3. WATER QUALITY

3.1 Introduction

Potential water quality impacts may arise during the construction of the proposed DGA as a result of dredging and filling activities for the breakwaters. Based on the most up-to-date information, underwater blasting of rock at the mooring locations would not be required. During the operational phase, key water quality issues include effects on tidal flow due to the presence of the breakwaters for the DGA, local impacts related to the discharge of wastes from vessels inside the DGA, and impacts in the event of fuel spillage, inside or outside the DGA.

This section presents the detailed assessment of the key water quality impacts likely to arise as a result of the construction and operation of the TLCDGA. The environmental acceptability of these potential water quality impacts is assessed, with a view to identifying appropriate mitigation measures to reduce any identified adverse impacts to acceptable levels. Impacts from the spillage of fuel on water quality, in and outside the DGA, are described in Chapter 4 under Fuel Spillage.

3.2 Environmental Legislation and Standards

The major legislation to protect the water quality in Hong Kong is the Water Pollution Control Ordinance (WPCO) (Cap. 358) established in 1980. This legislation established water control zones (WCZs) in which objectives were set for the water quality. Ten WCZs covering the whole territory were declared under the Ordinance and its subsidiary legislation. Corresponding statements of the Water Quality Objectives (WQOs) were stipulated for different water regimes (marine waters, inland waters, bathing beaches subzones, secondary contact recreation subzones and fish culture subzones) in the WCZ based on their beneficial uses. The proposed DGA site is located within the Western Buffer WCZ which was gazetted in 1993. Details of the WQOs statement for this WCZ are listed in Table 3.1.

3.3 Baseline Conditions

3.3.1 Existing Conditions

Marine Water Quality

The water quality in the study area of the Western Buffer Waters is well documented by the routine EPD marine water quality monitoring programme. The most useful source is provided by Station WM4 located to the south of Ma Wan and within the study area.

A summary of EPD monitoring data for 1996 is given in Table 3.2. According to the EPD's Publication *Marine Water Quality in Hong Kong for 1996*, full compliance with the WQOs for dissolved oxygen, total inorganic nitrogen and unionized ammonia was achieved in 1996.

Table 3.2 Summary statistics of marine water quality of Western Buffer WCZ for 1996

Determinand		Tsing Yi West	
		WM3	WM4
Number of samples		12	12
Temperature (°C)	Surface	23.3 (16.9 - 28.1)	23.4 (16.8 - 28.3)
	Bottom	22.4 (16.8 - 28.1)	22.5 (16.8 - 28.1)
Salinity (ppt)	Surface	29.8 (18.8 - 34.3)	29.2 (18.9 - 34.2)
	Bottom	33.0 (31.2 - 34.2)	32.8 (30.9 - 34.2)
Dissolved Oxygen (% Saturation)	Surface	83.3 (64.1 - 107.9)	81.2 (60.4 - 100.2)
	Bottom	73.8 (54.0 - 94.7)	74.0 (52.1 - 93.9)
Dissolved Oxygen (mg/L)	Surface	6.0 (4.7 - 7.5)	5.8 (4.6 - 6.9)
	Bottom	5.3 (3.7 - 6.9)	5.3 (3.6 - 6.8)
pH		8.0 (7.8 - 8.3)	8.1 (7.8 - 8.3)
Secchi Disc Depth (m)		1.8 (0.8 - 3.5)	2.2 (1.3 - 4.0)
Turbidity (NTU)		5.4 (2.7 - 8.6)	4.9 (1.8 - 8.6)
Suspended Solids (mg/L)		7.5 (3.4 - 14.3)	7.2 (3.4 - 14.0)
Silica (As SiO_2) (MG/L)		1.2 (0.4 - 2.9)	1.2 (0.4 - 2.6)
5-day Biochemical Oxygen Demand (mg/L)		0.5 (0.2 - 1.1)	0.4 (0.2 - 1.0)
Nitrite Nitrogen (mg/L)		0.03 (0.01 - 0.10)	0.03 (0.01 - 0.12)
Nitrate Nitrogen (mg/L)		0.15 (0.04 - 0.34)	0.16 (0.06 - 0.28)
Ammoniacal Nitrogen (mg/L)		0.11 (0.03 - 0.17)	0.09 (0.01 - 0.17)
Total Inorganic Nitrogen (mg/L)		0.29 (0.21 - 0.48)	0.28 (0.20 - 0.37)
Total Nitrogen (mg/L)		0.52 (0.34 - 0.85)	0.51 (0.38 - 0.84)
Ortho-phosphorus (mg/L)		0.03 (0.02 - 0.05)	0.03 (0.02 - 0.05)
Total Phosphorus (mg/L)		0.12	0.12

Table 3.1 Water Quality Objectives for Marine Waters of Western Buffer WCZ

Parameter	Objective	Part(s) of Zone
E. coli	annual geometric mean not to exceed 610/100 mL	secondary contact recreation subzones; fish culture subzones
	geometric mean not to exceed 180/100 mL during March to October inclusive in 1 year; sample should be taken at least 3 times in 1 calendar month at intervals of between 3 to 14 days	bathing beach subzones
	geometric mean of the most recent 5 consecutive samples taken at intervals of between 7 and 21 days not to be less than 1/100 mL	water gathering ground subzones
	geometric mean of the most recent 5 consecutive samples taken at intervals of between 7 and 21 days not to exceed 1000/100 mL	other inland waters
Dissolved Oxygen within 2 m of bottom	not less than 2 mg/L for 90% samples	marine waters
	not less than 2 mg/L for 90% samples	fish culture subzones
Depth averaged Dissolved Oxygen	not less than 4 mg/L for 90% samples	marine waters except fish culture subzones
	not less than 5 mg/L for 90% samples	fish culture subzones
pH value	within the range 6.5 to 8.5; change due to waste discharge not to exceed 0.2	marine waters except bathing beach subzones
	within the range 6.5 - 8.5	water gathering ground subzones
	within the range 6.0 - 9.0	other inland waters
Salinity	change due to waste discharge not to exceed 10% of natural ambient level	whole zone
Temperature	change due to waste discharge not to exceed 2°C	whole zone
Suspended solids	waste discharge not to raise the natural ambient level by 30%, nor cause the accumulation of suspended solids which may adversely affect aquatic communities	marine waters
	annual median not to exceed 20 mg/L	water gathering ground subzones
	annual median not to exceed 25 mg/L	other inland waters
Toxicants	not to be present at levels producing significant toxic effect, carcinogenic, mutagenic or teratogenic effects in humans, fish or any other aquatic organisms, with due regard to biologically cumulative effects in food chains and to interactions of toxic substances with each other	whole zone
	not to cause a risk to any beneficial use of the aquatic environment	whole zone
Un-ionized ammonia	annual mean not to exceed 0.021 mg/L	whole zone
Nutrients	not to be present in quantities that cause excessive growth of algae or other aquatic plants	marine waters
	annual mean depth average inorganic nitrogen not to exceed 0.4 mg/L	marine waters

Table 3.4 Summary of EPD Beach Water Quality within Tsuen Wan District

Beach Name	EPD Beach Water Quality Rank - 1996	EPD Beach Water Quality Rank - 1997	*E. coli* Geometric Mean (count per 100 mL) - 1996	*E. coli* Geometric Mean (count per 100 mL) - 1997
Tung Wan	Fair	Fair	59	110
Anglers	Very poor	Very poor	636	691
Gemini	Poor	Poor	512	458
Hoi Mei Wan	Poor	Poor	373	471
Casam	Poor	Poor	483	609
Lido	Poor	Poor	537	600
Ting Kau	Very poor	Very poor	2096	1583
Approach	Very poor	Very poor	1164	1009

Source : EPD's Publication *Bacteriological Water Quality of Bathing Beaches in Hong Kong for 1996 & 1997*

3.3.2 Future Conditions

Marine Water Quality

With the implementation of the Sewage Master Plan for Tuen Mun, Tsuen Wan, Kwai Chung and Tsing Yi, the marine water quality in the coastal areas near these districts is anticipated to improve in the future. As described in Section 2.1, a comprehensive residential development has been approved in the northeastern CDA and the adjacent 'Village Type Development' zone will be developed. In addition, a theme park (Ma Wan Park) has been "approved with conditions" at the western CDA, to the north of Lantau Link. With the significant increase in population on Ma Wan there will be a substantial increase in wastewater discharges and associated pollutant loadings. Therefore there is the potential for a reduction in marine water quality in the Ma Wan area. A sewage treatment works (STW) will be constructed at Pak Wan on northern Ma Wan to serve the committed developments. This proposed STW will provide treatment to secondary level and thereby reduce the pollutant load into the marine waters. Effluent discharged from the STW would comply with the discharge standards stipulated under the Technical Memorandum on *Standards for Effluents Discharged into Drainage and Sewerage Systems, Inland and Coastal Waters,* issued under section 21 of the WPCO.

