7. ECOLOGY

7.1 Environmental Legislation

7.1.1 International legislation relevant to this study includes:

- the UN Biodiversity Treaty which includes the Indo-Pacific humpback dolphin (Chinese white dolphin; *Sousa chinensis* Osbeck, 1765) as a protected species; and

- the Convention on the International Trade in Endangered Species of Flora and Fauna (CITES) which lists *Sousa chinensis* in Appendix One.

7.1.2 Relevant Hong Kong legislation includes:

- the Wild Animals Protection Ordinance (Cap. 170) 1980 which protects cetaceans;

- the Animals and Plants (Protection of Endangered Species) Ordinance (Cap. 187) 1988 which includes the protection of all stony corals, cetaceans and sea turtles;

- the Marine Parks Ordinance (Cap. 476) 1995 which applies to the marine park at Sha Chau and Lung Kwu Chau and limits certain activities in this area; and

- reference has also been made to Annexes 8 and 16 of the Technical Memorandum EIAO (Cap. 499) 1997 which sets out general criteria for evaluating the ecological importance of and hence the significance of potential ecological impacts and guidance for ecological assessment, respectively.

7.2 Key Sensitive Ecological Receivers

7.2.1 The proposed pipeline route passes through habitat utilised by Indo-Pacific Humpback dolphin. In addition, percussive piling for the jetty may have resulted in submarine noise that can be harmful to these marine mammals. Liu and Hills (1997) have stressed that in situations where an endangered species such as the Indo-Pacific Humpback dolphin is subjected to aggregated impacts, there is a strong case for a species-based ecological assessment which would seek an integrated and coordinated solution to predicting and mitigating potential impacts. For this reason, owing to the status and conservation importance of the dolphin, a species-based ecological assessment is required for the Indo-Pacific humpback dolphin. A location map showing the distribution of the key species of conservation concern and important ecological features in the study area is presented in Figure 6.2.

7.2.2 Construction of the pipeline and PAFF berthing jetty will not be approved unless it can be demonstrated that no unacceptable environmental impacts will result to the dolphins and other sensitive ecological receivers identified under this study. The ecological receivers potentially impacted by the PAFF (predominantly during the construction phase) comprise the following:

- benthic macro-invertebrate epifauna and infauna;
- corals;

- horseshoe crabs (*Tachypleus gigas*, *T. tridentatus* and *Carcinoscorpius rotundicauda*);
- Indo-Pacific Humpback dolphin (*Sousa chinensis*);
- artificial reefs (ARs) at Sha Chau; and
- Sha Chau and Lung Kwu Chau Marine Park.

7.3 Objectives of the Ecological Impact Assessment

7.3.1 The ecological assessment examines the faunal, floral and ecological attributes of the study area with an aim to protect, maintain or rehabilitate the existing condition and particular emphasis was placed on avoiding impacts to recognised sites of conservation importance such as the Sha Chau and Lung Kwu Chau Marine Park, the Artificial Reefs placed in the Marine Park and species of conservation interest such as the Indo-Pacific Humpback dolphin (*Sousa chinensis*), the three Horseshoe crab species present in Hong Kong waters (*Tachypleus gigas*, *T. tridentatus* and *Carcinoscorpius rotundicauda*), benthic communities and corals. In order to achieve the aforementioned measures relating to aquatic ecological impacts the following key issues were addressed:

- reference was made to Annexes 8 and 16 of the Technical Memorandum EIAO (Cap. 499) 1997 which sets out general criteria for evaluating the ecological importance of and hence the significance of potential impacts and guidance for ecological assessment, respectively;

- the assessment area included the Sha Chau and Lung Kwu Chau Marine Park and all areas within at least 500m from the project area including the pipeline alignment, areas with frequent vessel movement during the operational phase and any other areas further afield (i.e., at distances greater than the 500m required by the TMEIAO) potentially impacted by the project; and

- sites of conservation importance and other ecological sensitive areas including the Sha Chau and Lung Kwu Chau Marine Park and habitat of the Indo-Pacific Humpback dolphin (*Sousa chinensis*). The assessment identified and quantified as far as possible the potential ecological impacts during the construction and operation of the PAFF and evaluated the ecological acceptability of the proposed project.

7.3.2 The assessment also had the following major objectives:

- review and collate the findings of other studies in the study area and other available information regarding the ecological characteristics;

- evaluation of the information collected and identification of any information gaps relating to the assessment of potential ecological impacts to the marine environment;

- establish the general ecological profile and describe the characteristics of each habitat found and major information shall include:
  - description of the physical environment;

  - ecological characteristics of each habitat type such as size, type, species present, dominant species found, species diversity and abundance, community structure, seasonality and inter-dependence of the habitats and species, and presence of any features of ecological importance;
  - representative colour photographs of each habitat type and any important ecological features identified;
  - investigate and describe the existing wildlife uses of various habitats with special attention to those habitats with conservation interest; and
  - species found that are rare, endangered and/ or listed under local legislation, international conventions for conservation of wildlife or habitats or red data books.

- describe all recognised sites of conservation importance in the assessment area and describe how these sites will be affected by the proposed development;

- using suitable methodology, identify and quantify as far as possible, any direct, indirect, on-site, off-site, primary, secondary and cumulative ecological impacts such as destruction of habitats, reduction of species abundance or diversity, loss of feeding and breeding grounds, reduction of ecological carrying capacity and habitat fragmentation; with particular emphasis on the following:

  - impact of habitat disturbance associated with dredging and backfilling of the pipeline route;
  - impact of habitat loss and disturbance to wildlife arising from any works carried out in the Sha Chau and Lung Kwu Chau Marine Park;
  - impact on hard and soft bottom assemblages as well as other marine organisms; and
  - impacts upon resources of conservation importance during operations including spillage, maintenance as well as hazard risks (risk assessment of a fuel spill is presented in Section 11).

- assess the impact on the Indo-Pacific Humpback dolphin (*Sousa chinensis*) with particular emphasis on the following:

  - review and incorporate the findings of relevant studies including the previous dolphin studies and collate the available information regarding the ecological characters of the assessment area;
  - evaluate the information collected and identify any information gaps relating to the assessment of potential impacts on the dolphins;
  - assess the impacts on the dolphin due to disturbance, loss of habitat and food supply;
  - assess the cumulative impacts on the dolphins due to this project and any nearby dredging or reclamation works together with other existing or planned projects during construction;
  - assess the disturbance of the dolphins habitat and the risk of the individuals being hit by vessel traffic in the vicinity of the facility during operation;
  - identify precautionary and mitigation measures for protection of the dolphins. The proposed measures shall include those recommended in

previous EIA and dolphin studies, such as ecological monitoring of the dolphins during the construction phase.

- evaluate the significance and acceptability of the ecological impacts identified using well defined criteria;

- recommend all possible alternatives and practicable mitigation measures to avoid, minimise and/ or compensate for the adverse ecological impacts identified with particular emphasis on the following:

    - construction of the project at times that minimise impacts on the Indo-Pacific Humpback dolphin shall be considered, with the relative impacts of alternative schedules included; and
    - reinstatement of any habitats in the Sha Cha and Lung Kwu Chau Marine Park temporarily affected by the proposed development and enhancement of existing lower quality habitats otherwise unaffected by the project.

- evaluate the feasibility and effectiveness of the recommended mitigation measures and define the scope, type, location, implementation arrangement, subsequent management and maintenance of such measures;

- determine and quantify the residual ecological impacts after implementation of the proposed mitigation measures;

- evaluate the severity and acceptability of the residual ecological impacts using well-defined criteria; and

- review the need for and recommend any ecological monitoring programme, in particular on the Indo-Pacific Humpback dolphin during the construction and operational phase.

7.4 Description of Existing Conditions

7.4.1 Literature Review

7.4.1.1 A review of relevant scientific literature, reports and EIA's has been conducted in order to assist the assessment of baseline ecological conditions. The study area comprising the Northwestern waters is arguably one of the most extensively surveyed marine locations in Hong Kong and reports from the ongoing environmental monitoring and audit conducted at the contaminated mud pits (CMP's) at East of Sha Chau (Mouchel, 1996; 2001a; Meinhardt, 2006a) provided a large amount of the marine ecological information. As monitoring at the CMP's is on-going, the data also represents relevant and recent ecological information for the study area.

7.4.1.2 For the purposes of the ecological baseline assessment, owing to the higher mobility of certain faunal groups (such as dolphins and horseshoe crabs), the relative homogenous nature of the sediments (and hence benthos) and hard rock substrata present, the study area described in the following sections encompasses records of marine species that have been observed throughout the Northwestern waters roughly covering an area from

Sham Tseng in the east to Lung Kwu Chau in the west. These extensive data facilitate an improved description of the existing ecological conditions in the waters of the wider study area than is possible by focussing to only within 500m of the PAFF study area as stipulated in the TMEIAO. Such reasoning would appear to be appropriate for the evaluation of the marine environment as marine species are often relatively mobile (for example, their larval stages are dispersed over wide spatial areas) and are potentially capable of colonising suitable substrata over wide areas. It should be noted, however, that the available data for the Indo-Pacific Humpback dolphin is highly location-specific (owing to intensive survey effort) and it is possible to describe the species' distribution in the Northwestern waters to a greater level of accuracy.

7.4.1.3 Relevant scientific reports and papers have also been reviewed and a full list of studies cited is provided in the References section of this chapter. The major scientific studies and reports include the following:

- New Airport Master Plan (Greiner-Maunsell, 1991);
- Proposed Aviation Fuel Receiving Facility at Sha Chau: Environmental Impact Assessment (ERM, 1995);
- Feasibility Study & Environmental Impact Assessment for Aviation Fuel Pipeline (Montgomery Watson, 1996);
- EIA Study for Disposal of Contaminated Mud in the East Sha Chau Marine Borrow Pit (ERM, 1997);
- Feasibility Study for Additional Cross-border Links Stage 2 (Mouchel, 1998);
- EIA for the Proposed Sand Extraction from The Brothers' Marine Borrow Area (Hyder Consulting, 1998);
- Population Biology of the Indo-Pacific Hump-backed Dolphin (*Sousa chinensis* Osbeck 1765) in Hong Kong Waters. AFCD-funded study conducted by Ocean Park Conservation Foundation (Jefferson, 1998; 2000a , 2005; Hung, 2005).
- Environmental Monitoring and Audit for Contaminated Mud Pit IV at East of Sha Chau (ERM, 1999; Mouchel, 2001a; Meinhardt, 2006a); and
- EA Study for Backfilling of Marine Borrow Pits at North of the Brothers (Mouchel, 2002a).

7.4.1.4 The study area is located in the Northwestern waters of Hong Kong. The Tuen Mun Area 38 pipeline travels in a westerly direction to tie in to the existing pipeline in Sha Chau. The pipeline route and broad ecological study area is presented in Figure 3.1. Photographs of key species and habitats which are present in the study area and discussed in detail below are shown in Figures 7.6a-d.

7.4.1.5 The study area is located within the Pearl River Estuary and is strongly influenced by freshwater discharges especially during the wet season when the summer monsoon brings high levels of precipitation (peak wet season discharge of 1,800 M m^3 day^{-1}; Broom and Ng, 1996). The western waters are, therefore, predominantly low in salinity and high in turbidity and show a marked seasonality.

7.4.2 Present Eco-Physical Characteristics of the Study Area

7.4.2.1 There have been numerous assessments of the physical, chemical and biological environment conducted in the study area (Greiner-Maunsell, 1991; Binnie Consultants, 1995; Mouchel, 1996; ERM, 1997, 2005; Hyder Consultants, 1998; Meinhardt, 2006a). There have also been several past and ongoing studies conducted and notable are those involving investigations of Marine Borrow Areas and the ongoing monitoring at the Contaminated Mud Pits at East of Sha Chau conducted for the Civil Engineering and Development Department (CEDD). Several of these studies provide pertinent marine ecological baseline information for the current study and field visits have also been conducted to confirm that no natural intertidal habitat will be affected by the project. Then field survey data that form the basis of the assessment are presented in subsequent sections below and cover a duration of greater than the six months (wet season) required by the Study Brief. The PAFF tank farm is located on reclaimed land at Tuen Mun Area 38 and there is no natural coastal habitat that will be affected by the construction or operation of the project. The berthing jetty used by the tankers for fuel delivery is located 200m off-shore from Tuen Mun Area 38. The vertical seawall interfacing with the sea is shown in Plate 7.1.

7.4.2.2 The major conclusion from the previous work conducted in the study area is that the marine benthic environment in the western waters of Hong Kong are generally characterised by soft-bottom material composed of silts and clay as a homogenous layer or in loosely packed mud clasts bound in a puzzle fabric (Binnie Consultants, 1995; ERM, 1999; Mouchel, 2001a) although coarser material under the influence of strong tidal currents has been reported from the area to the Northeast of The Brothers (Greiner-Maunsell, 1991). There are also some hard substrates present although the soft-bottom sediments are characteristic of the study area. The upper sediment layers are reported to be well oxygenated (EVS, 1996) and typical images of the composition of the benthic sediments (and ecological characteristics present in both soft-bottom and hard substrate) are presented in Figure 7.1. The heterogeneity of sediments present in the study area provides a wide variety of niches although owing to the prevailing estuarine conditions that lead to fluctuations in physico-chemical parameters, it is nevertheless a ‘naturally stressed’ environment and this is reflected in the relatively low to moderate diversity of burrowing in-fauna present compared to other locations in Hong Kong (Shannon-Weiner index *H’* typically < 2; Mouchel, 2001a; Meinhardt, 2006c).

7.4.2.3 Comprehensive ecological surveys were conducted at the North of The Brothers MBA and around Chek Lap Kok in 1990 as part of the new airport core construction EIA (Greiner-Maunsell, 1991). These data together with the past ten years of extensive monitoring data obtained during the contaminated mud pit (CMP) monitoring at East of Sha Chau collected from various stations in Northwestern waters (ERM, 2001; Mouchel, 2001a; Meinhardt, 2006c) are the most relevant to the current study. The findings from the two aforementioned studies have, therefore, formed the basis for much of the following discussion.

