polycladida	Leptoplanidae	*Leptoplana* sp.	0	0	0	0	0.3636	0
Sipuncula	Phascolosomatidea	Phascolosomaliformes	Phascolosomatidae	*Apionsoma trichocephalus*	0	0	0	0	0	0

Annex 8C

Ranging patterns (95% kernel ranges) of individual Chinese White Dolphins with 10+ re-sightings that had ranges overlapped with the Project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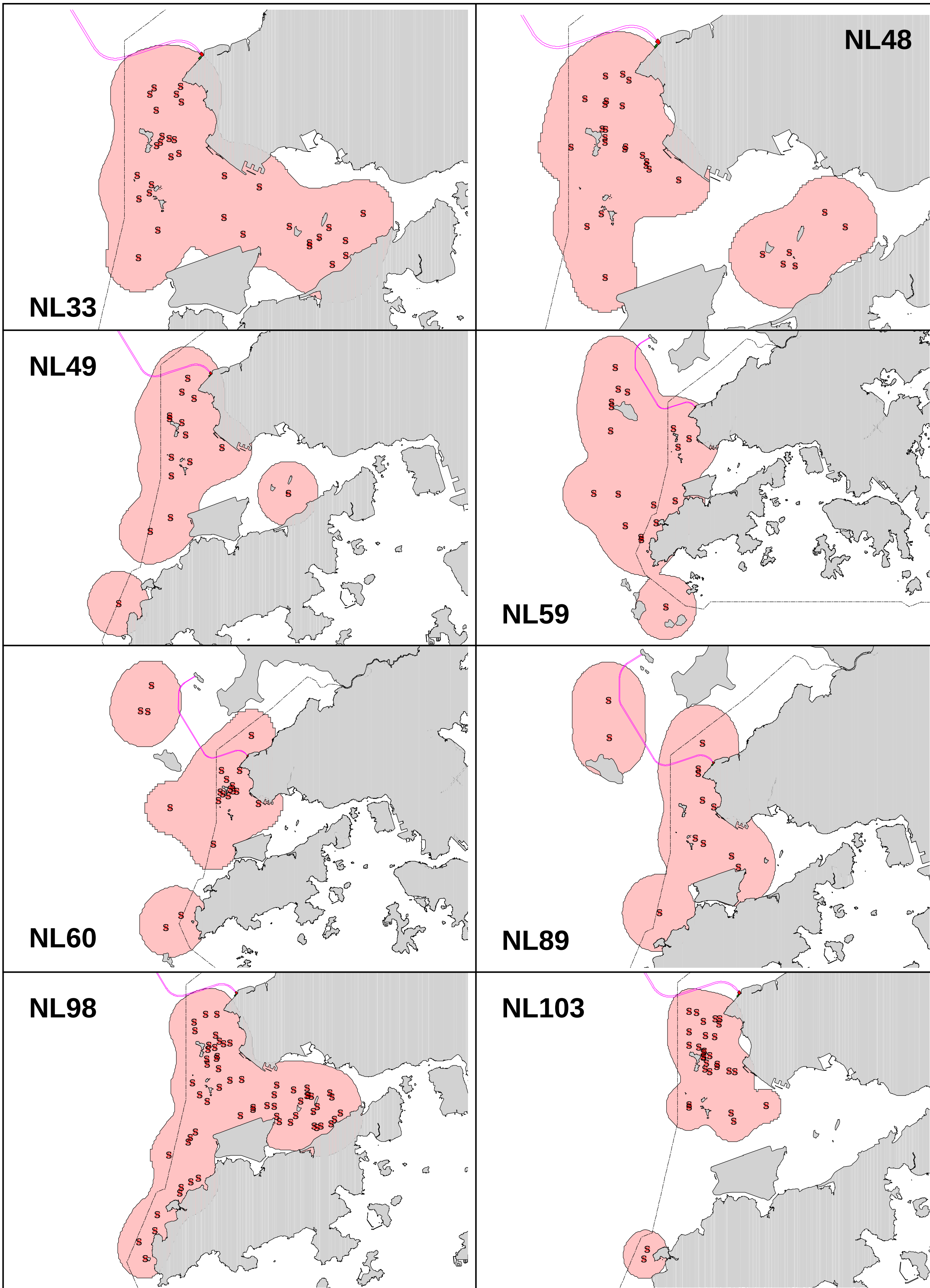
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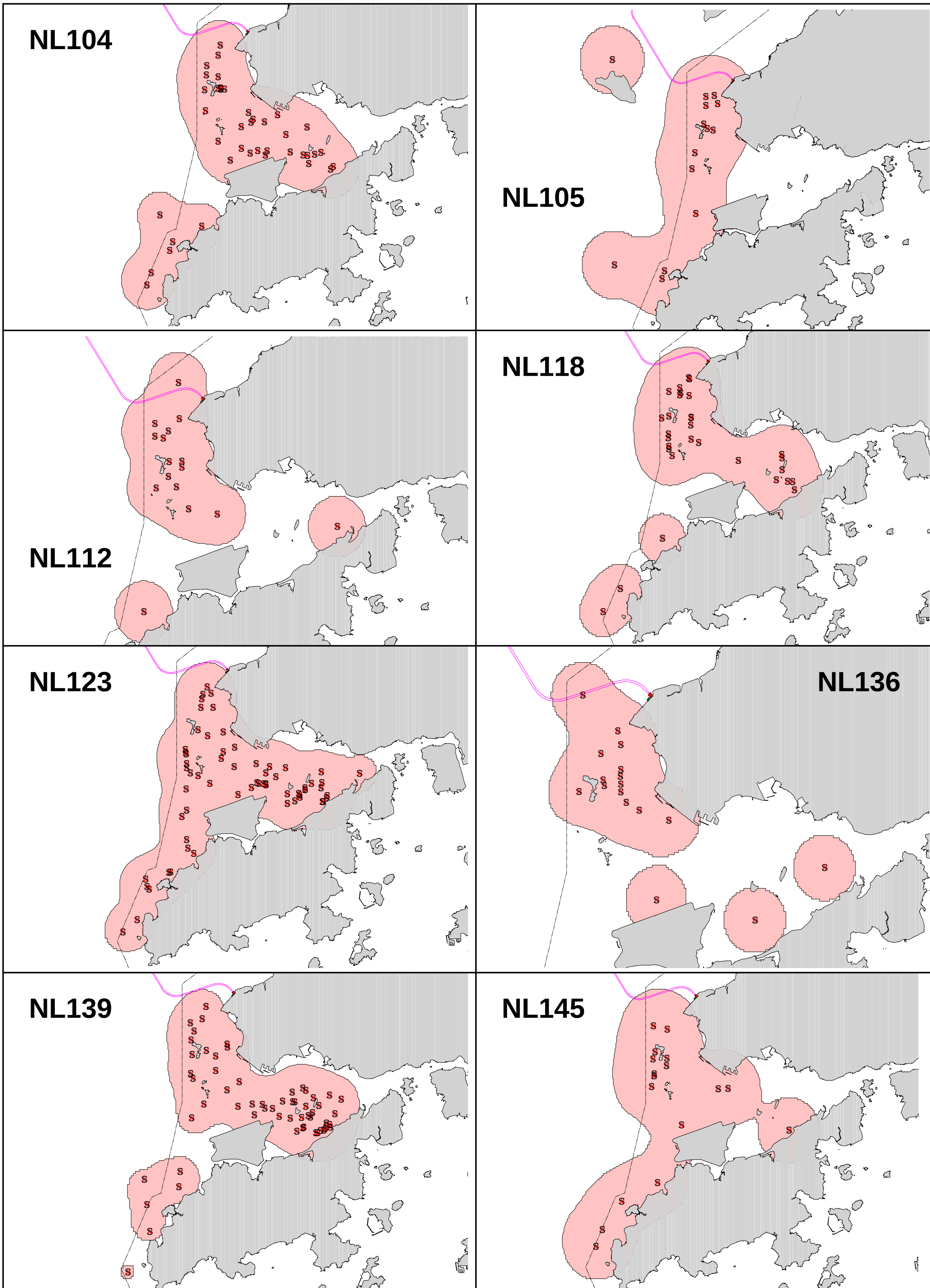
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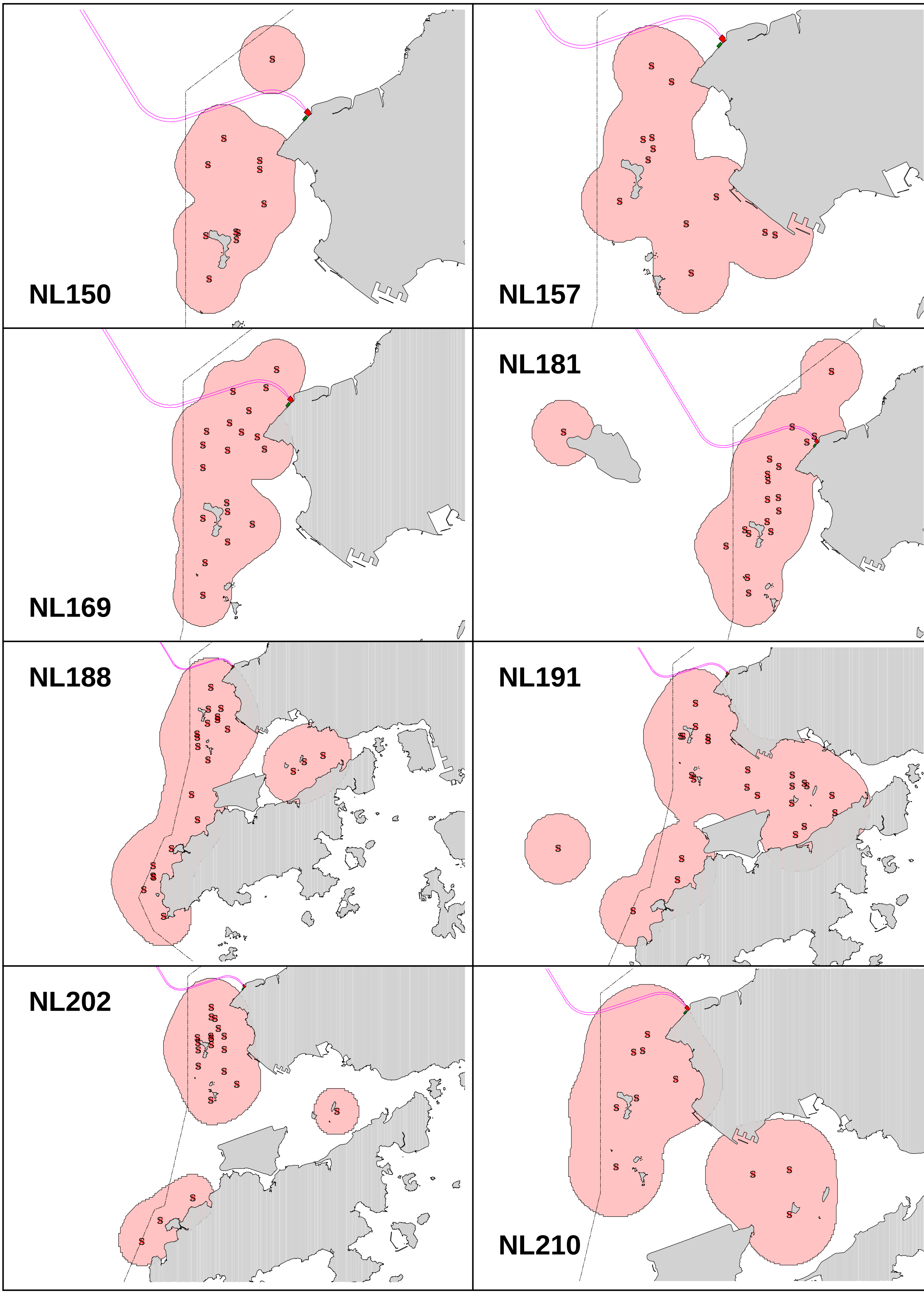
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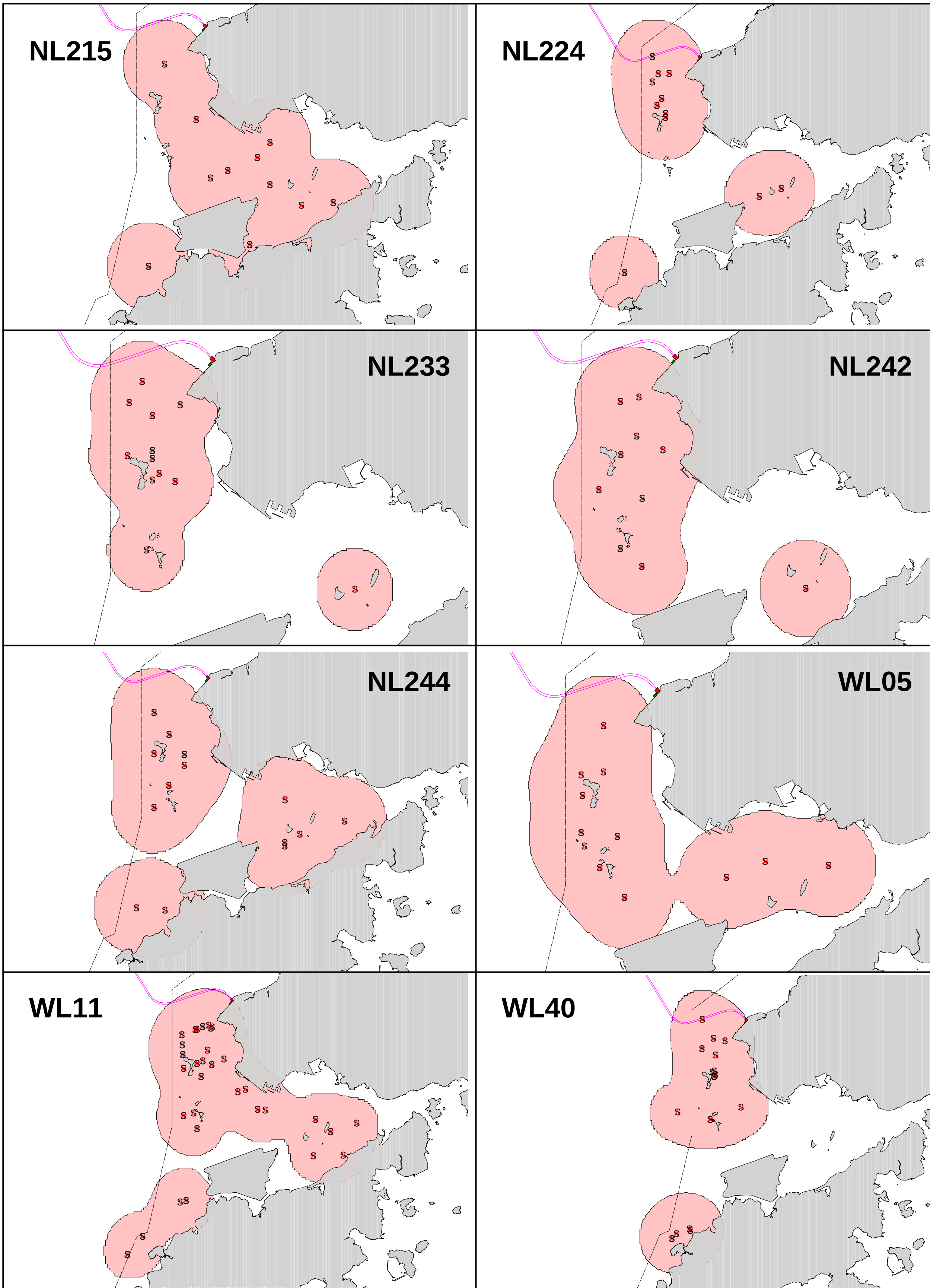
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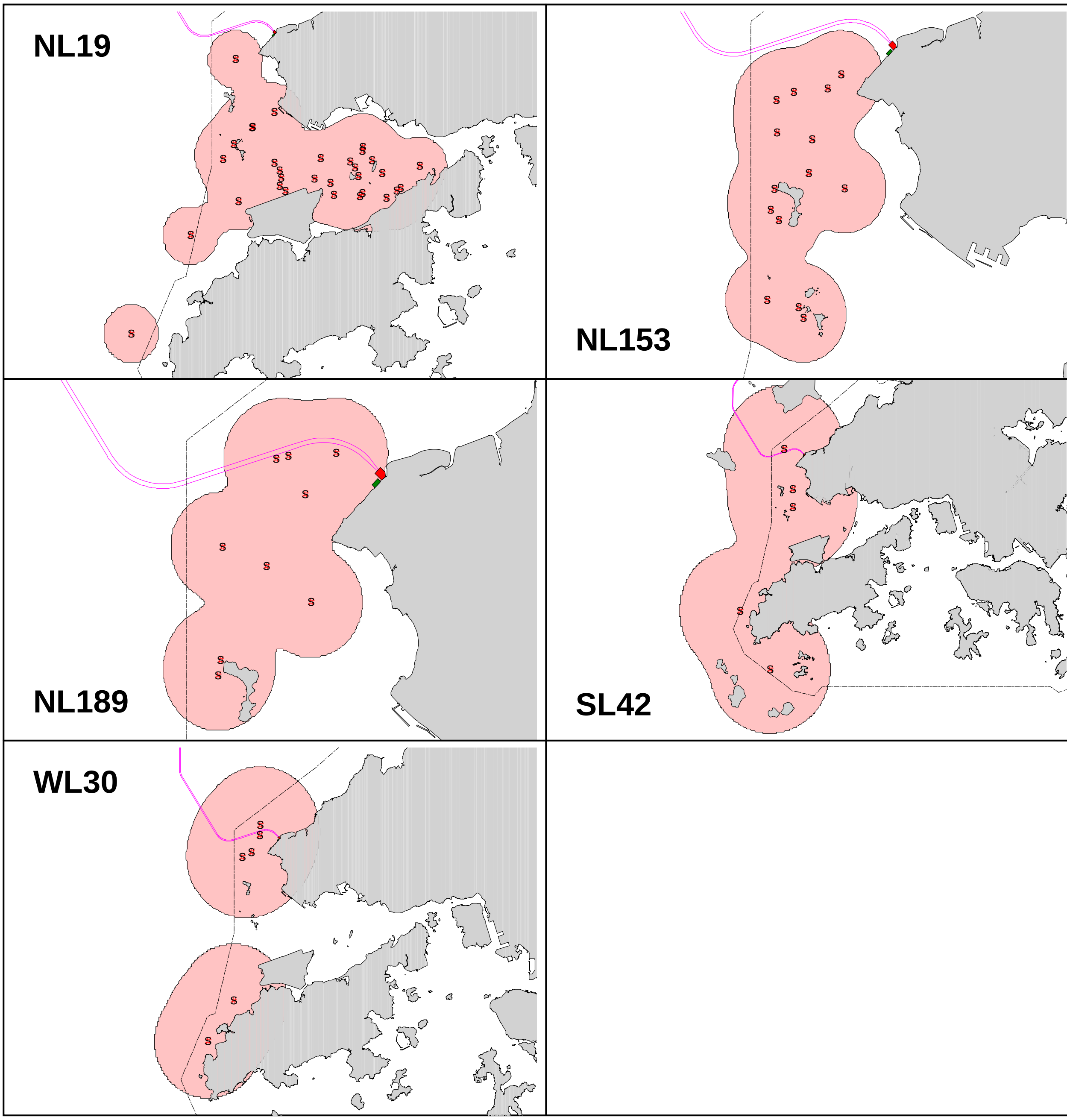
WL11
WL40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NL189
SL42
WL30

Section 9

Fisheries Assessment

CONTENTS

9 FISHERIES ASSESSMENT

9.1 INTRODUCTION

This section presents the findings of an impact assessment on existing capture and culture fisheries, including fisheries resources, fishing operations and fish/oyster culture activities, from the construction and operation of the Gas Receiving Stations (GRSs) and submarine gas pipelines in the Black Point area. It summarises baseline information on fisheries production around Black Point gathered from the literature review. The assessment of fisheries impacts is based on the Project Description (*Section 3*) and the findings of the Water Quality Assessment (*Section 6*).

9.2 RELEVANT LEGISLATION & ASSESSMENT CRITERIA

9.2.1 Technical Memorandum

The criteria for evaluating fisheries impacts are stated in the *EIAO-TM*. *Annex 17* of the *EIAO-TM* prescribes the general approach and methodology for assessing fisheries impacts caused by a project or proposal, to allow a complete and objective identification, prediction and evaluation of the potential impacts. *EIAO-TM Annex 9* recommends the criteria that are to be used for evaluation of fisheries impacts.

9.2.2 Other Legislation

Other legislation which applies to fisheries includes:

- *Fisheries Protection Ordinance* (Cap 171), which provides for the conservation of fish and other aquatic life, regulates fishing practices and prevents activities detrimental to the fishing industry.

- *Marine Fish Culture Ordinance* (Cap 353), which regulates and protects marine fish culture and other related activities and requires all marine fish culture activity to operate under licence in designated Fish Culture Zones.

- *Environmental Impact Assessment Ordinance (Cap 499), Section 5(7) - Environmental Impact Assessment Study Brief no. ESB-208/2009 Section 3.4.6*, which outlines the key fisheries impacts to be reviewed and assessed in the EIA Report.

9.3 BASELINE CONDITIONS & FISHERIES SENSITIVE RECEIVERS

The Study Area for fisheries was the same as that for the Water Quality Impact Assessment (see *Section 6*). A desktop review of existing information on commercial fisheries resources and fishing operations in waters of the Study Area has been undertaken, and the most up-to-date information was obtained primarily from the Agriculture, Fisheries and Conservation Department (AFCD). For a detailed description of the physical and biological characteristics of the marine environment of the Study Area please refer to *Sections 6* and *8* respectively.

9.3.1 *Overview of Hong Kong Fisheries*

Marine-based commercial fishing operations in Hong Kong are broadly classified into culture and capture fisheries.

Mariculture fishery operations occur at 26 Fish Culture Zones (FCZs) which altogether occupy about 209 ha of Hong Kong waters. They involve rearing of marine fish from fry or fingerlings to marketable size in cages suspended by floating rafts usually in sheltered coastal areas/ embayments. Fish farms are typically small scale, family-run operations comprising only one or two rafts with an average size of about 280 m^2. With effect from June 2002, the marine fish culture licence is transferable. In 2008, the marine fish culture industry produced about 1,370 tonnes of fish valued at HK$82 million which accounts for about 10 % of local demand for live marine fish.

For capture fisheries, the size of Hong Kong fishing fleet in 2008 was about 3,800 vessels which were manned by approximately 7,900 local fishers. In 2008, the yield of capture fisheries industry was about 158,000 tonnes which valued at about HK$1,780 million. The catch was mainly from waters outside Hong Kong on the traditional fishing grounds over the continental shelf of the South China Seas [(1)]. Main fishing methods include trawling, long-lining, gill-netting and purse-seining with the majority of the total catch obtained through trawling.

Based on the latest data from AFCD Port Survey 2006, the highest fisheries production (600 to 1,000 kg ha^{-1}) in Hong Kong was recorded in the vicinity of the Ninepin Island Group, Po Toi and Tap Mun [(2)]. These areas also recorded the highest number of fishing vessels. Scad (Carangidae), shrimp, rabbitfish (Siganidae), squid, croaker (Sciaenidae), crab, mullet (Mugilidae), sardine (Clupeidae), seabream (Sparidae) and anchovy (Engraulidae) were the top 10 families captured in Hong Kong waters.

Since 1999, Mainland Authorities have implemented an annual fishing moratorium for South China Sea fishing grounds. Since 2009, the moratorium lasts for 2.5 months during mid summer (from mid May to 1 August) of each year. Except by gill-netting, long-lining, hand-lining and

(1) AFCD (2009) Fisheries: Capture Fisheries Latest Status. <http://www.afcd.gov.hk/english/fisheries/fish_cap/fish_cap_latest/fish_cap_latest.html> Accessed on 2 Sept 2009

(2) AFCD (2009) *Op cit*

cage trapping, the moratorium prohibits other means of fishing activity by the Hong Kong fleet in the area.

9.3.2 *Culture Fisheries in the Study Area*

There are no Fish Culture Zones (FCZ) located close to the proposed reclamation and submarine gas pipelines (*Figure 9.1*). The closest AFCD designated FCZ is located at Ma Wan which is over 20 km from the proposed site).

Despite the long established oyster farming practice on the Deep Bay mudflats, there are no gazetted oyster farming locations in Hong Kong. The oyster production area located along the shore from Tsim Bei Tsui to Pak Nai (*Figure 9.1*) is about 4 km from the proposed reclamation and submarine pipelines.

9.3.3 *Capture Fisheries in the Study Area*

Fishing Operations

The area and number of vessels operating in the Study Area during 2005 are presented in *Figure 9.2* (3). Very low numbers of fishing vessels (10 – 50 vessels), mostly shrimp trawlers, hang trawlers, gill netters and sampans, operated in waters around the proposed facilities at Black Point in 2005. Elsewhere within the Study Area, moderate numbers of vessels (100 – 400 vessels) were recorded near the Sha Chau and Lung Kwu Chau Marine Park, the Brothers Island and off Tai O (*Figure 9.2*).

Fisheries Production

In Deep Bay waters where the proposed Project will be situated, the production of adult fish and value of catch ranked 12th among the 12 fishing sectors in Hong Kong waters, and in 1998 an estimated annual catch of 73 tonnes of adult fish and zero fry was recorded in these waters (4).

More recent data from the AFCD Port Survey 2006 indicated that fisheries production in waters around the proposed facilities at Black Point in 2005 was very low, with ≤ 50 kg ha^{-1} for adult fish with no documented fish fry production and accounting for ≤ HK$ 500 ha^{-1} in value (*Figures 9.3* to *9.5*) (5). Elsewhere within the Study Area, moderate level of adult fisheries production (200 – 400 kg ha^{-1}) were recorded near the Sha Chau and Lung Kwu Chau Marine Park, the Brothers Island and off Tai O, accounting for HK$ 2,000 – 10,000 ha^{-1} in value (*Figures 9.3* and *9.5*). Fisheries production for fish fry was not recorded within the Study Area in 2005 (*Figure 9.4*).

(3) AFCD (2009) *Op cit*

(4) ERM (1998) *Fisheries Resources and Fishing Operations in Hong Kong Waters, Final Report*, for Agriculture and Fisheries Department.

(5) AFCD (2009) *Op cit*

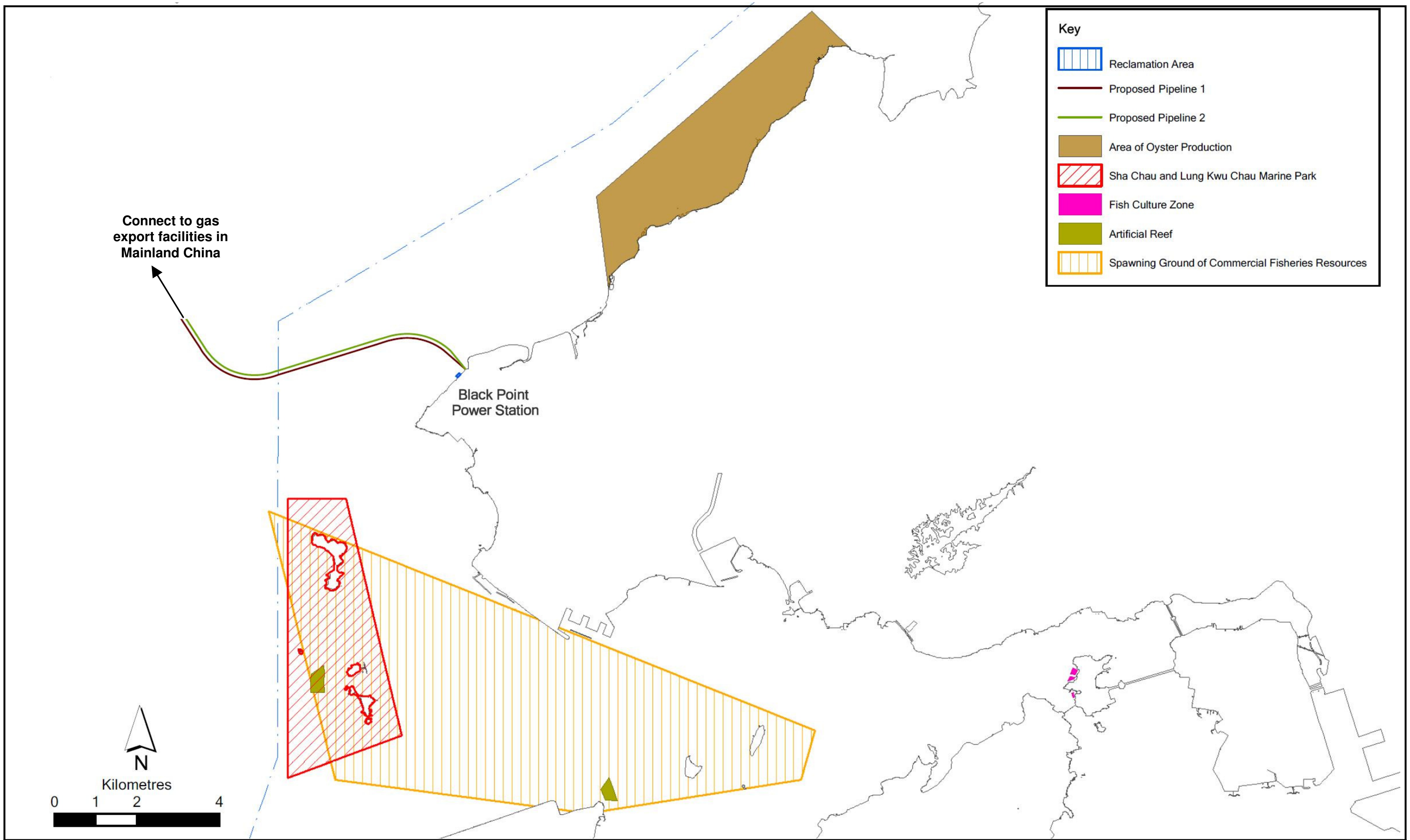

Figure 9.1

Fisheries Sensitive Receivers at Black Point and along the Proposed Pipeline Routes

File: 0104116_adult fish2.mxd
Date 13/10/2009

Environmental Resources Management

ERM

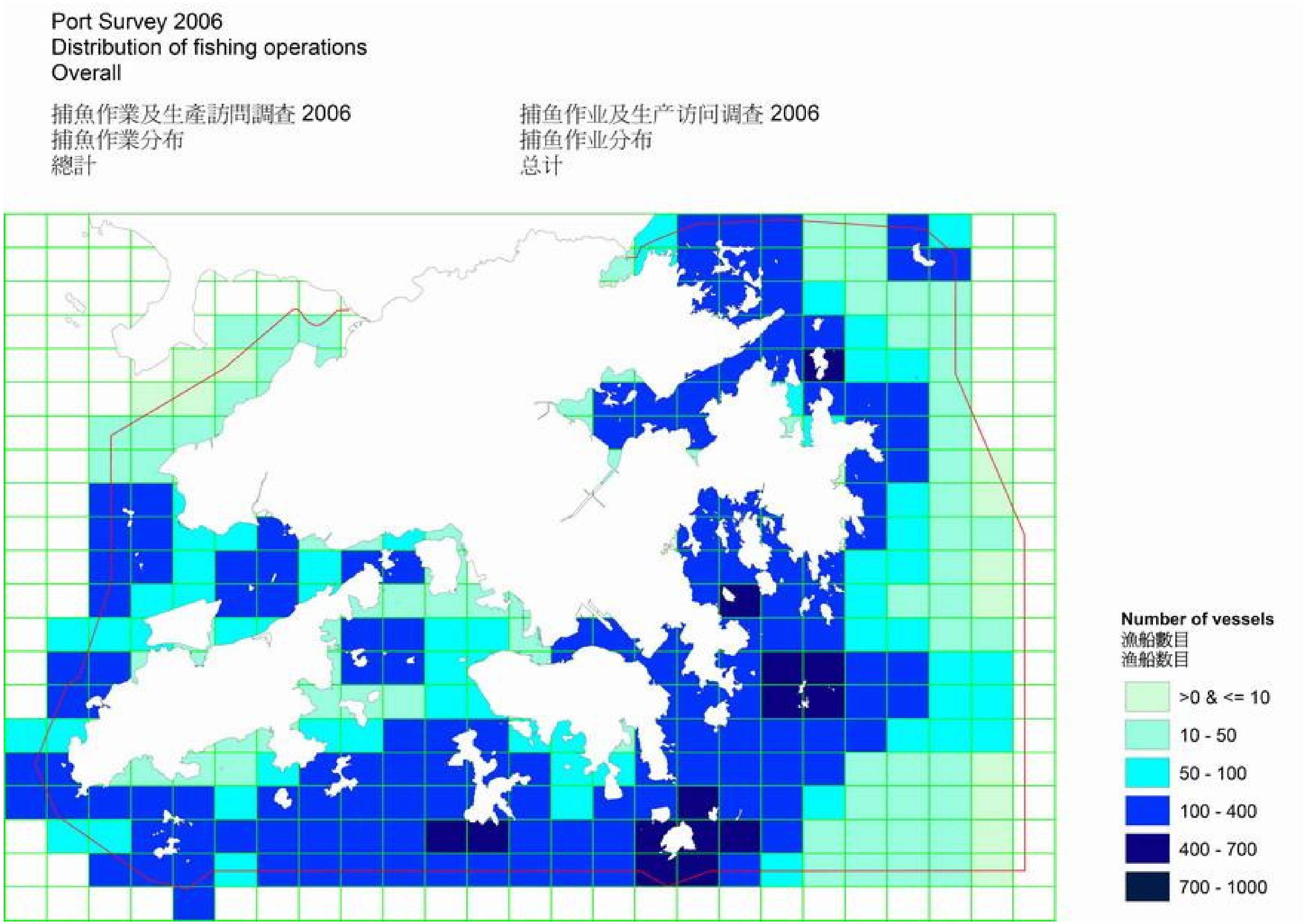

Figure 9.2

Distribution of Fishing Operations (All Vessels) in Hong Kong Waters as recorded by AFCD Port Survey 2006

File:
Date 21/08/2009

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Management

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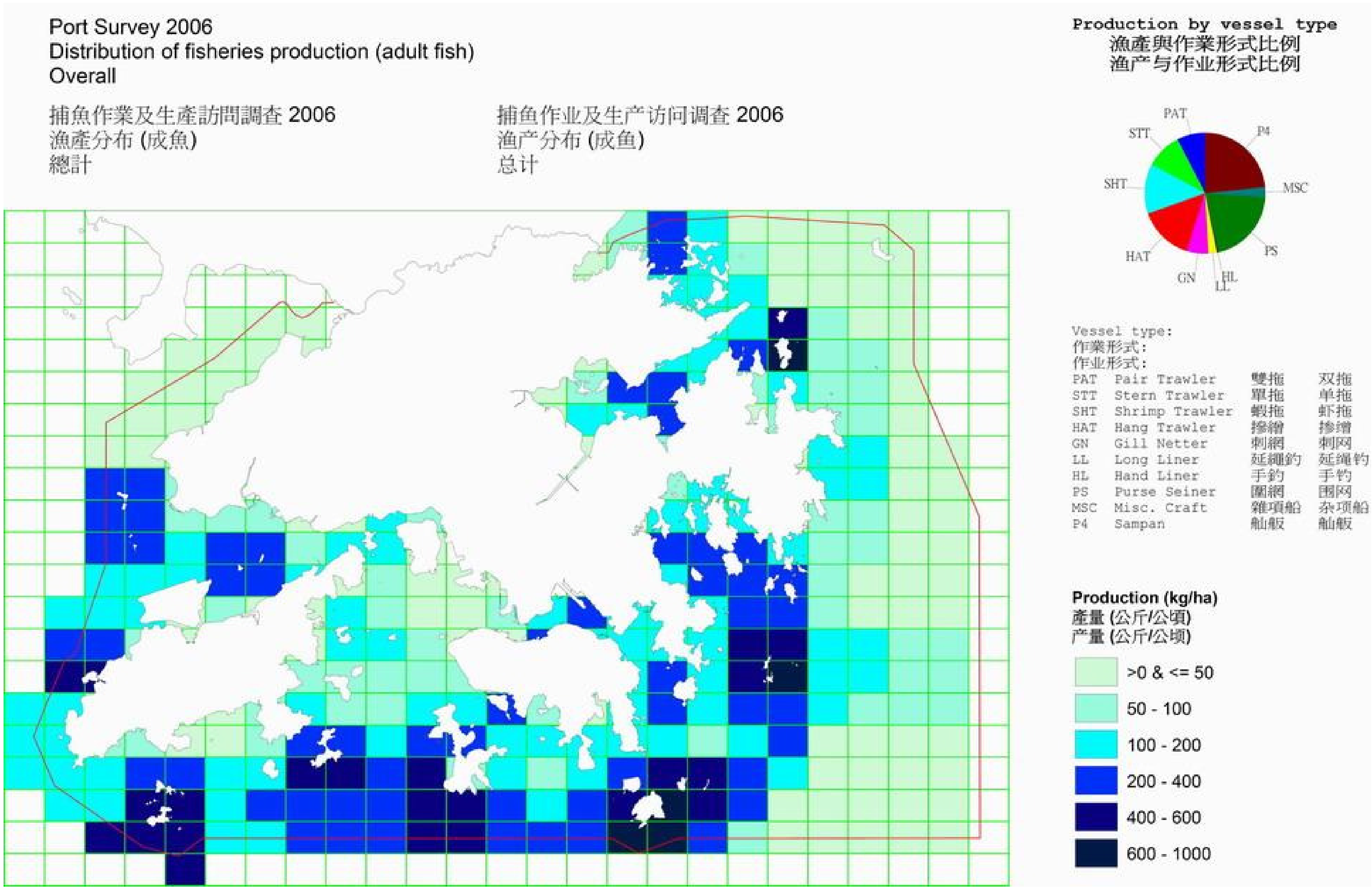


Figure 9.3

Distribution of Fisheries Production (Adult Fish) in terms of Weight (kg ha^{-1}) in Hong Kong Waters as recorded by AFCD Port Survey 2006

File:
Date 21/08/2009

Environmental Resources Management

ERM

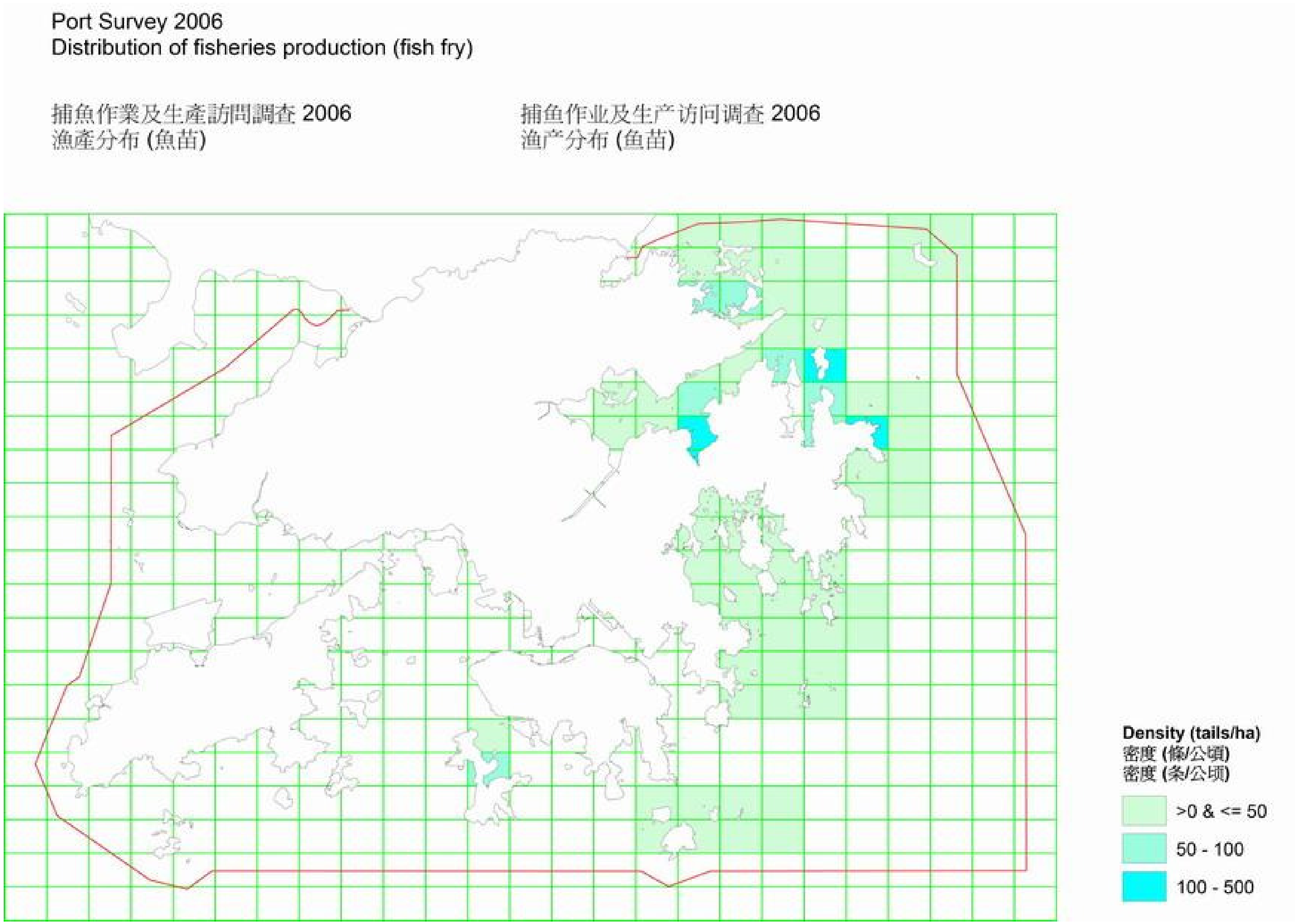


Figure 9.4

Distribution of Fisheries Production (Fish Fry) in terms of tails ha^{-1} in Hong Kong Waters as recorded by AFCD Port Survey 2006

File:
Date 21/08/2009

Environmental Resources Management

ERM

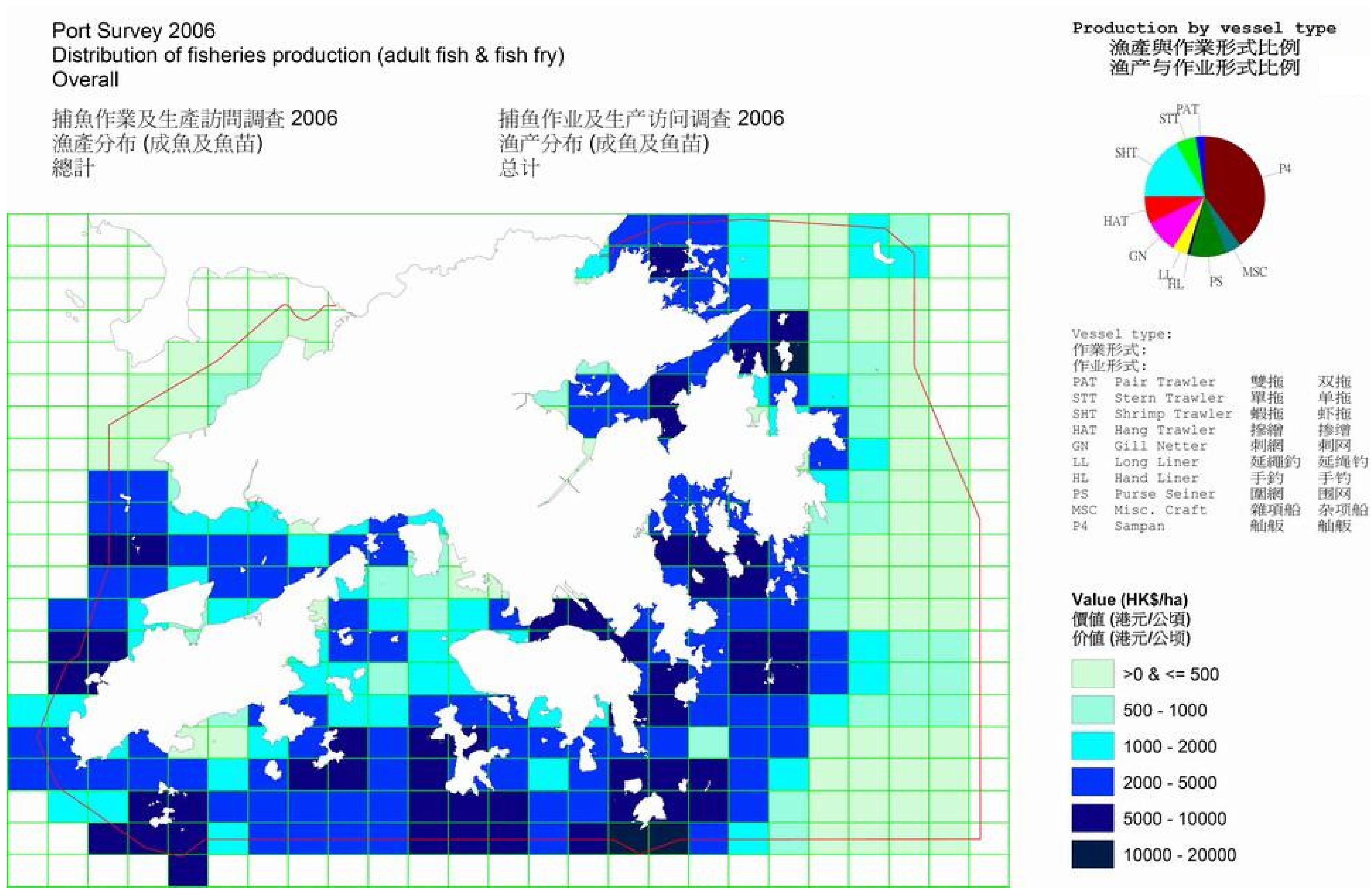


Figure 9.5

Distribution of Fisheries Production (Adult Fish & Fish Fry) in terms of Value (HK$ ha^{-1}) in Hong Kong Waters as recorded by AFCD Port Survey 2006

File:
Date 21/08/2009

Environmental Resources Management

ERM

Results of the Port Survey 2006 thus suggested that waters in outer Deep Bay and Black Point are not key fishing areas with very low fisheries production due to the shallow water depths which constrain vessel navigation and the abundance of cargo vessels that ply the waters between the Shenzhen River and the Pearl River. It is concluded that the level of fishing operations, fisheries production and catch value in these waters are very low comparing to elsewhere in Hong Kong waters.

9.3.4 *Fisheries Resources - Spawning Areas*

The northern Lantau waters were previously identified in 1998 as fisheries spawning grounds for high value commercial species (*Figure 9.1*) (6). This area is approximately 10 km long (from Tai Mo To island to Lung Kwu Chau Island) and 5 km wide (from Castle Peak to the northernmost tip of the Airport). *Leiognathus brevirostris* (ponyfish), *Lateolabrax japonicus* (seabass/perch) and *Clupanodon punctatus* (gizzard shad) were examples of the main commercial fish species recorded in the north Lantau spawning area. In Hong Kong, spawning period differs among fisheries species with the majority of commercial species aggregate and spawn in the open water during the period from June to September (7).

The recognised northern Lantau spawning area is located south of the proposed Project at a distance of about 4.7 km (*Figure 9.1*), and is considered unlikely to be affected by the construction and operation of this Project due to the large separation distance.

9.3.5 *Artificial Reef Deployment*

The AFCD has been undertaking a programme to enhance existing marine habitats and fisheries resources through the siting, construction and deployment of artificial reefs (ARs). Generally ARs provide hard bottom, high profile habitat in areas without natural cover and may potentially act as fish enhancement devices. In March 2000, the Sha Chau AR was deployed with the key objective of enhancing the marine habitat quality and fisheries resources (*Figure 9.1*) (8). A total of 42 units of concrete-coated container and 24 units of ferro-cement river barges with a total volume of 5,580 m^3 have been deployed on the seabed. They are located at least 7.8 km away from the proposed Project, and are considered unlikely to be affected by the construction and operation of this Project due to the large separation distance.

(6) ERM (1998). *Op cit*

(7) *Caranx kalla* (shrimp scad) spawns in the early summer (around June) whilst *Leiognathus brevirostris* (ponyfish) and croakers were found to be reproductive for a longer period throughout most of the year from May to December. Some fish species reported in the spawning grounds, including *Platycephalus indicus* (flathead) and *Clupanodon punctatus* (gizzard shad), spawn in the late winter/early spring (i.e. February to April) and a few are known to spawn in January. The spawning period of most of the crustacean species, including *Metapenaeus joyneri* was found to be from April to November

(8) AFCD (2003) Hong Kong Artificial Reef Deployment Study. http://www.artificial-reef.net/English/main.htm

Results of the water quality modelling exercise support this conclusion (*Section 6*).

9.3.6 *Fisheries Importance*

Based on the baseline information provided above, the importance of the fisheries within the Study Area is evaluated. The fishing areas within the Study Area, in particular within the Project's footprint, are being considered as of low commercial value. The small size and subsequent low value of the catches characterise the waters of the Project Area as of low importance to the Hong Kong fishing industry.

According to *Annex 9* of the *EIAO-TM*, spawning grounds can be regarded as an important habitat type as they are critical to the regeneration and long-term survival of many organisms and their populations. No spawning area has been identified within the footprint of the proposed Project. The closest recognised spawning area is located approximately 4.7 km south of the Project site.

9.3.7 *Sensitive Receivers*

Based on the preceding review of the available information on the capture and culture fisheries of the waters in the vicinity of the proposed Project, the potential sensitive receivers that may be affected by the Project activities are identified as follows:

- Recognised spawning ground of commercial fisheries resources in north Lantau (south of the proposed Project at a distance of about 4.7 km);
- Artificial reefs in the Sha Chau & Lung Kwu Chau Marine Park (located at least 7.8 km from the proposed Project);
- Oyster production area at Deep Bay (about 4 km from the proposed facilities).

The locations of the sensitive receivers are shown in *Figure 9.1*. FCZs are not expected to be affected by the Project due to their distances from the Project site and they are thus not considered to be sensitive receivers. The water quality modelling results presented in *Section 6* support this conclusion.

9.4 ASSESSMENT METHODOLOGY

A desktop literature review of baseline fisheries conditions was conducted for the purpose of establishing the fisheries importance of the waters in the vicinity of the proposed facilities at Black Point. Information from the water quality impact assessment (*Section 6*) was examined to refine the size of the Study Area as that is potentially affected by perturbations to water quality parameters. This area, refined to within 3 km from the Project facilities, became the main focus for this fisheries impact assessment. The importance of potentially impacted fisheries resources and fishing operations within this area was studied. The potential impacts due to the construction and operation of the Project were then assessed (with reference to the *EIAO-TM Annex 17* guidelines) and the impacts evaluated (with reference to the criteria in *EIAO-TM Annex 9*).

9.5 POTENTIAL IMPACTS & IMPACT ASSESSMENT ON FISHERIES RESOURCES

9.5.1 Construction Phase

As discussed in *Section 3*, the construction of the proposed GRS reclamation and installation of the submarine pipelines at Black Point Power Station (BPPS) will involve dredging/ jetting and reclamation works in Hong Kong and dredging/ jetting in Mainland waters. Potential impacts to fisheries resources and fishing operations arising from these works may be divided into those related to:

- Direct disturbances to that habitat;
- Underwater sound generated from marine construction activities; and
- Perturbations to key water quality parameters.

Habitat Disturbance

Direct impacts to fisheries resources and fishing operations include habitat disturbance caused by the dredging / jetting and reclamations works. Construction of the proposed reclamation and associated artificial seawall is predicted to lead to the permanent loss of approximately 0.5 ha of fishery habitat, and dredging/ jetting works are expected to cause temporary disturbance to an area of approximately 16.5 ha (see *Table 8.4*).

Owing to the very small area of the fishing ground permanently lost to reclamation and due to its low fisheries importance, unacceptable impacts to local fisheries resources and fishing operations are not expected.

Although a larger area is impacted by the dredging/ jetting activities in Hong Kong (approximately 16.5 ha) for the pipeline and seawall trenches, unacceptable impacts on the fishery resources and activities are also not expected due to the temporary nature of the interference (< 12 months for construction of one pipeline) and the low fisheries importance of the area. Furthermore, fisheries resources are expected to return to the area following the cessation of marine construction activities. Issuance of Marine Department Notice or other notifications is expected to reduce the risk of collision of increased marine traffic and fishing vessels to within acceptable levels.

Underwater Sound

Intermittent sounds, which occur during activities such as dredging / jetting and marine vessel movement, may have an impact on fisheries resources during the construction phase. Potential effects of increased underwater sound include physiological stress, avoidance and injury (at high pressure levels). The level of impact is however dependent upon background sound, number of fish present, type of species affected, attenuation properties of seabed sediments and hearing capabilities of the species affected, etc.

Most marine invertebrates do not possess air-filled space and thus it is generally considered that sound would have limited physiological or behavioural effects on marine invertebrates, except if they are located within a few metres of the sound source. Therefore underwater sound generated from marine works is expected to have negligible impact on fisheries resources such as crustaceans.

Fish, however, can detect underwater sound vibrations through two ways, the lateral line system and the inner ear for species containing air-filled swim bladders. Anthropogenic underwater sounds associated with vessels for this Project, such as barges, guard vessels, dredgers and jetting machine, exhibit major energy below 1,000 Hz and sound levels of between 170 and 190 dB re 1 μPa at 1 m and may be audible to most fish species (9). Waters within and around the Project site encompass the Urmston Road and have been identified as being subject to relatively high levels of marine traffic by similar types of vessels; therefore it is reasonable to assume that fish in these waters are habituated to a relatively high background level of underwater sound, and a small increase in vessel activity associated with the construction of this Project is not anticipated to result in unacceptable impacts on fisheries resources.

Changes in Water Quality

Indirect impacts to fisheries resources and fishing operations during the construction phase of the Project include sediment release associated with the marine works. Potential impacts to water quality from sediment release are as follows:

- Increased concentrations of suspended solids (SS);
- Decreased dissolved oxygen (DO) concentrations;
- An increase in nutrient concentrations in the water column.

(9) Richardson WJ, Greene CRG, Malme CI, Thomson DH (1995) *Marine Mammals and Noise*. Academic Press, San Diego, 576 pp

Suspended Solids (SS)

Dredging/ jetting and backfilling works for this Project are expected to generate SS within the water column and result in increased sediment deposition in close proximity of the works areas. The modelling works have analysed SS dispersion from construction works (*Section 6.7.1*).

Fluxes of SS naturally occur in the marine environment and as a result fish have evolved behavioural adaptations to tolerate changes in SS load (e.g. clearing their gills by flushing water over them). However, increased SS concentrations that would arise from the dredging/ jetting/ backfilling works would be uncharacteristic of the usual variable marine conditions. Concentrations of SS generated by these marine construction activities are expected to be greater, particularly in the immediate vicinity of the particular works area. Beyond the active marine works areas, dispersion can be expected to lead to a rapid decline in the SS concentrations.

Compared to adult fish, larvae and post-juvenile fish are relatively more susceptible to variations in SS concentrations as their sensory system is less developed. Adult fish are more likely to move away from area of disturbance when they detect sufficiently elevated SS concentrations and therefore are unlikely to be significantly impacted.

The SS level at which fish move into clearer water is defined as the tolerance threshold which varies among species and different stages of the life cycle. If SS levels exceed tolerance thresholds and the fish are not able to move away from the affected area, the fish are likely to become stressed, injured and may eventually die. The rate, timing and duration of SS elevations influence the type and extent of impacts upon fish and potentially crustaceans (10) (11).

Findings from literature reviews indicated that lethal responses had not been reported in adult fish at SS values below 125 mg L^{-1} (12) and that sublethal effects were only observed when levels exceeded 90 mg L^{-1} (13). However, as part of a study for AFCD, *Consultancy Study on Fisheries and Marine Ecological Criteria for Impact Assessment* guideline values have been identified for fisheries and selected marine ecological sensitive receivers. The values are based on international marine water quality guidelines for the protection of ecosystems (14). The AFCD study recommends a maximum SS concentration

(10) Species Profiles: Life Histories and Environmental Requirement (Gulf of Mexico) - Brown Shrimp, US Fish and Wildlife Service, 1983.

(11) The Shrimp Fishery of the Gulf of Mexico – A regional Management Plan, Gulf Coast Research Laboratory, 1977

(12) References cited in BCL (1994) Marine Ecology of the Ninepin Islands including Peddicord R and McFarland V (1996) Effects of suspended dredged material on the commercial crab, *Cancer magister*. in PA Krenkel, J Harrison and JC Burdick (Eds) Dredging and its Environmental Effects. Proc. Speciality Conference. American Society of Engineers.

(13) Alabaster JS & Lloyd R (1984) Water Quality Criteria for Freshwater Fisheries. Butterworths, London.

(14) City University of Hong Kong (2001). Agreement No. CE 62/98, *Consultancy Study on Fisheries and Marine Ecological Criteria for Impact Assessment*, AFCD, Final Report July 2001.

of 50 mg L^{-1} (based on half of the no observable effect concentrations). However, the study cautioned that site-specific data should be considered in environmental assessments on a case-by-case basis. In order to provide a more conservative assessment (i.e. with a lower tolerance criterion), the Water Quality Objectives (WQOs) for SS elevation are adopted instead in this study as the assessment criteria for fisheries sensitive receivers.

As discussed in *Section 6.7.1*, the water quality modelling results have indicated that at all fisheries sensitive receivers, SS elevations as a result of dredging/ jetting and backfilling works are predicted be compliant with the relevant WQOs for both wet and dry seasons (*Tables 6.10* to *6.16*). Elevated levels of SS as a result of these works are expected to be temporary in nature and localised to proximity of particular works area which is considered as of low fisheries importance. As such, unacceptable impacts from such works on fisheries are not expected to occur. The water quality assessment has also shown that unacceptable water quality impacts due to the release of heavy metals and organic micro-pollutants associated with suspended solids are not expected to occur (see *Section 6.7.5*).

Finally it should be noted that the Black Point Project site is at the mouth of Deep Bay on the eastern bank of the Pearl River Estuary. As a result of discharges from the Pearl River and the Shenzhen River in Deep Bay, the background variation in SS levels is acknowledged as being high. Water quality data gathered by EPD has revealed that in the vicinity of Project Site SS values can reach over 200 mgL^{-1}. Therefore, impacts to fisheries resources as a result of potential elevations of SS from the construction works are not expected to occur.

Dissolved Oxygen (DO)

The relationships between SS and DO are complex, with elevated SS in the water column together with a number of other factors to reduce DO concentrations. Elevated SS (and turbidity) reduces light penetration, lowers the rate of photosynthesis by phytoplankton (ie primary productivity) and thus lowers the rate of oxygen production in the water column. Furthermore, the potential release of sediment contaminants into the water column may consume the DO in the receiving water. The resulting overall DO depletion has the potential to cause an adverse effect on the eggs and larvae of fish and crustaceans, as at these stages of development high levels of oxygen in the water are required for growth to support high metabolic growth rates.

The results of the water quality assessment (see *Section 6.7.3*) have indicated that DO depletion as a result of dispersion of sediment plumes associated with marine works of the Project are predicted to remain compliant with the WQOs at all fisheries sensitive receivers for all construction scenarios. The largest reduction in DO levels is predicted to be localised to the immediate vicinity of the marine works area and the plumes would not extend to the fisheries spawning ground in north Lantau. Therefore, unacceptable impacts to fisheries from the reduction of DO concentration are not expected to occur.

Nutrients

High levels of nutrients (total inorganic nitrogen - TIN and ammonia) released from dredged sediments to seawater may potentially cause rapid increases in phytoplankton population, on occasions to the point that an algal bloom occurs. An intense algal bloom can cause sharp decreases in the levels of DO. This decrease would initially occur in the surface water, and then spread to deeper water as dead algae fall through the water column and decompose on the seabed.

The water quality modelling results have indicated that elevated nutrients concentrations are expected to remain compliant with WQOs at all fisheries sensitive receivers (see *Section 6.7.4*). Unacceptable impacts to fisheries are thus not expected to occur.

Contaminant Release

Clause 3.4.6.5 of the *Study Brief* requires an assessment of potential impacts on fisheries resources caused by potential release of contaminants from disturbance of bottom marine sediments. The potential for release of contaminants from dredged sediments has been assessed in *Section 6.7.5*, whereas, a comprehensive set of data on the marine sediment quality is provided in *Section 7 – Waste Management*.

As discussed in *Section 6.7.5*, unacceptable water quality impacts due to the potential leaching of heavy metals and micro-organic pollutants from the disturbed sediments into the water column are not expected to occur. Impacts on fisheries resources due to bioaccumulation of released contaminants from dredged sediments are thus not expected to occur.

In summary, predicted levels of SS, DO, nutrient and contaminant concentrations as a result of dredging/ jetting/ backfilling works of this Project are anticipated to be in compliance with the relevant assessment criteria. Unacceptable indirect water quality impacts from sediment release on fisheries sensitive receivers (*Section 9.3.7*) are thus not expected to occur.

9.5.2 *Operation Phase*

The potential impacts of the operational phase of the Project on the fisheries of the Study Area can be divided into two main categories:

- Impacts arising from the permanent loss of fisheries habitat;
- Secondary impacts arising from the alteration of the marine hydrodynamic regime and on water quality arising from the reclamation in terms of limited dispersion of cooling water discharged from the BPPS.

No impacts are expected to occur during the operation of the submarine pipelines. Impact to fishery trawling operations caused by the presence of submarine pipelines is avoided as the pipelines will be buried under the seabed and the seabed along the pipeline corridors is expected to return to the same level as the surrounding. Also, benthic resources, which may serve as food sources for fisheries resources, are expected to recolonise the affected seabed areas along the pipeline corridor (*Section 8.5.1*) and thus secondary impacts on fisheries are not expected.

Habitat Loss

As mentioned in *Section 9.5.1*, this Project would result in a permanent loss of about 0.5 ha of marine habitats due to the presence of the GRS reclamation. From the evaluation of the productivity and value of the local fisheries in *Section 9.3*, the affected fishing grounds are considered of low fisheries importance. Overall, the small size and low fisheries importance of the affected area suggest that unacceptable impacts to fisheries caused by permanent habitat loss are not expected to occur.

Hydrodynamic Regime & Secondary Water Quality Impacts

Impacts to fisheries resources may potentially occur if the shape of the proposed GRS reclamation causes a change to the hydrodynamic regime of the BPPS coastline or if the reclamation affects the dispersion of cooling water discharged from the BPPS outfall. Potential impacts of this nature are described in detail in *Section 8.5.2*.

Given the small scale of the reclamation, significant changes in the hydrodynamic regime, flushing capacity and sedimentation pattern around the BPPS area were not predicted (see *Section 6.8*) and thus unacceptable impacts on fisheries resources are not expected to occur.

As discussed in *Section 8.5.2*, in the presence of the GRS reclamation, temperature of cooling water from the seawater outfall of the BPPS is expected to dissipate rapidly upon discharge to a maximum of 2 °C difference from existing condition for a distance of ~ 1 km from the point of discharge. The temperature change is predicted to be confined to the surface layer with reduced impact to the bottom layer. Given the localised and small scale of the predicted temperature elevation, unacceptable impacts to fisheries resources in the vicinity are not expected to occur.

9.6 IMPACT EVALUATION

From the information presented above, the fisheries impact associated with the Project is not considered to be significant. An evaluation of the impacts according to *Annex 9* of the *EIAO-TM* is presented below:

- *Nature of Impact*: Permanent impacts are predicted to occur as a result of the loss of fishing grounds in the 0.5 ha area to be reclaimed for the proposed GRS. Short-term disturbance to fishing grounds in the Project's marine works areas is expected as a result of the dredging/ jetting to form the trenches for the proposed submarine pipelines and seawall. Potential impacts of elevated levels of underwater sound as a result of construction activities are not expected to be unacceptable. Temporary impacts to pelagic and demersal fisheries resources as a result of minor perturbations to water quality are predicted to occur in the immediate vicinity of marine construction works. Unacceptable secondary impacts on fisheries resources, due to changes in hydrodynamic regime and dispersion of BPPS cooling water discharges in the presence of GRS reclamation, are not expected.

- *Size of Affected Area*: The construction and operation of the Project is predicted to result in the permanent loss of approximately 0.5 ha of fishing ground. This loss is considered to be insignificant for local fishery resources and fishing operations given the very small size of habitat lost and low fisheries importance in these waters.

- *Size of Fisheries Resources/production*: The value of the fisheries resources/production of the marine waters around the GRS reclamation and submarine pipelines is low in comparison to other waters in Hong Kong.

- *Destruction and Disturbance of Nursery and Spawning Grounds*: No important spawning grounds have been identified within the Project Area. In north Lantau, a recognised spawning area for fisheries resources lies about 4.7 km from the proposed Project. As the water quality modelling results have indicated that impacts to water quality are predicted to be localised and short-term, impacts to important spawning grounds are not expected to occur.

- *Impact on Fishing Activity*: Due to the small size of the affected area and the low intensity of the fishing operations, impacts on fishing activity are expected to be minimal. Potential obstruction to fishing activities due to pipeline armour rock placement is not anticipated as it will be installed below or flush with the existing seabed. The seabed temporarily affected by the pipeline works is, therefore, expected to be restored to its original configuration.

- *Impact on Aquaculture Activity*: Fish Culture Zones and oyster production areas are too remote to be affected by the Project. Also no impact has been identified on mariculture activities as predicted SS elevations are compliant with the relevant assessment criteria/ standards.

9.7 MITIGATION MEASURES

In accordance with the guidelines in the *EIAO-TM* on fisheries impact assessment, the policy adopted in this EIA for mitigating impacts to fisheries, are:

- **Avoidance:** Potential impacts should be avoided to the maximum extent practicable by adopting suitable alternatives;
- **Minimisation:** Unavoidable impacts should be minimised by taking appropriate and practicable measures such as confining works in specific area or season, restoration (and possibly enhancement) of disturbed fisheries resources and habitats; and
- **Compensation:** When all possible mitigation measures have been exhausted and there are still significant residual impacts or when the impacts are permanent and irreversible, consideration shall be given to off-site compensation. It may include enhancement of fisheries resources and habitats elsewhere.

Construction impacts to fisheries resources and fishing operations have largely been avoided (i.e. important spawning area of commercial fisheries resources) and reduced through proper planning and design of the works, in particular those associated with the backfilling and dredging/ jetting activities (e.g. optimisation of project construction schedule, and to construct a completed seawall above the high water level with a 50 - 100 m opening for barge access before the commencement of the backfilling works for reclamation). The main works have been designed to confirm compliance with the assessment criteria at sensitive receivers and control water quality impacts to within acceptable levels and water quality mitigation measures will be implemented to further avoid/reduce potential impacts (see *Section 6*). These measures are expected to control and reduce potential impacts to fisheries resources as well, and no fisheries-specific mitigation measures or compensation are thus required during construction.

Significant impacts to fisheries resources and fishing operations are not expected to occur during the operational phase of the Project. No additional fisheries-specific mitigation measures or compensation are required during operation.

9.8 RESIDUAL ENVIRONMENTAL IMPACTS

The identified residual impact arising from the Project is the permanent loss of approximately 0.5 ha of fishing ground required for the GRS reclamation. The magnitude of this residual impact is considered to be within acceptable levels given the small size and low fisheries importance of the area being lost.

9.9 CUMULATIVE IMPACTS

9.9.1 *Project-Specific Cumulative Impacts*

The fisheries impact assessment has considered the cumulative effects of different activities of this Project on fisheries resources and fishing operations. The worst-case scenarios of concurrent construction of all Project facilities have been assessed in the *Water Quality Impact Assessment* (*Section 6*) and thus the cumulative impacts of this specific Project have been accounted for. As discussed in *Section* 6, the cumulative impacts of the various project-specific construction activities are not predicted to cause unacceptable impacts to water quality. Consequently, unacceptable cumulative impacts to fisheries resources are not expected to occur.

9.9.2 *Cumulative Impacts with Other Developments*

Information from publicly available sources suggested that the construction/ implementation programmes of the following major projects would coincide with the construction of this Project [15]:

- Hong Kong Link Road (HKLR) of the Hong Kong – Zhuhai – Macao Bridge (HZMB), which is about 15 km south of the pipeline corridor;
- Hong Kong Boundary Crossing Facilities (HKBCF) of the HZMB, which is about 12 km south of the pipeline corridor;
- Tuen Mun – Chek Lap Kok Link (TMCLKL), which is about 10 km from the pipeline corridor; and
- Contaminated Mud Pits (CMPs) at East of Sha Chau and South Brothers, which are at least 10 km from the pipeline corridor.

It is noted from the approved EIA reports of these projects that the anticipated cumulative impacts are not expected to be significant for fisheries resources in this part of Hong Kong. In addition, a discussion of potential cumulative water quality impacts arising from concurrent projects is provided in Sections 6 and *8.10.2*. Since it is unlikely for water quality mixing zone of this Project to overlap with those of other concurrent projects in this part of Hong Kong, it is thus concluded that cumulative impacts on water quality impacts and consequently on fisheries resources are not predicted to occur.

Unacceptable operational-phase impacts on fisheries resources are not expected to occur for this Project (*Sections 8.5.2*). Therefore, operational-phase cumulative impacts with other developments in and around Black Point are not predicted to occur.

(15) Information from the Shenzhen Port Tonggu Channel Developing Office indicates that maintenance dredging of the Tonggu Waterway may take place annually. Updated information to determine if there is any overlap with the construction for this Project is not available and this will be reviewed at a later stage

9.10 *ENVIRONMENTAL MONITORING & AUDIT*

As no unacceptable impacts have been predicted to occur during the construction and operation of this Project, monitoring of fisheries resources during these project phases is not considered necessary.

Monitoring activities designed to detect and mitigate any unacceptable impacts to water quality during construction phase are also expected to serve to protect against unacceptable impacts to fisheries. The details of the water quality monitoring programme are presented in the *EM&A Manual* attached to this EIA.

To confirm that the seabed affected by the pipeline works has restored to its original configuration, a geophysical survey will be conducted following completion of pipeline works.

9.11 *SUMMARY & CONCLUSIONS*

A literature review of baseline information on commercial fisheries resources and fishing operations surrounding the waters of the proposed Project has been undertaken. Results from the review indicate that fisheries production values in the vicinity of the Project Area are low when compared to other waters of Hong Kong. Sensitive receivers including spawning grounds, artificial reefs and oyster production area have been identified; however, the assessment of water quality impacts demonstrated that these areas will not be affected.

During construction of the Project, direct impacts arising from the proposed marine works include permanent loss of approximately 0.5 ha of fishing ground due to the GRS reclamation and temporary disturbance to approximately 16.5 ha of seabed during marine construction works. Given the small size of the fishing ground and temporal nature of the disturbance, no significant direct impacts are expected to occur. Potential impacts of elevated levels of underwater sound as a result of construction activities are not expected to be unacceptable. Indirect impacts to fisheries resources related to perturbations to key water quality parameters are also expected to be insignificant as the predicted changes in water quality are short term and localised to immediate vicinity of the works area. Marine construction works have been designed to reduce potential impacts on the water quality which will, in turn, reduce impacts on fisheries resources. No fisheries-specific mitigation measures are required during construction.

Unacceptable operational phase impacts to fisheries resources and fishing operations are not expected to occur. The permanent loss of 0.5 ha of fishing ground is not considered to be significant as the area is of small size and low fisheries importance. Secondary impacts to fisheries as a result of the physical presence of the reclamation are not expected to occur. Potential obstruction to fishing activities due to pipeline armour rock placement is not anticipated as it will be installed below or flush with the existing seabed. The seabed temporarily affected by the pipeline works is, therefore, expected to be restored to its original configuration. No additional fisheries-specific mitigation measures are required during operation.

All of the potential construction and operational fisheries impacts identified are deemed acceptable.

Section 10

Landscape and Visual Impact Assessment

CONTENTS

10 LANDSCAPE AND VISUAL IMPACT ASSESSMENT

10.1 INTRODUCTION

This *Section* presents the Landscape and Visual Impact Assessment (LVIA) for the proposed Gas Receiving Stations (GRSs) at the existing Black Point Power Station (BPPS).

In accordance with the *EIAO Guidance Note No. 8/2002*, the main components of the LVIA are as follows:

- Description of the Project;
- Review of the planning and development control framework;
- Broad Brush tree survey results;
- Baseline study of landscape character, landscape resources and also visual resources such as key views and the visual character and amenity of the Study Area;
- Landscape impact assessment during construction and operation of the Project;
- Visual impact assessment during construction and operation of the Project;
- Recommendations for landscape and visual mitigation measures for both the construction and operation phases; and
- Assessment of the residual impacts and conclusion on the acceptability of the Project.

10.2 LEGISLATION REQUIREMENTS AND EVALUATION CRITERIA

The LVIA was undertaken in accordance with the guidelines and requirements stipulated in *Annexes 10* and *18* of the *EIAO-TM* under the *EIAO* (Cap.499, S16), entitled "Criteria for Evaluating Visual and Landscape Impact" and "Guidelines for Landscape and Visual Impact Assessment", respectively and the *EIAO Guidance Note No. 8/2002 "Preparation of Landscape and Visual Impact Assessment Under the Environmental Impact Assessment Ordinance*." The study is also in accordance with the requirements of Study Brief No. *ESB – 151/2006*. The landscape assessment considers the potential impacts of the Project on the existing landscape and particularly on the landscape resources within 500m of the Project Site.

The visual assessment analyses the potential visual impacts of the proposed GRS on the existing views and the visual amenity, particularly from the Visually Sensitive Receivers (VSR) within visual envelope. In order to illustrate the visual impacts of the development, photomontages have been prepared from selected view points, which compare the existing conditions with the view after commissioning of the proposed GRS. The residual impacts are evaluated qualitatively, in accordance with the requirements of *Annex 10* of the *EIAO-TM*.

10.3 PLANNING

There are currently no Outline Zoning Plans (OZP's) covering the proposed Black Point site. Therefore, the LVIA will be assessed against the baseline conditions of the area.

10.4 TREE SURVEY

One mature *Casuarina equisetifolia* is in conflict with the proposed GRSs and will require removal. A Tree Felling Application will be prepared in accordance with the relevant technical circular during the detailed design stage and the loss of this tree will be compensated accordingly. The location of this tree and the possible location for compensatory planting are shown in *Figure 10.3.*

10.5 LANDSCAPE IMPACT ASSESSMENT

10.5.1 Methodology

In accordance with *Annex 18* of the *EIAO-TM*, the landscape impact assessment has covered the following:

- Description of the baseline landscape within 500m of the Project Site and the works area of the enabling works along the access routes;
- Description of the Landscape Character Areas (LCAs) and Landscape Resources (LRs);
- Mapping the distribution of the LCAs and LRs;
- Proposed a qualitative and quantitative assessment of significant thresholds which reflect the magnitude of change and sensitivity to change of a particular LCAs and LRs;
- Analysed the landscape impacts during construction, impact after development, and off-site landscape impacts. This section analyses the extent to which these landscape units and edges are changed, using both quantitative and qualitative assessments;

- Examined landscape mitigation measures that will contribute to reducing any landscape impacts or will enhance the landscape associated with the land based impacted areas of the GRS. This may include planting, new landscaped areas and re-vegetation. The residual landscape impacts are also analysed, and;

- Provides conclusions on the impacts of the Project.

10.5.2 *Baseline Landscape Conditions*

As specified by the EIA Study Brief, the Landscape Impact Assessment covers the area within 500m of the proposed works (see *Figure 10.1* and *10.3*). The landscape baseline study examines the potential impacts on the Project Site and surrounding areas in terms of both the LCAs and the LRs.

The LCAs and LRs of the Study Area have been categorised according to the presence of common elements. These include factors such as:

- Topography;

- Vegetation type (both species and age);

- Built forms;

- Evidence on human modifications;

- Land use (past and present); and

- Edges.

10.5.3 *General Landscape Description*

The GRSs are to be located at the Black Point Power Station. This site is a large heavily developed industrial site. To the south of the site are steeply sloping hill sides containing patchy vegetation, open rock areas and stabilised slopes. To the north of the site is open seascape.

10.5.4 *Landscape Sensitivity*

An understanding of the sensitivity to change of the LCAs and LRs is important when analysing the overall landscape impact of the Project.

Factors affecting the sensitivity of change for evaluation of landscape are:

- Quality of LCAs and LRs;

- Importance and rarity of special landscape elements;

- Ability of the landscape to accommodate change;

- Significance of the change in the local and regional context; and
- Maturity of the landscape.

The degree of sensitivity of the LCAs and LRs is classified as follows:

i) High – eg important components or landscape of particularly distinctive character susceptible to small changes;

ii) Medium – eg a landscape of moderately valued characteristics reasonably tolerant to change, and;

iii) Low – eg a relatively unimportant landscape which is able to accommodate extensive change.

The following section describes each of the LCAs and LRs within the Study Area (ie 500m from the Project boundary).

10.5.5 Landscape Character Areas

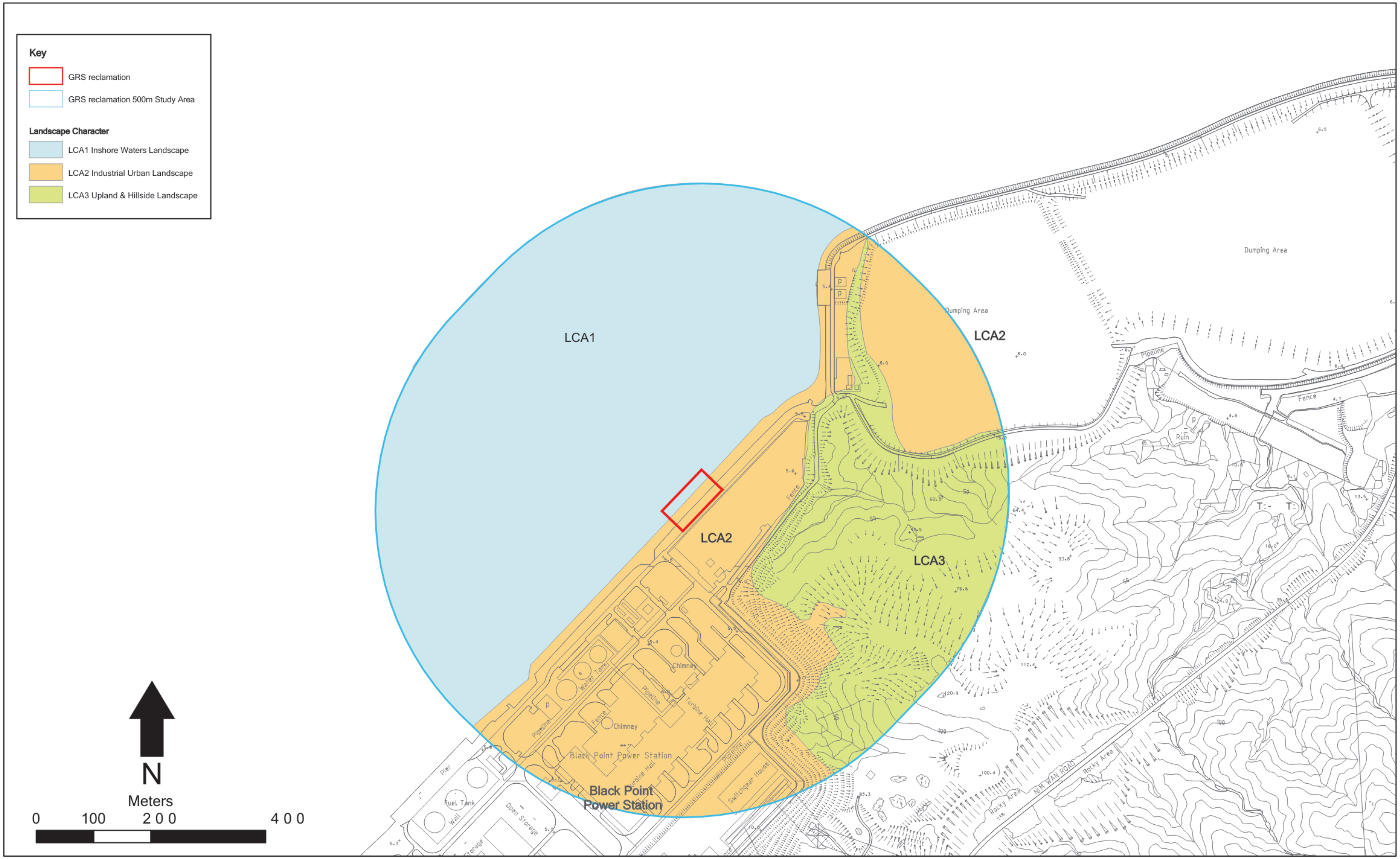
Three LCAs have been identified and are mapped on *Figure 10.1.*

LCA 1 – Inshore Waters Landscape

The *Appendix Descriptions on Landscape Character Types on The Planning Department of Hong Kong's* website describes Inshore Waters Landscape as:

These are areas of coastal water lying close to the shore and enclosed to a certain degree by landmasses or islands, which create a limited sense of enclosure or containment. Whilst these landscapes are characterized predominantly by the horizontality and muted hues of their coastal waters, they may also include small, isolated islands or outlying rocks and marine activities of all kinds, including fish farms, anchorages, commercial shipping lanes, ferry traffic and waterborne recreational activity. The result is a largely open, tranquil and natural landscape which is punctuated by the colours and noises of human features and activities. Examples of this type of landscape are outer Victoria Harbour and Port Shelter in Sai Kung.