Beach Water Quality

A number of sewerage works are proposed in the Tsuen Wan district. A sewerage network is proposed along the coast between Tsing Lung Tau and Ting Kau to collect sewage from the currently unsewered areas. The sewage will be conveyed to a new sewage treatment plant to be constructed at Sham Tseng. With the implementation of these sewerage works, the water quality of the bathing beaches in the Tsuen Wan district is anticipated to significantly improve. As described above for marine water quality, with the increase in wastewater discharges from the committed future development in north-eastern Ma Wan there is the potential for a reduction in beach water quality at the two beaches on eastern Ma Wan. The new STW proposed for northern Ma Wan will treat the wastewater discharges from the committed developments and thereby reduce the pollutant load into the coastal waters. However, the future beach water quality will also be dependent on the location of any new stormwater outfalls along the coastline.

Determinand		Tsing Yi West	
		WM3	WM4
		(0.07 - 0.18)	(0.07 - 0.25)
Phaeo-pigment (ug/L)		1.56 (0.20 - 7.40)	1.40 (0.20 - 5.63)
Chlorophyll-a (ug/L)		2.70 (0.40 - 12.67)	1.86 (0.53 - 7.37)
E.coli (cfu/100ml)		432 (41 - 17667)	160 (30 - 1133)
Faecal Coliforms (cfu/100ml)		702 (80 - 31000)	240 (40 - 2000)

Note: 1. Data presented are depth-averaged data, except as specified.
2. Data presented are annual arithmetic means except for E.coli and faecal coliform data which are geometric means.
3. Data enclosed in brackets indicate the ranges.

For this study, it has been agreed with EPD that the 95th percentile value (95%ile) of the monitoring data for station WM4 is the most appropriate value to use to represent the ambient suspended solids (SS) concentration in the study area. (This approach was adopted in the associated EIA study for the Tsuen Wan Bay Further Reclamation Feasibility Study). From analysis of the baseline monitoring data provided by EPD, which is recorded at 3 depths in the water column, the 95%ile of the SS concentration is calculated as 19.15 mg/L for a depth averaged value (Table 3.3). It is noted that there are likely to be limitations in using data sets recorded on a monthly basis to establish ambient SS concentrations as these rarely record fluctuations in high SS levels which may occur due to typhoons, shipping activity, etc. However, it is considered that natural variations in SS concentrations due to seasonal discharge from the Pearl River would be recorded as baseline data for a period of over 3 years was analyzed.

The WQO for SS states that the marine activities during the construction works must not cause the natural ambient level to be raised by more than 30% nor give rise to accumulation of suspended solids. By adopting the 95%ile depth-averaged value, an increase of SS not greater than 5.7 mg/L at the sensitive receivers will be deemed to be acceptable.

Table 3.3 Ambient Suspended Solids Concentration in the Study Area (mg/L)

Parameter	Bottom water depth	Mid water depth	Surface water depth	Depth-average
95%ile	28.95	20.85	13	19.15
WQO allowable increase for SS	8.7	6.3	3.9	5.7

Data source: EPD Monitoring Station WM4 for period 1/95 to 8/98

Beach Water Quality

The water quality at the gazetted beaches in the study area for the 1996 and 1997 bathing seasons was generally poor, as characterized by high *Escherichia coli* (*E. coli*)[1] concentrations. Only Tung Wan beach on the eastern coast of Ma Wan obtained a ranking of fair and showed compliance with the WQO for *E. coli* in bathing beach subzones. The annual beach water quality rank assigned to the beaches by EPD and the geometric mean *E. coli* count (for the bathing season) are presented in Table 3.4 below. As seen from the table below, the ranking of these beaches did not change in the 1997 bathing season.

[1] *E. coli* is a commonly used and widely accepted indicator bacterium. The concentration of *E. coli* is measured to study the bacterial content of marine water and to indicate faecal pollution.

Operational Phase

Effects on tidal flow

The TELEMAC 3D model has been used to predict the overall effects on tidal flow due to the presence of the TLCDGA. Four tide cases were tested. Discharge volumes for the 2004 baseline scenario and another scenario with the DGA were calculated for the major water channels in Hong Kong. These include Victoria Harbour, Rambler Channel, Ma Wan, Kap Shui Mun, East Lamma Channel and West Lamma Channel. Discussions and presentation of the results will be given in Section 3.7.2

Discharge of wastes inside the DGA

The major concern relates to sewage generated inside the DGA. Although the sewage load inside the DGA is expected to be small, its impact on the nearby beach is of concern since Tung Wan is only around one kilometre away from the DGA. As the DG vessels currently registered at the TWDGA would be the potential users of the TLCDGA, which comprise vessels licensed to carry Category 2 and 5 DG, the accidental discharge of chemical wastes from vessels is not an issue of concern. From a study of the allocation of moorings at the TWDGA undertaken in 1998 and 1993,[2] most vessels are licensed to carry Category 5 DG, Class 3 fuel oils.

To assess quantitatively the effects on nearby sensitive receivers, modelling work has been carried out to simulate dispersion of *E. coli* which is discharged as part of raw sewage from vessels moored within the TLCDGA. The BACTERIAL PLUME RW3D model was used and flow data was taken from the previous TELEMAC 3D Flow Model runs for the DGA. Simulations of the continuous discharge of bacteria have been carried for the four representative tide types in Hong Kong, the wet and dry season spring and neap tides.

To calculate the total daily bacterial load, it is assumed that there will be 15 vessels in a normal operation day, with an average of 6 persons per vessel. Adopting the load factor of 4.3×10^{10} *E.coli* counts/hd/day from the Sewerage Manual, the total loading will be 3.87×10^{12} counts/day. The discharge of this bacteria was simulated by having 15 release points in the model, spread evenly along the positions of the vessel moorings. The discharge was assumed to be constant and even throughout a 24 hour period. The release of the *E.coli* was simulated as point sources at the sea surface.

The T_{90} values for the bacteria (i.e. the time taken for 1 log reduction in numbers) were assumed to be 4 hours in the top 8m of the water column during the day and 40 hours for the night and for the whole day in the lower part of the water column where light will not penetrate. In order to simulate the worst-case in terms of bacterial concentrations at sensitive receivers, the start of the flood tide was set to correspond to the period when the T_{90} values for the surface layer are at their highest, 40 hours. This was because the closest sensitive receivers which are on Ma Wan are to the north of the DGA, which is in the flood direction.

The WQO for *E. coli* states that the annual geometric mean should not exceed 610 counts per 100 mL in secondary contact recreation subzones and fish culture subzones. For bathing beach subzones, the annual geometric mean of *E. coli* should not exceed 180 counts per 100 mL during the bathing season (i.e. from March to October inclusive).

2 The study undertaken in 1998 is the recent site visit undertaken by CES Ltd. in July 1998. The 1993 study is the previous site survey undertaken from 19 June to 2 July 1993, and reported in *Risk Assessment at TWDGA Phase 1. Volume 2 Appendices. ERM Hong Kong 1994.*

3.4 Assessment Methodology and Criteria

Construction Phase

Information related to the dredging operation will be gathered. Such information includes:

- the extent of the area to be dredged;
- the quantity of dredged materials;
- the quantity and distribution of contaminated mud among the dredged materials;
- the rate and duration of the dredging operation; and
- the dredging method and the numbers and types of dredgers to be deployed.