7.4.3 Present Pollution Status

7.4.3.1 The sediments in the Northwestern waters have recently been assessed using a suite of measurements to calculate a Pollution Index. The index is derived through chemical contaminant analysis, assessment of the benthic macro-infauna present and toxicity testing with a marine amphipod. Results indicated that the sediment Pollution Index for Northwestern waters was average and similar to the majority of other locations in Hong Kong with the exception of Victoria and Tolo Harbours which were ranked as poor and Port Shelter that was ranked as good (Shin and Lam, 2001).

7.4.3.2 Recently, further assessment of the pollution status of the marine sediments in the study area has been evaluated at stations located to the south of Sha Chau (between the airport and Sha Chau) using key biological indicator organisms (to facilitate the calculation of biotic indices) present in the benthic communities. Biotic indices are considered to be sensitive, easily-understood measures of pollution and provide a synoptic evaluation of both the prevailing sediment quality and overlying water chemistry thus adding further information on the benthic communities present in the study area. Biotic indices calculated for benthic macroinvertebrates collected at locations to the south of Sha Chau in May 2001 were indicative of slight pollution and an unbalanced benthic community (Mouchel, 2001a; Meinhardt, 2006c). A low biotic index is, however, often typical of estuaries owing to their highly dynamic physical and chemical nature and the benthic community diversity is also typically lower at these locations (Mouchel, 2001a; Meinhardt, 2006c).

7.4.4 Benthic Macro-Infauna

7.4.4.1 The macro-infauna consist of the organisms larger than 1mm living within the sediment (predominantly in the upper well-oxygenated layers). The foregoing discussion on the benthic macro-infauna present throughout the study area comprises data reviewed from several benthic community studies (review mostly based on Greiner-Maunsell, 1991; Binnie Consultants, 1995; ERM, 2001; Mouchel, 2001a, 2002b; CCPC, 2002; Meinhardt, 2006c) and species present are relatively similar throughout the North-western waters (and other areas in Hong Kong) and are representative of the general study area. As indicated below in Section 7.4.4.2, the major difference in the faunal groups/species recorded both in different studies and between locations in Northwestern waters is the occasional absence of echinoderms although this is more likely to be a reflection of freshwater inputs from the Pearl River (the larvae of these organisms are stenohaline) driving the distribution pattern. The benthic community results presented are, therefore, considered to be representative of the study area.

7.4.4.2 The monitoring results in the study area have tended to indicate that the benthic community recorded over approximately the past ten years has remained of similar composition and as with most benthic communities polychaetes are numerically abundant comprising between 44-71% of individuals present and molluscs, crustaceans and echinoderms are well represented components of the soft-bottom community (Binnie Consultants, 1995). Echinoderms are, however, not always recorded in the study area (Greiner-Maunsell, 1991) as the larvae of these organisms are often stenohaline (Nicholson, 2001) and unlikely to tolerate the wide salinity fluctuations associated with freshwater exposures from the Pearl River in the wet season.

7.4.4.3 Results of benthic sampling (collected with a Van Veen grab) conducted in the study area in the late wet season in August 2000 resulted in the collection of 72 sediment samples containing 6,512 macro-infaunal specimens belonging to 84 families comprising 9 different phyla (ERM, 2001). In terms of dominant families present in the soft sediments, the annelids, arthropods and molluscs were dominant and the latter group also constituted most of the biomass present (see Table 7.1a). Recent results of sampling conducted in May 2001 resulted in the collection of 72 sediment samples containing 9,283 macro-infaunal specimens belonging to 67 families comprising 9 different phyla (Mouchel, 2001a; see Table 7.1b). The total recorded biomass in May 2001 was 188.85 g and was largely due to the high mass of annelids and molluscs collected (see Table 7.1b). The benthic survey data collected in the late wet season in August 2001 ((Mouchel 2002b)) showed that in terms of families present, the annelids, arthropods and molluscs were again the most dominant. These families also comprised the majority of individuals present. Compared to the monitoring conducted in August 2000, there were fewer families recorded in both May and August 2001 although the annelids, arthropods and molluscs were consistently the most dominant families recorded. Comparing data within the early and late wet season of the same year, there were both more families and individuals recorded during the late wet season in August compared with May 2001. There was also higher biomass recorded in August compared to the previous monitoring in May 2001. In May 2001 a total biomass (wet weight) of 188.85g was recorded whereas 662.07g was recorded in August 2001. The precise reasons for the recorded differences between the data collected in May and August 2001 are difficult to ascertain although they may represent differences in recruitment variation between the late dry/early wet (May) and late wet (August) season months (Table 7.1b).

Table 7.1a Summary of the Macro-infauna Collected in August 2000

Phylum	Number of Identified Families	Total Number of Individuals	Total Biomass (g)
Annelida	34	4,914	27.88
Arthropoda	20	1,131	39.25
Chordata	3	5	3.24
Coelenterata	7	35	3.05
Echinodermata	4	80	53.75
Echiura	1	1	0.45
Mollusca	14	301	847.72
Nemertinea	0	19	1.51
Sipuncula	1	26	0.11
Total	**84**	**6,512**	**976.97**

Source: ERM (2001)

Table 7.1b Summary of the Macro-infauna Collected in May 2001

Phylum	Number of Identified Families	Total Number of Individuals	Total Biomass (g)
Annelida	30	2,204	45.609
Arthropoda	13	405	26.526
Chordata	2	2	2.352
Coelenterata	4	13	1.329
Echinodermata	2	15	0.723
Echinodetmata	0	1	0.194
Mollusca	11	6,600	95.562
Nemertea	1	1	0.261
Sipuncula	4	42	16.301
Total	**67**	**9,283**	**188.85**

Source: Mouchel (2001a)

Table 7.1c Summary of the Macro-infauna Collected in August 2001

Phylum	Number of Identified Families	Total Number of Individuals	Total Biomass (g)
Annelida	35	2,928	17.935
Arthropoda	17	902	42.259
Chordata	2	6	35.121
Coelenterata	4	10	6.330
Echinodermata	2	12	39.746
Mollusca	10	9,460[1]	515.473[1]
Sipuncula	2	18	5.208
Total	**72**	**13,336**	**662.07**

Note: [1]= including *Potamocorbula* sp. comprising 9390 individuals and biomass of 509.906 g. Source: Mouchel (2002b)

7.4.4.4 The 2000/2001 data available for the study area comprising data collected over 12 months (wet season data only) showed that in terms of families present, the annelids, arthropods and molluscs were dominant. The annelids, molluscs and arthropods usually comprised the majority of individuals present. Although the number of families and biomass were lower than previously recorded in August 2000 there were a higher number of total individuals recorded in both May and August 2001 (Mouchel, 2001a, 2002b). During the sampling conducted in August 2000, 84 families and a total of 6,512 individuals were recorded for a total biomass of 976.9 g (ERM, 2001). The recorded differences between the data collected in August 2000 and the recent data collected in May and August 2001 may, however, represent seasonal variation between the late dry/ early wet and late wet season months inducing subtle changes to the benthic macro-infauna assemblages present.

7.4.4.5 However, the most recent data available are the surveys conducted in January and October 2005 (Mouchel, 2005a; Meinhardt, 2006b) covering both the dry and late wet seasons and the results are summarised in Table 7.1d below. The results were consistent with earlier surveys conducted under the EM&A programme. The annelids, molluscs and arthropods comprised the majority of individuals present and subtle seasonal variations, slightly higher abundance during the wet season, were frequently recorded.

Table 7.1d Summary of the Macro-infauna Collected in 2005

Phylum	Number of Identified Families		Total Number of Individuals		Total Biomass (g)	
	January	October	January	October	January	October
Annelida	40	39	4,365	3,051	25.48	19.39
Arthropoda	17	11	617	264	25.35	16.66
Chordata	1	1	5	2	27.12	1.29
Coelenterata	7	7	28	33	64.17	59.86
Echinodermata	4	2	108	124	5.31	5.43
Echiura	1	1	1	1	0.00	0.06
Mollusca	10	12	164	70	171.92	81.75
Nemertinea	-	-	-	-	0.57	0.03
Sipuncula	1	2	43	67	0.31	23.01
Unidentified	-	-	-	-	1.04	-
Total	81	75	5,331	3,612	321.26	207.48

Source: Mouchel (2005a) and Meinhardt (2006b).

7.4.4.6 High numbers of macroinvertebrate infauna (67-81 families; Mouchel, 2001a; (Mouchel 2002b); (Mouchel 2005a)) have been recorded in the study area. Abundance patterns in the Northwestern waters appear to be reasonably similar to the macro-infauna recorded in the eastern waters of Hong Kong. For example, in March 1986, 58 grab (0.05m^2 Van Veen grab) samples were taken in Tolo Harbour and Mirs Bay and revealed the presence of 79 species of macroinvertebrate infauna comprising 37 polychaetes (annelids), 15 crustaceans (arthropods), 18 molluscs, 5 echinoderms, 1 echiuroid, 1 hemichordate and 2 fish (Shin, 1990). Consistent with the results of grab sampling in the Northwestern waters, annelids, arthropods and molluscs were dominant.

7.4.4.7 AFCD commenced a terrestrial-wide study on the marine benthic communities in Hong Kong in 2001 (CCPC, 2002) and concluded that in Hong Kong waters polychaetes, crustaceans and bivalves were the most abundant benthic fauna comprising over 70% of the total species. In terms of spatial pattern, it noted that the western waters, together with the north-eastern waters and Victoria Harbour showed distinct benthic composition as compared with the rest of the locations and the benthic species diversity and ecological importance of these three strata was generally lower. The estuarine conditions in the western waters largely accounted for the lower species diversity in the western waters.

7.4.4.8 Infauna diversity in the study area is relatively low (*H’* < 2) compared to other areas in Hong Kong which is likely due to the proximity of Pearl River Estuary (estuarine areas are often less diverse owing to their highly dynamic physical and chemical nature) and possibly due to the predominantly silt-clay composition of the seabed that tends not to support high diversity (Shin, 1998; Mouchel, 2001a, 2002b).

7.4.5 Benthic Macro-Epifauna Invertebrates

7.4.5.1 The macro-epifauna comprise the larger organisms (typically > 1mm) that tend to live on or in close association with the sediment surface. Trawl surveys were conducted within the study area (at locations around Sha Cha Island for the EIA for the Aviation Fuel Receiving Facility) during September 1994 and monthly from January to December

1995 (ERM, 1997). A local shrimp trawler was used to conduct four trawls at each of six stations using a trawl net of 1.8cm (mesh diameter) at the cod end. A total of 67 invertebrate species were recorded including 19 species of crab and 13 shrimp species and the area was considered biologically diverse (although note that the more recent findings using the Shannon-Weiner Diversity index have considered the area to have a lower diversity; Mouchel, 2001a). There were also numerous mollusc species present although in accordance with many other studies conducted in the Northwestern waters, there were few echinoderms. The invertebrate organisms recorded in trawl surveys are presented in Table 7.2.

Table 7.2 Summary of Invertebrate Trawl Catch in the Vicinity of Sha Chau (Jan-Dec 1995)

Phylum	Class	Common Name	Number of Species
Arthropoda	Crustacea	Crab	19
		Mantis shrimp	1
		Shrimp/ Prawn	13
Cnidaria	Anthozoa	Gorgonian coral	1
		Sea anemone	1
		Sea pen	4
Cnidaria	Hydrozoa	Hydroid	1
Echinodermata	Asteroidea	Starfish	1
	Echinoidea	Sea urchin	1
	Holothuroidea	Sea cucumber	1
	Ophiuroidea	Brittle star	1
Mollusca	Bivalvia	Bivalve	8
	Cephalopoda	Cuttlefish	2
		Octopus	1
		Squid	1
	Gastropoda	Snail and sea slug	10
Platyhelminthes	Turbellaria	Flatworm	1
Total No. of Species			**67**

Source: ERM (1997)

7.4.5.2 Data on the benthic macro-invertebrate epifaunal communities present are also available from demersal trawls conducted in the study area during May 2001 (early wet season) for the EM&A for the CMPs (Mouchel, 2001a). Six trawling stations were sampled, two of these located to the north and east of Lung Kwu Chau, two around the CMPs and two were also surveyed to the west of the airport. The trawling gear and methods were similar to those described above although five tows are conducted at each station and the cod end mesh was 2 cm in diameter. Trawling revealed that there were 113 invertebrate species present, see Table 7.3. As recorded previously, there were numerous mollusc and crustacean species present and fewer echinoderms. Thirty-five species of crab were recorded and these represented the most numerous group of epifaunal macro-invertebrates present. The epifaunal (demersal fish, crustaceans and gastropods) diversity recorded in the study area is low ($H' < 2$; Mouchel, 2001a) which may reflect both the naturally-occurring stressors such as periodic fluctuations in the physico-chemical environment associated with Pearl River run-off and anthropogenic impacts such as high trawling pressures.

Table 7.3 Summary of Invertebrate Trawl Catch in the Vicinity of Sha Chau Collected in May 2001

Phylum	Class	Common Name	No. of Species
Arthropoda	Crustacea	Crab	35
		Mantis shrimp	6
		Prawn or Shrimp	23
Cnidaria	Anthozoa	Sea anemone	1
		Sea pen	2
	Scyphozoa	Jellyfish	1
Echinodermata	Asteroidea	Sea star	1
	Echinoidea	Sea urchin	1
	Holothuroidea	Sea cucumber	3
Mollusca	Bivalvia	Bivalve	12
	Cephalopoda	Cuttlefish	1
		Octopus	1
		Squid	2
	Gastropoda	Snails and sea slugs	24
Total No. of Species			113

Source: (Mouchel, 2001a)

7.4.5.3 However, more recent data on the benthic macro-invertebrate epifaunal communities present are also available from demersal trawls conducted in the study area during both the dry (January 2005) and late wet season (October 2005) in 2005 for the EM&A for the CMPs (Mouchel, 2005b; Meinhardt, 2006d). The results of the recent trawling, as presented in Table 7.4, were similar to those recorded in 2000/2001. As recorded previously, there were numerous mollusc and crustacean species present and fewer echinoderms. Thirty to thirty-two species of crab were recorded and these represented the most numerous group of epifaunal macro-invertebrates present. The epifaunal diversity recorded in the study area is low ($H' < 2$; Mouchel, 2005b; Meinhardt, 2006d).

