6. WATER QUALITY ASSESSMENT

6.1 Environmental Legislation

6.1.1 Water Pollution Control Ordinance

6.1.1.1 The Water Pollution Control Ordinance 1980 (WPCO) (Cap. 358) is the principal legislation governing marine water quality in Hong Kong. Under the provisions of this Ordinance Hong Kong's waters have been divided into a series of Water Control Zones. Water Quality Objectives (WQOs) have been declared to protect the specific beneficial uses and conservation goals of each of the zones.

6.1.1.2 The proposed PAFF at Tuen Mun Area 38, the proposed submarine pipeline routes and the HKIA all lie within the North Western Waters Water Control Zone (NWW WCZ). Marine waters within the NWW WCZ are identified as having the following beneficial uses :

- a source of food for human consumption;
- a commercial fisheries resource;
- a habitat for marine organisms generally;
- recreational bathing beach;
- secondary contact recreation including diving, sailing and windsurfing;
- domestic and industrial supply;
- navigation and shipping; and
- aesthetic enjoyment.

6.1.1.3 Subsequent to the Gazettal of the NWW WCZ the waters around Lung Kwu Chau and Sha Chau have been declared a Marine Park primarily to protect marine mammals which are prevalent in this part of Hong Kong. Also the NWW WCZ is known to support a small coral population. Protection of these species represents key conservation goals for the Hong Kong Government.

6.1.1.4 Relevant Marine WQOs applicable to the NWW WCZ are summarised in Table 6.1 below.

Table 6.1 Water Quality Objectives for the North Western Waters Water Control Zone

Water Quality Objectives
Aesthetic Appearance ➢ There should be no objectionable odours or discolouration of the water. ➢ Tarry residues, floating wood, articles made of glass, plastic, rubber or any other substances should be absent. ➢ Mineral oil should not be visible on the surface. ➢ There should be no recognisable sewage derived debris. ➢ Floating, submerged and semi-submerged objects of a size likely to interfere with the free movement of vessels, or cause damage to vessels, should be absent.

Water Quality Objectives

Bacteria

- The levels of *Escherichia coli* should not exceed 180 counts per 100 ml at bathing beaches, calculated as the geometric mean of all samples collected from March to October inclusive. Samples have to be taken at least 3 times a month at intervals of between 3 and 14 days.
- The levels of *Escherichia coli* should not exceed 610 counts per 100 ml at secondary contact recreation sub-zones, calculated as the geometric annual mean.

Dissolved Oxygen

- The depth averaged concentration of dissolved oxygen should not fall below 4 mg/l for 90% of the sampling occasions during the whole year
- The concentration of dissolved oxygen should not be less than 2 mg/l within 2m of the seabed for 90% of the sampling occasions during the whole year.

pH

- The pH of the water should be within the range 6.5 – 8.5 units.
- Human activity should not cause the natural pH range to be extended by more than 0.2 units.

Temperature

- Waste discharges shall not cause the natural daily temperature range to change by more than 2.0^{o}C.

Salinity

- Waste Discharges shall not cause the natural ambient salinity to change by more than 10%.

Suspended Solids

- Human activity should neither cause the natural ambient level to be raised by more than 30% nor give rise to accumulation of suspended solids which may adversely affect aquatic communities.

Ammonia

- The un-ionised ammoniacal nitrogen level should not be more than 0.021 mg/l calculated as the annual average (arithmetic mean).

Nutrients

- Nutrients should not be present in quantities sufficient to cause excessive or nuisance growth of algae or other aquatic plants
- Without limiting the generality of the above point, the level of inorganic nitrogen should not exceed 0.5 mg/l, or 0.3 mg/l within Castle Peak sub-zone, expressed as the annual water column average.

Toxins

- Waste discharges shall not cause the toxins in water to attain such a level as to produce significant toxic, carcinogenic, mutagenic or teratogenic effects in humans, fish or other aquatic organisms, with due regard to biologically cumulative effects in food chains and to interactions of toxic substances with each other.
- Waste discharges shall not cause a risk to any beneficial use of the aquatic environment.

6.1.2 WPCO Technical Memorandum on Effluent Discharges

6.1.2.1 Any polluting wastewater effluent from the PAFF and associated infrastructure either during construction or subsequent operations would require a discharge permit issued in accordance with the provisions of the WPCO. In setting conditions on required effluent quality the Authority would be guided by the Technical Memorandum issued under Section 21 of the Ordinance. The Technical Memorandum indicates maximum permissible concentrations for a comprehensive suite of pollutants depending on the point of discharge.

6.1.3 EIAO Technical Memorandum on EIA Process

6.1.3.1 Annex 6 and Annex 14 of the EIAO Technical Memorandum stipulate Criteria for Evaluating Water Pollution and Guidelines for the Assessment of Water Pollution, respectively. These must be adhered to in the preparation of an EIA report submitted under the EIAO in pursuance of an Environmental Permit for the project.

6.1.4 Works Bureau Technical Circular on Management of Dredged Sediment

6.1.4.1 No ambient sediment quality acceptability criteria equivalent to the Water Quality Objectives have been defined for Hong Kong. However, an approach was first promulgated under Work Bureau Technical Circular 3/2000 (WBTC 3/2000) for the purposes of assessing the disposal requirements for dredged sediment and this document has now been superceded by the Environment, Transport, and Works Bureau Technical Circular (Works) No. 34/2002 (ETWB 34/2002) in August 2002. The assessment requirements and waste management implications of this document are elaborated in more detail in Section 14 of this report. Within the current Technical Circular, two sets of chemical criteria are identified for assessing potentially toxic sediments:

- Lower Chemical Exceedance Level (LCEL); and
- Upper Chemical Exceedance Level (UCEL).

6.1.4.2 The LCEL is intended to represent levels below which adverse biological effects (or ecotoxicity) are considered to be unlikely. In contrast the UCEL is intended to represent a level beyond which adverse biological effects are considered likely to occur. These criteria therefore represent a convenient means to broadly characterise sediment quality and identify potentially polluted sediments that might be of concern if they are disturbed in the course of the Project. The LCEL and UCEL for the contaminants of interest are presented in Table 6.2.

Table 6.2 ETWB 34/2002 Sediment Quality Criteria for the Classification of Sediment

Contaminants	Lower Chemical Exceedance Level (LCEL)	Upper Chemical Exceedance Level (UCEL)
Metals (mg/kg dry wt.)		
Cadmium (Cd)	1.5	4
Chromium (Cr)	80	160
Copper (Cu)	65	110
Mercury (Hg)	0.5	1
Nickel (Ni)*	40	40
Lead (Pb)	75	110
Silver (Ag)	1	2
Zinc (Zn)	200	270
Metalloid (mg/kg dry wt.)		
Arsenic (As)	12	42
Organic-PAHs (μg/kg dry wt.)		
Low Molecular Weight PAHs	550	3160
High Molecular Weight PAHs	1700	9600
Organic-non-PAHs (μg/kg dry wt.)		
Total PCBs	23	180
Organometallics (μg TBT/L in Interstitial water)		
Tributyltin*	0.15	0.15

* The contaminant level is considered to have exceeded the UCEL if it is greater than the value shown.

6.1.5 Others

6.1.5.1 Marine water pollution control is also effected by means of the Dumping at Sea Ordinance which covers the dumping of waste material, including dredged spoil, at sea. The implications of this are discussed separately in Section 14 of this report.

6.2 Existing Conditions

6.2.1 *Introduction*

6.2.1.1 The North Western Waters are situated at the mouth of the Pearl River Estuary and as such are heavily influenced by the massive freshwater flows from the hinterland. There is a distinct seasonality. The estuarine influence is especially pronounced in the wet summer months when the freshwater flows are greatest and a strong salinity and temperature stratification is evident. During winter months water conditions are more typically marine and salinity and other parameters vary less with depth.

6.2.1.2 Water temperature ranges between about 15^0C and 30^0C over an annual cycle with a mean of about 22^0C to 23^0C. Salinity typically varies within the range 10 to 32 ppt.

6.2.1.3 The Pearl River carries very heavy loads of suspended sediment and nitrates and as a consequence concentrations of these parameters within North Western Waters are variable but generally far higher than in the more oceanic influenced waters to the south and east of Hong Kong.

6.2.2 Existing Pollution Sources and Activities

6.2.2.1 The NWW WCZ contains several significant sewage outfalls (Pillar Point, Northwest New Territories and Siu Ho Wan) and cooling water discharges from a number of users including Castle Peak Power Station, Hong Kong International Airport (HKIA) and Shiu Wing Steelworks.

6.2.2.2 In the past, dredging of marine mud and sand extraction has been extensive in the North Western Waters coastal area for reclamation projects including the proposed PAFF site at Tuen Mun Area 38, the River Trade Terminal, Tin Shui Wai New Town and the HKIA platform at Chek Lap Kok. Mud dredging to construct and maintain the navigation channel in the Urmston Road and the berthing area at Castle Peak Power Station is periodic and on-going and the present temporary Aviation Fuel Receiving Facility (AFRF) at Sha Chau required the construction of a navigation channel and berthing area, which is also subject to maintenance dredging. To date, no adverse environmental impacts have been reported for any of these previous dredging exercises which have involved the removal of much larger quantities of marine mud than will be required for excavation of the pipeline route.

6.2.2.3 Disposal of contaminated dredged material, which began in 1992, is also on-going at the Contaminated Mud Pits (CMP) at East of Sha Chau. The capacity of existing pits were predicted to be exhausted by early 2009 and two potential sites for future CMPs near the HKIA have been identified (ERM, 2005) (Figure 6.1) and the EIA for the tentative sites have been approved by the DEP. Disposal of category M material that passes biological screening / uncontaminated dredged material continues intermittently at the North Brothers which has a remaining capacity of about 5 Mm^3. The operation of the open sea disposal ground at North Lantau Borrow pit has been suspended since 2000 and there is currently no schedule for the reopening of the facility.

6.2.2.4 Commercial trawling is undertaken over much of the North Western Waters and the Urmston Road is a very busy shipping channel for river trade vessels, high speed ferries, large coal vessels servicing Castle Peak Power Station and the existing temporary Aviation Fuel Receiving Facility delivery vessels.

6.2.2.5 The locations of the principal areas of seabed disturbance and the major sewage outfalls in the study area are indicated in Figure 6.1.

6.2.3 Sensitive Receivers

6.2.3.1 There are a number of potentially important sensitive receivers within the study area. These are illustrated in Figure 6.2. They include areas of ecological sensitivity and conservation importance areas, a commercial fishing resource, areas of direct human contact such as bathing beaches and various points where sea water is abstracted for domestic, commercial or industrial purposes. Notwithstanding the importance of protecting water quality generally throughout the NWW WCZ in accordance with the statutory Water Quality Objectives it is especially important to maintain the integrity of the water quality at these specific sites.