Collected information will be compared to those assumed in the sediment plume modelling carried out for the TLCDGA in late 1997 to assess the likely extent of water quality impact during dredging activities.

In the modelling work, it was assumed that three open grab dredgers were dredging under each of the three breakwater locations with a rate of 8,060 m^3/ day for each grab dredger. It was also assumed that 5% of the dredged materials would be lost to suspension, equivalent to a loss rate of 2.28 kg s^{-1} for each grab dredger. Flow data was obtained by the hydrodynamic modelling works for the study and sediment plume simulations were carried out for the wet season neap tide and dry season spring tide. These two simulations were representative of the range of conditions in Hong Kong waters in terms of tidal range and seasonal conditions.

Details of the scenarios simulated by the sediment plume model and the modelling results were presented in the *Final Report for TELEMAC 3D Tidal Flow and Sediment Plume Modelling (December 1997)* under the TWBFR Feasibility Study (and included in Appendix B of this Final Assessment Report). Relevant modelling results will be discussed in Section 3.6.2, and mitigation measures will be recommended should the predicted impacts on water quality be significant. The sediment plume modelling predicted the elevations in SS concentrations above ambient at the identified sensitive receivers and the results have been presented in time series plots for SS concentrations at each sensitive receiver. The predicted SS concentrations at the sensitive receivers will be compared against the applicable assessment criteria of the WQO for SS, as described below, so as to indicate compliance or noncompliance with the WQO.

The criteria for evaluating impacts on marine water quality are given in Annex 6 of the *Technical Memorandum* (TM) *on Environmental Impact Assessment Process* and have been adopted in this project. The WQO for SS states that the marine activities during the construction works must not cause the natural ambient level to be raised by more than 30% nor give rise to accumulation of suspended solids. As described in Section 3.3, by adopting the 95%ile depth-averaged value to represent ambient SS concentrations in the study area, an increase in SS concentrations of not greater than 5.7mg/L at the sensitive receivers will be deemed to be acceptable. (The calculated allowable increases in SS concentrations for the surface, middle and bottom water depths are shown in Table 3.3). In addition to the WQO for SS concentrations, fish culture zones have specific water quality criteria. According to the *ex-gratia* arrangements for mariculturists, at any one time the SS concentration must not exceed 50 mg/L or exceed by 100% the highest level recorded at the fish culture zone during the five years before commencement of works in the vicinity. It is understood that if these levels are exceeded, the mariculturists may opt for *ex-gratia* payments.

Table 3.5 Preliminary Production Rate of Dredging for Breakwater Foundation

Breakwater	Sediment Type	Rate (m^3/week)
South-west	Clean Contaminated	100,000 50,000
East	Clean	100,000
North	Clean	100,000
North-west	Clean	100,000

Following the removal of marine sediments by dredging, sandfill will be placed in the breakwater trenches. During the sandfilling works there would be release of fines into suspension and these fine particles would be carried away by the prevailing tidal currents. The placement of sandfill is likely to involve the use of one split trailing suction hopper dredger. THD are able to place sandfill in various ways including either bottom dumping and pumping through a pipeline. A production rate of 100,000 m^3/week is proposed for the sandfilling works.

Release of Contaminants during Dredging

The results of the sediment analysis undertaken during the preliminary site investigation indicate that the marine sediment at three vibrocore locations along the proposed south-west breakwater of the DGA are seriously contaminated, Class C material. This is due to the exceedance of the specified contamination criteria of the heavy metal Cu at the vibrocore locations VC2 (65 mg/kg), VC3 (66 mg/kg) and VC4 (120 mg/kg). It is noted that the Cu concentration at VC2 and VC3 just exceeds the Class C contamination criteria of 65 mg/kg or more and that contaminated sediment was found at one depth interval only in these core samples. The majority of the marine sediment along the other proposed breakwaters is classified as Class A, uncontaminated material. Class B, moderately contaminated material, was found at vibrocores VC5, VC7 and VC10. The total volume of contaminated dredged sediment (Class C) is estimated to be approximately 171,792 m^3. (Further discussion on the estimated quantity of dredged sediment and the likely disposal designation of the uncontaminated and contaminated sediments is presented in Section 7).

As the proposed DGA site is located offshore and there are currently no sewage effluent discharges in the area, it is not anticipated that nutrient levels in the sediment will be of concern. For the sediment quality analysis undertaken for the Tsuen Wan Bay Further Reclamation EIA study, the PCB and PAH concentrations in the composite sediment samples were all found to be less than 100 µg/kg and 0.3 mg/kg respectively. As the proposed DGA site is located offshore and away from the industrial areas of Tsing Yi and Tsuen Wan, it is anticipated that the levels of organic pollutants and trace organics in the sediment will be less than the above values recorded in Tsuen Wan Bay and thus these potential pollutants will not be of concern. The potential exists, however, for effects on water quality through the mobilization and release of heavy metals into the surrounding water column during the dredging of marine sediment.

Placement of Sediment within DGA

To meet the Marine Department's minimum requirement of 3 m of soft material cover at the location of mooring anchorages for the safe mooring of vessels, a possible measure is the importation of material to overlay the rock 'outcrops.' (A vibrocore survey undertaken in July 1998 found rock in the north-east corner of the DGA, near the northern entrance, and in the western part). This measure of mud laying is considered to be highly favourable over the alternative option of underwater blasting of rock in view of the past sightings of Chinese White Dolphins in the waters off the north-eastern Lantau coastline.

3.5 Sensitive Receivers

Figure 3.1 shows the marine water sensitive receivers. They can be mainly classified into two categories. The first group is the beaches along the coastline of Ma Wan, Tsuen Wan and Lantau. They may be gazetted or non-gazetted. The beaches closest to the site are Tung Wan and Tung Wan Tsai on the eastern coast of Ma Wan, at a distance of approximately 1 km and 1.2 km respectively. The second group of sensitive receivers is the fish culture zones. The most sensitive one, due to its proximity to the DGA, is the Ma Wan fish culture zone on the western side of Ma Wan. Others, located in Cheung Sha Wan (Lantau) and Lo Tik Wan (Lamma), are much further away.

Besides the two groups of sensitive receivers mentioned above, the site is considered to be active in fishery activities. Changes in water quality would have an effect on these activities and this will be further discussed in Chapter 9 on ecology.

3.6 Construction Phase Assessment

3.6.1 Potential Sources of Impacts

During the construction phase, major water quality issues include:

- Dredging and sandfilling works for breakwaters foundation;
- Release of contaminants during dredging of marine sediment;
- Placement of sediment within DGA; and
- Cumulative impacts on water quality.

Breakwaters with Dredged Foundations

The key issue during the construction phase would be potential impacts from dredging of mud from the seabed where the breakwaters are to be constructed. During the dredging works there would be release of fine sediments into suspension and these fine particles would be carried away by the prevailing currents to different areas depending on the tidal conditions. During transport by the tidal currents, the fine sediment will tend to flocculate forming larger particles and settle under gravity on the seabed. If the tidal currents become large enough, the settled material will be eroded and put back into suspension for further transport by the tidal currents, where the rate of erosion will depend on the tidal currents and degree of consolidation which may have taken place. The sediment plume modelling conducted has simulated the processes of transport deposition and re-erosion for sediment plumes formed during dredging activities.

In view of the short distance between the site and the sensitive receivers at Ma Wan (including a beach and a fish culture zone), it is necessary to assess whether these sediment plumes arising from dredging activities would reach the receivers, and the concentration of the plume when it arrives at the sensitive receivers.

The preliminary production rates for dredging of the breakwater foundations as adopted in the water quality assessment are given in Table 3.5 below. These proposed rates are for 3 grab dredgers working concurrently or one trailing suction hopper dredger (THD). (The use of a THD is being retained as an option for the breakwater construction). The dredging method to be adopted will be agreed during the detailed design.