Figure 10.2 shows that this LCA is dominated by the presence of the BPPS at its southern edge. There are also relatively few transient vessels in the area, with the exception of some small fishing vessels. This LCA is considered to have *medium* sensitivity.



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Baseline Landscape Character Area

Landscape Architecture & Urban Design

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Fig 10.1

LCA1   Inshore Waters Landscape

LCA2 Industrial Urban Landscape

LCA3   Upland and Hillside Landscape

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at Black Point Power Station
Photographs of
Landscape Character Areas

Fig 10.2

Landscape Architecture
& Urban Design

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979 Kings Road
Taikoo Place
Island East, Hong Kong

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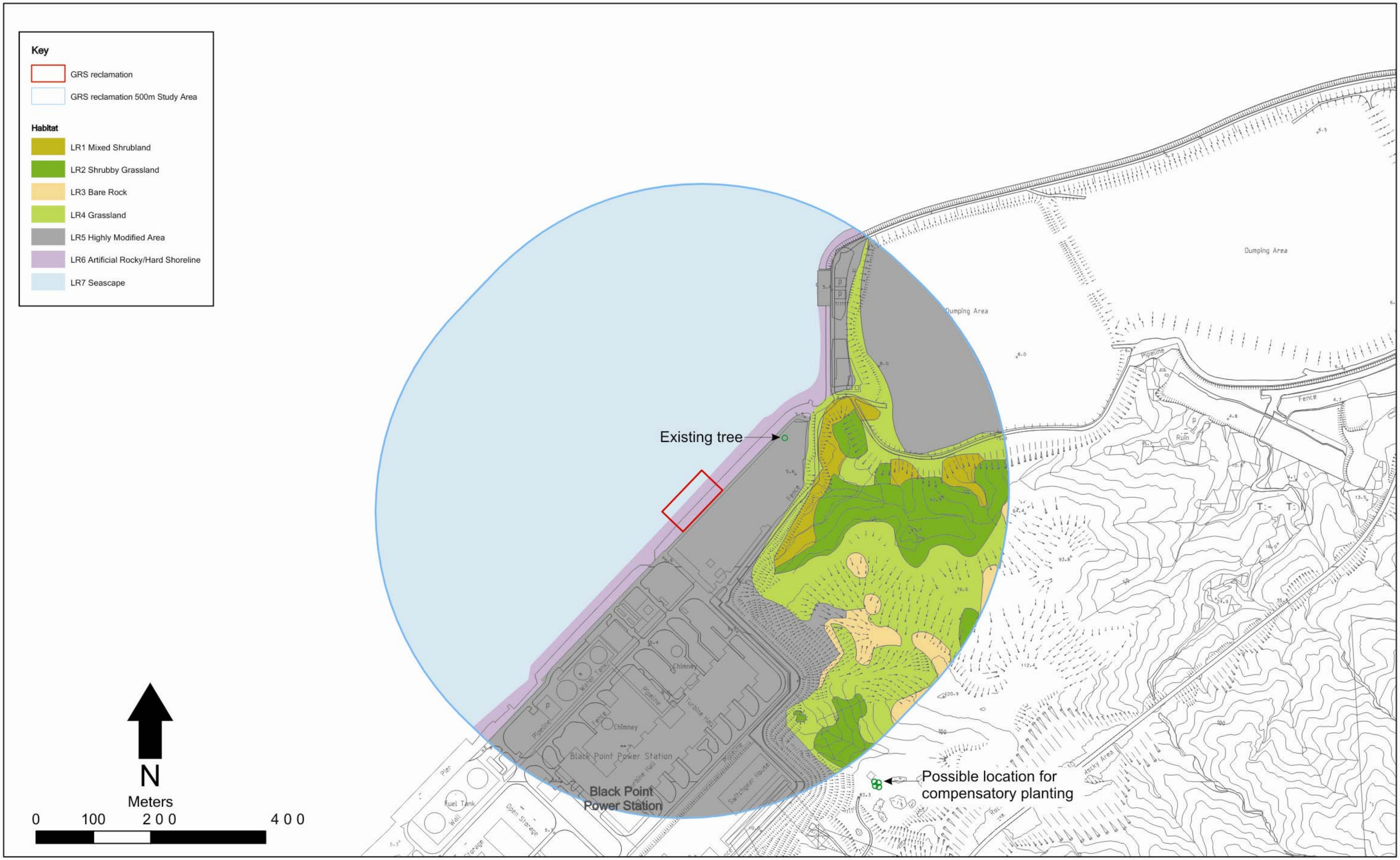

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Baseline Landscape Resources

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979 Kings Road
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Fig 10.3

LCA 2 – Industrial Urban Landscape

The *Appendix Descriptions on Landscape Character Types on The Planning Department of Hong Kong's* website describes Industrial Urban Landscape as:

Generally found on low-lying areas of reclaimed land and often along the coasts of urban areas, these are landscapes defined by their almost exclusively industrial land uses. They typically include areas of industrial buildings, often in very dense arrangements. Any occasional open areas are used for vehicle parking or open storage. Streets are mainly residual spaces, with little or no vegetation. On the peripheries, there may be areas of vacant land. These landscapes also include industrial estates: extensive areas of comprehensively developed low-rise buildings with wider roads, which are often tree lined, usually found at the edges of new towns, such as Yuen Long or Tai Po. Their unifying characteristics are their large utilitarian buildings, their limited coherence of spaces, features and materials, and absence of significant vegetation cover. Examples of this type of landscape include the container handling areas at Kwai Chung Container Terminal as well as the area of factory buildings at Wong Chuk Hang in Aberdeen.

Figure 10.2 shows this LCA is a highly modified landscape dominated by the existing BPPS. This LCA is considered to have a *low* sensitivity.

LCA 3 - Upland and Hillside Landscape

The *Appendix Descriptions on Landscape Character Types on The Planning Department of Hong Kong's* website describes Upland and Hillside Landscape as:

These are large scale upland landscapes lying between around 40mPD and 300mPD. Consisting of hillsides, knolls, ridges and spurs, they are generally covered in scrub vegetation with rocky outcrops or boulder fields. Woodland may be found on lower slopes or in sheltered gullies and ravines, where permanent of seasonal rocky streams tumble down these hillsides. Because of their elevated locations, they often contain few human features (other than footpaths or powerlines) and may retain a rugged, tranquil character, with rocky outcrops or boulder fields and muted natural colours. Examples of this type of landscape can be found across Hong Kong, such as on the lower slopes of the ridge of hills behind Kowloon.

Figure 10.2 shows this LCA is generally natural in appearance with patches of woodlands, plantation, grassland, and rocky slopes. This LCA is considered to have a *medium* sensitivity.

10.5.6 *Landscape Resources*

Seven LRs have been identified and are mapped in *Figure 10.3.*

LR 1 Mixed Shrubland

Mixed Shrubland is comprised of a mix of trees and shrubs common to Hong Kong. *Figure 10.4* shows this LR includes native species such as *Macaranga tanarius* and plantation species such as *Acacia* spp., *Melia azedarach* and *Casuarina* spp. The trees are generally of medium maturity and generally this LR is of medium quality. The sensitivity of this LR is considered to be *medium*.

LR 2 Shrubby Grassland

Figure 10.4 shows this landscape appears to be immature and the result of regeneration following past clearing. This LR is relatively abundant within the study area, and of low importance and rarity. Shrubby Grassland is considered to have a *low* sensitivity to change.

LR 3 Bare Rock Slopes

Figure 10.4 shows this LR consists of natural exposed rocky out crops and slope areas. This LR is relatively un-common within the study area, and is of high maturity. This LR is considered to have a *medium* sensitivity.

LR 4 Grassland

Figure 10.4 shows this LR consists mostly of low growing grass species. This LR relatively immature and is abundant within the study area. This LR is considered to have a *low* sensitivity.

LR 5 Highly Modified Area

Figure 10.4 shows this area consists of infrastructure associated with power generation including engineering structures, hardstand areas and access roads. This LR is common in the Study Area due to the large size of the BPPS and has low regional significance. It has a high ability accommodate change. The sensitivity of this LR is *low.*

LR 6 Artificial Rocky/Hard Shoreline

The artificial rocky/hard shoreline is comprised of a revetment structure along the edge of the BPPS that provides sea defence to the Power Station. *Figure 10.4* shows the revetment structure provides an artificial sea edge. This LR is of low quality, low rarity, significance and maturity. It therefore has a *low* sensitivity.


LR1 Mixed Shrubland


Lr2 Shrubby Grassland


LR3 Bare Rock Slopes


LR4 Grassland


LR5 Highly Modified Area


LR 6 Artificial Rocky/Hard Shoreline


LR7 Seascape

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Fig 10.4

LR 7 Seascape

Figure 10.4 shows this LR is generally of medium quality, ie the area has no significant characteristics such as colour, rock formations etc. It is also abundant, therefore is low in importance and rarity. Whilst this LR is considered to be of importance in Hong Kong, it is abundant, of high maturity and of medium quality in the Study Area. This LR is therefore considered to have a *medium* sensitivity.

10.5.7 *Distribution of LCAs and LRs*

The distribution of the existing LCAs and LRs is shown in *Table 10.1*

Table 10.1 Existing Landscape Character Areas (LCAs) and Landscape Resources (LRs)

ID	LCA/LR	Area (hectare) Within Study Area
LCA 1	Inshore Waters Landscape	65.1
LCA 2	Industrial Urban Landscape	38.7
LCA 3	Upland & Hillsides Landscape	21.3
LR 1	Mixed Shrubland	1.7
LR 2	Shrubby Grassland	5.9
LR 3	Bare Rock Slopes	1.8
LR 4	Grassland	11.9
LR 5	Highly Modified Area	35.1
LR 6	Artificial Rocky/Hard Shoreline	3.6
LR 7	Seascape	65.1

10.5.8 *Landscape Impacts During Construction*

The two key factors that affect the evaluation of LCA and LR impacts are the magnitude of change and the sensitivity of the landscape areas/resources. The sensitivity to change for each of the LCAs and LRs has been described above and the factors affecting the magnitude of change are outlined below.

Factors affecting the magnitude of change for assessing landscape impacts are:

- Compatibility of the proposed GRSs with the surrounding landscape, ie how well it will fit with its surroundings;
- Scale of the development, ie how big is the development relative to its surroundings; and,
- Reversibility of change, ie how easily changes to the landscape can be reversed.

The magnitude of change is classified as follows:

- Large – notable change in the landscape characteristics over an extensive area ranging to very intensive change over a more limited area;

- Intermediate – moderate changes to a local area;
- Small – small changes to specific landscape components; and
- Negligible – no changes to the baseline condition.

The landscape impact is a product of the magnitude of change the GRSs will have and the sensitivity of the LCA/LR. *Table 10.2* shows the significance threshold of the LCA/LR impacts.

Table 10.2 *Significance Threshold of Potential Landscape Resource Impact*

		Sensitivity to Change		
		Low	**Medium**	**High**
Magnitude of Change Caused by Project	**Large**	Moderate Impact	Moderate/Significant Impact	Significant Impact
	Intermediate	Slight/Moderate Impact	Moderate Impact	Moderate/ Significant Impact
	Small	Slight Impact	Slight/Moderate Impact	Moderate Impact
	Negligible	Negligible Impact	Negligible Impact	Negligible Impact

Table 10.3 provides some definitions of the significance thresholds for LCA and LR impacts.

Table 10.3 *Adverse / Beneficial Impact of Landscape Impact*

Level of Impacts (Negative / Beneficial/ Neither)			
Significant:	**Moderate:**	**Slight:**	**Negligible**
Adverse / beneficial impact where the Project would cause significant degradation or improvement in existing landscape baseline conditions	Adverse / beneficial impact where the Project would cause noticeable degradation or improvement in existing landscape baseline conditions	Adverse / beneficial impact where the Project would cause a barely noticeable degradation or improvement in existing landscape conditions or where the changes brought about by the Project would not be apparent in visual terms	The Project does not affect the existing landscape baseline conditions

10.5.9 *Unmitigated Landscape Impacts During Construction*

Table 10.4 shows the impact of the Project on each of the LRs and LCAs and the overall impact based on the preceding Landscape Impact Assessment Matrix.

Table 10.4 Unmitigated Landscape Impact Significance Threshold Matrix

ID	LR/LCA	Area (ha)	Area Affected by Proposed Development (Ha)	% of Area / Length Affected	Sensitivity to Change	Magnitude of Change	Significance Threshold of Landscape Impact
LCA 1	Inshore Waters Landscape	65.1	0.6	0.9%	Medium	Intermediate	Moderate
LCA 2	Industrial Urban Landscape	38.7	0.32	0.8%	Low	Small	Slight
LCA 3	Upland & Hillside Landscape	21.3	Nil	Nil	Medium	Negligible	Negligible
LR 1	Mixed Shrubland	1.7	Nil	Nil	Medium	Negligible	Negligible
LR 2	Shrubby Grassland	5.9	Nil	Nil	Low	Negligible	Negligible
LR 3	Bare Rock Slopes	1.8	Nil	Nil	Medium	Negligible	Negligible
LR 4	Grassland	11.9	Nil	Nil	Low	Negligible	Negligible
LR 5	Highly Modified Area	35.1	0.01	0.03%	Low	Small	Slight
LR 6	Artificial Rocky/Hard Shoreline	3.6	0.31	8.6%	Low	Small	Slight
LR 7	Seascape	65.1	0.6	0.9%	Medium	Intermediate	Moderate

10.5.10 *Summary of un-mitigated Landscape Impacts*

Landscape Character Areas

LCA 1 Inshore Waters Landscape

This LCA is considered to have a medium sensitivity. The GRSs will affect approximately 0.6 ha due to the reclamation area to provide a hardstand area for the GRS construction. Due to the irreversible nature of the reclamation, it is considered to cause an intermediate magnitude of change. The significance threshold is considered *moderate.*

LCA 2 Industrial Urban Landscape

This LCA is considered to have a low sensitivity due to its highly developed industrial nature. An area of 0.32 ha will be affected temporarily during construction and one tree will require removal, resulting on a small magnitude of change. The significance threshold is considered *slight.*

LCA 3 Coastal Upland and Hillside Landscape

There will be no impacts on this LR therefore the significance threshold is *negligible.*

Landscape Resources

LR1 – Mixed Shrubland

There will be no impacts on this LR therefore the significance threshold is *negligible.*

LR2 – Shrubby Grassland

There will be no impacts on this LR therefore the significance threshold is *negligible.*

LR3 – Bare Rock Slopes

There will be no impacts on this LR therefore the significance threshold is *negligible.*

LR4 – Grassland

There will be no impacts on this LR therefore the significance threshold is *negligible.*

LR5 – Highly Modified Area

This LR is considered to have a low sensitivity due to its low quality and rarity within the Study Area. An area of 0.1 ha will be affected resulting in a small magnitude of change. The significance threshold is considered *slight.*

LR6 – Artificial Rocky/Hard Shoreline

This LR has a low sensitivity due to its low landscape quality and its high ability to accommodate change. Approximately 0.31 of this LR will be affected resulting in a small magnitude of change. The significance threshold is considered *slight.*

LR7 – Seascape

This LR is considered to have a medium sensitivity due to its high maturity and abundance. Approximately 0.6 ha of this LR will be affected resulting in an intermediate magnitude of change. The significance threshold is considered *moderate.*

10.5.11 Landscape Mitigation Measures

The new GRSs are to be located within and adjacent to the existing BPPS, and therefore have a high compatibility. There are also strict operational and health and safety requirements within the BPPS. The following Landscape Mitigation Measures are proposed to reduce impacts further and integrate the new GRSs.

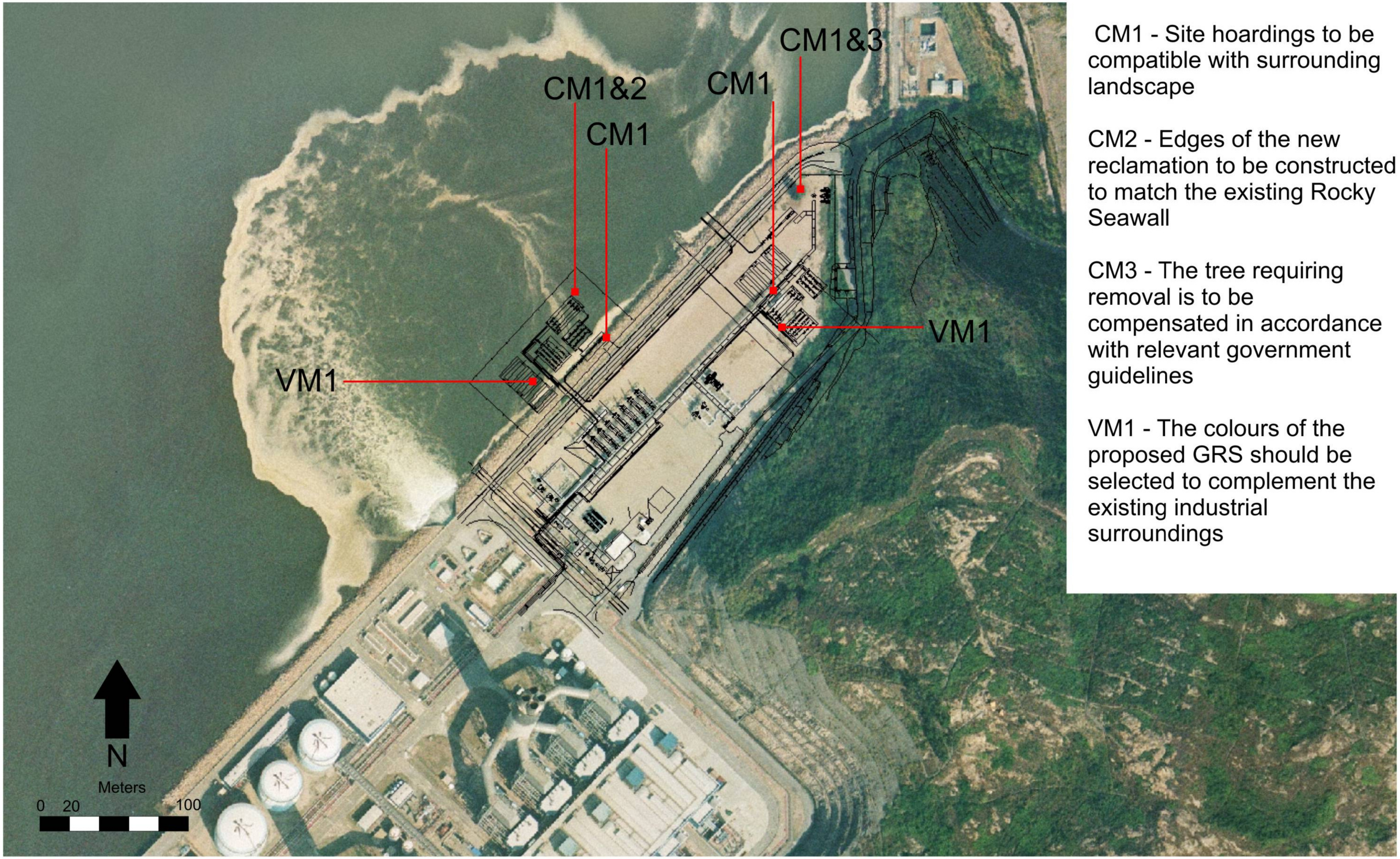
Table 10.5 Landscape Mitigation Measures

ID No.	Landscape Mitigation Measure	Funding Agency	Implementation Agency
CM1	Site hoardings to be compatible with surrounding landscape	Project Proponent	Contractor employed by the Project Proponent
CM2	Edges of the new reclamation to be constructed to match the existing Rocky Seawall	Project Proponent	Contractor employed by the Project Proponent
CM3	The tree requiring removal is to be compensated in accordance with relevant government guidelines	Project Proponent	Contractor employed by the Project Proponent

The landscape mitigation measures are located in plan in *Figure 10.5.*

Table 10.6 Mitigated and Un-mitigated Construction Impacts

	Un-mitigated Construction impacts		Recommended Construction Mitigation Measures	Mitigated Construction Impacts	
	Construction Impact threshold	**Adverse/ Beneficial/Neither**		**Construction Impact threshold following mitigation**	**Adverse/ Beneficial/Neither**
LCA 1 Inshore Waters Landscape	Moderate	Adverse	CM1 & 2	Slight	Adverse
LCA 2 Industrial Urban Landscape	Slight	Neither	CM1, 2 & 3	Negligible	Neither
LCA 3 Upland & Hillsides	Negligible	N/A	Nil	Negligible	Neither
LR 1 Mixed Shrubland	Negligible	N/A	Nil	Negligible	Neither
LR 2 Man made rocky sea-wall	Negligible	N/A	Nil	Negligible	Neither
LR 3 Bare Rock Slopes	Negligible	N/A	Nil	Negligible	Neither
LR 4 Grassland	Negligible	N/A	Nil	Negligible	Neither
LR 5 Highly Modified Area	Slight	Neither	CM1 & 2	Negligible	Neither
LR 6 Artificial Rocky/Hard Shoreline	Slight	Adverse	CM1 & 2	Negligible	Neither
LR 7 Seascape	Moderate	Adverse	CM1 & 2	Slight	Adverse



CM1 - Site hoardings to be compatible with surrounding landscape

CM2 - Edges of the new reclamation to be constructed to match the existing Rocky Seawall

CM3 - The tree requiring removal is to be compensated in accordance with relevant government guidelines

VM1 - The colours of the proposed GRS should be selected to complement the existing industrial surroundings

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Fig 10.5

Table 10.7 Mitigated and Un-mitigated Operation Impacts

	Un-Mitigated Impacts			Mitigated Impacts		
	Operation	**Adverse/ Beneficial/Neither**	**Recommended Mitigation**	**Operation Day 1**	**Operation Year 10**	**Adverse/ Beneficial/Neither**
LCA 1 Inshore Waters Landscape	Slight	Adverse	Nil	Slight	Slight	Adverse
LCA 2 Industrial Urban Landscape	Negligible	Neither	Nil	Negligible	Negligible	Neither
LCA 3 Upland & Hillsides	Negligible	Neither	Nil	Negligible	Negligible	Neither
LR 1 Mixed Shrubland	Negligible	Neither	Nil	Negligible	Negligible	Neither
LR 2 Man made rocky sea-wall	Negligible	Neither	Nil	Negligible	Negligible	Neither
LR 3 Bare Rock Slopes	Negligible	Neither	Nil	Negligible	Negligible	Neither
LR 4 Grassland	Negligible	Neither	Nil	Negligible	Negligible	Neither
LR 5 Highly Modified Area	Negligible	Neither	Nil	Negligible	Negligible	Neither
LR 6 Artificial Rocky/Hard Shoreline	Negligible	Neither	Nil	Negligible	Negligible	Neither
LR 7 Seascape	Moderate	Adverse	Nil	Slight	Slight	Adverse

10.5.12 *Effectiveness of Landscape Character Areas and Landscape Resource Mitigation Measures*

It will not be possible to completely mitigate the impacts on LCA 1 Inshore Waters Landscape and LR 7 Seascape. However, the mitigation measures proposed will effectively further reduce the impacts identified on the other LCAs and LRs. *Tables 10.6* and *10.7* show the effectiveness of the landscape mitigation measures in reducing the significance thresholds of the impacts on the LCAs and LRs.

10.5.13 *Summary of Residual Impacts on the Landscape Character Areas and Landscape Resources During Construction*

There will be *slight adverse* impacts on LCA 1 Inshore waters Landscape and LR 7 Seascape. There will be negligible residual construction impacts on all others LCAs and LRs.

10.5.14 *Summary of Residual Impacts on Landscape Character Areas During Operation*

There will be *slight adverse* residual impacts on LCA 1 Inshore waters Landscape and LR 7 Seascape. There will be negligible operation impacts on all others LCAs and LRs.

10.6 *VISUAL IMPACT ASSESSMENT*

10.6.1 *Introduction*

The following tasks were undertaken for the visual impact assessment.

Define the view shed that would be potentially impacted by the Project and map the areas of visual impact - Geographical Information System (GIS) software was utilised to determine areas that could potentially see the development during construction and operation. This GIS view shed analysis was based solely on topography and did not take into account the screening potential of vegetation, which would further reduce the actual view shed. The GIS view shed analysis also mapped the visibility of the development from roads and houses.

Assess indicative view points as a means of assessing the visual impact on the broader landscape - Visually Sensitive Receiver (VSR) view points around the development, have been selected as indicative of the range of views from accessible locations within the view shed. Photomontages have been prepared to show the existing landscape and the landscape with the development at the key VSRs.

Discuss visual mitigation measures - measures (if required) that will reduce any potential visual impacts have been identified. This may include planting and recommendations for material and finishes. These measures will also help improve the overall amenity of the Project. Residual impacts are also discussed.

10.6.2 *View Shed Determination and Areas of Potential Visual Impact*

The visual impact assessment is informed by an understanding of the existing visual qualities within the region that can be visually affected by a development. This area is referred to as the view shed.

Defining an appropriate view shed is the starting point to understanding the visual impacts of a development as the area of the view shed will vary depending on the nature and scale of the proposed development. The larger a development the greater the view shed as it may be visually apparent for a greater distance. Once the view shed is established, locations can be identified within the view shed that are either particularly sensitive or indicative of the visual impact for a number of locations. In some circumstances, view points may be identified beyond the view shed to recognise the visual impact on locations of particularly high sensitivity.

The proposed GRSs are the major visual element of the proposed development and may visually impact on the surrounding VSRs. As the viewer moves further away from these structures the visual impact decreases until it is no longer visible.

10.6.3 *Baseline Visual Character*

The general baseline visual character of the Project site is dominated by the existing BPPS. The flue stacks and fuel storage tanks are the most visible elements, particularly when viewed from the seaward side. The contrasting backdrop to the south is created by the steeply sloping hillsides with patches of vegetation. Numerous overhead power lines are also visible cross-crossing the landscape. To the north, the BPPS abruptly meets the sea, and the seascape view extends across to Shekou and the urban development areas of Guangdong.

All of the above elements combine to create an overall visual envelope that is generally of low quality due to the presence of large industrial facilities.

10.6.4 *Project Description and Sources of Impact*

Section 3 of this EIA provides a detailed description of the project elements. A detailed study has been undertaken to reduce the size and scale of the reclamation to reduce any potential impacts whilst meeting the operational and safety standards required for this type of installation.

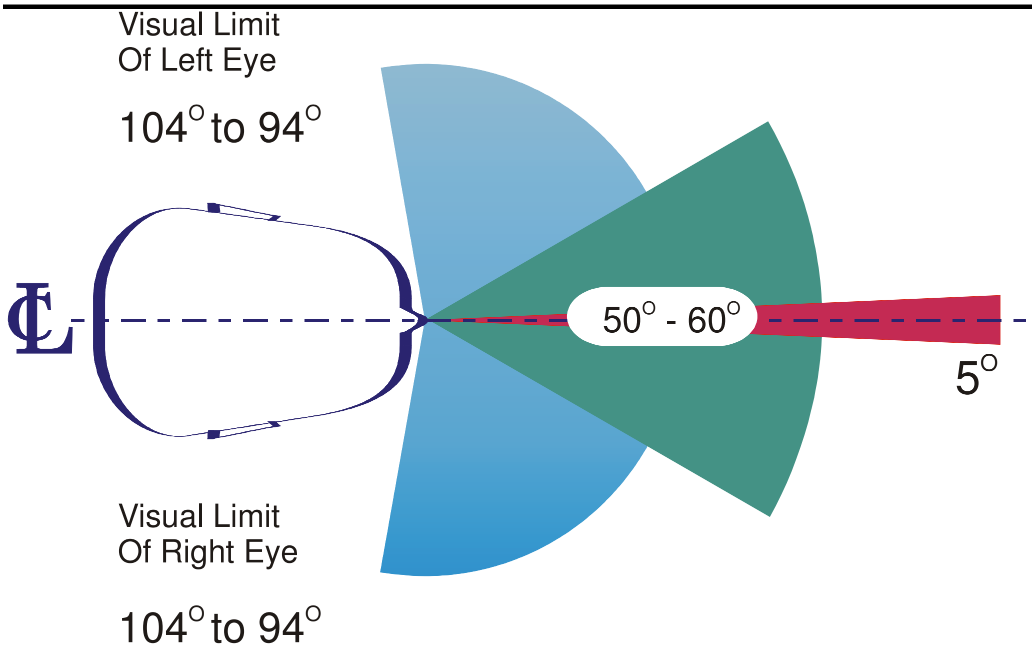
10.6.5 *Visually Sensitive Receivers*

The visual impact of a development can be quantified by reference to the degree of influence on a person's field of vision. *Figures 10.7* and *10.8* illustrate the typical parameters of human vision based on anthropometric data [(1)]. This data provides a basis for assessing and interpreting the impact of a development by comparing the extent to which the development would intrude into the central field of vision (both horizontally and vertically).

10.6.6 *Horizontal Field of View*

The central field of vision for most people covers an angle of between 50° and 60°. Within this angle, both eyes observe an object simultaneously. This creates a central field of greater magnitude than that possible by each eye separately. This central field of vision is termed the 'binocular field' and within this field images are sharp, depth perception occurs and colour discrimination is possible. These physical parameters are illustrated in *Figure 10.7* and *10.8.*

Figure 10.7 ***Horizontal Field of View***



The visual impact of a development will vary according to the proportion in which a development impacts on the central field of vision. Developments, which take up less that 5% of the central binocular field, are usually insignificant in most landscapes (5% of 50° = 2.5°).

(1) Human Dimension & Interior Space – A Source Book of Design Reference Standards, Julius Panero and Martin Zelnik, The Architectural Press Ltd. London, 1979

The GRS is comprised of a reclamation approximately 100 x 60m with a conglomeration of pipe galleries and equipment that is approximately 15m tall.

In assessing the visual impact of the GRS it is therefore assumed that the largest horizontal component is the reclamation, which based on the current preferred design is approximately 100 metres wide.

Table 10.8 Visual Impact Based on the Horizontal Field of View

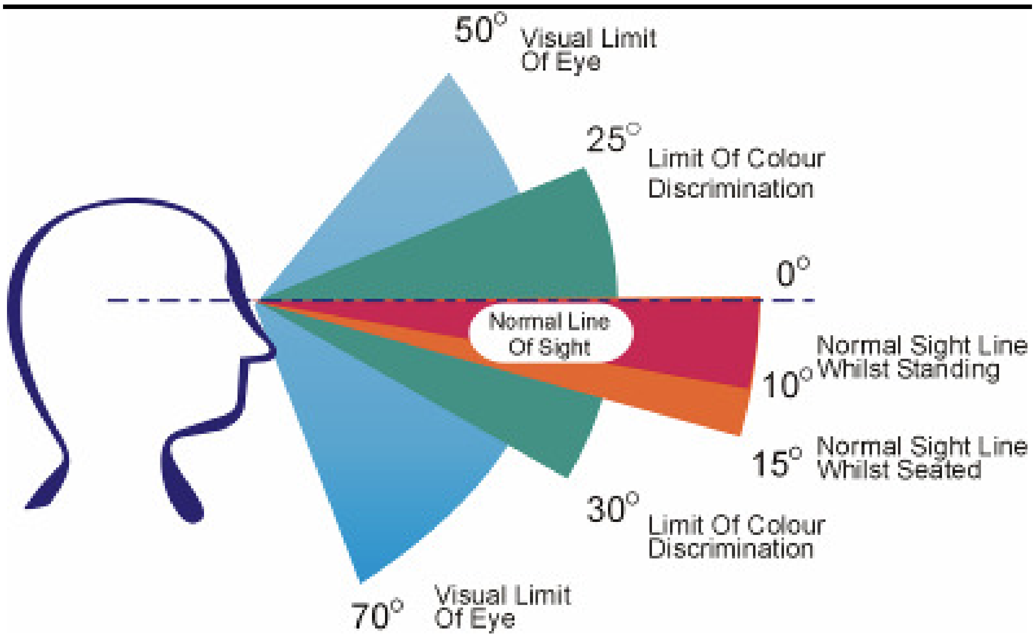
Horizontal Field of View	Impact	Distance from an Observer to a 100m wide reclamation
<2.5° of view	***Insignificant*** The development will take up less than 5% of the central field of view. The development, unless particularly conspicuous against the background, will not intrude significantly into the view. The extent of the vertical angle will also affect the visual impact.	>2.3km
2.5° – 30° of view	***Potentially noticeable*** The development may be noticeable and its degree of visual intrusion will depend greatly on its ability to blend in with its surroundings.	200m – 2.3km
>30° of view	***Potentially visually dominant*** Developments that fill more than 50% of the central field of vision will always be noticed and only sympathetic treatments will mitigate visual effects.	< 200m

As shown in *Table 10.8*, these calculations suggest that the impact of a 100 m wide reclamation would reduce to insignificance at about 2.3 km, as it would form less than 5% or 2.5° of the horizontal field of view.

10.6.7 Vertical Field of View

A similar analysis can be undertaken based upon the vertical field of view for human vision. As can be seen in the *Figure 10.8* the typical line of sight is considered horizontal or 0°. A person's natural or normal line of sight is normally a 10° cone of view below the horizontal and, if sitting, approximately 15°.

Figure 10.8 Vertical Field of View



Objects which take up 5% of this cone of view (5% of 10° = 0.5°) would only take up a small proportion of the vertical field of view, and are only visible when one focuses on them directly. Objects that take up such a small proportion of the vertical view cone are not dominant, nor do they create a significant change to the existing environment when such short objects are placed within a disturbed or man-modified landscape.

Table 10.9 shows the relationship between impact and the proportion that the development occupies within the vertical line of sight.

Table 10.9 Visual Impact Based on Vertical Field of View

Vertical Line of Sight	Impact	Distance from an Observer to a 15m Tall GRS
< 0.5° of vertical angle	***Insignificant*** A thin line in the landscape.	> 1.7 km
0.5° – 2.5° of vertical angle	***Potentially noticeable*** The degree of visual intrusion will depend on the development's ability to blend in with the surroundings.	350m – 1.7 km
> 2.5° of vertical angle	***Visually evident*** Usually visible, however the degree of visual intrusion will depend of the width of the object and its placement within the landscape.	< 350m

These calculations suggest distances at which the magnitude of visual impact of the GRS will reduce with distance. At distances greater than 1.7km, a fully visible GRS and reclamation would be an insignificant element within the landscape.

These calculations seem closer to the observed distances at which levels of impact seem to change. It is stressed that these ranges will only provide a guide for the visual impact assessment.

10.6.8 *Determining the Visual Extent of Impact*

Generally, the more conservative, or worse-case distances form the basis for the assessment of visual impacts. Therefore for this development the greater impacts would be associated with the vertical field of view. It is therefore proposed to use the vertical field of view and extend the view shed to 2.3 km.

10.6.9 *GIS Analysis*

A GIS view shed analysis has identified those areas that can potentially be visually impacted by the GRSs (*see Figure 10.6*). Such analysis is based on topography only, and shows those areas that would be screened by intervening hills, etc. It does not take into account intervening vegetation or buildings, nor does it take into account small variations in topography, such as road cuttings. Therefore it is a conservative assessment of those areas that may be visually impacted by the GRSs.

10.6.10 *Atmospheric Factors Which Will Affect Visual Impact*

Many climatic conditions result in changes to visibility. For example, sea haze will alter the visibility of the GRS. The diminution of visual clarity bought about by atmospheric conditions also increases with distance.

Sea Haze

Sea haze is a climatic condition along coastlines that can reduce visibility even on days when the weather is fine. Wind which blows across the ocean or other atmospheric conditions can cause a sea haze, limiting views to the GRSs from surrounding areas.

However, sea haze is unlikely to have much impact on the visibility of the development when viewed from close proximity, say less than 3.0km. When the same features are viewed from greater distances within the view shed the effect of sea haze will greatly reduce visibility and any potential visual impact.

Cloud Cover

Cloudy days can also reduce the visibility of the GRSs. During site inspections of similar facilities it was apparent that a backdrop of grey cloud reduced the visual impact of the facilities. Full cloud cover also reduced the apparent contrast on elements that extend above the landscape backdrop and as these elements were neither strongly shadowed nor reflective.

Figure 10.9 shows that in Hong Kong, for much of the year the percentage of cloud cover exceeds 50%.

Rainfall

The effect that rainfall has on visibility can be measured in two ways. Firstly, the event of falling rain reduces visibility as the water droplets obscure vision. This varies greatly depending on the heaviness of the precipitation, but even light rain obscures distant objects greatly. Secondly, the event of rain, particularly sustained rain periods, reduces visitor numbers. Therefore, the visual impact is reduced on those days as lesser viewers are visiting the area and looking at the development.

Figure 10.9 also shows that during the wet season, particularly from May through September, Hong Kong receives on average approximately 10mm of rain per day. These rain events can reduce visibility.

Reduced Visibility

The Hong Kong Observatory noted that in 2008 there were a total of 1951 hours of reduced visibility in Hong Kong. Reduced visibility is defined as:

Reduced visibility refers to visibility below 8 kilometres when there is no fog, mist, or precipitation.

On days when reduced visibility is being experienced in Hong Kong, the maximum view shed any development will reduce to less than 8 kilometres.

Assessment Scenarios

Whilst the above describes some of the climatic conditions that reduce the visibility of the GRSs, the following assessment is based on a worst case impact scenario on visual quality assuming perfectly clear viewing conditions. Mitigation measures are proposed to reduce these impacts.

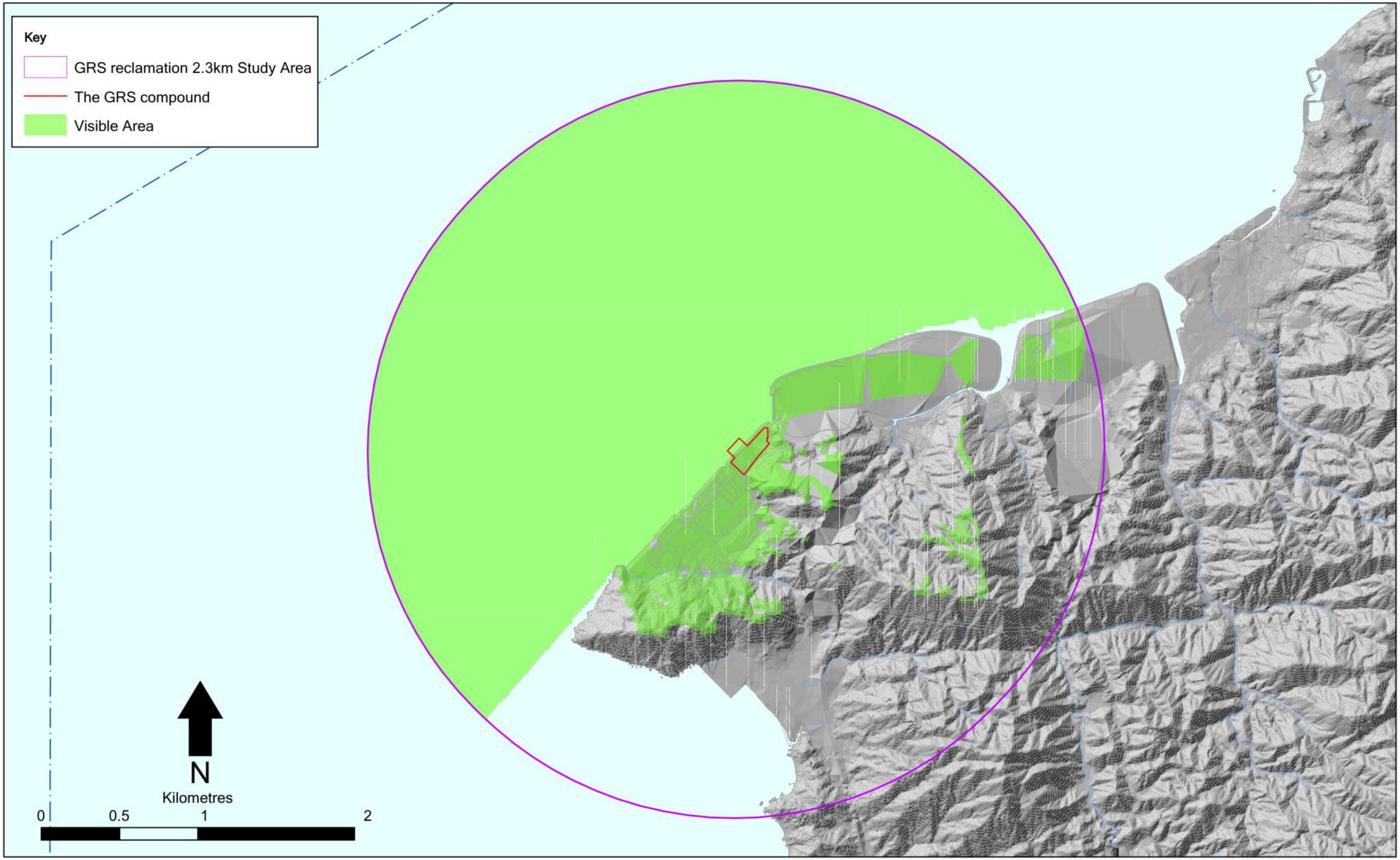
10.6.11 VSR Assessment

The following factors have been considered in the visual impact assessment.

VSR Sensitivity

The first set of criteria relate to the sensitivity of the VSRs. They include:

- Value and quality of existing views;
- Type and estimated number of receiver population;
- Duration of frequency of view; and
- Degree of visibility.



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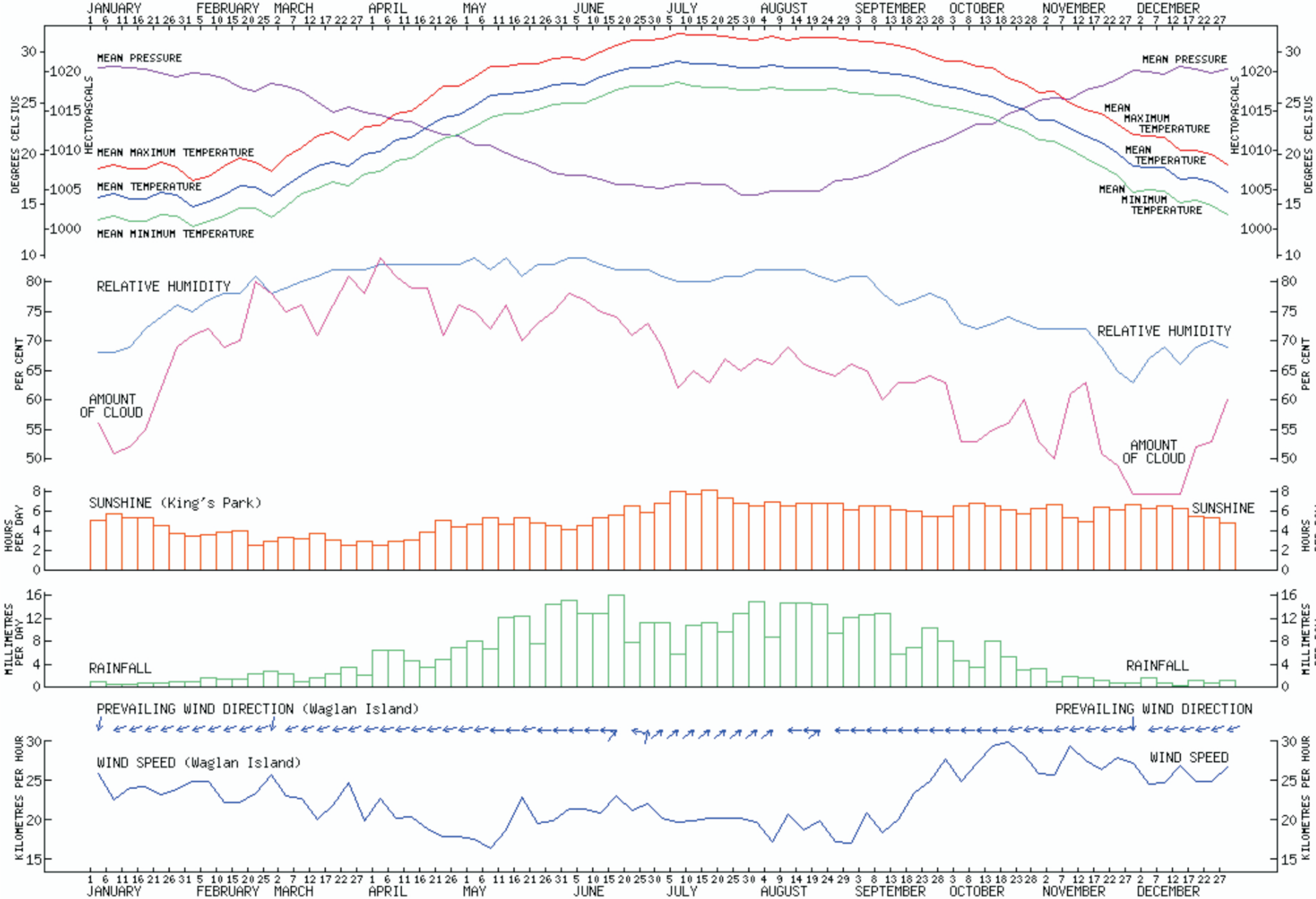
香港天文台
HONG KONG OBSERVATORY

5-DAY NORMALS OF THE METEOROLOGICAL ELEMENTS
FOR THE 30 YEARS 1961-1990 FOR HONG KONG



CAPCO Landscape Architecture & Urban Design

Proposed Gas Receiving Station at Black Point Power Station
Hong Kong Climate

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Fig 10.9

The views available to the identified VSRs were rated in accordance with their sensitivity to change using high, medium or low and are defined as follows:

- High
  - i. The nature of the viewer groups who expect a high degree of control over their immediate environment; and
  - ii. The viewer groups are in close proximity to the Proposed Development.
- Medium
  - iii. The nature of the viewer groups who have some degree of control over their immediate environment, eg people in transit.
- Low
  - iv. The nature of the viewer groups does not expect a high degree of control over their immediate environment.

It should be noted that the above only provides guidance, and each VSR regardless of type has been assessed according to its specific circumstances.

10.6.12 *Magnitude of Change*

This set of criteria is related to the specific details of the proposed development and how it relates to the existing landscape and the visible magnitude of change it will cause. The criteria to be assessed are:

- Compatibility of the Proposed Development with the surrounding landscape;
- Reversibility of change;
- Viewing distance;
- Potential blockage of view; and,
- Duration of impact under construction and operation phases.

The magnitude of change to a view was rated as large, intermediate, small or negligible and are defined as follows:

- Large: eg major change in view;
- Intermediate: eg moderate change in view;
- Small: eg minor change in view; and,

- Negligible: eg no discernible change in view.

The degree of visual impact or significance threshold was rated in a similar fashion to the landscape impact, ie significant, moderate, slight and negligible. Where the matrix table indicates a range within the significance threshold, eg; *Moderate – Significant*, the final significance threshold is assigned based on the overall severity of the impact.

The visual impact is a product of the magnitude of change to the existing baseline conditions, the landscape context and the sensitivities of VSRs. The significance threshold of visual impact was rated for the construction phase and for Day 1 and Year 10 of the operation phase.

10.6.13 *Visual Impact Assessment from Visually Sensitive Receivers (VSR)*

Figure 10.10 shows the locations of the selected VSRs from publicly accessible locations. The view points selected for photomontage preparation showing the GRSs have been selected to represent the range of views from accessible locations. Significance thresholds of residual impact (upon mitigation) are shown for Operation Day 1 and Year 10, in accordance with *EIAO Guidance Note No. 8/2002.*

During the assessment, all potential VSRs were explored. These included:

Residents at SheKou: These potential VSRs are approximately 8 km from the site and are outside the view shed, and due to the small scale of the development, the GRS will not be visible from this distance. In addition it is not common practice to assess VSRs outside of Hong Kong.

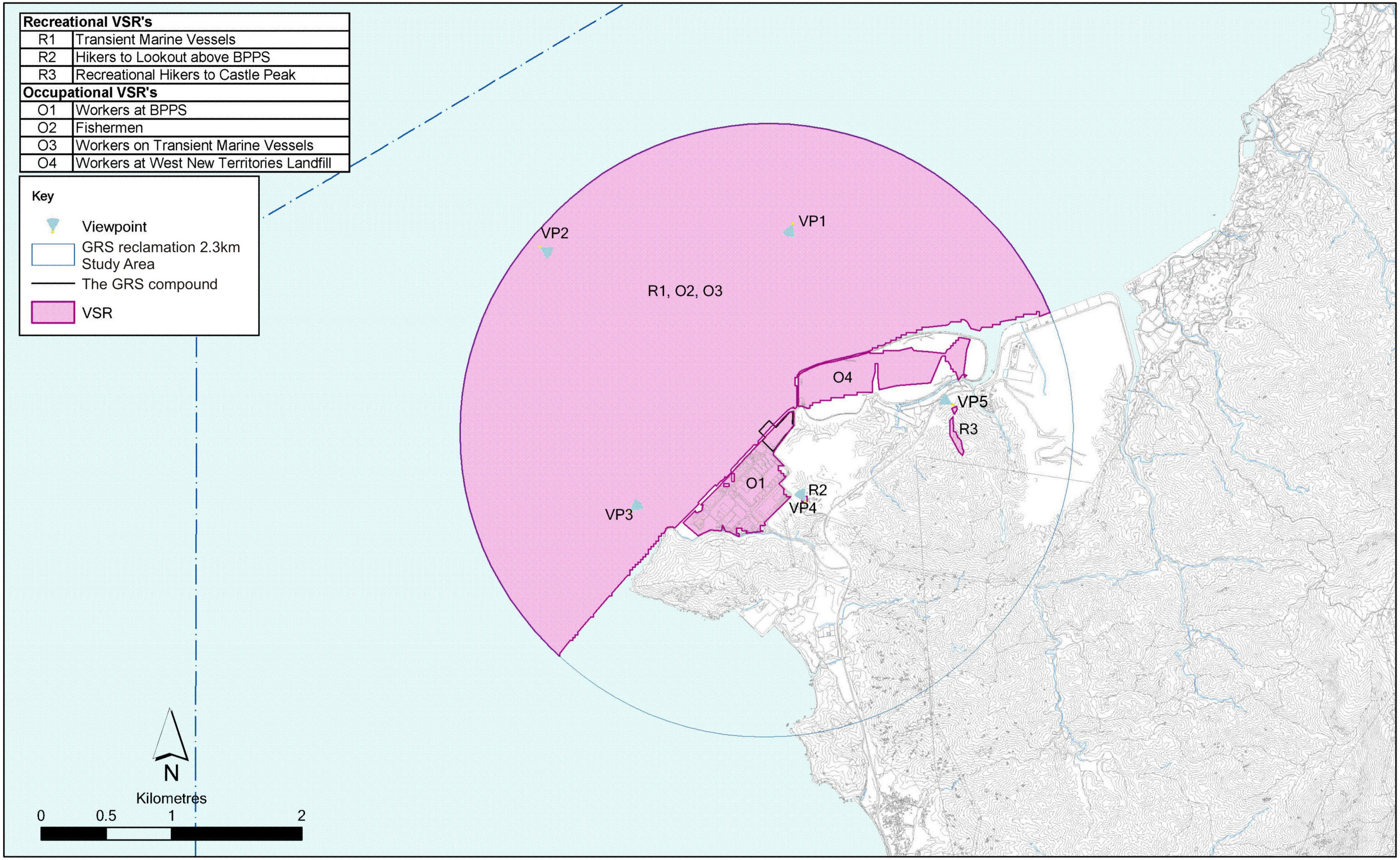
Users of Shenzhen Bay Bridge: These potential VSRs are approximately 7.5 km from the GRS and as with residents at SheKou are outside of the view shed and HK boundaries.

Residents at Pak Nai and Ha Pak Nai: A site visit to these locations showed that the proposed GRS would not be visible from these locations due to intervening topography. They are also over 3.5 km away and are outside the view shed.

Users of Nim Wan and Deep Bay Roads: Site inspections were conducted and the GRS will not be visible from any point along these roads.

Figure 10.6 shows that the GRSs will not affect any residential VSRs nor any travelling VSRs on Lung Kwu Tan road.

Figure 10.10 shows that seven VSRs have been identified as follows:



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Viewshed Analysis

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Fig 10.10

Recreational VSRs

R1 Recreational Transient Vessels

R2 Hikers to Lookout above BPPS

R3 Hikers to Castle Peak

The R1 VSRs may pass the northern seaward edge of the site in recreational marine vessels. The R2 visitors are likely to be employees or guests to the BPPS. It must be noted that access to the lookout above BPPS is restricted. R3 visitors are hikers on small trails up towards Castle Peak adjacent to the Tsang Chan Firing Range.

Table 10.10 Sensitivity / Quality

Items	Sensitivity / Quality
Value and quality of view	Low
Visitor numbers	Low
Availability and amenity of alternative views	Moderate
Duration and frequency of views to development	Low
Degree of visibility of Development	Low
Sensitivity/Quality of VSR	Low

Table 10.10 shows the value and quality of the view is considered low due to the heavily modified industrial surroundings. There are also low visitor numbers, with low duration and frequency to the development. The overall sensitivity is considered low for all recreational VSRs.

Table 10.11 Magnitude of Change

Items	Construction	Operation
Compatibility with surrounding landscape	High	High
Viewing Distance to Proposed Development	500m	500m
Potential blockage of view	Low	Low
Duration of impacts	Temporary	Permanent
Scale of development	Small	Small
Reversibility of change	Irreversible	Irreversible
Magnitude of change	Small	Small

Table 10.11 shows the compatibility of the proposed GRSs is high given it is located adjacent to the existing BPPS. The scale of the development is also small, resulting in a small magnitude of change for all recreational VSRs.

Table 10.12 Significance Threshold during Construction

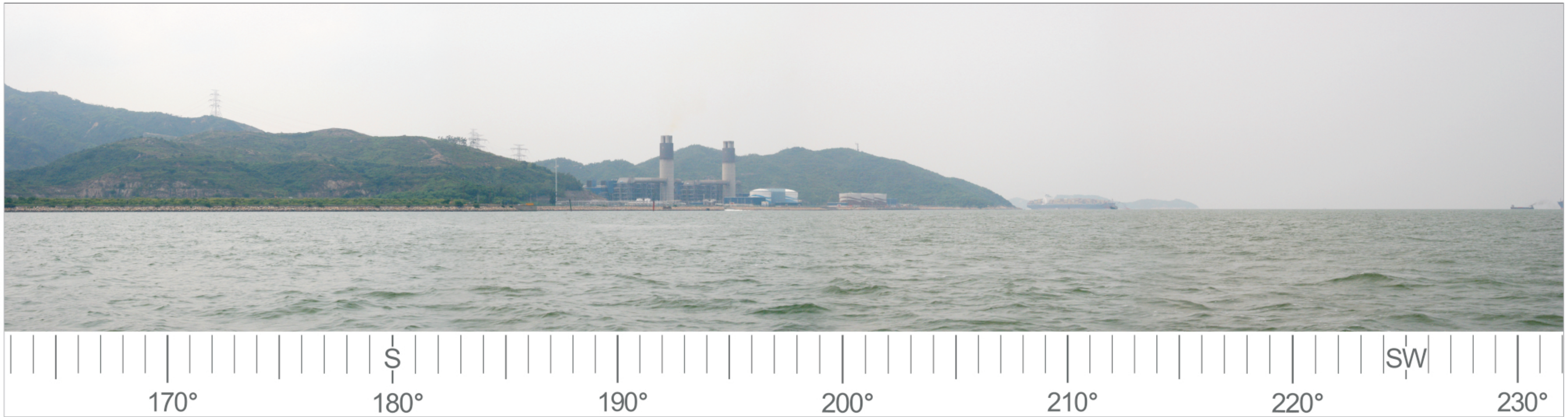
<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="3">Sensitivity / Quality</td><td rowspan="2">Beneficial</td></tr>
<tr><td>Low</td><td>Medium</td><td>High</td></tr>
<tr><td rowspan="4">Magnitude of Change</td><td>Large</td><td>Moderate Impact</td><td>Moderate - significant impact</td><td>Significant impact</td><td rowspan="2">Neither beneficial nor adverse</td></tr>
<tr><td>Intermediate</td><td>Slight – Moderate impact</td><td>Moderate Impact</td><td>Moderate-Significant impact</td></tr>
<tr><td>Small</td><td>Slight impact</td><td>Slight – Moderate impact</td><td>Moderate impact</td><td rowspan="2">Adverse</td></tr>
<tr><td>Negligible</td><td>Negligible impact</td><td>Negligible impact</td><td>Negligible impact</td></tr>
</table>

Table 10.12 shows that the low sensitivity of these VSRs along with the small magnitude of change resulting from the GRSs will result in a *slight adverse* construction impact for all recreational VSRs.

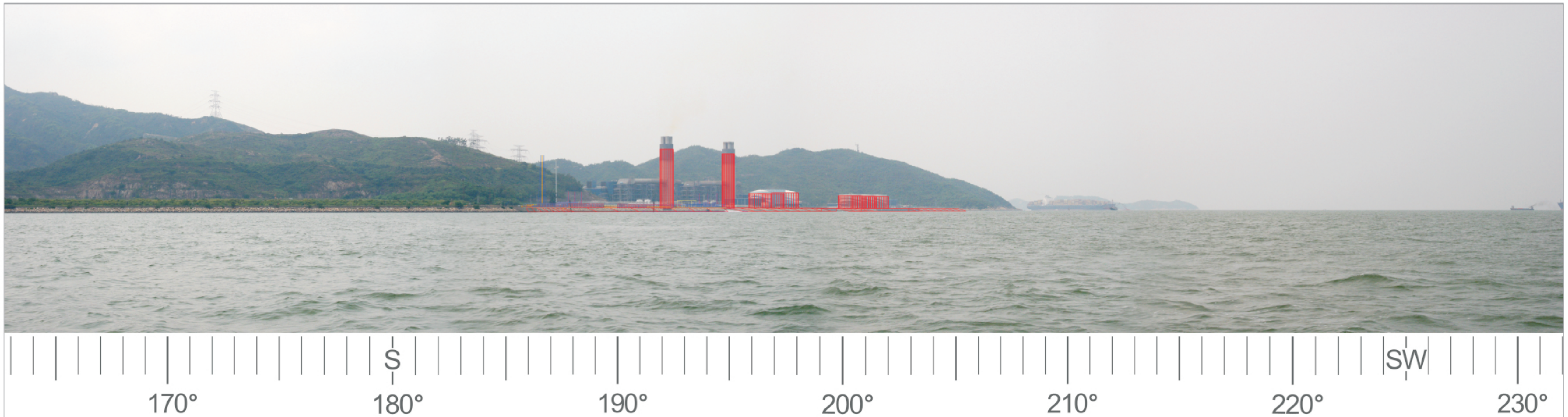
Table 10.13 Significance Threshold during Operation

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="3">Sensitivity / Quality</td><td rowspan="2">Beneficial</td></tr>
<tr><td>Low</td><td>Medium</td><td>High</td></tr>
<tr><td rowspan="4">Magnitude of Change</td><td>Large</td><td>Moderate Impact</td><td>Moderate - significant impact</td><td>Significant impact</td><td rowspan="2">Neither beneficial nor adverse</td></tr>
<tr><td>Intermediate</td><td>Slight – Moderate impact</td><td>Moderate Impact</td><td>Moderate-Significant impact</td></tr>
<tr><td>Small</td><td>Slight impact</td><td>Slight – Moderate impact</td><td>Moderate impact</td><td rowspan="2">Adverse</td></tr>
<tr><td>Negligible</td><td>Negligible impact</td><td>Negligible impact</td><td>Negligible impact</td></tr>
</table>

Figure 10.11 – 10.15 show photomontages of both development options from a range of view points. The change in the view before and after the proposed development is very small. *Table 10.13* also shows that the low sensitivity and small magnitude of change for all recreational VSRs will result in a *slight* impact during operation.



VP 1 - View of the GRS looking south - Existing condition at the Development Site.



View displaying the wire frame 3D Model of the Gas Receiving Station without Mitigation.

CAPCO

Proposed Gas Receiving Station
at Black Point Power Station
Photomontage From View Point-1

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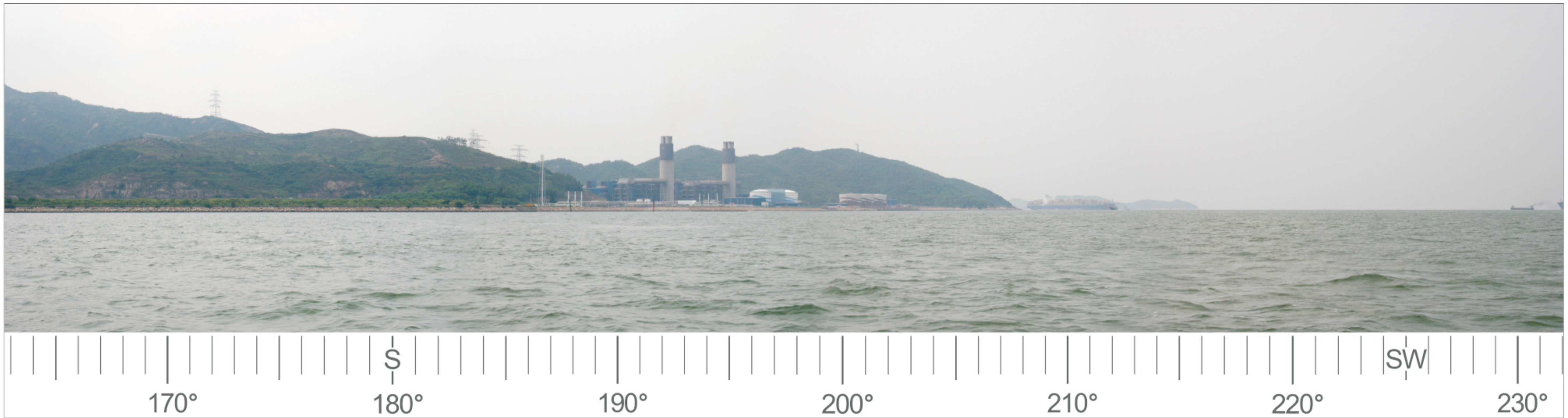
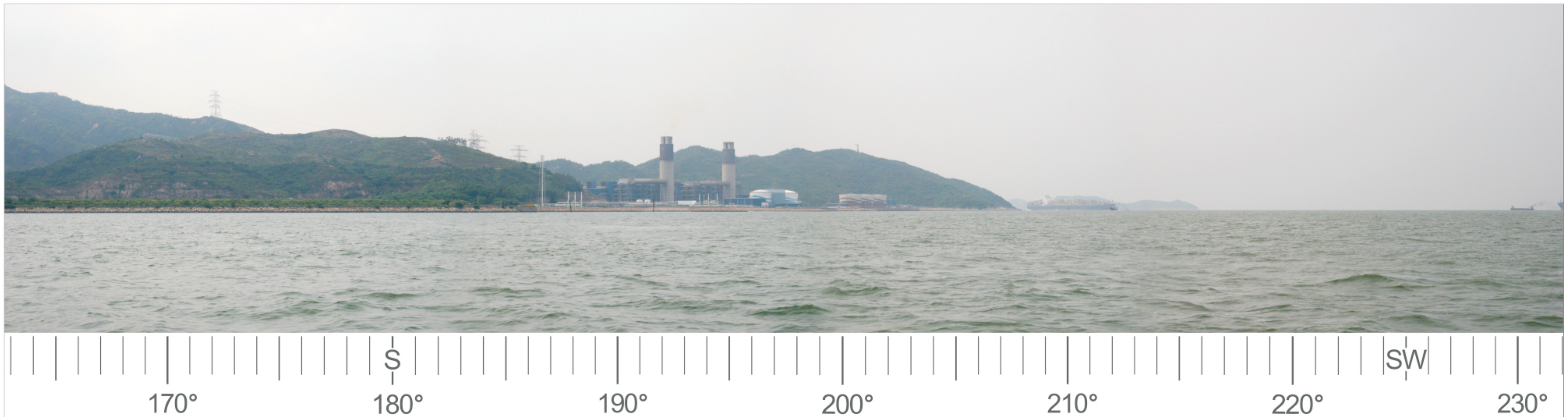
Fig 10.11



View displaying the 3D Model of the Gas Receiving Stations with Mitigation at Day 1 Operation.



View displaying the 3D Model of the Gas Receiving Stations with Mitigation at year 10 operation.

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Proposed Gas Receiving Station
at Black Point Power Station
Photomontage From View Point-1

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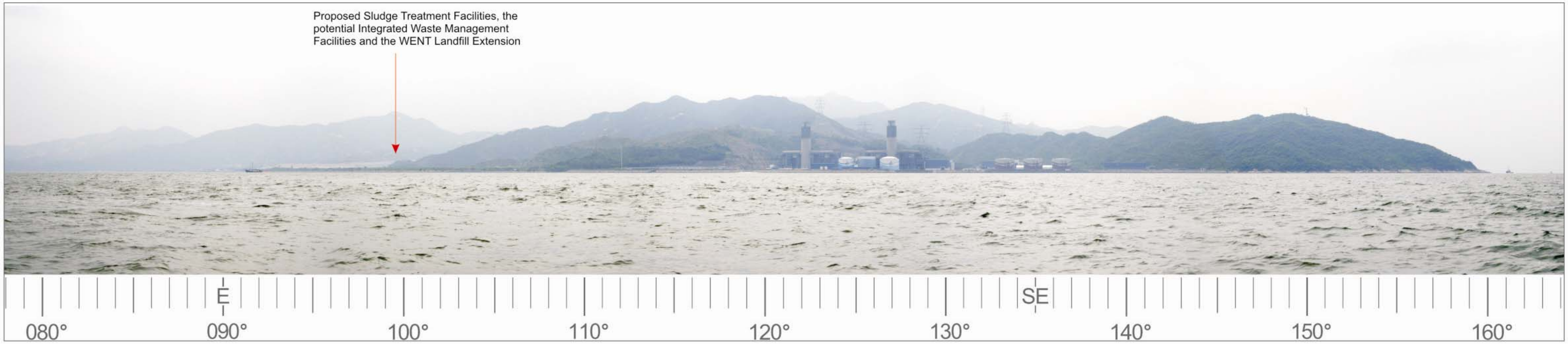
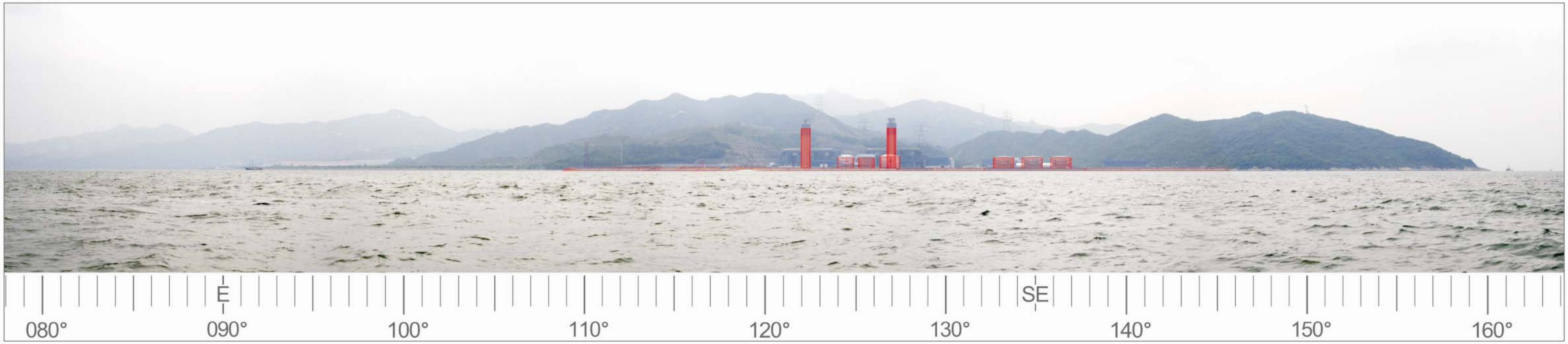
Fig 10.11



VP 2 - View of the GRS looking south west - Existing condition at the Development Site.



View displaying the wire frame 3D Model of the Gas Receiving Station without Mitigation.

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Proposed Gas Receiving Station
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Photomontage From View Point-2

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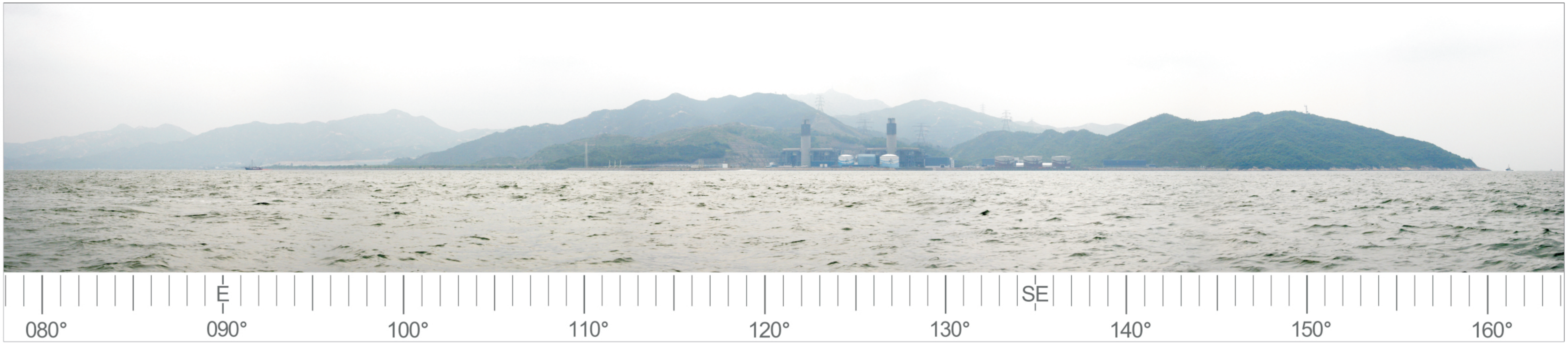
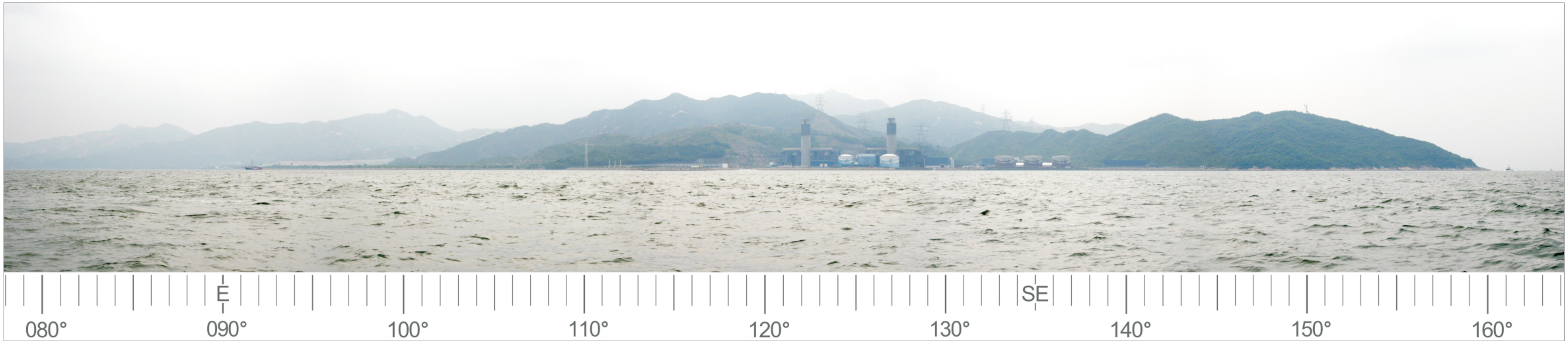
Fig 10.12



View displaying the 3D Model of the Gas Receiving Stations with Mitigation at Day 1 Operation.



View displaying the 3D Model of the Gas Receiving Stations with Mitigation at year 10 operation.

CAPCO
Proposed Gas Receiving Station
at Black Point Power Station
Photomontage From View Point-2

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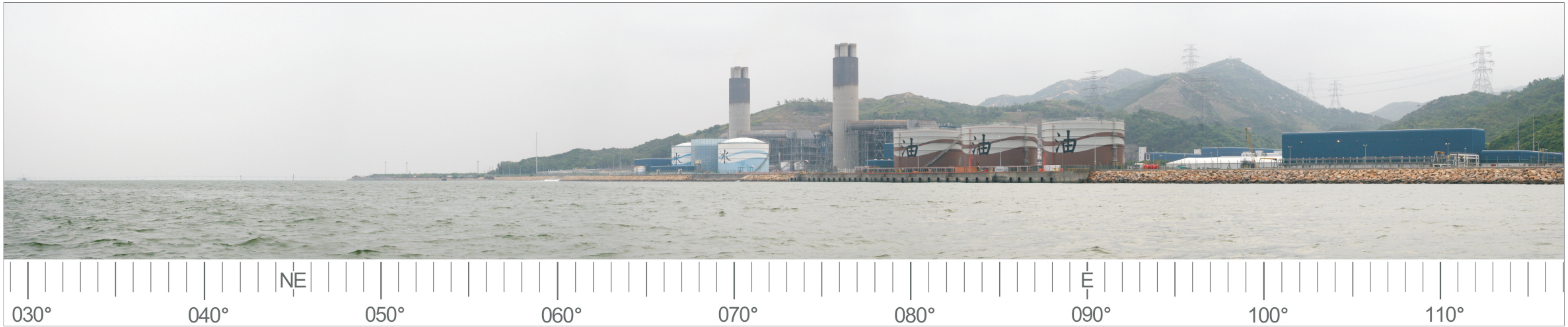
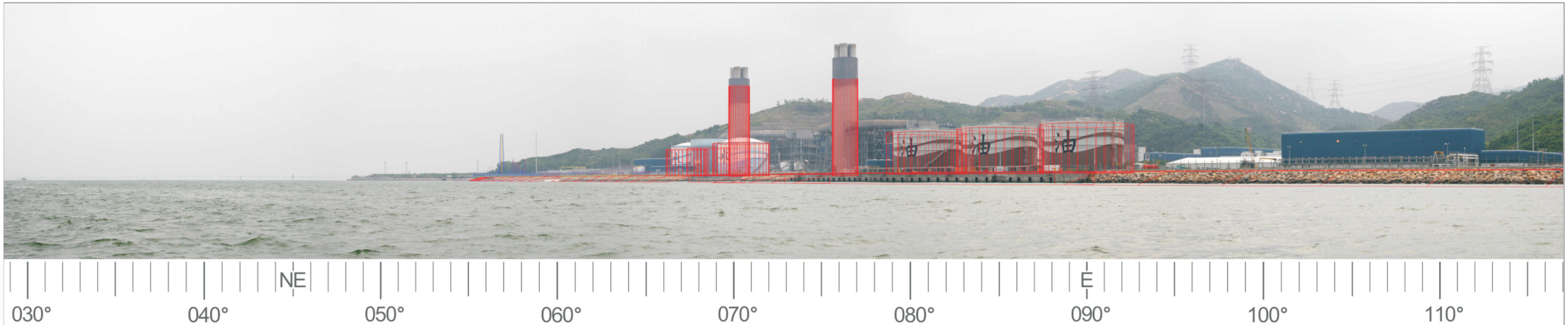
Fig 10.12



VP 3 - View of the GRS looking north east - Existing condition at the Development Site.



View displaying the wire frame 3D Model of the Gas Receiving Station without Mitigation.

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Proposed Gas Receiving Station
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Photomontage From View Point-3

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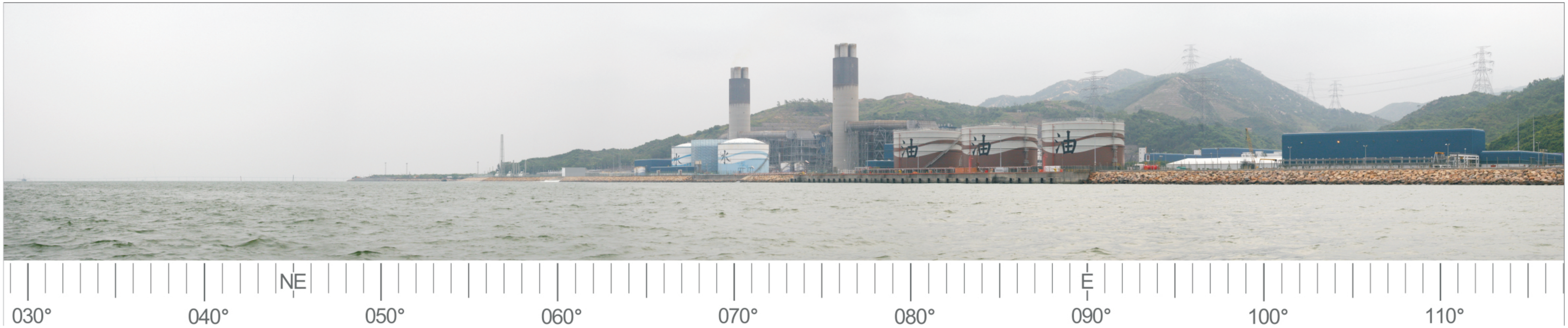
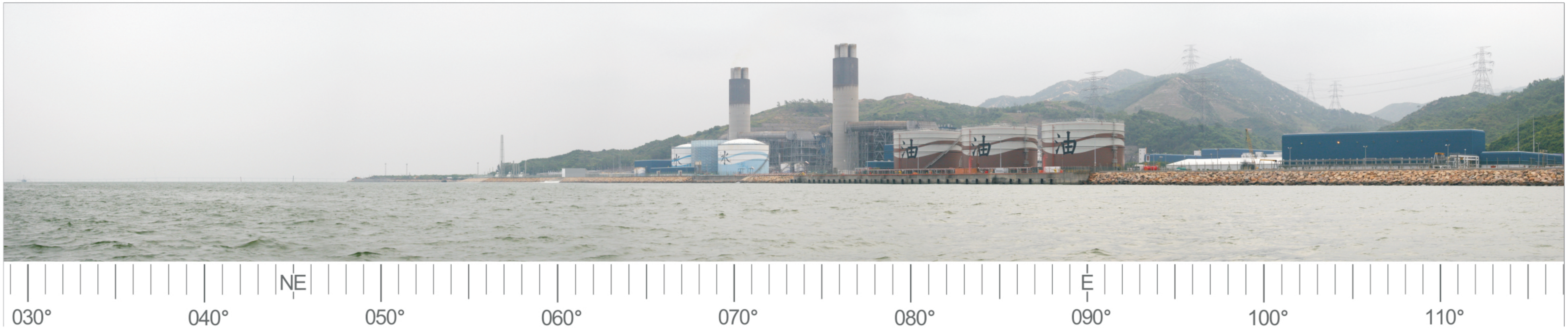
Fig 10.13



View displaying the 3D Model of the Gas Receiving Stations with Mitigation at Day 1 Operation.



View displaying the 3D Model of the Gas Receiving Stations with Mitigation at year 10 operation.

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Proposed Gas Receiving Station
at Black Point Power Station
Photomontage From View Point-3

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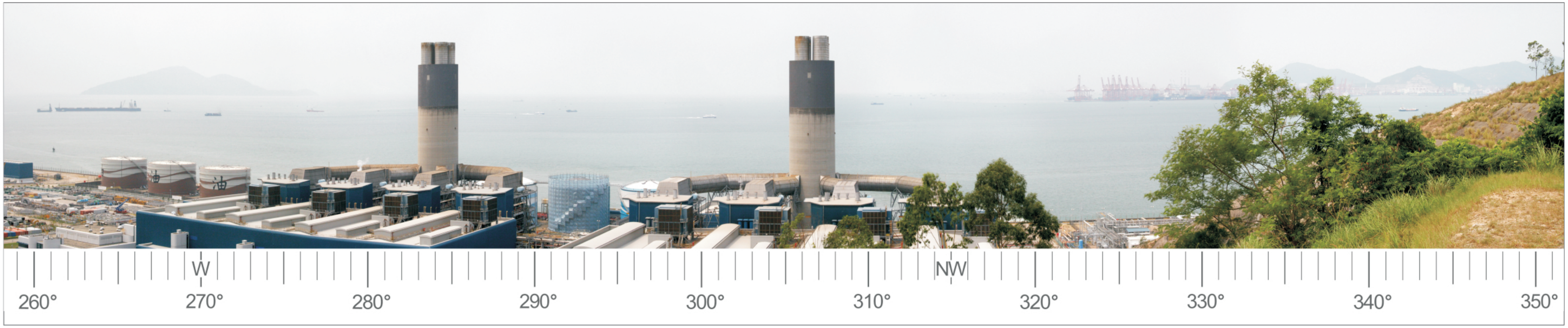
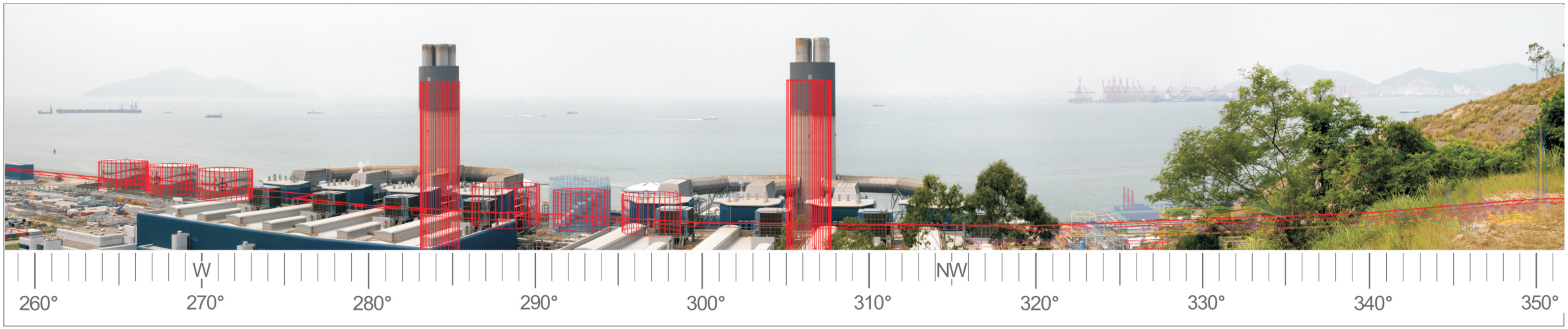
Fig 10.13



VP 4 - View of the GRS looking from Black Point Power Station lookout - Existing condition at the Development Site.