6.2.3.2 The Indo-Pacific humpback dolphin *(Sousa chinesis)* is frequently observed within the study area both in and around the Sha Chau and Lung Kwu Chau Marine Park. The North Western Waters of Hong Kong actually represent the eastern range of the Pearl River Estuary dolphin population which extends far into mainland Chinese waters.

6.2.3.3 Tuen Mun is home to a large offshore fishing fleet and the North Western Waters support an important spawning ground and commercial fishery industry for a variety of fish species and also *Penaeid* shrimps.

6.2.3.4 Other features of conservation concern in the wider study area include mangrove stands and seagrasses (*Zostera japonica*, *Halophilia ovata* and *Halopila beccarii*) at Tai Ho and along the Tung Chung Channel south of HKIA at Sha Lo Wan and San Tau. The area also provides preferred habitat for species of horseshoe crab (*Tachypleus gigas*, *Tachypleus tridentatus* and *Carcinoscorpius rotundicauda*) which have been seen near the beaches of Lung Kwu Tan, Lung Kwu Chau, The Brothers, San Tau and Tai Ho Wan. Previous surveys in the Sha Chau area have identified the presence of the stone coral *Faviidea* as well as gorgonians and sea pens which are also of ecological interest.

6.2.3.5 The study area contains two ungazetted bathing beaches at Lung Kwu Tan as well as a number of Gazetted bathing beaches. Butterfly Beach is the nearest of these, located about 3.8 km to the east of the proposed PAFF site. Further east still can be found Castle Peak Beach, Kadoorie Beach, Cafeteria Old and New Beaches and Golden Beach. These have historically suffered from high sewage derived bacterial loads. However as a result of recent pollution enforcement activities and sewerage infrastructure improvements water quality at all the gazetted beaches in the NWW WCZ is now deemed ‘fair’ according to EPD criteria and suitable for bathing (EPD, 2006).

6.2.3.6 As part of the mitigation for the temporary aviation fuel line at Sha Chau, artificial reefs have been deployed in the Sha Chau and Lung Kwu Chau Marine Park. These reefs are designed to enhance fisheries resources and promote feeding opportunities for the Chinese White Dolphins which frequent the area. In addition, the Hong Kong Jockey Club, with support from the Airport Authority, financed a project to deploy artificial reefs in the Chek Lap Kok Marine Exclusion Zone off the north-eastern corner of the HKIA.

6.2.3.7 There are a number of major seawater intakes in the study area serving Tung Chung new town, the HKIA and industrial users, particularly the Castle Peak Power Station and the Shiu Wing Steelworks immediately to the west of Tuen Mun Area 38. For the Castle Peak Power Station intake there is a specific requirement that suspended sediment concentrations must be maintained below a level of 150 mg/l within a 5 km radius of the intake. This radius encompasses much of the northern sections of the proposed pipeline route, see Figure 6.2.

6.2.4 Baseline Water Quality Conditions

6.2.4.1 Existing water quality and sediment quality in the North-western waters have been monitored for many years as part of the EPD Routine Monitoring Programme. Water quality is monitored monthly at six stations within the NWW WCZ as shown in Figure 6.3. Of these, station NM6 lies close to the southern section of the existing pipeline. The stations NM3, NM5 and NM8 lie in convenient close proximity to pipeline alignment to be able to represent conditions within the likely area of influence of the Project. A summary of the data published by EPD for the NWW WCZ for 2003 and 2004 is presented in Appendix D and in Table 6.3 below.

Table 6.3 Summary of EPD data for Suspended Sediments and Dissolved Oxygen in 2003 and 2004

Station	SS mg/l Depth Av *Mean*	SS mg/l Depth Av *Range*	DO mg/l Depth Av *Mean*	DO mg/l Depth Av *Range*	DO mg/l Bottom *Mean*	DO mg/l Bottom *Range*
2003 Dry Season						
NM3	11.3	3.4 – 23.3	6.7	5.4 – 8.5	6.9	5.7 – 8.4
NM5	17.4	6.7 – 37.7	6.9	5.6 – 8.4	6.8	5.5 – 8.3
NM6	14.6	5.2 – 25.8	6.5	5.4 – 7.8	6.7	5.7 – 7.7
NM8	22.3	7.6 – 51.3	6.3	5.4 – 7.4	6.5	5.7 – 7.2
2003 Wet Season						
NM3	9.1	5.1 - 14.3	4.8	3.2 – 6.2	4.4	2.5 – 6.2
NM5	17.1	8.7 - 35.3	4.7	3.4 – 5.7	4.1	2.4 – 5.7
NM6	9.1	2.0 - 16.7	5.2	4.3 – 5.8	4.9	3.3 – 5.9
NM8	13.1	5.5 - 30.9	5.6	4.5 – 6.6	5.0	2.7 – 6.4
2004 Dry Season						
NM3	9.6	6.9 – 13.7	6.3	4.6 – 7.4	6.4	4.6 – 7.4
NM5	14.5	5.4 – 28.7	6.2	4.4 – 7.4	6.3	4.6 – 7.4
NM6	14.9	7.4 – 26.7	6.6	5.2 – 7.4	6.7	5.2 – 7.4
NM8	11.8	5.9 – 21.0	6.6	4.6 – 7.4	6.6	4.6 – 7.4
2004 Wet Season						
NM3	9.3	7.5 – 12.2	5.4	4.2 – 7.4	5.1	3.6 – 7.8
NM5	10.3	6.1 – 18.8	5.4	4.1 – 8.3	5.1	3.9 – 7.2
NM6	7.7	4.4 – 11.8	5.8	4.5 – 8.2	5.9	4.5 – 8.9
NM8	11.5	7.0 – 28.2	6.4	5.4 – 8.1	6.5	5.4 – 8.6

Note: the data presented are seasonal averages and seasonal ranges

6.2.4.2 Some temporal and spatial variability is evident in this dataset but compliance is usually observed with the key WQOs for dissolved oxygen, total inorganic nitrogen and unionised ammonia notwithstanding generally eutrophic conditions resulting from the heavy nutrient load carried by the Pearl River. In general, the water quality parameters recorded in recent years were largely stable although a general rise of NH_4-N was recorded, similar to other waters of Hong Kong. There was, however, no corresponding increase in other nitrogenous compounds.

6.2.4.3 Of particular relevance to this assessment, the EPD for these two years indicate that suspended solid concentrations typically lie in the range of 3 to 40 mg/l with the highest recorded value being 51.3 mg/l at the Chek Kap Kok West station NM8 2003. Compliance with the WQO for dissolved oxygen was achieved throughout despite occasional dips in depth average measurements below the compliance value of 4 mg/l at stations including NM3 and NM5 to the east and west of the project site, respectively. Oxygen supersaturation is observed, particularly at the southwestern most stations NM6 and NM8, again indicative of eutrophication predominantly influenced by the Pearl River discharge.

6.2.4.4 In addition to EPD's long term programme, comprehensive water quality data sets have been obtained from various construction related environmental monitoring programmes, the most significant ongoing programme being that for the management of the Contaminated Mud Pits at East of Sha Chau. These data are essentially comparable with the longer-term EPD dataset and show general compliance with the WQOs in the region of the mud dumping operations. Data obtained to date from this programme support the hypothesis that the disposal activities have not had any significant adverse effect on water quality beyond the immediate confines of the pit areas during dumping (Mouchel 2000, Meinhardt 2006a, ERM 2000, 2001). Suspended sediment concentrations are again observed to range from less than 10 mg/l to over 80 mg/l although mean values tend to be a bit higher than reported by EPD. Over the period 1994 to 1997, for example, annual mean depth averaged suspended sediment concentrations ranged from about 18 to 40 mg/l illustrating the considerable variability for this parameter. Depth averaged dissolved oxygen varies at East Sha Chau within the range from 4 to 10 mg/l with a mean value of about 6.7 mg/l (Chan & Dawes 1999).

6.2.4.5 From Table 6.3, it can be seen that there are seasonal variations in the suspended sediment and dissolved oxygen concentrations with marginally higher average suspended solids concentrations in the dry season and higher dissolved oxygen concentrations also in the dry season. Compared to the longer term EPD data, however, the depth averaged suspended solids concentrations recorded in 2003 and 2004 appear to be lower than have been recorded in previous years.

6.2.4.6 The Airport Authority Hong Kong (AAHK) has also conducted a serious of non-statutory water quality monitoring for the periods 1999-2000, 2002-2003 and 2005-2006 and the average concentrations of suspended sediment recorded at mid-depth was 11.3 mg/l and the values ranged between 3 – 40 mg/l (Meinhardt, 2006b). The concentrations of dissolved oxygen recorded mid-depth ranged between 2.9 –15.8 mg/l with an average of 7.0 mg/l.

6.2.4.7 The statutory Water Quality Objective for suspended sediments is not defined in absolute numerical terms but instead is worded to require that human activities should not result in an elevation of more than 30% above ambient levels. This in part reflects the difficulty in trying to apply a single numerical value for environmental management purposes in the context of natural high variability characteristic of Hong Kong's marine waters. Previous workers assessing the environmental impacts associated with the temporary AFRF at Sha Chau adopted value up to 34 mg/l to represent ambient suspended solid concentrations in essentially the same study area as is being considered in this assessment (ERM, 1996). For the purposes of this assessment a slightly more conservative value of 30 mg/l has been adopted which is also seen to lie within the range of SS concentrations observed in 2003 and 2004. Based on the review above it can be seen that this value lies well within the natural range experienced in this region and the existing biological system is clearly able to tolerate concentrations at these levels.

6.2.5 Baseline Sediment Quality

6.2.5.1 There is an abundance of data on sediment quality in the study area. The stations monitored in the available studies and sediment quality classification based on the latest ETWB 34/2002 are summarised in Figure 6.4 and discussed below. Sediment quality is monitored by EPD every six months at four stations in the North Western Waters, namely NS2, NS3, NS4 and NS6. The locations of these stations are indicated in Figure 6.3. Maximum concentrations of key potential toxicants reported by EPD over the 5-year period 1995 – 1999 for these sites are presented in Table 6.4 while the same data for the recent 5-year period 2000-2004 are presented in Table 6.5. The corresponding LCEL criteria are presented in the same tables for convenient reference.