At Tung Wan Tsai beach for the dry season spring tide, a maximum increase in SS concentrations of up to 14 mg/L above ambient levels is predicted in layer 2 and an increase of up to 9 mg/L in the bed layer. As shown in **Figure 56** of Appendix B, this peak SS concentration of 14 mg/L occurs for less than an hour in the tidal cycle. At this beach, a maximum increase of almost 6 mg/L is predicted in the bed layer for the wet season neap tide, and an increase of 1 mg/L in layer 2.

The WQO for SS states that the marine activities during the construction works must not cause the natural ambient level to be raised by more than 30% nor give rise to accumulation of suspended solids. For this study, EPD routine monitoring data at Station WM4 (from 1/95 – 8/98) is used to establish the 95%ile of the baseline, which corresponds to a depth averaged value of approximately 19.15 mg/L (as described in Section 3.4). Adopting this value, an increase of SS not greater than 5.7 mg/L at the sensitive receivers will be deemed to be acceptable.

In terms of the WQO, the maximum predicted increases in SS concentrations at Tung Wan Tsai during the dry season spring and wet season neap tides are greater than 5.7 mg/L (although the predicted wet season neap tide SS concentration of 6 mg/L just exceeds the allowable increase). These WQO exceedances will necessitate mitigation measures, as recommended in Section 3.8, to be fully implemented to ensure that these exceedances do not occur. These measures include the use of closed grab dredgers for construction. The tidal flow modelling results (presented in Appendix B) for the baseline case, i.e. without the breakwaters, indicate maximum current speeds of around 0.8 m/s in the eastern and southern area of the proposed DGA for the wet season spring tide. The use of silt curtains is therefore not considered to be a practicable mitigation measure during the dredging of the breakwater foundations due to the high current speed.

With the use of closed grab dredgers (without silt curtain) the sediment loss rate and hence the maximum elevation in SS concentrations can be reduced by approximately 18 to 20% (Contaminated Spoil Management Study, Mott MacDonald 1991). Since the use of silt curtains is not considered to be feasible given the high current speed in the area to the south of Ma Wan, to further reduce the concentration of SS it is recommended that the rate of dredging should be reduced from that assumed in the modelling of 8,060 m^3/day (i.e. rate per grab dredger). With a proposed dredging rate of 4,760 m^3/day for a closed grab dredger (this is the daily rate derived from the preliminary production rate of 100,000 m^3/week), an increase of SS concentrations of approximately 6.6 mg/L above ambient is predicted at Tung Wan Tsai in the dry season spring tide. It is noted that this maximum predicted increase in SS concentrations at Tung Wan Tsai occurs in layer 2 for less than an hour. As shown in the time series plot for the dry season spring tide results (**Figure 56** of Appendix B), layer 2 is near the bed layer. The 95%ile of the baseline SS concentration for the bottom water depth is calculated to be 28.95 mg/L (as described in Section 3.3). Adopting this value, an increase of SS not greater than 8.7 mg/L at the sensitive receiver will be deemed to be acceptable. Therefore, with the above recommended mitigation measures in place, the predicted increase in SS concentration of 6.6 mg/L in layer 2 would comply with the WQO for SS at this water depth. The maximum predicted increases in SS concentrations at Tung Wan Tsai during mitigated and unmitigated dredging works are summarized in Table 3.6. As shown in Table 3.6 for the mitigated dredging works, the predicted increase in SS concentration of 4.1 mg/L for the depth-averaged value would comply with the WQO (depth-averaged value).

At the Ma Wan fish culture zone, a maximum increase in SS concentrations of 4.5 mg/L (bed layer) above ambient levels is predicted for the dry season spring tide and up to 3.5 mg/L (layer 2) above ambient levels for the wet season neap tide. In terms of the WQO, the predicted increases in SS concentrations comply with the acceptable increase of 5.7 mg/L (depth-averaged value). However, to ensure that exceedances of the WQO do not occur, the recommended mitigation measures should be implemented to maintain the water quality in accordance with the WQO. These measures include the use of closed grab dredgers and the employment of a dredging rate lower than that adopted in the sediment plume modelling. The maximum predicted increases in SS concentrations at the Ma Wan fish culture zone during mitigated and unmitigated dredging works are summarized in Table 3.6 below.

Following the completion of the breakwaters construction, it is proposed that filling materials be dumped in the necessary areas within the DGA to make up the required thickness of soft material. There is therefore the potential for impacts on water quality from the loss of fine materials into the water column.

Cumulative Impacts on Water Quality

Cumulative impacts on water quality may arise during the dredging and filling works for the DGA should there be other dredging and dumping activities in progress near the study area. Information has therefore been gathered on the construction programmes of these marine-based projects so as to identify possible concurrent projects.

3.6.2 Prediction and Evaluation of Impacts

Dredging of Marine Sediment

Dredging for the foundations of the TLCDGA breakwaters is likely to be carried out by grab dredgers, although the use of a trailing suction hopper dredger is being retained as an option. The sediment plume modelling has considered the worst-case scenario in terms of sediment lost to suspension of three open grab dredgers working concurrently, with one dredger at each of the three breakwaters. A rate of 8,060 m^3/day was assumed for each grab dredger. On comparison with the preliminary production rates proposed for dredging in the breakwater construction, as given in Table 3.5, the proposed rate of dredging for each grab dredger is around 4,760 m^3/day for dredging of clean sediment and 2,380 m^3/day for dredging of contaminated sediment. The rate of the dredging operation is therefore likely to be significantly lower than the rates adopted in the sediment plume modelling. Thus the extent of impacts on water quality from sediment lost to suspension will be less under the preliminary production rates proposed for the dredging works. The elevations in suspended sediment concentrations predicted by the sediment plume modelling have been scaled down to represent the impacts for these proposed preliminary production rates adopted in the water quality assessment.

For both the dry season spring tide and wet season neap tide scenarios, the highest suspended sediment concentrations are shown in the immediate vicinity of the dredging sites and around the south-eastern side of Ma Wan. On the flood tide, suspended sediment at low concentrations is shown to the west of Ma Wan and around the Brothers. Higher suspended sediment concentrations are shown in the bed layer than the surface layer because of sediment being re-eroded from the sea bed. This sediment re-erosion results in high suspended sediment concentrations south of Ma Wan for the wet season neap tide. On the ebb tide the dispersion of sediment is greater for the dry season spring tide than for the wet season neap tide. Low suspended sediment concentrations are shown extending along the western side of Lamma Island for the dry season spring tide, while for the wet season neap tide the suspended sediments do not reach Kau Yi Chau.

The plume modelling predicted the elevations in suspended solids (SS) concentrations above ambient at the identified sensitive receivers and the results have been presented in time series plots for SS concentrations at four depth intervals at each of the sensitive receivers. The dry season spring tide results are presented in **Figures 56** and **57** of Appendix B and the wet season neap tide results in **Figures 61** and **62** of Appendix B.

The predicted increases in SS concentrations are less than 1 mg/L on both tides for all of the beaches except Tung Wan Tsai. For the dry season spring tide, Butterfly, Cafeteria and Lido beaches are not affected by the dredging works and predicted SS concentrations at Anglers, Hoi Mei Wan, Casam and Gemini beaches are negligible. Similarly, for the wet season neap tide, Butterfly, Cafeteria and Lido beaches are not affected by the dredging works and predicted SS concentrations at Anglers, Casam Gemini and Hoi Mei Wan beaches are negligible.

The restriction of dredging and sandfilling works to ebb tide only has also been considered. However, this would lead to contractual management difficulties, a longer construction programme and hence longer period of overall water quality impact. This measure is therefore not recommended.