View displaying the wire frame 3D Model of the Gas Receiving Station without Mitigation.

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Proposed Gas Receiving Station
at Black Point Power Station
Photomontage From View Point-4

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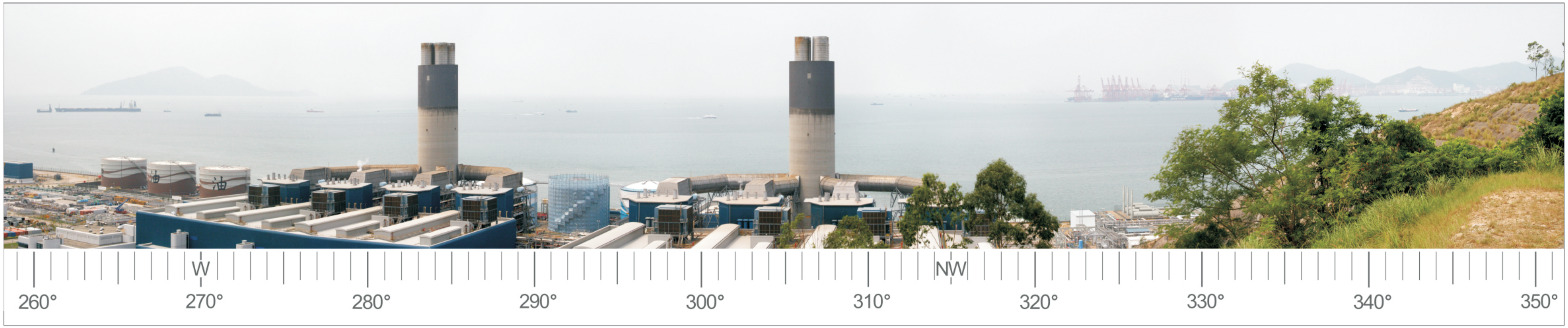
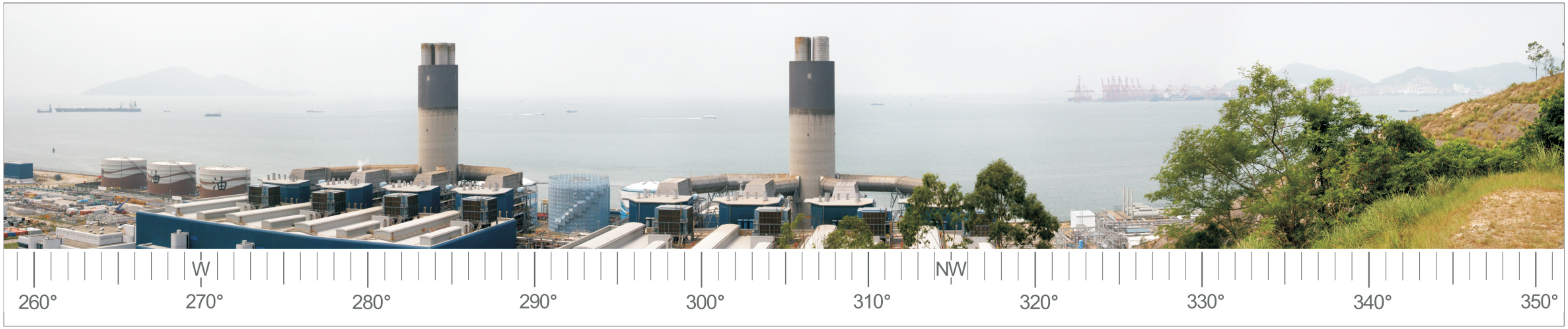
Fig 10.14



View displaying the 3D Model of the Gas Receiving Stations with Mitigation at Day 1 Operation.



View displaying the 3D Model of the Gas Receiving Stations with Mitigation at year 10 operation.

CAPCO

Proposed Gas Receiving Station
at Black Point Power Station
Photomontage From View Point-4

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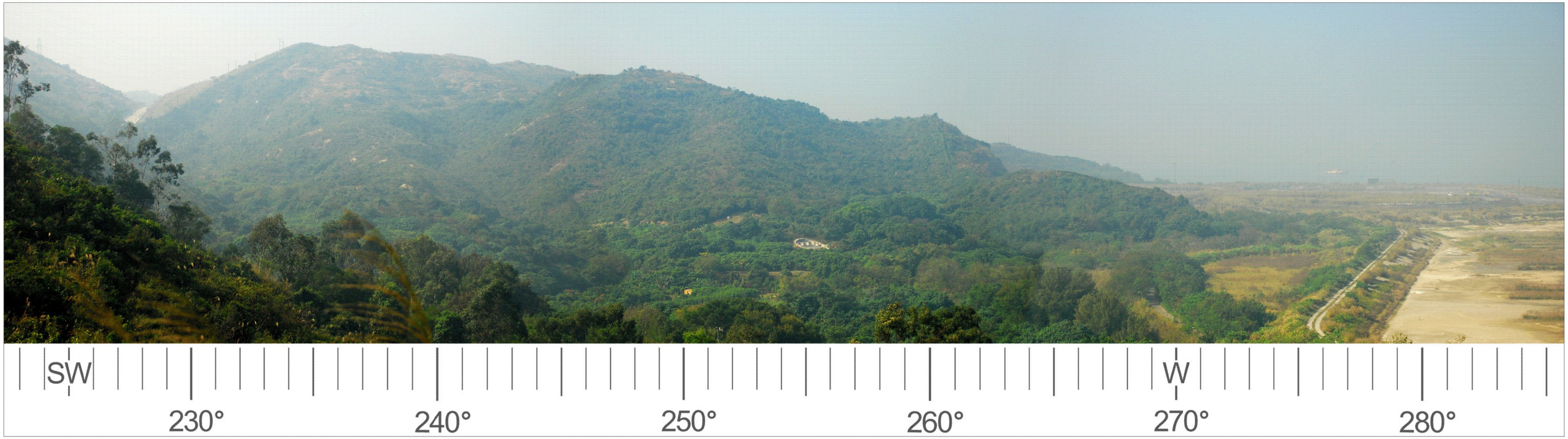
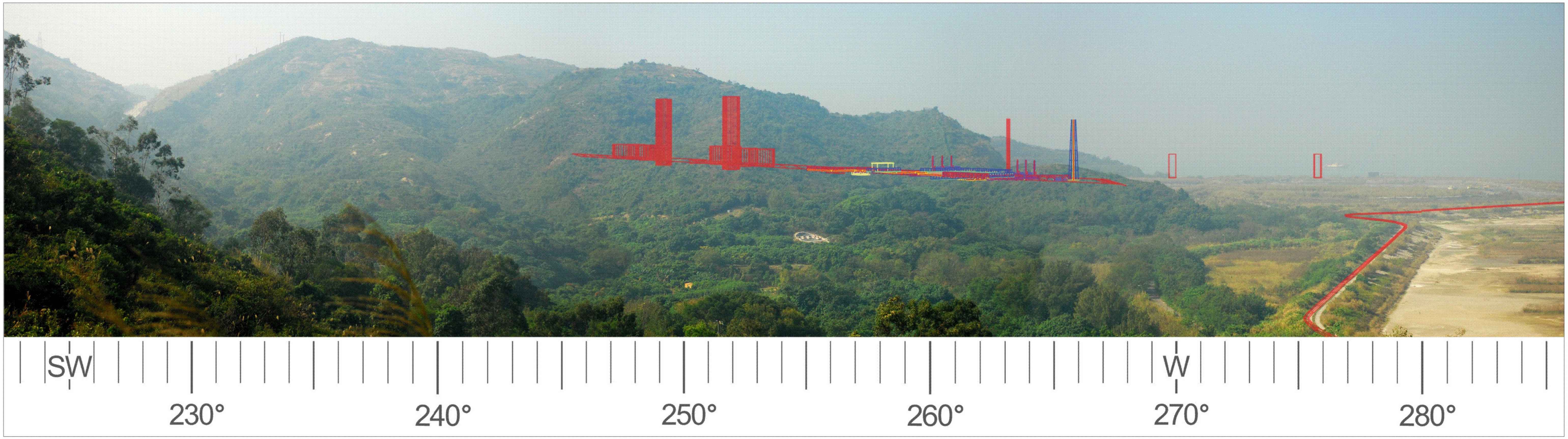
Fig 10.14



VP 5 - View of the GRS looking from hiking trail on Castle Peak - Existing condition at the Development Site.



View displaying the wire frame 3D Model of the Gas Receiving Station without Mitigation.

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Proposed Gas Receiving Station
at Black Point Power Station
Photomontage From View Point-5

Fig 10.15

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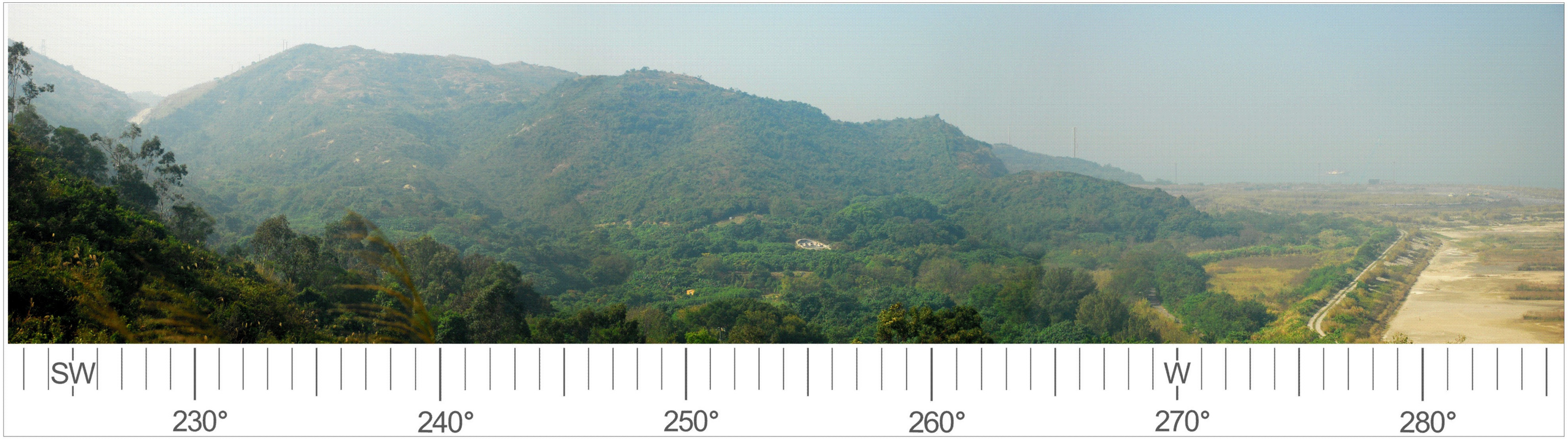
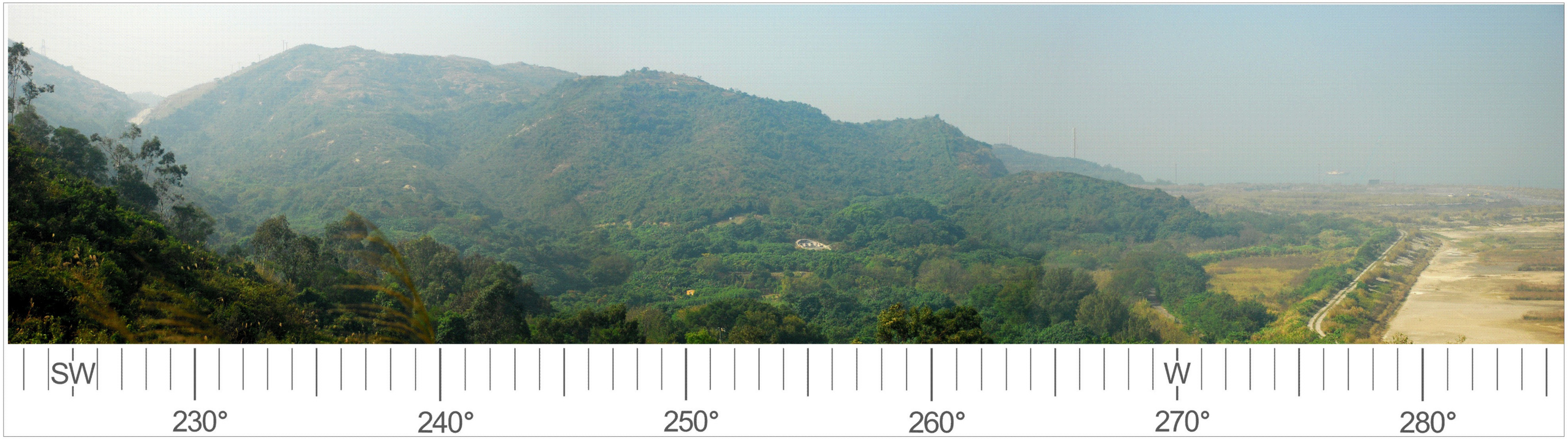


View displaying the 3D Model of the Gas Receiving Stations with Mitigation at Day 1 Operation.



View displaying the 3D Model of the Gas Receiving Stations with Mitigation at year 10 operation.

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Proposed Gas Receiving Station at Black Point Power Station

Photomontage From View Point-5

Fig 10.15

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Occupational VSRs

O1 Employees at BPPS

O2 Fishermen

O3 Workers on transient marine vessels

O4 Workers at West New Territories Landfill

The O2 and O3 VSRs may pass the northern seaward edge of the site in recreational marine vessels. The O1 and O4 VSRs are workers at either the BPPS or WENT Landfill.

Table 10.14 Sensitivity / Quality

Items	Sensitivity / Quality
Value and quality of view	Low
Visitor numbers	Low
Availability and amenity of alternative views	Moderate
Duration and frequency of views to development	Low
Degree of visibility of Development	Low
Sensitivity/Quality of VSR	Low

Table 10.14 shows the value and quality of the view is considered low due to the heavily modified industrial surroundings. There are also low visitor numbers, with low duration and frequency to the development. It is also reasonable to assume that occupational workers at large infrastructure operations generally have a low sensitivity to visual changes. The overall sensitivity is considered low for all VSRs.

Table 10.15 Magnitude of Change

Items	Construction	Operation
Compatibility with surrounding landscape	High	High
Viewing Distance to Proposed Development	500m	500m
Potential blockage of view	Low	Low
Duration of impacts	Temporary	Permanent
Scale of development	Small	Small
Reversibility of change	Irreversible	Irreversible
Magnitude of change	Small	Small

Table 10.15 shows the compatibility of the proposed GRSs is high given it is located adjacent to the existing BPPS. In addition, the GRSs will not be visible from many locations within the BBPS, further reducing the magnitude of change. The scale of the development is also small, resulting in a small magnitude of change for all occupational VSRs.

Table 10.16 Significance Threshold during Construction

		Sensitivity / Quality			Beneficial
		Low	**Medium**	**High**	
Magnitude of Change	**Large**	Moderate Impact	Moderate - significant impact	Significant impact	**Neither beneficial nor adverse**
	Intermediate	Slight – Moderate impact	Moderate Impact	Moderate-Significant impact	
	Small	Slight impact	Slight – Moderate impact	Moderate impact	**Adverse**
	Negligible	Negligible impact	Negligible impact	Negligible impact	

Table 10.16 shows that the low sensitivity of these VSRs along with the small magnitude of change resulting from the GRSs will result in a *slight adverse* construction impact for all occupational VSRs.

Table 10.17 Significance Threshold during Operation

		Sensitivity / Quality			Beneficial
		Low	**Medium**	**High**	
Magnitude of Change	**Large**	Moderate Impact	Moderate - significant impact	Significant impact	**Neither beneficial nor adverse**
	Intermediate	Slight – Moderate impact	Moderate Impact	Moderate-Significant impact	
	Small	Slight impact	Slight – Moderate impact	Moderate impact	**Adverse**
	Negligible	Negligible impact	Negligible impact	Negligible impact	

Figure 10.11 – 10.15 show photomontages of both development options from a range of view points. The change in the view before and after the proposed development is very small. *Table 10.17* also shows that the low sensitivity and small magnitude of change for all occupational VSRs will result in a *slight* impact during operation.

10.6.14 *Visual Mitigation Measures*

The following measures have been considered to reduce the slight impacts identified and improve the overall amenity of the development.

Table 10.18 Landscape Mitigation Measures

ID No.	Landscape and Visual Mitigation Measure	Funding Agency	Implementation Agency
VM1	The colours of the proposed GRS should be selected to complement the existing industrial surroundings.	Developer	Contractor

Figure 10.5 shows the locations of these measures and their application to each of the VSRs is shown in *Table 10.19*

Table 10.19 Un-mitigated and Mitigated Impacts at the VSRs

VSR	Un-Mitigated Visual Impact		Recommended Mitigation	Mitigated Impacts		
	Construction	Operation		Construction	Operation Day 1	Operation Year 10
R1 Transient Marine Vessels	Slight	Slight	VM1	Slight	Negligible	Negligible
R2 Hikers to look out above BPPS	Slight	Slight	VM1	Slight	Negligible	Negligible
R3 Hikers to Castle Peak	Slight	Slight	VM1	Slight	Negligible	Negligible
O1 Workers at BPPS	Slight	Slight	VM1	Slight	Negligible	Negligible
O2 Fishermen	Slight	Slight	VM1	Slight	Negligible	Negligible
O3 Workers on transient marine vessels	Slight	Slight	VM1	Slight	Negligible	Negligible
O4 Workers at West New Territories Landfill	Slight	Slight	VM1	Slight	Negligible	Negligible

10.6.15 *Cumulative Impacts*

The proposed works at the ash lagoons including the Sludge Treatment Facilities and the WENT Landfill Extension may be visible from seaward based vantage points. These will all be relatively minor alterations to the landscape and are unlikely to have any cumulative impact with the proposed GRSs as they will be located within the footprint of the BPPS, a completely separate visual element.

10.6.16 *Effectiveness of Visual Mitigation Measures*

The application of the visual mitigation measures will not reduce the significance threshold of the identified visual impacts for the VSRs during construction. However, due to the highly compatible nature of the GRSs with the BPPS infrastructure, the GRSs will appear as a part of the overall BPPS and therefore the significance threshold will reduce to negligible during operation for all VRSs. This is reflected in the photomontages showing the development at Day 1 of operation and Year 10 of operation.

10.7 CONCLUSIONS

A Landscape Impact Assessment was undertaken for the construction of two GRSs at the Black Point Power Station. Three Landscape Mitigation Measures were proposed. The residual landscape impacts identified are:

1. There will be slight residual impacts on LCA 1 Inshore Waters Landscape and LR 7 Seascape during construction and operation.

2. There will be negligible residual impacts on all other LCAs and LRs.

A Visual Impact Assessment was also undertaken and seven VSRs were identified and assessed based on their sensitivity and magnitude of change. One visual mitigation measure was proposed. There will be slight residual visual impacts during construction, reducing to negligible during operation for all VSRs.

According to *Annex 10* of the *Technical Memorandum on the Environmental Impact Assessment Process* (EIAO-TM) the Landscape and Visual Impacts are considered *acceptable with mitigation*.

Section 11

Cultural Heritage Assessment

CONTENTS

11 CULTURAL HERITAGE ASSESSMENT

11.1 INTRODUCTION

This section presents the results of the cultural heritage impact assessment (CHIA) for the construction and operation of the proposed submarine gas pipelines and Gas Receiving Stations (GRSs) at the Black Point Power Station (BPPS). It summarises information gathered from a literature review and field surveys to establish the baseline cultural heritage and archaeological conditions. Potential impacts have been evaluated and measures have been recommended to mitigate potentially adverse impacts, where appropriate.

In accordance with *Clause 3.4.8.2* of the *EIA Study Brief*, a Marine Archaeological Investigation was undertaken by a qualified marine archaeologist. The Study Area for this Marine Archaeological Investigation included the seabed that is expected to be affected by the marine works of the Project, which is broadly defined as within 500 m from either side of the centre line (CL) of the pipeline alignment and the GRS reclamation (*Figure 11.1*).

11.2 RELEVANT LEGISLATION & ASSESSMENT CRITERIA

The following legislation and guidelines are applicable to the assessment of sites of cultural heritage, marine archaeological and historic resources in Hong Kong:

- *Environmental Impact Assessment Ordinance (Cap 499 S16)* and the associated *Technical Memorandum on the EIA Process (EIAO TM)*;
- *Antiquities and Monuments Ordinance (Cap 53)*;
- *Land (Miscellaneous Provisions) Ordinance (Cap 28)*;
- *Hong Kong Planning Standards and Guidelines*;
- *Guidelines for Cultural Heritage Impact Assessment (CHIA)*; and
- *Guidelines for Marine Archaeological Investigation (MAI).*

11.2.1 *Environmental Impact Assessment Ordinance (Cap 499)*

According to the *EIAO*, *Schedule 1 Interpretation*, "Sites of Cultural Heritage" are defined as:

> *"an antiquity or monument, whether being a place, building, site or structure or a relic, as defined in the AM Ordinance and any place, building, site, or*

Figure 11.1

Study Area for Marine Archaeological Investigation

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structure or a relic identified by the Antiquities and Monuments Office to be of archaeological, historical or palaeontological significance".

Technical Memorandum on the EIA Process (EIAO TM)

The technical scope of cultural heritage impact assessments is defined within *Annex 10* of the *EIAO TM* that states that the criteria for evaluating impacts to sites of cultural heritage should include the following:

- The general presumption in favour of the protection and conservation of all sites of cultural heritage because they provide an essential, finite and irreplaceable link between the past and the future and are points of reference and identity for culture and tradition; and
- Adverse impacts on sites of cultural heritage shall be kept to an absolute minimum.

The *EIAO TM* outlines the approaches required in investigating and assessing the impacts on marine archaeological sites. The following sections of the *EIAO TM* are applicable:

Annex 19: "There is no quantitative standard in deciding the relative importance of these sites, but in general, sites of unique archaeological, historical or architectural value will be considered as highly significant. A baseline study shall be conducted: (a) to compile a comprehensive inventory of places, buildings, sites and structures of architectural, archaeological and historical value within the proposed project area; and (b) to identify possible threats of, and their physical extent, destruction in whole or in part of sites of cultural heritage arising from the proposed project."

The *EIAO TM* also outlines the criteria for assessment of impact on sites of cultural heritage as follows:

Annex 10: "The criteria for evaluating impact on sites of cultural heritage includes: (a) The general presumption in favour of the protection and conservation of all sites of cultural heritage because they provide an essential, finite and irreplaceable link between the past and the future and are points of reference and identity for culture and tradition; (b) Adverse impacts on sites of cultural heritage shall be kept to the absolute minimum."

The *EIAO TM* also outlines the approach in regard to the preservation in totality; and in part to cultural resources:

Annex 19: "Preservation in totality will be a beneficial impact and will enhance the cultural and socio-economical environment if suitable measures to integrate the sites of cultural heritage into the proposed project are carried out. If, due to site constraints and other factors, only preservation in part is possible, this must be fully justified with alternative proposals or layout designs, which confirm the impracticability of total preservation."

11.2.2 *Antiquities and Monuments Ordinance (Cap 53)*

In addition to the *EIAO*, the heritage resources of Hong Kong are protected by a range of legislative and planning mechanisms. The *Antiquities and Monuments Ordinance (Cap 53)* (*AM Ordinance*) provides statutory protection against the threat of development on Declared Monuments, historical buildings and archaeological sites to enable their preservation for posterity. The *AM Ordinance* also establishes the statutory procedures to be followed in making such a declaration.

"This Ordinance provides for the preservation of objects of historical, archaeological and palaeontological interest…"

The Ordinance defines an antiquity as a relic (a movable object made before 1800) and a place, building, site or structure erected, formed or built by human agency before the year 1800. The Ordinance also states, amongst other things, that the discovery of an antiquity shall be reported to the Authority (Secretary for Home Affairs); that ownership of all relics discovered after 1976 shall be vested in the Government; that the Authority can declare a place, building, site or structure to be a monument, historical building or archaeological or palaeontological site or structure (and therefore introducing certain additional controls for these sites); and that licences and permits can be granted for excavation and for other work.

In practice, the Antiquities and Monuments Office (AMO) also identifies Deemed Monuments (1) and then seeks to reach agreements with the owners of the monuments to provide for specific measures that will ensure preservation. Deemed Monuments have the potential to be upgraded to statutory Declared Monuments under the *AM Ordinance*.

A large range of potential sites of cultural heritage, among which are historical buildings and structures and archaeological sites, have been identified and recorded by AMO in addition to those for which a declaration has been made under the *AM Ordinance.*

Historic buildings and structures are recorded by AMO according to the grading system summarised in *Table 11.1.*

(1) Deemed Monument – a building that has been identified by AMO as historically significant. The owner of the building has entered an agreement with AMO to allow restoration work to take place and reasonable access for the public. This designation provides no legal protection over the building under the AM Ordinance.

Table 11.1 The Grading of Historical Buildings

Grade	Description
I	Buildings of outstanding merit, which every effort should be made to preserve if possible
II	Buildings of special merit; efforts should be made to selectively preserve
III	Buildings of some merit; preservation in some form would be desirable and alternative means could be considered if preservation is not practicable

It should be noted that the grading of historical buildings is intended for AMO's internal reference only and has no statutory standing. Although there are no statutory provisions for the protection of recorded archaeological sites and historical buildings and features (including deemed, graded and recorded), the Government has established a set of administrative procedures (2) for giving consideration to the protection of these resources.

Over the years, surveys have been undertaken to identify archaeological sites in Hong Kong. The AMO has established boundaries for the identified sites and a set of administrative procedures for the protection of the known archaeological sites. However, the present record of archaeological sites is known to be incomplete as many areas have not yet been surveyed. Therefore, procedures and mechanisms which enable the preservation and formal notification of previously unknown archaeological resources that may be revealed or discovered during project assessment or construction, must be identified and implemented at an early stage of the planning of a project.

Section 11 of the *AM Ordinance* requires any person who discovers an antiquity, or supposed antiquity, to report the discovery to the Antiquities Authority. By implication, construction projects need to ensure that the Antiquities Advisory Board (AAB) (3) is formally notified of archaeological resources which are discovered during the assessment or construction of a project.

11.2.3 *Land (Miscellaneous Provisions) Ordinance (Cap 28)*

Under this *Ordinance*, it is required that a permit be obtained for any excavation within government land prior to commencement of any excavation work commencing.

(2) Administrative procedures are adopted by AMO with the intention to protect sites of archaeological and historical interests that not protected under the provisions of AM Ordinance. For example, reserve area may be imposed on a particular area or building consultation with AMO for advice when development within the reserve area is proposed. These AMO measures are referred to as administrative procedures.

(3) The Antiquities and Monuments Office is the entry point to pass information to the AAB. The AAB is a statutory body consisting of expertise in relevant fields to advise on any matters relating to antiquities and monuments

11.2.4 Hong Kong Planning Standards and Guidelines

The HKPSG, *Chapter 10 (Conservation)*, provides general guidelines and measures for the conservation of historical buildings, archaeological sites and other antiquities.

11.2.5 Guidelines for Cultural Heritage Impact Assessment (CHIA)

The guidelines stated in *Appendix D* of the *EIA Study Brief No. ESB-208/2009* provide details on the criteria for the CHIA which include a baseline study, field evaluation and impact assessment.

11.2.6 Marine Archaeological Investigation (MAI) Guidelines

The guidelines stated in *Appendix E* of the *EIA Study Brief No. ESB-208/2009* provide details on the standard practices, procedures and methodology that must be utilised in determining the marine archaeological potential, presence of archaeological artefacts and establishing suitable mitigation measures. The first step, a Stage 1 MAI, involves a baseline review, geophysical survey and establishing archaeological potential. Subject to the results of the Stage 1 MAI, a Stage 2 MAI investigation may or may not be required.

11.3 ASSESSMENT METHODOLOGY FOR CULTURAL HERITAGE IMPACT ASSESSMENT

The CHIA methodology follows the criteria and guidelines in *Annexes 10* and *19* of the *EIAO TM* and the Guidelines for Cultural Heritage Impact Assessment (CHIA) and Guidelines for Marine Archaeological Investigation (MAI), as stated in *EIA Study Brief No. ESB-208/2009*.

It should be noted that the land-based Project Area of this Project is within the site boundary of the BPPS. There are no declared/ deemed monument, graded/ recorded heritage resources, Built Heritage or Archaeological Sites located within the proposed Project Area and works areas. No existing sites of cultural heritage protected under the *Antiquities and Monuments Ordinance (Cap 53)* have been identified within the proposed Project Area and works areas.

On the basis of the above, it is considered that the Project Area is of negligible archaeological potential. A terrestrial archaeological investigation is thus not deemed necessary.

A Marine Archaeological Investigation was undertaken by a qualified marine archaeologist, Dr Bill Jeffery. Findings of this Investigation are presented in the following sections.

11.3.1 *Baseline Study for Marine Archaeological Resources*

A baseline study was conducted with reference to the methodologies and guidelines laid out in the *EIA Study Brief No. ESB-208/2009* to compile a comprehensive inventory of cultural heritage resources within the marine-based Project Area. This has included a review of available literature, nautical charts produced by the AMO, the Hydrographic Office of Marine Department, geotechnical survey data, historical documents and United Kingdom Hydrographic Office (UKHO) 'Wreck' files to determine the archaeological potential of the waters of the proposed Project Area. Findings of this desktop literature review are presented below.

Review of Historic Documents

The waters between Shekou (situated in Shenzhen) and Black Point were used as a war junk anchorage from the 8th century. In the 8th century (Tang Dynasty), Black Point was within the military division area of Tunmen Bing Zhen (屯門兵鎮) whose 2,000 soldiers were under the command of one Defence Commissioner. The headquarters of this division was situated in the present Nantou (南頭) walled city of Shenzhen and its military division area also covered the HKSAR, as well as the Huizhou (惠州) and Chaozhou (潮州) areas [4]. The military division was serving the same area until the Yuan Dynasty (AD1279-1368).

In the late 16th century (Ming Dynasty), China was facing frequent disturbance from coastal invaders and more forts and beacon towers were set up to protect the key locations from Japanese pirates. The Nantou Military Division (南頭寨) was established in 1565 and commanded 53 war junks and 1,486 soldiers [5]. The military force was increased to 1,659 soldiers in 1645.

During this period, the Portuguese explorer, Jorge Alvares was permitted to land on Lintin Island (Neilingding 內伶仃) in 1513 [6]. He then built a fort and erected a stone column with a carving of the Portuguese national symbol. The Chinese navy attacked and demolished the Portuguese fort in 1518 [7]. In 1522, it was recorded that a sea battle between the Chinese navy and Portuguese ships was fought in the water between Lantau Island and Tuen Mun. The Chinese navy won the battle.

(4) Siu KK (1997) *Forts and Batteries: Coastal Defence in Guangdong During Ming to Qing Dynasties*, Hong Kong, Urban Council

(5) 蕭國健 (1994) 〈明代粵東海防中路之南頭頭寨〉，《香港歷史與社會》，香港教育圖書公司。

(6) Brage JM (1965) *China Landfall 1513, Jorge Alvares Voyage to China*, Macau, Imprensa Nacional

(7) Cortesão A (1944) *The Suma Oriental of Tome Pires and the Book of Francisco Rodrigues*. London, Hakluyt Society. 龍思泰 (Anders Ljungstedt) 1832, 1997 《早期澳門史》，北京，東方出版社。

A review of a historical chart of the mouth of the Pearl River dated 1658 (8), also indicated that the waters between Black Point and Lintin Island were part of the main shipping route from the West to the East.

During the Ming to Qing Dynasties (AD1368 -1911), Imperial Junks sailing from Guangdong to Southeast Asian countries were required to anchor at a bay known as Chiwan (赤灣) on the Nantou peninsula, located to the west of Shenzhen City (located some 9 km north of Black Point). The Nantou area used to zone as the Nantou Military Division. During the early Qing Dynasty in the 1660s, although the Nantou Military Division was replaced by Xin'an Camp (新安營), it was still situated within the Nantou Walled City (9). A Tin Hau Temple was established in this Chiwan Bay, probably in 1410 according to an inscription of the Temple where sailors worshipped Tin Hau seeking protection from mishaps at sea (10). Two stone forts were also built near the Tin Hau Temple during the Qing Dynasty and the remains of the forts can still be found.

Based on this historical review, it is considered that Black Point is located in the vicinity of a historically busy marine sea route. The waters at Black Point, Deep Bay and Neilingding Island have provided the main shipping channel between Guangdong and the Southern China Sea and Southeast Asian countries as well as East and West for centuries. On this basis, the waters at Black Point are considered to have marine archaeological potential.

A desktop review of other historical records and admiralty charts has been undertaken to examine if any resources of marine archaeological potential/ value are present within 500 m from either side of the centre line (CL) of the pipeline alignment and the proposed reclamation. A review of the *Study on the Potential, Assessment, Management and Preservation of Maritime Archaeological Sites in Hong Kong* undertaken in 1998 (11) identified a number of shipwrecks recorded some kilometres from the proposed pipeline route, but no shipwrecks were identified within 1 km of the proposed Project Area.

United Kingdom Hydrographic Office 'Wreck' File

The United Kingdom Hydrographic Office (UKHO) in Taunton maintains a database of known shipwrecks in the HKSAR. The aim of the UKHO in keeping the database is to maintain a list of shipwrecks/ obstructions that could be navigation hazards, wrecks through deterioration/ corrosion over time become less of a navigation hazard but still remain on their database and

(8) Nessel , Johan 1658 Tngqvin, in 格斯・冉福立 (Kees Zenlvliet) 江樹生 譯 1997 《十七世紀荷蘭人繪製的台灣老地圖》，台北，漢聲出版社。

(9) 靳文謨 1688 《新安縣志》，新安縣衙。

(10) 王應華 1660年代，2000〈赤灣天妃廟記〉，《明清兩朝深圳檔案文獻演繹》，廣州，花城出版社；蔡學元 1814，2000 〈重修赤灣天后廟記〉，《明清兩朝深圳檔案文獻演繹》，廣州，花城出版社。

(11) Ali S (1998) *Study on the Potential, Assessment, Management and Preservation of Maritime Archaeological Sites in Hong Kong*. Hong Kong: Lord Wilson Heritage Trust

if not removed could potentially become significant archaeological sites. The UKHO database is only one source of data, albeit an important source of historical data on shipwrecks, that combined with other historical sources on other types of sites (as well as some types of shipwrecks) and the geophysical surveys, it provides a significant contribution in ascertaining if a region encompasses submerged archaeological deposits.

The review indicated that a total of two shipwrecks were reported in the vicinity of the Study Area (*Table 11.2*, *Figure 11.2*, *Annex 11A*).

Table 11.2 UKHO Wrecks in the vicinity of the Study Area

Wreck Number	Geographical Coordinates	UTM Grid Coordinates	Status
46602	22.413833 N 113.873333 E	2481463 N 795808 E	Live
46685	22.429717 N 113.887783 E	2483251 N 797263 E	Lifted (ie Dead)

One 'live' (either chartered or unchartered but potentially still lying on the seabed) shipwreck might be present in the vicinity of the proposed pipeline alignment (*Figure 11.2*). The UKHO records state that this wreck was a 3130 ton Japanese freighter *Shirogane Maru* that was sunk during World War II. Its position was last verified by a diver on 20 October 1987. Chart No. HK1503 has an Obstruction marked ("Obstn") at the location of Wreck No. 46602 and is recorded as a Wreck on Chart 3026 (Dated 1990).

The Hong Kong Marine Department, Hydrographic Office could not provide any additional information beyond what was provided by the UKHO.

Although the UKHO shipwreck database suggest that the 'live' wreck (No. 46602) is located about 500 m south of the proposed Pipeline 1, results of comprehensive geophysical surveys conducted previously in the area confirm that this wreck no longer exists [(12)].

One 'dead' UKHO shipwreck (No. 46685; lifted from the seabed) and one Marine Department savaged wreck, which is a 10 m x 3 m x 2 m Chinese engineering vessel mostly damaged and about 30 years old, have been reported previously in this broad area (*Figure 11.2*). Shipwrecks/ Obstructions are continually salvaged in Hong Kong waters and it is potentially what happened to the 'live' wreck on the UKHO Wrecks Database.

Other Published Information

Comprehensive geophysical surveys, using multi beam echo sounder, side scan sonar and sub-bottom boomer profiling, have been conducted in the

(12) ERM (2006) *Liquefied Natural Gas (LNG) Receiving Terminal and Associated Facilities: EIA Study* (EIA Study Brief ESB-126/2005). Prepared for CAPCO

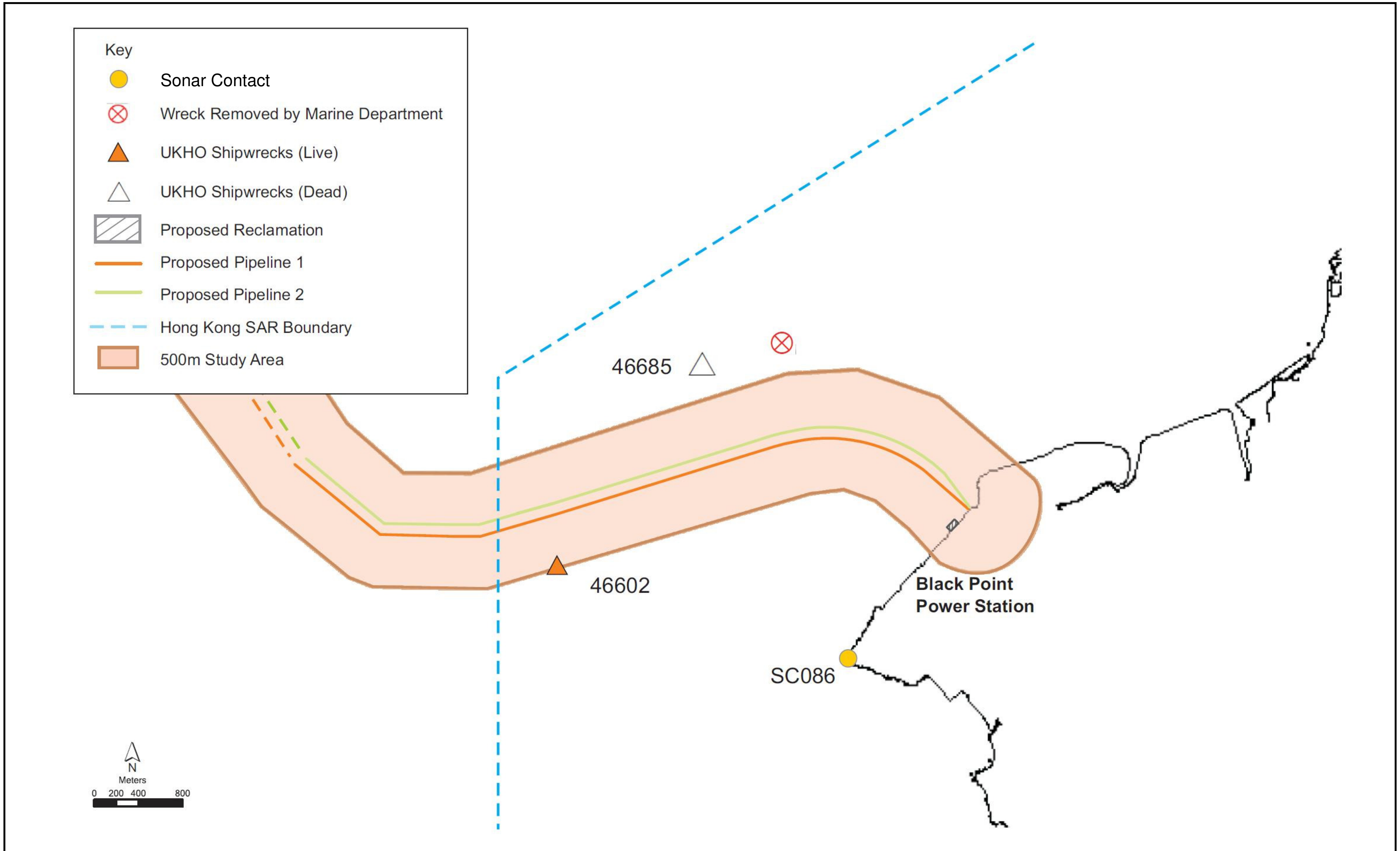

Figure 11.2

Location of Sonar Contact, Wreck Removed by the Marine Department and Recorded Shipwrecks Maintained by UK Hydrographic Office in the Study Area

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Black Point areas in 2005 as part of the HKLNG EIA (13) to assess the archaeological potential of the surveyed areas. The surveyed areas covered part of the Study Area, i.e. the area to the south of the proposed Pipeline 1, including the entire site for the proposed reclamation (*Figure 11.4*). Three Sonar Contacts, identified as possible wrecks, located within 1 – 2 km of the proposed pipeline alignment as were identified from the surveys (*Table 11.3*).

Table 11.3 ***List of the Three Sonar Contacts Identified in the Vicinity of the Study Area in the 2005 Geophysical Survey***

Contact Number	Latitude Longitude	Easting Northing	Dimensions (m)	Description
SC014	22° 24.389′ N 113° 52.407′ E	795836.0 E 2480649.0 N	6m x 1.3m x 0.3m	Possible Wreck
SC020	22° 24.360′ N 113° 52.354′ E	795745.0 E 2480594.0 N	13m x 5m x 0.25m	Possible Wreck
SC086	22° 24.388′ N 113° 54.072′ E	798693.9 E 2480702.4 N	10.77m x 3.31m x 2.03m	Possible Wreck

A magnetic survey was subsequently conducted for the Sonar Contacts to ascertain how much ferrous material (14) remained on the anomalies. Results of the magnetic survey indicated that whilst SC014 and SC020 would not be vessels or of marine archaeological potential, SC086 was considered as a Magnetic Anomaly and as a site of marine archaeological potential.

A more detailed side scan sonar and multi beam sonar survey was undertaken for the Sonar Contact SC086 in April 2006 to ascertain the nature of this anomaly. SC086 was interpreted as a 'recent' motorised wooden sampan. It is located about 1 km south of the CL of the proposed Pipeline 1 (see *Figure 11.2*). In the context of the *Antiquities and Monuments Ordinance (Cap 53)*, SC086 is not considered an antiquity or relic and is of no archaeological value.

Therefore, all three sonar contacts have been proven to be of no archaeological values in the context of the *Antiquities and Monuments Ordinance (Cap 53)* (15).

11.3.2 *Field Surveys for Marine Archaeological Resources*

Following a baseline review including review of literature and old maps, consultation with UK Hydrographic Office and Hong Kong Hydrographic Office on their database of shipwrecks, geophysical surveys were undertaken by CAPCO's geophysical contractor EGS (Asia) Limited (EGS) within the Study Area in March 2009 as part of this Project. The survey was focused on

(13) ERM (2006) *Op cit*

(14) While pre-1800 ships would have carried ferrous equipment and used ferrous material in their construction, post-1800 ships contained a significantly larger amount of ferrous material. It was considered that the amount of ferrous material detected during a Magnetic Survey could provide an indication of the relative age of the vessel

(15) ERM (2006) *Op cit*

the part of the Study Area that was not surveyed previously in 2005, i.e. the area to the north of the proposed Pipeline 1 (*Figure 11.3*).

The objective of the survey was to define the areas/ sites of greatest archaeological potential, assess the depth and nature of the seabed sediments and map any seabed and sub-bottom anomalies which may have archaeological material. The survey data obtained by EGS were reviewed and interpreted by a qualified marine archaeologist to identify features of possible archaeological potential. The detailed methodology and findings are described below.

The geophysical survey using multi beam echo sounder, side scan sonar and sub-bottom boomer profiling covered a 400 m wide corridor, centred on the proposed gas pipeline alignment with a route length of 5 km, giving a total of 278 km of survey data (*Figures 11.3* and *11.4*). Side Scan Sonar and Boomer data was collected from 20 m tracks along the length of the survey route. These tracks provided a comprehensive coverage of the area. Cross traverses every 100 m were also implemented. A similar thorough Side Scan Sonar and Boomer survey was implemented at all the other impacted areas off Black Point using similar distances between tracks and cross tracks. The vessel track plot of the surveys is presented in *Figure 11.4*. These surveys allowed for a comprehensive investigation of the seabed, and below the seabed.

The equipment used included:

- DGPS positioning and navigation, provided by the C-NAV GcGPS 2000 system, and C-View NAV Navigation software;
- Knudsen 320m echo sounder used to collect depth soundings;
- Reson 8125 multi-beam echo sounder
- DF 1000 side scan sonar system (employing a dual frequency system with nominal operating frequencies of 100 kHz and 500 kHz) and digital tow fish, used to map seabed features;
- C-Boom low voltage boomer system, used to provide profiles of seabed sediments;
- C-View logging systems

The geophysical survey data obtained by EGS were processed by in house geophysicists and reviewed by the marine archaeologist. Results of the geophysical survey showed that the seabed in the vicinity of the Project Site as composed of a mixture of silty sand and silty clay. The surveyed area has been impacted by anchoring, trawling and the dumping of materials and a few debris, navigation holes and buoys are present within this area (*Figure 11.5a*). Anchoring and trawling will reduce the archaeological potential of

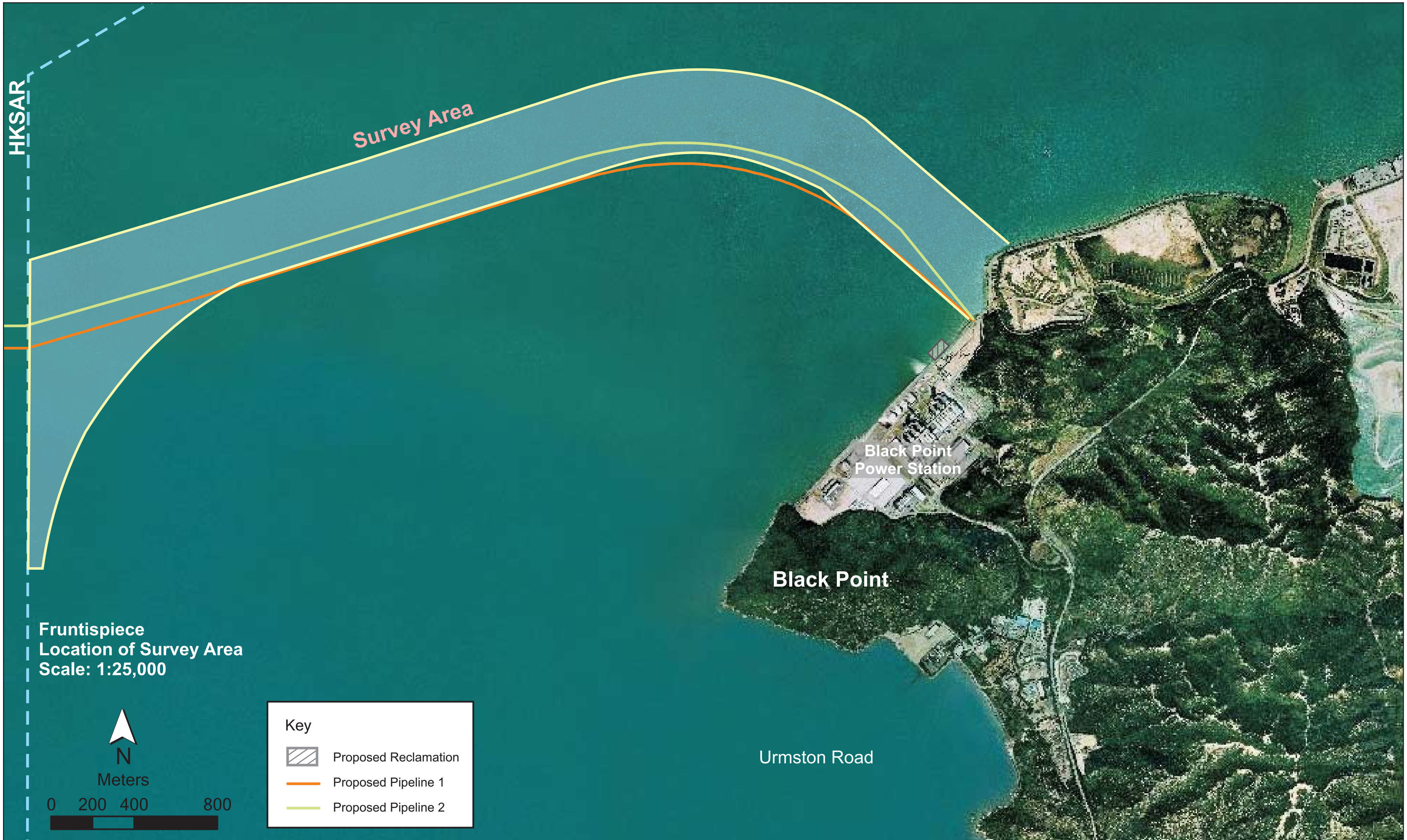

Figure 11.3

Survey Area for Geophysical Survey in March 2009

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the seabed in these areas as will the dumping of materials, although this activity can also enhance the archaeological potential by providing a protective covering over sites (it can also interfere/damage sites through this activity). It makes it very difficult, potentially impossible to assess the archaeological potential of these parts of the seabed.

In addition, the survey located 14 Sonar Contacts comprising debris, buoys, navigation poles and linear depression features (*Figures 11.5b, 11.6, 11.6a* and *11.6b*). Further review of these Sonar Contacts by geophysicists and marine archaeologists discounted them as wrecks, possible wrecks or sites of archaeological potential based on a combination of factors, which included the interpretation and a comparison of the geophysical signatures with those signatures that were clearly wrecks (and possibly wrecks), debris and dumped materials. Wrecks as seen in the side scan sonar images have identifiable relief (as seen in the shadows they develop on the side scan sonar images) and features that could be considered not-natural, such as straight lines delineating its boundaries. In comparison debris could show relief but it is characterised by natural, rounded features and boundaries. Dumped materials and some debris were characterised by areas of a darker/black section of the seabed on the side scan sonar images consisting of coarser materials/sediments with little or no relief. The assessment also included the context of the Sonar Contact with its surrounding seabed environment, where identifiable dumped materials/debris was found to be in the very near vicinity. The raw data for all the Sonar Contacts was reviewed by the marine archaeologist using the above criteria.

In some sections of the survey area, a small number of 'masked zones' were recorded. This applies to some of the seismic data, where gas masking affected the interpretation of the sediments/formations but only below the Hang Hau Formations (the zone which most likely to contain archaeological deposits). A review of the boomer data failed to identify any sub-bottom anomalies. It is important to note that the side scan sonar data were not masked, so there were no gaps in the geophysical surveys from an archaeological perspective.

The geophysical survey, therefore, did not locate any shipwrecks or other material of an archaeological nature, and no sites of potential archaeological potential/ values, e.g. possible wrecks or pre-1800 age shipwrecks, have been identified. The surveyed area contained minimal evidence of any sub-bottom anomalies and none which were interpreted as archaeological material.

The location of the UKHO wreck #46602 was thoroughly investigated but no trace of the 3,130 ton Japanese freighter *Shirogane Maru* could be seen (*Figure 11.7*). It is reasonable to assume that this wreck must have been removed, since it could not have deteriorated to an extent where it is not evident.

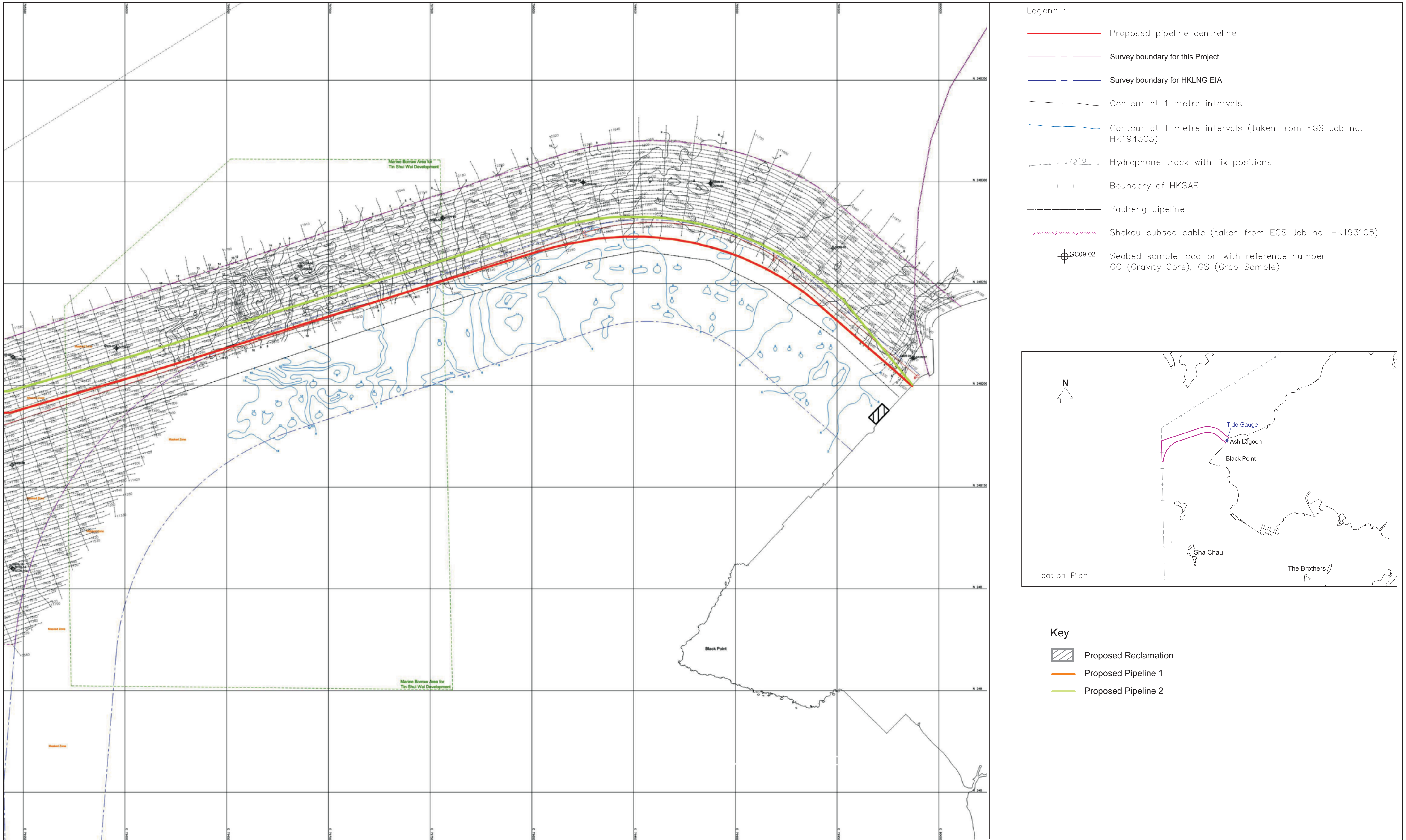

Figure 11.4

Survey Lines for March 2009 Geophysical Survey

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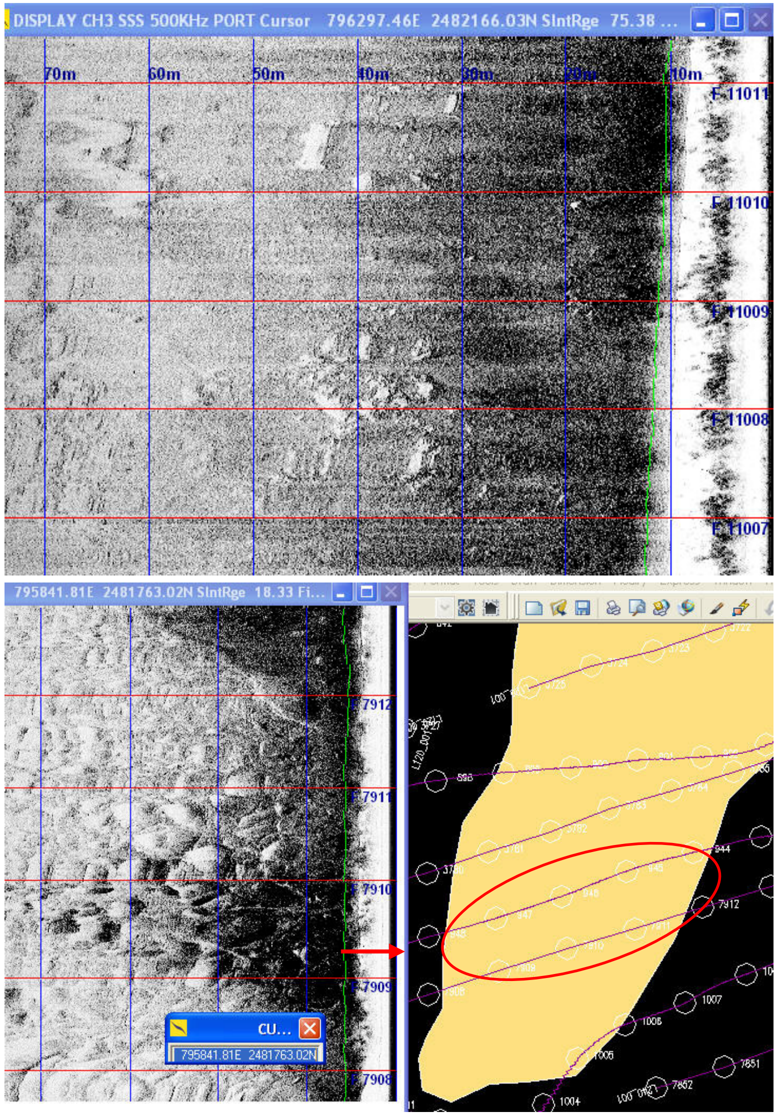
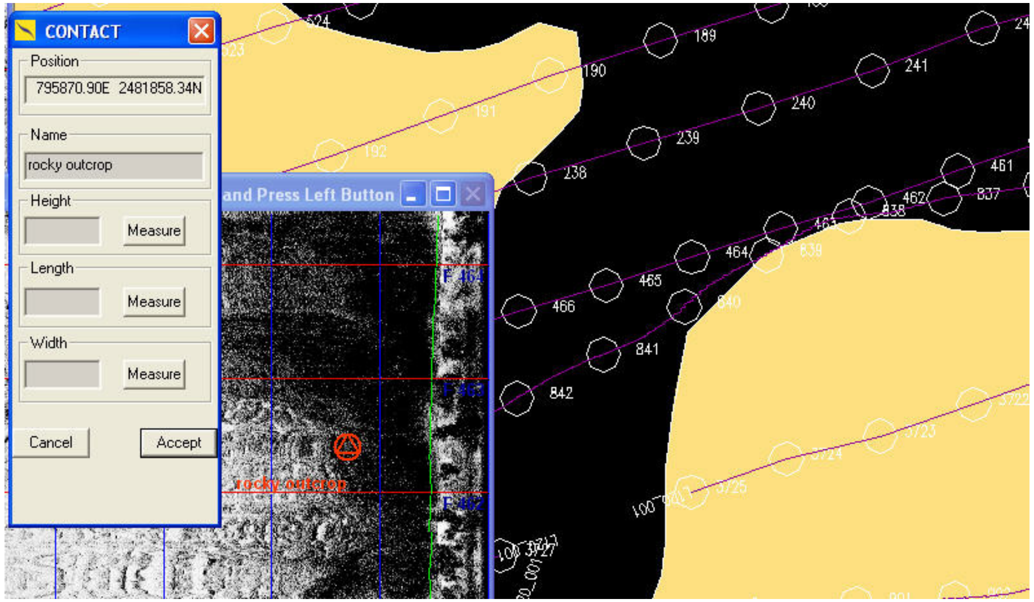


Seabed with Rocks and Debris



Rocky Outcrop

Figure 11.5a

Typical Images of the Survey Area collected in March 2009

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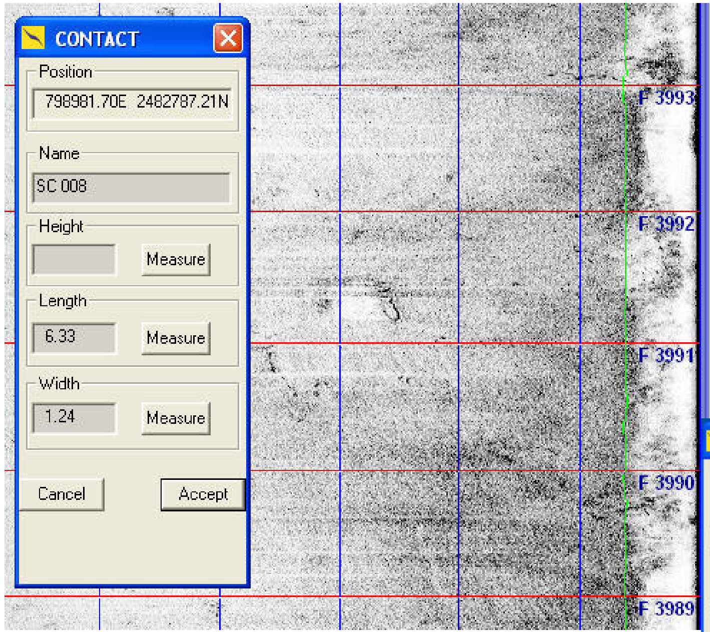
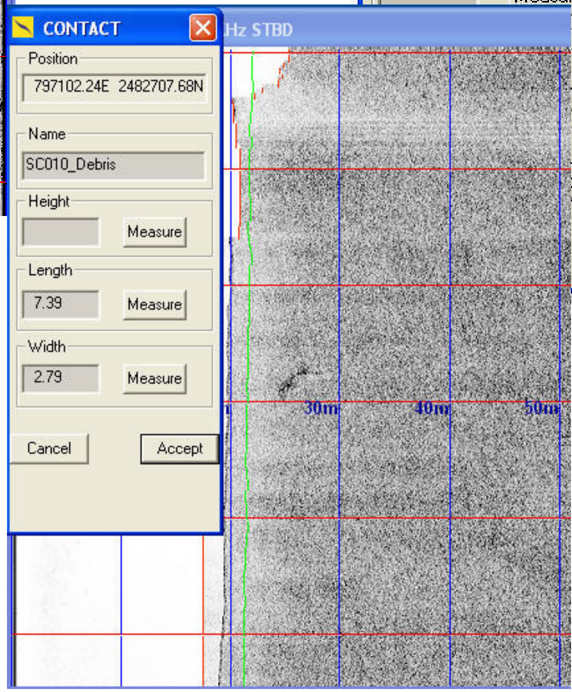
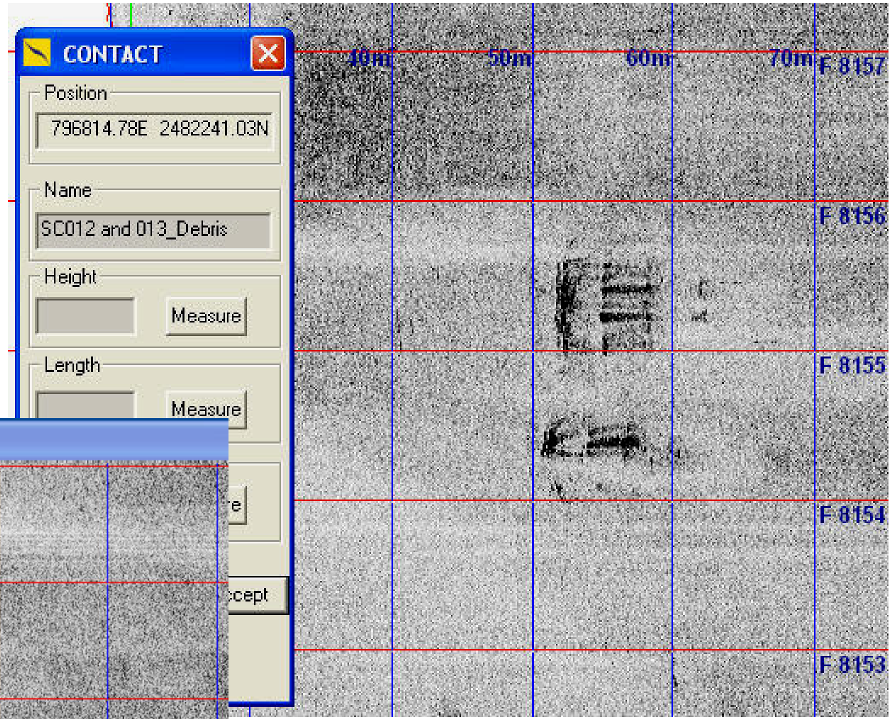


SC008 - Debris



SC010 - Debris



SC012 & SC013 – Debris

Figure 11.5b

Typical Images of Sonar Contacts Identified in March 2009

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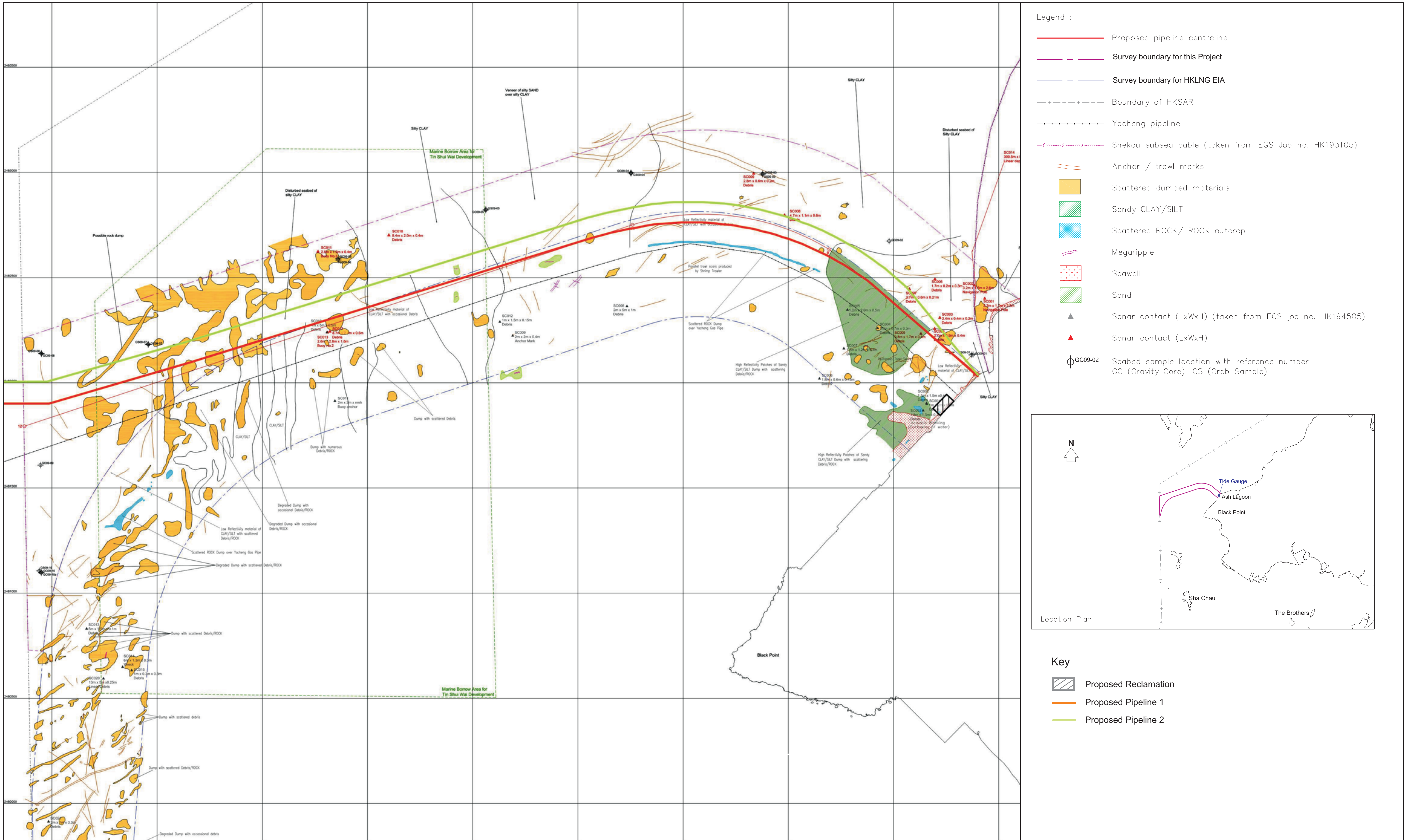

Figure 11.6

Seabed Features as Evaluated from March 2009 Geophysical Survey

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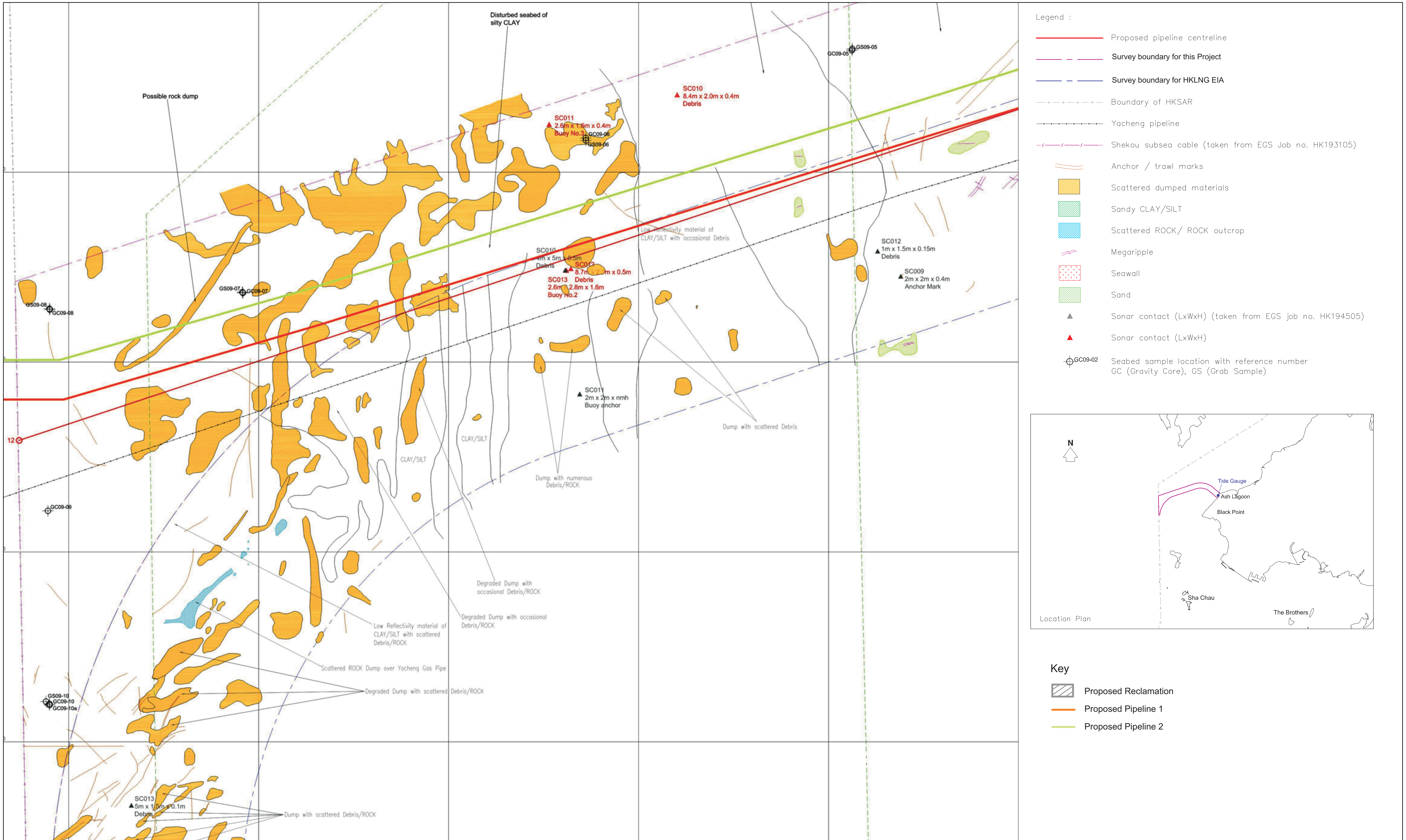

Figure 11.6a

Seabed Features as Evaluated from March 2009 Geophysical Survey

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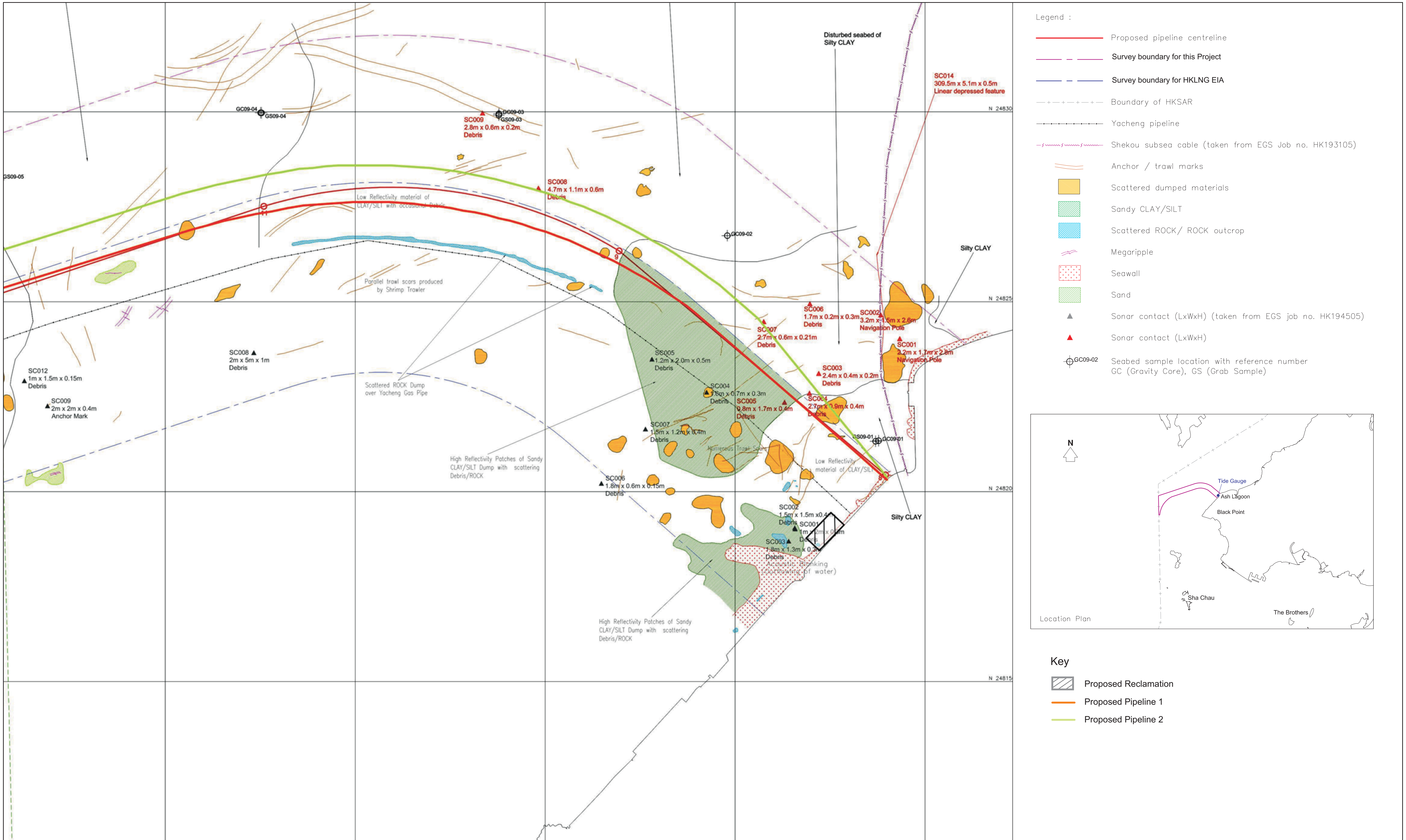

Figure 11.6b

Seabed Features as Evaluated from March 2009 Geophysical Survey

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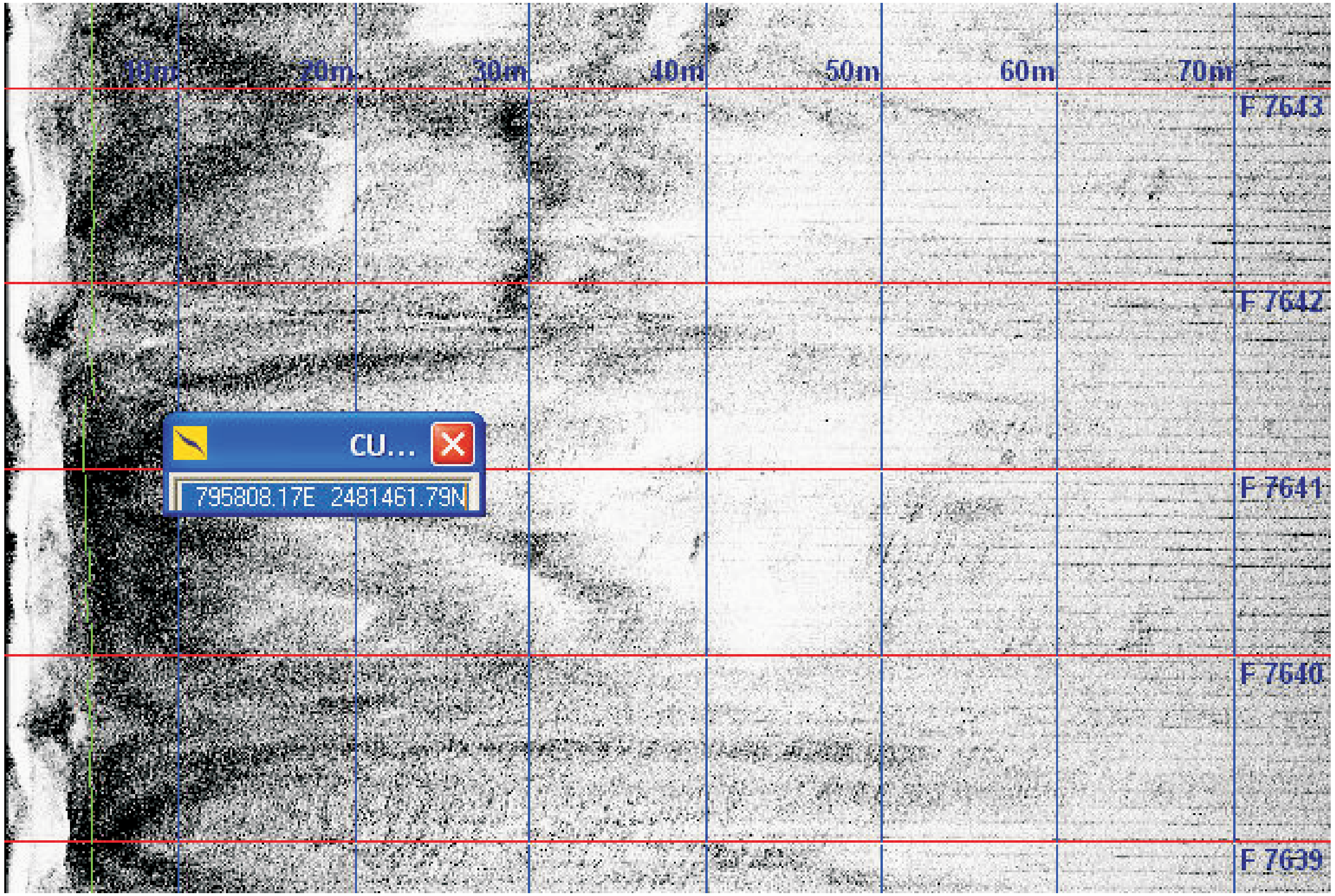

Figure 11.7

Seabed in the Location of UKHO Wreck No. 46602

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It is thus concluded that no marine sites of cultural heritage/archaeological value are present in waters surrounding Black Point and within the proposed Project Area.

11.3.3 *Establishing Marine Archaeological Potential*

The review of historical documents, literature and geophysical data from the 2005 and 2009 surveys indicates that the Study Area covering the proposed pipeline corridor and the reclamation site has little potential to contain archaeological material, with the exception that evidence from the UKHO found the Study Area could contain a shipwreck. The geophysical surveys in 2005 and 2009, however, found no evidence of the UKHO shipwreck #46602, other shipwrecks or other archaeological material either on the seabed of below it.

The proposed pipeline corridor and the reclamation site are, therefore, considered to be of little marine archaeological potential. As such, further marine archaeological investigation, i.e. magnetic survey, remote operated vehicle (ROV), visual diver survey or Watching Brief, is not considered necessary.

11.4 POTENTIAL SOURCES OF IMPACT

11.4.1 *Construction Phase*

The construction phase of a development may have direct or indirect impacts to sites of potential sites of cultural heritage. Such impacts may arise from the following activities:

- Direct loss of potential marine archaeological deposits due to seabed construction works, such as dredging, jetting and reclamation.