Table 7.4 Summary of Invertebrate Trawl Catch in the Vicinity of Sha Chau Collected in 2005

Phylum	Class	Common Name	No. of Species	
			January	**October**
Annelida	Polychaete	Polychaetes	-	1
Arthropoda	Crustacea	Crab	30	32
		Mantis shrimp	5	6
		Prawn or Shrimp	17	14
Cnidaria	Anthozoa	Gorgonian coral	1	1
		Sea anemone	1	1
		Sea pen	3	3
	Scyphozoa	Jellyfish	1	1
Echinodermata	Echinoidea	Sea urchin	2	1
	Holothuroidea	Sea cucumber	3	3
Echiurid	Echiuridae	Echiurids	1	-

Phylum	Class	Common Name	No. of Species	
			January	October
Mollusca	Bivalvia	Bivalve	11	13
	Cephalopoda	Cuttlefish	2	1
		Octopus	1	1
		Squid	1	1
	Gastropoda	Snails and sea slugs	29	17
Total No. of Species			**108**	**96**

Source: (Mouchel, 2005b; Meinhardt, 2006d)

7.4.6 Horseshoe Crab

7.4.6.1 There have been three species of horseshoe crab recorded in Hong Kong coastal waters and although these species are distributed throughout Southeast Asia they are considered to be scarce locally. The crabs (although these animals are generally termed crabs it should be noted that they are more closely related to spiders) are mostly distributed in the western waters of Hong Kong and have been recorded in locations throughout the Northwestern waters.

7.4.6.2 Most of the horseshoe crabs recorded in the Tuen Mun area have been previously identified as *Tachypleus gigas* (ERM, 1997; Chiu and Morton, 1999). In an extensive study of the distribution of horseshoe crabs in Hong Kong conducted between March 1995 and June 1998, however, *Tachypleus gigas* was not recorded although *T. tridentatus* (both adults and juveniles) was reported from locations both within and to the north of Tuen Mun at Nim Wan and Lung Kwu Sheung Tan (Chiu and Morton, 1999). Nim Wan and Lung Kwu Sheung Tan are reported to be nursery grounds. *Carcinoscorpius rotundicauda* was previously recorded from Sha Chau although records for all species of horseshoe crab tend to be variable with only the occasional individual either observed or landed accidentally during trawling. *T. tridentatus* and *C. rotundicauda* have also been recorded in the west of the Northwestern waters at Sha Lo Wan and Sham Wat Wan (Chiu and Morton, 1999). Although all three horseshoe crab species have been reported to occur in Hong Kong, it is likely that only two species of horseshoe crab (*Tachypleus tridentatus* and *Carcinoscorpius rotundicauda*) are currently resident in Hong Kong as no recent records of *T. gigas* are available (Chiu and Morton, 1999; AFCD pers. comm.). Liao *et al*. (2001) also did not record *T. gigas* in their extensive surveys (September 1994 to June 1998) of the South China Sea (from Hainan to Xiamen).

7.4.6.3 It has been suggested that the horseshoe crabs show a seasonal trend in Hong Kong coastal waters and spawning activity is pronounced in February to March although they remain abundant in local waters from April to May (ERM, 1995). Although trends in abundance may be evident due to spawning, the local distribution of *Tachypleus tridentatus* and *Carcinoscorpius rotundicauda* may also be influenced by hydrological conditions as both species tend to be predominantly found in the less saline western waters (Chiu and Morton, 1999).

7.4.6.4 Specimens of horseshoe crabs collected in the vicinity of the study area during March to September 1996 (ERM, 1997), records mostly from March 1995 to June 1998 (Chiu and Morton, 1999), September 2003 to May 2004 (Mouchel, 2004) and May 2001 to

January 2005 (Mouchel, 2005b) are presented below in Table 7.5. The spatial distribution of horseshoe crabs in Northwestern waters is presented in Figure 6.2.

Table 7.5 Horseshoe Crab Sightings and Landings in the Study Area between June 1987 and January 2005

Location	Species/ Remarks	Date	Number of Individuals	Biomass (g)
Lung Kwu Chau	*Tachypleus gigas*	Jun, 1996	1	380
	Tachypleus gigas	Aug, 1996	1	325
	Tachypleus sp.	May, 2001	1	Not recorded
	Tachypleus tridentatus adult female	Aug, 2001	1	Not recorded
East of Sha Chau	*Carcinoscorpius rotundicauda* adult	Jul, 1995	1	Not recorded
	Tachypleus tridentatus juvenile	Jan, 2004	1	Not recorded
Lung Kwu Sheung Tan	*Tachypleus tridentatus* mating pair	Jun, 1987	2	Not recorded
	Tachypleus tridentatus adult	Jun, 1905	1	Not recorded
	Tachypleus tridentatus mating pair	May, 1995	2	Not recorded
	Unknown juvenile	Mar, 1998	1	Not recorded
Sha Lo Wan	Unknown juvenile	Apr, 1995	1	Not recorded
Nim Wan	Unknown juveniles	May, 1995	8	Not recorded
Tuen Mun	*Tachypleus tridentatus* adult (dead)	Jun, 1995	1	Not recorded
The Brothers	Unknown juvenile	Apr, 1995	1	Not recorded
	Tachypleus gigas	Jun, 1996	1	1667
	Tachypleus gigas	Jun, 1996	1	1667
	Tachypleus gigas	Jun, 1996	1	3636
	Tachypleus gigas	Jun, 1996	1	3030
	Tachypleus gigas	Jun, 1996	1	227
	Tachypleus sp.	May, 2001	1	Not recorded
San Tau	Unknown	May, 1995	~ 13	Not recorded
	Tachypleus tridentatus and	Oct, 1997-	~ 15	Not recorded
	Carcinoscorpius rotundicauda juveniles	Jun, 1998		
	Tachypleus tridentatus 5 males, 6 females	Apr, 1997	11	Not recorded
	Tachypleus tridentatus juveniles	Jun, 2002	57	Not recorded
	Carcinoscorpius rotundicauda juvenile	Nov, 2003	1	Not recorded
	Tachypleus tridentatus juveniles	Nov, 2003	10	Not recorded
	Tachypleus tridentatus	May, 2004	11	Not recorded
Tung Chung Wan	*Tachypleus tridentatus* 5 males, 6 females	Apr, 1997	11	Not recorded
	Carcinoscorpius rotundicauda	Apr, 1997	1	Not recorded
	Carcinoscorpius rotundicauda juveniles	Jun, 2002	2	Not recorded
	Tachypleus tridentatus	May, 2004	15	Not recorded
	Tachypleus tridentatus 13 males, 8 females	Oct, 1997	21	Not recorded
Hau Hok Wan	*Carcinoscorpius rotundicauda* juvenile	Nov, 2003	1	Not recorded
	Tachypleus tridentatus juveniles	Nov, 2003	2	Not recorded
Sham Wat	Unknown juvenile	Oct, 2003	> 10	Not recorded
	Tachypleus tridentatus	Apr, 2004	1 and 3 molts	Not recorded
	Carcinoscorpius rotundicauda	Jan, 2005	1	189.4
Tai Ho Wan	Unknown juvenile	Sep, 1998	1	Not recorded
	Carcinoscorpius rotundicauda juvenile	Jun, 1999	8	Not recorded
	Carcinoscorpius rotundicauda mating pair	Jun, 1999	2	Not recorded
	Tachypleus tridentatus	Jun, 1999	2	Not recorded
	Carcinoscorpius rotundicauda juveniles	Dec, 2003	20	Not recorded
	Carcinoscorpius rotundicauda	May, 2004	14 and 3 molts	Not recorded

Note: Although *Tachypleus gigas* has been reported in the wider study area, it may have been misidentified as Chiu and Morton (1999) only recorded the similar *Tachypleus tridentatus* during extensive surveys of the Northwestern waters. Adapted from AFCD (pers. comm.); ERM (1997), Chiu and Morton (1999); Fong (1999); Huang (1997); Mott Connell Ltd (2003); Mouchel (2004; 2005b).

7.4.7 Corals

7.4.7.1 Solitary corals have been reported from the study area in the region around East Sha Chau and further to the east at Sham Tseng and Tsing Lung Tau adjacent to Castle Peak Road (ERM, 1997; Mouchel, 2001b). Stone corals (Faviidae) have also been recorded at Sha Chau (ERM, 1995). The distribution of hermatypic corals is largely controlled by the requirements of their photosynthesising zooxanthellae which require strong light and hence shallower water, whereas many of the soft corals that do not possess symbiotic algae can survive at greater depths (Morton, 1994; Morton and Morton, 1983).

7.4.7.2 Corals are usually adversely affected by reduced salinity (hyposalinity) and coupled to the high levels of suspended solids discharged by the Pearl River (and hence low light penetration) the absence of many hermatypic corals from the study area is not unexpected. The coral communities of the study area are sparse compared to rocky reefs of similar depth and exposure in the higher saline oceanic eastern and southern waters of Hong Kong although a number of ahermatypic cup corals (thought to be *Balanophyllia* or *Phyllangia* sp.), pale-blue gorgonian (*Euplexaura* sp.), *Dendronephthya* sp. colonies, isolated sea pens (*Virgularia* or *Pteroides* sp.) and one hermatypic coral *Oulastrea crispata* were recorded in June 2001 the far eastern Northwest waters (at Sham Tseng and Tsing Lung Tau; Mouchel, 2001b; Figure 7.1). Similar results were also recorded in dive surveys at Lung Kwu Chau in November 2001 (Maunsell, 2002). Coral dives survey conducted in Ocotber 2003 around along the tentative alignment for the HKZM Bridge recorded low abundance (<5% cover) of one hard ahermatypic coral, *Balanophyllia* sp. on hard substrate to the west of HKIA at Sham Wat/San Shek Wan, but not the eastern or southern side (Mouchel, 2004). Low abundance (<5% cover) soft coral *Echinomuricea* sp. was also recorded in the October 2003 survey at the eastern and southern sides of the HKIA, but not the western side (Mouchel, 2004). It is notable that the ahermatypic cup coral (*Balanophyllia* or *Phyllangia* sp.) and the pale-blue gorgonian (*Euplexaura* sp.) have only rarely been recorded in the oceanic eastern and southern waters of Hong Kong and it is likely that these species are adapted to the hyposaline waters of the study area (Mouchel, 2001b). The presence of the hermatypic (containing zooxanthellae) coral *Oulastrea crispata* is unusual for these waters although total cover was sparse (<1%) and many individuals were in poor condition (Mouchel, 2001b). There are also records of hard corals at Sha Chau. Dive surveys conducted in late 1994 at locations around Sha Chau revealed the presence of protected hard corals (Faviidae) in subtidal areas (ERM, 1995). The hard coral species recorded in the in the Northwestern waters are generally common in local waters (Scott, 1984) although are more abundant in the eastern waters and the study area (comprising Northwestern waters) may represent their westernmost distribution in Hong Kong. The locations of hard corals in the broader study area are presented in Figure 6.2.

7.4.8 Cetaceans (Dolphins and Porpoises)

7.4.8.1 There are sixteen recorded cetacean species from Hong Kong waters although only two of these species, the Indo-Pacific Humpback dolphin (*Sousa chinensis*) and Finless porpoise (*Neophocaena phocaenoides*) are resident (Parsons *et al*., 1995). Until the early 1990s there were few records of *Sousa chinensis* in Hong Kong waters (Jefferson and Leatherwood, 1997) although construction of the international airport at Chek Lap Kok drew attention to the presence of the Indo-Pacific Humpback dolphin in local waters and intensive research into the distribution and conservation requirements of the species have been ongoing since about the mid 1990s.

7.4.8.2 Although other cetaceans (Finless porpoise and False killer whale) have been found in the Northwestern waters, these are probably extralimmital records and only the Indo-Pacific Humpback dolphin has so far been consistently reported from the study area (comprising the area from Tuen Mun to the Southwest of the airport) where it is widely distributed (Parsons *et al*., 1995; Jefferson and Leatherwood, 1997; Jefferson, 2000a, 2005; Hung, 2005). There appears to be only limited overlap in distribution of the Indo-Pacific Humpback dolphin and Finless porpoise in local waters as the dolphin tends to be predominantly distributed in the western waters whereas the porpoise is usually recorded from areas further to the east of Hong Kong (the southern coast of Lantau around Fan Lau and the Soko Islands predominantly marks the western edge for the distribution of *Neophocaena phocaenoides*; Parsons *et al*., 1995; Jefferson, 2000a; Hung, 2005).

7.4.8.3 Globally, the Indo-Pacific Humpback dolphin is widely distributed throughout shallow (< 20 m) coastal waters of the Indian and Western Pacific Oceans, from South Africa in the west to northern Australia and Southern China in the east (Parsons *et al*., 1995; Jefferson, 2000a; Jefferson and Karczmarski, 2001). In Hong Kong, *Sousa chinensis* predominantly frequents the less saline brackish waters around the Pearl River Estuary although loss of habitat to numerous developments, fishing, shipping activity and pollution from various sources have reportedly placed increasing pressure on the local Indo-Pacific Humpback dolphin population (e.g., Liu and Hills, 1997; Jefferson, 2000a). Locally, the Indo-Pacific Humpback dolphin population is centred around the Pear River Estuary and in Hong Kong, Tuen Mun to Ma Wan represent the eastern part of this populations range (Jefferson, 2000a, 2005; Hung, 2005). The total size of the Pearl River breeding population is difficult to estimate accurately although has been estimated to comprise at least 1,171 individuals with about 91-207 inhabiting Hong Kong’s waters (Jefferson, 2005).

7.4.8.4 Groups of Indo-Pacific Humpback dolphin are consistently recorded from waters near Tuen Mun and off Lung Kwu Chau, Sha Chau and around HKIA although the distribution in Hong Kong may be presently more restricted than when the population was assumed to contain more individuals in the past (Parsons *et al*., 1995). It should be noted, however, that no reliable census data are available prior to the construction of the HKIA and the hypothesis that the population was larger in the past is only an assumption. The distribution of the dolphin tends to show a slight seasonal response (possibly related to feeding opportunities, as the species is known to feed predominantly on estuarine fish) as individuals tend to move further to the east of the study area during the summer monsoon when ambient seawater is lower in salinity (Jefferson, 2000a). In the dry season (winter and spring) the population tends to be concentrated in the waters around the Sha Chau and Lung Kwu Chau Marine Park and to the north of Chek Lap Kok, although individuals are recorded within the study area throughout the year (Jefferson, 2000a, 2005; Hung, 2005). The seasonal distribution of *Sousa chinensis* in the study area between November 1995 and November 1998 is presented in Figure 7.2a while the more recent sighting data recorded between April 2004 and March 2005 is presented in Figure 7.2b.