Table 3.7 Predicted maximum elevations in suspended solids concentrations during further mitigation

	Dredging – Unmitigated Works (modelled scenario)	Dredging – Further Mitigated Works
Total production rate	24,180 m^3/day (8,060 m^3/day per dredger with 3 grab dredgers (open) working concurrently)	9,524 m^3/day (4,762 m^3/day per dredger with 2 closed grab dredgers working concurrently)
Sediment loss rate	2.28 x 3 = 6.84 kg/s	2.15 kg/s
Maximum predicted increase in SS conc. at Tung Wan Tsai (dry season spring tide)	14 mg/L – layer 2 (i.e. near bed layer) 8.6 mg/L – depth average < 1 hour in tidal cycle	4.4 mg/L – layer 2 (i.e. near bed layer) 2.7 mg/L – depth average < 1 hour in tidal cycle
Maximum predicted increase in SS conc. at Ma Wan fish culture zone (dry season spring tide)	4.5 mg/L – bed layer 2.9 mg/L – depth average	1.4 mg/L – bed layer 0.9 mg/L – depth average

Notes:
1. WQO : allowable increase in SS (depth averaged value) is < 5.7 mg/L
2. WQO : allowable increase in SS at bottom water depth is < 8.7 mg/L
3. Further mitigated dredging works involves use of closed grab dredger & 60% reduction in dredging rate from modelled scenario

As shown in Table 3.7 for Tung Wan Tsai, the predicted maximum increase in SS concentration (depth-averaged value) of 2.7 mg/L is well below the WQO. With the adoption of the further mitigation measure, the predicted maximum increase in SS concentration of 4.4 mg/L in layer 2 (near the bed layer) would now also comply with the depth-averaged SS value under the WQO. At the Ma Wan fish culture zone, a maximum increase in SS concentrations of 1.4 mg/L (bed layer) above ambient levels is predicted for the dry season spring tide and up to 1.1 mg/L (layer 2) above ambient levels for the wet season neap tide. In terms of the WQO, the predicted increases in SS concentrations are well below the allowable increase of 5.7 mg/L (depth-averaged value).

Release of Contaminants during Dredging

During the dredging of contaminated sediments, the potential exists for effects on water quality through the mobilization and release of heavy metals into the surrounding water column. As stipulated in the EPD *Technical Circular No. 1-1-92, Classification of Dredged Sediments for Marine Disposal*, the seriously contaminated material must be dredged and transported with great care. The dredged sediment cannot be dumped in the gazetted marine disposal grounds and must be effectively isolated from the environment upon final disposal. Therefore appropriate dredging methods have been incorporated into the recommended mitigation measures and include the use of closed-grab dredgers.

In view of the fact that the dredging works would be carried out for a short period and that exceedance of the Class C sediment contamination criteria has been identified for one heavy metal species only, the potential release of metals into the water column would be localized and short-term. A quantification

Table 3.6 Predicted maximum elevations in suspended solids concentrations during dredging

	Dredging – Unmitigated Works (modelled scenario)	Dredging – Mitigated Works·
Total production rate	24,180 m^3/day (8,060 m^3/day per dredger with 3 grab dredgers (open) working concurrently)	14,286 m^3/day (4,762 m^3/day per dredger with 3 closed grab dredgers working concurrently)
Sediment loss rate	2.28 x 3 = 6.84 kg/s	3.23 kg/s
Maximum predicted increase in SS conc. at Tung Wan Tsai (dry season spring tide)	14 mg/L – layer 2 (i.e. near bed layer) 8.6 mg/L – depth average < 1 hour in tidal cycle	6.6 mg/L – layer 2 (i.e. near bed layer) 4.1 mg/L – depth average < 1 hour in tidal cycle
Maximum predicted increase in SS conc. at Ma Wan fish culture zone (dry season spring tide)	4.5 mg/L – bed layer 2.9 mg/L – depth average	2.1 mg/L – bed layer 1.4 mg/L – depth average

Notes:
1. WQO : allowable increase in SS at bottom water depth is < 8.7 mg/L
2. WQO : allowable increase in SS (depth averaged value) is < 5.7 mg/L
3. Mitigated dredging works involves use of closed grab dredger & 40% reduction in dredging rate from modelled scenario

As the sediment loss from trailing suction hopper dredgers (THD) would be significantly less than that from grab dredgers, the resulting SS concentrations at the identified impacted sensitive receivers will be lower if a THD is used. The elevations in SS concentrations predicted above for the use of an open grab dredger represent a worst-case scenario in terms of potential impacts on water quality. An indicative 'S' factor[3] for suction dredgers with no overflow or Automatic Lean Mixture Overboard (ALMOB) is typically 3 to 4 kg/m^3, whereas the 'S' factor for an open grab dredger (without silt curtain) is around 17 to 25 kg/m^3 (Contaminated Spoil Management Study, Mott MacDonald 1991). Thus with a reduction in 'S' factor of around five times of that for an open grab dredger, the maximum elevation in SS concentrations at Tung Wan Tsai and the Ma Wan fish culture zone is estimated to be approximately 3 mg/L (dry season spring tide) and <1 mg/L (wet season neap tide) respectively. The use of a trailing suction dredger is therefore not anticipated to result in unacceptable impacts on water quality at the identified sensitive receivers as the estimated SS concentrations are not anticipated to exceed the allowable increase of 5.7 mg/L under the WQO.

Despite that the WQO would be achieved by adoption of the mitigation measures recommended above, additional mitigation measures have been considered to further reduce the potential impact to the water sensitive receivers during the dredging and sandfilling works, particularly at the Ma Wan fish culture zone. The adoption of these additional mitigation measures is recommended for further protection. These additional measures include restricting the number of grab dredgers to not more than two working at one time, and conducting one of the weekly water quality monitoring events for impact monitoring during night-time hours should there be dredging or sandfilling works at this time. This proposed mitigatory measure would further reduce the elevation in SS concentrations at the water sensitive receivers through lowering the total production rate for dredging. The maximum predicted increases in SS concentrations at Tung Wan Tsai and the Ma Wan fish culture zone during these further mitigated dredging works are summarized in Table 3.7 below.

[3] 'S' factor is expressed in terms of the total quantity of sediment released by the dredger per cubic metre dredged, and provides a means of comparison of different dredging techniques.

Filling Activities

The placement of sandfill in the breakwater trenches is likely to involve the use of one split trailing suction hopper dredger (THD) of $5000m^3$ capacity. A spill loss of 2.77% of the total dumped mass[5] is assumed for fill placement by bottom dumping. A sediment loss rate of 392kg/s has been calculated for filling activities by bottom dumping from a THD, with sandfilling assumed to take place over 10 minutes per 3.5 hour cycle.

The maximum predicted elevations in SS concentrations at the sensitive receivers during sandfilling by bottom dumping are shown in Table 3.9 below (by extrapolation of the sediment plume modelling results for the unmitigated dredging works).

Table 3.9 Predicted maximum elevations in suspended solids concentrations during sandfilling

	Dredging – unmitigated (modelled scenario)	Sandfilling - unmitigated Bottom dumping	Sandfilling – mitigated Pipeline discharge method
Production rate	8,060 m^3/day per dredger 3 grab dredgers (open) working concurrently	5,000 m^3 for 10 mins	5,000 m^3 over 2 hours
Sediment loss rate	2.28 x 3 = 6.84 kg/s	392 kg/s	2.08 kg/s
Maximum predicted increase in SS conc. at Tung Wan Tsai (dry season spring tide)	14 mg/L – layer 2 (i.e. near bed layer) 8.6 mg/L – depth average < 1 hour in tidal cycle	802 mg/L – layer 2 493 mg/L – depth average over 10 mins	4.3 mg/L – layer 2 2.6 mg/L - depth average
Maximum predicted increase in SS conc. at Ma Wan fish culture zone (dry season spring tide)	4.5 mg/L – bed layer 2.9 mg/L – depth average	258 mg/L – bed layer 166 mg/L – depth average over 10 mins	1.4 mg/L – bed layer 0.9 mg/L – depth average

Notes:
1. WQO : allowable increase in SS at bottom water depth is < 8.7 mg/L
2. WQO : allowable increase in SS - depth averaged value - is < 5.7 mg/L
3. Mitigated sandfilling works involves discharge of sandfill through pipeline
4. Calculation of sediment loss rate - unmitigated option: 5,000 m^3 capacity THD – assume this load dumped over 10 mins. Maximum loss = 5000 m^3 x 1700 x 0.0277 = 235,450 kg/10 mins. = 392 kg/s (dry density of marine sand of 1700 kg/m^3 & 2.77% spill loss)
5. Calculation of sediment loss rate - mitigated option: 5,000 m^3 capacity THD – assume this load discharged over 2 hours. Maximum loss = 3kg/ m^3 x 5000 m^3 = 15000 kg/2 hours = 2.08 kg/s (assume same 'S' factor as trailer suction dredger)