11.4.2 *Operation Phase*

The operation phase of a development may have direct or indirect impacts to sites of potential sites of cultural heritage from the following activities:

- Indirect impact on access for future archaeological surveys; and
- Permanent access disturbance to standing heritage if the standing heritage are conserved within the developed area.

11.5 IMPACT ASSESSMENT

As there are no declared/ deemed monument, graded/ recorded heritage resources, Built Heritage or Archaeological Sites located within the Project Area and no sites of cultural heritage protected under the *AM Ordinance* have been identified, construction and operational impacts to sites of cultural heritage are not expected.

Findings of the Marine Archaeological Investigation concluded that no marine sites of cultural heritage/ archaeological value are present in waters surrounding Black Point and along the proposed pipeline corridor. As such, no impacts to marine archaeological resources are expected.

No impacts on potential cultural heritage and archaeological resources are expected to occur during the operation of the submarine pipelines and GRSs.

At present there are no planned projects on Black Point that could have cumulative cultural heritage impacts with the proposed Project.

11.6 MITIGATION MEASURES

As no impacts to cultural heritage and archaeological resources are expected, no mitigation measure is required.

11.7 CONCLUSIONS

A literature review supplemented by field survey has concluded that no cultural heritage and archaeological resources of archaeological potential have been identified within the proposed Project Area and works areas. The proposed Project is thus not expected to impose any archaeological impact and no mitigation measures are considered necessary. No cumulative impact or residual impact is expected.

Annex 11A

List of Known Shipwrecks in the Study Area of HKSAR, Database from The United Kingdom Hydrographic Office (UKHO), Taunton

Latitude = 22 24'.800 N **Longitude =** 113 52'.460 E [WGD] **Square Number =** 1113
State = LIVE

Wreck Number 46602 **Classification** = Unclassified
Symbol OB 4.7 **Largest Scale Chart** = 4123
Charting Comments

Old Number 111301208
Category Undefined

WGS84 Position **Latitude =** 22 24'.800 N **Longitude =** 113 52'.460 E
WGS84 Origin Original
Horizontal Datum WGD WGS (1984)

Position Method
Position Quality Precisely known
Position Accuracy
Area at Largest Scale No

Depth 4.7 metres
Drying Height
Height
General Depth 5 metres
Vertical Datum Lowest astronomical tide
Depth Method
Depth Quality Least depth known
Depth Accuracy
Conspic Visual NO **Conspic Radar** NO
Historic NO **Military** NO **Existence Doubtful** NO
Non Sub Contact NO

Last Amended 12/07/2003
Position Last Amended 12/07/2003
Position Last **Latitude =** 22 24'.830 N **Longitude =** 113 52'.400 E

Name SHIROGANE MARU
Type SS
Flag JAPAN
Dimensions **Length =** 318.0 metres **Beam =** 45.0 metres **Draught =** 24.0 metres
Tonnage 3130
Cargo
Date Sunk 19/09/1942

Sonar Dimensions **Length =** **Width =** **Shadow Height =**
Orientation 157/337

Magnetic Anomaly
Debris Field
Scour **Depth =** **Length =** **Orientation =**

Markers
General Comments

Circumstances of Loss
**BUILT BY HARIMA SB & ENG CO IN 1938, OWNED AT TIME OF LOSS BY NIPPON KAIUN KK. SUNK BY US SUBMARINE AMBERJACK. (B. DILLON)
Surveying Details
**H5641/45 & H5641/46 9.10.45 DW (MAST) SHOWN IN 222454N, 1135215E ON SURVEY [E8612]. - NM1929/45.
**H05434/53 24.9.53 G CAN LT BUOY LAID CLOSE SE OF WK. (NIDO 14677/53). - NM 2230/53.
**H05434/53 12.12.53 AMEND BUOY TO G CAN, FL.G.6S 347DEG, 2.15M FROM TUNG KWR LT. (TAI-PEI NM 61/53). - NM 2935/53.
** 21.10.55 NOW CHARTED IN 222450N, 1135218E. (AUTHORITY NOT STATED) NC F6960.
**H05434/53 12.5.61 AMEND BUOY TO G CAN. (HONG KONG NM 18/61). - NM 1146/61.
**H05434/53 23.11.62 AMEND BUOY TO G CAN, GP.FL(2)G.10S. (HONG KONG NM 28/62). - NM 2506/62.
**H05434/53 7.1.63 AMEND POSN OF BUOY TO SE OF WK. (DIRECTOR OF MARINE HK). - NM 2762/62.
**H05434/53 13.11.68 WK 4.4MTRS SHOWN WITHOUT BUOY, ON WP 1125. - NM 2006/68.
**H4668/74 6.12.79 AMEND TO WK 2.9MTRS. (PRC NM 93/79). - NM 2981/79.
**9.2.81 POSN NOW 222442N, 1135222E. (AUTHORITY NOT STATED). NC 1555.
**7.2.86 WK 2.9MTRS SHOWN IN 222450N, 1135224E ON PRC 9456 [1985 EDN]. NE 342.
**H1354/87 20.10.87 WK 4.0MTRS SHOWN IN 222453.7N, 1135217.1E ON HK SURVEY. POSN FIXED BY MOTOROLA, DEPTH VERIFIED BY DIVER AS 4.0MTRS IN GEN DEPTH OF 7.0MTRS.
**20.9.89 SHOWN IN 222451N, 1135225E [CHINESE DATUM]. NC 343.

POSITIONS BELOW THIS POINT ARE IN DEGREES, MINUTES AND DECIMALS OF A MINUTE
**HH550/406/05 11.10.00 OBSTN 4.7MTRS SHOWN IN 2224.83N, 11352.40E [UND] ON HONG KONG 1503. - NM 3957/00.

**12.7.03 SHOWN IN 2224.800N, 11352.460E [WGD] ON HONG KONG 1503 [APR'00 EDN, ADOPTION]. NC 4123.

Latitude = 22 25'.783 N **Longitude =** 113 53'.267 E [UND] **Square Number =** 1113
State = DEAD

Wreck Number 46685 **Classification** = Unclassified
Symbol DW PA **Largest Scale Chart** = 342
Charting Comments

Old Number 111302158
Category Dangerous wreck

WGS84 Position **Latitude =** 22 25'.783 N **Longitude =** 113 53'.267 E
WGS84 Origin Undefined
Horizontal Datum UND UNDETERMINED

Position Method
Position Quality Approximate
Position Accuracy
Area at Largest Scale No

Depth
Drying Height
Height
General Depth 14 metres
Vertical Datum Lowest astronomical tide
Depth Method
Depth Quality Depth unknown
Depth Accuracy
Conspic Visual NO **Conspic Radar** NO
Historic NO **Military** NO **Existence Doubtful** NO
Non Sub Contact NO

Last Amended 05/05/2000
Position Last Amended
Position Last **Latitude =** **Longitude =**

Name
Type
Flag
Dimensions **Length =** **Beam =** **Draught =**
Tonnage
Cargo
Date Sunk ??/??/1994

Sonar Dimensions **Length =** **Width =** **Shadow Height =**
Orientation

Magnetic Anomaly
Debris Field
Scour **Depth =** **Length =** **Orientation =**

Markers
General Comments

Circumstances of Loss

Surveying Details
**HH550/408/01 8.4.94 DW PA IN 222547N, 1135316E [UND]. (CHINESE NM 5/40/94). - NM 1204/94.
**HH550/408/02 18.2.97 WK REPORTED REMOVED BY SHEKOU PILOTS. (ISLAND PRINCESS, UNDATED HN, REC 17.2.97). NCA YET.
**HH550/408/02 1.7.97 DW IN 222548N, 1135315E HAS NOT BEEN REMOVED. (CHINA NAVIGATION PRESS, LTR DTD 14.5.97). RETAIN AS DW. NCA.

POSITIONS BELOW THIS POINT ARE IN DEGREES, MINUTES AND DECIMALS OF A MINUTE
**HH550/408/03 5.5.00 WK HAS BEEN REMOVED. (HONG KONG, CHINA, MARINE DEPT, FAX DTD 2.5.00). AMENDED TO DEAD. - NM 2306/00.
**22.8.02 STILL SHOWN AS DW PA ON CHINESE 15445 [2002 EDN]. NCA, PRESUMED PRC CHART NOT UPDATED FOR HONG KONG MARINE DEPT NM ABOVE.

**HH550/408/04 18.2.04 DELETE. (CHINESE NM 3/59/04). NCA.

Section 12

Quantitative Risk Assessment

CONTENTS

12 QUANTITATIVE RISK ASSESSMENT

This section of the impact assessment presents a summary of the analysis and findings of the Quantitative Risk Assessment (QRA) study undertaken for the proposed natural gas subsea pipelines from the Mainland to Black Point Power Station (BPPS) and two Gas Receiving Stations (GRSs) at BPPS.

This section is divided into three sub sections: *Section 12.1* relates to the general aspects of the QRA study, *Section 12.2* relates to the subsea pipelines while *Section 12.3* relates to the GRSs.

Further details of the analysis pertaining to each facility are presented in the respective annexes; *Annex 12A* covers the subsea pipelines, *Annex 12B* covers the new GRSs, while *Annex 12C* conducts an assessment of the GRSs together with the existing GRS.

An additional annex is provided to summarise all the assumptions adopted in the QRA study (*Annex 12D*).

12.1 GENERAL

12.1.1 Legislation Requirement and Evaluation Criteria

The key legislation and guidelines that are considered relevant to the development of the proposed pipelines and GRS are as follows:

- *Gas Safety Ordinance*, Chapter 51
- *Hong Kong Planning Standards and Guidelines (HKPSG)*, Chapter 12
- *Dangerous Goods Ordinance*, Chapter 295
- *Environmental Impact Assessment Ordinance (EIAO)*, Chapter 499
- *The EIA Study Brief (ESB-208/2009), Section 3.4.9*

There is some overlap in the requirements of the various pieces of legislation and guidelines. The requirement for a Quantitative Risk Assessment study is contained in the *EIAO* and HKPSG. Such a study, although not required explicitly in the *Gas Safety Ordinance*, is implied in the regulations and has been an established practice for similar installations in the SAR.

12.1.2 EIAO Technical Memorandum (EIAO-TM)

The requirement for a QRA of projects involving storage, use and transport of dangerous goods where risk to life is a key issue with respect to Hong Kong

Government Risk Guidelines (HKRG) is specified in *Section 12* of the *EIAO-TM*.

The relevant authority for a QRA study relating to a natural gas pipeline and GRS is the Gas Standards Office (GSO) of the Electrical and Mechanical Services Department (EMSD), as specified in *Annex 22* of *EIAO-TM*.

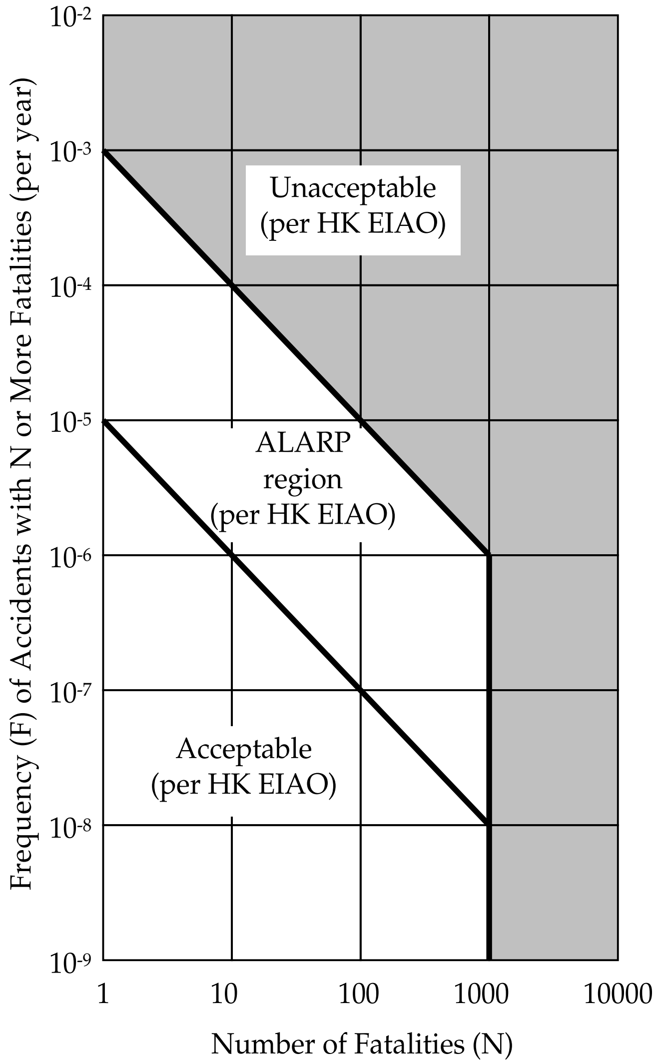
Annex 4 of *EIAO-TM* specifies the Individual Risk and Societal Risk Guidelines.

12.1.3 *Risk Measures and Hong Kong Government Risk Guidelines (HKRG)*

Individual risk is the predicted increase in the chance of fatality per year to a hypothetical individual who remains 100% of the time at a given stationary point. The individual risk guidelines require that the maximum level of off-site individual risk associated with a hazardous installation should not exceed 1 in 100,000 per year i.e. 1×10^{-5} per year.

Societal risk expresses the risks to the whole population. The HKRG is presented graphically in *Figure 12.1.* It is expressed in terms of lines plotting the frequency (F) of N or more deaths in the population from incidents at the installation. Two FN risk lines are used in the HKRG to demark "acceptable" or "unacceptable" societal risks. The intermediate region indicates the acceptability of societal risk is borderline and should be reduced to a level which is "as low as reasonably practicable" (ALARP). It seeks to ensure that all practicable and cost-effective measures which can reduce risks will be considered.

Figure 12.1 Hong Kong Government Risk Guidelines



12.1.4 *Study Objectives & Methodology*

The objective of the QRA study is to assess the risk to life of the general public including the workers of nearby plants from the proposed facilities during its operational phase. The results of the QRA are compared with the HKRG.

The detailed objectives of the study are:

- To identify all credible hazardous scenarios associated with storage, handling and operation of the pipeline and GRS facilities, which has potential to cause fatalities;
- To carry out the QRA expressing population risks in both individual and societal terms;
- To compare the individual and societal risks at the proposed development sites with the HKRG;

- To identify and assess practical and cost effective risk mitigation measures as appropriate; and

The elements of the QRA are shown schematically in *Figure 12.2*.

An overview of the methodology employed is provided here to briefly introduce the study approach, while the details are included in the respective sections/ annexes.

Relevant data on the proposed facilities such as their preliminary layout drawings and design basis as well as population data in the vicinity were collected and reviewed.

A Hazard Identification (HAZID) Study was conducted to identify all hazards, both generic and site specific. A review of literature and accident databases was also undertaken (*Annex 12A.4* and *Annex 12B.4*). These formed the basis for identifying all hazardous scenarios for the QRA Study.

The frequencies, or the likelihood, of the various outcomes resulting from a natural gas release scenario were derived from historical databases and, where necessary, these were modified to take into account local factors (*Annex 12A.5* and *Annex12B.5*).

For all identified hazards assessed as having a frequency of less than 10^{-9} per year, the frequency assessment will be documented but no quantification of consequences will be performed.

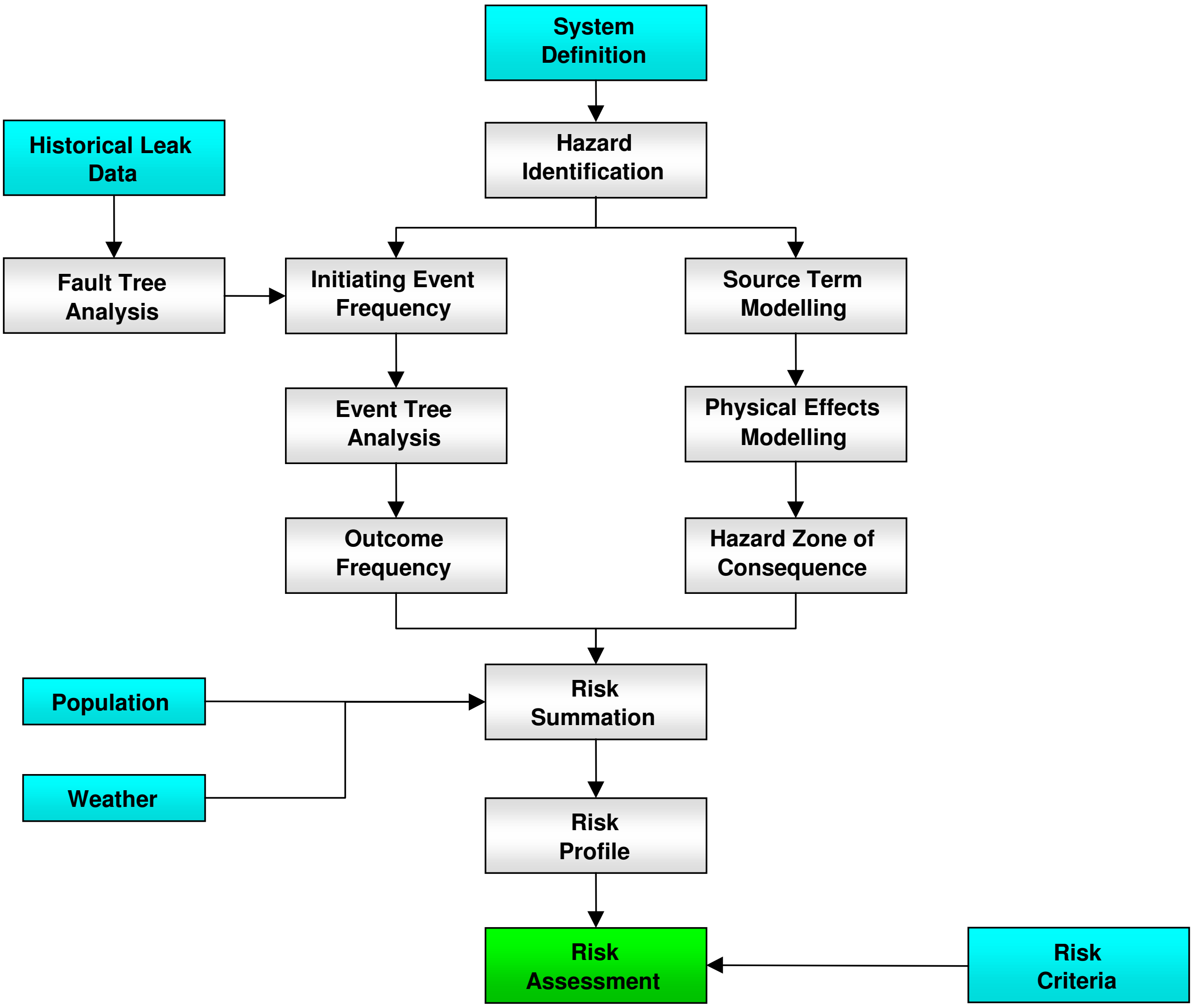
For hazards with frequencies greater than 10^{-9} per year, the consequences of each release were modelled.

Hydrocarbon releases have been modelled using the *PHAST* consequence modelling package developed by Det Norske Veritas, Inc. (DNV)

The consequence and frequency data were subsequently combined using ERM's proprietary software Riskplot™ to produce the required risk calculations.

Finally, the results from the risk assessment were compared with the HKRG and found to be acceptable. No mitigation measures are therefore proposed.

Figure 12.2 Schematic of QRA Process



12.2 PIPELINE

The proposed subsea pipelines will transport compressed natural gas from the Mainland to CAPCO's Black Point Power Station. Two pipelines are proposed and only 5 km of the pipeline alignment lies within Hong Kong SAR waters. It is this 5 km section of the route which is considered in this assessment. Details of the pipeline are preliminary at the time of writing but will likely consist of two pipes of between 32" and 42" diameter. These may be located in two separate trenches constructed about 2 years at different times and located 100 m apart. This section of the report presents a summary of the QRA study for the subsea pipelines while *Annex 12A* gives further details.

Whilst the construction of the first pipeline is expected to be in 2011, the construction of the second pipeline is expected to be in 2014. The additional risks arising from construction activities in 2014 (when the first pipeline is operational) are assessed but not found to be significant. Results are therefore presented for a single operational pipeline in 2011, and for 2 operational pipelines in the future year 2021. The assessment also takes into account the variation of marine traffic between 2011 and 2021.

12.2.1 *Pipeline and Marine Data*

Pipeline Route

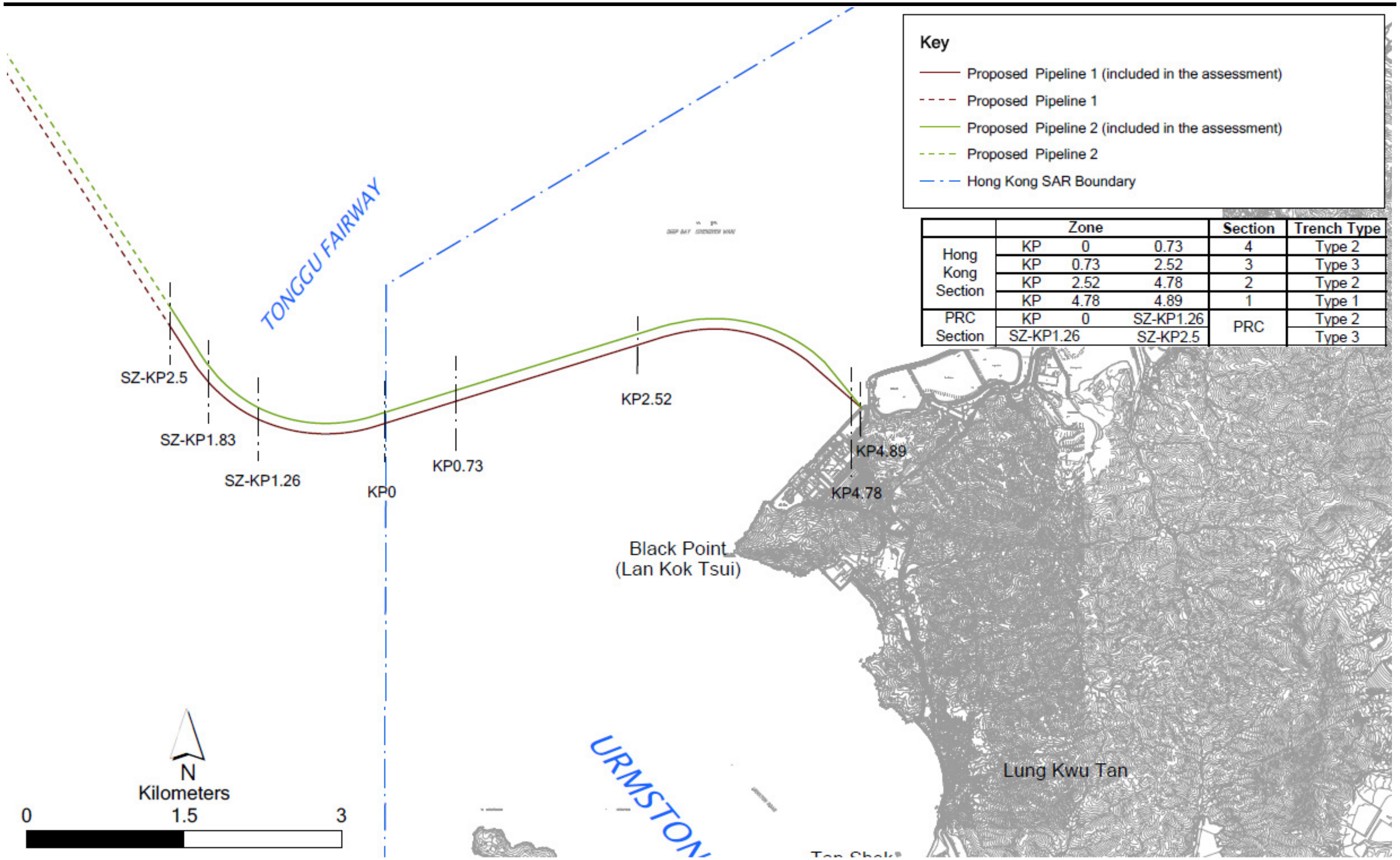
The proposed pipelines take a subsea route from the Mainland China to Black Point Power Station (*Figure 12.3*). The pipelines will cross the Urmston Road waterway (not a designated channel), and the Hong Kong section is only 5 km in length and passes about 100 – 200 m north of the existing Yacheng pipeline.

The pipelines will be buried to between 1.5 and about 5 m below the seabed with rock armour/ natural fill protection (*Figure 12.4*). Type 1 protection is used on the shore approach to Black Point and provides 1.5 m of rock armour backfill. This provides protection for anchors up to 3 tonnes, essentially protecting against anchors from all ships below about 10,000 dwt. Trench type 2 is used in shallow water areas away from the busy marine fairways. Trench type 2 consists of post-trenching with about 5 m of armour rock and natural backfill. This is designed for protection from 3 - 5 tonne anchors (i.e. from all ships below about 10,000 dwt) and any future dredging work. The Urmston Road waterway will have type 3 trenches consisting of 3 m of rock armour backfill. Type 3 is designed to protect against 19 tonne anchors. This covers the full range of ships currently operating in Hong Kong and also those expected in future.

Marine Traffic

A marine traffic assessment [1] studied the marine traffic in the vicinity of the pipeline using radar tracks. Based on the vessel speed and apparent size from the radar returns, vessels are divided into six categories (*Table 12.1*). The number of ships is also determined from the density of radar tracks. Although some interpretation of the data was required, the marine assessment provided the necessary information to determine the marine traffic volume crossing different sections of the pipeline.

Figure 12.3 Proposed Pipeline Alignment



		Zone		Section	Trench Type
Hong Kong Section	KP	0	0.73	4	Type 2
	KP	0.73	2.52	3	Type 3
	KP	2.52	4.78	2	Type 2
	KP	4.78	4.89	1	Type 1
PRC Section	KP	0	SZ-KP1.26	PRC	Type 2
	SZ-KP1.26		SZ-KP2.5		Type 3

Figure 12.4 Pipeline Trench Types

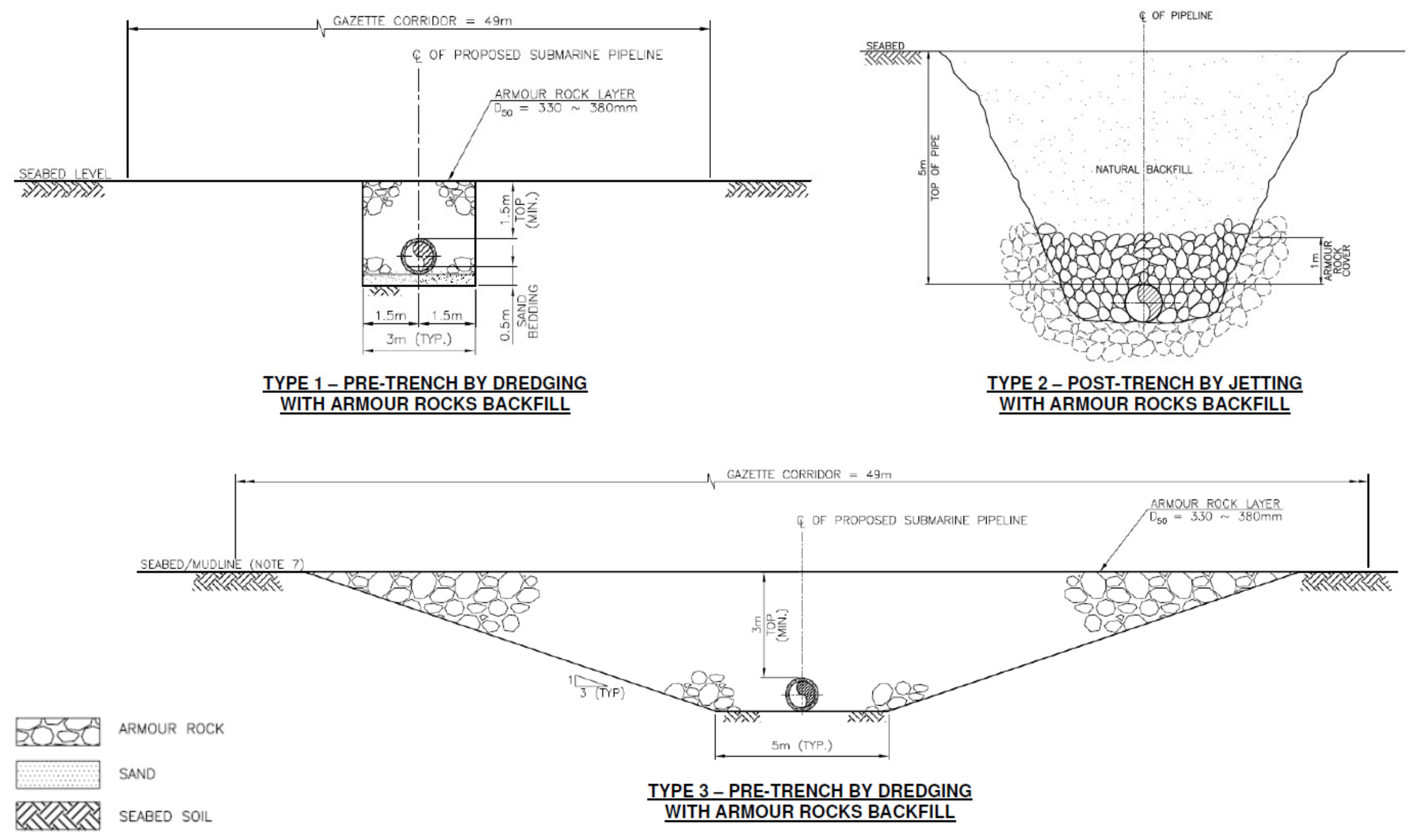
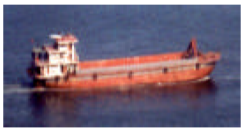


Table 12.1 Vessel Classes Adopted for Assessment

Class	Type	Typical Length (m)	Typical Beam (m)	Typical Draft (m)	Typical Displace -ment (tonnes)	Typical Anchor Size (tonnes)
"A1" - Fishing Vessels & Small craft		5 – 30	2 – 7.5	1 - 3	1 – 400	< 1
"B1" - Rivertrade coastal vessels		35 – 75	8 - 12	2.5 – 4.5	1,500	< 2
"C1" - Ocean-going Vessels		75 – 350	12 - 45	4 - 15	1,500 – 150,000	2 – 15
"A2" - Fast Launches and Fast Ferries		10 – 30	3 - 7.5	1 – 2.5	1 - 150	< 0.1
"B2" - Fast Ferries		30 - 50	7.5 - 12	1.5 - 2.5	100 – 150	< 0.5
"C2" - Fast Ferries & Ocean-going Vessel	*As above*					

It was also necessary to make some assumptions regarding the population of each class of vessel. These are given in *Table 12.2*.

Table 12.2 Vessel Population

Class	Population
Fishing vessels	5
Rivertrade coastal vessels	5
Ocean-going vessels	21
Fast launches	5
Fast ferries	450/350/280/175/105/35*
Other	5

* A distribution was assumed for the fast ferry population to reflect the occupancy at different time periods. This distribution is conservative when compared to the average load factor published by the Marine Department.

Segmentation of the Route

Based on considerations of the marine traffic data and the level of rock armour protection proposed for the pipeline, the pipeline route was divided into 4 sections for analysis (*Table 12.3*, *Figure 12.3*).

Table 12.3 Pipeline Segmentation

	Section	Kilometre Post From	Kilometre Post To	Section Length (km)	Typ. Water depth (m)	Trench type
4	Boundary Section	0	0.73	0.73	2-20	2
3	Urmston Road	0.73	2.52	1.79	20	3
2	Black Point West	2.52	4.78	2.26	5	2
1	Black Point Approach	4.78	4.89	0.11	2	1

The marine traffic used for this study, interpreted from vessel radar tracks [1], is as summarised in *Table 12.4*. Similar traffic tables were constructed for the future 2021 scenarios (*Tables 12.5*) by incorporating growth factors for the expected increase in traffic [1] These data take into account developments such as the Tonggu Waterway, which tends to shift ocean-going vessels away from Urmston Road and into Tonggu.

Table 12.4 Traffic Volume Assumed for Base Case 2011

		Traffic volume (ships per day)						
Section		Fishing	River-trade	Ocean-going	Fast Launch	Fast ferry	Other	Total
4	Boundary Section	21	3	0	24	30	8	86
3	Urmston Road	250	265	81	118	150	5	869
2	Black Point West	12	16	0	5	8	2	43
1	Black Point Approach	1	0	0	0	0	0	1
	Total	284	284	81	147	188	15	999

Table 12.5 Traffic Volume Assumed for Future Year 2021

		Traffic volume (ships per day)						
Section		Fishing	River-trade	Ocean-going*	Fast Launch	Fast ferry	Other	Total
4	Boundary Section	22	5	0	26	35	9	97
3	Urmston Road	262	290	81	129	177	6	945
2	Black Point West	12	17	0	6	9	2	46
1	Black Point Approach	1	0	0	0	0	0	1
	Total	297	312	81	161	221	17	1089

* The volume of ocean-going vessels through Urmston Road is expected to decrease due to the development of the Tonggu Waterway. However, as a conservative approach, the analysis assumes that ocean-going vessel traffic for 2021 and 2011 remain constant at 2003 levels.

Pipeline Protection

Varying levels of rock armour protection are proposed for each section of the pipeline based on earlier studies [2]. These levels of rock armour protection are assumed in the base case analysis as well as future traffic scenarios presented in this report.

12.2.2 *Methodology*

Key elements of the risk assessment methodology are described in the following sections.

Hazard Identification

Hazards were identified by reviewing worldwide databases [5], [6] and reports on incidents related to subsea pipelines [7], [8]. A HAZID (Hazard Identification) workshop was also conducted for the proposed pipeline to identify any route/site specific issues. The details of the hazard identification process are presented in *Annex 12A*.

The main hazard associated with a subsea pipeline is loss of containment resulting in gas release which could be ignited by a passing marine vessel. A loss of containment could occur from:

- Failures due to external impact (such as anchor drop/drag);
- Spontaneous failures from corrosion and material/weld defects; and
- Natural hazards (such as subsidence, seismic event).

Frequency Estimation

Frequency assessment is the estimation of the likelihood of occurrence of each scenario based on the hazard identification exercise. The approach adopted here for estimating frequency of pipeline failure is to apply worldwide historical data, with appropriate modifications for the specific pipeline environment.

The database that is most comprehensive and relevant is PARLOC 2001 [3]. This covers 300,000 km-years of subsea pipeline experience dating from the 1960s to 2000. This database provides failure frequencies for different causes such as corrosion, material defects, external impact etc. It also provides a breakdown by pipe diameter, location and contents of pipeline.

To validate this approach, particularly for anchor/impact damage where the specific marine traffic environment is more relevant, alternative calculations were performed for comparison. These were based on marine incident rates in Hong Kong waters, from which the likelihood of emergency anchoring events were estimated. This alternate approach was found to give similar failure frequencies to that derived from the PARLOC data. The frequencies used in the analysis are summarised in *Table 12.6* while details are presented in *Annex 12A*.

The CAPCO pipelines will have rock armour protection along its whole length. To allow for this, protection factors are incorporated into the analysis. Trench types 1 and 2 are designed to protect against 3 - 5 tonne anchors. They are assumed to be 99% effective. They are also assumed to provide some protection (50%) against larger anchors. Trench type 3 is designed to protect against 19 tonne anchors, covering all ships currently operating in Hong Kong and those expected in the future. This trench type was assumed to be 99% effective for large anchors and provide even greater protection (99.9%) against smaller anchors, i.e. below 2 tonnes (see *Table 12.6*). Note that the rock armour design will be finalised during the engineering stage based on these performance considerations. The above assumptions are therefore conservative.

The frequencies used in the analysis are summarised in *Table 12.6* while details are presented in *Annex 12A*. The probability of damage to the pipeline leading to a gas release is estimated as 0.0005 for the 5 km section during the lifetime of the facility, assumed as 25 years.

Table 12.6 Summary of Pipeline Failure Frequencies used in this Study

Pipeline section	Trench type	Corrosion /defects (/km/year)	Anchor/Impact			Others /km/year	Total* /km/year
			Frequency (/km/year)	Protection factor (%) anchor<2	Anchor>2		
Boundary Section	2	1.18×10^{-6}	1×10^{-4}	99	50	1.34×10^{-6}	3.5×10^{-6}
Urmston Road	3	1.18×10^{-6}	8.6×10^{-4}	99.9	99	1.34×10^{-6}	4.1×10^{-6}
Black Point West	2	1.18×10^{-6}	1×10^{-4}	99	50	1.34×10^{-6}	3.5×10^{-6}
Black Point Approach	1	1.18×10^{-6}	1.37×10^{-5}	99	50	1.34×10^{-6}	2.7×10^{-6}

* The calculation of total failure frequency takes into account the size distribution of ships (based on 2011 marine traffic) and the protection factors for anchors

Scenario Development

The outcome of a hazard is predicted using Event Tree Analysis (ETA) to investigate the way initiating events could develop. This considers the cause of failure, the hole size distribution, the likelihood that a marine vessel will be in the area and the probability that the gas will be ignited. Historical data is used where appropriate for the hole size distribution and ignition probability. The probability that a ship will pass through the flammable plume is calculated based on the size of the plume (obtained from dispersion modelling) and the marine traffic density.

Consequence Analysis

In the event of loss of containment in a subsea pipeline, the gas will release as a jet but is expected to lose momentum and bubble to the sea surface and disperse into the atmosphere as a buoyant gas. The dispersing plume may encounter an ignition source, say from a passing vessel, while within its flammable limits, leading to a flash fire, which will propagate through the gas cloud.

The flash fire could cause injury to personnel on marine vessels. It may also cause secondary fires on the vessel.

If a vessel passes close to the 'release area' (where bubbles of gas break through the sea surface), the vessel may be caught in the ensuing fire with more severe consequences. 100% fatality is assumed for this scenario. Once a fire has ignited, it is presumed that no further ships will be involved because the fire will be visible and other ships can take action to avoid the area. In other words, it is assumed that at most, only one ship will be affected.

12.2.3 Risk Results

Individual Risk

The individual risk (IR) is given in *Table 12.7*. The highest risks come from Urmston Road where the marine traffic is the highest. The individual risk for all sections, however, is less than 1×10^{-5} per year. Comparing the case of two operational pipelines with just one pipeline, the risk is essentially the same along most of the route since the 100m separation of the pipelines exceeds most of the hazard distances, i.e. there is little overlap of the risk contours. However, on the shore approach to Black Point, the pipeline alignments converge. The worst case IR is therefore about double the risk from a single pipeline, but this is still much below the 10^{-5} per year criterion.

Table 12.7 Individual Risk Results (per year)

Section		2011 1 pipeline	2021 2 pipelines
4	Boundary Section	9.2×10^{-8}	1.9×10^{-7}
3	Urmston Road	2.1×10^{-7}	4.3×10^{-7}
2	Black Point West	6.6×10^{-8}	1.3×10^{-7}
1	Black Point Approach	9.9×10^{-9}	2.0×10^{-8}

Societal Risk Results

Societal risks are presented in terms of per km to give a uniform basis for comparison between the various sections. Again, the highest risks are associated with Urmston Road (*Table 12.8*). The total Potential Loss of Life (PLL), or equivalent annual fatality, for the whole length of pipeline ranges from 2.0×10^{-5} per year for a single pipeline in 2011 to 4.2×10^{-5} per year for two pipelines in operation in 2021. Marine population differences between 2011 and 2021 are only marginal and hence the societal risk from two pipelines is essentially double that from a single pipeline.

Table 12.8 Potential Loss of Life Results (per km-year)

Section		2011 1 pipeline	2021 2 pipelines
4	Boundary Section	5.4×10^{-6}	1.1×10^{-5}
3	Urmston Road	5.8×10^{-6}	1.3×10^{-5}
2	Black Point West	2.5×10^{-6}	5.1×10^{-6}
1	Black Point Approach	5.0×10^{-8}	1.1×10^{-7}
	Total	2.0×10^{-5}	4.2×10^{-5}

The FN curves for each section are presented in *Figures 12.5* and *12.6.* These are also expressed on a per km basis for comparison with the HKRG.

The FN curves also show that the highest risks are associated with Urmston Road. Despite the high level of pipeline protection, the marine traffic volume is very high along this section. The approach to Black Point shows the lowest risks due to the very low marine activity in this area.

The FN curves for all sections of the pipeline lie within the *Acceptable Region*.

Figure 12.5 FN Curve for Single Pipeline in 2011

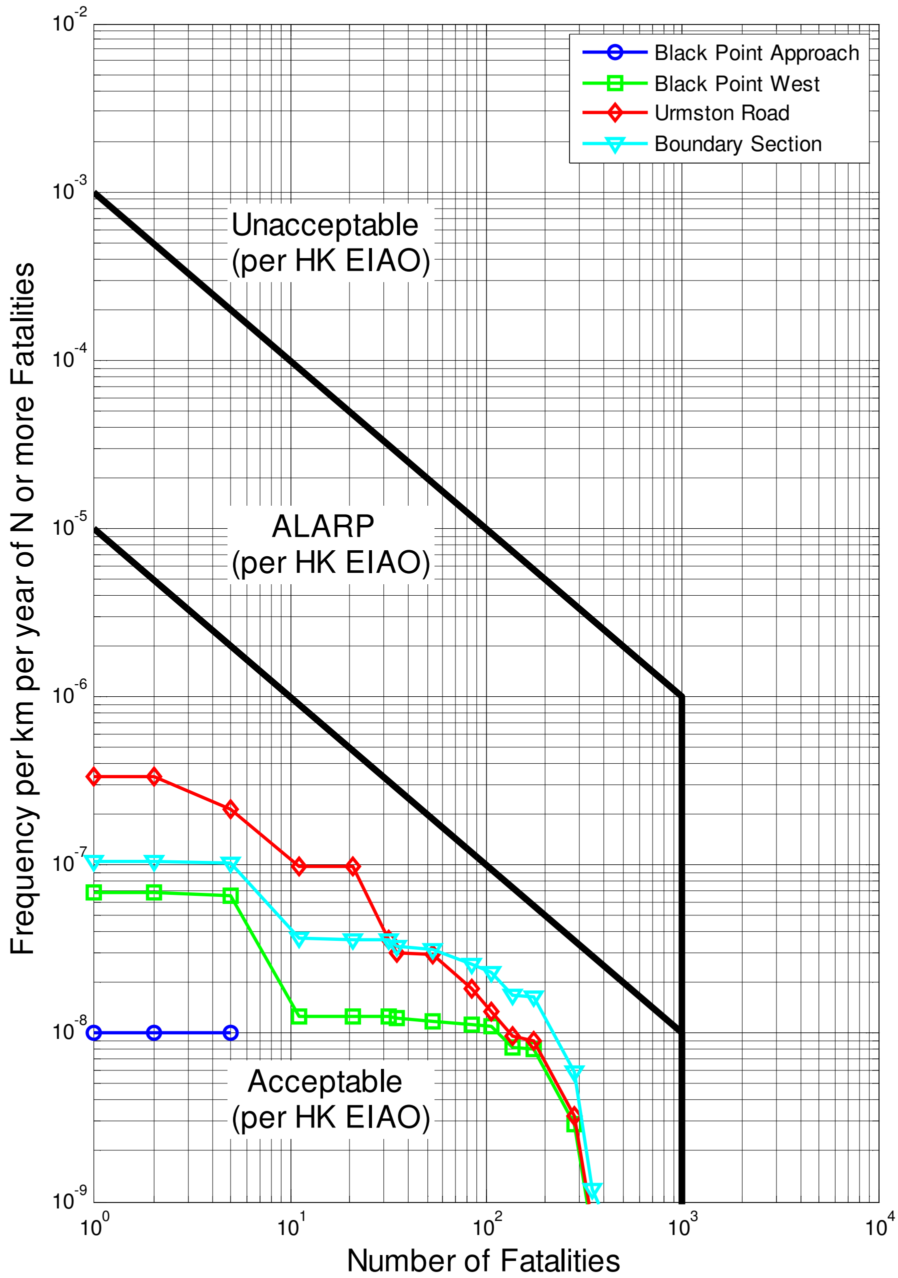
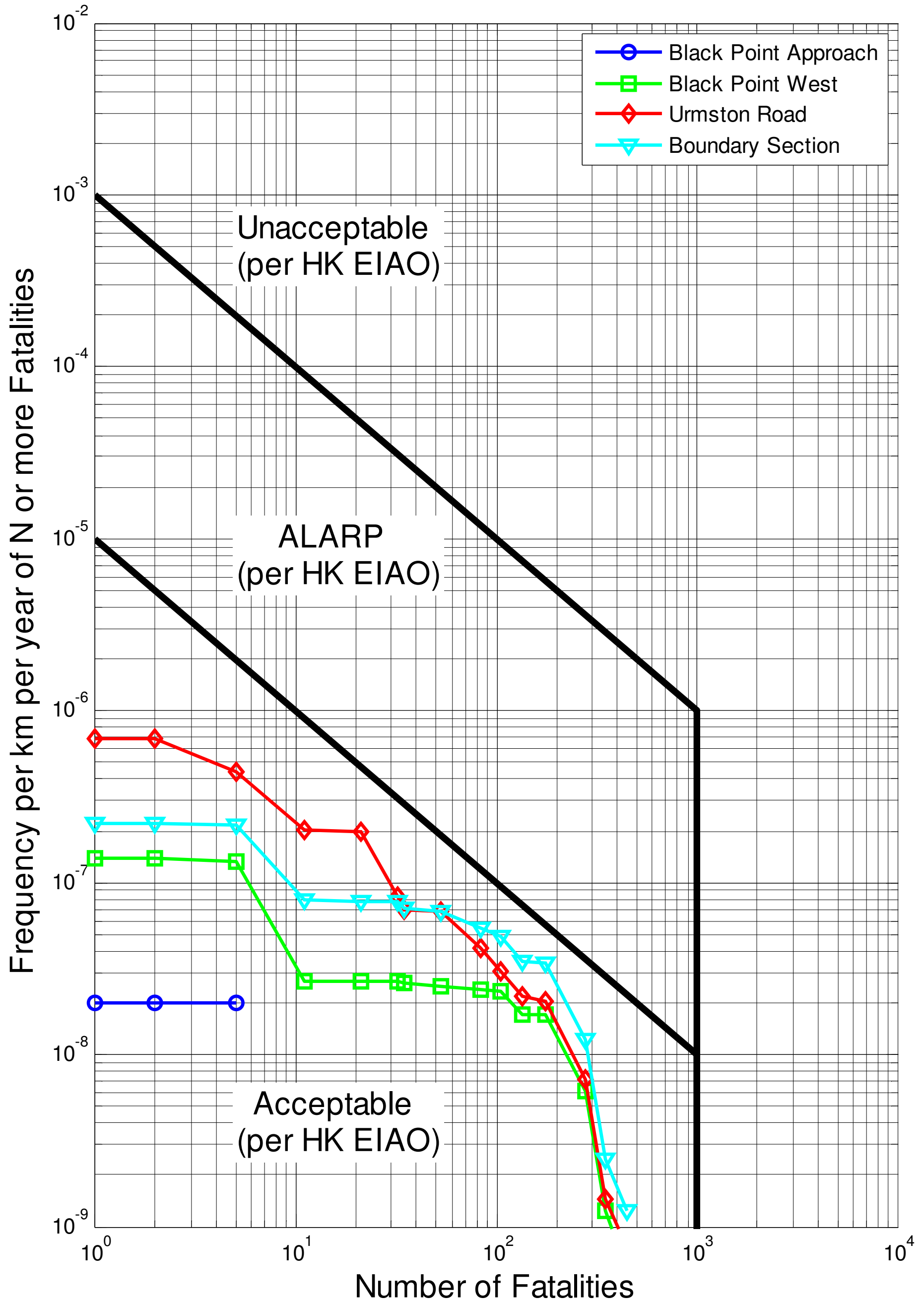


Figure 12.6 FN Curve for Two Pipelines in 2021



12.2.4 *Conclusions of Pipeline QRA Study*

A QRA study for the proposed CAPCO pipelines was conducted. The study considered the loss of containment that may occur due to all possible events, of which corrosion, material defects and third party damage from ship anchor drops/drags were identified as the major risk contributors. Based on a review of the hazards, the marine traffic density and pipeline rock armour protection, the 5 km pipelines within Hong Kong SAR waters was divided into four sections for assessment. Risks have been presented for each section on a per-km basis to provide a uniform basis for comparison.

The base case calculation used marine traffic data for 2011 and levels of rock armour protection for each section as proposed in the pipeline design. A future year 2021 was also assessed.

The calculated levels of risk were compared with the HK EIAO and the following conclusions were drawn:

- The FN curves for all sections of the pipeline lie within the *Acceptable Region*.
- The highest risks are generally associated with Urmston Road where the marine traffic has the highest density.
- IR for all sections are predicted to be less than the 1×10^{-5} per year as per HK EIAO criterion.

It is concluded that for all sections, the risks are acceptable per *HK EIAO* and no further mitigation measures are warranted for the pipelines.

12.3 GAS RECEIVING STATIONS (GRSS)

The proposed pipelines from the Mainland China will terminate at two gas receiving stations (GRSs) at BPPS. One will be located adjacent to the existing GRS (co-located GRS), the second will be located on reclaimed land to the north of the BPPS site (GRS on reclamation). The two GRSs are not expected to be constructed concurrently. The co-located GRS will be constructed in 2011 (i.e. First Phase construction) while the construction of the GRS on reclamation is expected to commence in 2014. Therefore, the following 3 cases were considered in the QRA:

- "Scenario 2011" considers the risks from the co-located GRS operating only;
- "Scenario 2014" considers the risks from the co-located GRS operating during construction of the GRS on reclamation; and
- "Scenario 2021" considers the risks from both co-located GRS and GRS on reclamation operating at the same time.

This section provides the QRA results for the GRSs.

12.3.1 *Methodology*

Details of the QRA analysis are provided in *Annex 12B*. A brief summary is provided here.

Each GRS will contain a pig receiver, inlet filter-separators, metering, pre-heaters and a pressure letdown station. An emergency isolation valve will be provided at the inlet to the station and also for individual section isolation in the event of any emergency. Process flow diagrams are included in *Annex 12B*.

The methodology for the QRA includes the identification of surrounding population, identification of hazards, frequency analysis, consequence analysis and risk summation.

Site Details

The BPPS is located in a remote area with very low levels of surrounding population. For the purpose of this QRA, the site is considered to include the new GRS facilities and the reclaimed land. There is no land based population that may be impacted by any gas releases from the GRS facilities. The main population that may be impacted is the marine population.

The effects of gas releases from the facility depend on weather conditions. Meteorological conditions from the most recent 5 years of data from Sha Chau Weather Station, obtained from the Hong Kong Observatory, were used in the analysis.

Scenario Definition

The identification of hazards was based on a review of past incidents at similar facilities worldwide and a HAZID workshop. The GRS facilities contain natural gas under high pressure, the main hazards of which are associated with the flammable properties of natural gas and the possibility of leaks followed by ignition. This may result in jet fires, fireball and flash fires.

Once the main hazards are understood, the facility is divided into sub-sections for further analysis. Nine sections were chosen for the current analysis, ranging from pig receiving facilities to the downstream distribution headers. A range of leak sizes, from small leaks to full ruptures, are considered in the analysis.

Frequency Analysis

The frequency of leaks and ruptures from each section of the GRS was estimated from published generic failure rates [4]. Event Tree Analysis is then used to model the development of releases into the final outcomes such as jet fires and flash fires. Special consideration was given to pigging operations which may lead to releases caused by human error.

Consequence Analysis

The PHAST suite of models is used to determine the hazard footprint for each leak scenario. This includes the modelling of discharge rates, dispersion and thermal radiation for jet fires, flash fires and fireballs.

12.3.2 Results

Individual Risk Results

The individual risk (IR) contours associated with the co-located GRS with 2011 population are shown in *Figure 12.7*. The maximum risk is less than 1×10^{-5} per year at all locations and hence meets the HKRG requirements. The IR for the construction phase in 2014 is the same since both cases have only one GRS operating and IR is independent of population.

IR for the future year 2021 is shown in *Figure 12.8*. With two GRSs operational, the IR has increased but remains below 10^{-5} per year at the site boundary and hence meets the HKRG requirements.

Figure 12.7 Individual Risk Contours (2011 and 2014)

Individual Risk Contour (2011)

Individual Risk Contour (2014)

10^{-6} per year

Figure 12.8 Individual Risk Contours (2021)

10^{-6} per year

Societal Risk Results

The potential loss of life for the gas receiving station is given in *Tables 12.9* to *12.11*. Values are very low for 2011, 2014 and 2021 given the low offsite population in the vicinity. The total PLL, respectively, is 1.49×10^{-8} per year for year 2011, 1.49×10^{-8} per year for year 2014, and 1.52×10^{-7} per year for year 2021, or equivalently, estimated one fatality every 10 million years.

It can be observed that the risks are higher for 2021 compared to 2011. This is due to two GRSs in operation instead of one. Also, the second GRS on reclaimed land is closer to the only affected population, the marine population.

Table 12.9 Potential Loss of Life (Year 2011 and 2014)

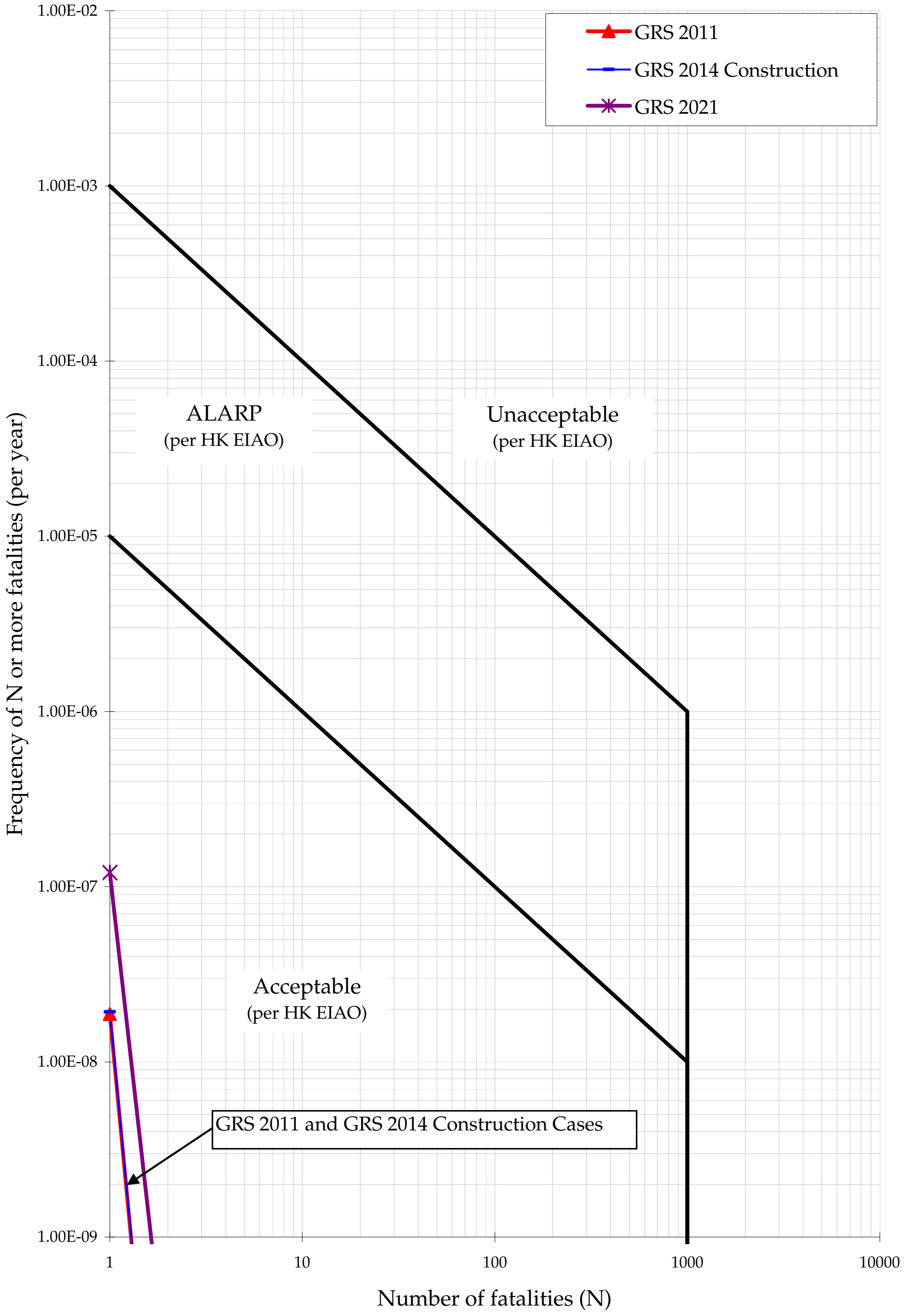
Section		PLL (per year)	
Piping from PRS to mixing station	G08	4.27×10^{-9}	28.5%
Heater Piping	G06	3.12×10^{-9}	20.8%
Pig receiver	G09	3.03×10^{-9}	20.3%
Piping from metering station to heaters	G05	2.25×10^{-9}	15.1%
Above ground gas piping from offshore pipeline to pig receiver	G01	1.33×10^{-9}	8.9%
Filter & inlet/outlet piping	G03	9.51×10^{-10}	6.4%
Total		**1.49×10^{-8}**	

Table 12.10 Potential Loss of Life (Year 2021)

Section		PLL (per year)	
Heater Piping	G06_B	3.94×10^{-8}	25.9%
Piping from metering station to heaters	G05_B	3.03×10^{-8}	19.9%
Piping from PRS to mixing station	G07_B	1.43×10^{-8}	9.4%
Above ground gas piping from offshore pipeline to pig receiver	G01_B	1.39×10^{-8}	9.1%
Piping from PRS to mixing station	G08_B	8.86×10^{-9}	5.8%
Pig receiver	G09_B	8.47×10^{-9}	5.6%
Filter & inlet/outlet piping	G03_B	7.86×10^{-9}	5.2%
Piping from PRS to mixing station	G08_B	7.73×10^{-9}	5.1%
Piping from PRS to mixing station	G08_A	3.72×10^{-9}	2.4%
Others		1.76×10^{-8}	
Total		**1.52×10^{-7}**	

Figure 12.9 shows the FN Curves for the GRS at the BPPS. It can be seen that the societal risk for the GRS is very low and within the *Acceptable Region* as per HK EIA Ordinance. The risk increases slightly during the construction phase due to increase in surrounding population (marine only), but the risks are still low and in the acceptable region.

Figure 12.9 *FN Curves for GRS*



The FN curve presented in *Figure 12.9* presents the results for the year 2014 when one GRS is in operation and the other one in construction. The analysis shows that risks to the offsite population will remain low and within acceptable region.

Risks Associated with the Existing GRS

As per the requirements set out in the EIA Study Brief (ESB-208/2009) the risks arising from the two new GRSs were assessed and found acceptable as compared to the criteria (as depicted in *Figure 12.9*). In addition to this, a quantitative assessment was conducted considering the hazards associated with the existing GRS. A summary of this assessment is provided in the following paragraphs while the detailed assessment is presented in *Annex 12C*. It should be noted that such an assessment is additional to the requirements by the EIA Study brief of the project.

Individual risks associated with the facilities, including the existing GRS and two new GRSs, meet the HKRG.

Societal risks associated with the operational phases of the project (including all 3 GRSs) are low and lie in the acceptable region of the FN curves.

Societal risks increase slightly during the construction phase due to slight increase in offsite population, which are at similar separation distances to the new GRSs. Recommendations are made in accordance with best practice to mitigate these construction phase risks:

- The most hazardous maintenance operations on the existing GRS will be avoided during the construction of the GRS on reclamation.
- Procedures for evacuation of construction workers will be in place in case of particularly hazardous operations on existing GRS and co-located GRS.
- Specific emergency procedures will be put into place for the evacuation of construction workers.
- Additional gas detectors along the boundary or gas and fire alarms for the detection from the GRSs in operation for escape and evacuation of construction workers will be considered.
- The construction of a temporary steel wall or other appropriate barrier between the existing GRS and the GRS on reclamation will be considered to prevent gas spreading towards the construction site in case of a gas leak in the existing GRS. This will also prevent the gas coming in contact with the ignition sources at the construction site, limit exposure of personnel to any direct flame from the existing GRS and provide time for construction personnel to evacuate the site.

These same recommendations may also be considered for the construction of the co-located GRS. Even though the separation distance to the existing GRS is greater, these recommendations would provide additional mitigation.

- During the construction of the co-located GRS and the GRS on reclamation, risks to the existing gas pipeline and the existing GRS could increase due to inadvertent damage caused by construction activity in the vicinity of existing installation. These risks will be managed by special procedures, for construction, and monitoring/supervision. This will include for example, a Job Safety Study conducted to assess the potential risk and failure modes of such construction operations and special precautions will be included in the procedures.

12.3.3 *Conclusions of GRS QRA Study*

A QRA study for the proposed CAPCO GRSs was conducted. Risks associated with the operational and construction phases of the facility are calculated to be low and within the HK EIAO criteria. No further mitigation measures are warranted for the GRSs.

In addition to the requirements set out in the EIA study Brief of the project, a quantitative assessment was performed in *Annex 12C* considering the aggregated risks from the new and the existing GRSs. The results show that the risks are acceptable during both phases of construction. Mitigation measures, in accordance with best practices, were proposed and detailed in *Annex 12C*.

12.4 REFERENCES

[1] BMT Asia Pacific Ltd, Marine Impact Assessment for Black Point & Sokos islands LNG Receiving Terminal & Associated Facilities, Pipeline Issues, Working Paper #3, Issue 5, Apr 2006.

[2] ERM-Hong Kong Ltd., Liquefied Natural Gas (LNG) Receiving Terminal and Associated Facilities EIA Report, October 2006.

[3] PARLOC 2001: The Update of Loss of Containment Data for Offshore Pipelines, 5th Edition, Health & Safety Executive, 2003

[4] Hawksley, J.L., Some Social, Technical and Economic Aspects of the Risks of Large Plants, CHEMRAWN III, 1984

[5] UK AEA, Major Hazard Incident Database (MHIDAS) Silver Platter.

[6] Institution of Chemical Engineers UK, The Accident Database, Version 2.01

[7] National Transportation Safety Board, Natural gas Pipeline Rupture and Fire During Dredging of Tiger Pass, Lousiana, October 23, 1998.

[8] National Research Council, Improving Safety of Marine Pipelines, 1994.

Annex 12A

Quantitative Risk Assessment (QRA) for Submarine Gas Pipelines

CONTENTS

12A QUANTITATIVE RISK ASSESSMENT FOR SUBMARINE GAS PIPELINES

12A.1 INTRODUCTION

This *Annex* covers details of the Quantitative Risk Assessment (QRA) for the two subsea pipelines from the Mainland China to Black Point Power Station. Details of the methodology are presented here whilst the results and conclusions are given in *Section 12* of the *EIA Report*.

Two 20 km pipelines are proposed, although and only 5 km of the pipeline alignment lies within Hong Kong SAR waters. It is this 5 km of pipelines that are the subject of this analysis.

The first pipeline will likely be completed towards the end of 2011 and so the assessment considers the population in this year as the base case. Construction of the second pipeline will likely take place in 2014. A future scenario is also considered for the year 2021 when both pipelines will be operational.

12A.2 DATA COLLECTION & REVIEW

The proposed pipelines from the Mainland China to Black Point are in many ways similar to the subsea pipeline that was proposed as part of the LNG terminal project for South Soko. The section of pipeline within Hong Kong SAR waters, for example, follows a similar alignment. Relevant information from these earlier studies has therefore been referenced where appropriate. The following information was reviewed and formed the basis of this study:

- Project Profile, ERM [1];
- Drawing HKLNG-WPL-00-PIIP-PL-009 detailing the pipeline trenching and backfill details, Worley Parsons [2];
- Marine vessel density data, BMT [3];
- Marine traffic data in Hong Kong waters, Marine Department (MD) [4, 5];
- UK Loss of Containment Database for Offshore Pipelines [6];
- Hydrographic & Geophysical Survey of the Seabed, EGS [7]; and
- Environmental and Risk Assessment Study for a LNG Terminal in Hong Kong, ERM [8].

12A.3 PIPELINE & MARINE DATA

This section of the report describes the subsea pipelines, their environment and details of marine traffic along the proposed route.

12A.3.1 *Subsea Pipelines*

The proposed pipelines take a subsea route from the Mainland China to Black Point Power Station. The pipelines will cross the Urmston Road waterway (not a designated channel) and only 5 km is within Hong Kong SAR waters (*Figure 12A.1*). The Hong Kong section passes about 100-200 m north of the existing Yacheng pipeline. The seabed for much of the route is classed as very soft clay [7]. The water depth varies between 2 and 20 m, with the deeper sections corresponding to the busy Urmston Road fairway.

Details of the pipeline are preliminary at the time of writing but will likely consist of two pipes of between 32" and 42" diameter. These will be located in separate trenches constructed about 2 years apart. These differences are not expected to make significant differences in the risk results but where there is uncertainty in the design, the analysis has made assumptions that err on the conservative side. For example, the larger diameter of 42" has been assumed in the analysis since this creates a larger gas inventory. Construction of the pipelines at different times has also been considered.

The operational pressure within the pipelines is expected to be 63 barg, however, the maximum operating pressure of 100 barg (design pressure) is used in the analysis, again as a conservative upper limit. The pipelines will have an anti-corrosion coating and sacrificial anodes for external corrosion protection and an outer layer of reinforced concrete for buoyancy control and to provide mechanical protection during pipeline installation and trenching operations. A summary of the pipeline details is given in *Table 12A.1*.

The composition of the gas is mainly methane (85-99.5 mol%) and is such that no internal corrosion is expected.

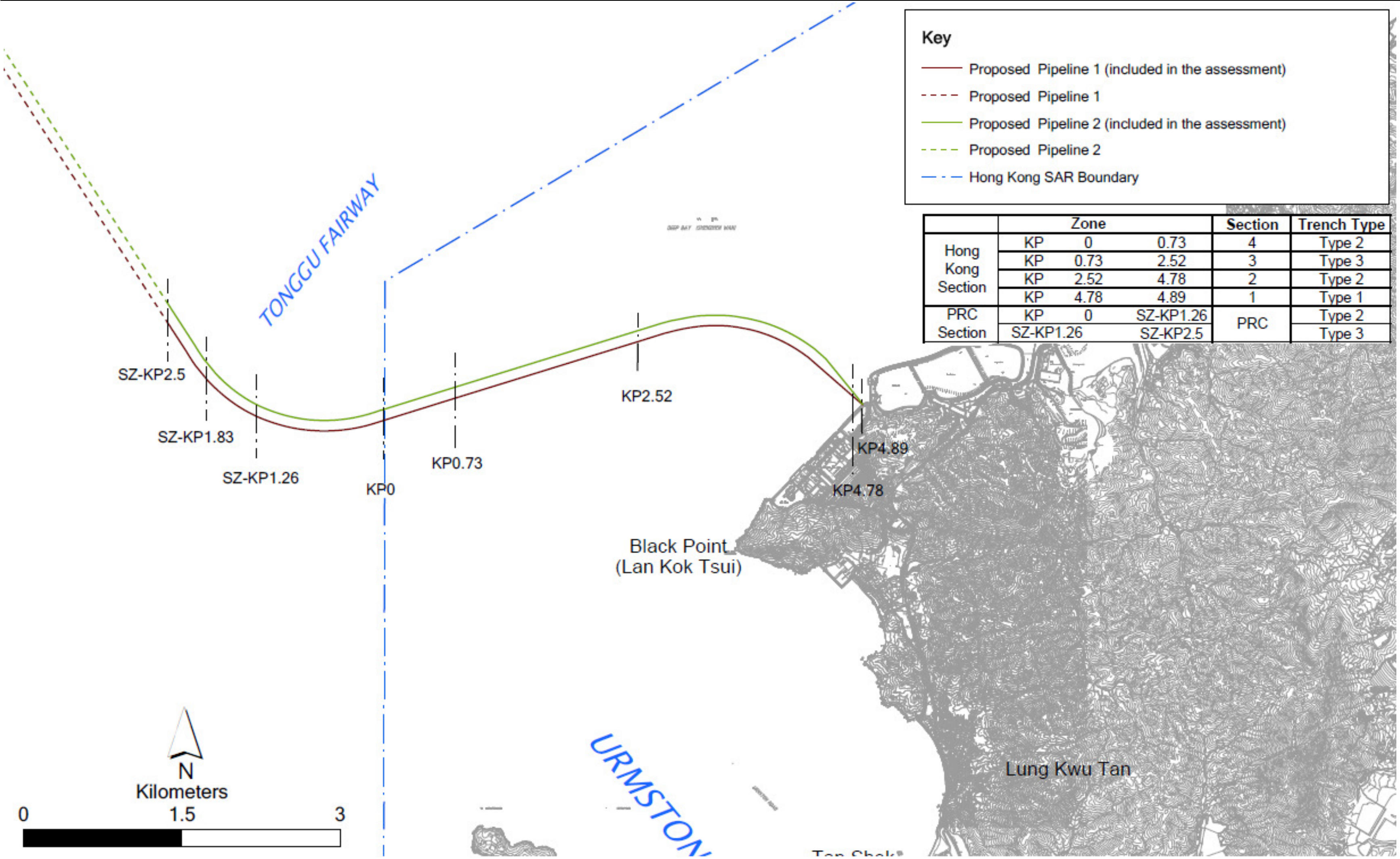
The pipelines will be buried below the seabed with varying levels of rock armour protection (*Figures 12A.1* and *12A.2*). Type 1 trenching will be used for the approach to Black Point. The type 1 trench involves dredging with 1.5m of rock armour backfill (measured from the top of the pipeline). This provides protection for anchors up to 3 tonnes, essentially protecting against anchors from all ships below about 10,000 dwt. Trench type 2 is used in shallow water areas away from the busy marine fairways. Type 2 consists of post-trenching with about 5 m of armour rock and natural backfill. This is designed for protection from 3 - 5 tonne anchors (i.e. from all ships below about 10,000 dwt) and any future dredging work.

Table 12A.1 Summary of Pipeline Details

Parameter	Details
Location	Mainland to Black Point Power Station
Length	20 km
Outside diameter	42″
Nominal wall thickness	1″
Line pipe grade	API 5L X70
External coating	anti-corrosion coating
Cathodic protection	Aluminium based sacrificial anodes
Design flowrate	1200 MSCFD
Design pressure	100 barg
Delivery pressure	63 barg
Maximum delivery pressure	100 barg
Pressure assumed for analysis	100 barg
Operating temperature	12 °C
Water depth	2 – 20 m
Seabed soil	Very soft clay becoming firmer with depth
Pipeline protection	Up to 3m cover with rock armour backfill
Design life	25 years

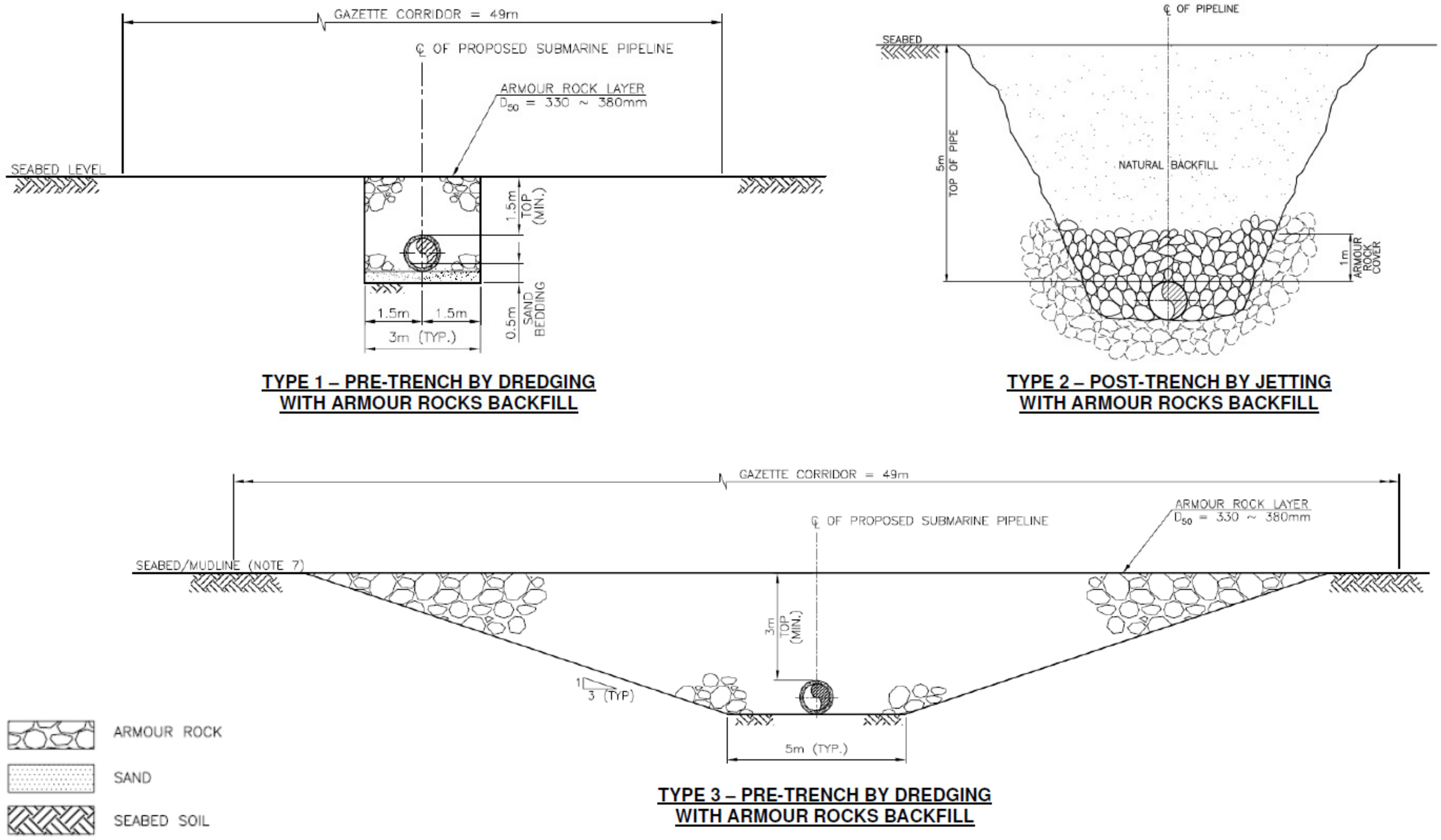
The busy waterway of Urmston Road will have type 3 trenches. This consists of pre-trenching with 3m of rock backfill. This is designed to protect against 19 tonne anchors. This covers the full range of ships currently operating in Hong Kong and also those expected in future.

Figure 12A.1 Pipeline Alignment and Trench Type



	Zone			Section	Trench Type
Hong Kong Section	KP	0	0.73	4	Type 2
	KP	0.73	2.52	3	Type 3
	KP	2.52	4.78	2	Type 2
	KP	4.78	4.89	1	Type 1
PRC Section	KP	0	SZ-KP1.26	PRC	Type 2
	SZ-KP1.26		SZ-KP2.5		Type 3

Figure 12A.2 Pipeline Trench Types



12A.3.2 *Marine Traffic*

The marine traffic influences the risks from the pipeline in two ways:

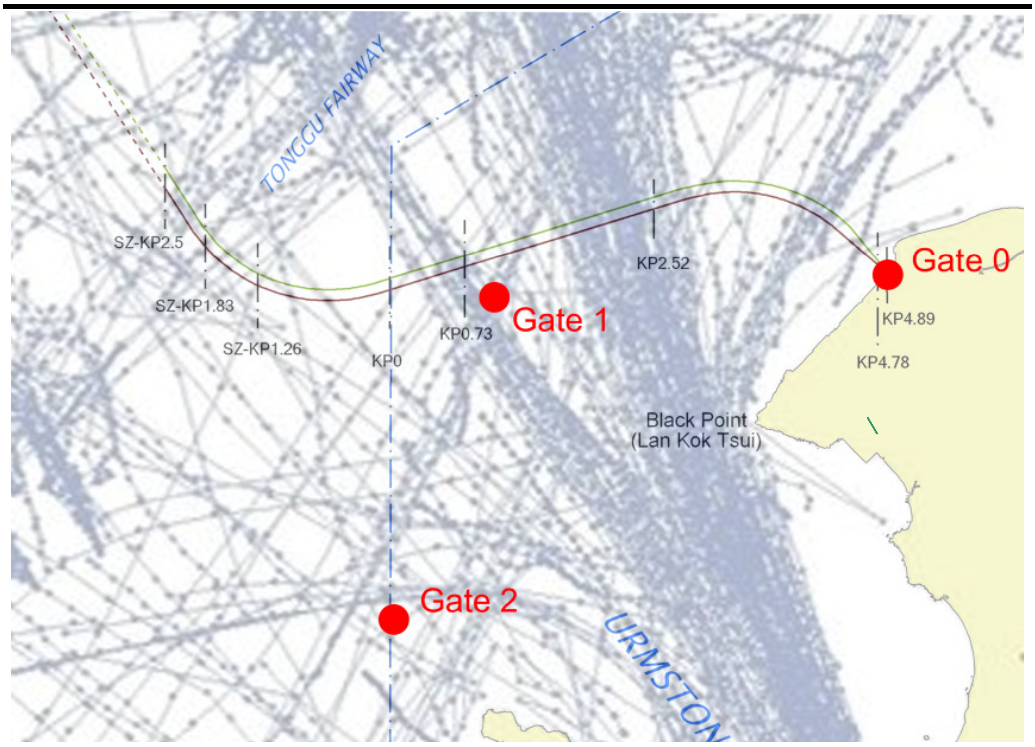
- It increases the potential for damage due to interference such as anchor drop/drag incidents; and
- In the event of a pipeline failure, marine traffic could exacerbate the consequential effects causing fatalities.

The marine vessel traffic volume was surveyed by BMT [3] using tracks of vessel movements obtained from radar (*Figure 12A.3*). Details from the BMT report that are pertinent to the current study are summarised below.

Marine Vessel Activity along Pipeline Route

The marine traffic report [3] divided the previous South Soko to Black Point pipeline route into sections using 'gate posts' that roughly corresponded to key locations along the alignment. Three of these gate posts remain applicable to the current study and were used to estimate marine traffic crossing the 5 km of pipeline within Hong Kong SAR waters (*Figure 12A.3*).

Figure 12A.3 Radar Tracks of Marine Traffic



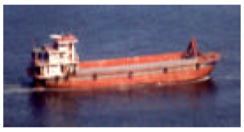
The section between gates 1 and 2 is used by fishing vessels and some rivertrade vessels en route between Tuen Mun and Zhuhai. The water is shallow in this region, ranging from 2 - 5 m deep. This precludes its use by large draft vessels.

Gate posts 0 and 1 span Urmston Road. Urmston Road is the main route for container ships, rivertrade vessels and fast ferries plying between Hong Kong and the ports of the Eastern Pearl River Delta.

Vessel Types

The marine traffic consultant calculated the marine traffic volume between pairs of gate posts based on radar tracks [3]. The vessel speeds and apparent size from the radar returns are interpreted into 6 marine vessel categories (*Table 12A.2*). The same categories are used for the current study.

Table 12A.2 Vessel Classes Adopted for Assessment

Class	Type	Typical Length (m)	Typical Beam (m)	Typical Draft (m)	Typical Displace -ment (tonnes)	Typical Anchor Size (tonnes)
"A1" - Fishing Vessels & Small craft		5 – 30	2 – 7.5	1 - 3	1 – 400	< 1
"B1" - Rivertrade coastal vessels		35 – 75	8 - 12	2.5 – 4.5	1,500	< 2
"C1" - Ocean-going Vessels		75 – 350	12 - 45	4 - 15	1,500 – 150,000	2 – 15
"A2" - Fast Launches and Fast Ferries		10 – 30	3 - 7.5	1 – 2.5	1 - 150	< 0.1
"B2" - Fast Ferries		30 - 50	7.5 - 12	1.5 - 2.5	100 – 150	< 0.5
"C2" - Fast Ferries & Ocean-going Vessel	*As above*					

Based on this vessel classification, the population used in this study are as given in *Table 12A.3*. The maximum population of fast ferries is assumed to be 450, based on the maximum capacity of the largest ferries operating in the area. However, the average load factor of ferries to Pearl River ports is only 31.8% [9]. Hence, a distribution in ferry population was assumed as indicated in *Table 12A.3*. This distribution gives an overall load factor of about 58% which is conservative and covers any future increase in vessel population. There is an additional category in the traffic volume data called 'Others' (see *Section 12A.3.2*). These are assumed to be small vessels with a population of 5.