Table 6.4 EPD Routine Sediment Quality Data for North Western Waters (1995-99)

Contaminant	Maximum Concentration (dry weight)	LCEL (dry weight)
Metals	**mg/kg**	**mg/kg**
Cd	<0.9	1.5
Cr	<49	80
Cu	<54	65
Pb	<64	75
Hg	<0.7	0.5
Ni	<34	40
Zn	<140	200
Metalloid	**mg/kg**	**mg/kg**
As	<14	12
Organics	**ug/kg**	**ug/kg**
PCBs	6-10	23
PAHs	51-100	low MW : 550, high MW : 1700

Table 6.5 EPD Routine Sediment Quality Data for North Western Waters (2000-2004)

Contaminant	Maximum Concentration (dry weight)	LCEL (dry weight)
Metals	**mg/kg**	**mg/kg**
Cd	<0.3	1.5
Cr	<45	80
Cu	<47	65
Pb	<50	75
Hg	<0.2	0.5
Ni	<27	40
Zn	<130	200
Metalloid	**mg/kg**	**mg/kg**
As	<22	12
Organics	**ug/kg**	**ug/kg**
PCBs	<15	23
PAHs	<148	low MW : 550, high MW : 1700

6.2.5.2 There is some marginal discrepancy between the lower reporting limits adopted by EPD and the LCEL for Hg and As for data collected before the year 2000 but this discrepancy does not occur for more recent data. It is clear that all other parameters comply comfortably with the LCEL. EPD amended their reporting limits in 2000 to align with the numerical values adopted for the LCEL and UCEL criteria. EPD data for stations NS2, NS3, NS4 and NS6 for the updated 10-year period 1995-2004 met the LCEL criteria for all the parameters listed in Tables 6.4 and 6.5 with the exception of arsenic. Upper range arsenic concentrations were observed to exceed the LCEL. EPD note in their annual water quality report for 2000 that these arsenic concentrations might be related to the high natural arsenic levels in the soil of some areas of the Northern New Territories which could then be transported to the marine environment through river discharges and storm run off.

6.2.5.3 On no occasion over the past 10 years have EPD detected arsenic concentrations in North Western Waters marine sediment above the UCEL criterion adopted to define a level above which adverse biological toxicological effects would be expected. Given that the arsenic concentrations in this region are likely to represent the result of gradual natural erosive processes over geologic timescales it seems reasonable to assume that the existing ecosystem is tolerant to the widespread presence of this element.

6.2.5.4 In summary it can be concluded that no significant toxicity would be expected at the sampling stations routinely sampled by EPD to assess sediment quality in these waters. NS3, NS4 and NS6 are conveniently situated around the study area for this assessment and thus it is reasonable to extrapolate this finding as being true also for the general conditions in the area of seabed likely to be impacted during construction of the proposed pipeline trench. The classification of sediment quality, following ETWB 34/2002, for NS3, NS4 and NS6 based on the averaged contaminant concentrations recorded between March 1998 and July 2004 was presented in Figure 6.4.

6.2.5.5 Dredged sediments identified to be contaminated have been disposed of to a series of sea bed pits in the East Sha Chau area since December 1992. These pits are subsequently capped with clean mud to isolate any potential toxicants from the wider environment. The facility has been closely scrutinised by means of a comprehensive monitoring programme administered by the Civil Engineering and Development Department assisted by EPD.

6.2.5.6 A comprehensive publication on this work (ERM, 2000) reports on the 2 year period November 1997 to October 1999. This work principally involved sediment sampling within and very close to the active disposal pits to detect any possible losses of contaminated sediment during the disposal operations. In addition, sampling was undertaken at a series of regional stations to monitor conditions in the wider region. The locations of these stations are indicated in Figures 6.4 and 6.5. All determinands for which LCEL criteria have been defined were tested for on a total of eight occasions. All parameters were observed to pass the LCEL criteria with the notable exception of arsenic which was commonly measured to exceed the LCEL throughout the entire area monitored (Figure 6.4). Background arsenic concentrations are known to typically exceed the LCEL throughout this region generally and this is attributed to natural geologic concentrations rather than any specific anthropogenic activity. The monitoring programme also detected DDT throughout the sampled area at levels comparable to those recorded elsewhere in Hong Kong's waters. There is no LCEL criterion for this substance.

6.2.5.7 Since publication of the data discussed above, the East Sha Chau programme has been amended (Mouchel 2001b) although the regional sediment sampling stations remain unchanged (see Figures 6.4 and 6.6). The most up to date information (Meinhardt, 2006a) reported at the time of this assessment is essentially comparable with that reported in previous years although it was noted that marginal excceedances of LCEL for mercury were infrequently recorded in recent times. Overall, taking the LCEL criteria as a reference, there is no reason to believe that sediments in this general region are of any ecotoxicological concern, although it is reasonable to expect some individual sediment samples may exhibit contaminant concentrations in excess of the LCEL in limited areas possibly due to local effluent sources.

6.2.5.8 A detailed sediment survey was undertaken in 1995 to assess sediment quality along the route for the existing AFRF pipeline from Sha Cha to HKIA and also in the vicinity of the existing AFRF jetty and dredged approach channel (see Figures 6.4 and 6.7). Some 50 locations were sampled and tested for seven heavy metals in accordance with the EPD Technical Circular 1-1-92, which preceded the current ETWB 34/2002. The parameters tested for and the then 'Class A' uncontaminated mud criteria are presented in Table 6.6. The table includes the currently used LCEL criteria for ease of comparison.

Table 6.6 Comparison of Historical Class A Criteria with current LCEL Criteria

Metal	Class A (mg/kg)	LCEL (mg/kg)
Cd	<0.9	<1.5
Cr	<49	<80
Cu	<54	<65
Hg	<0.7	<0.5
Ni	<34	<40
Pb	<64	<75
Zn	<140	<200

6.2.5.9 All samples were determined to comply with the Class A criteria in force at that time. The area was subsequently dredged and the resultant spoil categorised as "uncontaminated". It can be seen that the then Class A criteria are more stringent than the existing LCEL with the exception of that for mercury which has been tightened to < 0.5 mg/kg. A reanalysis of the original source data (ERM, 1996) reveals that at no station was mercury measured at a concentration of more than 0.23 mg/l which is comfortably within the existing LCEL. Based on the latest ETWB 34/2002 criteria, the sediment of these 50 samples could be classified as Category L uncontaminated, Figure 6.4, although it is noted only arsenic and silver were not tested. There is no reason to suspect that sediments in this area should be more contaminated at the present time than they were at the time that these samples were taken. On this basis no ecotoxicity from the 7 metals tested would be expected in this part of the study area. This area specifically includes the section of the proposed pipeline trench between Urmston Road and the existing AFRF at Sha Chau.

6.2.5.10 AAHK commissioned two rounds of sediment sampling in March 1999 and February 2000 at 10 stations around the perimeter of the airport platform (Figures 6.4 and 6.8). The suite of determinands included all LCEL parameters with the exception of TBT. The programme was principally intended to identify the possibility of contamination wash out from storm discharges from the airport site. TBT would not be expected to enter the marine environment from this source. The resultant data (Mouchel 2000) showed that none of the heavy metal concentrations observed were above the LCEL criteria. No PAHs were observed above a detection limit of 0.5 mg/kg again indicating compliance with the relevant LCEL criteria. No PCBs were observed above a detection limit of 0.1 mg/kg. This detection limit actually lies between the corresponding LCEL and UCEL criteria. However the fact that two rounds of sampling over 10 stations on each occasion failed to identify any PCB at all gives confidence that there is no contamination of concern from these substances. As seen elsewhere, arsenic was detected at concentrations equalling or exceeding the LCEL for about 50% of samples. No exceedance of the UCEL was detected.

6.2.5.11 AAHK also commenced a third round of sediment sampling in June 2003 to update the finding of the 1999/2000 study although only six stations (1, 2, 5, 6, 7 and 8 as shown in Figures 6.4 and 6.8) were sampled. The results of the 2003 study (ERM, 2004) were comparable with the previous study and other than arsenic, there were no LCEL exceedances in both heavy metals and trace organic contaminants. Although the recorded arsenic concentrations (15-25 mg/kg) exceeded the LCEL in most samples, none were close to the UCEL. PAHs and PCBs were also mostly non-detected in the 2003 monitoring.

6.2.5.12 This programme of work also indicated that there was no significant temporal difference between the annual sampling rounds in the study area. This gives support to the temporal extrapolation of spatially closer historical sediment quality data set to the present time in the study area although whenever possible recent site spseific data are adopted. The available spatially closer data set are discussed below.

6.2.5.13 A sediment quality assessment was commissioned in summer 1999 by Shiu Wing Steel Co. Ltd in respect of a requirement to undertake maintenance dredging at their jetty at Tap Shek Kok. The site adjoins the proposed location for the PAFF jetty and there are no pollution sources in between. Three boreholes were sampled and 5 depths and analysis was conducted for Cd, Cr, Cu, Ni, Pb Zn and Hg. All results were below the existing LCEL criteria and the sediments at the site were confirmed to be Class A or uncontaminated by EPD in August 1999 as defined by the relevant Technical Circular in force at that time, WBTC 22/92.

6.2.5.14 In addition, as a part of the preparatory work for the pipeline construction, 14 sediment vibrocore samples were collected for analysis along the pipeline alignment as shown in Figures 6.4 and 6.9 (June 2006). Chemical screening was conducted for the vertical sub-samples at seabed (0m), 0.9m down, 1.9m down, 2.9m down and then at a further 3m down for selected samples and biological screening were also conducted for selected pooled samples following the procedures stipulated in ETWB 34/2002. The results suggested that the surface sediment (up to 3m below seabed) along the pipeline was naturally contaminated with arsenic (3.5 to 17 mg/kg), which is consistent with other data sources. Interstitial TBT levels were also tested in selected samples (MVA1, 2 and 14) but none were detected above the analytical detection limit. The results, however, also suggested that the sediment near the Tuen Mun coast (MVA1-MVA4, 700m from the coast) was occasionally contaminated with low levels of copper (up to 72 mg/kg), lead (up to 84 mg/kg) and mercury (up to 0.69 mg/kg). These samples were classified as Category M because of contamination by the heavy metals and arsenic and they also failed the biological screening in the ecotoxicological testing. Sediment samples collected between 900–1,300m from the coast (MVA5-7) were classified as uncontaminated while samples collected further off (MVA8-13) were classified as Category M because of arsenic. The off-coast samples, however, passed the biological screening indicating that they have low potential to induce adverse biological responses.

6.2.5.15 It should, however, be noted that the coastal sample MVA14 (about 100m off the coast and 100m from MVA1) collected near MVA1 passed the biological screening although the chemical content other than TBT was not determined. The fact that only the coastal samples were contaminated with heavy metals while adjacent coastal samples yield contrasting results in biological screening suggest that there could be a highly localised source of contamination.

6.2.5.16 In conclusion there is an abundance of existing sediment quality data pertaining to the study area for this assessment which has been thoroughly characterised for various studies in the past and as part of the current impact assessment. Except for the local area offshore of the landing point at Tuen Mun Area 38, the sediment quality can be classified as Category L, uncontaminated. There may be concern, however, that the loss of moderately contaminated material to suspension could adversely affect water quality.

6.2.5.17 The data obtained from the previous and ongoing monitoring programmes for the disposal operation at East Sha Chau Contaminated Mud Pits, however, does not indicate that sediment contamination is having an impact on marine water quality and there is a clear weight of evidence to indicate that the sediments to be dredged for the pipeline are not contaminated such that they might reasonably be expected to exert any significant ecotoxicological impact if disturbed during the course of the Project. This issue, however, is addressed further below in the impact assessment.