It should be noted that the sandfilling operation is assumed to be carried out in a 3.5 hour cycle. In each cycle, the sediment loss would be concentrated during a period of 10 minutes, resulting in patches of water with elevated SS being transported by the currents. The elevation in SS concentration would thus be temporary and over a very short time interval. However, the maximum predicted increase in SS concentration (depth-average) at Tung Wan Tsai during bottom dumping is well in exceedance of the allowable increase under the WQO (around 86 times). It is noted that even if the THD was filled to half capacity, the increase in SS concentration at Tung Wan Tsai would still be very high and well above the WQO. Therefore sandfilling by bottom dumping is not considered to be an environmentally

5 A spill loss of 2.77% is the agreed assumption adopted in the assessment of filling activities by bottom dumping undertaken in the EIA for TWBFR Feasibility Study. The fines content of the fill material was assumed to be 20%.

of the predicted release of heavy metals from pore water during dredging is presented in Appendix G. This estimation is based on the equation adopted from the "Water Quality Prevention, Identification and Management of Diffuse Pollution" by Vladimir Novotny & Harvey Olem, Van Nostrand Reinhold, New York, 1994, and used in the water quality assessment undertaken in the EIA Study for the South East Kowloon Development Feasibility Study. As there is no existing legislative standard or guideline for individual heavy metals in marine water, the UK Water Quality Standards for Coastal Surface Water[4] is adopted as the assessment criteria. As shown in Table 3.8 below, only the predicted maximum desorbed concentration of copper in the pore water exceeds the UK Water Quality Standards. The maximum desorbed concentration of copper in the pore water is estimated to be about 1.7 times higher than the UK Water Quality Standards. However, taking into account the release rate of pore water and the dilution effect of the marine waters (for conservatism, the volume of marine water for dilution is assumed as $1m^3$), the copper concentration in the marine waters will be reduced. The instantaneous copper concentration in the marine waters surrounding the dredging site is predicted to be 0.027 μg/L. Details of the calculation are provided in Appendix G. The calculation shows that the predicted instantaneous copper concentration in the marine waters falls within the UK Water Quality Standards (5 μg/L). Therefore it is concluded that adverse water quality impacts arising from the heavy metal release of pore water from the contaminated sediment are not anticipated during the dredging works.

Table 3.8 Predicted Potential Heavy Metal Release from Dredging of Marine Sediment

Contaminant	Max. Desorbed Contaminant Concentration in pore water ($\mu g\ l^{-1}$)[b]	Max. Concentration in marine waters after $1m^3$ dilution ($\mu g\ l^{-1}$)[b]	Water Quality Standard ($\mu g\ l^{-1}$)[c]	Exceedance of Water Quality Standard (Yes/No)
Copper	8.54	0.027	5	No
Cadmium	3.24×10^{-1}	0.001	2.5	No
Chromium	8.33	0.026	15	No
Lead	9.22×10^{-1}	0.003	25	No
Nickel	4.24	0.013	30	No
Zinc	21.8	0.069	40	No
Mercury	8.20×10^{-3}	0.00003	0.3	No

a The minimum desorbed contaminant concentration in marine water is calculated based on the lower bound Kd value of the contaminant.

b The minimum desorbed contaminant concentration in marine water is calculated based on the upper bound Kd value of the contaminant.

c The water quality standards adopted are the Environmental Quality Standards and Assessment Levels for Coastal Surface Water (from HMIP (1994) Environmental Economic and BPEO Assessment Principals for Integrated Pollution Control) *(Source: Environmental Impact Assessment Study for Disposal of Contaminated Mud in the East Sha Chau Marine Borrow Pit, by ERM, January 1997).*

4 Environmental Quality Standards and Assessment Levels for Coastal Surface Water (from HMIP (1994) Environmental Economic and BPEO Assessment Principals for Integrated Pollution Control).

levels has been considered. However, due to the requirement that marine mud be dumped following the completion of the breakwaters, so as to minimize the dispersion of sediment plumes and resulting water quality impacts, this proposal on using the dredged material from the dredging works is not recommended.

Cumulative Impacts on Water Quality

Cumulative impacts on water quality may arise during the dredging and filling works for the DGA should other dredging and dumping activities be underway near the study area. As described in Section 2.7, the construction of the Tang Lung Chau DGA is estimated to commence in late 2000 for completion in approximately mid 2003. Possible concurrent projects are indicated in Table 3.10 below, together with details of the type of marine works and tentative construction programme where this information is available.

Table 3.10 Possible Concurrent Projects

Project	Commencement Date	Completion Date	Type of Works	Approx. Distance from DGA	Present stage of study
CT9	*1999 (approx. 3 year construction period)	*2001 – first berth operational	Dredging & filling	4.2 km	Design to commence late 1998
West of Sulphur Channel MBA	**	**	Sand borrowing for CT9	6.5 km	EIA study (1994)
South Tsing Yi MBA	**	**	Dumping for dredged materials from CT9	2.5 km to northern pit boundary	EIA study (1995)
Penny's Bay Reclamation	3rd quarter 1999	Late 2004	Dredging & filling	3.5 km	Design & Construction on-going
Kellet Bank Dredging	***	***	Dredging	4.2 km	EIA study on-going

* Contract for design study to be signed in late '98 and thus detailed construction programme not available at present.
** Marine works associated with CT9 construction.
*** Not known if dredging works at Kellet Bank will proceed.

From the above information, it can be seen that the Penny's Bay Reclamation is likely to be underway during the construction of the DGA. It is understood that the completion date for the reclamation is the end of 2004, although the dredging and filling works would be complete around the years 2001 or 2002. Marine-based construction works for Container Terminal No. 9 (CT9) are likely to be underway during the construction of the DGA. Associated with construction of CT9 will be sand borrowing at the West of Sulphur Channel Marine Borrow Area (MBA) and dumping of dredged sediments at the South Tsing Yi MBA and/or the South Cheung Chau marine disposal ground. Should dumping of dredged sediments take place at the South Tsing Yi MBA, it is likely that this pit would be used exclusively by CT9 during periods of peak dredging rates for the CT9 construction. The findings of the water quality impact assessments undertaken in the EIA studies for these possible concurrent projects are described below. In addition, the estimated sediment losses during dredging, dumping and filling works for these concurrent projects, as given in the respective EIA reports for these projects, are presented in Table 3.11.

acceptable method. On consideration of a significant reduction in the production rate, this would not be cost-effective nor feasible with respect to the programme requirements.

In view of the predicted high concentrations at the sensitive receivers, it is recommended that a pipeline be used to discharge the sandfill relatively close to the breakwater trench and thereby reduce the loss of fines to the water column. This mitigated method of sandfill placement is described in greater detail in Section 3.8. The THD is assumed to discharge the sandfill over a period of approximately 2 hours, giving a sandfilling rate of 2,500 m^3/hour. The cycle time for sandfilling therefore comprises sandfill discharge through the pipeline over 2 hours and an additional time of 3.5 hours required for transport of sandfill from the borrow area.

For the proposed mitigated method of sandfill placement, the maximum elevation in SS concentrations at Tung Wan Tsai is estimated to be approximately 4.3 mg/L for the dry season spring tide. In terms of the WQO for SS, this maximum increase in SS concentration is in compliance with the allowable increase of 8.7 mg/L for the bottom water depth. (As described earlier for the dredging activities, the maximum predicted increase in SS concentrations at Tung Wan Tsai occurs in layer 2, near the bed layer, for less than an hour of the tidal cycle). As shown in Table 3.9 for the mitigated sandfilling method, the predicted increase in SS concentration of 2.6 mg/L for the depth-averaged value would comply with the WQO (depth-averaged value). A maximum increase in SS of 1.9 mg/L (bed layer) is estimated for the wet season neap tide, which is in compliance with the WQO for SS in the bottom water depth.