Table 12A.3 Vessel Population

Class	Population	
Fishing vessels	5	
Rivertrade coastal vessels	5	
Ocean-going vessels	21	
Fast launches	5	
Fast ferries	450 (largest ferries in peak hours, 4 hours a day)	3.75% of trips
	350 (average ferry in peak hours, 4 hours a day)	3.75% of trips
	280 (80% capacity, peak hours, 4 hours a day)	22.5% of trips
	175 (50% capacity, daytime operation, 9 hours a day)	52.5% of trips
	105 (30% capacity, late evening, 4 hours a day)	12.5% of trips
	35 (10% capacity, night time, 7 hours a day)	5% of trips
Others	5	

Traffic Volume

The traffic volume as provided by BMT [3] is given in *Table 12A.4*. This is based on radar tracks for the year 2003. The current study takes year 2011 as the base case since this is the expected year of completion of the pipeline. A future case, year 2021, is also considered. BMT provided predictions for the traffic increase to years 2011 and 2021 (*Table 12A.5*). The traffic growth rates presented in *Table 12A.5* do not take into account the development of the Tonggu Waterway which has been implemented recently. This is expected to shift ocean-going vessels away from Urmston Road and into Tonggu instead. This is taken into account in the assessment by conservatively assuming that ocean-going vessel traffic remains at 2003 levels.

The data in *Table 12A.4* required further interpretation. Vessel class A2 is described as fast launches and fast ferries. The population of a fast launch is very different from that of a fast ferry and so a more precise breakdown is required. Some of these A2 fast ferries clearly belong in class B2 with the other fast ferries. Taking into consideration the timetable of ferries serving the Pearl River ports and information provided by the marine consultant [10], it was established that 55% of fast vessels along Urmston Road are fast ferries.

Class C2 is described as fast ferries and ocean-going vessels. Since all fast ferries have now been accounted for, class C2 are assumed to comprise of cargo ships only.

The data shows a small number of ocean-going vessels (class C1 and C2) along the route between gates 1 and 2. The shallow water along this section negates the possibility that these are large vessels. They must be vessels at the smallest end of the distribution of ocean-going vessels, no more than 100m long [10]. More likely, they are rivertrade vessels. They were therefore treated as smaller vessels in the analysis by reclassifying them as either rivertrade or 'other' vessels.

Table 12A.4 Traffic Volume across Gate Sections (Daily Average, 2003)

Vessel Class										
Vessel Speed (m/s)		0-5			5-25					
Vessel Length Range (m)		0-30	30-75	75+	0-30	30-75	75+			
From Gate	To Gate	"A1" Fishing Vessels and Small Craft	"B1" Rivertrade Coastal Vessels	"C1" Ocean-going Vessels	"A2" Fast Launches and Fast Ferries	"B2" Fast Ferries	"C2" Fast Ferries & Ocean-going Vessels	Others	Total
0	1	250	265	45	150	110	40	5	865
1	2	40	5	1	50	50	5	10	161

Notes: Values >5 are rounded to nearest 5
Daily values based on 9 day record. Some rounding applies

Table 12A.5 Traffic Growth Forecast

Vessel Type	2011 compared to 2003	2021 compared to 2003
Ocean-going Vessel*	-5%	+10%
Rivertrade Coastal Vessel	+5%	+15%
Fast Ferry	+10%	+30%
Fishing Vessel/ Small Craft/ Fast launch	+5%	+15%
Others	+5%	+15%

* The traffic growth forecasts for 2011 and 2021 do not take into account the development of the Tonggu Waterway. This waterway is expected to shift ocean-going vessels away from Urmston Road, resulting in a net decrease in traffic for large vessels. The analysis therefore retains 2003 traffic volumes for ocean-going vessels.

12A.3.3 *Sectionalisation of the Pipeline*

Based on the above discussions and the level of pipeline protection, the pipeline route was divided into 4 sections for analysis (*Table 12A.6*). The four sections include:

- Black Point Approach - the 0.1 km shoreline approach to BBPS;
- Black Point West - the shallow water section between Black Point and Urmston Road (between kilometre posts KP2.52 and KP4.78);
- Urmston Road - the Urmston Road fairway between KP0.73 and KP2.52 ; and
- Boundary Section - the shallow water section between Urmston Road and the boundary of Hong Kong SAR waters (KP0 to KP0.73).

Given that the pipeline sections do not correspond exactly with the gate posts used for determining the marine traffic, redistribution of the marine data was required. With insight gained from the radar tracks, knowledge of water depth and ferry activities, the following assumptions were made:

- 95% of the marine traffic between gates 0 and 1 is assumed to pass through Urmston Road;

- The remaining 5% of traffic observed between gates 0 and 1 are assigned to the Black Point West section. These marine vessels are assumed to be rivertrade vessels, fast launches, ferries and fishing boats. No large ocean-going vessels are expected here due to the shallow water;

- Although no radar tracks are observed within the 100m shore approach, a small number of small crafts are assigned to this section as a conservative measure;

- The mix of vessels observed between gates 1 and 2 is assumed to be representative of vessels crossing the Boundary Section of the pipeline. Half of the traffic observed between gates 1 and 2 is assumed to traverse the Boundary Section of pipeline.

Table 12A.6 Pipeline Segmentation

	Section	Kilometre Post		Length	Typ. Water	Trench type
		From	To	(km)	depth (m)	
4	Boundary Section	0	0.73	0.73	2-20	2
3	Urmston Road	0.73	2.52	1.79	20	3
2	Black Point West	2.52	4.78	2.26	5	2
1	Black Point Approach	4.78	4.89	0.11	2	1

Based on the above assumptions, the marine traffic volume used in the present analysis is summarized in *Table 12A.7*.

Table 12A.7 Traffic Volume Assumed for Base Case 2011

		Traffic volume (ships per day)						
Section		Fishing	River-trade	Ocean-going	Fast Launch	Fast ferry	Other	Total
4	Boundary Section	21	3	0	24	30	8	86
3	Urmston Road	250	265	81	118	150	5	869
2	Black Point West	12	16	0	5	8	2	43
1	Black Point Approach	1	0	0	0	0	0	1
	Total	284	284	81	147	188	15	999

Tables of traffic volume for the 2021 future scenario were created in a similar manner. This is given in *Annex 12* of the *EIA Report*.

Ocean-Going Vessel Distribution

All classes of ship, with the exception of ocean-going vessels, have anchor sizes below 2 tonnes (*Table 12A.2*), and it is noted that the entire length of the proposed pipeline will have rock armour protection designed to protect against at least 3 tonne anchors. Ocean-going vessels cover a very wide range of size. A breakdown of the size distribution for this class of marine vessels is given in *Table 12A.8* [3, 10]. These vessels are predominantly found in Urmston Road which has type 3 rock armour protection to protect against anchors up to 19 tonnes. From the size distribution, it can be seen that the majority of these ships are below about 110,000 tonnes displacement and so the majority of anchors are below 12 tonnes. 60% have anchor size below 5 tonnes.

Table 12A.8 Size Distribution of Ocean-Going Vessels

Size Range (dwt) †	Displacement (tonnes)*	Length (m)	Anchor Size (tonne)	Proportion of Ships (%)
1,500 – 25,000	1,500 – 35,000	75 – 200	2 – 5	60
25,000 – 75,000	35,000 – 110,000	200 – 300	5 – 12	35
75,000 – 100,000	110,000 – 150,000	300 – 350	12 – 15	5

† Dead Weight (dwt) = Cargo + Fuel + Water + others
* Displacement = Total Weight = Hull + Machinery + Outfit + Dead Weight
Displacement has been assumed to be ~ 1.4 × dwt

12A.4 HAZARD IDENTIFICATION

This section identifies the main hazards from the subsea gas pipelines. Hazard identification is based on a literature review of past incidents as well as HAZID studies (*Section 12A.4.2*) conducted for the proposed pipeline. Hazards identified from these studies are then carried forward for further consideration in the QRA.

12A.4.1 *Literature Review*

Incident Databases and Pipeline Reports

The Consultants (ERM) have examined incident databases such as the MHIDAS [11] and the IChemE Accident Database [12]. Only two pipeline incidents in offshore Vietnam have been reported in the Asia-Pacific region. These occurred at White Tiger and Vung Tau, both in 1994 and both were caused by anchor damage. No injuries were reported.

Relevant reports on major subsea pipeline failures (that caused fatality) by the National Transportation Safety Board have also been reviewed [13, 14]. A summary of a few main incidents from these sources are included in the following paragraphs.

Tiger Pass, Louisiana, 1996

On October 23, 1996, in Tiger Pass, Louisiana, the crew of the dredge *Dave Blackburn* dropped a stern spud (a spud is a large steel shaft that is dropped into the river bottom to serve as an anchor and a pivot during dredging operations) into the bottom of the channel in preparation for continued dredging operations. The spud struck and ruptured a 12" diameter submerged natural gas steel pipeline. The pressurised (about 930 psig) natural gas released from the pipeline enveloped the stern of the dredge and an accompanying tug. Within seconds of reaching the surface, the natural gas ignited and the resulting fire destroyed the dredge and the tug. All 28 crew members from the dredge and tug escaped into water or onto nearby vessels. No fatalities resulted.

The incident occurred due to incorrect information on the location of the gas pipeline that was passed on by the gas company to the dredging operator. The investigation report on the incident (by the National Transportation Safety Board) recommended that all pipelines crossing navigable waterways are accurately located and marked permanently.

Mississippi River Delta, 1979

In an incident in the Mississippi River Delta in 1979, four workers drowned attempting to escape a fire that resulted when a crane barge dropped a mooring spud into an unmarked high pressure natural gas pipeline.

Louisiana, 1987

In July 1987, while working in shallow waters off Louisiana, a fishing vessel, the menhaden purse seiner Sea Chief struck and ruptured an 8" natural gas liquids pipeline operating at 480 psi. The resulting explosion killed two crew members. Divers investigating found that the pipe, installed in 1968, was covered with only 6" of soft mud, having lost its original 3-foot cover of sediments.

Sabine Pass, Texas, 1989

A similar accident occurred in October 1989. The menhaden vessel Northumberland struck a 16" gas pipeline in shallow water near Sabine Pass, Texas. The vessel was engulfed in flames; 11 of the 14 crew members died. The pipeline, installed in 1974 with 8 to 10 feet of cover, was found to be lying on the bottom, with no cover at all.

Pipeline Failure Databases

There are a few international failure databases for gas and liquid transmission pipelines which are useful in identifying potential hazards and estimating the frequency of loss of containment incidents.

The most comprehensive database on offshore gas pipeline failures is available in a report published by the UK Health and Safety Executive entitled 'PARLOC 2001' [6]. The most recent version of this database covers incidents from the 1960s up to 2000. The information in this database is based on data obtained from regulatory authorities in the UK, Norway, the Netherlands, Denmark and Germany, Operators in the UK, Dutch and Danish sectors and published sources. The main causes of pipeline failure, as identified from a review of the PARLOC 2001 data, are listed in *Table 12A.9*. Based on this, it can be seen that anchor/impact followed by internal corrosion are the main contributors to subsea pipeline failures.

A similar database on incidents involving offshore pipelines in the US has also been referred to [15]. This is based on incidents that are required to be reported to the US Department of Transportation (DOT) under the Federal Regulations. Out of 109 incidents reported during the period 1985 to 1994, only one incident involved a fatality, and only one incident involved leak ignition. The main causes of pipeline failure, as identified from a review of the US DOT database, are listed in *Table 12A.10*. Based on this, it can be seen that third party damage and internal corrosion (characteristic of well fluid pipelines) are the main contributors to subsea pipeline failures.

Table 12A.9 Causes of Subsea Pipeline Incidents from PARLOC 2001 [6]

Main cause	**Detail**	**No. of Incidents of Loss of Containment**		
		Platform Safety Zone(1)	**Subsea Well Safety Zone(2)**	**Mid-line**
ANCHOR	Supply Boat	6	-	-
	Rig or Construction	-	-	-
	Other/ Unknown	0	-	2
	Total	*6*	-	*2*
IMPACT	Trawl	-	-	6
	Dropped Object	-	-	-
	Wreck	-	-	1
	Construction	1	-	-
	Other/ Unknown	-	-	1
	Total	*1*	-	*8*
CORROSION	Internal	3	4	7
	External	1	-	2
	Unknown	1	-	2
	Total	*5*	*4*	*11*
STRUCTURAL	Expansion	-	-	-
	Buckling	-	-	-
	Total	-	-	-
MATERIAL	Weld Defect	2	-	1
	Steel Defect	2	1	1
	Total	*4*	*1*	*2*
NATURAL HAZARD	Vibration	-	-	-
	Storm	-	-	-
	Scour	-	-	-
	Subsidence	-	-	-
	Total	-	-	-
FIRE/ EXPLOSION	*Total*	-	-	-

Main cause	Detail	No. of Incidents of Loss of Containment Platform Safety Zone(1)	Subsea Well Safety Zone(2)	Mid-line
CONSTRUCTION	*Total*	-	-	-
MAINTENANCE	*Total*	-	-	-
OTHERS	*Total*	2	*1*	*4*
TOTAL		18	6	27

(1) Platform safety zone and subsea safety zone refer to pipelines located within 500m of an offshore platform and subsea well respectively

(2) Mid-line refers to pipelines located more than 500m from a platform or subsea well.

Table 12A.10 Causes of Subsea Pipeline Incidents from US DOT Database [15]

Cause of Failure	Description of Cause	No. of Incidents	% of Total Incidents	Incidents Considered (1)
1. EXTERNAL FORCE		25	29.8%	24
Earth Movement	Subsidence, landslides	2	2.4%	2
Heavy Rains/Floods	Washouts, floatation, scouring	1	1.2%	
Third Party		21	25.0%	21
Previously Damaged Pipe	Where encroachment occurred in the past	1	1.2%	1
2. CORROSION		45	53.6%	3
External Corrosion	Failure of coating/CP	3	3.6%	3
Internal Corrosion		42	50.0%	
3. WELDS & MATERIALS		4	4.8%	4
Defective Fabrication Weld	Welds in branch connections, hot taps, weld-o-lets, sleeve repairs	2	2.4%	2
Defective Girth Weld		2	2.4%	2
4. EQUIPMENT & OPERATIONS		3	3.6%	
Equipment Failure	Malfunction of control or relief equipment, failure of threaded components, gaskets & seals	3	3.6%	
5. OTHERS		7	8.3%	7
Unknown		7	8.3%	7
TOTAL		**84**	**100%**	**38**

1. Only these incidents are considered relevant to the proposed pipeline.

Incident Records and Protection Measures for Pipelines in Hong Kong SAR Waters

A review of existing and proposed subsea pipelines in Hong Kong waters including the level of protection provided are reviewed in the following paragraphs.

Subsea Pipelines

Existing subsea pipelines in Hong Kong waters are as follows:

- The 28" *natural gas pipeline* from Yacheng Field, South China Sea (90km south of Hainan Island) to CAPCO's Black Point power station was constructed in 1994/95. The total pipeline length is 778 km. Within Hong Kong waters, the length of pipeline is about 5 km and the water depth varies from 4 m to 25 m. The pipeline is trenched with a minimum of 1m rock armour protection at sections where it crosses the shipping route Urmston Road and at the anchorage areas near the shore. Similar protection (i.e. 1m rock armour and 1 m backfill) is also provided outside Hong Kong waters at the Lingding channel crossing and Jiuzhou channel crossing. The pipeline is laid on the seabed for the remaining length. There has been no incident of damage reported in Hong Kong waters although an incident occurred during construction when the unprotected section of the pipeline was buckled by the anchor lines of the barge laying the rock armour.

- the 20" dual *aviation fuel pipelines* between Sha Chau jetty and the airport (about 5km length), installed in 1997, are laid in a 2.2 m trench and provided with sand cover plus rock armour protection. The water depth along the route varies from 4-7 m. There has been no incident of damage reported;

- the Airport Authority propose to construct another 5 km submarine *aviation fuel pipeline* from Sha Chau jetty to the new tank farm in Tuen Mun. The pipeline will be crossing the Urmston Road shipping route and similar protection as for the existing pipelines (i.e. rock armour protection) is proposed;

- the *town gas* subsea pipelines are also reported to have no damage record. These pipelines are laid at a depth of 2 to 3 m below seabed and protected by engineering backfill materials;

- the Hongkong Electric Company Limited recently laid a pipeline from its Lamma Power Station Extension to Shenzhen LNG Terminal. The pipeline is jetted to 3 m below seabed and protected with rock armour in high risk areas near the anchorages and shore approaches; and

- the recently installed *town gas* subsea pipeline from Shenzhen to Tai Po is jetted to 3 m below seabed with additional rock armour protection in high risk areas.

By comparison, the proposed CAPCO pipeline will be laid in waters between 2 and 20 m deep. The pipeline will be provided with 3 m of rock cover except in areas of shallow water where it will have 1.5 – 5 m of rock/ natural fill cover. These rock cover requirements are based on water depth (which determines the size of vessels) and marine traffic volume. The measures proposed are in line with, or exceed, comparable pipeline installations.

12A.4.2 HAZID Report

A Hazard Identification (HAZID) workshop was held in September 2009 as part of the risk assessment to identify issues specific to locality of the pipeline. The worksheets from this workshop are presented in *Table 12A.11*.

Table 12A.11 HAZID Worksheets

System: 1. Pipeline
Subsystem: 1. Operational

Hazards/ Keywords	Description/ Causes	Consequences	Safeguards	Recommendations
1. Internal corrosion	1. No issue for non corrosive, clean and dry gas			
2. External corrosion	1. Sea-water; corrosive environment	1. Loss of wall thickness leading to potential leak	1. Coating system 2. Sacrificial anode system 3. Designed for intelligent pigging	
3. Pressure cycling	1. Pipeline pressure will vary with time of day, loads etc	1. Metal fatigue leading to crack	1. Design will consider pressure cycles	
4. Material defect/ construction defect		1. Possible leaks	1. Quality control during manufacture and construction	
5. Impact from one pipeline to the other	1. No issues identified during operation			
6. Maintenance	1. Possible damage to one pipeline during maintenance/intervention on the second.	1. Possible damage to pipeline leading to potential leaks	1. Maintenance procedures: - proper equipment - surveying (GPS positioning) - marker buoys	

System: 1. Pipeline
Subsystem: 2. External hazards

Hazards/ Keywords	Description/ Causes	Consequences	Safeguards	Recommendations
1. Anchor Drag	1. Emergency anchoring for vessel underway due to loss of steerage, power or control, either due to mechanical problems or due to collision events.	1. Possibility of damage to external coating, damage to pipe requiring remedial action.	1. Engineered rock protection with respect to vessel sizes/types.	1. Periodic survey along the route to be carried out to ensure integrity of the protection.

System: 1. Pipeline
Subsystem: 2. External hazards

Hazards/ Keywords	Description/ Causes	Consequences	Safeguards	Recommendations
	2. Drag from anchorage areas under storm conditions.	2. Potential loss of containment leading to gas release. Impact on passing vessels and shore population. Vessel involved in the incidents may sink due to loss of buoyancy cause by the gas bubbling.	2. Depth of cover.	
	3. Anchoring by vessels outside anchorages.	3. Disturbance to the rock cover protection. Possible exposure of the pipe.	3. Route avoiding anchorage areas.	
			4. Concrete external coating.	
			5. Heavy wall pipe in shore approaches.	
			6. Marking marine charts of the pipeline route.	
			7. Shore population is at least 3km away along the route except near the shore approach.	
2. Anchor Drop	1. Same as cause 1 & 3 of anchor drag hazard	1. Same as consequence 1, 2 & 3 of anchor drag hazard but less severe.	1. Same as for anchor drag hazard.	
3. Dropped Object	1. Loss of cargo	1. Same as consequence 1, 2 & 3 of anchor drag hazard but less severe.	1. Same as safeguards 1, 2, 4, 5, & 7 of anchor drag hazard.	
	2. Construction activities			
4. Dumping	1. Dumping of construction waste and other bulk materials outside of designated dumping grounds.	1. Minor surface damage.	1. Same as safeguards 1, 2, 4, 5, & 7 of anchor drag hazard.	
5. Grounding	1. Navigation error, loss of control due to mechanical or	1. Same as consequence 1, 2 & 3 of anchor drag hazard.	1. Burial depth appropriate to the type of shipping activities	

System: 1. Pipeline
Subsystem: 2. External hazards

Hazards/ Keywords	Description/ Causes	Consequences	Safeguards	Recommendations
	adverse weather.	2. Displacement of the pipeline leading to exposure	2. Comprehensive risk based design has been conducted and the pipeline alignment minimizes exposure to major shipping lanes. Pipeline is routed through shallow water as far as possible.	
6. Vessel Sinking	1. Collision, foundering.	1. Same as consequence 1, 2 & 3 of anchor drag hazard.	1. Comprehensive risk based design has been conducted and the pipeline alignment minimizes exposure to major shipping lanes. Pipeline is routed through shallow water as far as possible.	
7. Fishing & Trawling	1. Operation of trawl board and other fishing/trawl gear.	1. No damage to the pipeline.	1. Pipeline is buried below the seabed with rock cover flush with seabed.	
8. Dredging	1. Impact from dredge bucket or drag head.	1. Same as consequence 1, 2 & 3 of anchor drag hazard but less severe.	1. Burial depth appropriate to the type of shipping activities based on Marine Department and CEDD guidelines.	
			2. Engineered rock protection with respect to vessel sizes/types.	
			3. Depth of cover.	
			4. Marking marine charts of the pipeline route.	
			5. Concrete external coating.	
9. Service crossing or other services in the vicinity	1. No crossings envisaged		1. Surveys have demonstrated no other services along the pipeline route	

System: 1. Pipeline
Subsystem: 3. Natural hazards

Hazards/ Keywords	Description/ Causes	Consequences	Safeguards	Recommendations
1. Scouring	1. Current and wave actions	1. Possible reduction of cover	1. Alignment is away from areas of high currents 2. Engineered rock cover	1. Periodic survey along the route to be carried out to ensure integrity of the protection.
2. Seismic event	1. Low seismic activity area	1. No damage	1. None required	
3. Subsidence	1. No issue			

System: 1. Pipeline
Subsystem: 4. Construction / future developments

Hazards/ Keywords	Description/ Causes	Consequences	Safeguards	Recommendations
1. Damage to pipeline during construction of second pipeline	1. Damage from construction activities	1. Damage to pipe and possible loss of containment	1. Design for appropriate separation distance 2. Construction procedures: - proper equipment - surveying (GPS positioning) - marker buoys. 3. Pipeline protection design covers foreseeable marine activities including dredging and anchoring	2. Design for second pipeline should be taken into account during construction of the first. Critical areas such as the shore approach should be pre-constructed in parallel for the two pipelines.
2. Reclaimed land over first pipeline	1. Weight of overburden may lead to subsidence and damage to first pipeline.	1. Overstressing of the first pipeline leading to catastrophic failure	1. Conservative design taking into account the overburden.	

12A.4.3 Hazardous Properties of Natural Gas

The natural gas to be transmitted by the pipeline predominantly contains methane (85 - 99.5 mol%). It is a flammable gas that is lighter than air (buoyant). The properties of natural gas are summarised in *Table 12A.12*.

Table 12A.12 Properties of Natural Gas

Property	Natural Gas
Synonyms	Methane
State	Gas
Molecular Weight	16.0 - 18.7
Density (kg/m^3)	0.55 (at atmospheric conditions)
Flammable Limits (%)	5 - 15
Auto-ignition Temperature (°C)	540

12A.4.4 Discussion on Subsea Pipeline Hazards

The incident records highlight the potential for damage to subsea pipelines from marine activity such as fishing, dredging and anchoring as well as the potential for the vessel (that caused damage) to become involved in the fire that follows.

A review of subsea pipeline incidents in Europe and the US suggests that third party damage (including anchor and impact incidents) and internal corrosion are the main contributors to subsea pipeline failures.

It is noted that the above databases cover a large proportion of well fluid pipelines where internal corrosion is relevant as compared to clean natural gas as considered in this study.

Most existing pipelines in Hong Kong waters have some rock cover protection in addition to being buried, although it is noted that these pipelines are either crossing shipping channels or laid in waters with high levels of marine activity.

A brief description of the main causes of failure of a subsea pipeline is included in the following paragraphs.

External Impacts

Anchor drop/drag is the dominant cause of potential failure or damage to a subsea pipeline. This occurs when a ship anchor is dropped inadvertently across the pipeline. The type of damage that could be caused will vary depending on the size of anchor and other factors such as pipeline protection.

Anchor Drop

The decision for a mariner when to drop an anchor depends on the particular circumstances and the proximity of the pipeline route to the flow of marine traffic, port/harbour areas and designated anchorage locations. In fairways, traffic will normally be underway where the necessity to drop anchor is expected to be low. Consistent with normal practice, the pipeline route will be identified on nautical charts. The mariner is then provided with the necessary information to avoid anchoring where the pipeline could be damaged.

Emergency situations may arise such as machinery failure or collision thereby limiting the choice where to drop anchor. Such a decision will, as part of a mariner's responsibility, be influenced by the particular circumstances and the pipeline route delineated on the navigation chart.

Although it is expected that vessels should be aware of all subsea installations (including gas pipelines) since these are marked on the admiralty nautical charts, erroneous dropping of anchor (i.e. error in position at the time of deployment) are known to occur.

Anchor Drag

Anchor drag occurs due to poor holding ground or adverse environmental conditions affecting the holding power of the anchor. The drag distance depends on properties of the seabed soil, the mass of ship and anchor and the speed of the vessel. If there is a subsea pipeline along the anchor drag path, anchor dragging onto the pipeline may result in localised buckling or denting of the pipeline, or over-stressing from bending if the tension on the anchor is sufficient to laterally displace the pipeline. A dragged anchor may also hook onto a pipeline during retrieval causing damage as a result of lifting the pipeline.

Vessel Sinking

Vessel sinking in the vicinity of the pipeline may cause damage to the pipeline resulting in loss of containment. Vessel sinking will depend on the intensity of marine activity in a given area. For the years 1990 to 2007, there were 492 incidents of vessel sinking in Hong Kong waters [16]. This averages 27 cases per year. Most of the recorded incidents occurred in Victoria Harbour and the Ma Wan Channel and involved mainly smaller vessels of less than 1,000 dwt, which will have less impact on a pipeline buried below the seabed. The probability that a vessel sinking incident will impact the proposed pipeline is therefore considered to be low, in comparison to anchor impact damage. Additionally, pipeline damage due to vessel sinking is included in the historical pipeline failure data for external impact used in this study (see *Table 12A.9*).

Dropped Objects

Objects other than anchors may be dropped from vessels passing over the pipeline or vessels operating in the vicinity. The dropped objects may include shipping containers, construction/maintenance equipment, etc. The pipelines will be lowered to at least 1 m below seabed and protected by rock armour. Given the likely sizes of dropped objects and the level of pipeline protection provided, loss of containment due to dropped objects is not considered to be a significant contributor to the risk. Such events will in any case be included in the historical pipeline failure data for external impact used in this study.

If any future construction work is conducted in the vicinity of the pipeline, procedures will be developed to safeguard the pipeline during the construction activities.

Aircraft Crash

The proposed pipeline route does not lie close to Chek Lap Kok or Macau airports or flight paths. As such, the possibility of an aircraft crashing onto the pipeline has a very small probability. Also, aircraft are constructed from light weight materials such that even a fully loaded Boeing 747 weighs only 400 tonnes. Aircraft also readily breakup on impact with water, scattering the debris over a larger area. Given that the pipeline is buried and protected and aircraft have limited weight, it is considered not possible for an aircraft to damage the pipeline.

Fishing Activity

Based on the BMT report [3], there is fishing activity along the proposed pipeline route. Many of the techniques involve towing of a variety of equipment along the seabed. Pipeline damage from fishing gear can occur due to impact, snagging of nets or trawl door on the pipeline or a "pull over" sequence. Impact loads mainly cause damage to the coating whilst pull over situations can cause much higher loads, which could lead to damage of the steel pipeline itself.

The vessels of concern are stern trawlers with lengths up to 30 m. Considering the size and weight of trawl gear and since the pipeline will be lowered to at least 1 m below seabed and protected by rock armour for the entire route, pipeline damage due to trawling activities are not possible and are not considered further.

Dredging and Construction Activities

Dredging vessels could cause damage due to dredging operations involving cutting heads. They could also cause damage to the pipeline by anchoring.

It is assumed that dredging operations will be closely monitored and controlled and therefore there is negligible potential for pipeline damage due to dredging.

Spontaneous Failures

Corrosion

Corrosion is one of the main contributors to pipeline failures. Corrosion is attributed mainly to the environment in which they are installed (external) and the substances they carry (internal).

The proposed pipeline will be protected against external corrosion by sacrificial anodes in addition to an anti-corrosion coating. However, ineffective corrosion protection due to a failure or breakdown of the protection system could cause external corrosion resulting in general or local loss of wall thickness leading to pipeline failure.

Historically, internal corrosion is a greater cause of pipeline failure compared to external corrosion. However, the proposed pipeline will transport gas that does not contain components that induce corrosion such as water/moisture, carbon dioxide, hydrogen sulphide, etc. This will largely reduce the chance of internal corrosion.

Despite these considerations, loss of containment due to corrosion (both internal and external) remains a possibility and is included in the analysis.

Mechanical Failure

Mechanical failure of the pipeline could occur for various reasons, including material defect, weld failure, etc. Stringent procedures for pipeline material procurement, welding and hydrotesting should largely mitigate against these hazards. In any case, it remains a credible scenario and is included in the frequency data.

Natural Hazards

Natural hazards such as subsidence, earthquake and typhoon may cause varying degrees of damage to pipelines.

Soft soil can sometimes suffer from localised liquefaction which can result in pipelines floating out of their trenches. The pipeline will be designed to withstand such loads, based on detailed seabed investigations.

Environmental loads (currents and waves) on the pipeline during the construction phase can compromise the lateral and vertical on-bottom stability of the pipeline on the seabed. This problem becomes more acute in shallower waters (near the shore) where the pipeline attracts a higher level of environmental loads. The pipeline will be designed to withstand these environmental loads. Once it is lowered below the seabed, it would not be exposed directly to 100 year return wave loads.

Based on the above considerations, it is considered that there is no disproportionate risk to the pipeline from natural hazards. These causes of failure are in any case included in the generic failure rates derived from historical incidents, as used in this study.

12A.5 FREQUENCY ANALYSIS

12A.5.1 Overview

This section presents the base failure frequency data for the hazards identified in *Section 12A.4*. The approach to frequency analysis is based on the application of worldwide historical data for similar systems, modified suitably to reflect local factors such as proximity of the pipeline to busy shipping channels and anchorages.

Event tree analysis was used to determine the probabilities of various hazard outcomes (such as flash fire) occurring, following a release.

12A.5.2 Historical Data

The international database that is most comprehensive in its coverage of subsea pipelines is PARLOC 2001 [6]. The most recent version of this database which was used in this study covers incidents from the 1960s until 2000. Incidents recorded in the database have been classified according to several categories, including:

- Failure location, i.e. risers, pipelines within 500 m of an offshore platform, pipelines within 500 m of a subsea well and mid-line (pipelines located more than 500 m from a platform or a subsea well). Failure data pertaining to risers is not relevant to this study and has therefore been excluded;

- Pipeline contents. The database includes both oil and gas pipelines. Where the contents in the pipeline have an impact on failure rate, such as corrosion, only incidents pertaining to gas pipelines are considered; and

- Pipeline type, i.e. steel pipelines (both pipe body and fittings) and flexible lines. Only failures involving the pipe body of steel pipelines are considered here.

A breakdown of the incidents recorded in PARLOC 2001 by failure location is shown in *Table 12A.13*. The number of incidents of loss of containment that have occurred within 500 m of a platform or a subsea well is almost equal to the number of incidents that have occurred away from it (i.e. mid-line). The higher failure rate in the vicinity of an offshore installation (one to two orders of magnitude higher than mid-line) is due to the effect of increased ship/barge movements in the vicinity and the potential for anchor damage as a result.

The proximity of some sections of the proposed pipeline route to high marine traffic environments could be regarded as similar to the environment in the vicinity of the platform safety zone although it is not strictly comparable.

Table 12A.13 Failure Rate Based on PARLOC 2001 [6]

Region of Pipeline	Operating Experience	No. of Incidents	Failure Rate
Mid-line	297,565 km-years	27	9.1×10^{-5} /km/year
Platform safety zone	16,776 years (8,388 km-years)*	18	1.1×10^{-3} /year (2.1×10^{-3} /km/year)
Subsea well safety zone	2,586 years (1,293 km-years)*	6	2.3×10^{-3} /year (4.6×10^{-3} /km/year)
Total	307,246 km-years*	51	1.66×10^{-4} /km/year

* The number of years in the case of platform and subsea well safety zone is multiplied by 0.5km of safety zone to obtain corresponding km-years

The main causes of pipeline failure are summarised in *Table 12A.14*, based on the causes identified in PARLOC 2001. As discussed earlier, anchor/impact and internal corrosion are the main contributors to pipeline failure.

Table 12A.14 Main Contributors to Subsea Pipeline Failure (PARLOC 2001)

Cause	Platform Safety Zone	Subsea Well Safety Zone	Mid-line	Total
Anchor/Impact	7 (39%)	-	10 (37%)	17 (33%)
Internal corrosion	3 (17%)	4 (67%)	7 (26%)	14 (27%)
Corrosion -others	2 (11%)	-	4 (15%)	6 (12%)
Material defect	4 (22%)	1 (17%)	2 (7%)	7 (14%)
Others	2 (11%)	1 (17%)	4 (15%)	7 (14%)
Total	18	6	27	51

Analysis of Failure Causes

The failure frequency derived from the PARLOC 2001 data is further filtered to take into account the local conditions in Hong Kong.

Corrosion and Material Defect

Based on experience in Europe (*Table 12A.14*), internal corrosion tends to be a greater problem than external corrosion. For the proposed pipeline, failures due to internal corrosion are expected to be less likely as the gas handled is clean, unlike sour gas transported from wells/platforms which may contain moisture and hydrogen sulphide. Also, it is assumed that the condition of the pipeline will be monitored periodically and maintenance work carried out as necessary.

Failures due to defects in materials and welds are also expected to be lower than implied by the historical record due to technological improvements. The database for PARLOC 2001 dates back to the 1960s; there have been significant improvements in pipe material and welding over the last 10 to 20 years. An 80% reduction is therefore assumed for all forms of corrosion and material defects.

Taking the mid-line data as the most representative for the proposed pipeline, the failure rate is therefore derived as 13 incidents in 297,565 km-years with 80% reduction, giving 8.7×10^{-6} /km/year.

The PARLOC 96 report [17] provides a breakdown of loss of containment incidents due to corrosion and material defect for gas pipelines greater than 5km in length. The failure rate for such pipelines is lower at 5.9×10^{-6} /km/year (0.7 failures in 119,182 km-years; the km-years are lower because only gas pipelines are considered). This value is considered more appropriate for the proposed pipeline. Unfortunately, a more current value could not be extracted from PARLOC 2001 due to a difference in presentation format of the data. However, a downward trend in failure frequencies is to be expected as technology improves and so 5.9×10^{-6} /km/year is considered to be reasonable. Incorporating an 80% reduction again gives a corrosion/defect frequency of 1.18×10^{-6} /km/year.

Anchoring/Impact Incidents

There is a significant difference in the failure rate due to anchor/impact incidents for pipelines within 500m of an offshore platform (8.3×10^{-4}/ km/ year) as compared to mid-line (3.4×10^{-5} /km/year). Further breakdown of incidents based on pipeline diameter is given in *Table 12A.15*.

Table 12A.15 Frequency of Loss of Containment Incidents due to Anchor/Impact-Breakdown by Pipe Diameter & Location

Location	**Frequency (per km per year)** **<10" diameter**	**10 to 16" diameter**	**18 to 24" diameter**	**24 to 40" diameter**
Mid-line	1.53×10^{-4}	2.26×10^{-5}	1.76×10^{-5}	1.37×10^{-5}
Safety zone	6.68×10^{-4}	1.94×10^{-3}	4.24×10^{-4}	8.6×10^{-4}

It is seen from the above that the failure rate (for mid-line) for larger diameter pipelines is lower by an order of magnitude in comparison to smaller diameter pipelines.

As discussed previously, it is considered that the likelihood of pipeline damage due to anchor/impact incidents may be related to the level of marine activity (this is taken to be a combination of marine traffic and anchoring activity). The frequency of pipeline failure due to these causes has therefore been derived as a function of three levels of marine activity: high, medium and low. Frequency values are based on the large diameters pipes of 24-40" as given in *Table 12A.15* since these are the most relevant to the proposed CAPCO pipeline.

For locations with high marine activity, a frequency of 8.6×10^{-4} /km/year is adopted. For low marine activity, 1.37×10^{-5} /km/year is used. An intermediate value of 10^{-4} /km/year is also applied to locations with medium levels of marine activity. This is discussed further in *Section 12A.5.3* where alternative calculations based on emergency anchor deployment frequency are also presented for comparison.

These failure frequencies from PARLOC assume minimal protection for the pipeline. The proposed CAPCO pipeline will be provided with rock armour protection over its entire length. To allow for this, the failure frequencies are reduced by appropriate factors as discussed in *Section 12A.5.4*.

Other Causes

"Other" causes include blockages, procedural errors, pressure surges etc. As with corrosion, improvements in technology and operating practices are expected to reduce this significantly and so a general 90% reduction is assumed for failures due to other causes. This gives a frequency of 1.34×10^{-6}/km/year (4 cases in 297,565 km-years with 90% reduction).

12A.5.3 Alternate Approach to Anchor Damage Frequency

While international data is commonly applied to infer failure rates for Hong Kong subsea pipelines, in this section an alternative approach is adopted for comparison. This is based on marine traffic incident rates, since such incidents are more likely to result in emergency anchoring. In the first instance, the effects of rock armour protection are neglected to allow these calculations to be compared with historical data from PARLOC. The effects of rock armour protection are then incorporated as described is *Section 12A.5.4*.

Frequency of Anchor Drop

Emergency Conditions

Vessels may drop anchor due to emergency conditions such as fog, storm, or due to collisions or machinery failure. The likelihood of anchoring due to adverse weather conditions is expected to be low especially for the larger vessels who will determine whether dropping an anchor is the safest option. Furthermore, knowledge of vessel position from onboard navigation systems should prevent inadvertent dropping of an anchor onto a pipeline delineated on the navigation chart.

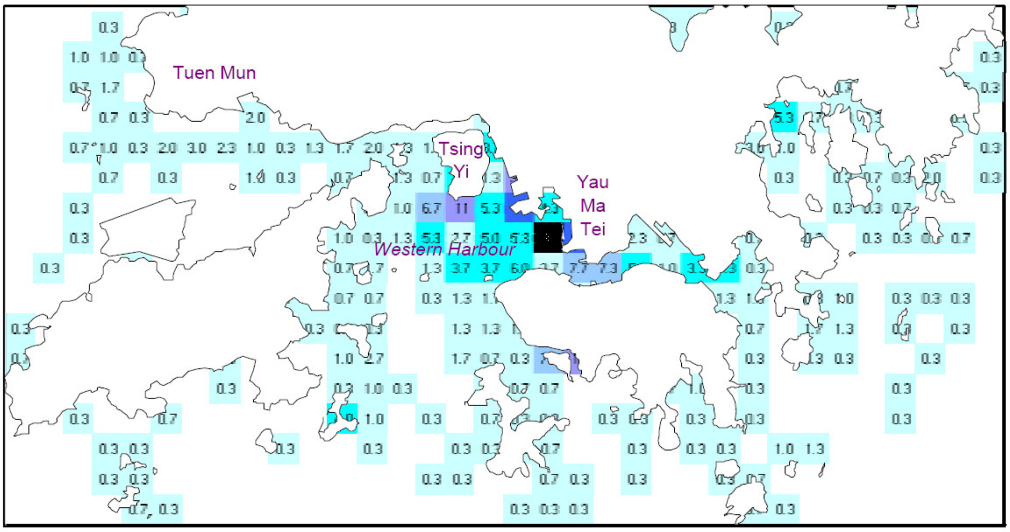
To estimate the frequency of emergency anchoring, data from the Marine Department of Hong Kong [5] is used. The distribution of incidents of all types (*Figure 12A.4*) shows that most incidents are concentrated in the harbour regions near Yau Ma Tei, Tsing Yi and Tuen Mun. The region near the proposed pipeline indicates low incident rates, although some areas of Urmston Road have slightly higher incident rates. This is due to the higher traffic density in this area.

Average values of 0.3 appearing in *Figure 12A.4* clearly refers to a single incident that occurred during the 3-year period from 2001 to 2003. The size of each cell in *Figure 12A.4* is one nautical mile, or approximately $1.852 \times 1.852 = 3.4\ km^2$. A value of 0.3 refers then to an incident frequency rate of $0.3/3.4 \cong 0.1\ /km^2/year$. This incident rate is taken to be appropriate for sections of the pipeline away from the busy Urmston Road.

The incident rate for Urmston Road is a little higher and is taken to be $1/nm^2/year$ (*Figure 12A.4*) or $0.3\ /km^2/year$.

For comparison, the total number of incidents from 1990-2008 in the 1830 km^2 area of Hong Kong SAR waters was 6491 [16]. This gives a territory average of $0.19\ /km^2/year$.

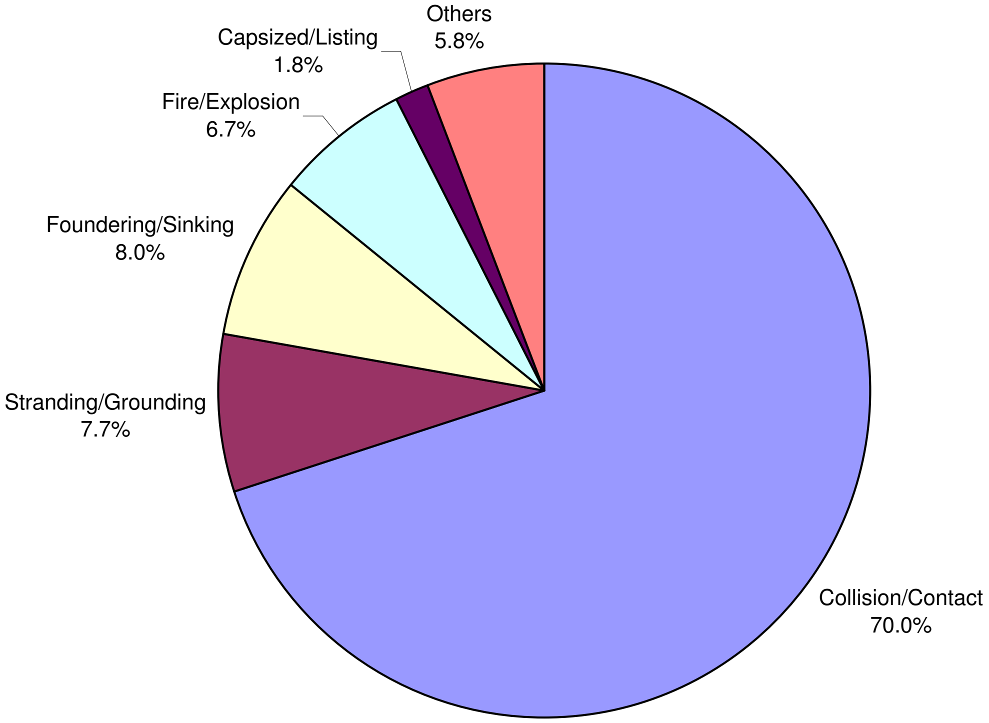
Figure 12A.4 Average Annual Incident Distribution (2001-2003)



The distribution by types of incidents (*Figure 12A.5*) shows that most incidents are collisions or contact. Not all incidents will result in an anchor drop. Most collisions, for example, are not serious. It is assumed therefore that only 10% of incidents will result in an emergency anchor drop.

Once the anchor is dropped, it may fall directly on the pipeline causing damage. A greater concern is the possibility of an anchor being dragged across the seabed and into the pipeline. In an emergency situation such as mechanical failure, it is possible that the vessel is still moving when the anchor is deployed. Since anchors can be dragged significant distances, the resulting pipeline contact frequencies tend to be higher compared to a simple anchor drop. In most instances, however, the ship master's first action will be to reduce speed to near stationary and then drop anchor if necessary. For the purpose of this analysis, it was assumed that 90% of ships drop anchor at near rest (1 knot), while the other 10% drop anchor at 4 knots due to mechanical failure and the uncontrolled advance of the vessel.

Figure 12A.5 Distribution of Incident Types (1990-2008)



The efficiency of an anchor is defined according to its holding capacity:

$$Holding\ capacity = anchor\ weight \times efficiency$$

The efficiencies for different classes of anchor [19] are given in *Table 12A.16*. It is believed that types E and F are common on large commercial vessels.

Table 12A.16 Anchor Efficiency

Class	Efficiency
A	33-55
B	17-25
C	14-26
D	8-15
E	8-11
F	4-6
G	<6

This definition can be used to calculate the drag distance. The work done in dragging an anchor through some distance must be equal to the change in kinetic energy in bringing the ship to rest.

Anchors are designed to penetrate into the seabed for maximum holding capacity. As an anchor is dragged across the seabed, it will begin to penetrate into the mud; the softer the soil, the greater the penetration. Maximum holding capacity is only reached once the maximum penetration depth has been reached i.e. the efficiency is a function of penetration depth. As a conservative approach, the lowest efficiency anchor, type E, is assumed for the calculations. The efficiency is halved again to allow for the varying restraining force with depth. The efficiency is therefore assumed to be 2.

Table 12A.17 gives some drag distances resulting from these calculations. It can be seen that most vessels will drag an anchor for less than about 20m. Ocean-going vessels can drag an anchor over significantly greater distances due to the larger mass and hence kinetic energy of the ship. This class of ship is subdivided into different sizes to reflect the distribution of ships expected along the proposed pipeline route (see *Table 12A.8*). A 150,000 tonne ship is the largest of ships visiting Hong Kong and this provides the upper limit to the drag distance of about 170m.

Table 12A.17 Drag Distances

Class	Size Range (dwt)	Displacement (tonnes)		Anchor (tonnes)	Drag Distance (m)
Fishing vessel		400		1	7
Rivertrade coastal vessels		1,500		2	13
Ocean-going vessels	1,500 – 25,000	1,500 – 35,000	(60%)	2 – 5	13 – 118
	25,000 – 75,000	35,000 – 110,000	(35%)	5 - 12	118 – 154
	75,000 – 100,000	110,000 – 150,000	(5%)	12 - 15	154 – 168
Fast Launches		150		0.1	25
Fast ferries		150		0.5	5
Other		200		0.2	17

The frequency of anchor drag impact can then be calculated as:

$$\textit{Impact freq} = \textit{incident freq (/year/km}^2\textit{)} \times \textit{probability of anchor drop} \times \textit{drag distance/1000} \quad (1)$$

where the drag distance is in metres. This gives an impact frequency per km of pipeline per year. If an impact occurs, the damage may not be severe enough to cause containment failure. Based on PARLOC 2001, approximately 22% of anchor /impact incidents result in containment failure when considering all pipe diameters. Larger pipes, however, fail three times less often. This suggests that 7% of incidents would result in a loss of containment.

This approach was applied to each section of the pipeline and to each class of vessel. The marine traffic incident rate was assumed to apply equally to all classes of vessel.

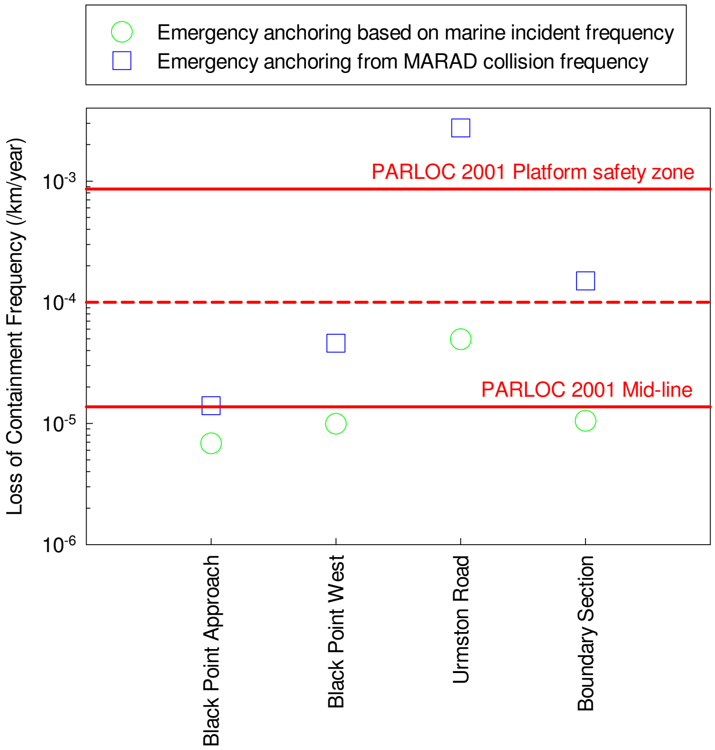
The hydrographic survey [7] identifies seabed conditions as very soft clay. Under these conditions, significant anchor penetration can occur [19]. For example, a 15 tonne anchor can penetrate to 17m, and a 2 tonne anchor can penetrate to 9m. These data apply to high efficiency anchors and less penetration is to be expected for the commonly used types E and F, but nevertheless, it is likely that a wide range of anchors sizes will be able to achieve 3m penetration during emergency anchoring scenarios and hence may interact with the proposed pipeline.

MARAD Study

An alternative to using the incident frequency from *Figure 12A.4* is to use data from the MARAD study [18] which reported that the frequency of collisions in Hong Kong waters of ocean-going vessels as 56 per million vessel-km. Since only 70% of incidents are collisions, this value of 56 per million vessel-km was scaled upwards to estimate the number of incidents of all types. 90% of these incidents resulted in only minor damage and so again it is assumed that only 10% will result in an emergency anchor drop. The approach is then similar to that described above for anchor dragging.

The results from this analysis are compared in *Figure 12A.6*. Also shown are the loss of containment frequencies obtained from PARLOC 2001 for the platform safety zone and mid-line. These are assumed to be representative of areas of high and low marine activity respectively. It can be seen that there is some spread in the predictions. The platform safety zone and mid-line frequencies differ by almost two orders of magnitude but effectively bound most of the other predictions.

Figure 12A.6 Anchor Damage Frequency Based on Marine Incidents



The calculations are broadly consistent with failure frequencies from PARLOC 2001. The frequency obtained from PARLOC 2001 for the mid-line is appropriate for regions of low marine vessel volume. The platform safety zone frequency is regarded as appropriate for the failure frequency in locations of high marine traffic. Some sections have intermediate levels of marine activity and so a frequency of 10^{-4} per km-year is adopted for these sections.

Based on the above considerations, the failure frequencies due to anchor impact used in this study are as summarized in *Table 12A.18*. A low frequency was assigned to the Black Point approach since no vessel movements were observed in this area from the marine radar tracks. Urmston Road was assigned a high frequency owing to the high marine traffic in this section. The remaining sections of pipeline were assigned a medium frequency.

Table 12A.18 Anchor Damage Frequencies used in this Study

Pipeline section	**Frequency (/km/year)**	**Comment**
Boundary Section	1×10^{-4}	Medium marine traffic
Urmston Road	8.6×10^{-4}	High marine traffic
Black Point West	1×10^{-4}	Medium marine traffic
Black Point Approach	1.37×10^{-5}	Low marine traffic

12A.5.4 *Pipeline Protection Factors*

Many pipelines are trenched to protect them from trawling damage. In the pipeline database in PARLOC 2001, 57% by length of all lines have some degree of protection, either trenching (lowering) or burial (covering) over part or all of their length. Considering large and small diameter lines, the proportion of lines with some degree of protection are 59% by length for lines <16" diameter and 68% for larger diameter lines. It is, however, concluded in the PARLOC report that there have been insufficient incidents to determine a clear relationship between failure rate and the degree of protection.

The loss of containment frequencies given in *Table 12A.18* assume minimal protection since they are based on the PARLOC data. The proposed CAPCO pipeline has rock armour protection specified for its whole length. To allow for this, protection factors were applied. Based on the classes of marine vessel found along the proposed route (*Table 12A.2*), most classes of ship have anchors below 2 tonnes in weight. Only ocean-going vessels have anchors up to 15 tonnes. The rock armour protection along the route is designed to protect against either 3 – 5 tonne anchors (trench types 1 and 2) or 19 tonne anchors (trench type 3). The analysis therefore assigns protection factors for the rock armour and makes a distinction between ocean-going vessels that have large anchors and other types of vessel which have smaller anchors.

Trench types 1 and 2 were assumed to provide 99%protection for anchors smaller than 2 tonnes. These trench types should also offer some protection against larger anchors. For ocean-going vessels, 60% of them have anchors below about 5 tonnes (*Table 12A.8*) and so trench type 1 should offer reasonable protection against these vessels. 50% protection was assumed for ocean-going vessels. For simplicity, trench type 2 was treated the same way as type 1 and 50% protection was assumed for large anchors. This is a little conservative since trench type 2 is designed to protect anchors up to 5 tonnes.

Trench type 3 (deigned to protect against 19 tonne anchors) was assumed to provide 99% protection for anchors greater than 2 tonnes, and greater protection of 99.9% for small anchors below 2 tonnes.

12A.5.5 *Summary of Failure Frequencies for the Proposed CAPCO Pipeline*

Based on the above discussions, the failure frequencies used in this study are as summarized in *Table 12A.19*.

The failure frequencies specified in *Table 12A.19* will apply to each of the two pipelines.

Table 12A.19 Summary of Failure Frequencies used in this Study

Pipeline section	Trench type	Corrosion /defects (/km/year)	Anchor/Impact			Others /km/year	Total* /km/year
			Frequency (/km/year)	Protection factor (%) anchor<2	Anchor>2		
Boundary Section	2	1.18×10^{-6}	1×10^{-4}	99	50	1.34×10^{-6}	3.5×10^{-6}
Urmston Road	3	1.18×10^{-6}	8.6×10^{-4}	99.9	99	1.34×10^{-6}	4.1×10^{-6}
Black Point West	2	1.18×10^{-6}	1×10^{-4}	99	50	1.34×10^{-6}	3.5×10^{-6}
Black Point Approach	1	1.18×10^{-6}	1.37×10^{-5}	99	50	1.34×10^{-6}	2.7×10^{-6}

* The calculation of total failure frequency takes into account the size distribution of ships (based on 2011 marine traffic) and the protection factors for anchors

12A.5.6 *Scenario Development*

The outcome of a hazard can be predicted using event tree analysis to investigate the way initiating events could develop. This stage of the analysis involves development of the release cases into discrete hazardous outcomes. The following factors are considered:

- Failure cause;
- Hole size;
- Vessel position and type; and
- Ignition probability.

The probabilities used in the event trees are discussed below.

Failure Cause

Failures due to corrosion and other events are considered separately from failures caused by anchor impact. This is because the hole size distribution is different in each case, as described below. Also, in the event of failure due to anchor impact, the probability of vessel presence is assumed to be higher, as discussed later.

Hole Size Distribution

The data on hole size distribution in PARLOC 2001 is summarised in *Table 12A.20*.

This data on hole size distribution is clearly limited, particularly for large diameter pipelines. One approach is to compare this distribution with that for onshore pipelines, which include a much larger database of operating data and failure data. For example, the US Gas database [15] is based on 5 million pipeline km-years of operating data as compared to 300,000 km-years in the PARLOC study.

Table 12A.20 Hole Size Distribution from PARLOC 2001

Pipeline size	Location	Hole size (mm) 0 to 20mm	20 to 80mm	>80mm
2 to 9"	Safety zone Mid line	6	3 (1 rupture)	2
		14	4 (2 ruptures)	1 (1 rupture)
10 to 16"	Safety zone Mid line	1	1	4 (3 ruptures)
		1		3
>16"	Safety zone Mid line	1		
		2		2 (2 ruptures)
Total		25 (55%)	8 (18%)	12 (27%)

An analysis of hole size distribution for onshore pipelines as given in the US Gas [15] and European Gas Pipelines databases [20] provides a hole size distribution as given in *Table 12A.21.*

Table 12A.21 Hole Size Distribution Adopted for Corrosion and Other Failures

Category	Hole Size	Proportion
Rupture (Half Bore)	22" or 558mm	5%
Puncture	4" or 100mm	15%
Hole	2" or 50mm	30%
Leak	<25mm	50%

The above distribution is largely similar to the distribution derived in the PARLOC report [6]. The only difference is the consideration of a small percentage of ruptures. It is a matter of debate whether ruptures could indeed occur although ruptures extending over several metres are reported in the various failure databases.

In this study, it is proposed that the hole size distribution given in *Table 12A.21* be adopted for failures caused by corrosion and 'other' failures (including material/weld defect). In the case of failures caused by anchor damage, the hole sizes are expected to be larger. The distribution given in *Table 12A.22* is adopted.

Table 12A.22 Hole Size Distribution for Anchor Impact

Category	Hole Size	Proportion
Rupture (Full Bore)	Full bore	10%
Major	22" or 558mm (half bore)	20%
Minor	4" or 100mm	70%

Vessel Position

In the case of failures due to corrosion/other events, the probability of a vessel being affected by the leak is calculated based on the traffic volume and the size of the flammable cloud. Dispersion modelling using PHAST [21] is used to obtain the size of the flammable cloud for each hole size scenario and four weather scenarios covering atmospheric stability classes B, D and F. Once the cloud size is known, the probability that a passing marine vessel will travel through this area within a given time can be calculated. A time period of 30 minutes is used since it is assumed that if a leak occurs, warnings will be issued to all shipping within 30 minutes. Further details on the dispersion modelling are given in *Section 12A.6*.

In the case of failures due to anchor impact, the following two scenarios are considered:

- "Vessels in vicinity" - the vessel that caused damage to the pipeline (due to anchoring) is still in the vicinity of the incident zone. The probability of this is assumed to be 0.3; and

- "Passing vessels" - ships approach or pass the scene of the incident following a failure. In this case, the probability of a vessel passing through the plume is calculated using the same method as for a corrosion failure; i.e. based on cloud size and traffic volume.

Event trees showing these scenarios are given in *Figures 12A.7* and *12A.8*. If a vessel passes through the flammable gas cloud, a distinction is further made between vessels passing directly over the release area and vessels passing through other parts of the cloud. This is discussed further in the following section.

Figure 12A.7 Event Tree for External Damage from Anchors

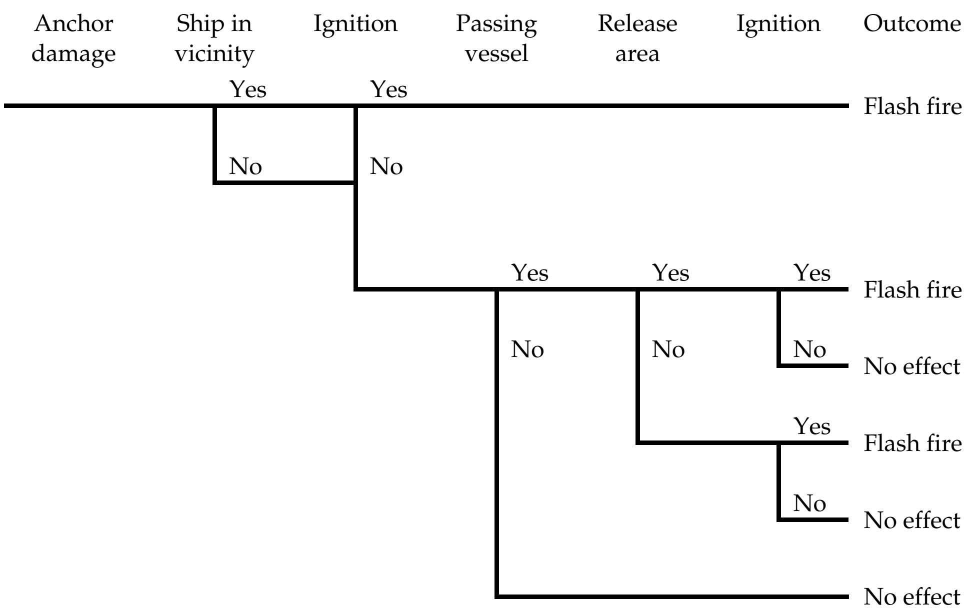
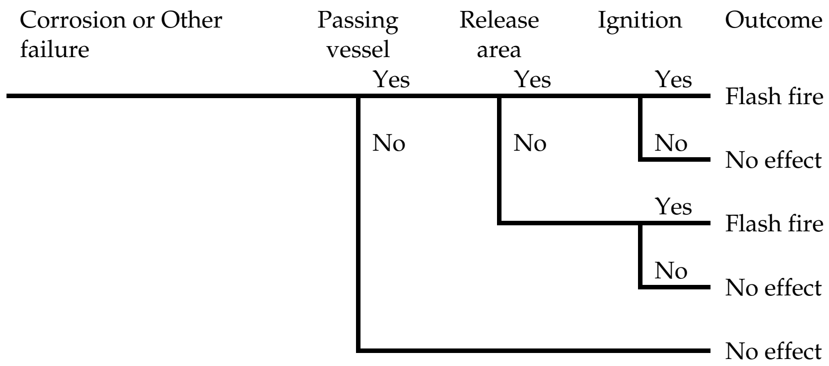


Figure 12A.8 Event Tree for Spontaneous Failures



It is assumed that at most, only one vessel will be affected by a pipeline failure. Once the flammable plume is ignited, the resulting fire will be visible and other ships will naturally avoid the area.

Vessel Type

The categorisation of vessel types follows those identified from the radar tracks (*Table 12A.2*), namely:

- Fishing vessels and small crafts;
- Rivertrade coastal vessels;
- Ocean-going vessels;
- Fast Launches;
- Fast ferries;
- 'Others' (assumed to be small vessels)

The relative proportion of the different vessel types will vary along the pipeline route, as indicated in *Table 12A.4*.

Ignition Probability

Ignition of the release is expected only from passing ships or ships in the vicinity. Ignition probabilities derived from offshore pipeline releases in the vicinity of an offshore platform are given in *Table 12A.23* [22]. Similar values are adopted in this study, as given in *Table 12A.24.*

Table 12A.23 Pipeline Hydrocarbon Release Ignition Probability in Platform Vicinity [23]

	Typical Ignition Probability (integrated platform)		
Location of release	**Massive gas release (>20 kg/s)**	**Major gas release (2-20 kg/s)**	**Minor gas release(<2 kg/s)**
Riser above sea*	0.168	0.026	0.005
Subsea	0.443	0.13	0.043
	Typical Ignition Probability (bridge linked platform)		
Location of release	**Massive gas release (>20 kg/s)**	**Major gas release (2-20 kg/s)**	**Minor gas release (<2 kg/s)**
Riser above sea*	0.078	0.013	0.002
Subsea	0.14	0.051	0.002

* 'Riser above sea' refers to pipeline riser portion that is above sea level

Table 12A.24 Ignition Probabilities used in Current Study

Release Case	**Ignition Probability**	
	Passing Vessels (1)	**Vessels in Vicinity (2)**
<25mm	0.01	n/a
50mm	0.05	n/a
100mm	0.1	0.15
Half bore	0.2	0.3
Full bore	0.3	0.4

1. Values applied to passing vessels for all types of incidents, i.e. corrosion, others and anchor impact.
2. Values applied only to scenarios where the vessel causing pipeline damage due to anchor impact is still in the vicinity.

12A.5.7 *Second Phase Construction Activities*

The second pipeline may be constructed concurrently with the first, or two years later in 2014. From a risk perspective, construction of the pipelines at different times may present an increase in risk due to construction activities from the second pipeline impacting on the first operational pipeline.

The project has taken this into consideration with the following safeguards:

- The two pipelines will be located 100 m apart;
- The pipelines are planned to run parallel without any crossing points and without crossing any other existing pipelines;
- Strict procedures for construction activities involving surveys, confirmation of location using Global Positioning Systems and the demarcation of alignment using marker buoys;
- The pipelines are protected against damage from dredging by rock protection along their full length; and

- Design for the second pipeline will be taken into account during construction of the first pipeline. Critical areas, such as the shore approaches will be pre-constructed in parallel for the two pipelines as far as practicable.

The Gas Production & Supply Code of Practice [24] provides a practical guidance in respect of the requirements of the Gas Safety Ordinance Cap 51 and the Gas Safety (Gas Supply) Regulations. Article 23A of these regulations requires that:

- No person shall carry out, or permit to be carried out, any works in the vicinity of a gas pipe unless he or the person carrying out the works has before commencing the works, taken all reasonable steps to ascertain the location and position of the gas pipe; and

- A person who carries out, or who permits to be carried out, any works in the vicinity of a gas pipe shall ensure that all reasonable measures are taken to protect the gas pipe from damage arising out of the works that would be likely to prejudice safety.

Work, 'in the vicinity' is defined according to *Table 12A.25* and these guidelines apply to both onshore and subsea pipelines. Although many of the activities listed are not directly relevant to the proposed CAPCO pipeline, *Table 12A.25* serves to indicate typical effects distances for different types of work and when special precautions are warranted. A separation distance of 100m is very significant compared to distances listed in *Table 12A.25*. This, combined with the strict procedures that will be followed and the pipeline protection provided, suggests that the likelihood of damage to the first operational pipeline from construction activities during phase 2 will be very low. This is therefore not considered further in this study.

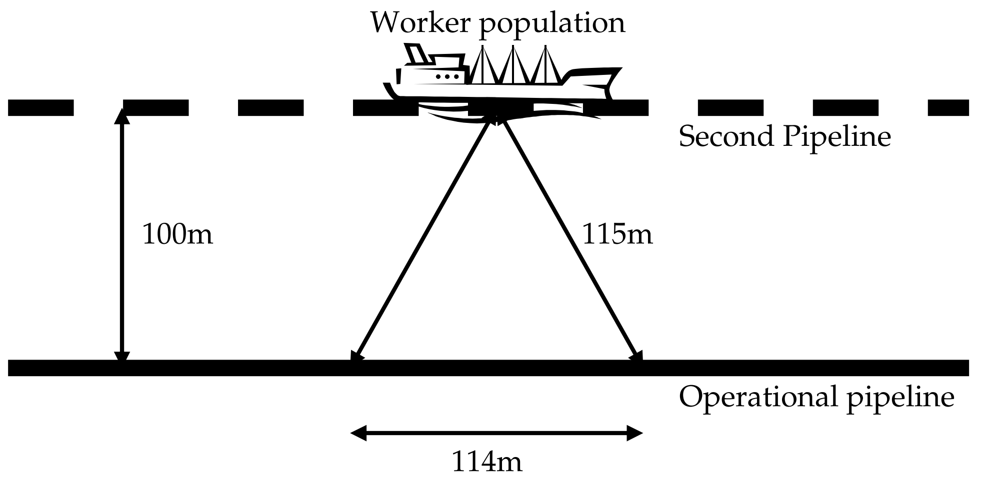
Table 12A.25 Works in the Vicinity of Gas Pipes

Type of Work	Distance
Trench or other excavation up to 1.5m in depth in stable ground	10m
Trench or other excavation over 1.5m and up to 5m in depth	15m
Trench or other excavation in stable ground over 5m in depth	20m
Welding or hot works near exposed gas pipes or above ground installations	10m
Piling, percussion moling or pipe bursting	15m
Works near high pressure pipelines	20m
Ground investigation and any kind of drilling or core sampling	30m
Use of explosives	60m

The construction activities may also increase risk by increasing the population within the vicinity of the operational pipeline. Any incident affecting the operational pipeline may impact on the construction workers and lead to a higher number of fatalities.

The hazard effects exceed 100m only for the half bore rupture case in weather condition 7D (refer to Consequence Analysis). This scenario has a hazard range of 115 m. Geometric considerations (*Figure 12A.9*) imply that a leak from a section of pipeline just 114m long has the potential to reach the workers 100 m away.

Figure 12A.9 Construction Workers' Proximity to Pipeline



An incident at the operating pipeline may be caused by internal failure or external impact.

Internal Failure

The failure frequency (*Table 12A.19*) for internal failure is 2.52×10^{-6} /km/year [(1)]. The frequency of events from the operational pipeline impacting on construction workers at the second pipeline may be estimated from:

$$freq = 2.52 \times 10^{-6} \times \frac{114}{1000} \times 0.695 \times \frac{1}{6} \times 0.05 \times 0.2 = 3.33 \times 10^{-10} \quad /\text{year}$$

Where the factor of 114/1000 arises from the geometric considerations and the fact that an incident must occur within a 114m length section of the pipeline to affect the workers. 0.695 refers to the probability of weather category 7D and a factor of 1/6 is applied to approximate the probability of the wind blowing towards the construction workers. The factor of 0.05 corresponds to the probability of the leak size being half bore rupture for internal failures and 0.2 corresponds to the ignition probability for this sized leak.

(1) Corrosion Frequency (/km/year) + Frequency of Other Causes (/km/year) = 1.18x10-6 + 1.34x10-6 = 2.52 x10-6 /km/year

External Impact

The highest frequency (ie. Urmston Road) for external damage is 1.58×10^{-6} /km/year (calculated from *Table 12A.19* (2)). The frequency of incidents affecting workers on the second pipeline may be estimated in a similar manner as above:

$$freq = 1.58\times10^{-6}\times\frac{114}{1000}\times0.695\times\frac{1}{6}\times0.2\times(1-0.3\times0.3)\times0.2 = 7.59\times10^{-10}$$

/year

Where the probability of half bore rupture is taken to be 0.2 for external damage and the factor of (1-0.3×0.3) represents the probability that the vessel causing the damage did not itself ignite the release (0.3 for the vessel that caused the damage is still present and 0.3 for the ignition probability). Other terms are the same as in the internal failure case.

Combining the internal and external failure scenarios gives a total frequency of 1.09×10^{-9} per year that the construction workers will be affected by an incident at the operational pipeline. Construction, however, is expected to take 11 months and will take place for 12 hours per day, except for the Urmston Road section where construction will be round-the-clock. Taking into account these presence factors reduces the frequency below the 10^{-9} /year and therefore construction related risks are not considered further in the assessment.

12A.6 CONSEQUENCE ANALYSIS

12A.6.1 *Overview*

In the event of loss of containment, the gas will bubble to the surface of the sea and then disperse. If it comes in contact with an ignition source, most likely from a passing marine vessel, it could lead to a flash fire which will propagate through the cloud to the point of release and result in a gas fire above the water surface.

If a marine vessel passes into a plume of gas and ignites it, then there is the possibility of fatalities on that ship due to the flash fire. If a vessel passes through the 'release area' of the release, the vessel will likely be affected also by the ensuing fire and the consequences will be more severe. If the release gets ignited, it is presumed that no further ships will be involved because the fire will be visible and other ships will naturally avoid the area. In other words, it is assumed that at most, only one ship will be affected.

Further details are described in the following paragraphs.

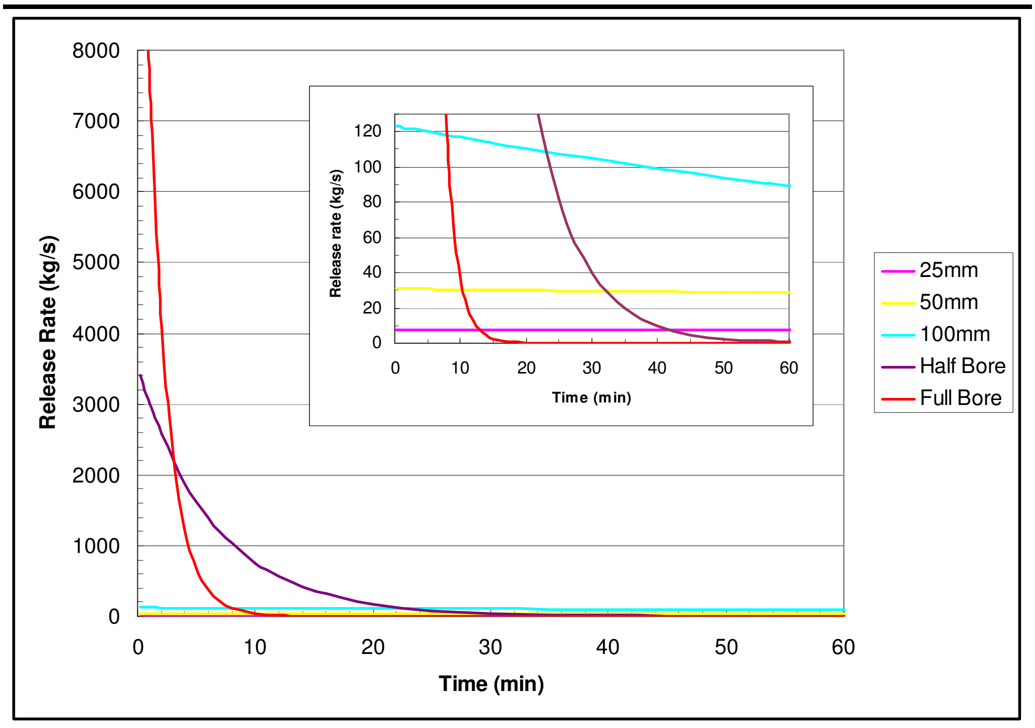
(2) Total Failure Frequency (/km/year) - Internal failure Frequency = 4.1x10-6 - 2.52x10-6 = 1.58x10-6 /km/year

12A.6.2 *Source Term Modelling*

The release rate is estimated based on standard equations for discharge through an orifice. The empirical correlation developed by Bell and modified by Wilson [23] is adopted. A maximum operating pressure of 100 barg is assumed.

The results are presented in *Figure 12A.10*. For holes with equivalent diameter smaller than about 100 mm, the discharge rate diminishes rather slowly because of the large inventory in each pipeline (about 1,380 tonnes). For half and full bore failures, the discharge rate diminishes more quickly over a period of about 30-60 minutes.

Figure 12A.10 Variation of Release Rate with Time

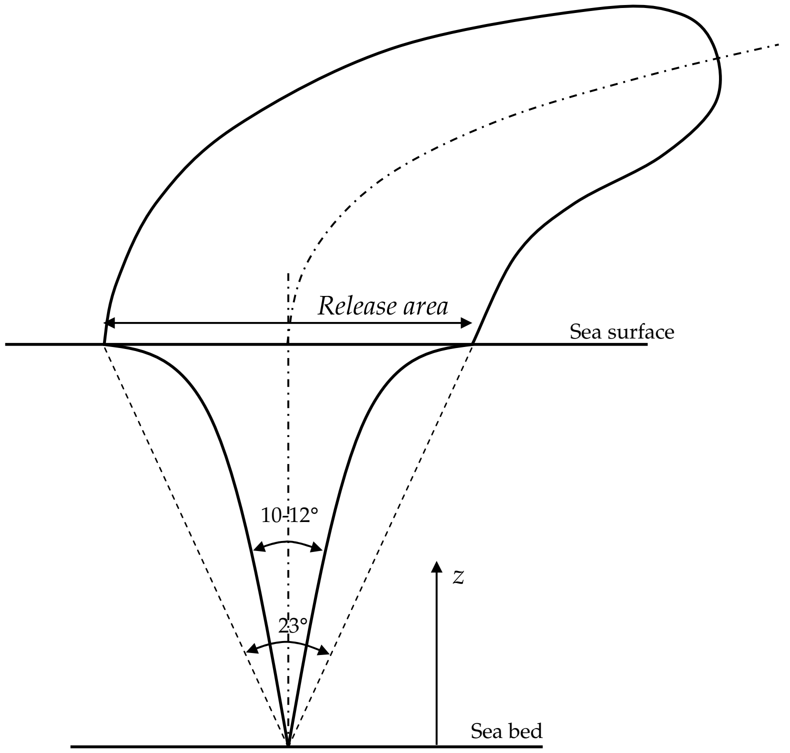


12A.6.3 *Dispersion Modelling for Subsea Releases*

In the event of a release from the subsea pipeline, the gas jet is expected to lose momentum and bubble to the surface. The simplest form of modelling applied to subsea releases is to assume that the dispersing bubble plume (driven by gas buoyancy) can be represented by a cone of fixed angle (*Figure 12A.11*) [23]. The typical cone angle is between 10 to 12°. However, Billeter and Fannelop [23] suggested that the 'release area' (where bubbles break through the surface) is about twice the diameter of the bubble plume. Hence, an angle of 23° was recommended and is used in this study.

Based on *Figure 12A.11*, the water depth is between 2-5m for much of the proposed pipeline route, increasing to 20m in Urmston Road. For this range of water depths, the cone model predicts the 'release area' to be in the range of 0.8 to 8 m diameter.

Figure 12A.11 Simple Cone Model for Subsea Dispersion



12A.6.4 Dispersion above Sea Level

The gas will begin to disperse into the atmosphere upon reaching the sea surface. The distance to which the flammable envelope of gas extends will depend on ambient conditions such as wind speed and atmospheric stability as well as source conditions. The extent of the flammable region is taken as the distance to 0.85 LFL (Lower Flammable Limit).

Conditions at the source such as momentum and buoyancy are important. At shallower depths and high release rates, the gas will have a large momentum at the sea surface resulting in a plume extending rapidly upwards into the atmosphere. For smaller releases or release from deeper water, the gas will lose all momentum by the time it reaches the sea surface resulting in a plume of greater horizontal extent. Dimensional analysis using the Froude number [23] suggests that momentum and buoyancy are both important over most release scenarios considered in the current study. Only full bore ruptures in shallow water result in a momentum dominated jet release.

The above sea dispersion was modelled using PHAST [21]. Based on the above discussion, to achieve realistic simulations it is important to give due consideration to the momentum and buoyancy of the source. The gas was assumed to gain heat from the sea water, during transport and following a release. The gas was therefore assumed to be released at 20°C and 100barg.

Being lighter than air, natural gas lifts away from the sea surface under all atmospheric conditions.

The cone model is believed to be a reasonable approach for estimating the 'release area' for small to moderate releases. The worst scenario is deep water, which produces a large 'release area' and hence low efflux momentum for a given mass release rate. The deepest water case of 20m was therefore chosen for analysis. A low momentum gives a lower plume rise and hence a larger hazardous area near the sea surface. The cone model, however, has not been validated for massive releases such as would occur in a half bore or full bore rupture. To err on the cautious side, a larger 'release area' was assumed for massive releases. The diameter of the release area was increased by 50% for half bore rupture and by 100% for full bore rupture scenarios. This lowers the source momentum and gives conservative results.

PHAST was used to model the plume dispersion as an area source on the surface of the ocean. The mass release rate, the release velocity and temperature were specified and the release was assumed to be vertical. The surface roughness parameter was assumed to be 0.043, a value appropriate for dispersion over water. Even though the release is a transient, particularly for the large release scenarios, the time constant for the release is still longer than the dispersion time scale. The modelling therefore assumed a steady release of gas at the maximum (initial) release rate. Again, this is conservative. Simulations were performed for atmospheric stability classes of B, D and F to cover the range of meteorological conditions expected. Given that the plume in all cases lifted away from the surface due to buoyancy, the length of the plume was taken to be the maximum extent of the plume in the windward direction up to the ship height which is assumed to be a maximum of 50m.

The relative occurrence of weather conditions 2F, 3D, 7D and 2.5B were taken to be 0.083, 0.070, 0.695 and 0.152 respectively to match conditions measured at the Sha Chau meteorology station (*Table 12B.6*). This is based on the average of the most recent 5 years of meteorological data from 2004 to 2008.

12A.6.5 *Impact Assessment*

Impact on Population on Marine Vessels

The hazardous distance was taken to be the distance to 0.85 LFL as discussed above. It was assumed that ships would be at risk for 30 minutes before warnings could be issued to advice vessels to avoid the area. Knowing the marine vessel traffic (in ships per day per km of pipeline), the probability that a passing ship will cross through the flammable plume during this 30 minutes is calculated as:

$$Prob. \quad = \quad traffic \quad (/\,km\,/\,day) \times length\ of\ \ plume \times \frac{0.5\,(hours)}{24\,(hours\,/\,day)} \qquad (3)$$

If a marine vessel comes into contact with the flammable plume and causes ignition, the resulting flash fire may lead to fatalities depending on the type of ship. Small open vessels such as fishing boats are expected to provide less protection to their occupants. Large ocean-going vessels will provide better protection. Fatality factors are therefore applied to each class of vessel to take into account the protection offered by the vessel. These take into consideration:

- The proportion of the passengers likely to be on deck or in interior compartments.
- The materials of construction of the vessel and the likelihood of secondary fires.
- The size of the vessel and hence the likelihood that it can be completely engulfed in a flammable gas cloud.
- The speed of the vessel and hence its exposure time to the gas cloud.
- The ability of gas to penetrate into the vessel and achieve a flammable mixture.

Considering fast ferries; they are air conditioned and travel at high speeds in excess of 30 knots (15m/s). If the occupants are to be affected by a flash fire, gas must penetrate into the interior of the vessel, achieve a flammable mixture and ignite. The time to transit the largest gas cloud of 95m is of the order of 7 seconds. Assuming typical air ventilation rates of 6 to 10 volume changes per hour, a time constant for changes in gas concentration within a ferry can be derived as 6 to 10 minutes. This implies that it would take several minutes for the gas concentration within a ferry to respond to changes in concentration in the ambient air. Given that the exposure time is mere seconds, it becomes apparent that it is very difficult to achieve a flammable mixture of gas within a ferry. Based on these considerations, the fatalities assumed in the current study for fast ferries and other vessels are as given in *Table 12A.26*.

If a ship enters the 'release area' and ignites the gas cloud, the vessel is more likely to be caught in the ensuing fire. This is assumed to result in more severe consequences with potential for 100% fatality of occupants. The probability of this is calculated using a similar equation as above (*Equation 3*) but replacing the cloud size with the release area diameter.

Table 12A.26 Fatality Probabilities

Class	Fatality	
	'Release area'	'Cloud area'
Fishing vessels	1	0.9
Rivertrade coastal vessels	1	0.3
Ocean-going vessels	1	0.1
Fast launches	1	0.9
Fast ferries	1	0.3
Others	1	0.9

If the failure is caused by corrosion, a passing ship may pass through the flammable plume or release area with a probability given by *Equation 3*. If the failure is caused by third party damage, then two scenarios are considered as mentioned in *Section 12A.5*. The vessel that caused the incident may still be in the area and may ignite the plume, or if this vessel is no longer present, a passing ship may pass through the plume. The probability that the vessel causing the incident is still present is assumed to be 0.3 and this is assumed to result in 100% fatality.