6.3 Key Issues

6.3.1 Construction Phase

6.3.1.1 The principal water quality concern associated with this project relates to disturbance to the seabed during the construction period. There will be a need to dredge a long channel to enable the pipelines to be placed below the existing seabed and then backfilling works to provide a protective rock armour cover. These operations will inevitably result in the loss of sediments and backfilling materials into the water column where they will add to the suspended sediment load.

6.3.1.2 During dredging works fine material will be displaced and may be carried downstream of the works area. The extent of the suspended sediment plume will depend on the rate of release and thus the working methods adopted, the particle size of the dredged material and its characteristic settling velocity, the prevailing currents and hydrodynamic conditions. As noted in Section 3, rock armour is necessary to protection of the pipeline and this will take for the form of graded rock which will be placed on top of the pipe within the trench. Amour rock placement is not expected to cause any significant water quality impacts as the material is inert and will comprise quarry rock without clay or silt contamination and have a very low fines content. In addition, any limited fines that are released will settle rapidly and likely within the confines of the trench. Thus, the principal concern relates to the period of dredging rather than backfilling.

6.3.1.3 Sediment laden plumes may directly affect marine organisms through abrasion and clogging of fish gills and other organs or possibly as a result of reduced light penetration.

6.3.1.4 From the review of sediment quality data in Sections 6.2.5.1 to 6.2.5.17 above, it can be concluded that the dredging operations would be most unlikely to release contaminants of potential ecotoxicological concern into the wider environment. In some situations dredging operations can give rise to concerns about possible release of nutrients or organically rich material which could result in water column oxygen depletion. These would typically be issues for long term dredging operations in relatively still or poorly flushed waters. However, there is very extensive experience of dredging operations for construction works similar to those intended for this project within the marine waters of Hong Kong. Nutrient enrichment or oxygen depletion has never been reported as a major concern for marine dredging works in Hong Kong previously and there is no reason to believe that these processes would be of concern in the well flushed North

Western Waters. No such impacts were observed during construction of the AFRF next to Sha Cha island, for example.

6.3.1.5 The project would entail significant land based works to construct the tank farm and associated facilities. These will be built on existing reclaimed land. The main water quality related issues will be to prevent erosion on site and minimise suspended sediment loads washed out in stormwater and well as the need to control waste water streams such as temporary sewage facilities, cementitious waters and general construction refuse. Toilets will be connected to the local sewerage system if possible during construction but if not feasible chemical toilets will be used. There is vast experience of managing this type of project in Hong Kong and it is considered that these issues would not be of any substantive concern provided that good site practice is adhered to.

6.3.1.6 The other principal construction activity associated with the project is the construction of the reception jetty. The jetty would be supported on piles which have already been driven. There is no requirement for dredging works on the seabed for the jetty. As with the land based works, provided good site practice is maintained there should be no particular concerns for water quality during the construction period.

6.3.2 Operational Phase

6.3.2.1 During the operational phase the likelihood of major spill events occurring is very low as presented and quantified in Section 10 of this report. The largest potential spill events from the operation of the PAFF are releases from tankers approaching the PAFF both due to grounding and collision. The most likely spill events come from the jetty operations, either due to general equipment failure or due to loading arm failure or striking/impact. Any spill to the sea from the tank farm is very unlikely due to the containment systems, except via the drainage system. The quantities expected to be released via the drainage system are generally less than those from marine incidents or incidents at the jetty. A release from the submarine pipeline to the AFRF is also possible, but at a very low frequency. Thus, the maximum release quantities are from marine transport incidents, including striking or impact at the jetty. The key scenario for assessment is therefore a release from a tanker at or near the jetty.

6.3.2.2 Thus, the largest potential spill events from the operation of the PAFF are releases from tankers approaching the PAFF both due to grounding and collision. The rupture of one or all of the tanks of an 80,000dwt tanker would result in the largest pools of oil at sea as detailed in Section 10. The fuel reception jetty will provide two berths to allow flexibility to accommodate a full range of vessels within the size range 10,000 to 80,000dwt. Fuel would typically be received at a frequency of three times per week rising to a forecasted average of 3.6 occasions per week at the 2040 planning horizon. While the actual risk of such a tanker incident has been determined to be very low as discussed in Section 10, some statistically quantifiable risk of failure will always remain and as such the effects of a spill need to be assessed. Details of the fuel spill modelling are provided in Section 11.

6.3.2.3 Aside from the risk of major spills there will be a need to prevent minor slops during routing operations e.g. coupling and uncoupling of vessel discharge hoses. This will be managed through design and operational practice. Similar concerns apply to the tank farm and mitigatory measures will also be required there to guard against leakage or other unintentional discharges. Mitigation measures to prevent and contain leakages from land based facilities are also identified in Section 13.5.

6.3.2.4 There will be no routine discharge of wastewater or contaminated surface drainage to sea or surface watercourse in the operational phase. Sewage from site offices will be minimal, amounting to only about 2.9m^3/day. The sewage will be stored in a sump pit. A specialist contractor with tanker will be employed for the removal of sewage from the sump pit by equipment with appropriate suction device. The existing public system is not available for use.

6.4 Construction Phase Impact Assessment

6.4.1 *Assessment Approach*

6.4.1.1 As discussed above, the principal water quality concerns in the construction period are those associated with dredging and backfilling for the submarine fuel pipeline. In this assessment, representative sediment plumes have been simulated using the Delft 3D tidal flow and water quality models. Since the sediment losses and migration during backfilling with coarse material will be very much less than those during dredging when fine silts may be resuspended, the latter case is simulated here for conservative assessment purposes.

6.4.1.2 It has been 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. Both have their pros and cons from an operational and also environmental point of view. 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. However the plume from a trailer dredger will predominantly be formed at depth close to the drag head whereas grab-dredging plumes, though less concentrated, are likely to originate throughout the water column as the grab is pulled to the surface. Also, grab dredging is considerably slower and thus the period of disturbance is much greater. There are important operational constraints also. The pipeline route must cross the busy Urmston Road marine fairway and it is unlikely that the Marine Department would allow the use of a relatively immobile slow working grab dredger in this congested area. Deployment of a self powered trailer would be considerably safer. However, trailers cannot operate in shallow or very near-shore areas where their manoeuvrability is impeded. Thus, some combination of methods could be expected in reality. For robust assessment purposes dredging for this project is simulated to represent deployment of both grab and trailer suction dredgers. Cross-sections of the pipelines in the trench are provided in Figure 3.3.

6.4.1.3 It is anticipated that a trailer suction hopper dredger (TSHD) will be used to excavate a trench in the Urmston Road, a major shipping channel with strong tidal flows and where anchoring a barge would be difficult and almost certainly unacceptable to the Marine Department. Over the shallower areas crossed by the pipeline and possibly inaccessible to a large TSHD at times during the tidal cycle, it is assumed that a grab dredger would be used.

6.4.2 *Computer Models*

6.4.2.1 Delft Hydraulics have established well calibrated three-dimensional hydrodynamic and water quality models of the Pearl Estuary and the whole of Hong Kong Territorial waters. These models have been calibrated and validated using a number of historic data sets. The latest model is referred to as the Update model and it could be applied directly in the present assessment of the fuel pipeline. However, the model grid resolution in the area of interest is considered to be too coarse and therefore another existing model of a smaller area covering the Western Harbour and North West New Territories, referred to as the Western Harbour Model, has been applied. The Western Harbour model of tidal flows extracts boundary conditions from the Update model and has also been fully validated by Delft Hydraulics for EPD. The grid size of this model in the area of interest is 200m x 200m. The areas covered by both the Update Model and the Western Harbour Model are shown in Figure 6.10. Details of the Western Harbour Model's mesh is presented in Figure 6.11.

6.4.2.2 The Delft3D model of tidal flows has been used to simulate tidal flows in the both the wet and dry seasons. While the Delft3D model of tidal flows has been used to simulate the water movements, the Delft3D model of water quality has been used to simulate the fate of sediment lost to suspension during dredging operations. The Delft3D water quality model has been used rather than the Delft3D random walk sediment plume model because the sediment plume model has a much simpler representation of erosion and deposition than the water quality model and this simpler representation can result in inaccurate simulations.

6.4.3 Model Parameters

Settling Velocities

6.4.3.1 The settling velocity of suspended cohesive sediment is concentration dependent. The simulations were carried out using a constant settling velocity of 0.5mm/s which is typical of low suspended solids concentrations. This represents a conservative assumption in that a higher sedimentation rate would actually be expected in the dense plume close to the drag head.

Erosion and Deposition

6.4.3.2 Erosion and deposition in the water quality model are defined in terms of a critical stress for deposition above which no deposition can take place and a critical stress for erosion above which erosion can take place. The critical stress for deposition was set at $0.2N/m^2$ with a restriction being imposed on deposition in shallow water where wave action would inhibit deposition. A water depth of 2m was selected as the minimum depth in which deposition can take place. The critical stress for erosion was set at $0.3N/m^2$ which is applicable to relatively soft new deposits with a density of around $200kg/m^3$ (HWR, 1993).

Assumed Sediment Losses

6.4.3.3 For the grab dredgers, it is assumed that 17kg/m^3 dredged will be lost to suspension and, for the TSHD, it is assumed that 10kg/m^3 dredged will be lost to suspension when dredging mud (Hyder, 1998). For the grab dredgers, it is assumed that the losses are evenly distributed over the water column while, for the TSHD, the losses are assumed to take place in the lowest layer in the model.

6.4.4 *Modelling Scenarios*

TSHD Dredging

6.4.4.1 The TSHD is assumed to have a capacity of 8,000m^3 with an assumed maximum production rate of around 6,000m^3/hour. However, for the purposes of the current assessment, an average production rate of 4,000m^3/hr has been assumed with a 2-hour period being required to travel to the disposal area and return to the dredging area, a total cycle time of 4 hours. As discussed above, it is likely that this method of dredging will be used in the Urmston Road and possibly for other stretches of the pipeline length. In terms of sediment release rates, the TSHD represents a worst case situation as compared to the grab dredging and as such, modelling runs have been carried out to simulate losses from the TSHD based upon this method being used for most of the pipeline alignment. The volume of material assumed to be dredged by the TSHD in the previous EIA (April 2002) was estimated to be 274,000m^3 based upon the latest information available at that time. Based upon this and, assuming continuous working with no downtime, it was assumed that all TSHD dredging will be completed within about 6 days and this was the basis for the modelling and assessment described below. This was considered a conservative estimate (in environmental impact terms) as production rates were not likely to be higher than this. However, following completion of these initial model studies, the dredged volume has been recalculated and found to be 340,000m^3 rather than the 274,000m^3 estimated initially. In addition, it should be noted that works for the pipeline dredging in the areas other than the Urmston Road will be constrained to 12 hours daytime working as mitigation to protect the Chinese White dolphins in the area, as detailed in Section 7. The Urmston Road section where works can continue for 24 hours per day is shown in Figure 7.5 and the amount of material to be dredged from this area is 247,000m^3. The main impact this will have on the assessment carried out and described below will be that the dredging works will last for approximately 9 days rather than around 6 days as previously assumed. However, as the rate of dredging and so the rate of sediment losses to suspension will remain the same as previously assessed, extending the dredging programme by a few days will not result in any significantly more severe environmental impacts.