It is noted that the point of release of sediment into suspension during the sediment plume simulations for dredging was assumed to be at the surface (Section 3.3 of Appendix B). This approach is stated to give a conservative simulation as the settling of sediment in the immediate vicinity of the release point was limited. For the proposed mitigated sandfilling method of pipeline discharge, the sandfill would tend to settle to the seabed and thus the loss of fines into suspension would be minimized. Therefore the SS concentrations presented in Table 3.9 represent a worst-case scenario as the actual elevations in SS concentrations at the sensitive receivers during the mitigated sandfilling works are likely to be less than those indicated. It is therefore anticipated that the elevations in SS concentrations at Tung Wan Tsai during the mitigated sandfilling works would comply with the WQO for SS.

The maximum elevation in SS concentrations at the Ma Wan fish culture zone is estimated to be 1.4 mg/L (bed layer) for the dry season spring tide and 1.1 mg/L (layer 2) for the wet season neap tide. The sandfilling works are therefore not anticipated to result in unacceptable impacts on water quality at the Ma Wan fish culture zone as these estimated SS concentrations do not exceed the allowable increase of 5.7 mg/L under the WQO (depth-averaged value). Furthermore, the estimated SS concentrations are well below the specific criterion of 50 mg/L for fish culture zones, as based on *ex-gratia* payment arrangements.

Placement of Sediment within DGA

Following the completion of the breakwaters construction, it is proposed that filling materials be dumped in the necessary areas within the DGA to make up the required thickness of soft material. Initial estimates indicate that around 40,000 m^3 of mud would be required, which is significantly less than the volume of dredging required for the breakwaters foundation (Table 7.3). It is anticipated that sediment plumes generated from the dumping of mud will largely remain localized due to the weak tidal currents inside the DGA and be contained by the breakwaters. Elevations in suspended sediment concentrations in the water column will be localized, within the immediate vicinity of the dumping location, and short-term. No unacceptable impacts on water quality are therefore anticipated to arise at the identified water sensitive receivers.

The MD's proposal on the beneficial use of dredged material (uncontaminated) from the dredging works for the breakwater foundations to provide soft anchorage material at the locations of high rock with existing sewage discharges in the area. The WAHMO modelling indicated that providing the navigation fairway south of Tsing Yi is realigned, the discharge of predicted pollutant loads of COD, BOD and NH_3-N will not have a significant impact on existing water quality in Rambler Channel. The potential for release of high levels of solids to the water column was identified. However, modelling of sediment plumes from dredging and the prediction of resulting SS concentrations at sensitive receivers was not performed. (Water quality sensitive receivers considered in the EA comprised a number of industrial water intakes along Rambler Channel and South Tsing Yi). The EA identified that the seawater intakes may be adversely affected by an increase in SS concentrations. A monitoring programme was recommended to ensure that turbidity does not exceed acceptable limits, particularly near the seawater intakes. The findings of the water quality impact assessments undertaken in the EIA studies for the West of Sulphur Channel MBA and South Tsing Yi MBA are described below.

The Focused EIA for the West of Sulphur Channel (WSC) MBA (Scott Wilson Kirkpatrick, Final Report 1994) included a worst-case scenario for dredging at WSC Pit 3 to supply sand for CT9; comprising dredging of marine sand at WSC Pit 3 and alluvial sand at South Tsing Yi Pit 2 (with release of fines during overflowing). The results of sediment plume modelling indicate that the sediment plume does not impact the Ma Wan fish culture zone and the two beaches on eastern Ma Wan (for all four tide types). A cumulative water quality assessment of a defined worst-case scenario was also modelled. This scenario assumed that dredging in the WSC Pit 3 will be concurrent with the East of Lamma Channel MBA and dredging works required for the Green Island Reclamation Public Dump advanced works seawall construction. The results of sediment plume modelling show that the sediment plume does not impact the Ma Wan fish culture zone and the Ma Wan beaches.

The EIA Study for the Backfilling of South Tsing Yi and North of Lantau MBAs (ERM Hong Kong, Final Report 1995) evaluated the effects on water quality arising from backfilling at these two MBAs simultaneously. The modelling scenarios simulated a rate of 10,000 m^3/day at the North of Lantau MBA and a range of rates for backfilling at the South Tsing Yi MBA. The scenarios simulated were not specific for the dumping of dredged material at the South Tsing Yi MBA associated with construction of CT9. The elevations in SS concentrations predicted at sensitive receivers for the modelled Scenario 2 (50,000 m^3/day at STY MBA & 10,000 m^3/day at NL MBA, wet season spring tide) and Scenario 4e (100,000 m^3/day at STY MBA & 10,000 m^3/day at NL MBA, dry season spring tide) are indicated in Table 3.12. Scenario 2 represents the lowest rate simulated for backfilling at the South Tsing Yi MBA, and Scenario 4e represents the recommended scenario for the allowable rates of simultaneous spoil dumping at both the South Tsing Yi and North of Lantau MBAs. The EIA study concluded that Scenarios 2 and 4e do not result in any predicted non-compliances of the WQO at the identified sensitive receivers (which include the Ma Wan fish culture zone and Tung Wan Tsai), and thus a rate equal to or lower than 100,000 m^3/day was considered acceptable for backfilling at the South Tsing Yi MBA. (In this EIA Study, the maximum allowable increase in SS concentration was 7.5 mg/L). The water quality assessment identified that significant elevations in SS concentration were predicted for only relatively short periods (1-4 hours typically) during the tidal cycle, as the main sediment plume is carried backwards and forwards on the tide.

Table 3.11 Estimated sediment losses for possible concurrent projects

Project	Total Dredged Volume (Mm^3)	Sediment loss rate
SETY Port Development for CT9	18	976 tonnes/day
Lantau Port Development Stage 1 (Penny's Bay)		
Advance Works Section 1	3	940 tonnes/day (17.4 kg/s)
Advance Works Section 2	2	813 tonnes/day (15.1 kg/s)
Local Breakwater	2.5	402 tonnes/day (9.3 kg/s)
Approach Channel	13.0	613 tonnes/day (14.2 kg/s)
West Sulphur Channel MBA -		
Cumulative scenario		
Pit 3 WSC		610 kg/s
Pit 2 WSC		240 kg/s
Green Island Reclamation Public Dump – seawall construction		8 kg/s
South Tsing Yi & North Lantau MBAs		
Scenario 2		2,378 tonnes/day (1,978 STY & 400 NL)
Scenario 4e		4,372 tonnes/day (3,972 STY & 400 NL)
Tang Lung Chau DGA	1.7	
Dredging – unmitigated scenario		591 tonnes/day (6.84 kg/s)
Dredging – mitigated scenario		279 tonnes/day (3.23 kg/s)
Dredging – further mitigated scenario		186 tonnes/day (2.15 kg/s)

Impacts on water quality arising from the Penny's Bay Reclamation were assessed in the EIA study for the Lantau Port Development – Stage 1 Container Terminals No. 10 & 11 Ancillary Works (Design) (Halcrow Asia Partnership Ltd. Final Report 1994). Sediment plume modelling was conducted to establish the extent and magnitude of sediment plumes from different dredging scenarios. The far field sediment modelling included dredging works for construction of the advance works, CT10 & 11, the breakwater and approach channel. The assessment concluded that impacts from changes in suspended sediment loads resulting from dredging will be small and within acceptable levels except in the immediate vicinity of the marine plant. The elevations in SS concentrations predicted at sensitive receivers for the Penny's Bay Advance Works and a cumulative assessment scenario (includes simultaneous dredging for advance works, breakwater and approach channel) are indicated in Table 3.12. It should be noted that under the present Design and Construction Study for Penny's Bay Reclamation, the scale of the development has been reduced from the Stage 1 Study. The access channel and local breakwater are not included in the scope of the present study and thus the quantity of dredging required will be considerably reduced. The modelled scenario for the Penny's Bay Advance Works is therefore more likely to represent the potential impacts of dredging on sensitive receivers from the proposed Penny's Bay Reclamation.