The analysis limits the number of ships involved to one. It is assumed that once the plume is ignited, other ships will avoid the area.

12A.6.6 Consequence Results

Hazard distances are determined from the dispersion modelling. Given that natural gas is buoyant and tends to lift away from the sea surface, the hazard distance is defined as the gas cloud width near sea level where ignition is possible by passing ships. Specifically, the hazard distance is taken to be the maximum width within 50m of the sea surface (*Figure 12A.12*). Based on this, the hazard distances obtained from dispersion modelling are summarised in *Table 12A.27*.

Figure 12A.12 Hazard Distance

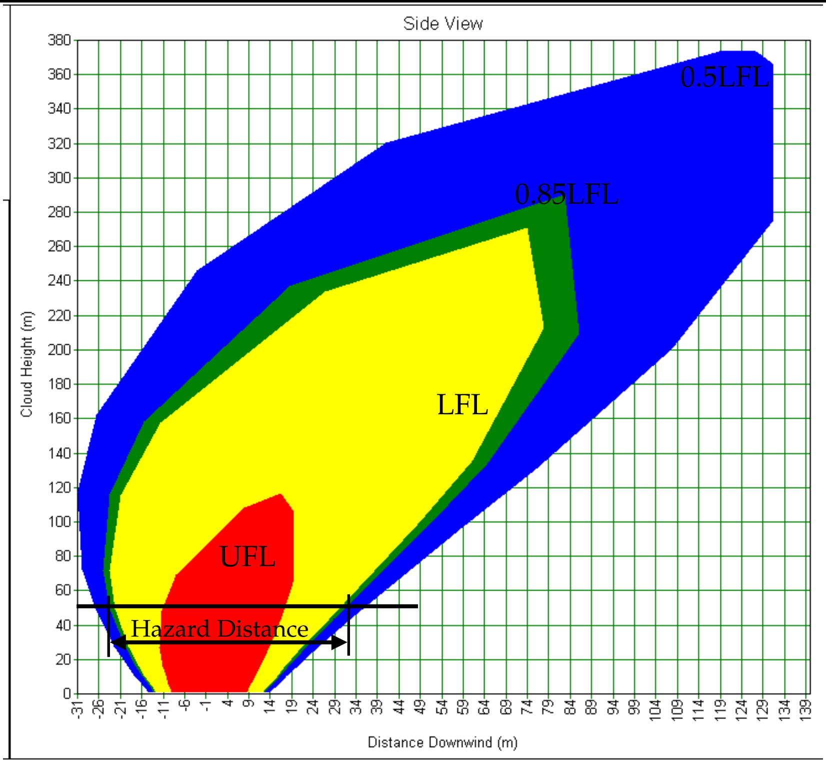


Table 12A.27 Hazard Distances for Gas Cloud Dispersion

Hole Size (mm)	End Point Criteria	Marine Vessel Hazard Distance (m)*			
		Weather conditions			
		2F	3D	7D	2.5B
Full bore	0.85LFL	56	57	82	63
Half bore	0.85LFL	53	53	115	56
100	0.85LFL	59	56	80	43
50	0.85LFL	35	37	52	32
25	0.85LFL	22	27	33	24

* Distances quoted are those for releases from 20m water depth. Deep water releases give higher hazard distances and were used in the assessment as conservative upper limits.

12A.7 RISK SUMMATION

The frequencies and consequences of the various outcomes of the numerous accident scenarios are integrated at this stage, to give measures of the societal risk (FN curves and Potential Loss of Life) and individual risk.

Risk results are compared with the criteria for acceptability as laid down in the Hong Kong Planning Standards and Guidelines, chapter 12 [25] and also in Annex 4 of the Technical Memorandum of EIAO. However, these risk guidelines cannot be applied directly for transport operations (such as pipelines). Since transport operations extend over several kilometres and communities, they cannot be equated with risks from fixed installations (such as an LPG plant, refinery or a petrochemical plant) which have a defined impact zone. As a result, a pipeline of 1 km length is considered as equivalent to a fixed installation for the application of risk criteria. This approach is adopted internationally [26] and was adopted by the consultant in similar studies for onshore and offshore high pressure gas pipelines. Based on this approach, the results are presented on a per-kilometre basis for each section of the pipeline.

The individual risk (IR) criterion for a potentially hazardous installation specifies that the risk of fatality to an offshore individual should not exceed 1×10^{-5} per year. It is generally accepted that the same IR criteria should also apply for transport operations.

Risk results are presented in the *Section 12* of the *EIA Report*.

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Annex 12B

Quantitative Risk Assessment (QRA) for Gas Receiving Stations

CONTENTS

12B QUANTITATIVE RISK ASSESSMENT FOR GAS RECEIVING STATIONS

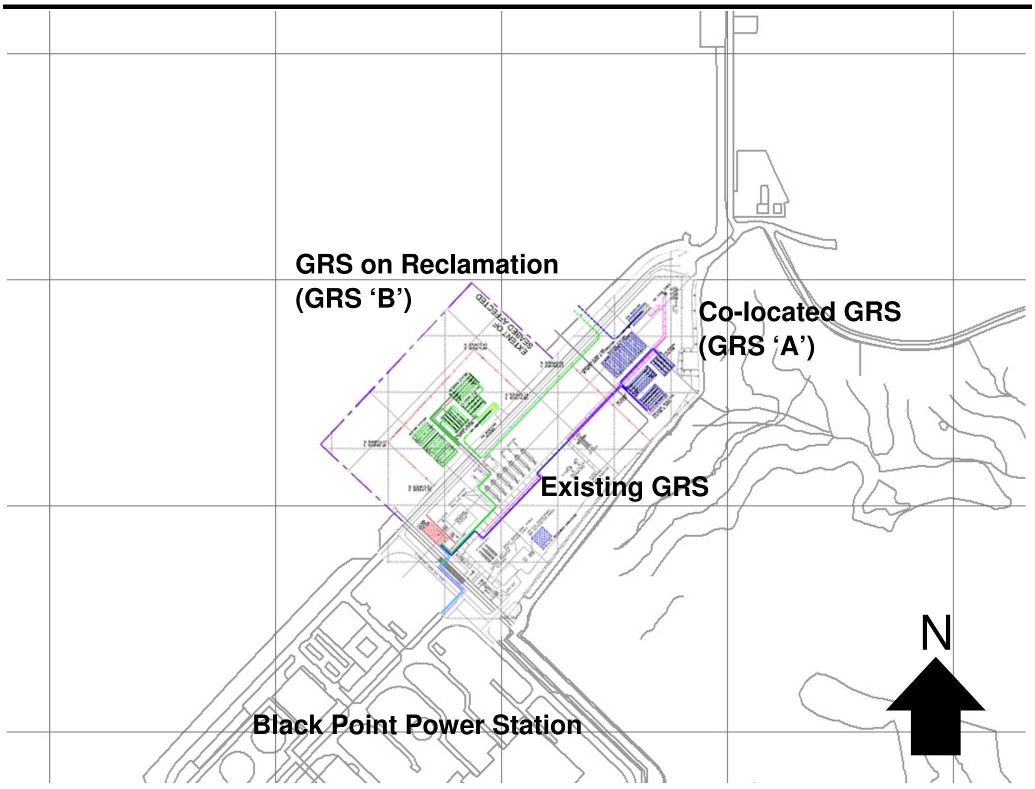
12B.1 INTRODUCTION

This study covers the details of the Quantitative Risk Assessment (QRA) for the Gas Receiving Stations (GRSs) at the Black Point Power Station (BPPS) which will receive natural gas through two subsea pipelines from the Mainland. Detailed information of the study methodology is presented here whilst the results and conclusions are given in the *Section 12* of the *EIA Report*.

The two pipelines to BPPS will terminate at two Gas Receiving Stations (GRSs), one for each submarine pipeline. The first GRS (GRS 'A') will be located adjacent to the existing GRS for the Yacheng pipeline, while the second (GRS 'B') will be located on reclaimed land on the north side of BPPS (*Figure 12B.1*). The first GRS will be constructed in 2011 with operations beginning in late 2011. The second GRS is expected to be constructed in around 2014. From a risk perspective, construction at different times represents the worst case and this is considered in the analysis.

The analysis considers a single GRS operating in 2011 as the base case, the Second Phase construction in 2014 and a future year 2021 when both GRSs will be operational.

Figure 12B.1 GRS Locations



12B.2 DESIGN DETAILS

Each GRS will comprise the following facilities:

- 2 emergency shutdown (ESD) valves;
- 1 pig receiver, with associated service piping;
- Station inlet header;
- 2 inlet filter-separators (plus 1 standby);
- 2 metering runs (plus 1 standby);
- 3-7 water bath gas heaters (3 to 4 large water bath heaters, or 6 to 7 smaller units);
- 2 pressure control runs (plus 1 standby); and
- Station export header.

A process flow diagram is shown in *Figure 12B.2*. The two GRSs are essentially similar. Gas will be received via the two offshore pipelines and the first major piece of equipment in the station will be an Emergency Shutdown (ESD) valve, which can be closed by means of the station ESD system in the event of an emergency, isolating the station from the source of gas. For emergency depressurization of the GRS facilities, a vent stack will be provided.

Downstream of the ESD valves will be the pig receiver. This enables the running of cleaning and inspection pigs in the pipeline. Following the pig receiver are the inlet filter units, metering runs, heaters and pressure letdown section where the pressure is reduced to about 38 barg. The gas is then sent out to distribution headers to supply the power station. The headers from GRS A and GRS B are combined at the mixing station.

The existing vent stack will provide a common vent for all 3 GRSs to allow depressurisation of equipment. The stack, however, will be relocated further northeast to make space for the co-located GRS.

Design details are yet to be finalised. Where there is uncertainty in the design, this analysis has erred on the conservative side. For example, there may be 3 or 4 large water bath heaters, or 6 or 7 smaller units. While the total heating capacity will be the same, a larger number of heaters creates a higher failure frequency and hence 7 heaters are assumed in the analysis as a conservative measure. Adopting such an approach ensures this QRA will remain valid, even if minor design changes are introduced during the detailed design stage. The layout for the two GRSs is shown in *Figure 12B.3*.

Figure 12B.2 Gas Receiving Station Process Flow Diagram

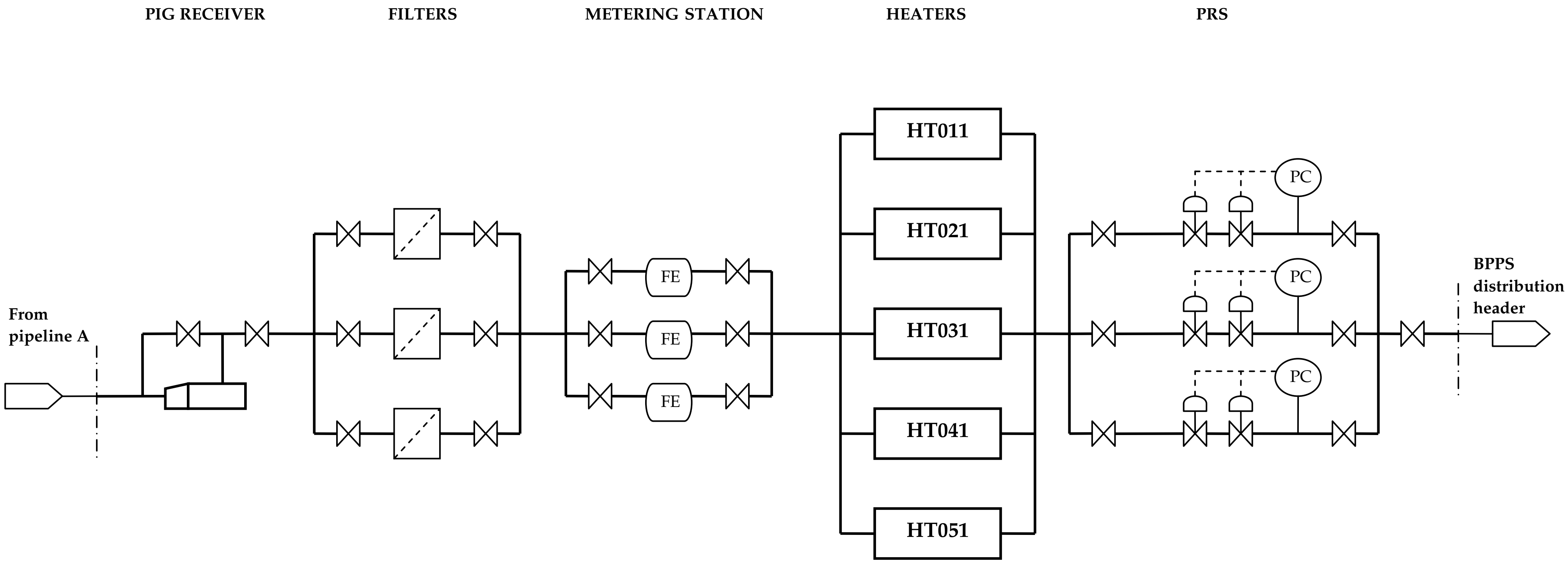
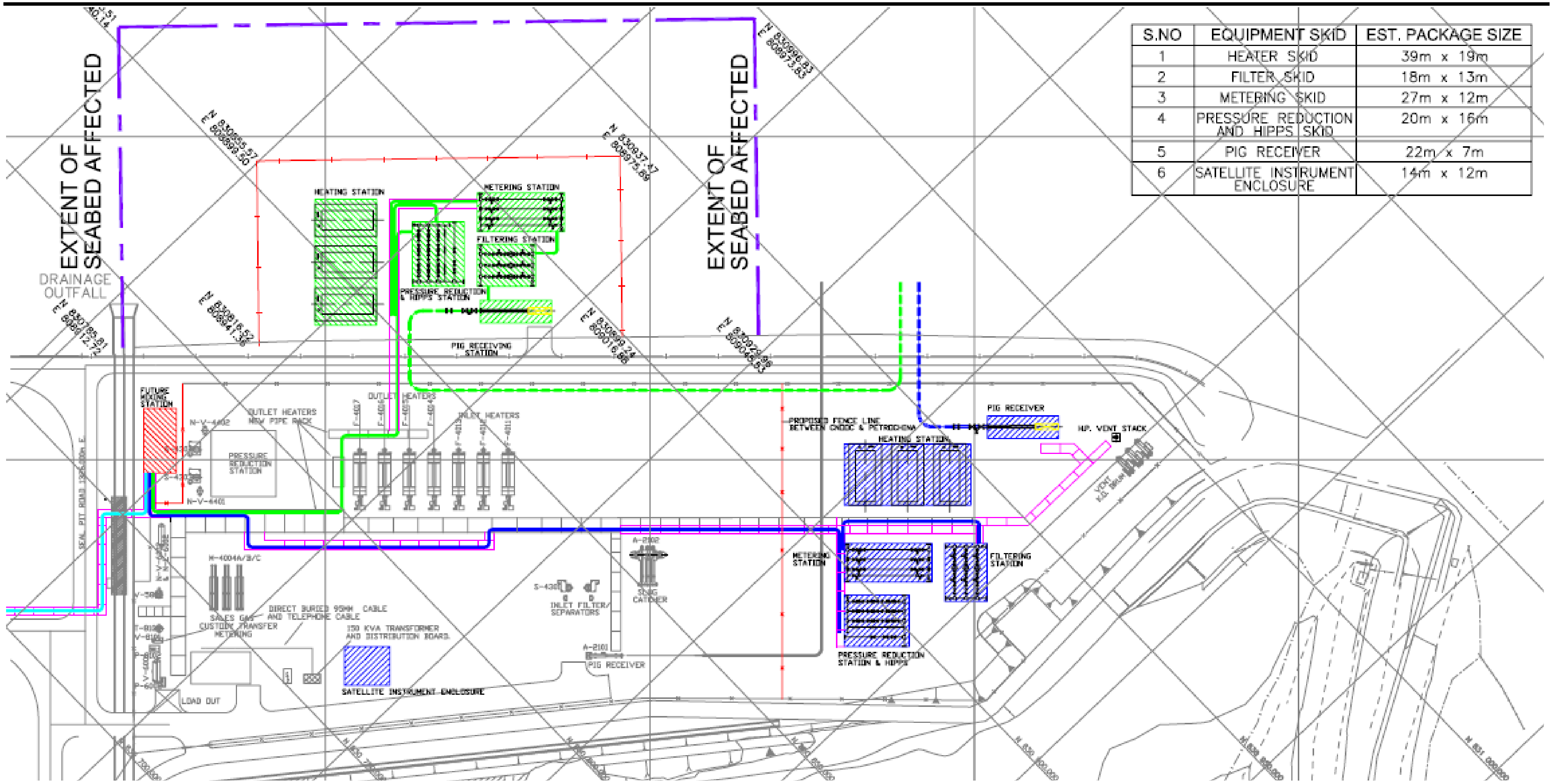


Figure 12B.3 GRS Layout



12B.3 SITE DESCRIPTION

12B.3.1 *Population Data*

The BPPS area is generally remote with very low population in the vicinity. Both land and marine populations are considered in the analysis, for the year 2011 (the expected year of completion of the 1st GRS), the phase 2 construction period in 2014 and a future year 2021. The consequence analysis (*Section 12B.6*) demonstrates that the maximum extent of hazard effects reach about 335 m. The population assessment therefore considered all offsite population within about 500 m of the proposed GRS. The population at the GRS sites, such as workers, are considered onsite population and therefore outside the scope of this QRA.

Land Population

There is no land based population within 500 m of the proposed GRSs.

The security entrance to BPPS is more than 600 m from the GRS facilities. The nearest industrial facilities in Lung Kwu Sheung Tan are about 1.4 km away and Lung Kwu Tan Road is more than 700 m away. None of these populations will be impacted by any release from the GRSs.

Marine Population Estimation

Black Point is situated near Deep Bay. The marine traffic in the vicinity includes passenger ferries, container ships and rivertrade vessels going to Guangzhou and other Pearl River Ports. Small fishing vessels and leisure crafts also contribute to the marine traffic in the Black Point region.

Vessel Population

The vessel population used in this study are as given in *Table 12B.1*. The figures are based on BMT's Marine Impact Assessment report [3] except those for fast ferries. The maximum population of fast ferries is assumed to be 450, based on the maximum capacity of the largest ferry operating in the area. However, the average load factor for fast ferries to Pearl River ports is only 31.8% [4]. Hence, a distribution in ferry population was assumed as indicated in *Table 12B.1*. This distribution gives an overall load factor of about 52% which is conservative and covers any future increase in vessel population. There is an additional category in the traffic volume data called 'Others'. These are assumed to be small vessels with a population of 5.

Table 12B.1 Vessel Population

Type of Vessel	Average Population per Vessel	% of Trips
Ocean-Going Vessel	21	
Rivertrade Coastal vessel	5	
Fast Ferries	450 (largest ferries with max population)	3.75
	350 (typical ferry with max population)	3.75
	280 (typical ferry at 80% capacity)	22.5
	175 (typical ferry at 50% capacity)	52.5
	105 (typical ferry at 30% capacity)	12.5
	35 (typical ferry at 10% capacity)	5.0
Tug and Tow	5	
Others	5	

Marine Vessel Protection Factors

The population on marine vessels is assumed to be provided with some protection from the vessel structure. The degree of protection offered depends on factors such as:

- Size of vessel;
- Construction material and likelihood of secondary fires;
- Speed of vessel and hence its exposure time to the flammable cloud;
- The proportion of passengers likely to be on deck or in the interior of the vessel; and
- The ability of gas to penetrate into the interior of the vessel and achieve a flammable mixture.

Small vessels such as fishing boats will provide little protection but larger vessels such as ocean-going vessels will provide greater protection. Fast ferries are air conditioned and have a limited rate of air exchange with the outside. Based on these considerations, the fatality probabilities assumed for each type of vessel are as given in *Table 12B.2*.

Table 12B.2 Population at Risk

Marine Vessel Type	Population	Fatality Probability	Population at Risk
Ocean-Going Vessel	21	0.1	2
Rivertrade Coastal Vessel	5	0.3	2
Fast Ferries	450	0.3	135
	350	0.3	105
	280	0.3	84
	175	0.3	53
	105	0.3	32
	35	0.3	11
Tug and Tow	5	0.9	5
Others	5	0.9	5

Methodology

In this study, the marine traffic population in the vicinity of Black Point has been considered as both point receptors and average density values. The population of all vessels are treated as an area average density except for fast ferries which are treated as point receptors.

The marine area around Black Point was divided into 12.67 km^2 grid cells, each grid being approximately 3.6 km × 3.6km. The transit time for a vessel to traverse a grid is calculated based on the travel distance divided by the vessel's average speed. The average speed [2] and transit time for different vessel types are presented in *Table 12B.3.*

Table 12B.3 Average Speed and Transit Time of Different Vessel Type [2]

Type of Vessel	Assumed Speed (m/s)	Transit Time (min)
Ocean-going vessel	6.0	9.9
Rivertrade Coastal vessel	6.0	9.9
Fast Ferries	15.0	4.0
Tug and Tow	2.5	23.7
Others	6.0	9.9

The number of vessels traversing each grid daily was provided by a previous marine study [2]. These are given in *Table 12B.4*, where the grid cell reference numbers are defined according to *Figure 12B.4*. The marine study was based on 2003 data, extrapolated to years 2011 and 2021.

The number of marine vessels present within each grid cell at any instant in time is then calculated from:

$$\textit{Number of vessels} = \textit{No. of vessels per day} \times \textit{grid length} \,/\, 86400 \,/\, \textit{Speed} \qquad (1)$$

This was calculated for each type of vessel, for each grid and for years 2011 and 2021. The values obtained represent the number of vessels present within a grid cell at any instant in time. Values of less than one are interpreted as the probability of a vessel being present.

Figure 12B.4 Grid Cell Numbering Scheme

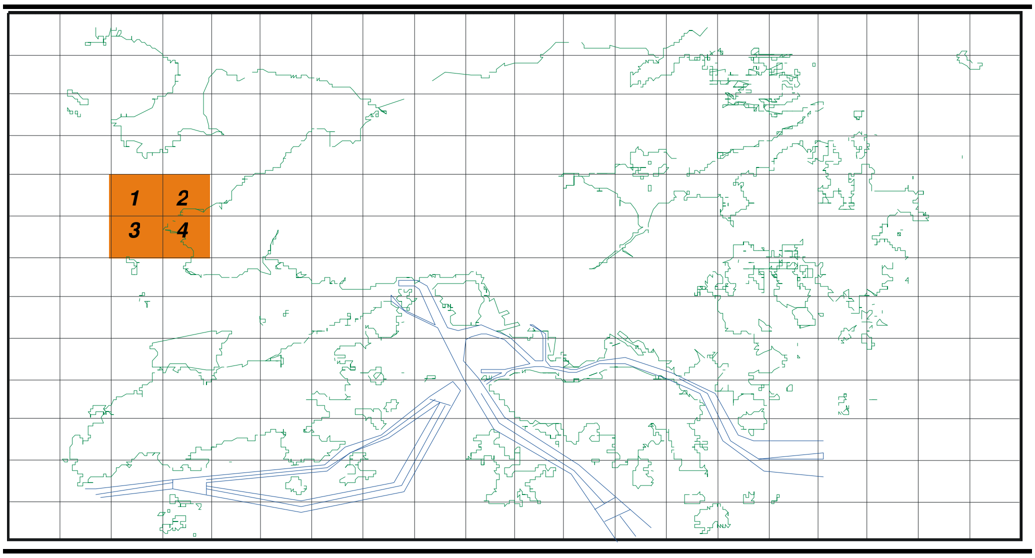


Table 12B.4 Number of Marine Vessels per Day

Grid No.	Average Number of Vessels Per Day									
	2011					2021				
	OG	RT	TT	FF(*)	OTH	OG	RT	TT	FF(*)	OTH
1	19	788	368	44	567	23	863	503	52	621
2	0	0	21	0	84	0	0	23	0	92
3	19	557	263	77	294	23	610	288	91	322
4	0	368	168	11	294	0	403	184	13	322

OG = Ocean-going vessels
RT = Rivertrade coastal vessels
TT = Tug & tow vessels
FF = Fast ferries
OTH = others
(*) Fast ferries are treated separately

Average Density Approach

The average marine population for each grid is calculated by combining the number of vessels in each grid (from *Equation 1*) with the population at risk for each vessel (*Table 12B.2*). The results are shown in *Figures 12B.5* and *12B.6*. This grid population is assumed to apply to all time periods. As can be seen, the growth in marine population from 2011 to 2021 is only marginal. Intermediate values are applied to the phase 2 construction in 2014. Note however that fast ferries are excluded since ferries are treated separately in the analysis (see below).

When simulating a possible release scenario, the impact area is calculated from dispersion modelling. In general, only a fraction of a grid area is affected and hence the number of fatalities within the grid is calculated from:

$$\textit{Number of fatalities} = \textit{grid population} \times \textit{impact area} \;/\; \textit{grid area} \qquad (2)$$

Figure 12B.5 Marine Population at Risk by Grid, Year 2011

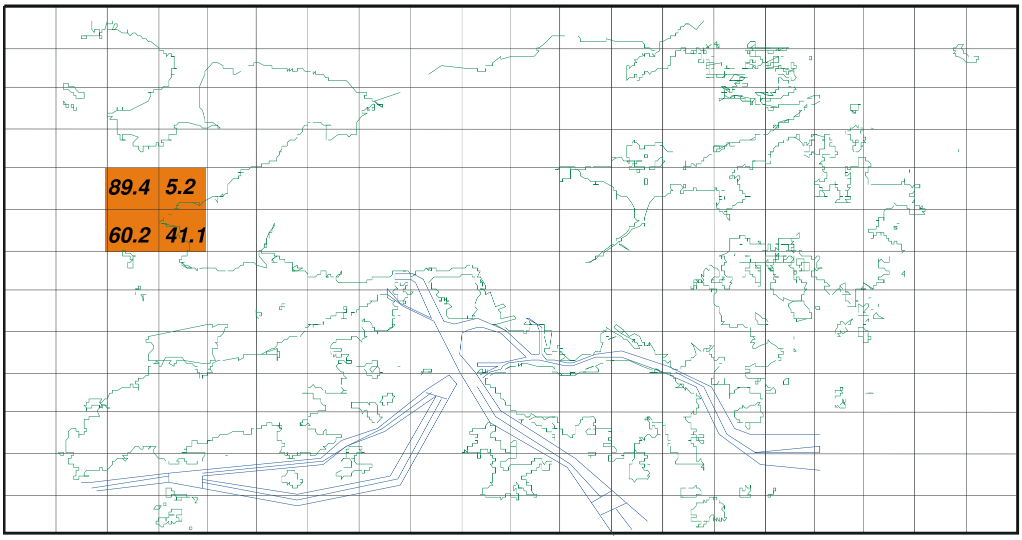
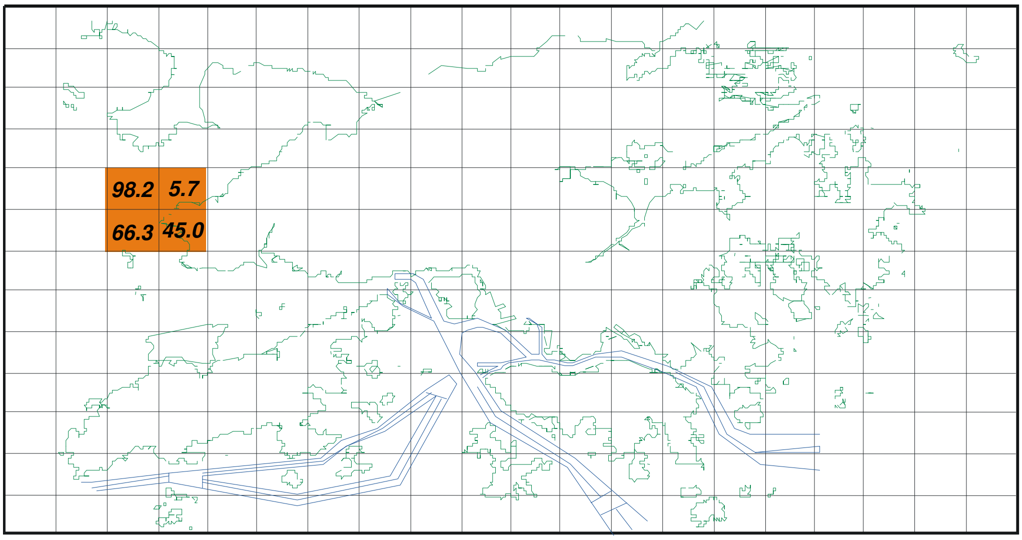


Figure 12B.6 Marine Population at Risk by Grid, Year 2021



Point Receptor Approach

The average density approach, described above, effectively dilutes the population over the area of the grid. Given that ferries have a much higher population than other classes of vessel, combined with a relatively low presence factor due to their higher speed, the average density approach would not adequately highlight the impact of fast ferries on the FN curves. Fast ferries are therefore treated a little differently in the analysis.

In reality, if a fast ferry is affected by an accident scenario, the whole ferry will likely be affected. The likelihood that the ferry is affected, however, depends on the size of the hazard area and the density of ferry vessels. To model this, the population is treated as a concentrated point receptor i.e. the entire population of the ferry is assumed to remain focused at the ferry location. The ferry density is calculated the same way as described above (*Equation 1*), giving the number of ferries per grid at any instant in time, or equivalently a "presence factor". A hazard scenario, however, will not affect a whole grid, but some fraction determined by the area ratio of the hazard footprint area and the grid area. The presence factor, corrected by this area ratio is then used to modify the frequency of the hazard scenario:

$$\textit{Prob. that ferry is affected} = \textit{presence factor} \times \textit{impact area} \ / \ \textit{grid area} \qquad (3)$$

The fast ferry population distribution adopted was described in *Table 12B.1*. Information from the main ferry operators suggests that 25% of ferry trips take place at night time (between 7pm and 7am), while 75% occur during daytime. Day and night ferries are therefore assessed separately in the analysis. The distribution assumed is given in *Table 12B.5*.

Table 12B.5 Fast Ferry Population Distribution for Day and Night Time Periods

Population	Population at Risk	% of Day Trips	% of Night Trips	% of All Trips (= 0.75 × day + 0.25 × night)
450	135	5	-	3.75
350	105	5	-	3.75
280	84	30	-	22.5
175	53	60	30	52.5
105	32	-	50	12.5
35	11	-	20	5.0

The ferry presence factor (*Equation 1*) and probability that a ferry is affected by a release scenario (*Equation 2*) are calculated for each ferry occupancy category and each time period.

<u>Stationary Marine Population</u>

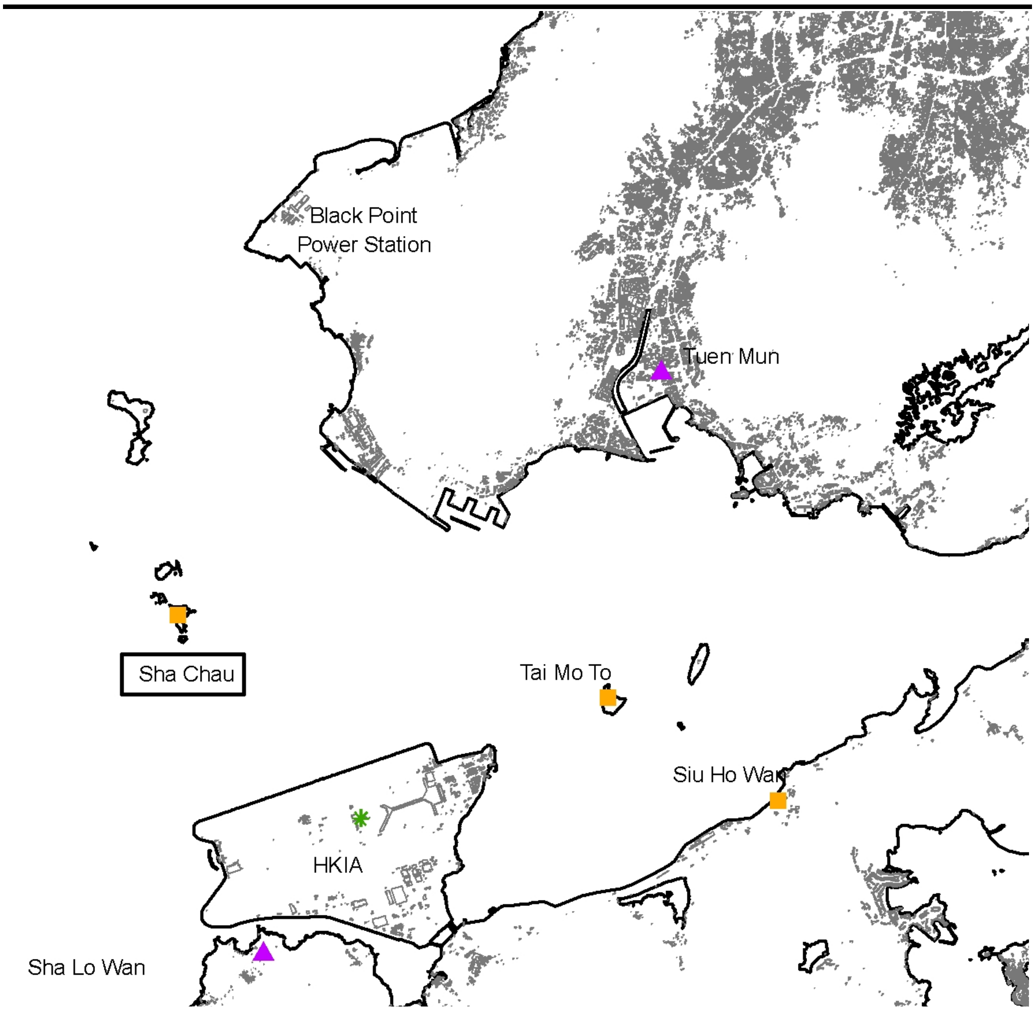
Other stationary marine population such as that for the Urmston Road Anchorage area are more than 500m from the proposed GRSs and were therefore neglected in the analysis.

12B.3.2 *Meteorological Data*

Data on local meteorological conditions such as wind speed, wind direction, atmospheric stability class, ambient temperature and humidity was obtained from the Hong Kong Observatory [20], [21].

The location of weather stations in the vicinity of the GRS is shown in *Figure 12B.7*. Data from the Sha Chau weather station was adopted for the GRS study as it is closest to the site and also the most relevant based on the topography. The meteorological data used in this study is based on the data recorded by the stations over a five year period from 2004 to 2008.

Figure 12B.7 Weather Stations in Vicinity of Black Point



The raw data from the Observatory is a series of readings taken hourly over the 5-year period. This data was rationalized into four combinations of wind speed and atmospheric stability class, denoted as 2.5B, 3D, 7D and 2F where 2F for example refers to a wind speed of 2m/s and atmospheric stability class F. The data is then further sorted in 12 wind directions. This sorting of meteorological data is performed for the two time periods, day and night.

The fraction of occurrence for each combination of wind direction, speed and atmospheric stability for each time period is presented in *Table 12B.6*.

Wind directions, such as 90°, refer to the direction of the prevailing wind. For example, 90° refer to an easterly wind, 0° is northerly, 180° is southerly and 270° is westerly.

Table 12B.6 Data from Sha Chau Weather Station (2004-2008)

	Day				Night			
Wind Speed (m/s)	2.5	3	7	2	2.5	3	7	2
Atmospheric Stability	B	D	D	F	B	D	D	F
Wind Direction	Fraction of Occurrence							
0°	0.052	0.006	0.140	0.005	0.000	0.005	0.114	0.010
30°	0.009	0.005	0.050	0.003	0.000	0.004	0.092	0.008
60°	0.005	0.004	0.009	0.002	0.000	0.006	0.021	0.010
90°	0.040	0.012	0.064	0.007	0.000	0.016	0.139	0.029
120°	0.053	0.007	0.136	0.005	0.000	0.009	0.228	0.023
150°	0.014	0.003	0.023	0.003	0.000	0.003	0.039	0.015
180°	0.029	0.004	0.032	0.004	0.000	0.003	0.048	0.012
210°	0.074	0.007	0.083	0.004	0.000	0.004	0.100	0.014
240°	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001
270°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
300°	0.008	0.001	0.001	0.001	0.000	0.000	0.001	0.003
330°	0.043	0.004	0.040	0.003	0.000	0.004	0.027	0.007

Note on Atmospheric Stability

The Pasquill-Gifford atmosphere stability classes range from A through F.

A: Turbulent
B: Very unstable
C: Unstable
D: Neutral
E: Stable
F: Very stable

Wind speed and solar radiation interact to determine the level of atmospheric stability, which in turn suppresses or enhances the vertical element of turbulent motion. The latter is a function of the vertical temperature profile in the atmosphere; the greater the rate of decrease in temperature with height, the greater the level of turbulence.

Class A represents extremely unstable conditions, which typically occur under conditions of strong daytime insolation. Category D is neutral and neither enhances nor suppresses atmospheric turbulence. Class F on the other hand represents moderately stable conditions, which typically arise on clear nights with little wind.

The annual average temperature for Black Point is 23.9 °C. Temperature data was not available from the Sha Chau station and so temperature readings were taken from the Hong Kong Airport instead. The average relative humidity is 78%. *Table 12B.7* below tabulates temperature statistics.

Table 12B.7 Temperature Statistics for Black Point

		Min.	Max.	Average
Ambient air (T°C)[1]	*BP*	6.7	35.1	23.9
Surface (T°C)[1]		20.9	25.7	23
Seawater (T°C)[2]	*BP*	16.2	27.8	23.9
Humidity (%)[1]		65	82	77

Source: 1. Hong Kong Observatory, "The Year's Weather – 2003"
2. HK EPD, "Summary water quality statistics of the Junk Bay and Deep Bay WCZs in 2002"

12B.4 HAZARD IDENTIFICATION

The hazard identification process is a formal review to identify all hazards for the Gas Receiving station. This consisted of a review of the hazardous properties of natural gas, a review of accidents that have happened at similar facilities worldwide and a HAZID workshop (see *Section 12B.4.4*). Hazards identified from these studies are then carried forward for further consideration in the QRA.

For all hazards assessed as having a frequency of less than 10^{-9} per year, the frequency assessment will be documented but no quantification of consequences will be performed.

All scenarios with a frequency greater than 10^{-9} per year and potential to cause fatalities have the consequences of the event quantified.

Hazard scenarios are excluded from the risk assessment if one of the following conditions is satisfied:

- The frequency is below 1×10^{-9} per year.
- The frequency of a particular event is significantly smaller than other causes of failure considered in the generic frequency.
- If the generic failure frequency is judged to include events of such kind, then such events are not assessed separately.
- If there are no consequences. If an event can be shown not to cause a loss of containment then the event is not considered further.

12B.4.1 *Hazards from Natural Gas*

Hazards associated with natural gas (NG) have been identified based on a review of known incident records worldwide and experience gained from operations at similar facilities. The details are included below.

The main hazards associated with natural gas arise from its flammability and the risk of fire. If NG is accidentally released, it will mix with air to form a flammable mixture. The plume will only ignite if it encounters an ignition source while concentrated within its flammability range. In some cases, static discharges may also cause immediate ignition of a release.

The characteristics of the possible hazardous effects are described below.

Jet Fire

Jet fires result from ignited releases of pressurised flammable gas. The momentum of the release carries the materials forwards in a long plume entraining air to give a flammable mixture. Jet fires only occur where the NG is being handled under pressure. Since the GRS will have NG at between 40 and 100 bar, jet fires are expected to be the main hazard.

Fireball

Immediate ignition of releases caused by a rupture of equipment/piping may give rise to a fireball upon ignition. Fireballs have very high thermal radiation, similar to jet fires although the duration of the event is short.

Flash Fire

Following a NG release, if the cloud is not ignited immediately, it will move with the wind and be diluted as a result of air entrainment. The dispersing cloud may subsequently come in contact with an ignition source and burn rapidly with a sudden flash. Direct contact with the burning gas may cause fatalities but the short duration of the flash fire means that thermal radiation effects are not significant outside the cloud and thus no fatalities are expected outside of the flash fire envelope.

Vapour Cloud Explosions

If a dispersing gas cloud accumulates in a confined or congested area and is subsequently ignited, significant overpressures (an explosion) may be generated. The GRS, however, will be located in an open area without such confinement and an unconfined cloud of natural gas is known not to produce damaging overpressures. Vapour cloud explosions are therefore not considered in this assessment; the worst effects from a delayed ignition of a release will be a flash fire.

12B.4.2 Main Hazards from the Gas Receiving Station

The main hazard from the GRS is loss of containment from piping and equipment leading to a gas leak and fire.

Loss of Containment Incidents

The principal causes for loss of containment are:

- corrosion - internal and external;

- third party interference due to work in adjoining areas, etc;
- material defect;
- construction defect;
- improper operations;
- defect caused by pressure cycling; and
- external - flooding, subsidence etc.

Review of Industry Incidents

A review of industry incidents at gas receiving stations was carried out. Incident records over the last few decades show releases and fires. These were associated with leaks from valves and process equipment.

Based on the accident databases (MARS, ARIA) and other information, some incidents examples are provided in *Table 12B.8*.

Table 12B.8 Incident Review

Date, place	Cause	Description	Source
15/11/2007, USA	Unknown	An explosion occurred at around 11.30 am in a natural gas treatment facility. It resulted in 4 injuries, two of them severe.	ARIA
23/09/2002, USA	Unknown	In a natural gas treatment facility, a flash fire like event occurred in the central part where the raw natural gas is washed to remove impurities. Four of the nearby employees are injured: 3 suffered severe burns and intoxication.	ARIA
28/12/2000, CANADA	Unknown	Explosion at a natural gas pumping station rattled windows 1.5 miles away. There was no rupture of the pipeline itself and the cause of the incident remains unknown. One man severely injured and gas pressure to customers affected	MHIDAS
28/05/2000, CANADA	Overpressure	A 42" pipe transporting natural gas ruptured during a pressure test. Authorities indicated that the gas inlet was promptly shut down; environmental effects were therefore assumed to be zero.	ARIA
04/01/1999, USA	Unknown	In a sub station of a natural gas pipeline, a leakage led to an explosion and a fire destroying a house and workshop. The incident, visible from 30 km was taken care of by firemen and controlled within 4 hours. Two firemen suffered mild injuries.	ARIA
14/08/1998, USA	External events	Lightning strike set fire to a natural gas compressor station. The resulting explosions sent a fireball 600ft into the air.	MHIDAS

Date, place	Cause	Description	Source
		5 people were injured. Gas supplies to the whole of the Florida peninsula were shut off. Residents within 2 miles were evacuated.	
02/04/1998, RUSSIA	Unknown	The metering unit of the natural gas distribution station was rocked by an explosion. A fire also occurred.	MHIDAS
25/06/2001, KAZAKHSTAN	Corrosion	Six metres of a one metre diameter pipe was thrown 40 metres in the blast. Corrosion of the pipeline is thought to have led to the leak that caused the blast. Fire quickly extinguished and supplies resumed through an alternative pipe after three hours.	MHIDAS
10/04/2001, USA	Mechanical failure	Residents were evacuated for about three hours after a volatile gas cloud formed over a natural gas facility. The source of the leak was tracked down to a section of pipe, which was repaired.	MHIDAS
28/05/2000, CANADA	Mechanical failure	A section of the 42" pipeline ruptured during pressure-testing of the pipe.	MHIDAS
18/11/1998, UK	Impact	Workmen caused a main gas pipeline to fracture, sending a 30ft plume of gas into the air. Local residents were evacuated and roads sealed off. It was several hours before the pressure had dropped enough for the pipe to be sealed off. No one was injured.	MHIDAS
27/06/1997, USA	Human factor	Gas escaped from a pipeline when equipment being used to take a metering station out of commission fractured a valve. No injuries were reported. People within a mile of the rupture were evacuated. No fire or explosion occurred.	MHIDAS
08/02/1997, USA	Unknown	A leakage occured on a natural gas pipeline of 660 mm diameter. The gas cloud exploded and a 100m high flame occurred. Nearby houses were shaken by the deflagration.	ARIA
01/01/1997, TURKEY	Human error	A natural gas leak occured on a badly closed valve on a pipe (pressure= 20 bar). This incident led to death by asphyxiation of the two employees who entered in the room, one equipped with an inappropriate mask and the other without equipment	ARIA
18/12/1995, RUSSIA	Mechanical failure	Section of pipeline exploded due to high pressure in pipe.	MHIDAS
22/11/1995, RUSSIA	Corrosion	An explosion followed by a fire occurred on a 0.5m diameter natural gas pipe. Corrosion is at the origin of the accident. 240 m of pipes were destroyed.	ARIA
19/03/1995, USA	Unknown	36" gas pipe ruptured. Leak caught fire & damaged reported 300ft section. Gas rerouted to two parallel lines	MHIDAS
29/07/1993, UK	Impact	1000 workers were evacuated as building contractors ruptured a mains pipe sending 40ft gas into the air. Roads were sealed off	MHIDAS

Date, place	Cause	Description	Source
		for about an hour while the leak was brought under control.	
18/05/1989, GERMANY	General maintenance	Repairs to product pipeline possibly caused explosions/fires which destroyed refinery pumping/mixing station. Blaze burned for 4hrs as fire fed by 100te of fuel leaking from broken pipe system.	MHIDAS

Pig Receiver Related Hazards

Operation of pig receivers poses a significant hazard. There have been a few incidents in the past relating to pig launcher/receiver operations. Usually it relates to the launcher and receiver not being properly depressurised. With pressure behind the pig, it launches like a cannon out the end of the launcher or receiver when the operator opens the hatch.

Reasons that the receiver may not depressurise properly include the following:

- Vent/ drain valves are prone to plugging. These are often small valves and can be plugged because of the dirty material that has been scraped from the pipeline by the pig;
- Stuck pig trap. The pig could be stuck if there is a restriction, probably a partially open valve, and there could be a trapped pocket of high pressure gas;
- Poor pressure indication;
- Human errors, e.g. opening the trap door while the vessel is under pressure.

Pigging is generally performed infrequently. It is conservatively assumed in this analysis that pigging operations will be performed once every 5 years. Therefore the risk contributed by the pigging facilities to the whole system is relatively low. However, the risk per pigging operation still remains high. Procedures and devices are available to avoid accidents during pigging, and the human error is therefore a major reason for pigging accidents. This issue is investigated further in the frequency analysis, *Section 12B.5.*

Review of Industry Incidents

A review of industry incidents related to pig facilities was carried out.

There are a number of well established international accident databases that were considered for identification of hazards and estimation of frequency of loss of containment incidents. The relevant accident databases are:

- MHIDAS, AEA Technology, UK [18]
- IChemE Accident Database [19]
- MARS (Major Accident Reporting System)

Based on the above accident databases and other information, incidents associated with pigging are summarised below:

a) At a location in the Netherlands, an uncontrolled release of approximately 10,000m^3 of wet gas occurred from a pig receiver at a drying facility due to the inadvertent opening of the pig receiver inlet valve. This occurred due to a malfunctioning motorised actuator that opened the receiver's isolation valve when the hinged door was not totally secure. (source : IChemE Accident database)

b) Somewhere in Western Europe, accidental closure by a pipeline workman of a main line valve at a pump station caused a scraper pig trap at an upstream facility to be over-pressurised. A spillage of 252 m^3 of jet fuel occurred. The pipeline was out of service for two days while the trap installation was modified. (source : IChemE Accident database)

c) An incident occurred in 2001 during pre-commissioning when a contractor was dewatering a 10 mile section after a hydrostatic test. They were pushing a foam pig with air to displace the water. The pig got stuck somewhere in the pipe and they began pressuring up the section to approximately 400 psig. The water was being removed from a 12" bypass line. They decided that the restriction was not allowing the pig to move freely so they opened the end of the temporary trap. At this point, the pig had a downstream pressure of ambient and upstream pressure of 400psig. In order to catch the pig, a large front end loader was placed in front of the open trap. However, the pig shot out of the trap, completely flipped the loader and continued to fly approximately 150 yards in the air, destroying a wooden platform along the way.

d) Two workers were attempting to remove a pig from a line that was launched the previous day. They found the pig was stuck in the reducer section but cleared the block valve so the valve could be closed. After depressurising pig receiver and opening it to atmosphere, both workers believed the pig can be removed. The pig had to be pulled into the receiver through the reducer to remove it so they fashioned a hook from some SS tubing. When worker hooked onto pig, the pig shot out and struck him in the face resulting in major injuries. Apparently, part of the pig had created a seal with a weld in the reducer section, which created a pressure trap behind the pig. (source : www.offshoreman.com)

e) There is also an incident reported to have occurred in the North Sea offshore when the pig barrel cover was blown away and the pig flew about 1.5km into the sea. The incident apparently occurred due to misoperation of the valves on the pig barrel leading to sudden impact of the pig on the barrel cover.

f) During a pigging operation, a 30" pipeline, bringing natural gas on-shore, failed between the emergency shut-down (ESD) valve and the pig trap. The intervention of the ESD valve from the control room failed and it had to be closed locally. Released natural gas did not ignite, but was a serious risk to personnel. (source: MARS database)

The above list of incidents shows the potential for misoperation leading to the barrel cover or the pig shooting out of the trap and causing damage to nearby equipment and buildings in addition to causing operator injury.

Vent Stack Related Hazards

A common vent stack will be provided for emergency depressurization of the existing and new GRS facilities. The vent will be designed according to appropriate standards such as API 521. This ensures that the concentration of gases at ground level or on any elevated structures will not reach the lower flammability limit. Also, in the event of an ignited release, thermal radiation at ground level and on elevated structures will meet the standards. As such, there is no consequence from emergency venting and the vent stack is not considered further in the analysis.

12B.4.3 External and Natural Hazards

Seismic Hazard

An earthquake has the potential to cause damage to pipework and process vessels. Damage to pipework could be due to ground movement/vibration, with guillotine failure of pipes.

Studies by the Geotechnical Engineering Office conducted in the last decades indicate that Hong Kong SAR is a region of low seismicity (e.g., GCO, 1991 [8]; GEO, 2002-2004 [9]). The seismicity in the vicinity of Hong Kong is considered similar to that of areas of Central Europe and the Eastern areas of the USA [10]. As Hong Kong is a region of low seismicity, an earthquake is an unlikely event. The generic failure frequencies adopted in this study are based on historical incidents that include earthquakes in their cause of failure. Since Hong Kong is not at disproportionate risk from earthquakes compared to similar facilities worldwide, it is deemed appropriate to use these generic frequencies without adjustment. There is no need to address earthquakes separately as they are already included in the generic failure rates.

Subsidence

For subsidence which would result in failure of pipework or vessels, the ground movement must be relatively sudden and severe. Normal subsidence events occur gradually over a period of months and thus appropriate mitigating action can be taken to prevent failures. In the worst cases, the plant would be shut down and the relevant equipment isolated and depressurised. The GRS will be built on coastal land with solid foundation. No undue risk from subsidence is therefore expected and failures due to this are deemed to be included in generic failure frequencies.

Lightning

Lightning strikes have led to a number of major accidents world-wide. For example, a contributory cause towards the major fire at the Texaco refinery in the UK in 1994 was thought to be an initial lightning strike on process pipework.

The installation will be protected with lightning conductors to safety earth direct lightning strikes. The grounding will be inspected regularly. The potential for a lightning strike to hit the facility and cause a release event is therefore deemed to be unlikely. Failures due to lightning strikes are taken to be covered by generic frequencies.

Storm Surges and Flooding

If the piping become submerged under water, it is possible for buoyancy forces to lift the pipes/tanks, causing damage and possible loss of containment.

Flooding from heavy rainfall is not possible due to the coastal location of the site. The slopes of the natural terrain will channel water to the sea. The primary hazard from typhoons is the storm surge. Winds, and to a lesser extent pressure, cause a rise in sea level in coastal areas. In general, storm surges are limited to several metres.

The GRS facilities, located +6mPD above sea level are therefore protected against any risk from storm surges, waves and other causes of flooding.

Tsunami

Similar to storm surges, the main hazard from tsunamis is the rise in sea level and possible floatation of piping and tanks. The highest rise in sea level ever recorded in Hong Kong due to a tsunami was 0.3m [15], and occurred as a result of the 1960 earthquake in Chile, the largest earthquake ever recorded in history at magnitude 9.5 on the Richter scale. The GRS site is approximately at +6mPD. The effect of a tsunami on the GRS is therefore considered negligible.

The reason for the low impact of tsunamis on Hong Kong may be explained by the extended continental shelf in the South China Sea which effectively dissipates the energy of a tsunami. Also, the presence of the Philippine Islands and Taiwan act as an effective barrier against seismic activity in the

Pacific [16]. Secondary waves that pass through the Luzon Strait diffract and lose energy as they traverse the South China Sea.

Seismic activity with the South China Sea area may also produce tsunamis. Earthquakes on the western coast of Luzon in the Philippines have produced localised tsunamis but there is no record of any observable effects in Hong Kong.

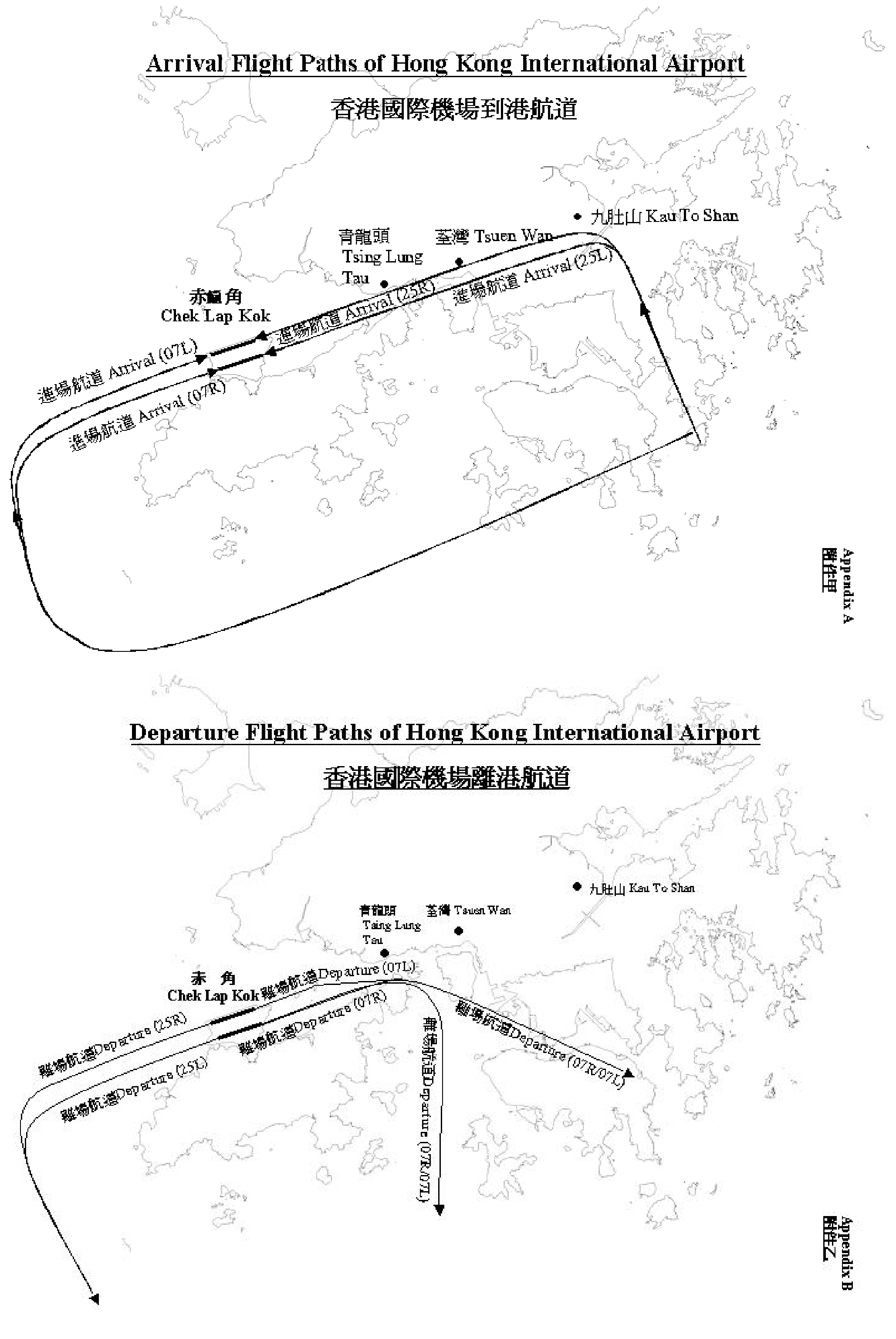
Summary of Natural Hazards

The GRS site and design of the facility are such that there will be no special risks from natural hazards. Natural hazards are therefore not treated separately in the analysis but are included in the generic failure frequencies.

Aircraft Crash

The Black Point site does not lie within the flight path of Chek Lap Kok (*Figure 12B.8)*, being about 10km from the nearest runway.

Figure 12B.8 Flight Paths at Hong Kong International Airport



The frequency of aircraft crash was estimated using the methodology of the HSE [11]. The model takes into account specific factors such as the target area of the proposed hazard site and its longitudinal (x) and perpendicular (y) distances from the runway threshold (*Figure 12B.9*). The crash frequency per unit ground area (per km^2) is calculated as:

$$g(x, y) = NRF(x, y) \quad (4)$$

Where N is the number of runway movements per year and R is the probability of an accident per movement (landing or take-off). $F(x,y)$ gives the spatial distribution of crashes and is given by:

Landings

$$F_L(x, y) = \frac{(x + 3.275)}{3.24} e^{\frac{-(x+3.275)}{1.8}} \left[\frac{56.25}{\sqrt{2\pi}} e^{-0.5(125y)^2} + 0.625 e^{-\frac{|y|}{0.4}} + 0.005 e^{-\frac{|y|}{5}} \right] \quad (5)$$

for $x > -3.275$ km

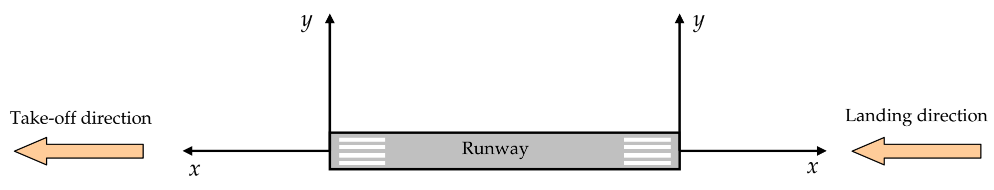
Take-off

$$F_T(x, y) = \frac{(x + 0.6)}{1.44} e^{\frac{-(x+0.65)}{1.2}} \left[\frac{46.25}{\sqrt{2\pi}} e^{-0.5(125y)^2} + 0.9635 e^{-4.1|y|} + 0.08 e^{-|y|} \right] \quad (6)$$

for $x > -0.6$ km

Equations 5 and *6* are valid only for the specified range of x values. If x lies outside this range, the impact probability is zero.

Figure 12B.9 Aircraft Crash Coordinate System



NTSB data [12] for fatal accidents in the U.S. involving scheduled airline flights during the period 1986-2005 are given in *Table 12B.9*. The 10-year moving average suggests a downward trend with recent years showing a rate of about 2×10^{-7} per flight. However, only 13.5% of accidents are associated with the approach to landing, 15.8% are associated with take-off and 4.2% are related to the climb phase of the flight [13]. The accident frequency for the approach to landings hence becomes 2.7×10^{-8} per flight and for take-off/climb 4.0×10^{-8} per flight. The number of flights at Chep Lap Kok for year 2011 is conservatively estimated at 394,000 (a 50% increase over 2005).

Table 12B.9 U.S Scheduled Airline Accident Rate [12]

Year	Accident rate per 1,000,000 flights for accidents involving fatalities	10-year moving average accident rate per 1,000,000 flights
1986	0.14	-
1987	0.41	-
1988	0.27	-
1989	1.10	-
1990	0.77	-
1991	0.53	-
1992	0.53	-
1993	0.13	-
1994	0.51	0.451
1995	0.12	0.475
1996	0.38	0.464
1997	0.30	0.446
1998	0.09	0.354
1999	0.18	0.295
2000	0.18	0.261
2001	0.19	0.208
2002	0.00	0.215
2003	0.2	0.173
2004	0.09	0.188
2005	0.27	

Considering landings on runway 25R for example, the values for x and y according to *Figure 12B.8* are 0.6 and 10.7km respectively. Applying *Equation 5* gives $F_L = 8.1\times10^{-5}$ km^{-2}. Substituting this into *Equation 4* gives:

$$g(x, y) = NRF(x, y) = \frac{394{,}000}{8} \times 2.7\times10^{-8} \times 8.1\times10^{-5} = 1.08\times10^{-7} \text{/year/km}^2$$

The number of plane movements has been divided by 8 to take into account that half of movements are take-offs and only a quarter of landings use runway 07R. This effectively assumes that each runway is used equally.

The target area is estimated at 12,000m^2 or 0.012km^2. This gives a frequency for crashes on the site associated with landings on runway 07R as 2.2×10^{-9} per year. Repeating the calculation for landings and take-offs from all runways gives the results shown in *Table 12B.10*.

Table 12B.10 Aircraft Crash Frequency onto the GRS

Runway	Landing (per year)	Take-off (per year)
07R	0	1.3×10^{-11}
07L	0	2.6×10^{-12}
25L	1.3×10^{-9}	0
25R	8.6×10^{-9}	0
Total	2.2×10^{-9}	1.6×10^{-11}

The combined frequency of all take-off and landing crashes onto the GRS from activities on all runways is less than 2.2×10^{-9} per year. This frequency is small compared to the generic frequencies used in the study. Aircraft crash is therefore neglected from the analysis.

Helicopter Crash

Helipad Activity

The Black Point Power Station site is provided with a helicopter landing pad although the frequency of use is expected to be low with perhaps one landing/take-off per week. The approach, landing and take-off stages of an aircraft flight are associated with the highest risk and therefore the possible impact of helicopter crashes on the facility were assessed.

Data from offshore helicopter activities [14] gives a helipad related helicopter crash frequency of 2.9×10^{-6} per flight stage (i.e. per take-off and landing). However, most of these incidents are minor such as heavy landings. For a helicopter incident to damage the facility, it must be a serious, uncontrolled impact. Only accidents involving fatalities were therefore considered in the analysis. 4% of incidents resulted in one or more fatalities and so the frequency of uncontrolled crashes was calculated as $2.9\times10^{-6} \times 0.04 = 1.2\times10^{-7}$ per flight stage. For one flight per week using the helipad, the annual crash frequency becomes $1.2\times10^{-7} \times 52 = 6.0\times10^{-6}$ /year.

Helicopter accidents during take-off and landing are confined to a small area around the helipad [11]. 93% of accidents occur within 100m of the helipad. The remaining 7% occur between 100 and 200m of the helipad. There have been no serious helipad related incidents resulting in a crash beyond 200m of the helipad.

The distance of Gas Receiving Station to the helipad is more than 400 metres. Helicopter crash is therefore not considered further in this study.

Passing Helicopters

There are no helicopter flight paths near BPPS. The possibility of a passing helicopter crashing into the GRS facility is therefore much smaller than the generic failure frequencies used in this study. Helicopter crashes are therefore not considered separately but are deemed to be included in the generic failure frequencies.

12B.4.4 HAZID Study

A Hazard Identification (HAZID) Study was conducted in September 2009. The potential hazards posed by the facility were identified based on the HAZID team's expert opinion, past accidents, lessons learnt and checklists. The details of the HAZID study can be found in *Table 12B.11*.

A systematic approach was adopted, whereby the facility was divided into a number of "subsystems" based on the layout and the process; guidewords from the checklist were then applied to each subsystem as relevant.

Table 12B.11 HAZID Worksheets

System: 2. GRS
Subsystem: 1. General/Process

Hazards/ Keywords	Description/ Causes	Consequences	Safeguards	Recommendations
1. Leak from tappings, flanges and piping	1. Corrosion, mechanical failure, etc	1. Potential loss of containment	1. Gas and fire detection	
	2. Mal operation during maintenance (including dropped object), pigging	2. Ignition and fire	2. Shutdown system	
	3. Leaks reaching the heaters leading to explosion		3. Operating and maintenance procedures	
			4. Area classification	
			5. Layout has positioned heating station upwind from process facilities	
			6. Heater design: - Flame arrestor on air intakes - Gas detectors - Shutdown system	
2. Fugitive emission	1. Leaks from seals / valves / analysers, operational losses	1. Environmental emission, potential ignition and fire	1. Area classification	
			2. Gas and fire detection	
3. Overpressure downstream of letdown valve	1. Control valve malfunction	1. Potential overpressurization and loss of containment	1. Active/monitor and slam shut system	
			2. HIPPS provided	
4. Pigging operations	1. Pig stuck in the pipeline	1. Operational interruption	1. Operating procedures	
		2. Possible damage to facility	2. Pigging is not a frequent operation, 1 in 5 years	
5. Ignition of gases from vent / PSVs	1. Due to lightning	1. Fire and / or explosion	1. Stack height will be determined based on thermal radiation threshold on adjoining equipment	
	2. Sparks / statics / smoking	2. Potential thermal radiation effects on adjoining equipment	2. All PSV releases are routed to vent stack	
			3. Snuffing system	
			4. Area classification	

System: 2. GRS
Subsystem: 1. General/Process

Hazards/ Keywords	Description/ Causes	Consequences	Safeguards	Recommendations
			5. Enforcement of protocol (no smoking on site)	
			6. Stack designed such that concentration of flammables will be below 25% of LFL at ground level.	
6. Air ingress into vent header	1. Air ingress into vent stack	1. Potential for flame flashback upon ignition of vent vapours	1. Dynamic seal on the vent tip	
7. Filter maintenance	1. Mal operation	1. Potential loss of containment	1. Operating procedures	
		2. Severe injury	2. Mechanical interlock on closure	
		3. Damage to the facility		
8. Metering section including Gas Chromatography (GC)	1. Regular discharge of small quantity of gas	1. Potential fire and/ or explosion	1. Area classification	
			2. Well ventilated area	
			3. Piping design vent to safe locations / vent header	
			4. Fire and gas detection	
9. N2 purging of GC	1. Changing N2 bottles	1. Damage to facility	1. Operating procedures	
		2. Injury	2. Designed to standards	
10. CO2 for vent snuffing system	1. Changing CO2 bottles	1. Damage to facility	1. Operating procedures	
		2. Injury	2. Designed to standards	
11. Water bath heaters	1. Burner mal function (explosion)	1. Damage to facility and possible escalation	1. Burner management system	
		2. Injury	2. Fire and gas detection	
		3. Environmental emission		
12. Water bath heaters	1. Burner flame-out	1. Possible low temperature and icing in the pressure let down section - personnel injury	1. Process temperature alarm	
			2. Standby unit available	
			3. Under normal operating condition no icing expected	
			4. Burner management system	
13. Water bath heaters	1. Loss of water due to evaporation	1. Heater shutdown on low water level; possible low temperature and icing in the pressure let down section - personnel injury	1. Under normal operating condition no icing expected	
			2. Standby unit available	
			3. Process alarms	

System: 2. GRS
Subsystem: 1. General/Process

Hazards/ Keywords	Description/ Causes	Consequences	Safeguards	Recommendations
14. Pressure letdown	1. Fugitive emissions	1. Fire and / or explosion	1. Area classification	
			2. Well ventilated area	
			3. Piping design, vent to safe locations / vent header	
			4. Fire and gas detection	
15. Mixing station	1. Fugitive emission	1. Fire and / or explosion	1. Area classification	
			2. Well ventilated area	
			3. Piping design, vent to safe locations / vent header	
			4. Fire and gas detection	
16. Commissioning	1. Unplanned events	1. Fire	1. Commissioning procedures	
			2. Toolbox / Briefings	
17. Instrument enclosure	1. Loss of instrument enclosure due to external event	1. Loss of control of GRS	1. GRS is designed to fail safe	

System: 2. GRS
Subsystem: 2. Natural hazards

Hazards/ Keywords	Description/ Causes	Consequences	Safeguards	Recommendations
1. Earthquake	1. Damage to piping and equipment	1. Fire and / or explosion	1. Area of low seismic activity	
			2. Fire and gas detection	
2. Waves	1. Damage to piping and equipment	1. Fire and / or explosion	1. Site at +6mPD	
			2. Fire and gas detection	
3. Tsunami	1. Waves higher than predicted	1. Possible damage to structures / facilities due to high wave and associated flooding	1. Black Point not susceptible to tsunami	
			2. Site at +6mPD	
			3. Storm water drainage system	
4. Storm / flooding	1. Waves higher than predicted	1. Fire and / or explosion due to damage to piping and equipment	1. Site at +6mPD	
			2. Fire and gas detection	
5. High wind - typhoon	1. No issue			
6. Subsidence / movement	1. Damage to piping and equipment	1. Fire and / or explosion	1. Fire and gas detection	
7. Extreme weather - temperature	1. No issue			

System: 2. GRS
Subsystem: 2. Natural hazards

Hazards/ Keywords	Description/ Causes	Consequences	Safeguards	Recommendations
8. Lightning	1. Damage to piping and equipment	1. Ignition of fugitive emissions	1. Lightning conductors	
		2. Fire and / or explosion		
		3. Damage to equipment		
9. Landslide	1. No issue			
10. Hill fire	1. Source of ignition from suspended ash	1. Ignition of vented / leaking gas	1. Procedures to maintain equipment and prevent leaks	
			2. Station emergency procedures	
			3. Separation distances and control of combustibles on site	

System: 2. GRS
Subsystem: 3. External hazards

Hazards/ Keywords	Description/ Causes	Consequences	Safeguards	Recommendations
1. Fuel oil tank on fire or fuel oil tank rupture at BPPS	1. Fuel oil stored as emergency back up fuel for gas turbine	1. Facility is about 500m away and hence impact due to fire not likely		
2. H2 fire/ explosion at BPPS	1. H2 stored at BPPS for generator cooling	1. Potential for projectiles causing damage to the facility	1. Trailer bay located in a concrete compound with ventilation, leak/fire detection	
			2. No. of cylinders in a trailer limited to 12 or 26 and max 2 trailers	
			3. Trailer house about 200m from GRS	
3. Projectiles from turbine accidents at BPPS	1. Mechanical failure of turbine or lube oil failure	1. Potential for projectiles causing damage to the facility	1. Periodic inspection of the turbine	
			2. Turbine located in a housing and turbine housing is within a structure	
4. Gas leaks at BPPS	1. Leak in the open or in the gas turbine enclosure	1. Fire or explosion in the BPPS; impact on GRS considered less likely due to the separation distance of more than 200m	1. Gas leak detection and shutdown system at BPPS	
5. Boiler explosion	1. High pressure (100 bar) steam boiler	1. Potential for projectiles causing damage to the facility	1. Boiler controls/ inspection and maintenance	
6. Pipeline leak from BPPS to CPPS	1. Pipe at about 38barg, 6km long and 600mm dia.	1. Possible impact on the access road to BPPS and GRS; impact on	1. Pipeline is buried with shutdown valve at either end	

System: 2. GRS
Subsystem: 3. External hazards

Hazards/ Keywords	Description/ Causes	Consequences	Safeguards	Recommendations
		the GRS is considered less likely due to the separation distance	2. Pipeline inspection and maintenance	
7. Aircraft crash	1. During take-off / landing / approach	1. Damage to the facility and fire	1. Black Point site not in the flight path; site about 20km away from airport	
8. Helicopter crash	1. Helipad at BPPS and at the radar station	1. Damage to the facility and fire	1. Helipad at the radar station near BPPS used for specific purpose and not frequent (about once per week)	
			2. Helipad about 500m away from the GRS	
9. Vessel crash	1. No issue			
10. Dropped objects	1. Lifting of objects over operational equipment	1. Damage to existing equipment. Potential fire and explosion hazard.	1. Lifting plans need to comply with operating plant procedures and guidelines (eg weight limits for lifting over operational plant)	
			2. Procedures (Brownfield and constructability workshops)	
11. Neighbouring facilities - ash lagoon	1. Ash lagoon to be developed in future (landfill site). Any development at this site has to take into account the risk to the existing facilities at BPPS/GRS			
12. Neighbouring facilities - Yacheng system	1. Gas leak from the Yacheng system	1. Fire and /or explosion; possible escalation to GRS/Yacheng	1. Adequate separation distance	
	2. Gas leak from the GRS impacting Yacheng		2. Fire and gas detection	
13. HV cables	1. No issue			
14. Sabotage/Security	1. Intentional acts by access from the sea	1. Damage to facilities	1. Security system / perimeter fence	

System: 2. GRS
Subsystem: 4. Material hazards

Hazards/ Keywords	Description/ Causes	Consequences	Safeguards	Recommendations
1. Pressurized air	1. Generated onsite for process and instrument requirements	1. Pressure system hazards	1. Design procedures 2. Operating and safety procedures	
2. Dry chemical powders	1. Used for fire fighting	1. Personnel hazards (inhalation) while handling	1. Operating and safety procedures	

System: 2. GRS
Subsystem: 5. Loss of utilities

Hazards/ Keywords	Description/ Causes	Consequences	Safeguards	Recommendations
1. Loss of Power supply	1. Power will be supplied from BPPS	1. GRS will shutdown in safe mode	1. UPS for critical users/systems including lighting, controls and other safety critical systems 2. Double cables supply	
2. Loss of Instrument air supply		1. System designed to go to safe shutdown mode	1. Redundant air compressors; air receiver; emergency power supply	

System: 2. GRS
Subsystem: 6. Layout

Hazards/ Keywords	Description/ Causes	Consequences	Safeguards	Recommendations
1. Layout	1. Layout review has been carried out and will be reviewed to address separation distances, access and emergency egress issues			3. Review recommendations from layout review for any relevance to the HAZID study

System: 2. GRS
Subsystem: 7. Interface with existing facility

Hazards/ Keywords	Description/ Causes	Consequences	Safeguards	Recommendations
1. Tie-ins	1. Unplanned events during tie-in	1. Loss of containment; fire and explosion	1. Procedures and emergency response plan (Brownfield and constructability workshops)	
2. Control	1. Impact on GRS from process upsets in BPPS and vice versa	1. Operational inconvenience		4. Control and ESD interfaces with existing facility to be established

System: 2. GRS

Subsystem: 8. Construction / future developments

Hazards/ Keywords	**Description/ Causes**	**Consequences**	**Safeguards**	**Recommendations**
1. Access for installation / construction	1. Possible interference with existing equipment	1. Damage to existing equipment. Potential leaks and fire.	1. Procedures (Brownfield and constructability workshops)	
			2. Access from both sides of the site for each GRS	
2. Dropped objects	1. Lifting of objects over operational equipment	1. Damage to existing equipment. Potential fire and explosion hazard.	1. Lifting plans need to comply with operating plant procedures and guidelines (eg weight limits for lifting over operational plant)	
			2. Procedures (Brownfield and constructability workshops)	
3. General construction hazards	1. Welding, cutting, excavation, hydrotesting, etc.	1. Possible damage to operational equipment and personnel injuries.	1. Procedures (Brownfield and constructability workshops)	
			2. Permit to work, procedures need to comply with operating plant procedures and guidelines	
			3. Construction safety plan (PPE, training, briefings, etc.)	

12B.4.5 Scenarios for the QRA Study

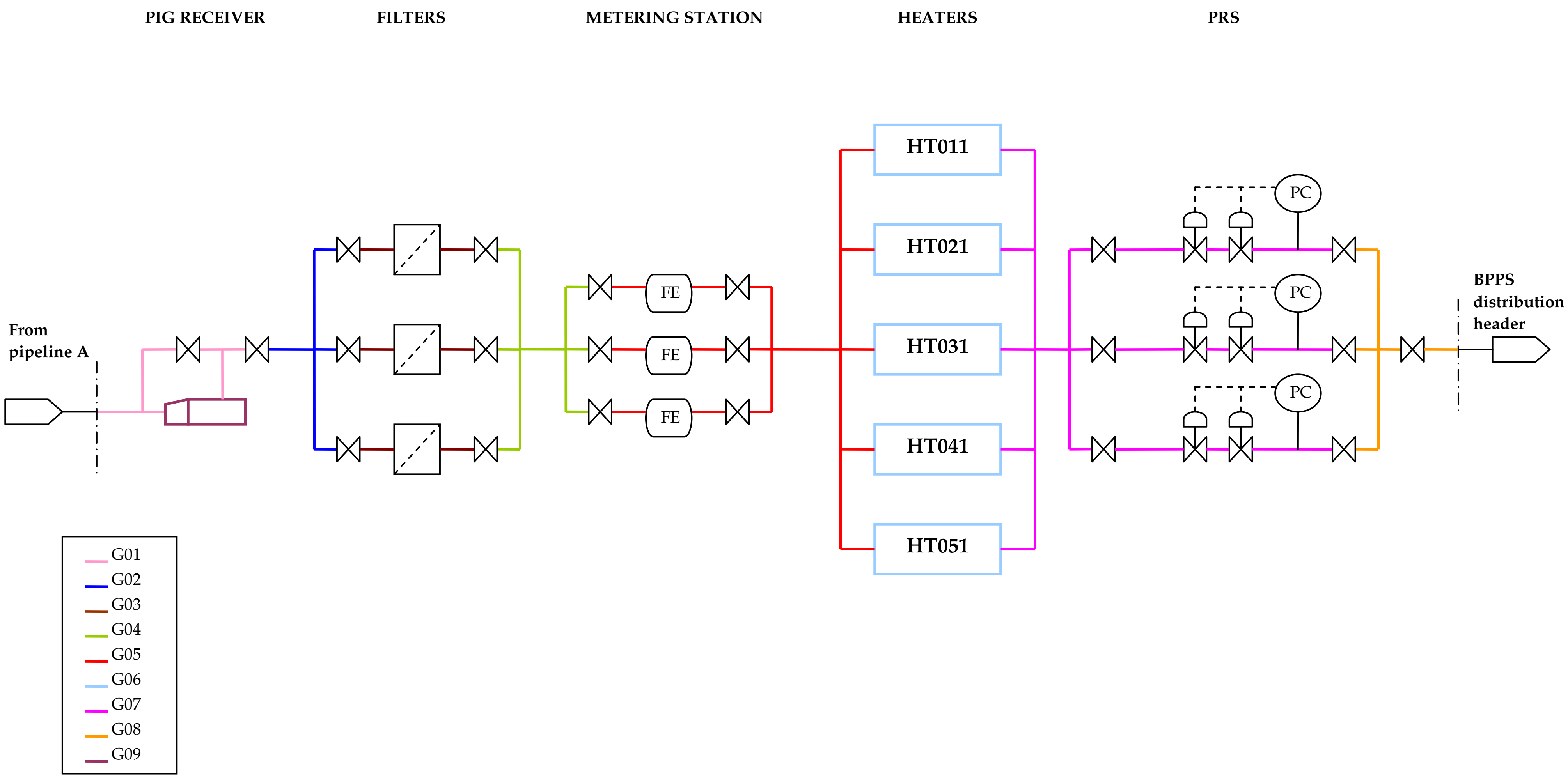
Scenarios for the QRA study were identified based on the HAZID Study as well as a review of incident records. The GRS facility was broken down into sections for further analysis (*Table 12B.12* and *Figure 12B.10*). For each section, a range in leak sizes was considered from small 10mm leaks to full ruptures.

Table 12B.12 Scenarios for QRA Study

Code	Plant Section	Initiating Event	No. of items (for each train)	Potential Outcome Scenarios	Length of section (m) GRS A	Length of section (m) GRS B	Pipe diameter (mm)	Operating Pressure	Design Pressure*	Temperature
G01	Above ground piping from shore end to pig receiver	Leak, rupture	1	Jet fire, Gas dispersion/Flash fire, Fireball	38	205	1067	91bara	100bara	12-30°C
G02	Piping from receiver to gas filter	Leak, rupture	1	Jet fire, Gas dispersion/Flash fire, Fireball	77	20	700	91bara	100bara	12-30°C
G03	Filter & inlet/outlet piping	Leak, rupture	3	Jet fire, Gas dispersion/Flash fire, Fireball	17	17	400	91bara	100bara	12-30°C
G04	Piping from filter to metering station	Leak, rupture	1	Jet fire, Gas dispersion/Flash fire, Fireball	72	36	700	91bara	100bara	12-30°C
G05	Piping from metering station to heaters, including metering runs	Leak, rupture	1	Jet fire, Gas dispersion/Flash fire, Fireball	160	175	700	91bara	100bara	12-30°C
G06	Heater Piping	Leak, rupture	7	Jet fire, Gas dispersion/Flash fire, Fireball	11	11	350	91bara	100bara	12-30°C
G07	Piping from heater to PRS, including PRS	Leak, rupture	1	Jet fire, Gas dispersion/Flash fire, Fireball	122	129	700	89bara	100bara	12-78°C
G08	Piping from PRS to mixing station	Leak, rupture	1	Jet fire, Gas dispersion/Flash fire, Fireball	320	226	700	39bara	40bara	12-78°C
G09	Pig receiver	Leak, rupture	1	Jet fire, Gas dispersion/Flash fire, Fireball, Projectile hazard	8710mm		914.4	91bara	100bara	12-30°C

* The assessment used design pressures as a basis for the calculations

Figure 12B.10 Plant Sections for QRA study



12B.5 FREQUENCY ANALYSIS

12B.5.1 Base Frequency Estimation

Table 12B.13 lists the failure frequencies adopted for the various release scenarios used in the GRS study. Section G09 is considered separately in later sections.