6.4.4.2 As discussed above, losses from the TSHD have been simulated over a 6 day period spanning both large and small amplitude tides to ensure all representative tidal conditions are considered. Sediment losses were simulated along the pipeline route between the Tuen Mun Area 38 shore and the boundary of the Marine Park. The dredging point was moved continuously along the pipeline route to simulate a dredger progressing at a rate of 0.5 ms^{-1} for a period of two hours followed by a two hour gap to represent the end of the dredging cycle and a period in which the dredger leaves the site to travel to and from the disposal site.

Grab Dredgers

6.4.4.3 For grab dredgers, it is assumed that dredging is continuous with a production rate of 7,000m^3/day and, as discussed above, this represents a worst case scenario. Sediment losses have been simulated over a spring-neap tidal cycle with the grab dredger assumed to move progressively away from the existing AFRF jetty at Sha Chau toward the Urmston Road at a rate of 100m per day.

6.4.5 Environmental Assessment Criteria

6.4.5.1 For the purposes of this assessment, the results from the model simulations in terms of suspended solids concentrations and deposition rates are assessed with respect to the Water Quality Objectives (WQO) for the North Western Waters Water Control Zone. Sensitive receivers likely to be impacted have been identified on Figure 6.2 and include the Lung Kwu Chau and Sha Chau Marine Park, artificial reefs and other important habitat, cooling water intakes and bathing beaches. As discussed in Section 6.2.4.8, for the purposes of this assessment a background suspended sediment concentration of 30mg/l is assumed. The WQO allows for a 30% increase as a result of anthropogenic activity and thus a maximum contribution from dredging activity of 9mg/l.

6.4.5.2 It is considered most unlikely that sediment losses will have a significant impact on dissolved oxygen concentrations. Nevertheless, for completeness, the possibility of dissolved oxygen depletion is calculated from the predicted suspended solids concentrations using the method of ERM, 1997. Any oxygen sag can be compared against background levels (Section 6.2.4.5 refers) and the relevant WQOs.

6.4.5.3 It has already been concluded in Section 6.2.5.17 that there is no reason to believe that the dredged sediments would be contaminated such that they might reasonably be expected to exert any significant ecotoxicological hazard. However, in order to confirm this conclusion, the maximum worst case increases in dissolved contaminants which might be generated by the dredging works have been calculated based on the predicted elevations in suspended sediment concentrations assuming that all sediment to be dredged is moderately contaminated (Category M) with contaminant concentrations equal to the UCEL for each contaminant of interest. In carrying out these calculations, it has also been assumed that all contaminants adsorbed on the sediments on the seabed desorb and go into solution in the water column. The results for the estimated contaminant concentrations can then be compared with environmental quality standards for each contaminant where such a standard has been set.

6.4.6 Impact Assessment

6.4.6.1 The water quality modelling results are presented in full in Appendix E. For each scenario, modelled plots are provided of:

- depth averaged suspended sediment contours at high and low water for each day of the model simulation;
- time history plots in the upper, middle and bed layers at sensitive receivers in the study area throughout the period of the model simulation; and

- sediment deposition plots at high and low water for each day of the model simulation.

6.4.6.2 The water levels shown in the plots were recorded at a location in the vicinity of the Brothers which is representative of the North-western waters. The location of the sensitive receivers considered in the modelling work is indicated on Figure 6.12.

6.4.6.3 Vector diagrams showing the current flow in the surface, middle and lower layers of the water column during wet and dry seasons at ebb and flood tides are also presented in Appendix E.

Trailer Suction Hopper Dredging

6.4.6.4 The model output suggests consistently acceptable water quality conditions. Depth averaged suspended sediment concentrations are predicted to be below the assessment criterion of 9 mg/l above ambient at all times and in fact rarely increase by more than about 5 mg/l throughout the study area. The water quality objective would be complied with at all times. As discussed above, a mean production rate of 4,000m^3/hr has been assumed in the model studies. If the TSHD achieved the maximum assumed production rate of $6{,}000^3$/hr, 50% higher than simulated, then it is to be expected that elevations in SS concentrations would also be 50% higher than simulated. However, even at this higher production rate, achievement of the WQO would be no different from that predicted for a production rate of 4,000m^3/hr.

6.4.6.5 The time history output from the model indicates that there would be complete compliance with the water quality objective for suspended sediments at all times for all sensitive receivers during the dry season.

6.4.6.6 In the wet season the waters within the dredged area are markedly influenced by freshwater flows from the Pearl River. The waters are strongly stratified particularly on the ebb tide. This would tend to decrease mixing of sediment disturbed at depth by the trailer arm and higher suspended sediment concentrations might be expected at depth compared to in the dry season when there is vertical mixing across the whole water column. These effects are reflected in the model output.

6.4.6.7 Periodic suspended sediment elevations in the bed layer are predicted within the marine park when the dredger approaches the marine park boundary during the wet season simulation. A maximum value of about 25 mg/l is predicted in the bottom layer to the east of Sha Chau. Such peak concentrations would not be expected to extend beyond 100-200m from the dredger and these peaks are short lived and quickly fall to zero on the turn of the tide. Suspended sediment levels at the surface and in the middle of the water column are predicted to be low, below 5 mg/l at this site at all times. These bottom layer conditions are well within the range of natural variability and do not present any ecological concern. Suspended sediment concentrations are not expected to impact on the artificial reef site in the marine park where compliance with the water quality objectives is predicted.

6.4.6.8 The model output shows a one-off and short lived suspended sediment concentration spike of about 40mg/l in vicinity of the Shiu Wing steelworks intake. This incident represents an occasion in the wet season when the dredger is working close to the Tuen Mun Area 38 shore and within about 100-200m from the dredger. The elevation is only observed in the very bottom layer of the water column. Increases in sediment concentrations are not expected in middle and upper layers of the water column and on no other occasion are levels predicted to exceed 5 mg/l. This incident would not detrimentally affect the quality of water abstracted by the steelworks.

6.4.6.9 The model does not predict that there would be any substantial accumulation of re-deposited sediments likely to adversely affect benthic ecology or particularly susceptible species such as corals. No locations beyond the immediate vicinity of the worked area would experience settlement rates greater than a value of 200 $g.m^{-2}day^{-1}$ that has been used by previous workers as an indicator level above which sustained deposition could harm sediment sensitive hermatypic corals. (Binnie, 1996). Soft corals typical of the study area would be even more tolerant and thus there is no reason to believe that they would be impacted. Some recent studies have used an impact criterion of 100 $g.m^{-2}day^{-1}$ for the protection of corals. No locations beyond the immediate vicinity of the worked area adjacent to the dredger would experience settlement rates greater than this value. (Figures D46-D60 and W46-W60 in Appendix E for the grab and TSHD respectively show the total accumulated deposition each day over a 15 day period).

6.4.6.10 The degree of oxygen depletion exerted by a sediment plume is a function of the sediment oxygen demand of the sediment, its concentration in the water column and the rate of oxygen replenishment.

6.4.6.11 For the purposes of this assessment, the impact of the sediment oxygen demand on dissolved oxygen concentrations has been calculated based on the following equation (ERM, 1997):

$$DO_{Dep} = C * SOD * K * 0.001$$

where DO_{Dep} = Dissolved Oxygen depletion (mg/l)
C = Suspended Solids concentration (kg/m^3)
SOD = Sediment Oxygen Demand
K = Daily oxygen uptake factor (set at 0.23 in ERM 1997)

6.4.6.12 An SOD of 15,000 mg/kg has been taken with reference to EPD Marine Monitoring data as a suitably representative value for sediments in the North Western Waters region.

6.4.6.13 The analysis using the above equation does not allow for re-aeration which would tend to reduce any impact of the suspended sediment on the water column DO concentrations. The analysis, therefore, errs on the conservative side so as not to underestimate the extent of DO depletion. Further, it should be noted that, for sediment in suspension to exert any oxygen demand on the water column will take time and, in that time, the sediment will be transported and mixed/dispersed with oxygenated water. As a result, the oxygen demand and the impact on dissolved oxygen concentrations will diminish as the suspended sediment concentrations decrease.

6.4.6.14 The highest levels of suspended sediment predicted for any sensitive receiver in the modelling run described above is to be found in the bed layer of water at a point to the east of Sha Chau during the wet season simulation. The time history plot for this site is presented in Appendix E (Drawing WH14 for the TSHD). Figure 6.13 shows the daily averaged SS concentrations. It can be seen that the occasionally higher near bed suspended sediment concentrations only persist for a relatively short time intervals. No corresponding suspended sediment elevation is observed in the upper layers at this location.

6.4.6.15 Oxygen depletion is not instantaneous and thus previous workers have assumed that the impact of suspended sediment on dissolved oxygen will depend on tidally averaged suspended sediment concentrations (ERM, 1997). The previous studies (ERM, 1997) assumed that the oxygen demand would be satisfied at the same rate as the biological demand which equates to a K value of 0.23/day. However for the purposes of this demonstration the actual time history plot for suspended sediment has been used as the basis for the calculation in order to identify the hypothetical worst case. As such, the daily uptake factor, K, in the equation above was set to be equal to 1 which indicates instantaneous oxidation of the sediment oxygen demand and represents a worst case to ensure oxidation rates are not underestimated. The resulting calculated dissolved oxygen deficit, therefore, is expected to be much larger than would be experienced in reality.

6.4.6.16 A plot of the predicted average dissolved oxygen depletion based on these various conservative assumptions for the bed layer during the time of plume incursion is presented in Figure 6.14. The 'worst case' calculated dissolved oxygen deficit is just over 0.36 mg/l. This calculated instantaneous dissolved oxygen deficit is expected to be much larger than would occur during the dredging operations but, as indicated in Figure 6.15, there would still be no perceptible oxygen sag at this location. Thus it is concluded that the sediment plumes predicted from the modelling run described above would have negligible effect on dissolved oxygen conditions in the receiving waters. The Water Quality Objectives for dissolved oxygen would easily be complied with at all times.

6.4.6.17 As noted above, contaminant release from the sediment lost to suspension maybe of concern and, in order to address this potential issue, a number of assumptions have been made in order to address the worst case scenario:

- The maximum depth averaged elevation in suspended sediment concentration due to the dredging works at each sensitive receiver was used as the basis for estimating potential contaminant concentrations in the water column. Although the peak elevations in suspended sediment concentrations only persist for a short period at each sensitive receiver, assuming the maximum elevation at each sensitive receiver will give the worst case scenario;
- The sediment to be dredged is expected to be uncontaminated except in the area local to Tuen Mun identified above where some moderately contaminated (Category M) sediment was found. However, for the worst case scenario, it will be assumed that all sediment losses are Category M with contaminant concentrations equal to their respective UCELs; and
- It was farther assumed that all contaminants adsorbed onto the sediments desorb and pass into solution in the water column.