7.4.8.5 In addition, a six day baseline monitoring survey of Indo-Pacific Humpback dolphins in and around the project area was conducted in late 2005 using transects (Figure 7.3a) as part of the pre-construction dolphin abundance monitoring required by the previous Environmental Permit (EP-139/2002/A). Over the six days survey, the number of sightings per survey day varied between 3 to 11 and the group sizes ranged between 1 to 8, although 1 to 2 individuals were observed in the majority of the cases. The locations of the sightings recorded during the baseline survey are presented in Figure 7.3b and the original report is presented in Appendix F3.

7.4.9 Marine Habitat Quality

7.4.9.1 The ecological value of each habitat present in the study area is largely based on the species present. For example, habitat that contains species of conservation interest or serve as a nursery or breeding grounds are considered to have high ecological value. The marine waters present in the study area are the media used by the species of highest ecological importance, the Indo-Pacific Humpback dolphin. The waters within the Marine Park are important to dolphins and are, therefore, of high ecological value. Impacts on marine waters were discussed earlier in Section 6 of this report. A species-based impact evaluation for the construction and operational phases of the PAFF has been conducted for the dolphin population inhabiting the waters of the study area. The Indo-Pacific Humpback dolphin impact assessment is discussed further in Sections 7.6-7.7.

7.4.9.2 Criteria for evaluating ecological impacts to habitats in the study area were determined in accordance with criteria stipulated in Table 2 (Annex 8) of the TM. The ecological value of both the soft and hard substrates present within the study area are discussed below in Sections 7.4.9.3-7.4.9.7.

<u>Soft-Bottom Benthic and Littoral Habitat</u>

7.4.9.3 The benthic habitats in the western waters of Hong Kong are generally characterised by soft-bottom material composed of silts and clay as a homogenous layer or in loosely packed mud clasts bound in a puzzle fabric (Binnie Consultants, 1995; ERM, 1999) although coarser material under the influence of strong tidal currents has been reported from the area to the Northeast of The Brothers (Greiner-Maunsell, 1991). The species present in the benthos are common and have been recorded in similar habitats throughout Hong Kong (e.g., Shin and Thompson, 1982; Shin 1990; CCPC, 2002).

7.4.9.4 There is also the occasional sandy shore present in the study area, notably at Sha Chau. Previous surveys of the sandy shore at Sha Chau have however revealed that it is biologically depauperate. Similar findings were also recorded in the more recent field surveys conducted at Lung Kwu Chau (Maunsell, 2002). Extremely low species numbers and biological diversity are, however, typical of exposed sandy shores in the study area where the substrate is unstable (Morton and Morton, 1983; ERM, 1995).

<u>Hard-bottom Benthic and Littoral Habitat</u>

7.4.9.5 Based on trawl surveys that have collected organisms that are exclusively found on hard substrate (such as mytilid mussels and certain corals) there is evidence of some hard bottom habitat within the study area. The hard substrates present would, however, appear to only form a small proportion of the overall study area. Hard substrate benthic habitat is not typical of the study area to be affected, although trawl surveys occasionally reveal the presence of exclusively hard substrate fauna such as mytilid mussels (e.g., *Perna viridis;* Mouchel, 2001a) indicating the presence of some small patches of hard benthic substrate (i.e., occasional rocks and small boulders). Closer to shore, there is also hard subtidal substrate present and although this habitat is not directly impacted by the project, there is the possibility that any significant alteration of water quality due to the release of suspended solids during dredging for example, may impact communities such hard corals that are present further afield; isolated hard corals have for example been recorded at Sha Chau (ERM, 1995) and further afield at Sham Tseng (Mouchel, 2001b). Although some hard and soft corals have been recorded on the hard subtidal substrates within the study area, they are mostly comprised of isolated colonies, have low percentage cover and many individuals are in poor condition as these waters probably represent the western most limit for many of the coral species present (Mouchel, 2001b, 2004). The influence of the Pearl River in the Northwest leads to a low salinity, sediment-laden water body that is known to inhibit coral growth and the absence of a well develop coral community is largely due to the prevailing estuarine waters present (Morton, 1994).

7.4.9.6 The littoral communities present on the rocky and boulder shores in study area are mostly comprised of common intertidal species that are found on these habitat types elsewhere in Hong Kong (Morton and Morton, 1983; Greiner-Maunsell, 1991; ERM, 1995; Maunsell, 2002). Biological diversity is not, therefore, considered to be high on the hard substrates present within the study area.

7.4.9.7 An evaluation of the ecological quality of the benthic soft-bottom habitat and hard substrate habitat is presented below in Tables 7.6 and 7.7, respectively.

Table 7.6 Ecological Evaluation of Soft-bottom Benthic Habitat Within the Study Area

Criteria	Soft-bottom Benthic Habitat
Naturalness	Natural habitat (although note that this habitat is disturbed both naturally and due to activities such as demersal trawling)
Size	Relatively large as majority of study area composed of soft-bottom silt-clay material. Temporary loss of 360,000 m^3 benthic habitat predicted due to pipeline installation
Diversity	Infauna diversity is relatively low (*H'* < 2) compared to other areas in Hong Kong due to the proximity of the Pearl River Estuary and possibly due to the predominantly silt-clay composition of the seabed that tends not to support high diversity (Shin, 1998; Mouchel, 2001a, 2005a; CCPC, 2002) Epifauna (demersal fish, crustaceans and gastropods) diversity is also low (*H'* < 2; Mouchel, 2001a, 2005a)
Rarity	No rare species present
Re-creatability	Easily recreated as disturbed soft-bottom sediments readily recolonised
Fragmentation	Highly connected to adjacent homogeneous habitat
Ecological linkage	Functionally linked to overlying water column

Criteria	Soft-bottom Benthic Habitat
Potential value	Low
Nursery/ breeding ground	No species of conservation interest known to use soft-bottom sediments in the study area as a nursery or breeding ground[1]
Age	The majority of deposits are considered to be derived locally although some are transported into the study area by the Pearl River. Local seabed muds are considered to be Holocene post-glacial sediments deposited over the past 12 000 years (Whiteside, 2000)
Abundance/ Richness of wildlife	High number of macroinvertebrate infauna (67-81 families)[2] and epifauna (113 species)[2] present. Abundance is similar to the eastern waters where 79 species of macroinvertebrate infauna have been recorded at Tolo Harbour and Mirs Bay in 1986 (Shin, 1990).
Overall Ecological value	Low

Notes: [1]Horseshoe crab nursery areas are outside of the study area; [2]Based on the most recent infauna and epifauna (trawl) data available from the study area collected in May and August 2001 and January and October 2005 (Mouchel, 2001a; 2002b; 2005a; Meinhardt, 2006d).

Table 7.7 Ecological Evaluation of Hard Substrate Benthic Habitat Within the Study Area

Criteria	Hard Substrate Benthic Habitat
Naturalness	Natural habitat
Size	Hard substrate intertidal habitats are not directly affected by this project. There is, however, potential for indirect impacts related to alterations in water quality. The only hard-substrates, relatively small in area compared to soft bottom sediment, likely to be directly impacted are the rocks and boulders occasionally found in the soft-bottom seabed.
Diversity	Low
Rarity	No rare species recorded although protected hard corals reported on substrate at Sha Chau (and likely on other hard substrates in the study area based on dive studies in Northwestern waters; Mouchel, 2001b, 2004)
Re-creatability	Readily re-creatable
Fragmentation	Naturally fragmented from adjacent homogeneous soft-bottom seabed
Ecological linkage	Connected to overlying water column and soft-bottom seabed
Potential value	Moderate given the potential for presence of some corals
Nursery/ breeding ground	No species of conservation interest known to use hard-substrates in the study area as a nursery or breeding ground
Age	Hard substrate in study area largely composed of Jurassic/ Cretaceous granitoids
Abundance/ Richness of wildlife	The only species of conservation interest present are isolated colonies of hard corals many of which often appear in poor condition
Overall Ecological value	Low

7.5 Ecological Impact Assessment Methodology

7.5.1 The objective of the ecological assessment is to predict the direct, indirect, primary and secondary, on-site and off-site impacts of the PAFF. The significance of ecological impacts have been evaluated based on the criteria stipulated in Table 1, Annex 8 of the TM using the following criteria:

- habitat quality;
- species affected;
- size/ abundance of habitats affected;
- duration of impacts;
- reversibility of impacts; and
- magnitude of environmental changes.

7.5.2 Impacts are ranked as “minor”, “moderate” or “severe”, although in a few cases, “insignificant” (less than “minor”) or “extremely severe” may also be given. The ranking of a given impact will vary based on the criteria listed above. For example, an impact might be ranked as “minor” if it affected only common species and habitats, or if it affected only small numbers of individuals or small areas, whereas it might be ranked as “severe” if it affected rare species or habitats, large numbers of individuals or large areas. The major factors giving rise to a ranking of “moderate” or “severe” are spelled out in the text as far as possible. As noted in Annex 16 of the TM, a degree of professional judgement is involved in the evaluation of impacts.

7.5.3 Impacts to species or groups assessed as **‘minor’** are predicted to cause a slight, and/or short term reduction in the local population numbers or geographic distribution of a species or group, but the species or groups are predicted to recover from the perturbation with no long-term adverse impacts. Habitat impacts are considered ‘minor’ when no species of conservation or regulatory concern are found, and when the habitat in question was widely distributed locally.

7.5.4 Impacts to species or groups assessed as **‘moderate’** are predicted to cause local reduction of species or group population numbers. The reductions would be long-term, and probably not recoverable, but the species or groups in question are considered widely distributed or common, and abundant on a local, regional, or global scale. Habitat impacts are judged ‘moderate’ when the habitat in question was of limited local or regional distribution or declining in extent, and when the potential for the habitat to support fauna and flora was considered of conservation or regulatory importance.

7.5.5 Impacts to species or groups are assessed as **‘severe’** when they are judged to adversely affect species or groups which are of conservation or regulatory concern locally, regionally, or globally due to scarcity or declining population or distribution trends. Impacts to habitats are considered ‘severe’ when the habitats are found to be limited or declining in geographic distribution, contain plant species of regulatory or conservation concern, or are generally considered by the scientific community to be of local, regional or global importance to the support of wild fauna.

7.5.6 If ecological impacts are found to be significant (i.e., minor to severe) mitigation needs to be carried out in accordance with the TM. Mitigation measures are not required for insignificant impacts. The policy for mitigating significant impacts on habitats and wildlife is to seek to achieve impact avoidance, impact minimisation and impact compensation in that order of priority. Impact avoidance typically consists of modifications to the project design, but may in extreme cases require abandonment of the project (the "no-go" alternative). Impact minimisation includes any means of reducing the scope or severity of a given impact, e.g., through timing of construction works, modification in design, or ecological restoration of disturbed areas following the completion of works. Impact compensation assumes that an irreversible impact will occur upon a given habitat or species and attempts to compensate for it elsewhere, for example, by enhancement or creation of suitable habitat. Compensation may take place on-site or off-site.

Cumulative Impacts

7.5.7 In order to assess the potential ecological impacts from other activities in the study area, cumulative impacts were also examined with respect to the pipe installation and berthing jetty construction. There are numerous other operations in the overall study area that could potentially lead to cumulative impacts and these include disposal of contaminated dredged material in the East Sha Chau CMPs and The Brothers MBA and neighbouring works that may result in cumulative ecological impacts. There is also the potential for impacts due to dredging of a new contaminated mud pit facility at Airport East or East of Sha Chau although it should be noted that this project is only tentatively scheduled for commencement in early 2008 and overlappling with the PAFF construction (due for completion in 2009) will be minimal. Impacts from marine pollution, fishing and shipping activity also require consideration. The cumulative impacts are, therefore, wider in scope than the potential impacts attributable to the aviation fuel facility.

7.6 Prediction and Evaluation of Construction Phase Impacts

7.6.1 *Potential Ecological Impacts*

7.6.1.1 Many of the ecological issues also overlap with the sections of this EIA relating to water quality and risk assessment. Consequently, many of the key ecological issues referred to in previous sections are most likely to be influenced by water quality impacts. The major activities likely to impact on the marine ecology of the study area are anticipated to be predominantly related to the construction phase of the project. Construction related impacts may arise from the installation of a submarine pipeline which will require dredging and backfilling (estimated to last for a duration of about 62 days for a grab dredger, based upon the most recent volume of material to be dredged and the need to restrict the dredging to 12 hours a day outside the Urmston Road).

7.6.1.2 It should be noted that while percussive piling works, as were required for the jetty, have the potential to cause impacts to the Indo-Pacific Humpback dolphin, the piling works for PAFF have been completed under the previous Environmental Permit EP-139/2002/A. Details of the mitigation measures applied at that time are summarised in Section 7.8.2.

7.6.2 Alteration of Water Quality

7.6.2.1 The pipe installation and jetty construction will lead to localised increase (patches) in suspended solid concentrations in the water column. Suspended solids also contain organic matter and consequently also have an oxygen demand. Elevated suspended solids, therefore, have the potential to cause limited oxygen depletion of the water column although it should be noted that no reduction in ambient dissolved oxygen in Northwestern waters has been recorded even at high suspended solids concentrations (100 mg l^{-1}; Mouchel, 2001c). Suspended solids can also smother the benthos when they settle-out. Impacts related to elevated suspended solids are mostly observed in benthic sessile organisms that are unable to migrate from the affected habitat. Increased suspended solids can clog the gills of filter-feeding sessile organisms such as bivalves and fish leading to suffocation. High suspended solids also reduce incident solar radiation from reaching the benthos which can impair photosynthesis. It should be noted, however, that owing to seasonal inputs from the Pearl River, suspended solids in the Northwestern region of Hong Kong vary over a wide range (occasionally exceeding levels of 100 mg l^{-1} in the dry season; Mouchel, 2001c) and it is likely that the organisms present are adapted to short-term elevated suspended solid inputs (Greiner-Maunsell, 1991).

7.6.2.2 Reference to the water quality predictions for the Northwestern waters indicated that the potential for impacts from suspended solids concentrations on sensitive receivers (such as corals) were insignificant. Where predictions have indicated that suspended solid concentrations may prove unsuitable to sensitive receivers, appropriate mitigation measures were recommended for incorporation during the pipeline and berth construction.