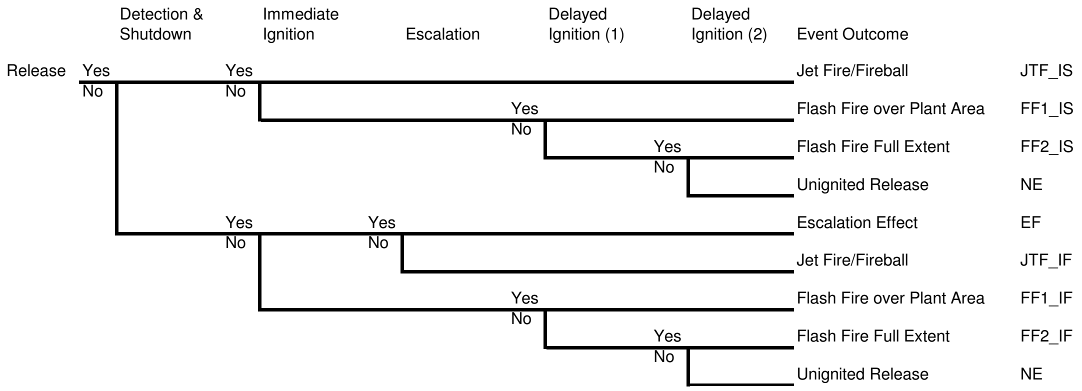
Table 12B.13 Gas Release Event Frequencies

Section Code	Piping Diameter (mm)	Hole Size (mm)	Initiating Event Frequency	Unit	Reference
G01	1067	10	1.00E-07	per metre	Hawksley [5]
		25	1.00E-07	per year	
		50	7.00E-08		
		100	7.00E-08		
		FB	3.00E-08		
G02	700	10	1.00E-07	per metre	Hawksley [5]
		25	1.00E-07	per year	
		50	7.00E-08		
		100	7.00E-08		
		FB	3.00E-08		
G03	400	10	3.00E-07	per metre	Hawksley [5]
		25	3.00E-07	per year	
		50	1.00E-07		
		100	1.00E-07		
		FB	5.00E-08		
G04	700	10	1.00E-07	per metre	Hawksley [5]
		25	1.00E-07	per year	
		50	7.00E-08		
		100	7.00E-08		
		FB	3.00E-08		
G05	700	10	1.00E-07	per metre	Hawksley [5]
		25	1.00E-07	per year	
		50	7.00E-08		
		100	7.00E-08		
		FB	3.00E-08		
G06	350	10	3.00E-07	per metre	Hawksley [5]
		25	3.00E-07	per year	
		50	1.00E-07		
		100	1.00E-07		
		FB	5.00E-08		
G07	700	10	1.00E-07	per metre	Hawksley [5]
		25	1.00E-07	per year	
		50	7.00E-08		
		100	7.00E-08		
		FB	3.00E-08		
G08	700	10	1.00E-07	per metre	Hawksley [5]
		25	1.00E-07	per year	
		50	7.00E-08		
		100	7.00E-08		
		FB	3.00E-08		

12B.5.2 *Scenario Development*

Event Tree Analysis (ETA) is used to model the development of a scenario from its initial leak through to the final outcome such as jet fire or flash fire. A generic event tree is shown in *Figure 12B.11* and the branch probabilities are discussed below.

Figure 12B.11 Generic Event Tree



Nomenclature:
IS = Isolation Success
IF = Isolation Failure
FF1 = Flash Fire over the Plant Area
FF2 = Flash Fire, Full Extent
EF = Escalation Effect
JTF = Jet Fire
FBL = Fire Ball
NE = No Effect

Detection and Shutdown

For loss of containment events from piping and equipment, it is assumed that detection and shutdown would occur 90% of the time (based on safety integrity level 1 for emergency shutdown systems which has an associated probability of failure on demand of 0.1).

If the release is detected and the process is shutdown, it is assumed that the duration of a release will be limited and will not lead to escalation. Escalation is, however, considered if isolation fails and if the hazard effects of a jet fire are able to reach and impinge on neighbouring equipment.

Gas releases are all pressurised releases and ignition would result in a jet fire. For rupture scenarios, a short duration fireball is assumed to occur if isolation is successful, else a long duration jet fire is assumed to occur if isolation fails.

Ignition Probabilities

Table 12B.14 summarises the ignition probabilities used in the study. The total ignition probability is 0.07 for small leaks (considered to be 10mm and 25mm leaks) and 0.32 for large leaks and ruptures. These ignition probabilities are consistent with the model of Cox, Lees and Ang [6].

The ignition probabilities are distributed between immediate ignition and delayed ignition. Delayed ignition is further divided between delayed 1 and delayed 2 to take into account that a dispersing gas cloud may ignite at different points during its dispersion. Delayed ignition 1 results in a flash fire and takes into account the possibility that ignition could occur within the plant area due to the presence of ignition sources on site. Delayed ignition 2 gives a flash fire after the gas cloud has expanded to its maximum (steady state) extent.

If delayed ignition does not occur, the gas cloud disperses with no effect.

Table 12B.14 Ignition Probabilities Assumed

	Immediate Ignition	Delayed Ignition 1	Delayed Ignition 2	Delayed Ignition Probability	Total Ignition Probability
Small leak	0.02	0.045	0.005	0.05	0.07
Large leak/rupture	0.1	0.2	0.02	0.22	0.32

For isolation failure scenarios, the delayed ignition probabilities given in *Table 12B.14* are doubled. The longer duration and larger inventory release from a non-isolated release is assumed to make it more likely that ignition takes place.

Escalation

An initially small release may escalate into a larger, more serious event if a jet fire impinges on neighbouring equipment for an extended time (more than about 10 minutes). This is taken into account in the modelling for the isolation fail branch of the event tree. If neighbouring piping is within range of the flame zone of a jet fire, an escalation probability of 1/8 is taken to conservatively estimate the directional probability and chance of impingement. Escalation is assumed to cause a rupture of the affected piping.

Outcome Frequencies

A summary of outcome frequencies for the events considered in the GRS study are listed in *Table 12B.15*.

Table 12B.15 Outcome Frequency Summary

Release Event	**Release Scenario [*]**					
	10mm	**25mm**	**50mm**	**100mm**	**IS_FB**	**IF_FB**
G01/ G02/ G04/ G05/ G07/G08_FF2	5.50E-10	5.50E-10	1.54E-09	1.54E-09	5.4E-10	1.20E-10
G01/ G02/ G04/ G05/ G07/G08_FF1	4.95E-09	4.95E-09	1.54E-08	1.54E-08	5.40E-09	1.20E-09
G01/ G02/ G04/ G05/ G07/G08_JTF	1.95E-09	1.95E-09	6.83E-09	6.83E-09		3.00E-10
G01/ G02/ G04/ G05/ G07/G08_FBL					2.70E-09	
G03/G06_FF2	1.65E-09	1.65E-09	2.20E-09	2.20E-09	9.00E-10	2.00E-10
G03/G06_FF1	1.49E-08	1.49E-08	2.20E-08	2.20E-08	9.00E-09	2.00E-09
G03/G06_JTF	5.85E-09	5.85E-09	9.75E-09	9.75E-09		5.00E-10
G03/G06_FBL					4.50E-09	

[*] Frequencies are per metre per year

12B.5.3 *Pig Receiver Failure Scenarios*

The pig barrel is normally not in operation, and the pipeline will be pigged on average once every 5 years. During pigging operations, the operator will need to strictly follow procedures; however, there is chance of pig barrel failure if the operator fails to follow these procedures. In order to assess the probability of human error, a HEART analysis (Human Error Assessment and Reduction Technique, from Lees) [7] is performed and a value of 4×10^{-4} per operation is assumed for a highly trained operator working under a non-stress situation. This gives a frequency of 8×10^{-5} per year per pig receiver due to misoperation for pigging operations performed once in 5 years.

Two potential failure scenarios are assessed for the pig barrel:

G09-1: Opening of pig trap door

During pigging operations, the operator could mistakenly try to open the pig trap door when the barrel is still pressurised. This could lead to a small leak, the pig being projected from the barrel, or in the worst case a continuous release of high pressure gas from the pipeline end. An event tree for this case is shown in *Figure 12B.12*. The relevant intermediate events and their probabilities are described in the following paragraphs.

<u>Pressure Interlock</u>

The pig trap door is fitted with a mechanical interlock to prevent its opening when pressurised. It is assumed that the possibility for this interlock to fail is 0.1, which is a standard probability of failure on demand.

<u>Size of Release</u>

As per all equipment/piping failures, most releases are of minor nature affecting only its immediate surroundings. 90% of the releases are assumed to be minor and are modelled as a 25mm hole. 10% assumed to be major failures, modelled as a full rupture.

<u>Ignition</u>

The remainder of the event tree uses the same ignition probabilities as discussed earlier for the generic ETA.

For large leaks and ejection of the pig, the direction of the release is assumed to be aligned to the orientation of the pig receiver.

G09-2: Misoperation leading to pig impact on the barrel cover

The pig trap door may get blown off during pigging due to human error e.g. due to valve or flow misalignment etc. leading to an impact of the pig on the barrel cover. The relevant events and their probabilities are similar to *G09-1* except that the pressure interlock will not prevent this event from happening. *Figure 12B.13* shows the event tree for this case.

The total frequency of a pig being blow away is 8.8×10^{-6}/year for each pig receiver. Due to the orientation of the pig receivers, if a pig is blown away, it will be launched across the sea or unpopulated areas. Taking the ship density in the nearest grid cell for future year 2021 (see *Section 12B.3*), and the size of each type of marine vessel, the probability of a pig striking a ship is estimated at 7×10^{-6}. With a launch frequency of 8.8×10^{-6}/year, the frequency of a ship being struck by a pig is estimated at 6×10^{-11}/year. This is below 10^{-9} per year and is therefore not considered further.

Figure 12B.12 Misoperation to Open Pig Barrel Door

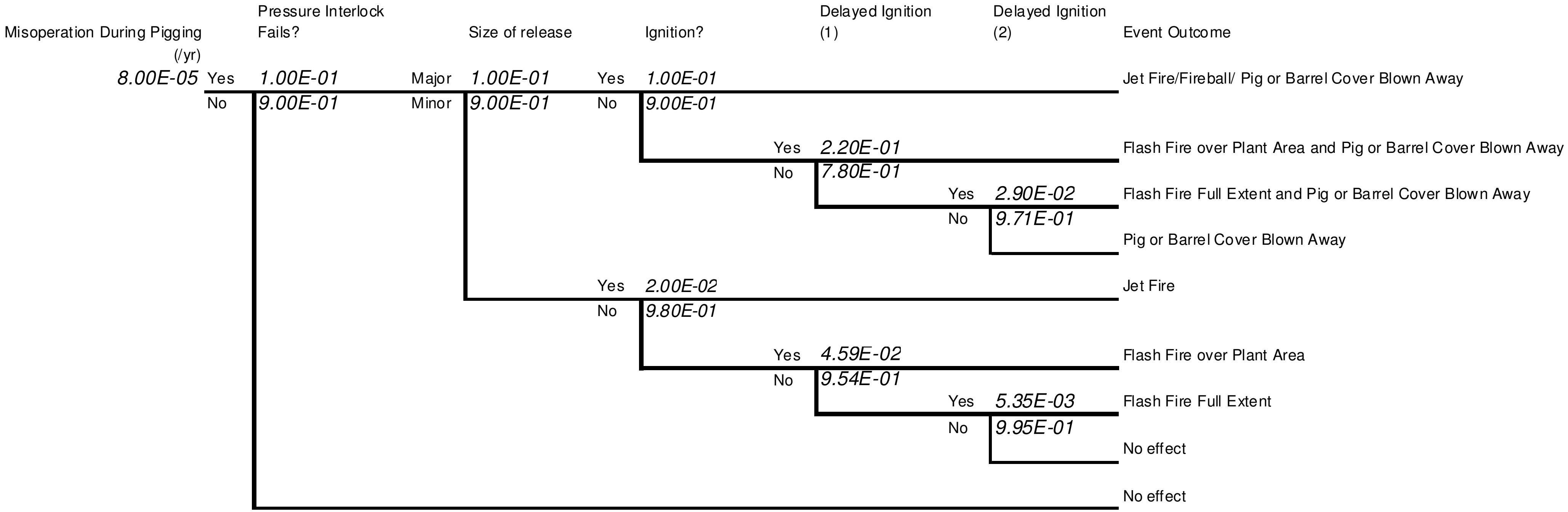
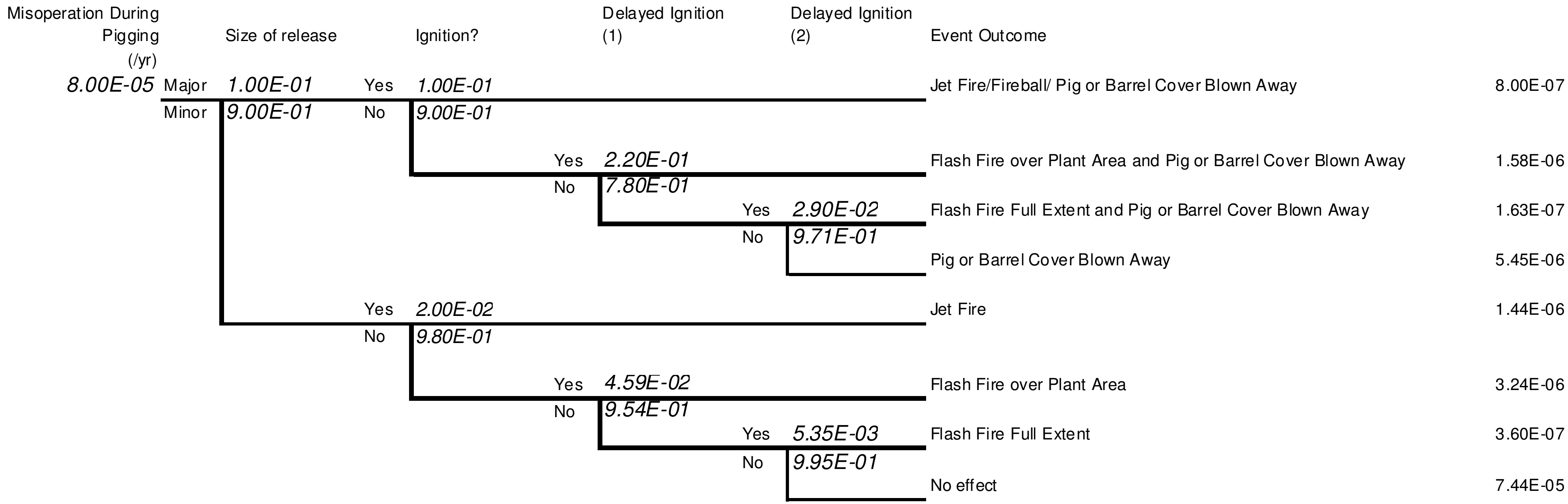


Figure 12B.13 Misoperation Leading to Pig Impact on the Barrel Cover



12B.5.4 *Construction Activities*

The GRS construction may present an increase in risk due to construction activities from the GRS impacting on existing facilities.

The project has taken this into consideration with the following safeguards:

- Safety management system and procedures will be developed for the new GRSs. Details of the system and procedures will be given in the safety case study for the new GRSs. Systems relating to construction activities, such as Fire and Safe Work Permit System, risk assessment, and emergency response procedure, will be in place and enforced before commencement of work. Recommendations in accordance with best practice have also been given to protect the workers at the sites (see *section 12.3.2*);

- Good access is provided to construction areas with access roads from at least 2 sides of the site;

- The reclamation itself will be formed mostly by accessing from the sea.

The Gas Production & Supply Code of Practice [17] provides a practical guidance in respect of the requirements of the Gas Safety Ordinance Cap 51 and the Gas Safety (Gas Supply) Regulations. Article 23A of these regulations requires that:

- No person shall carry out, or permit to be carried out, any works in the vicinity of a gas pipe unless he or the person carrying out the works has before commencing the works, taken all reasonable steps to ascertain the location and position of the gas pipe; and

- A person who carries out, or who permits to be carried out, any works in the vicinity of a gas pipe shall ensure that all reasonable measures are taken to protect the gas pipe from damage arising out of the works that would be likely to prejudice safety.

Work, 'in the vicinity' of gas pipes is defined according to *Table 12B.16*. Although many of the activities listed are not directly relevant to the GRS, *Table 12B.16* serves to indicate typical effects distances for different types of work and when special precautions are warranted. The GRS separation distances mostly exceed those listed in *Table 12B.16*. However, some of the minimum separation distances specified in *Table 12B.16* are not met. These activities include but not limited to the following:

- Construction of the pre-heaters and pressure reduction station for Phase 1 close to the existing underground high pressure gas pipe line (~10 m)

- Construction of new pipe racks adjacent to the existing pipe rack

- Construction of the inlet pipeline for Second Phase close to the existing pre-heaters (~20 m)

Special consideration may be given to the underground high pressure pipe line since the external load on the ground by the crane and the drilling operation may pose additional risk of damage. However, with the implementation of safety procedures, the risk is not expected to be significantly higher than the generic failure frequencies adopted. Nevertheless, a Job Safety Study will be conducted to assess the potential risk and failure modes of such construction operations and special precautions will be included in the procedure.

Based on the above, the likelihood of damage to the operational facilities from construction activities will be low. This is therefore not considered further in this study.

Table 12B.16 Works in the Vicinity of Gas Pipes

Type of Work	Distance
Trench or other excavation up to 1.5m in depth in stable ground	10m
Trench or other excavation over 1.5m and up to 5m in depth	15m
Trench or other excavation in stable ground over 5m in depth	20m
Welding or hot works near exposed gas pipes or above ground installations	10m
Piling, percussion moling or pipe bursting	15m
Works near high pressure pipelines	20m
Ground investigation and any kind of drilling or core sampling	30m
Use of explosives	60m

12B.6 CONSEQUENCE ANALYSIS

12B.6.1 Source Term Modelling

The process facility was divided into 9 isolatable sections. *Table 12B.12* listed the process details adopted for each process section. Discharge rates for each given leak size were modelled using standard orifice type calculations contained within the PHAST suite of models. Design pressures were used as a conservative approach in the consequence modelling.

12B.6.2 Consequence Modelling

Table 12B.17 shows the list of release scenarios along with the corresponding consequence model used in *PHAST*.

Table 12B.17 Release Scenarios and Consequence Models Applied

Release Scenario	Release Type	Model Applied in PHAST
10mm leak	Leak	Leak
25mm leak	Leak	Leak
50mm leak	Leak	Leak

100mm leak	Leak	Leak
Full bore rupture	Rupture	Catastrophic Rupture

The consequence modelling parameters for PHAST are listed in *Table 12B.18*.

Table 12B.18 Consequence Modelling Parameters

BLEVE Parameters		
Maximum SEP for a BLEVE	400.00	kW/m2
Fireball radiation intensity level 1	7.00	kW/m2
Fireball radiation intensity level 2	14.00	kW/m2
Fireball radiation intensity level 3	21.00	kW/m2
Mass Modification Factor	3.00	
Fireball Maximum Exposure Duration	30.00	s
Ground Reflection	Ground Burst	
Ideal Gas Modelling	Model as real gas	
Discharge Parameters		
Continuous Critical Weber number	12.50	
Instantaneous Critical Weber number	12.50	
Venting equation constant	24.82	
Relief valve safety factor	1.20	
Minimum RV diameter ratio	1.00	
Critical pressure greater than flow phase	0.34	bar
Maximum release velocity	500.00	m/s
Minimum drop size allowed	0.00	mm
Maximum drop size allowed	10.00	mm
Default Liquid Fraction	1.00	fraction
Continuous Drop Slip factor	1.00	
Instantaneous Drop Slip factor	1.00	
Pipe-Fluid Thermal Coupling	0.00	
Number of Time Steps	100.00	
Maximum Number of Data Points	1,000.00	
Non-Return Valve velocity head losses	0.00	
Pipe roughness	0.046	mm
Shut-Off Valve velocity head losses	0.00	
Excess Flow Valve velocity head losses	0.00	
Default volume changes	3.00	/hr
Line length	10.00	m
Elevation	1.00	m
Atmospheric Expansion Method	Closest to Initial Conditions	
Tank Roof Failure Model Effects	Instantaneous Effects	
Outdoor Release Direction	Horizontal	
Dispersion Parameters		
Dense cloud parameter gamma (continuous)	0.00	
Dense cloud parameter gamma (instant)	0.30	
Dense cloud parameter k (continuous)	1.15	
Dense cloud parameter k (instantaneous)	1.15	
Jet entrainment coefficient alpha1	0.17	
Jet entrainment coefficient alpha2	0.35	
Ratio instantaneous/continuous sigma-y	1.00	
Ratio instantaneous/continuous sigma-z	1.00	

Distance multiple for full passive entrainment	2.00	
Quasi-instantaneous transition parameter	0.80	
Impact parameter - plume/ground	0.80	
Expansion zone length/source diameter ratio	0.01	
Drop/expansion velocity for inst. release	0.80	
Drag coefficient between plume and ground	1.50	
Drag coefficient between plume and air	0.00	
Default bund height	0.00	m
Maximum temperature allowed	626.85	degC
Minimum temperature allowed	-263.15	degC
Minimum release velocity for cont. release	0.10	m/s
Minimum integration step size (Instantaneous)	0.10	s
Maximum integration step size (Instantaneous)	1,000.00	s
Minimum integration step size (Continuous)	0.10	m
Maximum integration step size (Continuous)	100.00	m
Maximum distance for dispersion	50,000.00	m
Maximum height for dispersion	1,000.00	m
Minimum cloud depth	0.02	m
Expansion energy cutoff for droplet angle	0.69	kJ/kg
Droplet evaporation thermodynamics model	Rainout, Non-equilibrium	
Flag for mixing height	Constrained	
Accuracy for integration of dispersion	0.00	
Accuracy for droplet integration	0.00	
Richardson number criterion for cloud lift-off	-20.00	
Flag to reset rainout position	Do not reset rainout position	
Surface over which the dispersion occurs	Water	
Minimum Vapor Fraction for Convection	0.00	fraction
Coefficient of Initial Rainout	0.00	
Minimum Continuous Release Height	0.00	m
Flag for finite duration correction	Finite Duration Correction	
Near Field Passive Entrainment Parameter	1.00	
Jet Model	Morton et.al.	
Maximum Cloud/Ambient Velocity Difference	0.10	
Maximum Cloud/Ambient Density Difference	0.02	
Maximum Non-passive entrainment fraction	0.30	
Maximum Richardson number	15.00	
Core Averaging Time	18.75	s
Ground Drag Model	New (Recommended)	
Flag for Heat/Water vapor transfer	Heat and Water	
Richardson Number for passive transition above pool	0.02	
Pool Vaporization entrainment parameter	1.50	
Modeling of instantaneous expansion	Standard Method	
Minimum concentration of interest	0.00	fraction
Maximum distance of interest	10,000.00	m
Model In Use	Best Estimate	
Maximum Initial Step Size	10.00	m
Minimum Number of Steps per Zone	5.00	
Factor for Step Increase	1.20	
Maximum Number of Output Steps	1,000.00	

Flammables Parameters

Height for calculation of flammable effects	0.00	m
Flammable result grid step in X-direction	10.00	m
LFL fraction to finish	0.85	
Flammable angle of inclination	0.00	deg
Flammable inclination	Variable	
Flammable mass calculation method	Mass between LFL and UFL	
Flammable Base averaging time	18.75	s
Cut Off Time for Short Continuous Releases	20.00	s
Observer type radiation modelling flag	Planar	
Probit A Value	-36.38	
Probit B Value	2.56	
Probit N Value	1.33	
Height for reports	Centreline Height	
Angle of orientation	0.00	deg
Relative tolerance for radiation calculations	0.02	fraction
General Parameters		
Maximum release duration	3,600.00	s
Height for concentration output	0.00	m
Jet Fire Parameters		
Maximum SEP for a Jet Fire	400.00	kW/m2
Jet Fire Averaging Time	20.00	s
Jet fire radiation intensity level 1	7.00	kW/m2
Jet fire radiation intensity level 2	14.00	kW/m2
Jet fire radiation intensity level 3	21.00	kW/m2
Rate Modification Factor	3.00	
Jet Fire Maximum Exposure Duration	30.00	s
Model Correlation Type	Shell	
Weather Parameters		
Atmospheric pressure	1.01	bar
Atmospheric molecular weight	28.97	
Atmospheric specific heat at constant pressure	1.00	kJ/kg.degK
Wind speed reference height (m)	10.00	m
Temperature reference height (m)	0.00	m
Cut-off height for wind speed profile (m)	1.00	m
Wind speed profile	Power Law	
Atmospheric Temperature and Pressure Profile	Temp.Logarithmic; Pres.Linear	
Atmospheric temperature	23.00	degC
Relative humidity	0.77	fraction
Surface Roughness Parameter	0.043	
Surface Roughness Length	0.912	mm
Roughness or Parameter	Parameter	
Dispersing surface temperature	23.00	degC
Default surface temperature of bund	23.00	degC
Solar radiation flux	0.50	kW/m2
Building Exchange Rate	4.00	/hr
Tail Time	1,800.00	s

12B.6.3 *Consequence End-Point Criteria*

The end-point criteria are used to define the impact level at which a fatality could result.

Thermal Radiation

The following probit equation [1] is used to determine impacts of thermal radiation from jet fires to persons unprotected by clothing.

$$Y = -36.38 + 2.56 \ln (t\, I^{4/3}) \quad (1)$$

where I is the radiant thermal flux (W/m^2) and Y is the probit function which is related to the probability of fatality. This equation gives the data points presented in *Table 12B.19*, assuming a 30-second exposure time. For areas lying between any two radiation flux contours, the equivalent fatality level is estimated as follows:

- For areas beyond the 50% fatality contour, the equivalent fatality is calculated using a 2/3 weighting towards the lower contour. For example, the equivalent fatality between the 1% and 50% contours is calculated as 2/3 x 1 + 1/3 x 50 = 17%;
- For areas within the 50% contour, the equivalent fatality is calculated with a 2/3 weighting towards the upper contour. For example, the equivalent fatality between the 90% and 50% contours is calculated as 2/3 x 90 + 1/3 x 50 = 77%.

The different approach above and below the 50% fatality contour is due to the sigmoid shape of the probit function.

Table 12B.19 ***Levels of Harm for 30s Exposure to Heat Fluxes***

Incident Thermal Flux (kW/m^2)	Fatality Probability for 30s Exposure	Equivalent Fatality Probability for Area between Radiation Flux Contours
7.3	1%	
		17%
14.4	50%	
		77%
20.9	90%	
		97%
35.5	99.9%	

Fireballs are modelled in a similar manner as jet fires, using the same probit equation. However, fireballs are generally of shorter duration than 30 seconds and hence the actual duration of the fireball was used to determine harm probabilities.

Flash Fire

With regard to flash fires, the criterion chosen is that a 100% fatality is assumed for any person outdoors within the flash fire envelope. In this study, the extent of the flash fire is assumed to be the dispersion distance to 85% of the LFL for a conservative evaluation.

12B.6.4 Consequence Results

A complete list of hazard distances obtained from the consequence modelling is provided in *Table 12B.20*.

Table 12B.20 Consequence Results

Section		Phase L/G	Leak size (mm)	Hazard effects	End point criteria	Hazard extent (m) Weather conditions F, 2 m/s	D, 3 m/s	D, 7 m/s	B, 2.5 m/s
G01	Above ground gas piping from offshore pipeline to pig receiver	G	10	Jet fire	35.5 kW/m2	13	14	15	14
					20.9 kW/m2	15	15	16	15
					14.4 kW/m2	16	16	17	16
					7.3 kW/m2	19	19	19	19
				Flash fire	0.85 LFL	13	13	11	12
			25	Jet fire	35.5 kW/m2	33	34	38	33
					20.9 kW/m2	38	38	41	38
					14.4 kW/m2	41	41	44	41
					7.3 kW/m2	47	47	49	47
				Flash fire	0.85 LFL	37	37	37	37
			50	Jet fire	35.5 kW/m2	61	62	70	61
					20.9 kW/m2	69	71	76	70
					14.4 kW/m2	76	77	81	77
					7.3 kW/m2	89	90	92	90
				Flash fire	0.85 LFL	84	84	90	82
			100	Jet fire	35.5 kW/m2	107	109	120	108
					20.9 kW/m2	122	125	133	123
					14.4 kW/m2	136	138	143	137
					7.3 kW/m2	165	165	166	164
				Flash fire	0.85 LFL	180	180	195	180
			Full bore (isoln. succ.)	Fireball	35.5 kW/m2	137	137	137	137
					20.9 kW/m2	180	180	180	180
					14.4 kW/m2	216	216	216	216
					7.3 kW/m2	300	300	300	300
				Flash fire	0.85 LFL	38	38	55	38
			Full bore (isoln. fail.)	Jet fire	35.5 kW/m2	147	148	160	147
					20.9 kW/m2	165	169	179	167

Section		Phase L/G	Leak size (mm)	Hazard effects	End point criteria	Hazard extent (m) Weather conditions F, 2 m/s	D, 3 m/s	D, 7 m/s	B, 2.5 m/s
					14.4 kW/m2	185	187	194	186
					7.3 kW/m2	226	227	227	226
				Flash fire	0.85 LFL	260	260	287	260
G02	Gas piping from receiver to gas filter	G	10	Jet fire	35.5 kW/m2	13	14	15	14
					20.9 kW/m2	15	15	16	15
					14.4 kW/m2	16	16	17	16
					7.3 kW/m2	19	19	19	19
				Flash fire	0.85 LFL	13	13	11	12
			25	Jet fire	35.5 kW/m2	33	34	38	33
					20.9 kW/m2	38	38	41	38
					14.4 kW/m2	41	41	44	41
					7.3 kW/m2	47	47	49	47
				Flash fire	0.85 LFL	37	37	37	37
			50	Jet fire	35.5 kW/m2	61	62	70	61
					20.9 kW/m2	69	71	76	70
					14.4 kW/m2	76	77	81	77
					7.3 kW/m2	89	90	92	90
				Flash fire	0.85 LFL	84	84	90	82
			100	Jet fire	35.5 kW/m2	107	109	120	108
					20.9 kW/m2	122	125	133	123
					14.4 kW/m2	136	138	143	137
					7.3 kW/m2	165	165	166	164
				Flash fire	0.85 LFL	180	180	195	180
			Full bore (isoln. succ.)	Fireball	35.5 kW/m2	70	70	70	70
					20.9 kW/m2	93	93	93	93
					14.4 kW/m2	112	112	112	112
					7.3 kW/m2	155	155	155	155
				Flash fire	0.85 LFL	19	19	26	19

Section		Phase L/G	Leak size (mm)	Hazard effects	End point criteria	Hazard extent (m) Weather conditions F, 2 m/s	D, 3 m/s	D, 7 m/s	B, 2.5 m/s
			Full bore (isoln. fail.)	Jet fire	35.5 kW/m2	147	148	160	147
					20.9 kW/m2	165	169	179	167
					14.4 kW/m2	185	187	194	186
					7.3 kW/m2	226	227	227	226
				Flash fire	0.85 LFL	260	260	287	260
G03	Filter piping	G	10	Jet fire	35.5 kW/m2	13	14	15	14
					20.9 kW/m2	15	15	16	15
					14.4 kW/m2	16	16	17	16
					7.3 kW/m2	19	19	19	19
				Flash fire	0.85 LFL	13	13	11	12
			25	Jet fire	35.5 kW/m2	33	34	38	33
					20.9 kW/m2	38	38	41	38
					14.4 kW/m2	41	41	44	41
					7.3 kW/m2	47	47	49	47
				Flash fire	0.85 LFL	37	37	37	37
			50	Jet fire	35.5 kW/m2	61	62	70	61
					20.9 kW/m2	69	71	76	70
					14.4 kW/m2	76	77	81	77
					7.3 kW/m2	89	90	92	90
				Flash fire	0.85 LFL	84	84	90	82
			100	Jet fire	35.5 kW/m2	107	109	120	108
					20.9 kW/m2	122	125	133	123
					14.4 kW/m2	136	138	143	137
					7.3 kW/m2	165	165	166	164
				Flash fire	0.85 LFL	180	180	195	180
			Full bore (isoln. succ.)	Fireball	35.5 kW/m2	45	45	45	45
					20.9 kW/m2	60	60	60	60
					14.4 kW/m2	72	72	72	72

Section		Phase L/G	Leak size (mm)	Hazard effects	End point criteria	Hazard extent (m) Weather conditions F, 2 m/s	D, 3 m/s	D, 7 m/s	B, 2.5 m/s
					7.3 kW/m2	101	101	101	101
				Flash fire	0.85 LFL	11	11	16	11
			Full bore (isoln. fail.)	Jet fire	35.5 kW/m2	147	148	160	147
					20.9 kW/m2	165	169	179	167
					14.4 kW/m2	185	187	194	186
					7.3 kW/m2	226	227	227	226
				Flash fire	0.85 LFL	260	260	287	260
G04	Gas piping from filter to metering station	G	10	Jet fire	35.5 kW/m2	13	14	15	14
					20.9 kW/m2	15	15	16	15
					14.4 kW/m2	16	16	17	16
					7.3 kW/m2	19	19	19	19
				Flash fire	0.85 LFL	13	13	11	12
			25	Jet fire	35.5 kW/m2	33	34	38	33
					20.9 kW/m2	38	38	41	38
					14.4 kW/m2	41	41	44	41
					7.3 kW/m2	47	47	49	47
				Flash fire	0.85 LFL	37	37	37	37
			50	Jet fire	35.5 kW/m2	61	62	70	61
					20.9 kW/m2	69	71	76	70
					14.4 kW/m2	76	77	81	77
					7.3 kW/m2	89	90	92	90
				Flash fire	0.85 LFL	84	84	90	82
			100	Jet fire	35.5 kW/m2	107	109	120	108
					20.9 kW/m2	122	125	133	123
					14.4 kW/m2	136	138	143	137
					7.3 kW/m2	165	165	166	164
				Flash fire	0.85 LFL	180	180	195	180
			Full bore (isoln. succ.)	Fireball	35.5 kW/m2	153	153	153	153

Section	Phase L/G	Leak size (mm)	Hazard effects	End point criteria	Hazard extent (m) Weather conditions F, 2 m/s	D, 3 m/s	D, 7 m/s	B, 2.5 m/s
				20.9 kW/m2	201	201	201	201
				14.4 kW/m2	242	242	242	242
				7.3 kW/m2	335	335	335	335
			Flash fire	0.85 LFL	43	43	63	43
		Full bore (isoln. fail.)	Jet fire	35.5 kW/m2	147	148	160	147
				20.9 kW/m2	165	169	179	167
				14.4 kW/m2	185	187	194	186
				7.3 kW/m2	226	227	227	226
			Flash fire	0.85 LFL	260	260	287	260
G05 Gas piping from metering station to heaters, including metering runs	G	10	Jet fire	35.5 kW/m2	13	14	15	14
				20.9 kW/m2	15	15	16	15
				14.4 kW/m2	16	16	17	16
				7.3 kW/m2	19	19	19	19
			Flash fire	0.85 LFL	13	13	11	12
		25	Jet fire	35.5 kW/m2	33	34	38	33
				20.9 kW/m2	38	38	41	38
				14.4 kW/m2	41	41	44	41
				7.3 kW/m2	47	47	49	47
			Flash fire	0.85 LFL	37	37	37	37
		50	Jet fire	35.5 kW/m2	61	62	70	61
				20.9 kW/m2	69	71	76	70
				14.4 kW/m2	76	77	81	77
				7.3 kW/m2	89	90	92	90
			Flash fire	0.85 LFL	84	84	90	82
		100	Jet fire	35.5 kW/m2	107	109	120	108
				20.9 kW/m2	122	125	133	123
				14.4 kW/m2	136	138	143	137

Section		Phase L/G	Leak size (mm)	Hazard effects	End point criteria	Hazard extent (m) Weather conditions F, 2 m/s	D, 3 m/s	D, 7 m/s	B, 2.5 m/s
					7.3 kW/m2	165	165	166	164
				Flash fire	0.85 LFL	180	180	195	180
			Full bore (isoln. succ.)	Fireball	35.5 kW/m2	135	135	135	135
					20.9 kW/m2	177	177	177	177
					14.4 kW/m2	213	213	213	213
					7.3 kW/m2	295	295	295	295
				Flash fire	0.85 LFL	38	38	54	38
			Full bore (isoln. fail.)	Jet fire	35.5 kW/m2	147	148	160	147
					20.9 kW/m2	165	169	179	167
					14.4 kW/m2	185	187	194	186
					7.3 kW/m2	226	227	227	226
				Flash fire	0.85 LFL	260	260	287	260
G6	Gas Heater Piping	G	10	Jet fire	35.5 kW/m2	13	14	15	14
					20.9 kW/m2	15	15	16	15
					14.4 kW/m2	16	16	17	16
					7.3 kW/m2	19	19	19	19
				Flash fire	0.85 LFL	13	13	11	12
			25	Jet fire	35.5 kW/m2	33	34	38	33
					20.9 kW/m2	38	38	41	38
					14.4 kW/m2	41	41	44	41
					7.3 kW/m2	47	47	49	47
				Flash fire	0.85 LFL	37	37	37	37
			50	Jet fire	35.5 kW/m2	61	62	70	61
					20.9 kW/m2	69	71	76	70
					14.4 kW/m2	76	77	81	77
					7.3 kW/m2	89	90	92	90

Section		Phase L/G	Leak size (mm)	Hazard effects	End point criteria	Hazard extent (m) Weather conditions F, 2 m/s	D, 3 m/s	D, 7 m/s	B, 2.5 m/s
				Flash fire	0.85 LFL	84	84	90	82
			100	Jet fire	35.5 kW/m2	107	109	120	108
					20.9 kW/m2	122	125	133	123
					14.4 kW/m2	136	138	143	137
					7.3 kW/m2	165	165	166	164
				Flash fire	0.85 LFL	180	180	195	180
			Full bore (isoln. succ.)	Fireball	35.5 kW/m2	135	135	135	135
					20.9 kW/m2	177	177	177	177
					14.4 kW/m2	213	213	213	213
					7.3 kW/m2	295	295	295	295
				Flash fire	0.85 LFL	38	38	54	38
			Full bore (isoln. fail.)	Jet fire	35.5 kW/m2	147	148	160	147
					20.9 kW/m2	165	169	179	167
					14.4 kW/m2	185	187	194	186
					7.3 kW/m2	226	227	227	226
				Flash fire	0.85 LFL	260	260	287	260
G7	Gas piping from heater to PRS, including PRS	G	10	Jet fire	35.5 kW/m2	12	12	13	12
					20.9 kW/m2	13	14	14	13
					14.4 kW/m2	14	15	15	15
					7.3 kW/m2	17	17	17	17
				Flash fire	0.85 LFL	11	11	11	11
			25	Jet fire	35.5 kW/m2	30	31	34	31
					20.9 kW/m2	34	35	37	34
					14.4 kW/m2	37	37	39	37
					7.3 kW/m2	42	43	44	43
				Flash fire	0.85 LFL	34	34	34	32
			50	Jet fire	35.5 kW/m2	56	56	64	56

Section		Phase L/G	Leak size (mm)	Hazard effects	End point criteria	Hazard extent (m) Weather conditions F, 2 m/s	D, 3 m/s	D, 7 m/s	B, 2.5 m/s
					20.9 kW/m2	63	64	69	64
					14.4 kW/m2	69	70	74	69
					7.3 kW/m2	81	81	83	81
				Flash fire	0.85 LFL	72	76	79	68
			100	Jet fire	35.5 kW/m2	98	99	58	99
					20.9 kW/m2	112	114	59	113
					14.4 kW/m2	124	126	65	125
					7.3 kW/m2	149	150	85	150
				Flash fire	0.85 LFL	155	147	160	136
			Full bore (isoln. succ.)	Fireball	35.5 kW/m2	135	135	135	135
					20.9 kW/m2	177	177	177	177
					14.4 kW/m2	213	213	213	213
					7.3 kW/m2	295	295	295	295
				Flash fire	0.85 LFL	38	38	54	38
			Full bore (isoln. fail.)	Jet fire	35.5 kW/m2	146	147	160	146
					20.9 kW/m2	164	168	178	166
					14.4 kW/m2	184	186	193	185
					7.3 kW/m2	225	226	225	225
				Flash fire	0.85 LFL	215	215	228	192
G8	Gas piping from PRS to mixing station	G	10	Jet fire	35.5 kW/m2	0	0	0	0
					20.9 kW/m2	9	9	9	0
					14.4 kW/m2	10	10	10	10
					7.3 kW/m2	11	11	11	11
				Flash fire	0.85 LFL	8	8	8	8
			25	Jet fire	35.5 kW/m2	0	22	24	22
					20.9 kW/m2	24	24	26	24
					14.4 kW/m2	26	26	28	26
					7.3 kW/m2	30	30	31	30

Section	Phase L/G	Leak size (mm)	Hazard effects	End point criteria	Hazard extent (m) Weather conditions F, 2 m/s	D, 3 m/s	D, 7 m/s	B, 2.5 m/s
			Flash fire	0.85 LFL	21	21	21	21
		50	Jet fire	35.5 kW/m2	40	41	47	42
				20.9 kW/m2	46	47	51	47
				14.4 kW/m2	50	51	54	50
				7.3 kW/m2	58	58	60	58
			Flash fire	0.85 LFL	47	47	49	47
		100	Jet fire	35.5 kW/m2	73	74	84	73
				20.9 kW/m2	83	85	92	84
				14.4 kW/m2	92	93	98	92
				7.3 kW/m2	109	109	111	109
			Flash fire	0.85 LFL	102	102	106	95
		Full bore (isoln. succ.)	Fireball	35.5 kW/m2	114	114	114	114
				20.9 kW/m2	150	150	150	150
				14.4 kW/m2	180	180	180	180
				7.3 kW/m2	250	250	250	250
			Flash fire	0.85 LFL	30	30	42	30
		Full bore (isoln. fail.)	Jet fire	35.5 kW/m2	145	147	159	146
				20.9 kW/m2	163	167	178	165
				14.4 kW/m2	183	186	192	184
				7.3 kW/m2	224	225	225	224
			Flash fire	0.85 LFL	205	205	215	180
G09 Pig receiver	G	25	Jet fire	35.5 kW/m2	33	34	38	33
				20.9 kW/m2	38	38	41	38
				14.4 kW/m2	41	41	44	41
				7.3 kW/m2	47	47	49	47
			Flash fire	0.85 LFL	37	37	37	37
		Full bore	Jet fire	35.5 kW/m2	147	148	160	147
				20.9 kW/m2	165	169	179	167

Section	Phase L/G	Leak size (mm)	Hazard effects	End point criteria	Hazard extent (m)			
					Weather conditions			
					F, 2 m/s	D, 3 m/s	D, 7 m/s	B, 2.5 m/s
				14.4 kW/m2	185	187	194	186
				7.3 kW/m2	226	227	227	226
			Flash fire	0.85 LFL	260	260	287	260

12B.7 RISK SUMMATION

The frequencies and consequences of the various outcomes of the numerous accident scenarios are integrated at this stage, to give measures of the societal risk (FN curves and Potential Loss of Life) and individual risk.

Risk results are compared with the criteria for acceptability as laid down in the *Hong Kong Planning Standards and Guidelines*, *Chapter 12* and also in *Annex 4* of the *Technical Memorandum of EIAO*.

Risk results are presented in the *Section 12* of the *EIA Report*.

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[21] Hong Kong Observatory, " The Year's Weather – 2003"

Annex 12C

Quantitative Risk Assessment (QRA) for Gas Receiving Stations – Assessment including existing GRS

CONTENTS

12C *QUANTITATIVE RISK ASSESSMENT FOR EXISTING GAS RECEIVING STATION*

12C.1 INTRODUCTION

The study presented in *Annex 12B* covers the details of the Quantitative Risk Assessment (QRA) for the two Gas Receiving Stations (GRSs) to be built at the Black Point Power Station (BPPS) which will receive natural gas through two subsea pipelines from the Mainland. This section extends the analysis to consider also the existing GRS (*Figure 12C.1*), although this is not included in the EIA Study Brief.

The proposed pipelines from the Mainland China will terminate at two gas receiving stations (GRSs) at BPPS. One will be located adjacent to the existing GRS (co-located GRS), the second will be located on reclaimed land to the north of the BPPS site (GRS on reclamation). The two GRSs are not expected to be constructed concurrently. The co-located GRS will be constructed in 2011 (i.e. First Phase construction) while the construction of the GRS on reclamation is expected to commence within 24 months of commissioning of the first pipeline, in around 2014.

As the two GRSs are not expected to be constructed concurrently, the following cases can be considered in the analysis:

1) Existing GRS operating and co-located GRS under construction (2011);

2) Existing and co-located GRS operating (2011);

3) Existing and co-located GRS operating and GRS on reclamation under construction (2014);

4) 3 GRSs operating (2021).

In *Annex 12B*, the following cases have already been assessed:

a) Only co-located GRS in operation;

b) Co-located GRS in operation and construction of the GRS on reclamation;

c) Both co-located and GRS on reclamation operating.

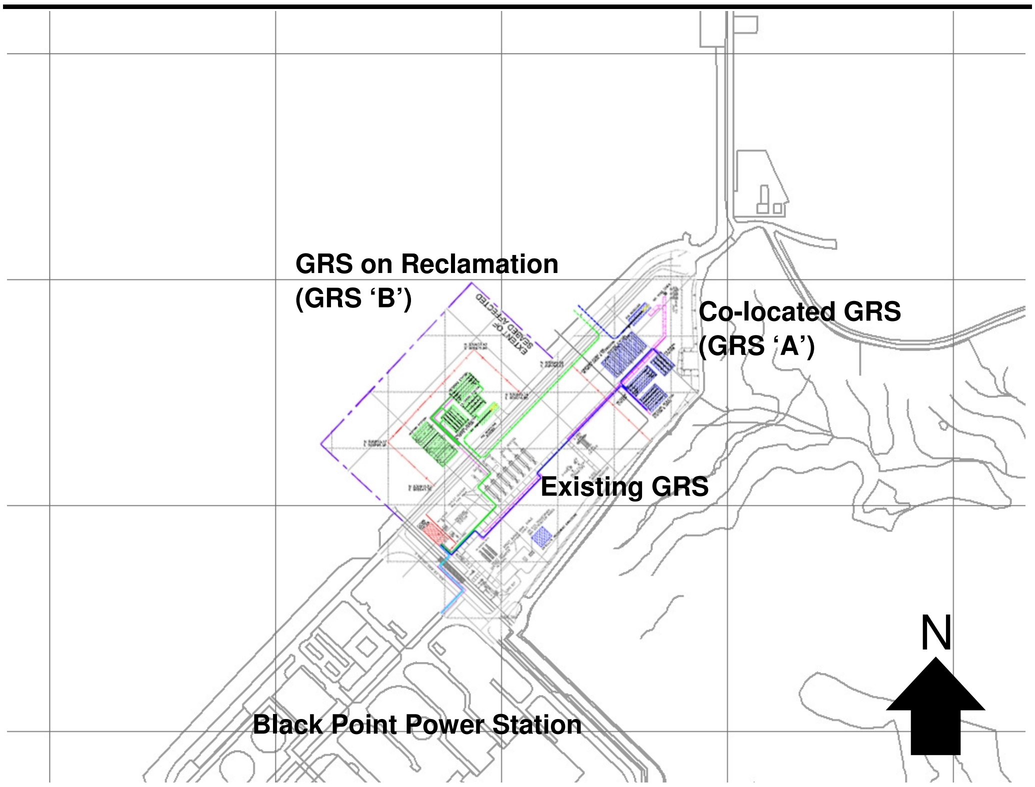
Since the separation distances between the existing and co-located GRS is similar to that between the co-located GRS and the GRS on reclamation, the results of case b) and c) can be applied respectively to case 1 and case 2.

Therefore, this Annex focuses on results for the following two cases:

- Case 3: Existing and co-located GRS operating and GRS on reclamation under construction (2014); and
- Case 4: All 3 GRSs operating (2021)

Detailed information of the study methodology is presented in *Annex 12B*. The same methodology is applied for the existing GRS, except that coordinates are updated to reflect the actual location of equipment and leak frequencies are modified to take into account the different lengths of piping and number of equipment items such as heaters.

Figure 12C.1 GRS Locations



12C.2 RESULTS

Individual Risk Results

The individual risk (IR) contours associated with the case 3 in 2014 are shown in *Figure 12C.2*. The maximum risk is less than 1×10^{-5} per year at all locations and hence meets the HKRG requirements.

Figure 12C.2 Individual Risk Contours (2014) – Case 3

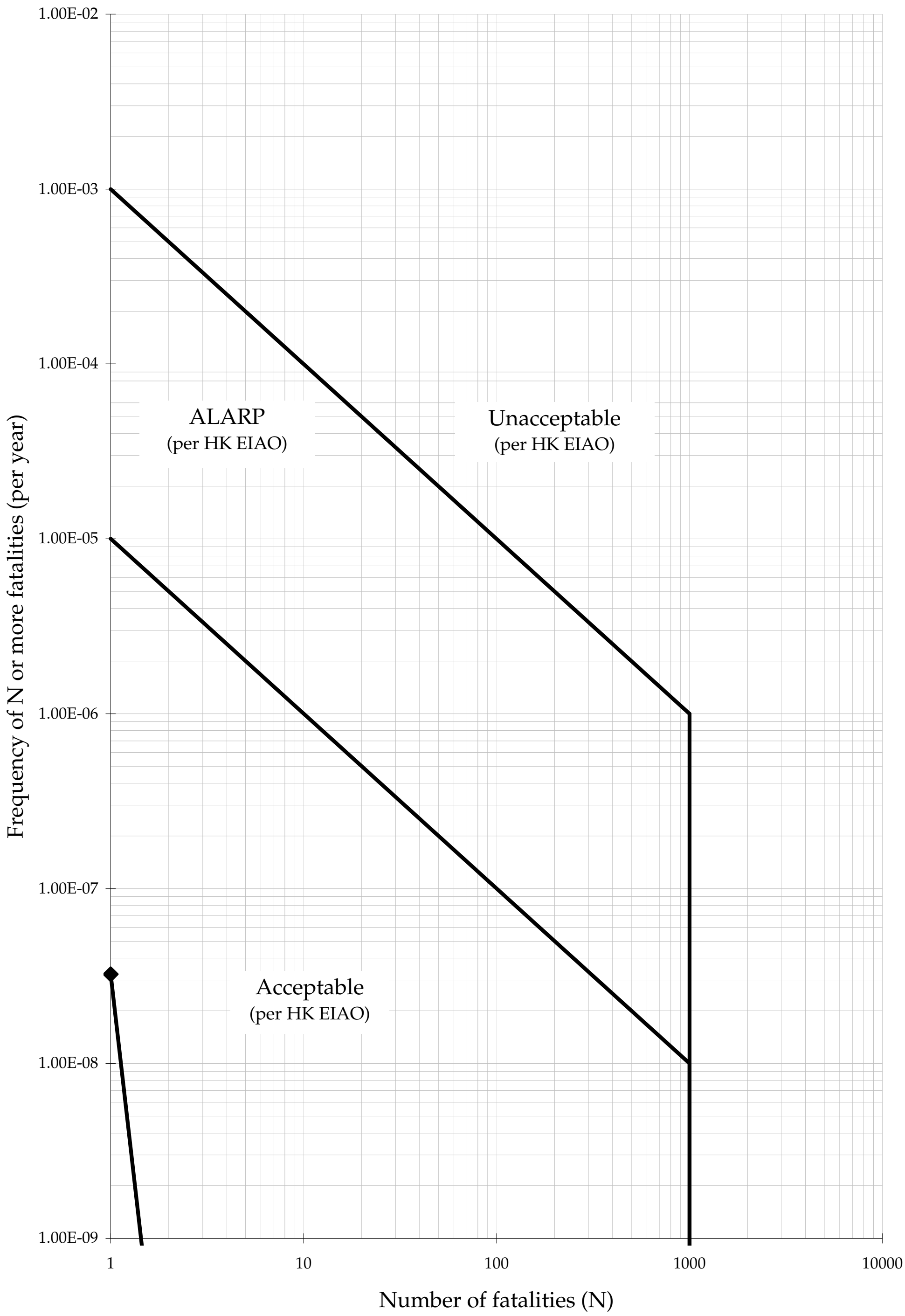
The results for case 4 in 2021 are presented in *Figure 12C.3*. With three GRSs operational, the IR has increased and exceeds in some locations 10^{-5} per year. However, the 10^{-5} per year contour does not extend offsite and hence meets the HKRG requirements.

Figure 12C.3 Individual Risk Contours (2021) – Case 4

Societal Risk Results

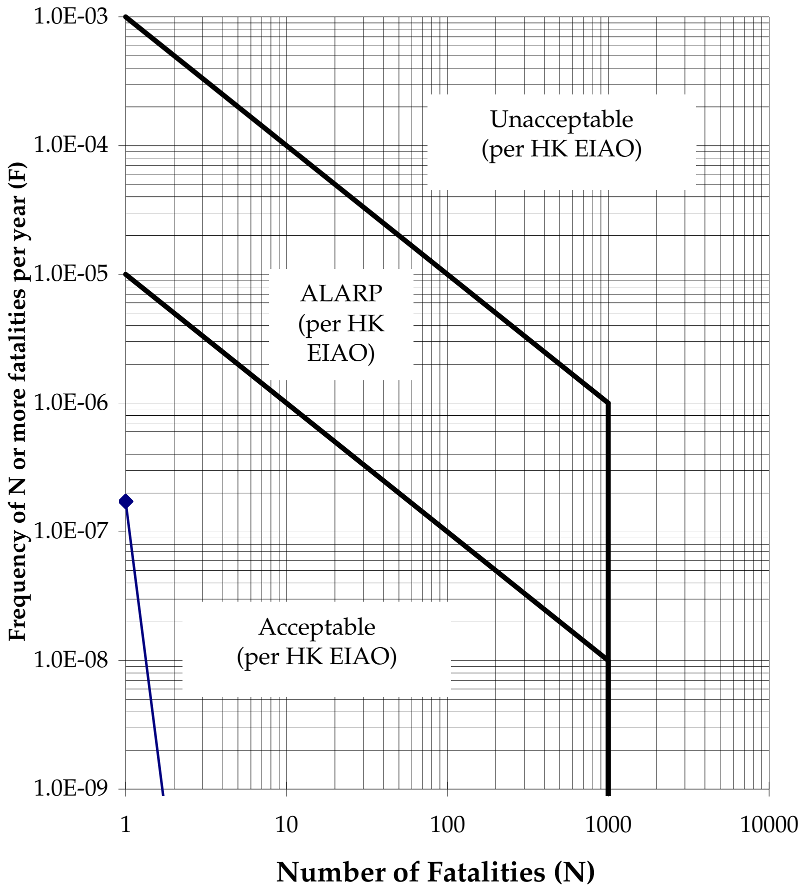
Figure 12C.4 shows the FN Curves for the GRS at the BPPS for construction year 2014 with 2 GRS in operation and the GRS on reclamation being constructed. Compared to the results presented in *Figure 12.9*, *Section 12*, the risks have only increased slightly due to the predicted slight increase in surrounding marine population. The results are within the acceptable region.

Figure 12C.4 FN Curves for GRS – case 3 in year 2014



For the year 2021, when all 3 GRSs will be operational, the risks are low (*Figure 12C.6*) due to the remote location of the site and low population in the vicinity.

Figure 12C.5 FN Curves for GRS – case 4 in year 2021



12C.3 CONCLUSIONS

Individual risks associated with the facilities meet the HKRG.

Societal risks associated with the operational phases of the project are low and lie in the acceptable region of the FN curves.

No significant increase in societal risks was found for the construction phases of the project. The slight increases found are due to increase in marine population predicted. Recommendations are nevertheless made in accordance with best practice to mitigate these construction phase risks:

- The most hazardous maintenance operations on the existing GRS will be avoided during the construction of the GRS on reclamation.
- Procedures for evacuation of construction workers will be in place in case of particularly hazardous operations on existing GRS and co-located GRS.
- Specific emergency procedures will be put into place for the evacuation of construction workers.

- Additional gas detectors along the boundary or gas and fire alarms for the detection from the GRSs in operation for escape and evacuation of construction workers will be considered.

- The construction of a temporary steel wall or other appropriate barrier between the existing GRS and the GRS on reclamation will be considered to prevent gas spreading towards the construction site in case of a gas leak in the existing GRS. This will also prevent the gas coming in contact with the ignition sources at the construction site, limit exposure of personnel to any direct flame from the existing GRS and provide time for construction personnel to evacuate the site.

Annex 12D

Tables of Assumptions

CONTENTS

12D TABLES OF ASSUMPTIONS

This section summarizes the assumptions adopted in the QRA study. These are broadly categorised as population, meteorological, frequency, consequence and plant data assumptions.

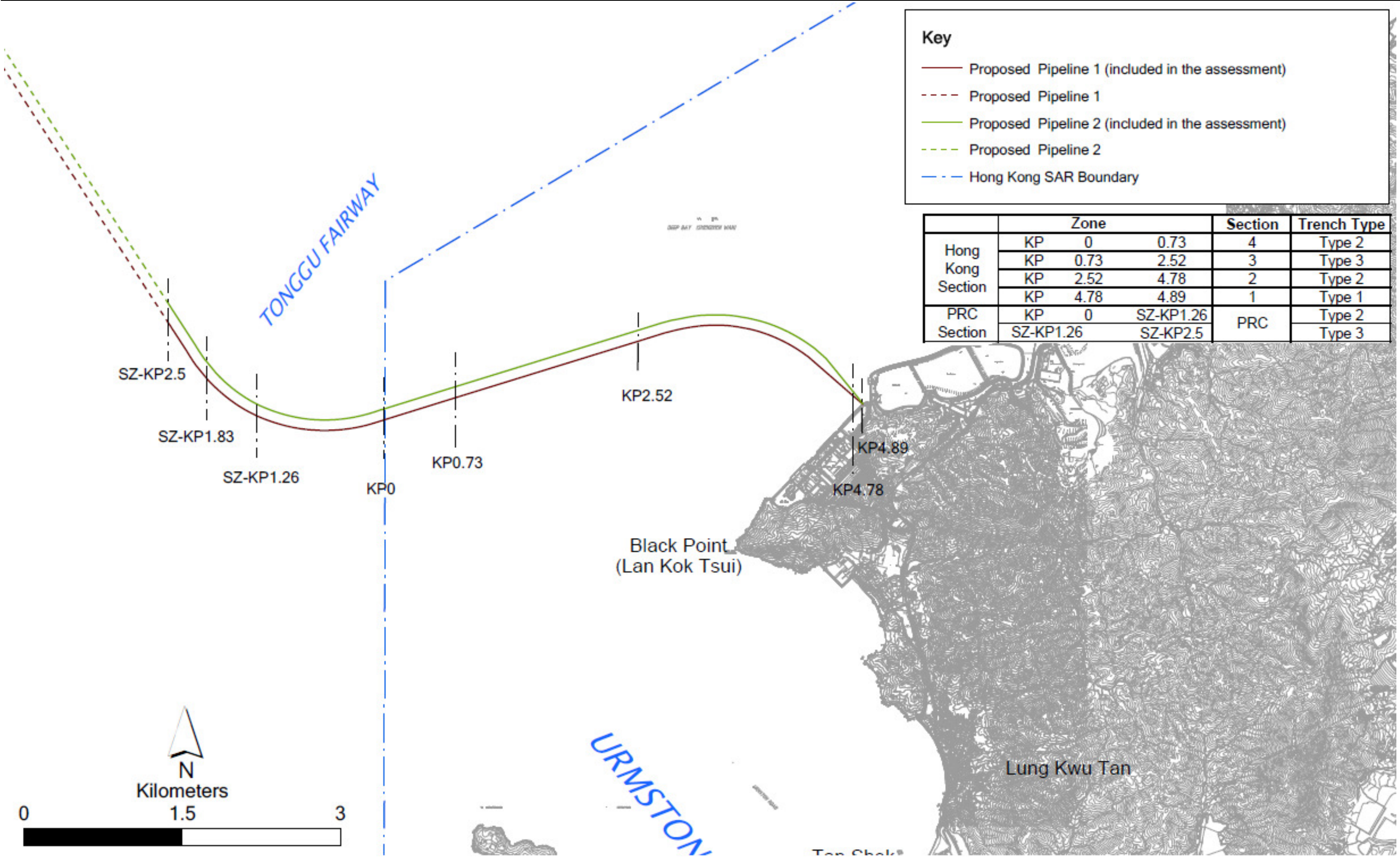
12D.1 PIPELINES

12D.1.1 *Segmentation of Route*

Table 12D.1 Pipeline Segmentation

	Section	Kilometre Post From	Kilometre Post To	Length (km)	Typ. Water depth (m)	Trench type
4	Boundary Section	0	0.73	0.73	2-20	2
3	Urmston Road	0.73	2.52	1.79	20	3
2	Black Point West	2.52	4.78	2.26	5	2
1	Black Point Approach	4.78	4.89	0.11	2	1

Figure 12D.1 Pipeline Alignment and Trench Type



	Zone			Section	Trench Type
Hong Kong Section	KP	0	0.73	4	Type 2
	KP	0.73	2.52	3	Type 3
	KP	2.52	4.78	2	Type 2
	KP	4.78	4.89	1	Type 1
PRC Section	KP	0	SZ-KP1.26	PRC	Type 2
	SZ-KP1.26		SZ-KP2.5		Type 3

12D.1.2 *Marine Vessel Classification*

Table 12D.2 Vessel Classes Adopted for Assessment

Class	Type	Typical Length (m)	Typical Beam (m)	Typical Draft (m)	Typical Displace-ment (tonnes)	Typical Anchor Size (tonnes)
"A1" - Fishing Vessels & Small craft		5 – 30	2 – 7.5	1 - 3	1 – 400	< 1
"B1" - Rivertrade coastal vessels		35 – 75	8 - 12	2.5 – 4.5	1,500	< 2
"C1" - Ocean-going Vessels		75 – 350	12 - 45	4 - 15	1,500 – 150,000	2 – 15
"A2" - Fast Launches and Fast Ferries		10 – 30	3 - 7.5	1 – 2.5	1 - 150	< 0.1
"B2" - Fast Ferries		30 - 50	7.5 - 12	1.5 - 2.5	100 – 150	< 0.5
"C2" - Fast Ferries & Ocean-going Vessel	*As above*					

12D.1.3 Marine Traffic

Table 12D.3 Traffic Volume across Gate Sections (Daily Average, 2003)

Vessel Class									
Vessel Speed (m/s)		0-5			5-25				Total
Vessel Length Range (m)		0-30	30-75	75+	0-30	30-75	75+		
From Gate	To Gate	"A1" Fishing Vessels and Small Craft	"B1" Rivertrade Coastal Vessels	"C1" Ocean-going Vessels	"A2" Fast Launches and Fast Ferries	"B2" Fast Ferries	"C2" Fast Ferries & Ocean-going Vessels	Others	
0	1	250	265	45	150	110	40	5	865
1	2	40	5	1	50	50	5	10	161

Notes: Values >5 are rounded to nearest 5
Daily values based on 9 day record. Some rounding applies

Table 12D.4 Traffic Growth Forecast

Vessel Type	20112 compared to 2003	20212 compared to 2003
Ocean-going Vessel*	-5%	+10%
Rivertrade Coastal Vessel	+5%	+15%
Fast Ferry	+10%	+30%
Fishing Vessel/ Small Craft/ Fast launch	+5%	+15%
Others	+5%	+15%

* The traffic growth forecasts for 20112 and 20212 does not take into account the development of the Tonggu Waterway. This waterway is expected to shift ocean-going vessels away from Urmston Road, resulting in a net decrease in traffic for large vessels. The analysis therefore retains 2003 traffic volumes for ocean-going vessels.

Table 12D.5 Traffic Volume Assumed for Base Case 2011

		Traffic volume (ships per day)						
Section		Fishing	River-trade	Ocean-going	Fast Launch	Fast ferry	Other	Total
4	Boundary Section	21	3	0	24	30	8	86
3	Urmston Road	250	265	81	118	150	5	869
2	Black Point West	12	16	0	5	8	2	43
1	Black Point Approach	1	0	0	0	0	0	1
	Total	284	284	81	147	188	15	999

Table 12D.6 Traffic Volume Assumed for Future Year 2021

Section		Traffic volume (ships per day)						
		Fishing	River-trade	Ocean-going	Fast Launch	Fast ferry	Other	Total
4	Boundary Section	22	3	0	26	35	9	95
3	Urmston Road	262	290	81	129	177	6	945
2	Black Point West	12	17	0	6	9	2	46
1	Black Point Approach	1	0	0	0	0	0	1
	Total	297	310	81	161	221	17	1087

12D.1.4 Marine Vessel Population

Table 12D.7 Vessel Population

Class	Population	
Fishing vessels	5	
Rivertrade coastal vessels	5	
Ocean-going vessels	21	
Fast launches	5	
Fast ferries	450 (largest ferries in peak hours, 4 hours a day)	3.75% of trips
	350 (average ferry in peak hours, 4 hours a day)	3.75% of trips
	280 (80% capacity, peak hours, 4 hours a day)	22.5% of trips
	175 (50% capacity, daytime operation, 9 hours a day)	52.5% of trips
	105 (30% capacity, late evening, 4 hours a day)	12.5% of trips
	35 (10% capacity, night time, 7 hours a day)	5% of trips
Others	5	

12D.1.5 Frequency Analysis

Table 12D.8 Anchor Damage Frequencies used in this Study

Pipeline section	Frequency (/km/year)	Comment
Boundary Section	1×10^{-4}	Medium marine traffic
Urmston Road	8.6×10^{-4}	High marine traffic
Black Point West	1×10^{-4}	Medium marine traffic
Black Point Approach	1.37×10^{-5}	Low marine traffic

Table 12D.9 Summary of Failure Frequencies used in this Study

Pipeline section	Trench type	Corrosion /defects (/km/year)	Anchor/Impact			Others /km/year	Total* /km/year
			Frequency (/km/year)	Protection factor (%) anchor<2	Protection factor (%) Anchor>2		
Boundary Section	2	1.18×10^{-6}	1×10^{-4}	99	50	1.34×10^{-6}	3.5×10^{-6}
Urmston Road	3	1.18×10^{-6}	8.6×10^{-4}	99.9	99	1.34×10^{-6}	4.1×10^{-6}
Black Point West	2	1.18×10^{-6}	1×10^{-4}	99	50	1.34×10^{-6}	3.5×10^{-6}
Black Point Approach	1	1.18×10^{-6}	1.37×10^{-5}	99	50	1.34×10^{-6}	2.7×10^{-6}

* The calculation of total failure frequency takes into account the size distribution of ships (based on 20122011 marine traffic) and the protection factors for anchors

12D.1.6 Scenario Development

Table 12D.10 Hole Size Distribution Adopted for Corrosion and Other Failures

Category	Hole Size	Proportion
Rupture (Half Bore)	22" or 558mm	5%
Puncture	4" or 100mm	15%
Hole	2" or 50mm	30%
Leak	<25mm	50%

Table 12D.11 Hole Size Distribution for Anchor Impact

Category	Hole Size	Proportion
Rupture (Full Bore)	Full bore	10%
Major	22" or 558mm (half bore)	20%
Minor	4" or 100mm	70%

Table 12D.12 Ignition Probabilities used in Current Study

Release Case	Ignition Probability	
	Passing Vessels (1)	Vessels in Vicinity (2)
<25mm	0.01	n/a
50mm	0.05	n/a
100mm	0.1	0.15
Half bore	0.2	0.3
Full bore	0.3	0.4

1. Values applied to passing vessels for all types of incidents, i.e. corrosion, others and anchor impact.
2. Values applied only to scenarios where the vessel causing pipeline damage due to anchor impact is still in the vicinity.

12D.2 GAS RECEIVING STATIONS

12D.2.1 Population

Land Population

There is no land based population within 500m of the proposed GRSs.

The security entrance to BPPS is more than 600m from the GRS facilities. The nearest industrial facilities in Lung Kwu Sheung Tan are about 1.4km away and Lung Kwu Tan Road is more than 700m away. None of these populations will be impacted by any release from the GRSs.

Marine Population

The marine study was based on 2003 data, extrapolated to years 2011 and 2021.

Table 12D.13 Population at Risk

Marine Vessel Type	Population	Fatality Probability	Population at Risk
Ocean-Going Vessel	21	0.1	2
Rivertrade Coastal Vessel	5	0.3	2
Fast Ferries	450	0.3	135
	350	0.3	105
	280	0.3	84
	175	0.3	53
	105	0.3	32
	35	0.3	11
Tug and Tow	5	0.9	5
Others	5	0.9	5

Figure 12D.2 Marine Population at Risk by Grid, Year 20112

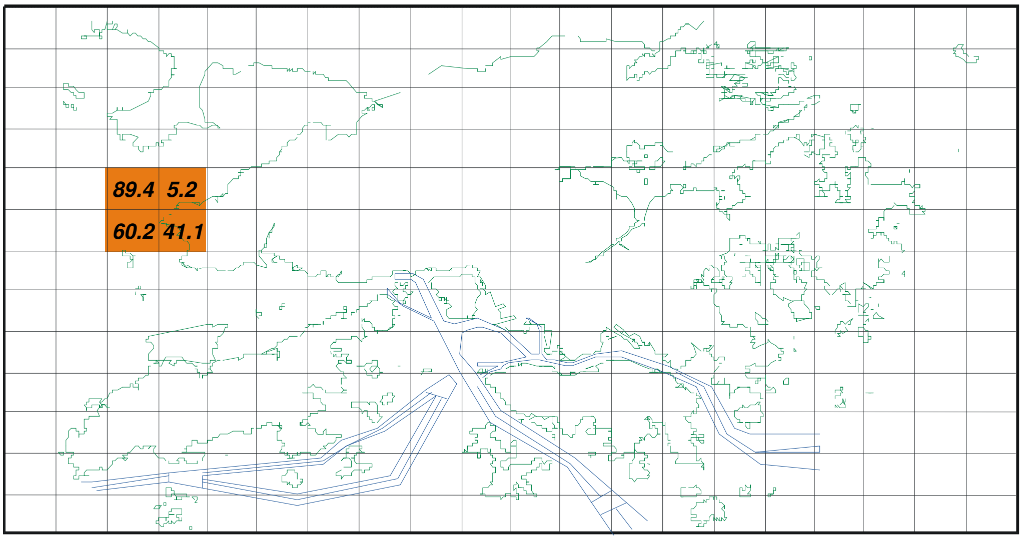


Figure 12D.3 Marine Population at Risk by Grid, Year 20212

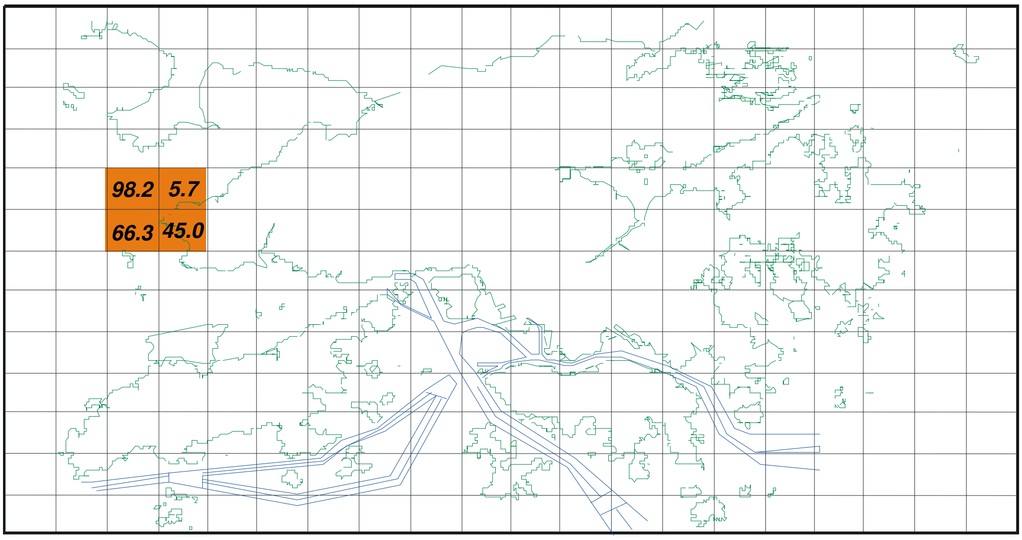


Table 12D.14 Fast Ferry Population Distribution for Day and Night Time Periods

Population	Population at Risk	% of Day Trips	% of Night Trips	% of All Trips (= 0.75 × day + 0.25 × night)
450	135	5	-	3.75
350	105	5	-	3.75
280	84	30	-	22.5
175	53	60	30	52.5
105	32	-	50	12.5
35	11	-	20	5.0

Stationary Marine Population

Other stationary marine population such as that for the Urmston Road Anchorage area are more than 500m from the proposed GRSs and were therefore neglected in the analysis.

12D.2.2 Meteorological Data

Table 12D.15 Data from Sha Chau Weather Station (2004-2008)

	Day				Night			
Wind Speed (m/s)	2.5	3	7	2	2.5	3	7	2
Atmospheric Stability	B	D	D	F	B	D	D	F
Wind Direction	Fraction of Occurrence							
0°	0.052	0.006	0.140	0.005	0.000	0.005	0.114	0.010
30°	0.009	0.005	0.050	0.003	0.000	0.004	0.092	0.008
60°	0.005	0.004	0.009	0.002	0.000	0.006	0.021	0.010
90°	0.040	0.012	0.064	0.007	0.000	0.016	0.139	0.029
120°	0.053	0.007	0.136	0.005	0.000	0.009	0.228	0.023
150°	0.014	0.003	0.023	0.003	0.000	0.003	0.039	0.015
180°	0.029	0.004	0.032	0.004	0.000	0.003	0.048	0.012
210°	0.074	0.007	0.083	0.004	0.000	0.004	0.100	0.014

	Day				Night			
240°	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001
270°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
300°	0.008	0.001	0.001	0.001	0.000	0.000	0.001	0.003
330°	0.043	0.004	0.040	0.003	0.000	0.004	0.027	0.007

12D.2.3 *Frequency Analysis*

Table 12D.16 Gas Release Event Frequencies

Section Code	Piping Diameter (mm)	Hole Size (mm)	Initiating Event Frequency	Unit	Reference
G01	7501067	10	1.00E-07	per metre	Hawksley
		25	1.00E-07	per year	
		50	7.00E-08		
		100	7.00E-08		
		FB	3.00E-08		
G02	700	10	1.00E-07	per metre	Hawksley
		25	1.00E-07	per year	
		50	7.00E-08		
		100	7.00E-08		
		FB	3.00E-08		
G03	400	10	3.00E-07	per metre	Hawksley
		25	3.00E-07	per year	
		50	1.00E-07		
		100	1.00E-07		
		FB	5.00E-08		
G04	700	10	1.00E-07	per metre	Hawksley
		25	1.00E-07	per year	
		50	7.00E-08		
		100	7.00E-08		
		FB	3.00E-08		
G05	700	10	1.00E-07	per metre	Hawksley
		25	1.00E-07	per year	
		50	7.00E-08		
		100	7.00E-08		
		FB	3.00E-08		
G06	350	10	3.00E-07	per metre	Hawksley
		25	3.00E-07	per year	
		50	1.00E-07		
		100	1.00E-07		
		FB	5.00E-08		
G07	700	10	1.00E-07	per metre	Hawksley
		25	1.00E-07	per year	
		50	7.00E-08		
		100	7.00E-08		
		FB	3.00E-08		
G08	700	10	1.00E-07	per metre	Hawksley
		25	1.00E-07	per year	
		50	7.00E-08		
		100	7.00E-08		
		FB	3.00E-08		

12D.2.4 *Scenario Development*

Table 12D.17 Ignition Probabilities Assumed

	Immediate Ignition	Delayed Ignition 1	Delayed Ignition 2	Delayed Ignition Probability	Total Ignition Probability
Small leak	0.02	0.045	0.005	0.05	0.07
Large leak/rupture	0.1	0.2	0.02	0.22	0.32

* Small leak = 10 and 25mm. Large leak = 50 and 100mm holes

Section 13

Summary of Environmental Outcomes

CONTENTS

13 SUMMARY OF ENVIRONMENTAL OUTCOMES

13.1 INTRODUCTION

This section summarises the key environmental outcomes arising from the assessments completed in this EIA Report for the proposed Gas Receiving Stations (GRSs) at the Black Point Power Station (BPPS) and submarine gas pipelines connected to BPPS. For each of the environmental components assessed, a summary of key environmental sensitive receivers is completed, together with an overview of the key potential environmental impacts and key mitigation measures, highlighting their benefits where necessary.

The summary of each of the components is structured as follows:

- List of sensitive receivers;
- Key Environmental Problems Avoided / Environmental Outcomes;
- Assessment Methodology and Criteria;
- Construction Impacts;
- Operation Impacts;
- Key Mitigation Measures;
- Residual Impacts; and
- Compliance with the guidelines and criteria of the *Environmental Impact Assessment Ordinance - Technical Memorandum* (EIAO-TM).

13.2 AIR QUALITY

Table 13.1 presents a summary of the findings of the assessment of impacts to air quality as a result of the construction and operation of this Project. Full details of the assessment and mitigation measures are presented in *Section 4* of this *EIA Report*.

Table 13.1 Summary of Environmental Assessment and Outcomes – Air Quality

- AIR QUALITY -	
Air Sensitive Receivers (ASRs)	• In accordance with the Study Brief, the study area for the air quality assessment is generally defined by a distance of 500 m from the boundary of the Project site. Air Sensitive Receivers (ASRs) were identified in accordance with the criteria in *EIAO-TM Annex 12*. • The nearest ASR is the Administration Building at Black Point Power Station (~ 360 m).
Key Environmental Issues Avoided / Environmental Outcomes	• Air sensitive receivers have been avoided by choosing a remote location for the GRSs and a route to BPPS for the offshore pipelines that avoids ASRs.
Assessment Methodology and Criteria	• An air dispersion model, Industrial Source Complex (ISCST3), recommended in the EPD's Guideline of Choice of Models and Model Parameter, was employed to predict the air quality impacts. The "rural" dispersion mode was used in the model run. In addition, the local terrain has also been incorporated into the model to account for terrain-induced impacts to dispersion. • A highly conservative approach was adopted during the air quality impact assessment modelling exercise by assuming that the emissions from the gas heaters were continuous. • Isopleths of predicted maximum hourly, daily average and annual average concentrations of NO_2 at 1.5 m, 5 m and 10 m above ground level were plotted, taking the background concentrations into consideration for comparison with the relevant criteria.
Key Construction Impacts	• Potential nuisance from dust generating activities and gaseous emission from construction plant during construction of the GRSs have been assessed and were found to be minimal. Impact on air quality at the ASR is not anticipated.
Key Operation Impacts	• The emission of key pollutants at all identified ASRs are well within the respective AQO criteria, even allowing for the very conservative assumptions used for the project-related emissions.
Key Mitigation Measures	Construction Phase: • Dust control measures stipulated in the *Air Pollution Control (Construction Dust) Regulation* will be implemented during the construction of the GRSs to control the potential fugitive dust emissions. • Site practices such as regular maintenance and checking of the diesel powered mechanical equipment will be adopted to avoid any black smoke emissions and to minimize gaseous emissions. Operation Phase: • No exceedance of the NO_2 and CO criteria is anticipated at the ASRs and therefore no mitigation measures are required.
Residual Impacts	Construction Phase: • With the implementation of the recommended dust and gaseous emissions control measures, no residual impacts are anticipated. Operation Phase: • No adverse residual operation air quality impact is anticipated.

- AIR QUALITY -	
Compliance with *EIAO-TM*	• The assessment and the impacts are acceptable and in compliance with the *EIAO-TM Annexes 4* and *12* and applicable assessment standards/ criteria.

13.3 NOISE

Table 13.2 presents a summary of the findings of the assessment of impacts to ambient noise as a result of the construction and operation of this Project. Full details of the noise assessment are presented in *Section 5* of this *EIA Report*.

Table 13.2 Summary of Environmental Assessment and Outcomes - Noise

- NOISE -	
Noise Sensitive Receivers (NSRs)	• In accordance with the Study Brief, the Study Area for the noise assessment includes all areas within 300 m from the Project Boundary. • No existing Noise Sensitive Receiver (NSR) as per the criteria in *EIAO-TM Annex 13* has been identified within the Study Area, and no planned NSR has been identified within 2 km from the Project Site.
Key Environmental Problems Avoided / Environmental Outcomes	• NSRs have been avoided by choosing a remote location for the GRSs and an offshore pipeline route to BPPS which will avoid NSRs during its construction phase.
Assessment Methodology and Criteria	• The methodology for the noise impact assessment is in accordance with the procedures outlined in the *GW-TM*, which is issued under the NCO and the *EIAO-TM*. • Using a conservative approach, each work activity has been assumed to operate simultaneously. Based on the construction programme, cumulative noise impact throughout the construction phase has been assessed.
Key Construction Impacts	• Findings of the detailed desktop review indicate that no NSRs were identified within the Study Area. Further quantitative assessment for predicting construction noise levels at NSRs was therefore not undertaken.
Key Operation Impacts	• There will be no significant plant emitting noise in the GRSs, hence significant noise associated with the operation of this Project is not anticipated.
Key Mitigation Measures	• No unacceptable potential noise impact is anticipated and thus mitigation measures are not required for the construction and operation phases.
Residual Impacts	• No adverse residual construction or operation noise impact is anticipated.
Compliance with *EIAO-TM*	• The assessment and the impacts are acceptable and in compliance with the *EIAO-TM Annexes 5* and *13* and applicable assessment standards and criteria.