6.4.6.18 Based on these worst case assumptions, the potential increases in dissolved contaminants which might be generated from the dredging operations were calculated and are presented in Tables 6.7a & 6.7b for the wet and dry seasons respectively together with the Environmental Quality Standards (EQS) for each contaminant where such a standard has been established (Cole *et al*., 1999). It should be noted, however, that the EQS refer to long term persistent levels (annual average concentrations) of contaminants in the water column and so employing them for comparison with potential elevations in contaminant concentrations lasting for less than one hour (for which no data is available) is particularly stringent.

6.4.6.19 Information on background contaminant concentrations in the water column is available from the environmental monitoring programme being carried out for the disposal of contaminated material at East of Sha Chau. Under that monitoring programme, no impact on contaminant concentrations in the water column has been found and so the data obtained can be considered to be representative of the background contaminant concentrations in the North Western waters. Based on the analysis of all water samples collected from and including April 2001 to November 2005, it was found that most of the contaminants of interest were rarely detected with the exception of copper and nickel. All other contaminants were detected so infrequently (detected in 0% to 22% of the samples) it was not considered appropriate to carry out any statistical analysis for these contaminants. None of the contaminants, when detected exceeded the relevant EQS values, except for copper where EQS exceedances were recorded infrequently (<2%). Overall, it can be assumed that, apart from copper and nickel, all other contaminants are not a persistent problem in these coastal waters. Copper and nickel were detected in 65% and 76% of the samples which were tested and had mean concentrations of 1.4µg/L and 1.9µg/L respectively. By comparison with Tables 6.7a & 6.7b, it can be seen that the existing background concentrations for copper and nickel lie well below their EQS values and the estimated increase in dissolved contaminants based on worst case assumptions would not result in the EQS value being exceed for any of the contaminants considered.

Table 6.7a Wet Season Estimated Elevations in Contaminant Concentrations Based on the Maximum Predicted Depth Averaged Suspended Sediment Concentrations

			Sensitive Receivers																	
			Airport Exclusion Zone Artificial Reef		Sha Chau Marine Park		San Tau		Tai Ho		Airport 1		Airport 2		Butterfly Beach		Cafeteria Beach		Cement Plant	
Suspended Solids (mg/L			1.42		2.84		<0.005		0.42		0.13		0.77		0.67		0.11		0.50	
Contaminant	UCEL	EQS	Estimated Increase in Contaminant Concentration																	
			(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)
Cd	4	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cr	160	15	0.2	1.3	0.5	3.3	0.0	0.0	0.1	0.7	0.0	0.0	0.1	0.7	0.1	0.7	0.0	0.0	0.1	0.7
Cu	110	5	0.2	4.0	0.3	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.0	0.1	2.0	0.0	0.0	0.1	2.0
Pb	110	25	0.2	0.8	0.3	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.1	0.4	0.0	0.0	0.1	0.4
Hg	1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ni	40	30	0.1	0.3	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zn	270	40	0.4	1.0	0.8	2.0	0.0	0.0	0.1	0.3	0.0	0.0	0.2	0.5	0.2	0.5	0.0	0.0	0.1	0.3
As	42	25	0.1	0.4	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ag	2	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A

			Sensitive Receivers																	
			Castle Peak Beach		Castle Peak Power Station		East Sha Chau		Kadoorie Beach		Lung Kwu Chau		Lung Kwu Lower		Lung Kwu Upper		Ma Wan 1		Ma Wan 2	
Suspended Solids (mg/L			0.02		1.82		5.91		0.11		2.58		0.32		0.40		0.19		0.06	
Contaminant	UCEL	EQS	Estimated Increase in Contaminant Concentration																	
			(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)
Cd	4	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cr	160	15	0.0	0.0	0.3	2.0	0.9	6.0	0.0	0.0	0.4	2.7	0.1	0.7	0.1	0.7	0.0	0.0	0.0	0.0
Cu	110	5	0.0	0.0	0.2	4.0	0.7	14.0	0.0	0.0	0.3	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pb	110	25	0.0	0.0	0.2	0.8	0.7	2.8	0.0	0.0	0.3	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hg	1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ni	40	30	0.0	0.0	0.1	0.3	0.2	0.7	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zn	270	40	0.0	0.0	0.5	1.3	1.6	4.0	0.0	0.0	0.7	1.8	0.1	0.3	0.1	0.3	0.1	0.3	0.0	0.0
As	42	25	0.0	0.0	0.1	0.4	0.2	0.8	0.0	0.0	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ag	2	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A

			Sensitive Receivers											
			Ma Wan 3		Nim Wan		Sha Lo Wan		Sham Wat		Shui Wing Steel		The Brothers	
Suspended Solids (mg/L			0.20		0.88		0.06		0.20		6.07		0.68	
Contaminant	UCEL	EQS	Estimated Increase in Contaminant Concentration											
			(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	% of EQS	(ug/L)	(% EQS)
Cd	4	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cr	160	15	0.0	0.0	0.1	0.7	0.0	0.0	0.0	0.0	1.0	6.7	0.1	0.7
Cu	110	5	0.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0	0.7	14.0	0.1	2.0
Pb	110	25	0.0	0.0	0.1	0.4	0.0	0.0	0.0	0.0	0.7	2.8	0.1	0.4
Hg	1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ni	40	30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.7	0.0	0.0
Zn	270	40	0.1	0.3	0.2	0.5	0.0	0.0	0.1	0.3	1.6	4.0	0.2	0.5
As	42	25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.2	0.0	0.0
Ag	2	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A

Table 6.7b Dry Season Estimated Elevations in Contaminant Concentrations Based on the Maximum Predicted Depth Averaged Suspended Sediment Concentrations

			Sensitive Receivers																	
			Airport Exclusion Zone Artificial Reef		Sha Chau Marine Park		San Tau		Tai Ho		Airport 1		Airport 2		Butterfly Beach		Cafeteria Beach		Cement Plant	
Suspended Solids (mg/L			1.00		1.10		<0.001		0.09		0.07		0.31		0.34		0.08		3.00	
Contaminant	UCEL	EQS	Estimated Increase in Contaminant Concentration																	
			(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)
Cd	**4**	**2.5**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cr	**160**	**15**	0.2	1.3	0.2	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.7	0.0	0.0	0.5	3.3
Cu	**110**	**5**	0.1	2.0	0.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	6.0
Pb	**110**	**25**	0.1	0.4	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.2
Hg	**1**	**0.3**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ni	**40**	**30**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3
Zn	**270**	**40**	0.3	0.8	0.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.1	0.3	0.0	0.0	0.8	2.0
As	**42**	**25**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4
Ag	**2**	**N/A**	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A

			Sensitive Receivers																	
			Castle Peak Beach		Castle Peak Power Station		East Sha Chau		Kadoorie Beach		Lung Kwu Chau		Lung Kwu Lower		Lung Kwu Upper		Ma Wan 1		Ma Wan 2	
Suspended Solids (mg/L			< 0.003		2.42		1.98		0.08		2.11		0.62		0.39		0.26		0.11	
Contaminant	UCEL	EQS	Estimated Increase in Contaminant Concentration																	
			(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)
Cd	**4**	**2.5**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cr	**160**	**15**	0.0	0.0	0.4	2.7	0.3	2.0	0.0	0.0	0.3	2.0	0.1	0.7	0.1	0.7	0.0	0.0	0.0	0.0
Cu	**110**	**5**	0.0	0.0	0.3	6.0	0.2	4.0	0.0	0.0	0.2	4.0	0.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Pb	**110**	**25**	0.0	0.0	0.3	1.2	0.2	0.8	0.0	0.0	0.2	0.8	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Hg	**1**	**0.3**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ni	**40**	**30**	0.0	0.0	0.1	0.3	0.1	0.3	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zn	**270**	**40**	0.0	0.0	0.7	1.8	0.5	1.3	0.0	0.0	0.6	1.5	0.2	0.5	0.1	0.3	0.1	0.3	0.0	0.0
As	**42**	**25**	0.0	0.0	0.1	0.4	0.1	0.4	0.0	0.0	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ag	**2**	**N/A**	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A

			Sensitive Receivers											
			Ma Wan 3		Nim Wan		Sha Lo Wan		Sham Wat		Shui Wing Steel		The Brothers	
Suspended Solids (mg/L			0.26		0.79		< 0.002		0.07		2.03		0.83	
Contaminant	UCEL	EQS	Estimated Increase in Contaminant Concentration											
			(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	(% EQS)	(ug/L)	% of EQS	(ug/L)	(% EQS)
Cd	**4**	**2.5**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cr	**160**	**15**	0.0	0.0	0.1	0.7	0.0	0.0	0.0	0.0	0.3	2.0	0.1	0.7
Cu	**110**	**5**	0.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0	0.2	4.0	0.1	2.0
Pb	**110**	**25**	0.0	0.0	0.1	0.4	0.0	0.0	0.0	0.0	0.2	0.8	0.1	0.4
Hg	**1**	**0.3**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ni	**40**	**30**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.0	0.0
Zn	**270**	**40**	0.1	0.3	0.2	0.5	0.0	0.0	0.0	0.0	0.5	1.3	0.2	0.5
As	**42**	**25**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.0	0.0
Ag	**2**	**N/A**	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A

6.4.6.20 In assessing the dissolved contaminant concentrations in the water column, the estimated dissolved contaminant concentrations at each sensitive receiver have been compared with the EQS in Tables 6.7a and 6.7b. Maximum elevations in most contaminant concentrations at most sensitive receivers were predicted to remain below 0.5% of the EQS. Copper was predicted to have the largest relative elevation in dissolved concentration but it was found that the short term elevation in copper concentrations did not exceed 14% of the EQS in the wet season and 6% of the EQS in the dry season at any sensitive receiver (it should be noted that at 7 sensitive receivers in the wet season and at 9 sensitive receivers in the dry season, elevations in all contaminant concentrations were predicted to remain below 0.05% of the EQS value).

6.4.6.21 The predicted elevations in depth averaged suspended solids concentrations only persist for a short time (< 1 hour say for maximum concentrations, Appendix E) whereas the EQS refer to long term (annual) average concentrations. As a result, the potential impact of these short term elevations in dissolved contaminant concentrations on the marine ecosystem will be much smaller still than the simple comparison made with the EQS above might suggest. The estimated short period (<1 hour) elevations in maximum worst case dissolved contaminant concentrations and the comparison with the EQS employed, however, do serve to demonstrate that adverse impacts from dissolved contaminant levels in the water column are not to be expected and that short period elevations in contaminant concentrations will remain well below those set for long term exposure for the preservation of marine life.