7.6.3 Disturbance to the Benthic Habitat and Habitat Loss

7.6.3.1 There will be a temporary loss of sublittoral habitat and associated benthic communities resulting from the pipeline installation due to disturbance of the seabed. There is potential for localised resuspension of sediment particles due to the pipeline construction leading to impacts associated with suspended solids as described in the preceding section on alterations to water quality. The twin submarine pipelines are each about 500mm in diameter and will be placed in a trench in the seabed that is dredged using either a grab or trailer dredger.

7.6.3.2 It is likely that dredging will cause localised suspension of sediments in the vicinity of the area undergoing dredging activity. It should be noted that for much of its length the pipeline passes through soft-bottom sediment that is already subjected to dredging (for example, dredging activity associated with maintaining access channels to the existing AFRF at Sha Chau and Castle Peak Power Station) and intense trawling pressures (which also disturbs the seabed) and species present are either tolerant of these activities and/or have rapid recolonisation potential. Re-suspension of bottom sediments is unlikely to lead to elevated suspended solids further afield and only those fauna directly adjacent to the dredging activity are likely to be affected.

7.6.3.3 The benthic areas temporarily disturbed during pipeline installation will likely return to their pre-dredged state rapidly as uncontaminated sediments are colonised in Hong Kong rapidly (Meinhardt Mouchel, 2004; Meinhardt, 2006a). For example, recolonisation of defaunated sediment has been shown to be rapid and peaks in macroinvertebrate abundance are reached after only three months (Lu and Wu, 1998). Similarly, recolonisation of the clean material used to cap the exhausted borrow pits at East Sha Chau has also been shown to be rapid (Mouchel, 2001a). The survey data available for the study area showed that the macro-infaunal and epifaunal species composition is mostly comprised of filter-feeding and deposit-feeding representatives including polychaetes, molluscs, crustaceans and echinoderms and these representatives typically account for 95% of the benthic assemblage present (ERM, 1997) and are characteristic of soft-bottom benthic communities throughout Hong Kong (Shin and Thompson, 1982; Shin, 1989; CCPC, 2002). Both historical and recent data have indicated that no rare infaunal or epifaunal macroinvertebrate species are present in the study area.

7.6.3.4 The pipeline will be installed by dredging to a depth of approximately 2.2m below the existing seabed surface and placed within a submarine trench protected by rock armour, as shown in Figure 3.3. The total length of the pipeline is approximately 4.8km long and it is estimated that the total area of benthic habitat temporarily lost will amount to 124,975m^2 and 340,000m^3 but this is considered insignificant. As the pipeline is located below the seabed surface it will likely be backfilled by dredger using rock armour. Pipe installation will result in a temporary change in the composition of the habitat and also dislodge and smother the benthic fauna present. Furthermore, following completion of the installation operations, faunal colonisation will take place and a soft-bottom community should recolonise the material deposited on the rock armour and soft-bottom areas disturbed through construction activity should return to a pre-ploughed condition rapidly. Prolonged benthic habitat fragmentation is, therefore, highly unlikely. The ecological impacts, disturbance and temporary loss of benthic habitat during the construction phase are considered to represent an insignificant ecological impact to the soft-bottom benthos of the study area.

7.6.4 Disturbance to Corals

7.6.4.1 The Northwestern waters of Hong Kong are strongly influenced by the Pearl River and the prevailing estuarine conditions are not conducive for the establishment of many hard coral communities owing to the lower salinity and high turbidity of these waters. Surveys have revealed the presence of soft corals (such as sea pens and gorgonians) that appear to be distributed throughout the Northwestern waters (e.g., Greiner-Maunsell, 1991; ERM, 1996; Mouchel, 2001a; 2001b; Maunsell, 2002) and are of some ecological interest although are less sensitive to significant hydrological alterations (such as through elevations in ambient suspended solid concentrations). Records of hard/stony corals are less extensive although there are hard corals (Faviidae) present subtidally near to Sha Chau (ERM, 1995) and Lung Kwu Chau (Maunsell, 2002) and isolated hard corals were also recorded more recently (June 2001) in the broader study area at Tsing Lung Tau and Sham Tseng (Mouchel, 2001b).

7.6.4.2 The faviid corals recorded previously at Sha Chau (ERM, 1995) are approximately over 1.2km to the southwest from the pipeline construction (at the nearest point). The isolated hard corals present along the New Territories coastline at Tsing Lung Tau and Sham Tseng (Mouchel, 2001b) are approximately 11-12km to the east from the location of dredging required at Tuen Mun Area 38 (Figure 6.2).

7.6.4.3 Dredging is required for this project for twin submarine pipelines (each 20 inches in diameter) that will be placed in a trench in the seabed that is dredged through either grab or trailer dredger. As discussed in Section 6.4, the major water quality issues in the construction period are those associated with elevated suspended solids as a result of dredging and backfilling for the submarine fuel pipeline. For the impacts to sensitive receivers it was assumed that the pipeline trench could either be dredged mechanically using a barge mounted grab or hydraulically by means of a trailer suction hopper dredger. From the environmental perspective, the instantaneous sediment loss rates associated with grab dredging are likely to be less than that for trailer dredging. Thus, the intensity and extent of a sediment plume emanating downstream of a working dredge is likely to be less for a grab than a trailer and thus trailer suction dredgers are generally regarded as being more environmentally damaging than grab dredgers. The plume from a trailer dredger will, however, predominantly be formed at depth close to the drag head whereas grab-dredging plumes, though less concentrated, are likely to disperse throughout the water column as the grab is pulled to the surface. In order to determine whether water quality alterations with respect to suspended solids would have an impact on hard corals that are known to be relatively intolerant to deposited sediments (e.g., Brown and Howard, 1985; Rogers, 1990), water quality modelling was conducted as described in detail in Section 6 of this report.

7.6.4.4 Certain coral species appear particularly susceptible to suspended solids through direct impacts such as smothering and clogging of filter-feeding polyps and also indirect secondary impacts such as reduction in light penetration leading to impaired photosynthetic capacity of the symbiotic zooxanthellae (e.g., Rogers, 1990). It should be noted, however, that impacts from suspended solids are largely dependent on several factors including the species of coral concerned, duration of smothering and the toxicity of deposited particles. In a review of the natural and anthropogenic stressors that impact corals, Brown and Howard (1985) present the findings of several studies on the effects of sedimentation. Although dredging and increased sedimentation led to mortality of plating species such as *Porites astreoides* due to an inability to reject sediment, there are numerous other examples where corals were unaffected by dredging and have even survived smothering by 2200 tons of kaolin clay on a reef in the Hawaii islands (Brown and Howard, 1985). Although sub-lethal effects could not be discounted for the apparent lack of effect in the aforementioned case studies, the insignificant impacts associated with the kaolin spill were attributable to the non-toxic nature of the material, the small particle size, the presence of water (which presumably aided dislodgement), rapid dispersal of the plume, and, rapid removal of sediment through natural coral cleansing mechanisms (such as ciliary activity, tentacle and polyp expansion). Sediment rejection (cleansing) mechanisms are predominantly a function of coral morphology, orientation, growth habitat and behaviour (Rogers, 1990). Such mechanisms are thought to rapidly aid the recovery process in most lobate and branching corals which tend to be less impacted than platelike forms (Brown and Howard, 1985; Rogers, 1990).

7.6.4.5 The water quality modelling (based on suspensions of sediment attributable to worst-case trailer suction hopper dredging) described in Section 6 predicted that the elevations in suspended solids would be highly localised and mostly confined to the bed layer and well within the range of natural variability for Northwestern waters and hence do not represent any ecological concern. The model also predicted that there would not be any substantial accumulation of re-deposited sediments likely to adversely affect either benthic organisms or particularly susceptible species such as hard corals (see Section 6).

No locations beyond the immediate vicinity of the worked area would experience settlement rates greater than 200 g m^{-2} day^{-1} that represents a value that has been used by previous workers as an indicator level above which sustained deposition could harm sediment-sensitive hermatypic corals (Rogers, 1990). It is unlikely that either hard or soft corals outside of the dredged areas will encounter unacceptable impacts and it should be noted that the majority of species within the study area are generally ahermatypic (i.e., do not contain symbiotic zooxanthellae which require high light levels for photosynthesis). Soft corals that are more typical of the study area would, therefore, be even more tolerant and there is no reason to believe that they would be impacted.

7.6.4.6 In summary, sedimentation impacts on hard corals are well documented and toxicity and mortality are dependent on whether the deposited material is toxic (sediments in the study area are considered to be comparatively non-contaminated see Section 6), the duration of smothering (likely to be of short duration owing to the rapid currents present in part of the study area such as along the Urmston Road) and the species of coral present as platelike forms appear more sensitive although they have not been recorded in the study area. Sea pens such as *Pteroides esperi* are widespread throughout the soft-bottom seabed of study area and were previously recorded by ERM (1996) and Mouchel (2001a; 2001b; 2005b). The soft gorgonian coral *Ellisella gracilis* has also been recorded from the northeast of Sha Chau (ERM, 1996). These soft corals are not particularly susceptible to high suspended solid loadings as they do not possess symbiotic zooxanthellae. Gorgonians are typically branching corals that are probably less susceptible than other forms to sedimentation (Brown and Howard, 1985) and it is unlikely that localised suspension of the seabed through dredging will have an impact on corals such as *Ellisella gracilis*. There are also records of protected stony corals (faviids) from near Sha Chau (ERM, 1995) although they are distant (approximately 1.2km to the southwest) and in any case suspended solids settlement rates greater than 200 g m^{-2} day^{-1} that represents a value above which sustained deposition could harm sediment-sensitive hermatypic corals (Rogers, 1990) are not predicted. Construction-phase impacts to hard and soft corals are, therefore, considered to be insignificant.

7.6.5 *Disturbance to Indo-Pacific Humpback Dolphins*

<u>Background</u>

7.6.5.1 There is increasing pressure being placed on the Northwestern waters due to numerous infrastructural developments in this location. As the area also holds the majority of Hong Kong's Indo-Pacific Humpback dolphins (and these are part of the Hong Kong-Pearl River Estuary population) it is important to ensure suitable protection of this species. The dolphin is protected in Hong Kong, although the survival of the local population is being affected adversely by pollution, fishing pressures (and loss of food), habitat loss and an increase in marine traffic (Liu and Hills, 1997; Jefferson, 1998; 2000a; Morton, 1998; Jefferson and Hung, 2004). Although extirpation of the local population is considered unlikely and the dolphin remains reasonably abundant, there is nevertheless a clear need for effective protection of this species to ensure its long-term survival in Hong Kong waters (Jefferson, 1998, 2000a; Jefferson and Hung, 2004). It is, therefore, important that any project within the dolphins' habitat is carefully evaluated to ensure the long-term conservation requirements of this species are not compromised. The sections below provide a species-based ecological impact assessment for the Indo-

Pacific Humpback dolphin and discuss the likely impacts attributable to the construction phase activities associated with PAFF to the local dolphin population.

Noise

7.6.5.2 Cetaceans use two functional classes of sound, these are echolocation and communication. Echolocation is used for orientation, navigation, prey detection and learning about the surrounding environment, whilst communication is used for intraspecies signalling (Richardson, 1995). Indo-Pacific Humpback dolphin vocalise through the production of clicks, rapid click sequences (screams) and whistles (Wursig, 1995a). Noise is transmitted efficiently through water and cetaceans are known to be able to detect submarine noise created by activities such as shipping over several kilometers from the source (Richardson, 1995). Sounds introduced into the marine environment have the potential to interfere with the dolphins ability to detect calls from other individuals, echolocation pulses or other natural sounds (Richardson, 1995). Noise can also lead to a disruption of dolphin behaviour. Disruption of feeding, resting and social interactions have all been attributed to elevated sounds (Richardson, 1995). Elevated noise of sufficient intensity can also damage the hearing sensitivity which may be either acute or chronic (Richardson, 1995). The loud impulsive sounds from activities not only have the potential to cause disturbance, but also cause physical injury and in extreme cases mortality. The organs used in hearing and air-filled cavities such as the lungs are particularly susceptible to physical injury from extremely loud impulsive sounds. Clearly, elevated noise levels are potentially the most important impact to the dolphin population in the study area. It should be noted, however, that if the sounds emitted are lower than background, there is unlikely to be any significant impact to dolphins (Richardson, 1995).

7.6.5.3 High levels of noise potentially will be emitted from construction work activity such as crane barges. Research has indicated that dolphins have acute hearing above 500 Hz and echolocate and communicate well into ultrasound above 20 kHz (Wursig *et al*., 2000). Owing to the propagation of sound in water, frequencies below 10 kHz tend to travel longer distances than those reaching into ultrasound and consequently these lower frequencies can be more disruptive to cetaceans (Wursig *et al*., 2000). Activities such as pile driving have their highest energy at lower frequencies from about 20 Hz to 1 kHz and whilst smaller cetaceans (~ 3-4 m) are not known to be highly sensitive to sounds below 1 kHz they can hear in much of this range and sounds in their vicinity could induce changes in behaviour, interfere with communication and even cause physiological and morphological damage (Greene and Moore, 1995; Wursig *et al*., 2000).

7.6.5.4 A piled jetty is required for creation of the PAFF berthing facility at Tuen Mun. Piled structures are preferable to blockwork or closed structure designs as they have less impacts to marine ecology, including dolphins, owing to a smaller footprint, and colonisation of piles being more rapid than with blockwork structures. Piled structures also have less marine ecological impacts, as invertebrates and fish assemblages are attracted to these structures, which may also attract dolphins (Wursig, 1995b). It should be noted, however, that the piled foundation has been already constructed (see Section 1) and no further piling is required. The piling was undertaken in accordance with the previous EP-139/2002/A and the mitigation measures applied at that time to avoid impacts to the Indo-Pacific Humpback dolphin are summarised in Section 7.8 for information.