13.4 WATER

Table 13.3 presents a summary of the findings of the assessment of impacts to water quality as a result of the construction and operation of this Project. Full details of the assessment are presented in *Section 6* of this *EIA Report*.

Table 13.3 Summary of Environmental Assessment and Outcomes – Water Quality

- WATER QUALITY-	
Sensitive Receivers (SRs)	The following Sensitive Receivers have been identified (values in brackets indicate approximate distance from Project): Fisheries Resources: • Oyster production area at Deep Bay (~ 4 km) • Recognised spawning grounds of commercial fisheries resources in north Lantau (> 4.5 km); • Artificial Reef Deployment Area at Sha Chau and Lung Kwu Chau (> 7.5 km); Marine Ecological Resources: • Mangroves: Sheung Pak Nai, Ngau Hom Shek (> 5 km); • Marine Park: Sha Chau and Lung Kwu Chau (~ 3 km); • Intertidal Mudflats: Ha Pak Nai (~ 2.5 km); • Seagrass Beds: Ha Pak Nai, Pak Nai (> 3 km); • Horseshoe Crab Nursery Grounds: Ha Pak Nai, Pak Nai, Sheung Pak Nai and Ngau Hom Shek (> 3 km); Water Quality: • Non-gazetted Beaches: Lung Kwu Sheung Tan, Lung Kwu Tan (> 2 km); • Secondary Contact Recreation Subzone: NW WCZ • Seawater Intakes: Black Point Power Station, Castle Peak Power Station, Tuen Mun Area 38, Shiu Wing Steel Mill (> 1 km).
Key Environmental Issues Avoided / Environmental Outcomes	• Disturbance to sensitive receivers has been avoided as a result of the site/ route selection process of the GRS reclamation and pipelines. • Potential project layouts, construction design and methods were examined on the basis of their potential environmental impacts. The adopted layout has reduced the reclamation to approximately 0.5 ha. • Impacts to water quality have been reduced by the adoption of optimal installation techniques for all sections of the pipelines. • The amount of material to be dredged and hence disposed of has been reduced by optimising project design and phasing, thereby reducing impacts to water quality during dredging and disposal operations.

- WATER QUALITY-	
Assessment Methodology and Criteria	• The potential impacts due to the construction and operation of the Project and associated developments were assessed following the *EIAO-TM Annex 6* guidelines and the impacts evaluated based on the criteria in *EIAO-TM Annex 14*. • Impacts due to the dispersion of fine sediment in suspension during the construction of the GRS reclamation and submarine pipelines have been assessed using computational modelling (Delft3D-FLOW and Delft3D-WAQ models). • The simulation of operation impacts on water quality has also been studied by means of computational modelling. The models have been used to simulate the effects of the physical presence of the reclamation of hydrodynamic regime, flushing and sedimentation patterns, and water quality changes. • Analysis of EPD routine water quality data from the years of 1998 to 2007 has been undertaken to determine the allowable increase in suspended solids concentrations.
Key Construction Impacts	The water quality modelling works have indicated that the construction works (i.e. dredging, jetting and backfilling) can proceed at the recommended working rates without causing unacceptable impacts to water quality sensitive receivers. • *Suspended Solids (SS)*: The majority of SS elevations in water have been predicted to remain within relatively close proximity to the dredging and jetting works and, as such, the majority of sediment has been predicted to settle within relatively close proximity to the works areas. Thus, no unacceptable impacts are expected to be posed by the works. Results of modelling works also indicated that pipeline installation works in Mainland waters are not expected to cause unacceptable impacts to sensitive receivers in Hong Kong. • *Water Quality (Dissolved Oxygen, Nutrients, and Heavy Metals)*: The dispersion of sediment due to dredging / jetting operations is not expected to impact the general water quality of the receiving waters. Effects will be transient, localised in extent, of small magnitude and compliant with applicable standards. Thus, no unacceptable impacts are expected to be posed by the works. • *Other Discharges*: Wastewater discharges, land based construction activities, vessel discharges and contaminants are not predicted to cause unacceptable impacts to the water quality sensitive receivers.
Key Operation Impacts	• *Hydrodynamics*: The reclamation footprint is very small and as such, adverse impacts to hydrodynamics were demonstrated as not to occur. No adverse impacts to water quality as a result of these minor changes in hydrodynamics were predicted. • *Deep Bay Flushing and Sedimentation Pattern*: The reclamation footprint is very small and adverse impacts were demonstrated as not to occur.

- WATER QUALITY-	
Key Mitigation Measures	• *Siting:* The GRS reclamation and submarine pipelines are sited with the principal aim of avoiding direct impacts to sensitive receivers. • *Reduction in Indirect Impacts*: The GRS reclamation and submarine pipelines are located at distances from water quality sensitive receivers where the dispersion of sediments from the construction works does not affect the receivers at levels of concern (as defined by the WQO and tolerance criterion). • *Adoption of Acceptable Construction Rates*: The modelling work has demonstrated that the selected working rates for the dredging/ jetting operations will not cause unacceptable impacts to the receiving water quality. Aside from these pro-active measures that have been adopted, a number of operational constraints and standard site practice measures for dredging/ jetting and construction activities are also recommended.
Residual Impacts	• No unacceptable residual impacts have been predicted to occur during the construction phase and operation phase.
Compliance with *EIAO-TM*	• The assessment and the impacts are acceptable and in compliance with the *EIAO-TM Annexes 6* and *14* and applicable assessment standards/criteria.

13.5 *WASTE MANAGEMENT*

Table 13.4 presents a summary of the findings of the assessment of impacts to waste management as a result of the construction and operation of this Project. The details of the assessment are presented in full in *Section 7* of this *EIA Report*.

Table 13.4 Summary of Environmental Assessment and Outcomes – Waste Management

- WASTE MANAGEMENT -	
Key Environmental Problems Avoided / Environmental Outcomes	• Potential project layouts, construction design and methods, use of jetting and phasing of dredging, were examined on the basis of their potential environmental impacts. The preferred alternatives have led to the reduction in the amount of dredged material expected to be produced and, therefore, have brought about an overall reduction in waste management impacts.
Assessment Methodology and Criteria	The potential environmental impacts associated with the handling and disposal of waste arising from the construction and operation of this Project are assessed in accordance with the criteria presented in *Annexes 7* and *15* of the *EIAO-TM*: • Estimation of the types and quantities of the wastes to be generated; • Assessment of the secondary environmental impacts due to the management of waste with respect to potential hazards, air and odour emissions, noise, wastewater discharges and traffic; and • Assessment of the potential impacts on the capacity of waste collection, transfer and disposal facilities.

- WASTE MANAGEMENT -	
Key Construction Impacts	The key potential impacts during the construction phase are related to wastes generated from dredging, reclamation, seawall construction, filling and concreting. • It is noted that the First Phase Construction is expected to generate about 0.253 Mm^3 (bulk volume) of contaminated marine sediments for off-site disposal. For the Second Phase it is estimated that in total approximately 0.409 Mm^3 (bulk volume) of contaminated marine sediment from the construction of the reclamation and submarine gas pipelines will require off site disposal. • Other wastes produced during the construction phase are of small quantity and will be disposed of accordingly to their nature and relevant regulations, avoiding any potential adverse impact.
Key Operation Impacts	• Small amount of industrial waste and chemical waste will be produced during the operation phase. The potential environmental impacts associated with waste storage, handling, collection, transport and disposal will meet the criteria specified in the *EIAO-TM*, thus no unacceptable operational waste management impact is anticipated.
Key Mitigation Measures	• A Waste Management Plan will be devised which incorporates mitigation measures that have been proposed to avoid or reduce potential adverse environmental impacts associated with handling, collection and disposal of waste arising from the construction and operation of this Project.
Residual Impacts	• With the implementation of the recommended mitigation measures, in particular the establishment and implementation of the Waste Management Plan, no adverse residual impacts are anticipated from the construction and operation of this Project.
Compliance with *EIAO-TM*	• The assessment and the impacts are acceptable and in compliance with the *EIAO-TM Annexes 7* and *15* and applicable assessment standards/criteria.

13.6 MARINE ECOLOGY

Table 13.5 presents a summary of the findings of the assessment of impacts to marine ecology as a result of the construction and operation of this Project. The details of the assessment are presented in full in *Section 8* of this *EIA Report*.

Table 13.5 Summary of Environmental Assessment and Outcomes – Marine Ecology

- MARINE ECOLOGY -	
Marine Ecology Sensitive Receivers	The following marine ecological sensitive receivers were identified (values in brackets indicate approximate distance from Project): • Seagrass Beds: Pak Nai, Ha Pak Nai (> 3 km); • Marine Parks: Sha Chau and Lung Kwu Chau (~ 3 km); • Intertidal Mudflats: Ha Pak Nai (~ 2.5 km); • Mangroves: Sheung Pak Nai, Ngau Hom Shek (> 5 km); • Horseshoe Crab Nursery Grounds: Ha Pak Nai, Pak Nai, Sheung Pak Nai, Ngau Hom Shek (> 3 km)
Key Environmental Problems Avoided/ Environmental Outcomes	• Disturbance to marine ecologically sensitive habitats has been avoided as a result of the site/route selection process of the GRS reclamation and pipelines. • Potential project layouts, construction design and methods were examined on the basis of their potential environmental impacts. The adopted layout has reduced the reclamation to approximately 0.5 ha with no loss of natural coastline. • Impacts to marine ecology have been reduced through the adoption of optimal installation techniques for the pipelines. This results in less adverse effect on the water quality of the surrounding areas and thus to the marine ecosystems.
Assessment Methodology and Criteria	• A literature review was supplemented by a programme of field surveys that covered intertidal and subtidal assemblages. Additional comprehensive review of marine mammals was also conducted. • The potential impacts due to the construction and operation of the proposed Project were assessed following the *EIAO-TM Annex 16* guidelines and the impacts evaluated based on criteria in *EIAO-TM Annex 8* and *Guidance Notes*.
Key Construction Impacts	• Potential construction phase impacts to marine ecological resources, as well as impacts to marine mammals, may arise from the permanent loss of habitat due to reclamation and disturbances to benthic habitats in the pipeline corridor and reclamation works area as a result of the dredging, jetting, reclamation and installation of the gas pipelines. • Water quality impacts arising from the proposed dredging/ jetting works will be compliant with assessment criteria, transient and confined to the works areas and, therefore will not give rise to adverse impacts to marine ecological resources or marine mammals.
Key Operation Impacts	• Unacceptable operation phase impacts to marine ecological resources, as well as impacts to marine mammals, are not expected to arise from the physical presence of the reclamation on hydrodynamic regime, flushing and sedimentation patterns, and water quality changes.

<table>
<tr><th colspan="2">- MARINE ECOLOGY -</th></tr>
<tr><td>Key Mitigation and Precautionary Measures</td><td>

Avoid Direct and Reduce Indirect Impacts to Ecologically Sensitive Habitats: The site for the GRS reclamation has been selected based on a review of alternative locations and has avoided natural coastline, key habitats for the Indo-Pacific humpback dolphin (e.g. Sha Chau and Lung Kwu Chau Marine Park) and areas of high marine mammal sighting density. The location of the reclamation at BPPS has a low sighting density of marine mammals. The dispersion of sediment from dredging/ jetting and backfilling does not affect the receivers at levels of concern.
Pipeline Alignment: The alignment chosen for the pipelines is at a sufficient distance from key ecological sensitive habitats, such as the Sha Chau and Lung Kwu Chau Marine Park, so that the transient elevation of suspended sediment concentrations from the installation works is not expected to result in unacceptable impacts to sensitive receivers.
Installation Equipment: The use of optimal techniques during the installation of the pipelines will reduce the severity of perturbations to water quality and hence allow compliance with the impact assessment criteria at sensitive receivers. The careful selection of installation equipment and optimisation of works schedule will help avoid impacts to sensitive ecological receivers, such as marine mammals.
Adoption of Acceptable Working Rates: The modelling work has demonstrated that the selected working rates for dredging/ jetting works will not cause unacceptable impacts to the receiving water quality. Consequently, unacceptable indirect impacts to marine ecological resources have been avoided.

The mitigation measures designed to mitigate impacts to water quality to acceptable levels (compliance with assessment criteria) are also expected to mitigate impacts to marine ecological resources.</td></tr>
<tr><td>Key Mitigation and Precautionary Measures (cont'd)</td><td>

Specific mitigation measures have been designed to reduce impacts to the population of marine mammals which include restrictions on vessel speed, the use of pre-defined and regular routes by construction traffic, and adoption of marine mammal exclusion zones around the marine works areas during the dredging / jetting works.
</td></tr>
</table>

- MARINE ECOLOGY -	
Residual Impacts	The following residual ecological impacts have been identified: • The loss of approximately 100 m of artificial shoreline which is of low ecological value. The residual impact is considered to be acceptable, as the loss of these habitats will be compensated by the provision of 200 m of seawalls that are expected to become recolonised by intertidal and subtidal assemblages of a similar nature after construction. • The permanent loss of approximately 0.5 ha of subtidal soft bottom assemblages within the reclamation site. The residual impact is considered to be acceptable as the habitat is of low ecological concern and very small in size in the context of surrounding similar habitat. • The loss of about 0.5 ha of marine waters within the reclamation site which may serve as marine mammal habitats. The residual impact is considered to be acceptable since the habitat which would be lost is not considered as key marine mammal habitat and with relatively low dolphin densities. • Approximately 16.5 ha of benthic habitats along the pipeline route and reclamation works area will be lost during dredging/ jetting, but similar subtidal benthos will recolonise over time. The residual impacts are considered to be acceptable as the habitats are of low ecological value and because infaunal organisms and epibenthic fauna are expected to recolonise the sediments after the pipelines have been laid.
Compliance with *EIAO-TM*	• The assessment and the residual impacts are acceptable and in compliance with the *EIAO-TM Annexes 8* and *16* and applicable assessment standards/criteria.

13.7 FISHERIES

Table 13.6 presents a summary of the findings of the assessment of impacts to fisheries as a result of the construction and operation of this Project. The details of the assessment are presented in full in *Section 9* of this *EIA Report*.

Table 13.6 Summary of Environmental Assessment and Outcomes – Fisheries

- FISHERIES -	
Fisheries Sensitive Receivers	• Recognised spawning grounds of commercial fisheries resources in north Lantau (> 4.5 km); • Artificial reefs in the Sha Chau & Lung Kwu Chau Marine Park (> 7.5 km); • Oyster production area at Deep Bay (~ 4 km).

- FISHERIES -	
Key Environmental Issues Avoided/ Environmental Outcomes	• Potential project layouts, construction design and methods were examined on the basis of their potential environmental impacts. The adopted layout has reduced the reclamation to approximately 0.5 ha. • The submarine pipelines will be buried in the seabed and protected. The protection measures will be either flush with, or below, the existing seabed level. This will avoid interference with fishing operations.
Assessment Methodology and Criteria	• A literature review was conducted to establish the fisheries importance of the area surrounding the proposed Project. • The potential impacts due to the construction and operation of the Project and associated developments were assessed following the *EIAO-TM Annex 17* guidelines and the impacts evaluated based on the criteria in *EIAO-TM Annex 9*.
Key Construction Impacts	• The permanent loss of about 0.5 ha of marine habitat due to reclamation and temporary disturbances to about 16.5 ha benthic habitats within the pipeline corridor and reclamation works area are not expected to be unacceptable given the small size and low fisheries importance of the areas affected. • Increase in underwater sound caused by minor increase in marine traffic is not anticipated to result in unacceptable impacts to fisheries resources. • Water quality impacts arising from the proposed dredging/ jetting or backfilling works are predicted to be largely confined to the specific works areas and the predicted elevations in suspended sediment concentrations are predicted to comply with relevant assessment criteria. Consequential impacts to any fishing grounds or species of importance to the fishery are therefore not anticipated.
Key Operation Impacts	• Unacceptable operation phase impacts to fisheries resources and fishing operations are not expected to occur. The permanent loss of about 0.5 ha of fishing ground is not considered to be significant as the area is of small size and low fisheries importance. • Secondary impacts to fisheries as a result of the physical presence of the reclamation are not expected to occur.
Key Mitigation Measures	• The mitigation measures designed to mitigate impacts to water quality to acceptable levels (compliance with assessment criteria) are expected to mitigate impacts to fisheries resources. • Construction impacts to fisheries resources and fishing operations have largely been avoided through the planning and design of the marine works; in particular those associated with the backfilling and dredging/ jetting. No fisheries-specific mitigation measures are required during construction. • Unacceptable operation phase impacts are not expected and so no additional fisheries-specific mitigation measures are required during operation.
Residual Impacts	• The identified residual impact occurring during the construction phase is the permanent loss of approximately 0.5 ha of seabed associated with the GRS reclamation. • The magnitude of this residual impact is considered to be within acceptable levels given the small size and low fisheries importance of the area being lost.

- FISHERIES -	
Compliance with *EIAO-TM*	• The assessment and the impacts are acceptable and in compliance with the *EIAO-TM Annexes 9* and *17* and applicable assessment standards/criteria.

13.8 LANDSCAPE & VISUAL IMPACT

Table 13.7 presents a summary of the findings of the assessment of impacts to the landscape and visual environment as a result of the construction and operation of this Project. The details of the assessment are presented in full in *Section 10* of this *EIA Report*.

Table 13.7 Summary of Environmental Assessment and Outcomes – Landscape & Visual

- LANDSCAPE AND VISUAL -	
Visually Sensitive Receivers (VSRs), Landscape Resources (LRs) and Landscape Character Areas (LCAs)	• Three Recreational VSRs: Recreational Transient Vessels, Hikers to Lookout above BPPS and Hikers to Castle Peak - these include views seen by visitors when passing through the vicinity • Four Occupational VSRs: Employees at BPPS, Fishermen, Workers on transient marine vessels and Workers at West New Territories Landfill - these include views seen by workers in the vicinity • Seven LRs: Mixed Shrubland, Shrubby Grassland, Bare Rock Slopes, Grassland, Highly Modified Area, Artificial Rocky/ Hard Shoreline and Seascape • Three LCAs: Inshore Waters Landscape, Industrial Urban Landscape and Upland and Hillside Landscape
Key Environmental Problems Avoided	• Sensitive VSRs have been avoided by choosing a remote location for the GRSs. • Landscape impacts have been reduced through sighting of the GRSs on previously disturbed landscape resources.
Assessment Methodology and Criteria	• The methodology of the LVIA was based on *Annexes 10* and *18* in the *EIAO-TM* under the *EIA Ordinance* and associated *Guidance Notes*. • The landscape assessment considered the impact of the proposed development on the existing landscape and particularly on the landscape character units within 500 m of the development site. • The visual assessment examined the impact of the proposed development on the existing views and the visual amenity, particularly from the VSRs within the viewshed. • In order to illustrate the visual impacts of the proposed GRSs, photomontages prepared from selected viewpoints compare the existing conditions with the view after construction. The residual impacts are evaluated qualitatively, in accordance with the requirements of *Annex 10* of the *EIAO-TM*.

- LANDSCAPE AND VISUAL -	
Key Impacts	The proposed GRSs will only be visible from a limited number of locations, and these impacts will only be significant at close proximity to the Black Point Power Station. The analysis has shown that at distances greater than 2.3 km, the GRSs will not have a substantial negative impact on the visual environment. • The GRSs are expected to have negligible to moderate landscape impact on the existing LCAs and LRs of the Study Area, as these LCAs and LRs are of low to medium sensitivity to change and the magnitude of change is expected to be negligible to intermediate. • The GRSs are expected to have slight visual impacts on the existing VSRs of the Study Area, as these VSRs are of low sensitivity to change and the magnitude of change is expected to be small.
Key Mitigation Measures	The analysis has shown that all seven VSRs selected for analysis will experience a slight visual impact. The following Visual Mitigation Measures (VMMs) are proposed to reduce the slight impacts identified and improve the overall amenity of the development • VM 1: The colours of the proposed GRS should be selected to complement the existing industrial surroundings. To reduce the potential impacts on the existing LRs and LCAs and provide a potential enhancement of the existing landscape quality, Landscape Mitigation Measures (CM) are proposed in accordance with future Landscape Specification and relevant best practice guidelines: • CM1: Site hoardings to be compatible with surrounding landscape. • CM2: Edges of the new reclamation to be constructed to match the existing Rocky Seawall • CM3: The tree requiring removal is to be compensated in accordance with relevant government guidelines
Residual Impacts	• No significant adverse residual impacts have been identified. The Landscape and Visual Mitigation Measures proposed will help to mitigate the impacts on the LCAs, LRs and VSRs. Overall the residual impacts are assessed as negligible to slight.
Compliance with *EIAO-TM*	• The assessment and the impacts are acceptable with mitigation and in compliance with the *EIAO-TM Annexes 10* and *18* and applicable assessment standards/criteria.

13.9 CULTURAL HERITAGE

Table 13.8 presents a summary of the findings of the assessment of impacts to cultural heritage as a result of the construction and operation of this Project. The details of the assessment are presented in full in *Section 11* of this *EIA Report*.

Table 13.8 Summary of Environmental Assessment and Outcomes – Cultural Heritage

- CULTURAL HERITAGE -	
Sensitive Receivers	• There is no declared/ deemed monument, graded/ recorded heritage resources, Built Heritage or Archaeological Sites located within the proposed land-based Project Area and works areas. No existing sites of cultural heritage protected under the *Antiquities and Monuments Ordinance* have been identified within the proposed Project Area and works areas. • No marine sites of cultural heritage/ archaeological value are present in waters surrounding Black Point and along the proposed pipeline corridor
Key Environmental Issues Avoided/ Environmental Outcomes	• Potential layouts were examined on the basis of their potential environmental impacts. The selected layout has reduced the area impacted by the footprint of the Project and hence reduced potential impact on cultural heritage sites.
Assessment Methodology and Criteria	• The study methodology follows the criteria and guidelines as stated in *Annexes 10* and *19* of the *EIAO-TM* and the criteria for *Cultural Heritage Impact Assessment (CHIA)* and *Guidelines for Marine Archaeological Investigation (MAI)* as stated EIA Study Brief No. ESB-208/2009. • The baseline study included a desktop literature review and a Marine Archaeological Investigation.
Key Impacts	• Findings of the Marine Archaeological Investigation concluded that no marine sites of cultural heritage/ archaeological value are present in waters surrounding Black Point and along the proposed pipeline corridor. As such, no impacts to marine archaeological resources are expected.
Key Mitigation Measures	• No impacts to marine archaeological resources have been identified and hence no specific mitigation measures are necessary.
Residual Impacts	• No residual impact is expected.
Compliance with *EIAO-TM*	• The assessment and the residual impacts are acceptable and in compliance with the *EIAO-TM Annexes 10* and *19* and applicable assessment standards and criteria.

13.10 HAZARD TO LIFE

Table 13.9 presents a summary of the findings of the assessment of impacts to quantitative risk as a result of the operation of this Project. The details of the assessment are presented in full in *Section 12* of this *EIA Report*.

Table 13.9 Summary of Environmental Assessment and Outcomes – Quantitative Risk Assessment

QUANTITATIVE RISK ASSESSMENT	
Key Environmental Issues Avoided	• The Project has been located in a remote location avoiding populated areas.
Assessment Methodology and Criteria	• The Quantitative Risk Assessment (QRA) study undertaken for this Project has assessed the risk associated with the GRSs as well as the associated submarine gas pipelines from Black Point Power Station (BPPS) to Mainland China. • The methodology involved five main components: review of baseline data (review of GRS layout and surrounding population), risk assessment on generic and site specific risks, frequencies and likelihood calculation, consequence assessment and risk assessment. • The results from the risk assessment were compared with the HKRG and, mitigation measures identified and assessed where appropriate.
Key Impacts	Submarine Gas Pipelines: • The FN curves for all sections of the pipelines lie within the Acceptable Region. • Individual risk (IR) for all sections are predicted to be less than the 1 x 10^{-5} per year as per *Annex 4* of the *EIAO-TM*. Gas Receiving Stations: • It can be seen that the societal risk for the GRSs is within the Acceptable Region as per *Annex 4* of the *EIAO-TM*. • The IR is less than 1 x 10^{-5} per year (i.e. less than one in every 100,000 years) everywhere on site and at the site boundary, and hence meets the requirements of *Annex 4* of the *EIAO-TM*.
Mitigation Measures	• No unacceptable risks are foreseen as a result of the operation of the GRSs and submarine gas pipelines. No mitigation measures are thus deemed necessary.
Residual Impacts	• No residual impact is expected.
Compliance with *EIAO-TM*	• The assessment and the impacts are in compliance with the *EIAO-TM Annex 4*.

Section 14

Environmental Monitoring and Audit Measures

CONTENTS

14 ENVIRONMENTAL MONITORING & AUDIT MEASURES

14.1 INTRODUCTION

This EIA Study has focused on the assessment and mitigation of the potential impacts associated with the construction and operation of the Project. One of the key outputs has been the identification of mitigation measures to be undertaken so that residual impacts comply with regulatory requirements including the *EIAO TM*. To confirm effective and timely implementation of the mitigation measures, it is considered necessary to develop Environmental Monitoring and Audit (EM&A) procedures and mechanisms by which the *Implementation Schedule (Annex 14A)* may be tracked and its effectiveness assessed.

14.1.1 *Implementation of EIA Findings & Recommendations*

Sections 4 to *12* have, where appropriate, identified and recommended the implementation of mitigation measures to reduce the potential construction and operational impacts of the Project. These findings and recommendations form the primary deliverable from the whole EIA process. Once endorsed by the EPD, they will form an agreement between CAPCO and the Government as to the measures and standards that are to be achieved. It is therefore essential that mechanisms are put in place to verify that the mitigation measures prescribed in the *Implementation Schedule (Annex 14A)* are fully and effectively implemented during construction.

The required format for the *Implementation Schedule* is specified in the EIA Study Brief. The format requires the specification of implementation agent(s), timing, duration and location for each of the recommended mitigation measures. Apart from the mitigation measures identified in the EIA, there are also procedures for other requirements to be included within the finalised Implementation Schedule. Prior to the issue of an Environmental Permit, there is an EIA Determination Period. During this period the EIA Report is reviewed and commented upon by both the public and professional bodies. Where recommendations are made and accepted by either the Advisory Council on the Environment (ACE) or its EIA subcommittee, these measures will be included within the Implementation Schedule, where appropriate.

14.1.2 *Statutory Requirements*

As the Project constitutes a Designated Project under the *EIAO*, an Environmental Permit must be obtained before construction or operation of the Gas Receiving Stations (GRSs) and submarine gas pipelines.

Upon approval of the EIA Report, CAPCO can apply for an Environmental Permit. If the application is successful, the Environmental Permit may, have conditions attached to it, which must be complied with. In addition, CAPCO and its appointed Contractor(s) must also comply with other controlling environmental legislation and guidelines, which are discussed within the specific technical chapters of this Report.

14.2 EM&A MANUAL

The EPD requires the submittal of an EM&A Manual prior to the commencement of construction for approval. The EM&A Manual defines the mechanisms for implementing the EM&A requirements specific to each phase of the work. The EM&A Manual provides a description of the organisational arrangements and resources required for the EM&A programme based on the conclusions and recommendations of this EIA. It stipulates details of the construction monitoring required and actions that shall be taken in the event of exceedances of the environmental criteria. In effect, the EM&A Manual forms a handbook for the on-going environmental management during construction.

The EM&A Manual comprises descriptions of the key elements of the EM&A programme including:

- Appropriate background information on the construction of the Project with reference to relevant technical reports;
- Organisational arrangements, hierarchy and responsibilities with regard to the management of environmental performance during the construction phase. The EM&A team, the Contractor(s) team and the CAPCO's representatives are included;
- A broad construction programme indicating those activities for which specific mitigation is required and providing a schedule for their timely implementation;
- Descriptions of the parameters to be monitored and criteria through which performance will be assessed including: monitoring frequency and methodology, monitoring locations (typically, the location of sensitive receivers as listed in the EIA), monitoring equipment lists, event contingency plans for exceedances of established criteria and schedule of mitigation and best practice methods for reduced adverse environmental impacts;
- Procedures for undertaking on-site environmental performance audits as a means of ensuring compliance with environmental criteria; and
- Reporting procedures.

The EM&A Manual will be a dynamic document which will undergo a series of revisions, as needed, to accommodate the progression of the construction programme.

14.2.1 *Objectives of EM&A*

The objectives of carrying out EM&A for the Project include:

- Providing baseline information against which any short or long term environmental impacts of the projects can be determined;
- Providing an early indication should any of the environmental control measures or practices fail to achieve the acceptable standards;
- Monitoring the performance of the Project and the effectiveness of mitigation measures;
- Verifying the environmental impacts identified in the EIA;
- Determining Project compliance with regulatory requirements, standards and government policies;
- Taking remedial action if unexpected results or unacceptable impacts arise; and
- Providing data to enable an environmental audit to be undertaken at regular intervals.

The following sections summarise the recommended EM&A requirements and further details are provided in the EM&A Manual.

14.3 AIR QUALITY

The EIA study concluded that no air sensitive receivers (ASRs) will be affected by construction dust through the implementation of mitigation measures to reduce dust levels. During the operation phase, emissions will be controlled by integrated measures, regular inspections and relevant emissions licenses. Emissions from construction or operation phase are not predicted to yield concentrations that would lead to significant air quality impacts at the ASRs. Therefore, no air quality monitoring will be required for either the construction or operation phase, aside from that required by specific emissions licenses.

Regular site inspections and audits will be carried out during the construction phase in order to confirm that the mitigation measures are implemented and are working effectively.

14.4 NOISE

The EIA study of the Project concluded that no existing noise sensitive receiver (NSR) has been identified within the 300 m Study Area, and no planned NSR has been identified within 2 km from the Project Site. This applies to both the proposed GRSs and submarine gas pipelines. Based upon this, no noise monitoring is necessary for both the construction and operation phases.

Regular site inspections and audits will be carried out during the construction phase in order to verify compliance with the regulatory requirements and conformity of the Contractor with regard to noise control and contract conditions.

14.5 WATER QUALITY

14.5.1 *Construction Phase*

A number of operational constraints and standard site practice measures for marine construction activities have been recommended to reduce potential impacts to water quality sensitive receivers. Regular site inspections and audits will be carried out during the construction phase in order to confirm that these measures are implemented and are working effectively.

The EIA indicated that water quality monitoring will be required during the construction phase for the following activities:

- Dredging works for the seawall construction and backfilling works at the reclamation area at Black Point Power Station (BPPS);
- Dredging/ jetting works for the submarine gas pipelines in Hong Kong waters; and
- Monitoring in Hong Kong waters when dredging/ jetting works for the submarine gas pipelines in Mainland waters is within 2.5 km of the HKSAR boundary.

Water quality monitoring results will be compared to Action and Limit levels to determine whether impacts associated with the works are acceptable. An Event and Action Plan provides procedures to be undertaken when monitoring results exceed Action or Limit levels. The procedures are designed to confirm that if any significant exceedances occur (either accidentally or through inadequate implementation of mitigation measures on the part of the Contractor(s)), the cause is quickly identified and remedied, and that the risk of a similar event re-occurring is reduced.

Action and Limit levels will be used to determine whether modifications to the operations are required. Action and Limit levels are environmental quality standards chosen such that their exceedance indicates potential deterioration of the environment. Exceedance of Action levels can result in an increase in the frequency of environmental monitoring, modification of operations and implementation of the proposed mitigation measures. Exceedance of Limit Levels indicates a greater potential deterioration in environmental conditions and may require the cessation of works unless appropriate remedial actions, including a critical review of plant, working methods and mitigation measures, are undertaken. Before construction work commences four consecutive weeks of baseline monitoring will be undertaken at stations identified as detailed in the EM&A Manual.

The full details of the EM&A programme for water quality are presented in the EM&A Manual for this Project.

14.5.2 *Operation Phase*

As no unacceptable impacts have been predicted to occur during the operation of the GRSs at BPPS, monitoring of impacts to marine water quality during the operation phase is not considered necessary.

14.6 WASTE MANAGEMENT

A Waste Management Plan will be devised which incorporates mitigation measures that have been proposed in the EIA Report to avoid or reduce potential adverse environmental impacts associated with handling, collection and disposal of waste arising from the construction and operation of this Project. Proposed measures are based on good management, control and site practices.

In order to confirm that the construction Contractor(s) has(have) implemented the recommendations of the EIA Report, regular site inspections and audits will be conducted of the waste streams, to determine if wastes are being managed in accordance with the approved procedures and the site Waste Management Plan. The inspections/audits will look at all aspects of waste management including waste generation, storage, recycling, transport and disposal. The first inspection/audit will be conducted at the commencement of the construction works.

14.7 MARINE ECOLOGY

The dredging/ jetting operations have been shown to proceed at rates that maintain environmental impacts to within acceptable levels following application of mitigation measures. The mitigation measures designed to mitigate impacts to water quality to acceptable levels (compliance with assessment criteria) are expected to mitigate impacts to marine ecological resources and thus specific measures are not deemed necessary.

Specific mitigation measures have been established to reduce impacts to marine mammals which include restrictions on vessel speed, the use of pre-defined and regular routes by construction traffic. Marine Mammal exclusion zones will be implemented during the dredging/ jetting works off Black Point waters. Additional marine mammal monitoring will also be implemented during the pre-construction, construction and post-construction phases of the Project. The EM&A Manual provides complete details of the marine mammal monitoring programme.

The water quality monitoring programme will provide management actions and supplemental mitigation measures to be employed should impacts arise, thereby ensuring the environmental acceptability of the Project.

During the operation phase, adverse impacts are not expected to occur. Therefore, no marine mammal monitoring will be required for the operation phase.

14.8 FISHERIES

The mitigation measures designed to mitigate water quality impacts to acceptable levels (compliance with assessment criteria) are expected to mitigate impacts to fisheries resources. Since the impacts to fisheries resources and fishing operations are small and of short duration, the development and implementation of a monitoring and audit programme specifically designed to assess the effects on commercial fisheries resources is not deemed necessary.

The water quality monitoring programme will provide management actions and supplemental mitigation measures to be employed should impacts arise, thereby ensuring the environmental acceptability of the Project.

To confirm that the seabed affected by the pipeline works has returned to its original configuration, a geophysical survey will be conducted following completion of pipeline works.

14.9 LANDSCAPE & VISUAL

The Landscape and Visual Assessment of the EIA recommended a series of mitigation measures for the construction phase to mitigate the landscape and visual impacts of the Project. Details of all the recommended mitigation measures are included within the Implementation Schedule provided in *Annex 14A*.

Implementation of the mitigation measures for landscape and visual resources recommended by the EIA will be monitored through the site inspection and audit programme.

During the operation phase, adverse impacts are not expected to occur. Therefore, no landscape and visual monitoring will be required for the operation phase.

14.10 CULTURAL HERITAGE

The EIA study of the Project concluded that terrestrial sites of cultural heritage/ archaeological potential are not identified within the Project Site. Findings of the Marine Archaeological Investigation also concluded that no marine sites of cultural heritage/ archaeological value are present in waters surrounding Black Point and along the proposed pipeline corridor. No impact to cultural heritage and archaeology is thus predicted and hence no EM&A is required.

14.11 HAZARD TO LIFE

The EIA study concluded that no unacceptable risks are foreseen as a result of the operation of the GRSs and submarine gas pipelines. No mitigation measures are thus deemed necessary and no monitoring will be required for the construction and operation phases.

Annex 14A

Implementation Schedule of Mitigation & Precautionary Measures

Annex 14A-1 Implementation Schedule for Environmental Protection Measures for the Black Point Gas Supply Project

EIA Ref.	Environmental Protection Measures	Location/Duration of Measures/Timing of Completion of Measures	Implementation Agent	Implementation Stage				Relevant Legislation & Guidelines
				Des	C	O	Dec	
1. Air Quality Measures								
S4.8	Dust control measures stipulated in the *Air Pollution Control (Construction Dust) Regulation* will be implemented during the construction of the GRSs to control the potential fugitive dust emissions.	Land Site / During Construction	Contractor(s)		✓			Air Pollution Control (Construction Dust) Regulation
S4.8	Site practices such as regular maintenance and checking of the diesel powered mechanical equipment will be adopted to avoid any black smoke emissions and to minimize gaseous emissions.	Land Site / During Construction	Contractor(s)		✓			-
S4.10	EM&A in the form of site inspection and audit of dust generating activities.	Land Site / During Construction	Environmental Team (ET) & Independent Environmental Checker (IEC)		✓			Environmental Impact Assessment Ordinance
2. Noise No mitigation measures were specified in the EIA report as no noise sensitive receivers are located in the Project Area.								
3. Water Quality								
S6 Annex 6A	Dredging/ jetting plants will be required to comply with the rates modelled in the EIA (*S6 Annex 6A*) for the various activities assessed.	Marine works areas / During Construction	Contractor(s) and ET		✓			-
S6.9	Dredged marine mud will be disposed of in a gazetted marine disposal area in accordance with the *Dumping at Sea Ordinance (DASO)* permit conditions.	Dredged areas/ During Construction	Contractor(s)		✓			Dumping at Sea Ordinance
S6.9	Disposal vessels will be fitted with tight bottom seals in order to prevent leakage of material during transport.	Dredged areas/ During Construction	Contractor(s)		✓			Dumping at Sea Ordinance

EIA Ref.	Environmental Protection Measures	Location/Duration of Measures/Timing of Completion of Measures	Implementation Agent	Implementation Stage				Relevant Legislation & Guidelines
				Des	C	O	Dec	
S6.9	Barges will be filled to a level, which ensures that material does not spill over during transport to the disposal site and that adequate freeboard is maintained to ensure that the decks are not washed by wave action.	Dredged areas/ During Construction	Contractor(s)		✓			-
S6.9	After dredging, any excess materials will be cleaned from decks and exposed fittings before the vessel is moved from the dredging area.	Dredged areas/ During Construction	Contractor(s)		✓			Dumping at Sea Ordinance
S6.9	The contractor(s) will confirm that the works cause no visible foam, oil, grease, litter or other objectionable matter to be present in the water within and adjacent to the dredging site.	Dredged areas/ During Construction	Contractor(s)		✓			-
S6.9	Monitoring and automation systems will be used to improve the crew's information regarding the various dredging parameters to improve dredging accuracy and efficiency.	Dredged areas/ During Construction	Contractor(s)		✓			-
S6.9	Control and monitoring systems will be used to alert the crew to leaks or any other potential risks such as chemicals and oils.	Dredged areas/ During Construction	Contractor(s)		✓			-
S6.9	When the dredged material has been unloaded at the disposal areas, any material that has accumulated on the deck or other exposed parts of the vessel will be removed and placed in the hold or a hopper. Under no circumstances will decks be washed clean in a way that permits material to be released overboard.	Dredged areas/ During Construction	Contractor(s)		✓			Dumping at Sea Ordinance
S6.9	Dredgers will maintain adequate clearance between vessels and the seabed at all states of the tide and reduce operations speed to ensure that excessive turbidity is not generated by turbulence from vessel movement or propeller wash.	Dredged areas/ During Construction	Contractor(s)		✓			-
S6.9	Mitigation measures to be implemented during reclamation sand-filling, reclamation dredging and submarine pipeline installation activities are presented in *Annex 14A-2*.	Marine works at Various Locations	Contractor(s)		✓			-

EIA Ref.	Environmental Protection Measures	Location/Duration of Measures/Timing of Completion of Measures	Implementation Agent	Implementation Stage				Relevant Legislation & Guidelines
				Des	C	O	Dec	
S6.9	Channels, earth bunds or sand bag barriers will be provided on site to direct stormwater to silt removal facilities. The design of silt removal facilities will make reference to the guidelines in *Appendix A1* of *ProPECC PN 1/94*. All drainage facilities and erosion and sediment control structures will be inspected on a regular basis and maintained to confirm proper and efficient operation at all times and particularly during rainstorms. Deposited silt and grit will be removed regularly.	Land Site / During Construction	Contractor(s)		✓			ProPECC PN 1/94 TM standard under the WPCO
S6.9	Earthworks to form the final surfaces will be followed up with surface protection and drainage works to prevent erosion caused by rainstorms.	Land Site / During Construction	Contractor(s)		✓			-
S6.9	Appropriate surface drainage will be designed and provided where necessary.	Land Site / During Construction	Contractor(s)		✓			-
S6.9	The precautions to be taken at any time of year when rainstorms are likely together with the actions to be taken when a rainstorm is imminent or forecasted and actions to be taken during or after rainstorms are summarised in *Appendix A2* of *ProPECC PN 1/94*.	Land Site / During Construction	Contractor(s)		✓			ProPECC PN 1/94
S6.9	Oil interceptors will be provided in the drainage system where necessary and regularly emptied to prevent the release of oil and grease into the storm water drainage system after accidental spillages.	Land Site / During Construction	Contractor(s)		✓			-
S6.9	Temporary and permanent drainage pipes and culverts provided to facilitate runoff discharge will be adequately designed for the controlled release of storm flows.	Land Site / During Construction	Contractor(s)		✓			-
S6.9	The temporary diverted drainage will be reinstated to the original condition when the construction work has finished or when the temporary diversion is no longer required.	Land Site / During Construction	Contractor(s)		✓			-
S6.9	During the early stages of work, portable chemical toilets will be used and the effluent will either be shipped offsite or be disposed of at sewage treatment work (STW) at BPPS.	All facilities / During Construction	Contractor(s)		✓			-

EIA Ref.	Environmental Protection Measures	Location/Duration of Measures/Timing of Completion of Measures	Implementation Agent	Implementation Stage				Relevant Legislation & Guidelines
				Des	C	O	Dec	
S6.9	Debris and refuse generated on-site will be collected, handled and disposed of properly to avoid entering the nearby WSRs. Stockpiles of cement and other construction materials will be kept covered when not being used.	All facilities / During Construction	Contractor(s)		✓			-
S6.9	Oil leakage or spillage will be contained and clean up immediately. Waste oil will be collected and stored for recycling or disposal, in accordance with the *Waste Disposal Ordinance*.	All facilities / During Construction	Contractor(s)		✓			Waste Disposal Ordinance
S6.10	Water quality monitoring shall be undertaken for suspended solids, salinity, turbidity, and dissolved oxygen. If exceedances occur due to dredging/ jetting activities, event and action plan shall be adopted.	Designated monitoring stations as defined in EM&A Manual / Construction period for dredging/ jetting works	ET		✓			Environmental Impact Assessment Ordinance
S6.9	The surface runoff from the GRSs should be connected to a storm water channel via a grit and oil interceptor. These grit and oil interceptors will be regularly cleaned and maintained in good working condition. Trapped oil and grease should be disposed of periodically by waste collection contractor using a suitable liquid waste collection vehicle	GRSs/ During Operation	CAPCO			✓		-
S6.9	Any oil leakage or spillage will be contained and cleaned up immediately.	GRSs/ During Operation	CAPCO			✓		-
S6.9	Waste oil will be collected and stored for recycling or disposal in accordance with the *Waste Disposal Ordinance*.	GRSs/ During Operation	CAPCO			✓		Waste Disposal Ordinance
4. Waste Management								
S7.5	The Contractor shall identify a coordinator for the management of waste.	Contract mobilisation / During construction	Contractor(s)		✓			-
S7.5	The waste coordinator shall prepare and implement a Waste Management Plan which specifies procedures such as a ticketing system, to facilitate tracking of loads and protocols for the maintenance of records of the quantities of wastes generated, recycled and disposed.	Contract mobilisation / During construction	Contractor(s)		✓			-

EIA Ref.	Environmental Protection Measures	Location/Duration of Measures/Timing of Completion of Measures	Implementation Agent	Implementation Stage				Relevant Legislation & Guidelines
				Des	C	O	Dec	
S7.5	The Contractor shall apply for and obtain the appropriate licenses for the disposal of public fill, chemical waste and effluent discharges.	Contract mobilisation / During construction	Contractor(s)		✓			Waste Disposal (Chemical Waste) (General) Regulation Code of Practice on the Packaging, Labelling and Storage of Chemical Wastes WBTC No 5/99, Trip-ticket System for Disposal of Construction and Demolition Material Water Pollution Control Ordinance
S7.5	No waste shall be burnt on site. Wastes shall be collected by licensed waste haulier and be disposed of at licence sites.	Land site/ During construction	Contractor(s)		✓			Air Pollution Control Ordinance
S7.5	Rock and soil may be excavated from site formation works and that will be reused as fill material for the reclamation within the Project as far as practicable.	Land site / During construction	Contractor(s)		✓			WBTC No. 2/93, Public Dumps
S7.5	Material shall be reused on site as far as practicable, including formwork plywood, topsoil and excavated material.	Land site / During construction	Contractor(s)		✓			WBTC 32/92, The Use of Tropical Hard Wood on Construction Site

EIA Ref.	Environmental Protection Measures	Location/Duration of Measures/Timing of Completion of Measures	Implementation Agent	Implementation Stage				Relevant Legislation & Guidelines
				Des	C	O	Dec	
S7.5	C&D materials will be sorted on site into inert waste (public fill) and non-inert waste (construction waste). Public fill will be disposed of at public fill reception facilities (e.g. Tuen Mun Area 38 or other locations as agreed with CEDD). Construction waste, such as timber, paper, plastics and general refuse, cannot be reused and need to be disposed of at the West New Territories (WENT) Landfill.	Land site / During construction	Contractor(s)		✓			-
S7.5	The site and surroundings shall be kept tidy and litter free. Waste storage area shall be properly cleaned and shall not cause windblown litter and dust nuisance.	All areas / During construction	Contractor(s)		✓			WBTC Nos. 6/2002 and 6/2002A, Enhanced Specification for Site Cleanliness and Tidiness. Works Bureau, Hong Kong SAR Government
S7.5	Stockpiled material shall avoid vegetated areas.	Land site / During construction	Contractor(s)		✓			
S7.5	Stockpiles shall be covered by tarpaulins and/or watered as needed.	Land site / During construction, particularly dry season	Contractor(s)		✓			Air Pollution Control (Construction Dust) Regulation
S7.5	Storage of material on site shall be kept to a minimum. Construction materials shall be planed and stocked carefully to reduce amount of waste generated and avoid unnecessary generation of waste.	All areas / During construction	Contractor(s)		✓			-

EIA Ref.	Environmental Protection Measures	Location/Duration of Measures/Timing of Completion of Measures	Implementation Agent	Implementation Stage				Relevant Legislation & Guidelines
				Des	C	O	Dec	
S7.5	Use of reusable non-timber formwork to reduce the amount of C&D materials	All areas / During construction	Contractor(s)		✓			Works Branch Technical Circular (WBTC) No. 32/92, The Use of Tropical Hard Wood on Construction Site
S7.5	Wheel washing facilities shall be used by all trucks leaving the site to prevent the transfer of mud onto public roads.	Site entrances and exits / During construction	Contractor(s)		✓			Air Pollution Control (Construction Dust) Regulation
S7.5	Suitable chemical waste storage areas shall be formed at the works site for temporary storage pending collection. Chemical wastes shall be separated for special handling and shall be disposed at appropriate treatment at the Chemical Waste Treatment Centre at Tsing Yi.	Land site / During construction	Contractor(s)		✓			Waste Disposal (Chemical Waste) (General) Regulation Code of Practice on the Packaging, Labelling and Storage of Chemical Wastes
S7.5	Any unused chemicals and those with remaining functional capacity shall be recycled to the extent practical.	Land site / During construction	Contractor(s)		✓			-
S7.5	A licensed contractor shall be employed to collect chemical waste for delivery to a licensed treatment facility.	Chemical Waste Treatment Centre at Tsing Yi/ During construction	Contractor(s)		✓			Waste Disposal (Chemical Waste) (General) Regulation Code of Practice on the Packaging, Labelling and Storage of Chemical Wastes

EIA Ref.	Environmental Protection Measures	Location/Duration of Measures/Timing of Completion of Measures	Implementation Agent	Implementation Stage				Relevant Legislation & Guidelines
				Des	C	O	Dec	
S7.5	Temporary storage areas for general refuse shall be enclosed or contained to avoid environmental impacts.	All areas / During construction	Contractor(s)		✓			WBTC Nos. 6/2002 and 6/2002A, Enhanced Specification for Site Cleanliness and Tidiness.
S7.5	Sufficient dustbins shall be provided for storage of waste.	All areas / During construction	Contractor(s)		✓			WBTC Nos. 6/2002 and 6/2002A, Enhanced Specification for Site Cleanliness and Tidiness. Works Bureau, Hong Kong SAR Government
S7.5	General refuse shall be timely cleared and shall be disposed of to the nearest licensed facility.	All areas / During construction	Contractor(s)		✓			WBTC Nos. 6/2002 and 6/2002A, Enhanced Specification for Site Cleanliness and Tidiness.
S7.5	Waste oils, chemicals or solvents shall not be disposed of to drain. Drainage systems, sumps and oil interceptors shall be cleaned and maintained regularly.	All facilities / During construction	Contractor(s)		✓			-
S7.5	Standard site practice shall be implemented to avoid waste generation and promote waste minimisation.	All facilities / During construction	Contractor(s)		✓			-

EIA Ref.	Environmental Protection Measures	Location/Duration of Measures/Timing of Completion of Measures	Implementation Agent	Implementation Stage				Relevant Legislation & Guidelines
				Des	C	O	Dec	
S7.5	Waste materials such as paper, metal, timber and waste oil shall be recycled as far as practicable. Different types of waste shall be segregated and stored of in different containers, skips or stockpiles to enhance reuse or recycling of material and their proper disposal. Recycling bins will be provided at strategic locations to facilitate recovery of aluminium can and waste paper from the site.	Land Site / During construction	Contractor(s)		✓			ETWBTC No. 33/2002, Management of Construction and Demolition Material Including Rock
S7.5	Dredged marine mud shall be disposed of in a gazetted marine disposal ground under the requirements of the *Dumping at Seas Ordinance*. Marine mud shall be assessed in accordance with the PNAP 252 prior to the dredging to identify the suitable disposal ground.	Dredging / During construction	Contractor(s)		✓			Dumping at Sea Ordinance
S7.5	Waste containers shall be in good condition and fitted with lids or covers to prevent waste from escaping or the ingress of water.	All facilities / During construction	Contractor(s)		✓			WBTC Nos. 6/2002 and 6/2002A, Enhanced Specification for Site Cleanliness and Tidiness.
S7.5	Waste containers shall be in a secure area on hardstanding.	All facilities / During construction	Contractor(s)		✓			WBTC Nos. 6/2002 and 6/2002A, Enhanced Specification for Site Cleanliness and Tidiness.
S7.5	Proper storage and site practices shall be adopted to reduce the potential for damage or contamination of construction materials.	All facilities / During construction	Contractor(s)		✓			-

EIA Ref.	Environmental Protection Measures	Location/Duration of Measures/Timing of Completion of Measures	Implementation Agent	Implementation Stage				Relevant Legislation & Guidelines
				Des	C	O	Dec	
S7.5	Emergency equipment to deal with any spillage or fire shall be kept on site.	All facilities / During construction	Contractor(s)		✓			Waste Disposal (Chemical Waste) (General) Regulation Code of Practice on the Packaging, Labelling and Storage of Chemical Wastes
S7.5	Containers used for storage of chemical waste shall be: • Maintained in good condition and clearly labelled in both English and Chinese; • Suitable for the substance they are holding, resistant to corrosion, and securely closed; and • Capacity of less than 450 L unless the specifications have been approved by the EPD.	All facilities / During construction	Contractor(s)		✓			Waste Disposal (Chemical Waste) (General) Regulation Code of Practice on the Packaging, Labelling and Storage of Chemical Wastes
S7.5	Storage areas for chemical waste shall: • Be clearly labelled and used solely for the storage of chemical waste; • Be enclosed on at least 3 sides; • Have adequate ventilation; • Be arranged so that incompatible materials are appropriately separated • Have an impermeable floor and bunding, of capacity to accommodate 110% of the volume of the largest container or 20% by volume of the chemical waste stored in that area, whichever is the greatest; and • Be covered to prevent rainfall from entering	All facilities / During construction	Contractor(s)		✓			Waste Disposal (Chemical Waste) (General) Regulation Code of Practice on the Packaging, Labelling and Storage of Chemical Wastes

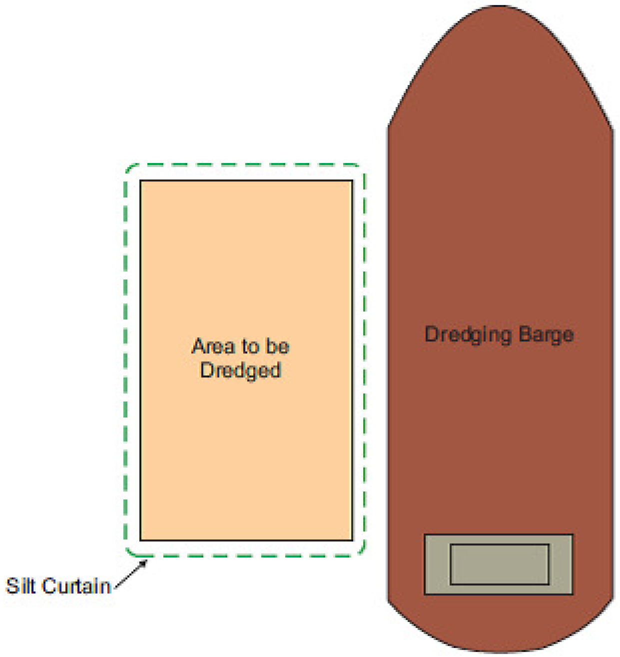
EIA Ref.	Environmental Protection Measures	Location/Duration of Measures/Timing of Completion of Measures	Implementation Agent	Implementation Stage				Relevant Legislation & Guidelines
				Des	C	O	Dec	
S7.5	Leaking containers shall be contained and removed from site as soon as is reasonably practicable.	All facilities / During construction	Contractor(s)		✓			Waste Disposal (Chemical Waste) (General) Regulation Code of Practice on the Packaging, Labelling and Storage of Chemical Wastes
S7.5	Training shall be provided to site personnel in proper waste management and chemical handling procedures, the concepts of site cleanliness and appropriate waste management procedures, including waste reduction, reuse and recycling.	All facilities / During construction	Contractor(s)		✓			-
S7.5	EM&A of waste handling, storage, transportation, disposal procedures and documentation through the site inspection and audit programme shall be undertaken.	All facilities / During construction	ET and IEC		✓			-
S7.5	Nomination of approved personnel to be responsible for standard site practices, arrangements for collection and effective disposal to an appropriate facility of the wastes generated at the site.	All facilities / During construction	Contractor(s)		✓			-
S7.5	Appropriate measures to reduce windblown litter and dust transportation of waste by either covering trucks or by transporting wastes in enclosed containers.	All facilities / During construction	Contractor(s)		✓			-
S7.5	Regular cleaning and maintenance programme for drainage systems, sumps and oil interceptors. A recording system for the amount of wastes generated/recycled and disposal sites.	All facilities / During construction	Contractor(s)	✓				-
5. Marine Ecology (Marine Mammals)								
S8.8	The vessel operators will be required to control and manage all effluent from vessels	Marine works area / During construction	Contractor(s) and ET		✓			-

EIA Ref.	Environmental Protection Measures	Location/Duration of Measures/Timing of Completion of Measures	Implementation Agent	Implementation Stage				Relevant Legislation & Guidelines
				Des	C	O	Dec	
S8.8	A policy of no dumping of rubbish, food, oil, or chemicals will be strictly enforced. This will also be covered in the contractor briefings	Marine works area / During construction	Contractor(s) and ET		✓			-
S8.8	All vessel operators working on the Project construction phase will be given a briefing, alerting them to the possible presence of dolphins in the area, and the guidelines for safe vessel operation in the presence of cetaceans. If high speed vessels are used by the contractors, they will be required to slow to 10 knots when passing through a high density dolphin area (Sha Chau and Lung Kwu Chau)	Marine works area / During construction	Contractor(s) and ET		✓			-
S8.8	The vessel operators engaged during the construction phase will be required to use predefined and regular routes, as these will become known to dolphins using these waters	Marine works area / During construction	Contractor(s) and ET		✓			-
S8.8	A marine mammal exclusion zone within a radius of 250 m from dredgers/ jetting machine will be implemented during the construction phase. Qualified observer(s) will scan the 250 m-exclusion zone for at least 30 minutes prior to the start of dredging. If cetaceans are observed in the exclusion zone, dredging/ jetting will be delayed until they have left the area. As per previous practice in Hong Kong, should cetaceans move into the works area during dredging/ jetting, it is considered that cetaceans will have acclimatised themselves to the works therefore cessation of dredging is not required	Works areas along the pipeline route / During Dredging/ Jetting for the Gas Pipeline Installation	Contractor(s) and ET		✓			-
S8.8	Except for the pipeline section along Urmston Road, dredging/ jetting works shall be restricted to a daily maximum of 12 hours with daylight operations. Because of marine traffic constraints, dredgers/ jetting machine may need to operate 24 hours on the pipeline section which crosses the Urmston Road channel off Black Point enabling completion in the shortest possible time	Works areas along the pipeline route / During Dredging/ Jetting for the Gas Pipeline Installation	Contractor(s) and ET		✓			-

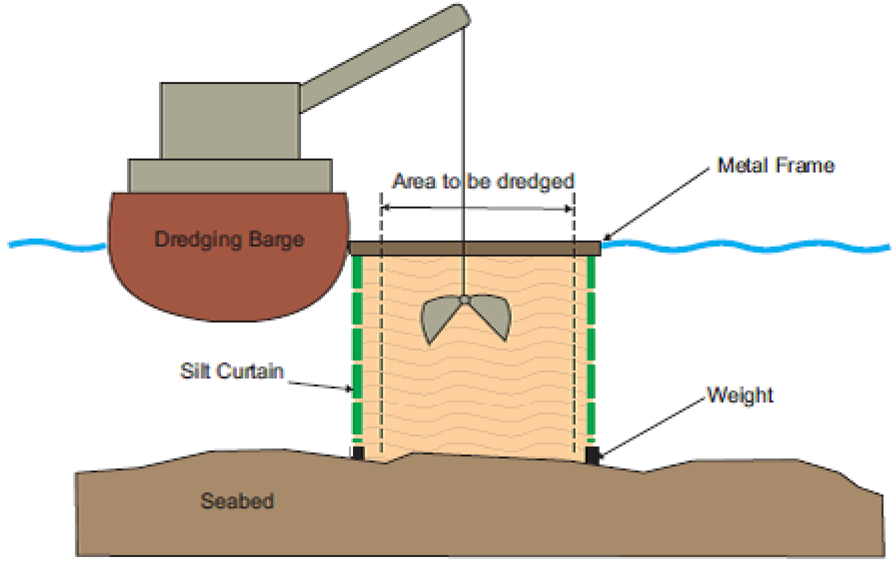
EIA Ref.	Environmental Protection Measures	Location/Duration of Measures/Timing of Completion of Measures	Implementation Agent	Implementation Stage				Relevant Legislation & Guidelines
				Des	C	O	Dec	
S8.8	Monitoring will be conducted for the distribution and abundance of dolphins during the construction and post-construction phase of the project. A suitable pre-construction period of dolphin monitoring will also be conducted. The protocols for this will be agreed with AFCD in advance.	Marine works areas / Pre-construction, during construction and post-construction	CAPCO		✓			-
6. Fisheries								
S9.10	Geophysical survey will be conducted during the post-construction of pipeline works to confirm the seabed would be reinstated to its original level.	Post-construction after pipeline works	ET		✓	✓		-
7. Landscape & Visual								
S10.5.11	Site hoardings to be compatible with surrounding landscape.	Land site / During Construction	Contractor(s)		✓			-
S10.5.11	Edges of the new reclamation to be constructed to match the existing Rocky Seawall.	Land site / During Construction	Contractor(s)	✓	✓			-
S10.5.11	The tree requiring removal is to be compensated in accordance with relevant government guidelines	Land site / During Construction	Contractor(s)		✓			-
S10.6.13	The colours of the proposed GRS should be selected to complement the existing industrial surroundings.	Land site / Pre-Construction (Detail Design)	Contractor(s)	✓				-
8. Cultural Heritage No mitigation measures were specified in the EIA report as no sites of terrestrial or marine archaeological potential are located in the Project Area.								
9. Hazard to Life No unacceptable risks are foreseen as a result of the operation of the GRSs and submarine gas pipelines and no mitigation measures are thus deemed necessary.								

Annex 14A-2 *Summary of Mitigation Measures during the Dredging/ Jetting Activities for this Project*

Marine Work Location (Zone)	Marine Work & Plant Type	No. of Plant	Proposed Mitigation Measures
Gas Receiving Station at Black Point	Dredging by Closed Grab Dredger	2	Not required due to no predicted WQO exceedances.
Gas Receiving Station at Black Point	Sandfilling of reclamation area by Pelican Barge	1	A constructed seawall (above the high water level with a 50 - 100 m opening for barge access) in place prior to sandfilling of the reclamation area.
Gas Pipeline – Shore Approach (KP 4.89 – KP 4.78)	Dredging by Closed Grab Dredger	1	Not required due to no predicted WQO exceedances. However, silt curtain(s) will be installed during grab dredging operations along this pipeline section.
Gas Pipeline – Black Point to Urmston Road (KP 4.78 – KP 2.52)	Trenching by Jetting Machine	1	Not required due to no predicted WQO exceedances. However, silt curtain(s) will be installed along the marine works areas during jetting operations for the installation of this pipeline section. The extent of silt curtain(s) installation will be determined based on site condition (e.g. bathymetry of the works area) and navigation safety considerations. Details of the design and implementation of the silt curtain(s) will be developed before construction and verified by the Independent Environmental Checker (IEC) and agreed with EPD. Should non-compliance occur at the respective impact station during water quality monitoring, the use of additional mitigation measures will be examined by the ET, discussed with the Contractor, EPD and CAPCO.
Gas Pipeline – across Urmston Road (KP 2.52 – KP 0.73)	Dredging by Closed Grab Dredger	1	Not required due to no predicted WQO exceedances. Should non-compliance occur at the respective impact station during water quality monitoring, the use of additional mitigation measures, such as cage-type silt curtain (*Figure 14A.1*), will be examined by the ET, discussed with the Contractor, EPD and CAPCO.
Gas Pipeline – from Urmston Road to HKSAR boundary (KP 0.73 – KP 0)	Trenching by Jetting Machine	1	Not required due to no predicted WQO exceedances. Should non-compliance occur at the respective impact station during water quality monitoring, the use of additional mitigation measures will be examined by the ET, discussed with the Contractor, EPD and CAPCO.



(a) Cage Type Silt Curtain Arrangement for Grab Dredging



(b) Cross-secton of Cage Type Silt Curtain Arrangment

Figure 14A.1

Indicative Arrangement of Cage Type Silt Curtain

File:
Date 17/10/2009

Environmental
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Management

ERM

Section 15

Conclusions

CONTENTS

15 CONCLUSIONS

15.1 INTRODUCTION

This *Section* presents a summary of the key conclusions of this EIA associated with the construction and operation of two submarine gas pipelines and two Gas Receiving Stations (GRSs) at the Black Point Power Station (BPPS). The purpose of the assessment was to thoroughly evaluate the proposed Project in terms of predicted impacts to key environmental sensitive receivers and to determine whether this option can meet the requirements of the *EIAO-TM*.

15.2 CONSIDERATION OF ALTERNATIVES

This EIA Study has examined a series of Alternatives as follows:

- Consideration of Alternative GRS Locations (*Section 2.1*); and
- Consideration of Alternative Construction Methods & Sequences (*Sections 2.2* to *2.4*).

15.2.1 *Consideration of Alternative GRS Locations*

An alternative site location study was conducted to determine the most suitable location(s) in proximity to the BPPS for the GRSs. The study was conducted to investigate not only the environmental considerations of each location, but to include an in depth examination of the engineering and technical aspects of the GRSs at each location. The preferred location that was taken forward to the EIA stage was based on locating one GRS on existing land within the site boundary of the BPPS, and locating the other GRS on newly reclaimed land adjacent to the existing GRS at BPPS at the same location proposed as part of the HKLNG EIA [(1)]. This location provided a series of environmental benefits when compared to the other locations examined, including:

- A reduction in the seabed areal extent of the reclamation, as one of the new GRSs will be located on existing land within BPPS;
- Avoidance of potential impacts on terrestrial ecology as vegetation clearance and slope cutting is avoided; and
- A reduction in dredging volumes through siting one GRS on existing land and through selection of reclamation design and construction

(1) ERM (2006) *Liquefied Natural Gas (LNG) Receiving Terminal and Associated Facilities: EIA Study* (EIA Study Brief ESB-126/2005). Prepared for CAPCO

methodology, hence reducing off-site impacts during disposal of dredged muds.

15.2.2 *Consideration of Alternative Construction Methods & Sequences*

- *Reclamation*: Two construction options have been considered, the Fully Dredged Option and the Partially Dredged Option. In line with local construction practice, the Partially Dredged Option will be adopted for the Project.

- *Submarine Gas Pipelines*: The submarine gas pipelines will require protection measures against anchor drop and drag and so trenching for pipelines will be necessary in some sections. An evaluation of three installation methods, including grab dredging, dredging by trailing suction hopper dredger and jetting, was undertaken to evaluate their engineering feasibility, schedule implications and overall environmental performance. It was concluded that although all three methods are viable and environmentally acceptable, grab dredging and jetting will be adopted for this Project. The use of jetting for certain sections of the pipelines alignment will reduce the volumes of dredged material substantially from 0.428 Mm^3 to 0.253 Mm^3 (bulk volume) per pipeline. The adoption of jetting will also shorten the period for marine construction works and hence reduce the severity of impacts to marine ecological resources

- *Phasing*: The Project will involve two phases of construction works:

  - First Phase: installation of the first pipeline (Pipeline 1) and construction of the co-located GRS; and

  - Second Phase: installation of the second pipeline (Pipeline 2) and construction of the reclamation and the associated GRS.

  The construction of the two phases is expected to be separate with the First Phase construction commencing in 2011 in order to receive the replacement gas in 2012. The Second Phase of construction is expected to commence within 24 months following commissioning of the First Phase. By phasing the works the arisings of dredged muds will be spread out over a longer time period.

15.3 AIR QUALITY

The potential impacts to air quality caused by construction and operational activities of this Project have been assessed in *Section 4* of this EIA Report. The impacts have been identified and analysed to be in compliance with the criteria and guidelines stated in the *EIAO TM Annexes 4* and *12* respectively.

One Air Sensitive Receiver (ASR, at the BPPS Administration Building) was identified and the potential impacts arising from the construction and operation phases of the Project to the ASR have been evaluated.

With the implementation of standard mitigation measures, no adverse impact associated with potential dust nuisance from dust generating activities is anticipated during the construction phase. Gaseous emissions from the construction plant are also minimal and no adverse impact to the ASR is anticipated.

During the operation phase, air emissions from the gas heaters at the Gas Receiving Stations at BPPS were identified as potential sources of air quality impacts. As a conservative assumption, it was assumed that the gas heaters were operating continuously. Even with this set of assumptions, the modelling indicated that the air quality impacts are low and well within the respective criteria at the identified ASR. No unacceptable air quality impact is thus anticipated during operation of the project.

15.4 NOISE

The potential impacts of noise caused by construction and operational activities of this Project have been assessed in *Section 5* of this EIA Report. The impacts have been identified and analysed to be in compliance with the criteria and guidelines stated in the *EIAO TM Annexes 5* and *13* respectively.

No existing NSR has been identified within the Study Area, and no planned NSR has been identified within 2 km from the Project Site. Potential noise impacts arising from the construction and operation phases have been evaluated and it was considered that potential noise impacts arising from the Project are expected to be insignificant and acceptable. In view of the insignificant construction and operation noise impacts, mitigation measures are therefore not required and noise monitoring is also not considered to be necessary.

15.5 WATER QUALITY

The potential impacts to water quality caused by construction and operational activities of this Project have been assessed in *Section 6* of this EIA Report. The impacts have been identified and analysed to be in compliance with the criteria and guidelines stated in the *EIAO TM Annexes 6* and *14* respectively.

Sensitive receivers potentially affected by construction and operational activities of the Project have been identified and the potential impacts have been evaluated. The key sensitive receivers include the Sha Chau and Lung Kwu Chau Marine Park, commercial fisheries spawning habitat, ecologically sensitive areas, beaches and water intakes. The assessment, utilising water quality and hydrodynamic models, has examined the potential impacts caused by marine works (i.e. dredging, jetting, reclamation and pipeline installation) on water quality due to the increases of suspended sediments concentrations, potential decreases of dissolved oxygen and increases in nutrients concentration, as well as those caused by operational activities such as the alteration of the hydrodynamic regime.

Potential impacts arising from the proposed marine construction works are predicted to be mainly confined to the specific works areas. Modelling results indicate that the suspended solids elevations as a result of the proposed marine works are expected to be compliant with the assessment criteria at the point specific sensitive receivers in both seasons. The predicted elevations of suspended sediment concentrations during the construction phase are transient in nature and not predicted to cause adverse impacts to water quality at the sensitive receivers.

Results of operation-phase computational modelling indicated that unacceptable impacts to hydrodynamic regime, water quality and sedimentation pattern as a result of the proposed reclamation are not expected to occur as the reclamation is very small.

Projects that are planned to be constructed at the same time of this Project have been evaluated for potential cumulative water quality impacts and the assessment indicates that cumulative impacts are not expected to occur due to the large separation distance of these concurrent projects with this Project.

Water quality monitoring is recommended for the construction phase and the specific monitoring requirements are detailed in the *Environmental Monitoring and Audit* (*EM&A*) *Manual* associated with this EIA Report. As no unacceptable impacts have been predicted to occur during the operation of the GRSs and submarine pipelines, no mitigation measures or monitoring are considered necessary.

15.6 WASTE MANAGEMENT

The potential impacts to waste management caused by construction and operational activities of this Project have been assessed in *Section 7* of this EIA Report. The impacts have been identified and analysed to be in compliance with the criteria and guidelines stated in the *EIAO TM Annexes 7* and *15* respectively.

The key potential impacts during the construction phase are related to wastes generated from dredging, reclamation, seawall construction, filling and concreting. The storage, handling, collection, transport, disposal and/or re-utilisation of these materials and their associated environmental impacts have been the primary focus of the assessment.

The Project is planned to take place in phases. For the First Phase of the Project, Sections 1 and 3 of the pipeline would be installed by dredging while Sections 2 and 4 of the pipeline would be installed by jetting. About 0.253 Mm^3 (bulk volume) sediment will be generated from Sections 1 and 3 of the pipeline. The final volumes will be subject to detailed sediment sampling, testing and analysis in accordance with the *PNAP 252* and disposal method reviewed prior to the commencement of the dredging activities. About 0.029 Mm^3 (bulk volume) of the dredged sediment is expected to be Category L sediment. MFC has no objection in-principle to allocating disposal space for the M_{fail} sediment dredged from Sections 1 and 3 of the pipeline route (about 0.060 Mm^3 bulk volume), subject to the availability of disposal space at the time of CAPCO's application and at the proposed programme for disposal. CAPCO is exploring alternative disposal sites (such as cross boundary disposal to Mainland China (2)) for the remaining 0.164 Mm^3 (bulk volume) of Category M_{pass} sediment. A dumping permit will be applied from the DEP prior to the commencement of the dredging work.

The Second Phase Project is expected to also generate approximately 0.253 Mm^3 (bulk volume) from the installation of the submarine pipeline. At present the dredging works for the reclamation for the second GRS are expected to give rise to a bulked volume of 0.156 Mm^3 of contaminated mud.

It is estimated that a total bulk volume of 0.828 Mm^3 of fill materials are required for this Project, and surplus public fill material is not anticipated. Other wastes produced during the construction phase are of small quantity and will be disposed of according to their nature, avoiding any potential adverse impact.

The operation of the GRSs will generate minimal quantity of waste, and the potential environmental impacts associated with the storage, handling, collection, transport and disposal of waste produced during operational activities have been estimated to be not significant and will therefore meet the criteria specified in the *EIAO TM*.

Potential impacts as a result of the waste produced during the construction phase have been reduced through the adoption of specific mitigation measures and in particular through the establishment and implementation of a Waste Management Plan (WMP).

In order to confirm that the construction Contractor(s) has implemented the recommendations of the EIA Report, regular site inspections and audits will be conducted of the waste streams, to determine if wastes are being managed in accordance with the approved procedures and the site WMP. An appropriate inspection programme should be undertaken with the first

(2) At the time of this EIA CAPCO is preparing a submission to the relevant authorities to determine the feasibility of this option.

inspection conducted at the commencement of the construction works. Routine site inspections should also include waste management issues.

15.7 *MARINE ECOLOGY*

The potential impacts to marine ecology caused by construction and operational activities of this Project have been assessed in *Section 8* of this EIA Report. The impacts have been identified and analysed to be in compliance with the criteria and guidelines stated in the *EIAO TM Annexes 8* and *16* respectively.

Ecologically sensitive receivers have been identified and the key sensitive receivers include the Sha Chau and Lung Kwu Chau Marine Park and ecologically sensitive areas.

A series of detailed field surveys were conducted during the dry and wet season of 2009 to examine the baseline conditions of the habitats and assemblages within and around the Project's footprint. A comprehensive data review of marine mammal baseline conditions was also undertaken using data collected from January 2005 to June 2009 in the Deep Bay and western Northwest Lantau areas to provide up-to-date data for the Indo-Pacific humpback dolphin *Sousa chinensis* in the vicinity of the Project Site. Findings of the field surveys and data review confirm that marine ecological resources in close proximity to the proposed Project are regarded to be of low to low-to-moderate ecological values.

Permanent habitat loss due to 0.5 ha of reclamation and short-term disturbance of habitats are considered as environmentally acceptable since the areas affected are relatively small in the context of the extent of similar habitat available in the vicinity and the generally low ecological value of the affected assemblages. Disturbed habitats are also expected to be recolonised by similar assemblages. Results of the water quality modelling activities indicate that the impacts arising from the marine works will be transient and confined to the works areas. It is therefore predicted that there will be no unacceptable impacts to the marine ecology (including marine mammals) of the Study Area as a result of construction activities. During the operation phase, since unacceptable impacts to water quality are unlikely to occur, indirect impacts to marine ecology are also not anticipated.

Projects that are planned to be constructed at the same time of this Project have been evaluated for potential cumulative impacts and the assessment indicates that cumulative impacts are not expected to occur due to the large separation distance of these concurrent projects with this Project.

Potential impacts to marine mammals, have been reduced through the adoption of specific mitigation measures including the use of predefined/ regular routes and speed limit for marine works vessels in this Project, and the adoption of marine mammal exclusion zones during marine dredging/ jetting works. Additional marine mammal monitoring programme are also recommended for the construction phase and details of the marine mammal monitoring programme are presented in full in the *EM&A Manual* associated with this EIA Report. Marine ecology specific operation phase monitoring is not considered necessary.

The mitigation measures designed to mitigate impacts to water quality to acceptable levels (compliance with assessment criteria) are also expected to mitigate impacts to marine ecological resources. Monitoring activities designed to detect and mitigate any unacceptable impacts to water quality during construction phase are also expected to serve to protect against unacceptable impacts to marine ecological resources. The water quality monitoring programme will provide management actions and supplemental mitigation measures to be employed should impacts arise, thereby ensuring the environmental acceptability of the Project.

15.8 FISHERIES

The potential impacts to commercial fisheries caused by construction and operational activities of this Project have been assessed in *Section 9* of this EIA Report. The impacts have been identified and analysed to be in compliance with the criteria and guidelines stated in the *EIAO TM Annexes 9* and *17* respectively.

Fisheries sensitive receivers have been identified and the key sensitive receivers include spawning ground of commercial fisheries resources in north Lantau, artificial reefs in the Sha Chau & Lung Kwu Chau Marine Park and oyster production area at Deep Bay. Findings of the desktop review of baseline conditions of commercial fisheries resources and fishing operations suggest that the Project Area is of low importance to the Hong Kong fishing industry.

Potential impacts to fisheries resources and fishing operations during the construction phase may arise from the permanent loss of habitat due to reclamation, short-term disturbances to fishing grounds, and increased underwater sound, as a result of the marine works. The water quality modelling activities completed in *Section 6* indicate that the impacts arising from the marine works are predicted to be largely confined to the specific works areas and the predicted elevations in suspended sediment concentrations are not predicted to cause large areal exceedances of the assessment criterion. Adverse impacts to water quality are thus not predicted and neither are consequential impacts to any fishing grounds or species of importance to the fisheries. During the operation phase, since unacceptable impacts to water quality are unlikely to occur, indirect impacts to fisheries are also not anticipated. Potential obstruction to fishing activities due to pipeline armour rock placement is not anticipated as it will be installed below or flush with the existing seabed. The seabed temporarily affected by the pipeline works is, therefore, expected to be restored to its original configuration.

No fisheries-specific mitigation measures are required during construction or operation activities as impacts to the fisheries resources and fishing operations are small and of short duration. The mitigation measures designed to mitigate impacts to water quality to acceptable levels (compliance with assessment criteria) are expected to mitigate impacts to fisheries resources. The water quality monitoring programme will provide management actions and supplemental mitigation measures to be employed should impacts arise, thereby ensuring the environmental acceptability of the Project. To confirm that the seabed affected by the pipeline works has restored to its original configuration, a geophysical survey will be conducted following completion of pipeline works.

15.9 LANDSCAPE & VISUAL

The potential impacts to the landscape and visual sensitive receivers caused by the presence of the GRSs at BPPS have been assessed in *Section 10* of this EIA Report. The impacts have been identified and analysed to be in compliance with the criteria and guidelines stated in the *EIAO TM Annexes 9* and *17* respectively.

The assessment has covered a wide range of potential landscape impacts including the alteration of the landscape caused by the reclamation, the introduction of the GRSs in BPPS's industrialised landscape and the impacts on existing and planned sensitive receivers during construction and operation of the GRSs. The overall residual impacts on the Landscape Resources are assessed as *negligible* to *slight*.

There will be very limited views of the GRSs from most land based viewing locations. The visual impacts will be larger for the ocean based VSR's from the Ferry Lane. Following consideration of the low user numbers in these areas and the analysis of the residual impacts, the overall visual impact is assessed as *slight.*

According to *EIAO TM* the Landscape and Visual Impacts are considered *acceptable with mitigation.* Measures have been proposed to mitigate the effects of the development.

15.10 CULTURAL HERITAGE

The potential impacts to cultural heritage caused by construction and operational activities of this Project have been assessed in *Section 11* of this EIA Report. The impacts have been identified and analysed to be in compliance with the criteria and guidelines stated in the *EIAO TM Annexes 10* and *19* respectively. The assessment has included a Marine Archaeological Investigation.

There are no declared/ deemed monument, graded/ recorded heritage resources, Built Heritage or Archaeological Sites located within the Project Area, and no sites of cultural heritage protected under the *AM Ordinance* have been identified. Therefore construction and operational impacts to sites of cultural heritage are not expected.

Findings of the Marine Archaeological Investigation concluded that no marine sites of cultural heritage/ archaeological value are present in waters surrounding Black Point and along the proposed pipeline corridor. As such, no impacts to marine archaeological resources are expected.

No impacts on potential cultural heritage and archaeological resources are expected to occur during the operation of the submarine pipelines and GRSs. As no impacts are expected, no mitigation measure is required.

15.11 *HAZARD TO LIFE*

The assessment has evaluated the hazards to life associated with the submarine gas pipelines and the GRSs. The assessment has concluded that the risks related to the operation of the submarine gas pipelines and the GRSs are acceptable as per the individual and societal risk criteria set out in *Annex 4* of the *EIAO TM*.

15.12 *ENVIRONMENTAL MONITORING & AUDIT*

The construction and operation of the proposed Project has been demonstrated in this EIA Report to comply with the *EIAO-TM* requirements. Actual impacts during the construction works will be monitored through a detailed Environmental Monitoring and Audit (EM&A) programme. Full details of the EM&A programme are presented in the *EM&A Manual* attached to this EIA Report. This programme will provide management actions and supplemental mitigation measures to be employed should impacts arise, thereby ensuring the environmental acceptability of the construction and operation of this Project.

15.13 *ENVIRONMENTAL OUTCOMES*

No unacceptable residual impacts have been predicted for the construction and operation of this Project. It must be noted that for each of the components assessed in the *EIA Report*, the assessments and the residual impacts have all been shown to be acceptable and in compliance with the relevant assessment standards/criteria of the *EIAO TM* and the associated *Annexes*.

15.14 ENVIRONMENTAL & OTHER BENEFITS OF THE PROJECT

There are a number of advantages to the commissioning of this gas supply project for BPPS, which are summarized below.

1. **Support of Government policy:** Natural gas is widely recognised as a comparatively clean burning fuel and its use is encouraged in the 2005 Policy Address and the current Air Quality Objective Consultation to control emissions from existing power stations in Hong Kong. As such, this Project is critical to meet the Government policy in a sustainable manner.

2. **Fuel security and reliable supply of electricity:** Dependable fuel sources are critical to maintain reliable power supply to our customers while providing environmental benefits. This Project allows CAPCO to secure sufficient and dependable replacement gas in a timely manner and to meet ongoing and future needs.

3. **Environmental benefits:** With sufficient replacement natural gas, CAPCO will be able to maintain compliance with air emission standards. As natural gas emits virtually no particulates and negligible SO_2, as well as less NO_x and CO_2 than other fossil fuels, it will contribute to further improvements in the regional and local air quality.