6.4.6.22 The assessment of the dredging works on dissolved contaminant levels in the current study has been based on worst case assumptions and it has been concluded that the dredging works would have a negligible impact on dissolved contaminant levels. It is also noted that, in the EIA carried out for the contaminated mud pits at East of Sha Chau (ERM 1997), it was also concluded following detailed modelling of contaminant losses that the impact of sediment losses (similar to those assessed in the current study) during disposal operations on dissolved contaminant concentrations would also be negligible. The evidence indicates that short period elevations in dissolved contaminant concentrations will be negligible and that adverse impacts on the water column and marine life are not to be expected.

6.4.6.23 In summary, the impact on water quality from the use of a trailer dredger to form the pipeline trench is considered to be within acceptable bounds.

6.4.6.24 As noted in Section 6.4.4.1 above, following completion of the initial model studies, the dredged volume was recalculated and found to be 340,000m^3 rather than the 274,000m^3 estimated initially. In addition, works outside the Urmston Road will be restricted to 12 hours per day only instead of the 24 hour working assumed in order to comply with the ecological mitigation measures to the Chinese White Dolphin as detailed in Section 7. The main impact these changes will have on the assessment carried out and described above will be that the dredging works will last for approximately 9 days rather than around 6 days. The rate of dredging and so rate of sediment losses to suspension will remain the same and, as noted in paragraph 6.4.4.1, extending the dredging programme by a few days will not result in any significantly more severe environmental impacts and, providing the work rate remains at or below that assumed above, will not result in higher levels of suspended sediment concentrations or higher deposition rates than have been assessed above.

Grab Dredger

6.4.6.25 The principal difference between grab dredging scenarios compared with trailer dredging scenarios is that the instantaneous sediment release rate for the grab dredging scenarios is approximately 1.4 kg/s as compared to 11.1 kg/s for the trailer dredger. For the trailer dredger it is assumed that the main disturbance is at the sea bed close to the drag head and thus the sediment release is to the bed layer. For the grab dredging scenario account must be taken of sediment losses as the grab is pulled to surface and thus the model simulates sediment release over all depths. These differences are reflected in the model output provided in Appendix E.

6.4.6.26 For the dry season full compliance with the WQOs is predicted at all sensitive receivers at all times. Away from the immediate dredging point suspended sediment is quickly dissipated and the sediment plume is weak and short-lived. The depth average contour plots show that levels in the study area are well below the assessment criterion of 9 mg/l and in fact very rarely exceed a level of 5 mg/l.

6.4.6.27 For the wet season the model again predicts compliance with the assessment criterion of 9 mg/l throughout the study area and as with the other scenarios simulated, sediment levels are rarely increased by more than 5 mg/l above ambient. Complete compliance with the Water Quality Objectives is predicted at all sensitive receivers at all times. On one occasion a spike in suspended sediment concentration approaching 8 mg/l was predicted at a location east of Sha Chau close to a working dredger. This concentration rapidly falls back to near zero in just a few hours. Elsewhere suspended sediment increases are not expected to amount to more than 2-3 mg/l on any occasion.

6.4.6.28 As illustrated above when assessing the impacts of trailer dredging on dissolved contaminant levels in the water column, by the same argument, no adverse impacts on dissolved contaminant levels are expected if grab dredgers are employed.

6.4.6.29 In both seasons sediment re-deposition rates are not expected to exceed the conservative assessment criterion of 200 g/m^2/day.

6.4.6.30 In summary, the impact on water quality from the use of a grab dredger to form the pipeline trench is considered to be well within acceptable bounds at all times.

6.4.6.31 As noted above, the total volume of material has now been calculated to be 340,000m^3 rather than the 274,000m^3 which was estimated initially and upon which the modelling scenarios were based. In addition, works outside the Urmston Road will be restricted to 12 hours per day only instead of the 24 hour working assumed in order to comply with the ecological mitigation measures to the Chinese White Dolphin as detailed in Section 7. The main impact these changes this will have on the assessment carried out and described above will be that the grab dredging works will last for approximately 62 days rather than around 40 days. However, the rate of dredging and so rate of sediment losses to suspension will remain the same and, as noted in paragraph 6.4.4.1, extending the dredging programme will not result in any significantly more severe environmental impacts and, providing the work rate remains at or below that assumed above, will not result in higher levels of suspended sediment concentrations or higher deposition rates than have been assessed above. In fact, the proposed 12 hours on and 12 hours off dredging scenario required by the ecological mitigation may likely give rise to less cumulative impacts in comparison to continuous dredging, as there will be time for released sediments to settle before dredging commences.

6.5 Operational Phase Impact Assessment

6.5.1 *Assessment Method*

6.5.1.1 In the operational phase the principal concern for water quality relates to the risk of aviation fuel spillage. The likelihood of a major spill is quantifiably very low as described in Section 10, but nevertheless in the worst case, the potential impacts on water quality and for sensitive receivers including biota are severe but are transient only. These risks will be minimised through design, operational practice and contingency planning as discussed in Section 11. The consequences of aviation fuel spills from a number of conjectured incident scenarios are simulated by means of the Delft 3D model suite and discussed in Section 11. These scenarios cover some worst case leaks and spills from the approaching tankers and the submarine pipeline.

6.6 Consideration of Alternatives

6.6.1 Subject to implementation of the various mitigatory measures identified in Section 6.7 below, the only significant water quality impact associated with the project will be the generation of sediment plumes in the water column during dredging and, to a lesser extent, backfilling of the protective rock armour. The assessment above has been made on a worst case scenario basis and it is concluded that these impacts are within acceptable bounds. The plumes will not adversely affect any sensitive receiver and they are of no biological concern. Nevertheless it is prudent to fully explore possible alternatives to ensure that any adverse impacts can be kept to a practical minimum.

6.6.2 The assessment above has assumed flexible use of grab or trailer dredgers to suit operational need. To minimise the impacts of dredging in sensitive areas such as within the marine park it would be preferable to constrain the use of trailers and just use a closed grab if this possibility is not precluded in any case on account of the shallow depth. This would reduce the instantaneous sediment loss rates and the intensity of sediment plumes in the bed layer and thus keep any disturbance to a practical minimum.

6.6.3 Current technology does not offer any environmentally preferable means to lay the submarine pipeline into the seabed. As discussed in Section 3, post trenching techniques such as ploughing are not obviously advantageous and in fact would offer less security in the operational phase because the protective rock armour would likely have to protrude above the seabed. Bedding fluidisation methods such as jetting would potentially release even more sediment into the water column than dredging itself.

6.7 Mitigation Measures

6.7.1 Construction Phase

6.7.1.1 Works within the Marine Park need to be particularly carefully controlled. There should be no access to the shore or working from land within the Marine Park. No marine anchors should be used within the Marine Park.

6.7.1.2 There is a need to dredge a short length of pipeline trench (approximately 400m) within the Marine Park. Whilst the impact of a trailer dredger working in these waters is expected to be within acceptable bounds, it is recommended that the use of hydraulic suction dredgers within the Marine Park should be avoided to minimise instantaneous sediment losses and the intensity of plumes at the point of dredging. Any dredging within the Marine Park should instead be carried out by means of a closed mechanical grab.

6.7.1.3 The pipeline would run in an easterly direction from Sha Chau underneath the existing maintained dredged channel which provides tanker access to the AFRF. The existing AFRF will be retained as a strategic emergency backup facility once the PAFF is commissioned. It must be maintained in working order with tanker access at all times. Maintenance dredging of this channel will continue even on commissioning of the PAFF. The opportunity therefore exists to combine the one-off dredging for the trench with a regular maintenance dredging operation to avoid any duplication of dredging activity and to minimise overall dredging requirements.

6.7.1.4 Dredging operations should be undertaken in such a manner as to minimise resuspension of sediments. Standard good dredging practice measures should therefore be implemented including the following requirements which should be written into the dredging contract. These measures are also summarised in the Environmental Mitigation Implementation Schedule in Appendix B.

- trailer suction hopper dredgers shall not allow mud to overflow;
- use of Lean Material Overboard (LMOB) systems shall be prohibited;
- mechanical grabs shall be designed and maintained to avoid spillage and should seal tightly while being lifted;
- barges and hopper dredgers shall have tight fitting seals to their bottom openings to prevent leakage of material;
- any pipe leakages shall be repaired quickly. Plant should not be operated with leaking pipes;
- loading of barges and hoppers shall be controlled to prevent splashing of dredged material to the surrounding water. Barges or hoppers shall not be filled to a level which will cause overflow of materials or pollution of water during loading or transportation;
- excess material shall be cleaned from the decks and exposed fittings of barges and hopper dredgers before the vessel is moved;
- adequate freeboard shall be maintained on barges to reduce the likelihood of decks being washed by wave action;
- all vessels shall be sized such that adequate clearance is maintained between vessels and the sea bed at all states of the tide to ensure that undue turbidity is not generated by turbulence from vessel movement or propeller wash; and
- the works shall not cause foam, oil, grease, litter or other objectionable matter to be present in the water within and adjacent to the works site.

6.7.1.5 Placement of pipeline trench backfill should be undertaken in a controlled manner to minimise impacts. Backfilling with rock should be undertaken either down pipe or by a reverse grab operation or other controlled technique to ensure that this material does not mound on the seabed.

6.7.1.6 General construction activities on land should also be governed by standard good working practice. Specific measures to be written into the works contracts should include :

- ♦ wastewater from temporary site facilities should be controlled to prevent direct discharge to surface or marine waters;
- ♦ sewage effluent and discharges from on-site kitchen facilities shall be directed to Government sewer in accordance with the requirements of the WPCO or collected for disposal offsite. The use of soakaways shall be avoided;
- ♦ storm drainage shall be directed to storm drains via adequately designed sand/silt removal facilities such as sand traps, silt traps and sediment basins. Channels, earth bunds or sand bag barriers should be provided on site to properly direct stormwater to such silt removal facilities. Catchpits and perimeter channels should be constructed in advance of site formation works and earthworks;
- ♦ silt removal facilities, channels and manholes shall be maintained and any deposited silt and grit shall be removed regularly, including specifically at the onset of and after each rainstorm;
- ♦ temporary access roads should be surfaced with crushed stone or gravel;
- ♦ rainwater pumped out from trenches or foundation excavations should be discharged into storm drains via silt removal facilities;
- ♦ measures should be taken to prevent the washout of construction materials, soil, silt or debris into any drainage system;
- ♦ open stockpiles of construction materials (e.g. aggregates and sand) on site should be covered with tarpaulin or similar fabric during rainstorms;
- ♦ manholes (including any newly constructed ones) should always be adequately covered and temporarily sealed so as to prevent silt, construction materials or debris from getting into the drainage system, and to prevent storm run-off from getting into foul sewers;
- ♦ discharges of surface run-off into foul sewers must always be prevented in order not to unduly overload the foul sewerage system;
- ♦ all vehicles and plant should be cleaned before they leave the construction site to ensure that no earth, mud or debris is deposited by them on roads. A wheel washing bay should be provided at every site exit;
- ♦ wheel wash overflow shall be directed to silt removal facilities before being discharged to the storm drain;
- ♦ the section of construction road between the wheel washing bay and the public road should be surfaced with crushed stone or coarse gravel;
- ♦ wastewater generated from concreting, plastering, internal decoration, cleaning work and other similar activities, shall be screened to remove large objects;
- ♦ vehicle and plant servicing areas, vehicle wash bays and lubrication facilities shall be located under roofed areas. The drainage in these covered areas shall be connected to foul sewers via a petrol interceptor in accordance with the requirements of the WPCO or collected for off site disposal;
- ♦ the contractors shall prepare an oil / chemical cleanup plan and ensure that leakages or spillages are contained and cleaned up immediately;
- ♦ waste oil should be collected and stored for recycling or disposal, in accordance with the Waste Disposal Ordinance;

- all fuel tanks and chemical storage areas should be provided with locks and be sited on sealed areas. The storage areas should be surrounded by bunds with an ultimate capacity of at least 150% (by 2040) of the storage capacity of the largest tank. The initial storage capacity after the Phase I construction in 2009 will be about 175% with 4 tanks in each of the two bunded areas; and
- surface run-off from bunded areas should pass through oil/grease traps prior to discharge to the stormwater system.