Dredging and Impacts from Suspended Solids

7.6.5.5 There is no reason to assume that suspended solid releases during pipeline construction will have an impact on dolphins. Indo-Pacific humpback dolphins are naturally exposed to high levels of suspended solids in the Pearl River Estuary; the sediments to be dredged in the study area are generally not contaminated, and water quality modelling has predicted that suspended solid elevations during pipeline construction are highly localised (Section 6). Release of suspended solids to the water column are not predicted to have any impact on dolphins (Section 6). There is also some evidence to suggest that dredging activities attract dolphins, regardless of ambient suspended solid concentrations (Hyder, 1998; Jefferson pers. comm.). It is probable that dredging disturbs invertebrates inhabiting the sediment which provides feeding opportunities for fish and subsequently dolphins. There appears to be no documented evidence to suggest dredging has adverse impacts on dolphins although potential disturbance impacts should be carefully considered when dredging in areas that are important to the dolphin population (Jefferson pers. comm.). However, in order to ensure that dredging does not impact the dolphin population both within the Marine Park and along the pipeline, an exclusion zone should be implemented around the dredger for al dredging works.

7.6.6 Sha Chau and Lung Kwu Chau Marine Park

7.6.6.1 The study area associated with the pipeline is located within the Sha Chau and Lung Kwu Chau Marine Park, although only about 400m of the 4.8km pipeline will be within the park boundary. There are several sensitive receivers known to inhabit the park, including the Indo-Pacific Humpback dolphin, horseshoe crabs and coral communities. The Marine Park comprises 1200 ha of estuarine waters around the islands of Sha Chau and Lung Kwu Chau and was designated marine park status on 22 November 1996. The marine park was specifically designated due to the importance of the habitat for the Indo-Pacific Humpback dolphin.

7.6.6.2 Construction phase impacts described in the sections on impacts to the benthos and corals detailed above, are also applicable to the Sha Chau and Lung Kwu Chau Marine Park. The dredging at the access channel for the aviation fuel receiving facility at Sha Chau currently occurs at a frequency of approximately once every four years (maintenance dredging is still required to maintain access to the AFRF as the facility is required as a back-up in event of failure to the PAFF). There does not appear to be any evidence that this dredging has deleterious impacts to the marine ecology in the Marine Park.

7.6.6.3 The species-based ecological impact assessment to the Indo-Pacific Humpback dolphin should be consulted as the predicted impacts also apply to individuals inhabiting the Marine Park although it should be noted that the majority of individuals within the Marine Park are found to the north at Lung Kwu Chau (Jefferson, 2000a, 2005; ERM, 2006 also refer to Figures 7.2a and 7.2b for relative density of Indo-Pacific Humpback dolphin). There will be a temporary (unavoidable) loss of a small amount (400m long) of benthic habitat in the Marine Park due to pipeline construction which may affect the feeding opportunities of fish and dolphins (although it should be noted that dislodged infauna are in fact likely to attract fish and prove beneficial to dolphins). As described above, the temporary loss of benthic habitat is considered insignificant owing to the likelihood of rapid recolonisation by benthic fauna once the trench supporting the pipeline has been covered in sand and sediments. In addition, the dredging of the access channel for the AFRF that is required to maintain the facility for emergency backup will disturb the seabed in this area approximately once every 3-4 years and no ecological impacts are evident in the Marine Park. The one-off benthic disturbance through construction of the pipeline is similarly not expected to result in any cumulative impacts or significant disturbance as the loss of benthic habitat is only for a short duration and colonisation of the sediment overlying the rock armour is predicted to be rapid.

Artificial Reefs

7.6.6.4 Artificial Reefs (ARs) were placed in the Sha Chau and Lung Kwu Chau Marine Park in May 2000 to mitigate loss of habitat to the temporary aviation fuel line at Sha Chau and are also considered a key sensitive receiver as they provide habitat for the aggregation of fish. The ARs are located to the west of Sha Chau and were designed to enhance fisheries resources and promote feeding opportunities for the Indo-Pacific Humpback dolphin population that frequents the area.

7.6.6.5 The proposed pipeline from the PAFF to Sha Chau is distant to the ARs (approximately 1 km away at the nearest point) and suspended solids lost to the water column during construction of the pipeline are not expected to have any water quality impacts on the ARs (see Section 6). It is interesting to note that the ARs and fishing exclusion zone in-place near the airport are close to the East of Sha Chau contaminated mud disposal facility. Effects from contaminated mud disposal (and other activities such as major dredging and maintenance capping that is required for the backfilled pits) would have a higher impact than the localised suspension of uncontaminated seabed sediments predicted by the water quality modelling described earlier in Section 6 for the PAFF pipeline construction. The area close to the airport nevertheless has been found to contain abundant fisheries resources that are probably related to the ARs (Mouchel, 2001a; Meinhadt, 2006a) aggregating fisheries resources in the area. The proposed pipeline construction is not, therefore, considered likely to have an ecological impact on the ARs located within the Sha Chau and Lung Kwu Chau Marine Park.

7.6.7 Cumulative Ecological Impacts (Marine Ecology and Indo-Pacific Humpback dolphin)

Marine Ecology

7.6.7.1 Marine systems are exposed to a wide range of impacts although, to date, few studies in Hong Kong have addressed cumulative ecological impacts associated with construction projects. Cumulative ecological impact assessments need to consider all activities in the study area in addition to the impacts predicted directly from the PAFF. The cumulative impacts are, therefore, likely to be wider in scope than the potential impacts attributable only to the PAFF.

7.6.7.2 Whilst it is acknowledged that activities from the current project may slightly increase the pressure on ecological resources due to concurrent dredging and backfilling at the ESC CMPs and North of the Brothers MBA, together with other developments in the area, the predicted impacts from this study are predominantly confined to the construction phase and of short duration, with pipeline dredging anticipated to take a maximum of about 62 days depending upon the dredging technique applied and the ultimate amount of material to be dredged. No operational phase maintenance dredging is required. The activities described above that are concurrent to the PAFF construction phase which may cause cumulative impacts to the marine ecology of the study area may result in the following (ERM, 1997):

- a prolonged period of impact;
- an increased intensity of the impact; and
- induced synergistic impacts (i.e., effects that are greater in combination than singularly).

7.6.7.3 It is anticipated that the ecological impacts due to the pipe laying and PAFF construction are associated with the potential for suspension of sediments and alteration to dissolved oxygen. Section 6 of this EIA on Water Quality has concluded that no sensitive receivers are predicted to be impacted. As the predicted impacts are predominantly confined to the construction phase and hence are short-term, project-specific impacts are not expected to result in unacceptable impacts to water quality and hence unacceptable marine ecological cumulative impacts are similarly not anticipated.

<u>Indo-Pacific Humpback Dolphin</u>

7.6.7.4 There could be potential for cumulative impacts to the Indo-Pacific Humpback dolphin in the study area due to unmitigated noise from construction activities and ambient industrial sources such as Shekou, coupled to the aggregated pressures from fishing, shipping, mud disposal at the CMP's and pollution arising from numerous sources both in Hong Kong and Southern China. However, as the piling works have been completed under the EP-139/2002/A and further piling is not required, the PAFF is unlikely to increase the duration of the aforementioned pressures and is not likely to increase the intensity of impact and synergistic impacts are not predicted. As such, no significant adverse cumulative marine ecological impacts due to the PAFF construction are envisaged.

<u>Cumulative Impacts to the Marine Park and SSSI</u>

7.6.7.5 Previous studies that have evaluated the potential impacts from contaminated mud disposal at the empty marine borrow pits at East Sha Chau (ERM, 1997) and sand dredging around The Brothers (Hyder Consultants, 1998) have concluded that there is likely to be no cumulative impacts to the Sha Chau and Lung Kwu Chau Marine Park through these activities. Based on the aforementioned studies, it is not envisaged that cumulative impacts attributable to PAFF will impact the Sha Chau and Lung Kwu Chau Marine Park as the construction-phase of the PAFF project is short-term (months) whereas the aforementioned dumping and dredging projects are longer-term (years). The PAFF project also has less overall potential impacts than would be associated with disposal of contaminated muds. The potential cumulative construction-phase impacts to the Marine Park are, therefore, considered to be insignificant.

7.7 Prediction and Evaluation of Operational Phase Impacts

7.7.1 Aviation Fuel Spill

7.7.1.1 As discussed in Section 7.6 above, the majority of potential ecological impacts are associated with the construction phase. During operation of the PAFF there is potential for ecological impacts due to an accidental fuel spillage or leakage from a ruptured pipe. The major ecological risks associated with fuel spills are discussed in Section 11.

7.7.2 Disturbance to the Benthic Habitat

7.7.2.1 No disturbance of the seabed due to the operation of the PAFF is anticipated as maintenance dredging will not be required for the PAFF project. There will, therefore, be no operational impacts to benthic fauna and corals as a result of the operation of the project.

7.7.3 *Disturbance to Indo-Pacific Humpback Dolphin*

7.7.3.1 The major potential operational impacts to the dolphin are associated with potentially elevated submarine noise due to vessel movement and berthing, the potential for physical impacts with vessels and cumulative effects attributable to this and other projects in the PAFF study area.

<u>Noise</u>

7.7.3.2 Cetaceans are known to be sensitive to elevated noise and generally avoid areas subjected to high levels of noise disturbance. Noise generated through the operation of the fuel transporting vessels (such as through pumping of fuel) is the major sources of operational phase sounds.

7.7.3.3 The primary sources of sounds from vessels are due to the boat propeller and related machinery (Greene and Moore, 1995). Larger vessels create stronger and lower frequency sounds as they have greater power than smaller vessels and also have slower turning engines and propellers (Greene and Moore, 1995). Noise from smaller boat traffic has led to changes in the acoustic behaviour of Indo-Pacific Humpback dolphin populations in Australia and dolphins significantly increased their rates of whistling during passage of boats within a range of 1.5 km and it was hypothesised that noise emitted from passing vessels affects social group cohesion (Van Parijs and Corkeron, 2001). Mother and calf pairs appeared to be the most affected by transiting vessels and increased rates of whistling were attributed to the need to re-establish vocal contact (Van Parijs and Corkeron, 2001). Whether such increased rates of whistling have a long-term detrimental effect on dolphins is unclear and these observations may only reflect normal behaviour to re-establish contact with the calf when threatened by predators (or perceived predators such as fast moving vessels).

7.7.3.4 The lower frequency sounds (< 250 Hz) emitted from larger vessels, however, although still detectable by dolphins, have less of an impact than high frequency sound (ERM, 1995; Wursig *et al*., 2000) and based upon this the PAFF tankers are not predicted to induce considerable disturbance above that already caused by the high volume of vessel traffic in the area. Anecdotal evidence suggests that the dolphins avoided the area around The Brothers during the airport construction (although this was a considerably larger project than the PAFF) however they returned on cessation of construction activities suggesting that disturbance impacts are transient and only present during the construction phase (Hyder, 1998). Further evidence for noise-induced avoidance was observed immediately after the AFRF construction. Immediately following construction of the AFRF, dolphin numbers declined in the area (recorded during the period of Spring 1997) although further surveys (Summer and Autumn 1997; and more recent survey work) revealed that there was an influx of individuals back into the area (Jefferson, 2000a, 2000b, 2005) indicating that temporary avoidance of areas due to noise does not have a long-term detrimental effect on the population.

7.7.3.5 It should be noted that the waters adjacent to the PAFF are used by a large number of vessels and a busy shipping channel (Urmston Road) is also present although the area is nevertheless highly utilised by dolphins. It would, therefore, appear that dolphin populations have habituated to the high density of vessel traffic present in the Northwestern waters. It is unlikely that the level of noise generated by the fuel vessels visiting the PAFF during the operational phase will be significantly above background, with the vessels predicted to constitute only 0.2%of the existing marine traffic volume (see Table 3.3).

7.7.3.6 The sounds emitted from the largest ocean-going vessels (supertankers) are lower (~ 170 dB) than those from strong transient sources such as percussive piling (Greene and Moore, 1995; Wursig *et al*., 2000). Owing to the transient nature of the fuel vessels visiting the PAFF (initially about three vessels will visit and later less than four per week are predicted during the maximum operation in 2040), the overall reduction in fuel vessel traffic in the study area and the current high utilisation of these waters by dolphin populations, the potential for habituation to vessel traffic appears noise to be strong. The operational noise from the fuel vessels is, therefore, likely to represent an insignificant impact to Indo-Pacific Humpback dolphins.

Collisions with Fuel Vessels

7.7.3.7 There is evidence in Hong Kong to suggest that some injuries observed on stranded Indo-Pacific Humpback dolphins are due to collisions with marine vessels and ship propellers (Jefferson, 2000a, 2005; Parsons and Jefferson, 2000a). It is likely that the majority of these injuries are caused by fast-moving vessels such as motorboats where avoidance measures are more difficult to implement.

7.7.3.8 The study area is presently utilised by a large volume of marine traffic (mostly comprised of cargo vessels, tugs, barges and fishing vessels; Jefferson, 2000b) and a relatively small number of strandings appear to be due to direct boat collisions (three dolphin carcasses were recorded in Hong Kong with wounds consistent with injuries attributable to vessel collisions between May 1993 and March 1998; Parsons and Jefferson, 2000a). Although only three carcasses were recorded during this period with physical injuries consistent with vessel collision, the small number is likely to be an underestimate of deaths due to collisions as the cause of death is often difficult to ascertain due to decomposition of the carcass. The vessels used for transporting the fuel are, however, large (10,000-80,000 dwt) and relatively slow compared to the motorboats used by fishermen and the high-speed ferries operating in the area (also note that fuel vessels will unlikely to operate at full speed when traversing the area and during the berthing at the PAFF jetty). The fuel-transporting ships that will berth at the PAFF have a greater capacity than those currently berthing at the AFRF. These larger fuel vessels will also only need to berth at the PAFF at a frequency of three per week compared to the current more frequent visits required at the AFRF (where fuel transporting vessels currently berth about 14 times per week). Even during maximum operation, it is also only anticipated that a small number of vessels will visit the PAFF and operational impacts due to physical impact with fuel-carrying vessels are, therefore, extremely unlikely (three visits per week are initially required and an average of 3.6 vessels per week are predicted during maximum operation in 2040, Table 3.2). There is, therefore, an overall reduction in the number of vessels in the study area and the potential for collision with the fuel vessels is predicted to represent an insignificant impact.

7.8 Mitigation Measures

7.8.1 Marine Ecology

7.8.1.1 As presented in Annex 16 of the TM, mitigation measures for projects in important habitat and relating to wildlife in order of priority are:

- avoidance;
- minimising; and
- compensation.

7.8.1.2 The preferred location for construction of the PAFF and pipeline options has been assessed previously (see Section 2) and the proposed scheme selected in order to avoid the key ecological receivers present and important habitats, primarily the key ecological receivers present in the study area including the Indo-Pacific Humpback dolphin.

7.8.1.3 No adverse changes in water quality have been predicted. As detailed in Section 6.4.6, based on trailer suction hopper dredging (this represents the worst case and covers the use of the grab dredger), suspended solids in the upper surface layer rarely exceed 5 mg l^{-1} throughout the whole study area. Although a short-lived patch of 10 mg l^{-1} was predicted in waters to the east of Lung Kwu Chau and this concentration is well below the ambient background levels occasionally recorded in the study area (often > 100 mg l^{-1}; Mouchel, 2001a; 2001c). The highest sediment concentrations suspended during dredging are predicted in the bottom layers. It should be noted that the patches generated by the trailer dredger are predicted to be highly localised generally below 10mg l^{-1} within a few hundred meters of the dredging point. These sediment patches generated in the deeper waters are predicted to be generally quickly dissipated (such as by the fast currents of the Urmston Road). Patches in the shallower waters around Sha Chau and Lung Kwu Chau may persist longer although no significant deposits are predicted in the study area. As the suspended solids generated by trailer suction hopper dredging are predicted to be short-lived localised pulses, they are not of ecological concern to the sensitive receivers such as hard corals in the study area.

7.8.1.4 The mitigation measures designed to prevent adverse impacts to water quality (for example, using dredging operations that minimise sediment suspension) will also be effective in preventing impacts to the marine ecological receivers. It is, therefore, anticipated that no specific mitigation measures to protect marine ecological receivers (with the exception of Indo-Pacific Humpback dolphin) are required. Owing to the sensitive nature of project near the Sha Chau and Lung Kwu Chau Marine Park, the pipeline has made use of the dredged channel for the AFRF and in doing so has avoided impacts on previously undisturbed seabed and associated fauna.

7.8.1.5 As cetaceans are affected by noise, certain project-specific mitigation measures relating to noise mitigation have been recommended for the protection of the dolphin population inhabiting the area. These recommended mitigation measures are described below.

7.8.2 Indo-Pacific Humpback Dolphin

7.8.2.1 There was intensive monitoring of the noise emissions from the hammer used in the piling at the AFRF (Wursig *et al*., 2000) and these data can be used to provide suitable information for comparison of the magnitude of likely impacts in the proposed PAFF. As the hammer used in the piling of PAFF jetty is similar and likely to emit similar noises, impacts to dolphins would be considered to be of a similar magnitude.

7.8.2.2 Unmitigated construction-phase percussive piling was considered to represent a moderate to severe but transient (estimated to last a duration of about 120 days) impact to dolphin populations in the vicinity (within 500m) of the PAFF jetty construction works and minor impacts may be induced further afield (up to a 1000 m from the piling at which distance piling noise cannot be differentiated with confidence from background; Wursig *et al*., 2000).

7.8.2.3 However, it should be noted, that as detailed in Section 1, some construction works have been undertaken in accordance with Environmental Permit EP-139/2002/A and before works were suspended following the Judgement of the Court of Final Appeal of July 2006. As detailed in Table 1.1, the percussive piling for the jetty was one of the activities that has been completed. The EP required that numerous mitigation measures be undertaken before, during and after the marine piling was undertaken. The following measures were undertaken in accordance with the EP:

- Bubble Jacket and Bubble Jacket Trail: In order to mitigate the submarine noise from the percussive piling, a piling system based on a sequestered air-stream bubble jacket or similar, as presented in Figure 7.4, was recommended in the previous EIA (April 2002) to counter the problem of bubble dispersion as the air stream and ensure the bubbles are enclosed by an outer jacket thereby concentrating the bubbles vertically up the pile. Condition 3.2 of the previous EP-139/2002/A stated that a trial of the bubble jacket should also be carried out to demonstrate a noise attenuation effect of 3dB and achieve the following underwater mitigated noise levels:

Distance from Piling (m)	dB goal
250	162
500	152
1000	145

Based upon this requirement, a trail of the bubble jacket was undertaken in March 2004 and a Bubble Jacket Trial Summary Report issued in January 2005. A copy of the report is provided in Appendix F1. The 3 day trial considered two general designs of the bubble jacket, termed the Canadian Bubble Jacket and the Fixed Steel Bubble Jacket with variations of these designs creating 7 options for assessment overall. The results showed that Option 7, a Fixed Steel Bubble Jacket combined with the lowest ring of the Canadian bubble jacket mitigated the noise sufficiently within the Dolphin Sensitive Range to meet the above requirements at all distances. The details and recommendations of the Bubble Jacket Trial were presented to the Advisory Council on the Environment (ACE) on 14th March 2005 and approved the recommendations of the report. The paper submitted to the ACE, together with their approval letter, is detailed in Appendix F2. The recommended Bubble Jacket Design was applied during the percussive piling.

- Dolphin Exclusion Zone Around the Piling Barge: this was implemented within a radius of 500m around the piling barge during piling activities and the area visually inspected for dolphins for a period of 30 minutes (thereby adequately spanning the approximate maximum dive time of the dolphins of 4 minutes) prior to commencement of each piling episode.

- Acoustic Monitoring: Spot acoustic monitoring of the exclusion zone was undertaken for three days of the first week of piling in order to confirm that dolphins were not being missed by the visual monitoring.

- Noise Monitoring During Piling: This was undertaken in order to confirm the underwater noise levels indicated above were achieved. Measurements were taken at three testing locations from the pile driver, namely 250, 500 and 1000m meter intervals west of the pile driver and recordings taken over the initial three days of the first week of piling.

- Seasonality of Piling: The piling avoided April to June to avoid the highest frequency of calving.

- Acoustic Decoupling: Air compressors and other noisy equipment mounted on the steel piling barge was acoustically-decoupled to the greatest extent feasible.

- “Ramping-up” of Piling Hammer: The piling hammer was “ramped–up” to gradually increase the noise levels after the 30 minute visual inspection had been completed. The "ramp-up" period lasted about 2-3 minutes, to allow dolphins to move a safe distance from the area.

- Dolphin Data Review: It was recommended that a review of longer term data would be needed as the construction period would be going on several years after the initial review and the distribution of dolphins and densities may change over time. Therefore, prior to the commencement of construction works a review of all new available dolphin data for North Lantau waters was recommended. As some construction activities commenced in November 2005, before the Judgement of the Court of Final Appeal of July 2006, the baseline review for dolphins was undertaken in late 2005 and the results are provided in Appendix F3. The post piling monitoring specified below (Section 7.8.2.8) should ensure that any shifts in dolphin distribution due to piling are detected.

- Dolphin Monitoring: In order to ensure that any shifts in dolphin distribution due to piling are detected and to determine the efficacy of the recommended mitigation measures, six one-day pre-construction monitoring surveys of dolphin abundance were undertaken in late 2005 and the results are provided in Appendix F3. The results will be compared with the post-construction dolphin abundance monitoring, due to be undertaken for 6 days during a period of 28 days prior to the operation of the PAFF. The methodology used for the pre-construction dolphin abundance monitoring is the same as that recommended for the post-construction surveys detailed in Section 7.8.2.8 below.

7.8.2.4 However, while the piling activities have been completed, the dredging for the pipeline will need to be undertaken and as such the following mitigation measures are recommended.

Dolphin Exclusion Zone: Around the Dredger

7.8.2.5 There does not appear to be any evidence to suggest that dredging activity has any deleterious impact to dolphins. No unacceptable adverse impacts are predicted to dolphin populations as a consequence of pipeline construction and as such no mitigation is required. Nevertheless, several precautionary measures detailed in this section and the sections below are recommended to further minimise any possible impacts. Such measures include the use of an exclusion zone around the dredging operation within the Marine Park and along the entire length of the pipeline should be implemented and dredging should not commence until the area is clear of dolphins. A dolphin exclusion zone within a radius of 250m around the dredger should be implemented and the area visually inspected for dolphins prior to commencement of dredging. Although this exclusion zone is smaller than required for piling, as dredging is a considerably less intrusive activity, 250m is considered appropriate (Jefferson pers. comm.). In addition, as indicated in Section 6.4.6, the dredging plume is not expected to extend more than 100-200m from the dredger and as such a 250m exclusion zone is considered to be sufficient. The dolphin exclusion zone should be monitored by independent dolphin observers with an unobstructed, elevated view of the area. Dredging should not begin until the observer certifies that the area is continuously clear of dolphins for a period of 30 minutes (thereby taking into account the approximate maximum dive time of the dolphins of 4 minutes). Following the 30 minute scan and when the area is found to be clear of dolphins, dredging may commence. Should dolphins move into the area during dredging, cessation of dredging is not required.

7.8.2.6 In addition, as such a measure relies on the visual detection of dolphins, it is not suitable during evening and nighttime. Based upon this, dredging works will be restricted to a daily maximum of 12 hours within daylight hours except for the section crossing Urmston Road Channel. The Urmston Road section of the pipeline is shown in Figure 7.5.

Avoidance of Calving Season

7.8.2.7 According to recent dolphin data (AFCD, 2005) the dolphin calving season is from March to August and about 76% of calves are born in this period. Thus, in order to minimise disturbance to mother and calves, it is recommended that the dredging along the entire length of the pipeline will avoid this main calving season.

Dolphin Monitoring

7.8.2.8 In order to ensure that any shifts in dolphin distribution due to piling are detected and to determine the efficacy of the recommended mitigation measures, post construction monitoring of dolphin abundance is required for comparison with the pre-construction monitoring undertaken prior to the piling works in late 2005 as detailed above. Should dolphin sighting numbers be significantly different (taking into account naturally occurring alterations to distribution patterns such as due to seasonal change) to the pre-construction activity (following the post-construction monitoring) recommendations for a further post-construction monitoring survey will be made. Data should then be re-assessed and the need for any further monitoring established. Comparison of the post construction dolphin monitoring with that of over the pre-construction dolphin monitoring will allow the assessment of the overall efficacy of the project-specific mitigation measures and an Action Plan for the dolphin is included in the EM&A Manual and Appendix F4 of this report.

7.8.2.9 A monitoring programme is required to be undertaken during both a 28 day period prior to construction activities and during a period of 28 days on cessation of construction. The period required for the post-construction monitoring is based on the monitoring conducted for the AFRF and is considered to be adequate to derive a reasonably large amount of data thereby allowing any significant trends in dolphin distribution to be detected (Jefferson pers. comm.). Six, one-day survey events will be undertaken within the 28 consecutive day period for the post-construction monitoring events (Jefferson and Leatherwood, 1997).

7.8.2.10 The monitoring should also be undertaken by a suitably qualified person (in biology) and should be independent of the construction contractor and should form part of the independent Environmental Team (ET). The IEC may audit the work of the ET if deemed necessary. Monitoring will be conducted following the methodology detailed below.

Vessel-based Observations

7.8.2.11 Line transect surveying techniques have now been standardised in Hong Kong Special Administrative Region Waters so that data from all surveys are directly comparable. The study area with line transects is presented in Figure 7.3a. In order to provide a suitable long-term dataset for comparison, post construction phase dolphin monitoring will employ an identical methodology and follow the same line transects as those presented in Figure 7.3a.

7.8.2.12 On each survey day, the survey vessel will depart from Tung Chung New Pier. Observation for incidental sighting will begin immediately on departure from the assigned pier and continue until the vessel reaches the survey area. The survey vessel shall have an open upper deck, allowing for observer eye heights of 4 to 5m above water level and relatively unobstructed forward visibility between 270° and 90°. When on-effort, the vessel shall travel along the survey lines at a speed of approximately 7 to 8 knots (13 to 15 km/hr). The direction of the survey shall be alternated on different days to avoid possible biases related to the timing of the survey coverage.

7.8.2.13 Vessel-based transect observations by a three-person team shall be conducted by searching the 180° swath in front of the survey vessel (270° to 90°). The area behind the vessel need not be searched, although dolphins observed in this area should be recorded as off-effort sightings. The primary observer will scan the entire search path (270° to 90°) continuously with Fujinon 7X50 marine binoculars or equivalent as the second member of the team, designated the data "recorder", scans the same area with the naked eye and occasional binocular check. The third observer on the boat is required to rotate into the observation team after half an hour, thus relieving one of the initial team. Observers should rotate every half an hour. While on-effort, observers shall ignore potential sighting cues that could bias the sighting distance calibration (eg pair-trawl fishing vessels).

7.8.2.14 A critical consideration in the survey will be to ensure a strict timed quantification of "sighting effort" in order to maximise the comparative value of the field survey results. The time and position for the start and end of a period of intensive, uninterrupted effort, and the sighting conditions such as visibility range and Beaufort scale associated with it shall be recorded. The collection of effort data allows comparisons within a single study as well as between studies. Strict recording of time and speed travelling along the assigned transect ("on-effort") shall, therefore, be recorded. Time spent during any deviation from the transect will be recorded as "off-effort".

7.8.2.15 During periods of poor weather, when visibility is hindered (e.g., below 1km) or when a Beaufort force 5 is reached, the survey should normally be postponed.

7.8.2.16 Sightings distant to 500m perpendicular distance and sightings of single dolphins that were hard to track should not be pursued (although those distant to 500m ahead of the vessel should be pursued). The initial sighting distance between the dolphin and the survey vessel and sighting angle shall be recorded in order to estimate the positions of the dolphins. These and other details of the sighting, including the exact location of the sighting and number of individuals should be agreed among the observation team and recorded immediately. Distances and angles shall be as accurate as possible.

7.8.2.17 A global positioning system shall be used during the surveys. A sighting record shall be filled out at the initial sighting with time, position, distance and angle data filled in immediately and verified between primary observer and recorder. All other information on sea state, weather conditions (Beaufort Scale), as well as notes on dolphin appearance, behaviour, and any other information shall also be completed.

7.8.2.18 An action plan has also been defined to indicate that should dolphin numbers be significantly different (taking into account naturally occurring alterations to distribution patterns such as due to seasonal change) to the pre-construction activity following the 28 days post-construction monitoring, recommendations for a further 6 days monitoring within a 28 day period will be required. The action plan should be undertaken within a period of 1 month after a significant difference has been determined. For the purpose of the EM&A works, the "significance" level which will trigger the action plan shall be proposed by the ET as part of the post-construction monitoring programme design to be agreed with AFCD prior to the monitoring being undertaken. The action plan is detailed in Appendix F4 of this report and in the EM&A Manual.