6.7.1.7 Following construction of the pipeline it will be necessary to clean and de-water the aviation fuel pipeline prior to commissioning. Any water lying within the pipeline will be driven out by means of a pressure driven pig. It is recommended that any wastewater thus collected be temporarily stored in a wastewater / slop tank at the tank farm for chemical analysis, pre-treatment as necessary and safe disposal in accordance with the WPCO. The water may be enriched with iron oxides although the presence of toxic substances is not anticipated. Water from this one-off operation that cannot be adequately treated on site should be tankered to the Chemical Waste Treatment Centre for treatment and disposal.

6.7.2 Operational Phase

6.7.2.1 The single most important mitigation measure in the operational phase is the placement of a rock armour protective layer positioned to cover the pipeline but not protrude above the sea bed. This will prevent possible mechanical damage, for example from trailing anchors or trawling nets. To provide additional security it is recommended that the pipeline shall be fitted with a leak detection system. The system shall be monitored on a 24 hour basis by the control centre at the Tuen Mun Area 38 site. In the unlikely event of any failure this warning system should trigger the emergency shutdown.

6.7.2.2 Other mitigation measures recommended for the operational phase include the following. These measures are also summarised in the Environmental Mitigation Implementation Schedule in Appendix B:

- detailed emergency response procedures shall be drawn up. These will include requirements to maintain floating oil booms, absorbent materials and skimmers on site at all times;
- routine losses and spills will also be prevented through design. Coupling points on the jetty will be protected with slop collection utilities;
- auxiliary tanks shall be permanently maintained at the tank farm for recovered fuel and slops;
- oily drainage systems and slop collection systems will connect to an oil/water separator;
- all tanks shall be bunded to a capacity of at least 150% of the largest individual tank in each compound at the ultimate phase of 2040. For the initial development phase, as only 4 tanks will be present in each bund, a containment capacity of about 175% will be achieved. Tank pits shall be protected by an impermeable bed (e.g. geotextile sheeting) to prevent seepage of aviation fuel to ground. A leak detection system shall be installed beneath the containment membrane;

- there shall be no direct outlet from the bund. A collection sump shall be included in the base. Removal of accumulated rainwater shall be activated manually and discharged to storm drain via an oil / water separator;
- contingency procedures shall be drawn up to ensure containment and safe disposal of any fuel lost from tanks or pipework. Suitable absorbent materials (e.g. sand or earth) shall be kept on site to deal with spillages; and
- valves shall be installed within the storm drainage system to facilitate the retention of spillages.

6.7.2.3 A schematic diagram showing the general storm water drainage of the tank farm and the tank leak drainage containment arrangement within the bunded areas is provided in Figure 6.16.

6.7.2.4 In addition, it is recommended that the Franchisee undertake some routine monitoring of water quality in the vicinity of the PAFF site to check the effectiveness of the proposed precautionary measures implemented for on-site spill control. The details of the monitoring to be undertaken will be prepared by the Franchisee as part of the PAFF Operations Manual and the details will be agreed with the relevant authorities within 3 months of the commencement of operation of the PAFF. However, the monitoring should include but not be limited to the parameters of TPH and PAH and reference should be made to the existing monitoring programme undertaken for the fuel tank farm on the HKIA platform.

6.8 Residual Impacts

6.8.1 With the implementation of the identified mitigation measures the only disturbance to water quality during construction will arise during dredging and construction of the submarine pipeline and placement of its protective wall and rock armour. However, the above assessment has demonstrated that any such disturbance will be well within acceptable bounds and thus no adverse residual impacts are anticipated.

6.8.2 With the implementation of the mitigation measured recommended for the operation phase no adverse residual impacts would be expected.

6.9 Cumulative Impacts

6.9.1 Backfilling operations have been on-going at the contaminated mud disposal facility at East Sha Chau since 1992 (Figure 6.2). The impact on water quality has been assessed both predictively using mathematical models similar to those employed in this assessment and in the field through a comprehensive field monitoring programme.

6.9.2 Mathematical modelling studies carried out in support of the EIA for the disposal site (ERM, 1997 and ERM, 2005) indicated that mud dumped at the site would predominantly settle within the confines of the pit. On strong flood tides the water current is such that sediment suspended in the water column would be carried at low concentrations in a northwesterly direction towards Sha Chau and Lung Kwu Chau before dissipating. Concentrations of suspended sediments at these locations were predicted to be generally very low, typically under 1 mg/l with peak at levels of the order of 3-4 mg/l for short periods within the tidal cycle. These levels are not of any environmental concern and such a 'plume' would probably be indistinguishable from ambient conditions in the absence of mud dumping.

6.9.3 Project specific monitoring work has been undertaken at East Sha Chau for nearly a decade and has enabled a definitive conclusion to be drawn that the disposal activities have not had any significant effect on water quality beyond the immediate confines of the pit during dumping (ERM, 2000, Meinhardt 2006a).

6.9.4 In summary it can be seen that previous studies have clearly established that the mud disposal operations have a negligible impact on water quality away from the immediate vicinity of the disposal pits. There is no reason to suspect that overlapping plumes from the disposal operations at East Sha Chau would contribute to any adverse cumulative impacts if carried our concurrently with construction works for the PAFF pipeline.

6.9.5 It is noted that, in the coming years, the North Brothers Marine Borrow Area will be backfilled and a new contaminated mud facility will be constructed at East of Sha Chau or the Airport East (Figure 6.1) with a higher preference to the East of Sha Chau site. Based on the EIA report, construction of the new CMP was tentatively scheduled for 2008 while backfilling of the existing pit (CMP IVc) will continue although it is noted that whether the new CMPs will be implemented or not remains uncertain at the time. The PAFF project will be operational by 2009 and the construction period may overlap with the dredging and backfilling of the CMPs. Based on the scale of the work, however, it will only take about 9 days to complete the dredging for the pipeline if a TSHD is used. As has been modelled in the EIA for the new CMPs, there would be no significant adverse impacts to the sensitive receivers even with concurrent backfilling, capping and dredging operations at various cells of the CMPs. Given the short duration of the dredging works for the pipelaying, it is unlikely the PAFF will cause any significant cumulative impacts.

6.9.6 The proposed LNG Terminal project at Soko Island will comprise the construction of a pipeline between the terminal itself and Blackpoint and as such dredging for the pipeline laying has the potential for cumulative impacts if the works are undertaken at the same time as the PAFF pipeline dredging. The LNG Terminal EIA Report (2006) does not specify and exact timescale for the construction of the project but it is noted that the preferred Soko Island option is expected to be completed by 2011 and it would take about 4 years to construct. This would mean the project would need to commence by 2008. The proposed timescale for the PAFF pipeline dredging is currently between September 2007 and February 2008. However, it is not anticipated that the LNG Terminal pipeline dredging will occur in the first 2 months of the construction period, assuming it did in fact commence in January 2008. As such, no cumulative impacts are expected.

6.9.7 There are no other confirmed marine works projects likely to give rise to overlapping plumes concurrent with those caused by dredging and pipelaying for the PAFF project. It is therefore concluded that there will not be any adverse cumulative impacts resulting from construction of the PAFF facility at the same time as other known works projects are in progress.

6.10 Environmental Monitoring and Audit

6.10.1 The implementation of good construction works practice and good dredging practice as well as the various specific mitigation measures identified above is important to prevent pollution of marine water in the construction phase. It is therefore recommended that construction activities both on land and offshore should be subject to a routine audit programme throughout the construction period. Further details on the scope of this audit are provided in the project EM&A manual.

6.10.2 With the implementation of the recommended mitigatory measures no residual adverse impacts on water quality would be expected. Nevertheless in view of the close proximity of the key sensitive receiver, the Lung Kwu Chau and Sha Chau Marine Park, it is considered appropriate to implement a water quality monitoring programme when construction works are taking place within 1000m of the Marine Park boundary to verify that the intensity of sediment plumes caused by activities associated with dredging and pipelaying are within the predicted acceptable bounds.

6.10.3 For monitoring during other dredging activities, water quality impact monitoring stations shall be positioned 500m to the north/northwest and south/southeast of any dredger when operating at a distance greater that 1 km from the boundary of the Lung Kwu Chau and Sha Chau Marine Park. These stations will provide data on water quality when dredging is in progress outside the Marine Park. These stations shall be located upstream (IMO1) and downstream (IMO2) of the dredger and shall move on a daily basis so that they are in current streams that could be affected by the dredging.

6.10.4 The monitoring programme shall form an integral part of a management and control programme with a clearly defined Action Plan to trigger implementation of any necessary revision to works practice or provision of supplementary mitigation measures in the unlikely event that adverse impacts are identified. Further details of the monitoring programme and accompanying Action Plan are provided in the EM&A manual.

6.10.5 The principal mitigation features in the operational phase will be established through the design and construction of the facility and the implementation of an aviation fuel spill emergency response contingency plan. No adverse impacts on water quality are anticipated in the operational phase. However, it is recommended that the Franchisee undertake some routine monitoring of water quality in the vicinity of the PAFF site to check the effectiveness of the proposed precautionary measures implemented for on-site spill control. The details of the monitoring to be undertaken will be prepared by the Franchisee as part of the PAFF Operations Manual and the details will be agreed with the relevant authorities within 3 months of the commencement of operation of the PAFF. However, the monitoring should include but not be limited to the parameters of TPH and PAH and reference should be made to the existing monitoring programme undertaken for the fuel tank farm on the HKIA platform.

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