7.8.2.19 It should be noted that as some construction activities commenced in November 2005, before the Judgement of the Court of Final Appeal of July 2006, the pre-construction abundance monitoring was undertaken in late 2005 and the results are provided in Appendix F3. As such, the post-construction dolphin abundance monitoring will be required to be undertaken for during a period of 28 days prior to the operation of the PAFF.

7.9 Conclusions and Recommendations

7.9.1 Providing good on-site working practice and the recommended mitigation measures are adhered to, significant ecological impacts are not anticipated from either the construction or operational phase of the PAFF project. The major sensitive ecological receiver of concern in the study area is the Indo-Pacific Humpback dolphin. Noise from percussive piling for the jetty at Tuen Mun Area 38 was determined to be the major potential impact to this species and the mitigation measures recommended in the previous EIA (April 2002) and the EP-139/2002/A were followed during the piling activities, which are now complete. Further precautionary mitigation measures are also detailed above and based upon the implementation of these, insignificant impacts are predicted.

7.10 Residual Ecological Impacts

7.10.1 Provided that the mitigation measures recommended above are implemented, there are no adverse residual ecological impacts predicted for either the construction or operational phases of the project.

7.11 Environmental Monitoring and Audit Requirements

7.11.1 The post construction monitoring will prove valuable in assessing the overall efficacy of the project-specific mitigation measures implemented. The monitoring shall be undertaken in accordance with the methodology detailed above. An action plan has also been defined to indicate that should dolphin numbers be significantly different (taking into account naturally occurring alterations to distribution patterns such as due to seasonal change) to the pre-construction activity following the 6 days of post-construction monitoring, recommendations for a further period of monitoring will be required. This action plan is detailed in the EM&A Manual and also presented in Appendix F4 of this report.

7.11.2 It should be noted that as some construction activities commenced in November 2005, before the Judgement of the Court of Final Appeal of July 2006, the pre-construction abundance monitoring was undertaken in late 2005 and the results are provided in Appendix F3. As such, the post-construction dolphin abundance monitoring will be required to be undertaken for 6 days during a period of 28 days on cessation of construction.

7.11.3 As no other significant impacts on other marine fauna is predicted, no further EM&A is considered to be required during either the construction or operational phases of this project. EM&A requirements during the construction phase are described in more detail in Section 15 of this report and in the EM&A Manual.

7.12 References

Binnie Consultants (1995). *REMOTS and Grab Survey to Assess Benthic Recolonisation following backfilling at East of Sha Chau (East) Marine Borrow Pit*. Prepared for CED.

Broom MJ, Ng AKM (1996). Water quality in Hong Kong and the influence of the Pearl River. In: *Coastal Infrastructure Development in Hong Kong: A Review*. Proceedings of the Symposium on Hydraulics of Hong Kong Waters. Civil Engineering Department, Hong Kong Government, pp. 193-213.

Brown BE, Howard LS (1985). Assessing the effects of 'stress' on reef corals. In: *Advances in Marine Biology*. (Eds. Blaxter JHS, Russel FS and Yonge CM) Academic Press, London, Volume 22, pp. 1-63.

CCPC (2002). *Consultancy Study on Marine Benthic Communities in Hong Kong*. Prepared for AFCD.

Chiu HMC, Morton B (1999). The distribution of horseshoe crabs (*Tachypleus tridentatus* and *Carcinoscorpus rotundicauda*) in Hong Kong. *Asian Marine Biology* **16**, 185-196.

ERM (1995). *Proposed Aviation Fuel Receiving Facility at Sha Chau: Environmental Impact Assessment*. Prepared for the Provisional Airport Authority.

ERM (1997). *Environmental Impact Assessment Study for Disposal of Contaminated Mud in the East of Sha Chau Marine Borrow Pit*. Prepared for CED.

ERM (2001). *Environmental Monitoring and Audit for Contaminated Mud Pit IV at East Sha Chau*. Twelfth Quarterly Report, August to December 2000. Prepared for CED.

ERM (2005). *Detailed Site Selection Study for a Proposed Contaminated Mud Disposal Facility within the Airport East/East of Sha Chau Area. Environmental Impact Assessment and Final Site Selection Report*. Prepared for the CEDD.

ERM (2006). *Permanent Aviation Fuel Facility (EP-139/2002/A) Revised Baseline Review and Pre-Construction Phase Dolphin Monitoring Report*. Prepared for Airport Authority Hong Kong.

EVS (1996). *Review of Contaminated Mud Disposal Strategy and Status Report on Contaminated Mud Disposal Facility at East Sha Chau*. Prepared for CED.

Fong TCW (1999). Tai Ho Wan: breeding and nursery ground of horseshoe crabs. *Porcupine!* **20**: 8.

Greene CR, Moore SE (1995). Man-made noise. In: *Marine Mammals and Noise*. (Eds. Richardson WJ, Greene CR, Malme CI and Thomson DH). Academic Press. London, pp. 101-158.

Huang Q (1997). Hong Kong's horseshoe crabs. *Porcupine!* **16,** 17-18.

Hung SKY (2005). *Monitoring of Chinese White Dolphins (Sousa chinensis) in Hong Kong Waters. Data Collection Final Report*. Prepared for AFCD.

Hyder (1998). *Supplement EIA for the Proposed Sand Extraction from the Brothers Marine Borrow Area*. Prepared for CED.

Jefferson TA (1998). *Population Biology of the Indo-Pacific Hump-backed Dolphin (*Sousa chinensis *Osbeck, 1765) in Hong Kong Waters: Final Report*. Prepared for AFD.

Jefferson TA (2000a). Population biology of the Indo-Pacific Hump-backed dolphin in Hong Kong waters. *Wildlife Monographs* **144**, 1-65.

Jefferson TA (2000b). *North Lantau Dolphin Monitoring, Operation Phase B Aviation Fuel Receiving Facility at Sha Chau*. Prepared for AFSC Operations Ltd.

Jefferson TA (2005). *Monitoring of Indo-Pacific Humpback Dolphins (Sousa chinensis) in Hong Kong Waters. Data Analysis Final Report*. Prepared for AFCD.

Jefferson TA, Karczmarski L (2001). *Sousa chinensis*. *Mammalian Species* No. 655, 1-9.

Jefferson TA, Leatherwood S (1997). Distribution and abundance of Indo-Pacific Hump-backed dolphins (*Sousa chinensis* Osbeck, 1765) in Hong Kong waters. *Asian Marine Biology* **14**, 93-110.

Jefferson TA, Hung SKY (2004). A review of the status of the Indo-Pacific humpback dolphin in Chinese waters. *Mammalian Species* (*Special Issue*) **30**: 3-17.

Liao YY, Hong SG, Li XM (2001). A survey on the horseshoe crabs in the north of South China Sea. *Acta Zoologica Sinica* **47,** 108 – 111.

Liu JH, Hills P (1997). Environmental planning, biodiversity and the development process: the case of Hong Kong's Chinese white dolphins. *Journal of Environmental Management* **50**, 351-367.

Lu L, Wu RSS (1998). Recolonization and succession of marine macrobenthos in organic-enriched sediment disposed from fish farms. *Environmental Pollution* **101**, 241-251.

Maunsell (2002). Environmental Impact Assessment Study for Construction of Lung Kwu Chau Jetty Final Environmental Impact Assessment Report. Prepared for CED.

Meinhardt (2006a). *Environmental Monitoring and Audit for Contaminated Mud Pit IV at East Sha Chau (2000-2005). 4th Annual Review Report*. Prepared for CEDD.

Meinhardt (2006b). *Environmental Monitoring and Audit for Contaminated Mud Pit IV at East Sha Chau (2000-2005). 17th Quarterly Report for May to July 2005*. Prepared for CEDD.

Meinhardt (2006c). *Environmental Monitoring and Audit for Contaminated Mud Pit IV at East Sha Chau (2000-2005). 18th Quarterly Report for August to October 2005*. Prepared for the CEDD.

Meinhardt (2006d). *Environmental Monitoring and Audit for Contaminated Mud Pit IV at East Sha Chau (2000-2005). 19th Quarterly Report for November to December 2005*. Prepared for the CEDD.

Meinhardt Mouchel (2004). Ecological Monitoring for Uncontaminated Mud Disposal - Investigation. Prepared for the CEDD.

Morton B (1994). Hong Kong's coral communities: Status, threats and management plans. *Marine Pollution Bulletin* **29**, 74-83.

Morton B (1998). Hong Kong's Marine Parks Ordinance and designation of the first marine parks and reserve: where next? In: *The Marine Biology of the South China Sea*. Proceedings of the Third International Conference on the Marine Biology of the South China Sea, Hong Kong. (Ed. B Morton). Hong Kong University Press, pp. 541-561.

Morton B, Morton J (1983). *The Sea Shore Ecology of Hong Kong*. Hong Kong University Press, Hong Kong.

Mott Connell Ltd. (2003). *Tung Chung Cable Car Project, EIA*. Prepared for MTR Corporation.

Mouchel (1996). *Environmental Monitoring and Audit for Contaminated Mud Pits II and III at East Sha Chau*. Prepared for CED.

Mouchel (2001a). *Environmental Monitoring and Audit for Contaminated Mud Pit IV at East Sha Chau*. First Quarterly Report, May to July 2001. Prepared for CED.

Mouchel (2001b). *Marine Ecology Baseline Survey for Castle Peak Road Improvements between Area 2 and Ka Loon Tsuen Wan*. Prepared for Highways Department.

Mouchel (2001c). *Environmental Monitoring and Audit for Contaminated Mud Pit IV at East Sha Chau. Additional Monitoring Programme: Final Report on Intensive Water Quality Monitoring for Maintenance Capping (October 2001).* Prepared for CED.

Mouchel (2002a). *Environmental Assessment Study for Backfiling of Marine Borrow Pits at North of the Brothers. Environmental Assessment Report*. Prepared for CED.

Mouchel (2002b). *Environmental Monitoring and Audit for Contaminated Mud Pit IV at East Sha Chau (2000-2005). 2nd Quarterly Report for May to July 2001*. Prepared for CED.

Mouchel (2004). *Hong Kong- Zhuhai- Macao Bridge: Hong Kong Section and the North Lantau Highway Connection: Ecological Baseline Survey Final 9 Month Ecological Baseline Survey Report*. Prepared for the Highways Department.

Mouchel (2005a). *Environmental Monitoring and Audit for Contaminated Mud Pit IV at East Sha Chau (2000-2005). 15th Quarterly Report for November 2004 to January 2005*. Prepared for the CEDD.

Mouchel (2005b). *Environmental Monitoring and Audit for Contaminated Mud Pit IV at East Sha Chau (2000-2005). 16th Quarterly Report for February to Apirl 2005*. Prepared for CEDD.

Nicholson S (2001). Biological-based screening in the management of contaminated dredged sediment in Hong Kong. *Setac Globe* **2** (4), 38-40.

Parsons ECM, Felley ML, Porter LJ (1995). An annotated checklist of cetaceans recorded from Hong Kong's territorial waters. *Asian Marine Biology* **12**, 79-100.

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

Richardson WJ (1995). Introduction. In: *Marine Mammals and Noise*. (Eds. Richardson WJ, Greene CR, Malme CI and Thomson DH). Academic Press. London, pp. 1-13.

Rogers CS (1990). Response of coral reefs and reef organisms to sedimentation. *Marine Ecology Progress Series* **62**, 185-202.

Scott PJB (1984). *The Corals of Hong Kong*. Hong Kong University Press, Hong Kong.

Shin PKS (1989). Natural disturbance of benthic infauna in the offshore waters of Hong Kong. *Asian Marine Biology* **6**, 193-207.

Shin PKS (1990). Benthic invertebrate communities in Tolo Harbour and Mirs Bay: A review. In: *The Marine Flora and Fauna of Hong Kong and Southern China*. Proceedings of the Second International Marine Biological Workshop. (Ed. B Morton). Hong Kong University Press, pp. 883-898.

Shin PKS (1998). Biodiversity of subtidal benthic polychaetes in Hong Kong coastal waters. In: *The Marine Biology of the South China Sea*. Proceedings of the Third International Conference on the Marine Biology of the South China Sea, Hong Kong. (Ed. B Morton). Hong Kong University Press, pp. 57-74.

Shin PKS, Lam WKC (2001). Development of a marine sediment pollution index. *Environmental Pollution* **113**, 281-291.

Shin PKS, Thompson GB (1982). Spatial distribution of the infaunal benthos of Hong Kong. *Marine Ecology Progress Series* **10**, 37-47.

Tam NFY, Wong YS (2000). *Hong Kong Mangroves*. City University of Hong Kong Press.

Van Parijs SM, Corkeron PJ (2001). Boat traffic affects the acoustic behaviour of Pacific humpback dolphins, *Sousa chinensis*. *Journal of the Marine Biological Association of the U.K.* **81**, 533-538.

Whiteside, PGD (2000). Natural geochemistry and contamination of marine sediments in Hong Kong. In: *The Urban Geology of Hong Kong* (Eds. A Page and SJ Reels). Geological Society of Hong Kong Bulletin number 6, pp. 109-121.

Wu RSS, Richards J (1981). Variation in benthic community structure in a sub-tropical estuary. *Marine Biology* **64**, 191-198.

Wursig B (1995a). *Potential Effect of a Proposed Aviation Fuel receiving Facility at Sha Chau on the Health and Survivability of the Indo-Pacific Humpback (Chinese White) Dolphin,* Sousa chinensis, *in Waters North of Lantau Island, Hong Kong Territory*. Prepared for the Provisional Airport Authority.

Wursig B (1995b). *Health and Survivability of the Indopacific Humpback (Chinese White) Dolphin,* Sousa chinensis*: Recommended Mitigation and Research Needs Relative to a Proposed Aviation Fuel Receiving Facility at Sha Chau, Northwest Hong Kong*. Prepared for the Provisional Airport Authority.

Wursig B, Greene CR, Jefferson TA (2000). Development of an air bubble curtain to reduce underwater noise of percussive piling. *Marine Environmental Research* **49**, 79-93.

AFCD (2005). *Monitoring of Indo-Pacific Humpback Dolphins (Sousa chinensis) in Hong Kong Water – Data Analysis, Final Report*.