The evaluation of impacts on water quality arising from construction of CT9 was reported in the South-East Tsing Yi Port Development Planning and Engineering Feasibility Study for Container Terminal No. 9 (Final Report 1991, Maunsell-Scott Wilson). The Environmental Assessment (EA) identified that dredging and fill activities at the South-East Tsing Yi (SETY) reclamation site, Rambler Channel, marine borrow areas and Kellett Bank, in the vicinity of the proposed fairway realignment, may result in excess turbidity generation. The potential for depletion of dissolved oxygen and release of nutrients from dredging activities within Rambler Channel were assessed by calculating the approximate values of oxygen demand and nutrient load associated with the dredged mud which may be lost to the water column. Comparisons were made of the effects of dredging on oxygen demand and nutrient loadings

From the predicted elevations in SS concentrations presented in Table 3.12, an indication is given of the maximum increase in SS at the sensitive receivers during the dredging and filling activities for the TLCDGA should there be other dredging and dumping projects in progress near the study area. This increase in SS concentrations is calculated for the following three "cumulative" scenarios:

- PB Advance Works (dry season spring tide), WSC MBA and NL & STY MBAs Scenario 4e (dry season spring tide);
- PB Advance Works (wet season neap tide), WSC MBA and NL & STY MBAs Scenario 2 (wet season spring tide) &; and
- LPD Cumulative (wet season neap tide), WSC MBA and NL & STY MBAs Scenario 2 (wet season spring tide)

In carrying out this assessment of cumulative impacts, the SS concentrations have been directly added together to give the upper limit on possible combined impacts. The SS concentrations presented in Table 3.12 therefore represent the likely maximum levels at the sensitive receivers based on the increases predicted by the modelling exercises undertaken in the EIA studies. It is considered that this approach is likely to over-estimate the resulting SS concentrations at the sensitive receivers as it assumes all relevant project activities will be occurring at the same time.

For the NL & STY MBAs Scenario 2, data is only available for the wet season spring tide and thus this scenario has been considered in the prediction of impacts arising from the dredging and sandfilling activities at the TLCDGA during the wet season (sediment plume modelling for TLCDGA was conducted for the neap tide in the wet season). As described earlier, the results of modelling for the WSC MBA (both worst-case scenario and cumulative scenario) indicate that the sediment plume does not impact on the Ma Wan fish culture zone and the two beaches on Ma Wan.

As shown in Table 3.12 for the identified "cumulative" scenarios, the predicted maximum increases in SS concentrations at Tung Wan Tsai and the Ma Wan fish culture zone during dredging and sandfilling activities at the TLCDGA are within the allowable increase stipulated by the WQO for SS. On considering the specific criterion of 50 mg/L for fish culture zones (as based on *ex-gratia* payment arrangements), the predicted maximum increases in SS concentrations at the Ma Wan fish culture zone during both dredging and sandfilling activities are well below this specific criterion.

Although the EIA study for CT9 did not include a prediction of the increase in SS concentrations at sensitive receivers in the study area, it is possible that the sediment plumes from marine works may extend as far as the plumes generated by dredgers working at the TLCDGA site and give cumulative impacts on the sensitive receivers at Ma Wan. Therefore, the resulting SS concentrations at the sensitive receivers may be higher than the levels indicated in Table 3.12. The total potential sediment load to the water column associated with dredging in the Rambler Channel and at the SETY reclamation area was estimated to be 976 tonnes/day (SETY Port Development Planning and Engineering Feasibility Study for CT9 Final Report Appendices). If the assumption is made that these dredging works for CT9 were to take place at the location of the South Tsing Yi MBA, the resulting maximum increase in SS concentration at the Ma Wan fish culture and Tung Wan Tsai is predicted to be 0.7 mg/L and 1.3 mg/L respectively (by extrapolation of the NL & STY MBAs modelled results for the scale of SETY reclamation & Rambler Channel dredging). Thus it is considered that even with dredging works for CT9 in progress at the SETY reclamation area and in Rambler Channel, the maximum increase in SS concentration at the fish culture zone would not exceed the specific criterion of 50 mg/L. It is noted that the actual SS concentration at the fish culture zone would be lower due to the distance of Rambler Channel from the STY MBA, however, this impact cannot be quantified in the absence of sediment plume modelling for the EIA Study for CT9.

From the information available at this stage, it appears that there is the potential for construction activities for the DGA to be concurrent with dredging and filling works for the Penny's Bay Reclamation and CT9 (including associated works at the West Sulphur Channel MBA and South Tsing Yi MBA). An assessment of potential cumulative impacts on water quality resulting from these

Table 3.12 Summary of Predicted Elevations in Suspended Solids (mg/L) at Sensitive Receivers and Potential Cumulative Impacts

	Tung Wan Tsai	Tung Wan	Ma Wan FCZ	Anglers	Gemini	Lido	Hoi Mei Wan	Casam
Backfilling at North Lantau & South Tsing Yi MBAs								
Scenario 2 : WS	0	-	1	4	0	0	0	0
Scenario 4e : DS	1.4	-	2.9	1.5	2.9	2	1.8	4
West Sulphur Channel MBA								
WSC MBA (worst-case scenario)	0	0	0	-	-	-	-	-
Cumulative Scenario	0	0	0	-	-	-	-	-
Lantau Port Development – Stage 1 CT10 & CT11 Ancillary Works (Design)								
LPD Cumulative : WN	0.5 Ma Wan East	0.5	2.1	-	-	-	-	-
Penny's Bay Advance Works : DS/WN	- / <0.5 Ma Wan East	1.2 / -	<0.5 / 1.2	-	-	-	-	--
Tang Lung Chau DGA								
Dredging – mitigated : DS/WN	6.6 / 2.9 (4.1/1.1)	-	2.1 / 1.7 (1.4/0.9)	0.3 / 0	0.2 / 0	0 / 0	0 / 0	0 / 0
Sandfilling – mitigated : DS/WN	4.3 / 1.9 (2.6/0.7)	-	1.4 / 1.1 (0.9/0.6)	0.2 / 0	0.13 / 0	0 / 0	0 / 0	0 / 0
Maximum Increase in SS Dredging : DS/WN1/WN2	8 / 3.4 / 3.4 (5.5 / 1.6 / 1.6)	-	5.5 / 3.9 / 4.8 (4.8 / 3.1 / 4)	1.8 / 4 / 4	3.1 / 0 / 0	2 / 0 /0	1.8 / 0 / 0	4 / 0 / 0
Maximum Increase in SS Sandfilling : DS/WN1/WN2	5.7 / 2.4 / 2.4 (4 / 1.2 / 1.2)	-	4.8 / 3.3 / 4.2 (4.3 / 2.8 / 3.7)	1.7 / 4 / 4	3 / 0 / 0	2 / 0 / 0	1.8 / 0 / 0	4 / 0 / 0
Exceedance of WQO for SS Exceedance of FCZ criterion	No	-	No No*	No	No	No	No	No

Notes:
1. Unit of SS concentration is mg/L. DS = Dry Season Spring Tide, WN = Wet Season Neap Tide.
2. At Tung Wan Tsai, the maximum predicted increase in SS concentrations during dredging & sandfilling works for the DGA occurs in layer 2, near the bed layer, for less than 1 hour in tidal cycle. Values given in brackets indicate the predicted depth-averaged SS concentrations where this is known (as based on modelling results).
3. For Maximum Increase in SS Dredging, following 3 "cumulative" scenarios considered: (i) DS = NL & STY MBAs Scenario 4e, PB Advance Works & WSC MBA; (ii) WN1 = NL & STY MBAs Scenario 2, Advance Works & WSC MBA; (iii) WN2 = NL & STY MBAs Scenario 2, LPD Cumulative & WSC MBA.
4. For Maximum Increase in SS Sandfilling, following 3 "cumulative" scenarios considered: (i) DS = NL & STY MBAs Scenario 4e, PB Advance Works & WSC MBA; (ii) WN1 = L & STY MBAs Scenario 2, PB Advance Works & WSC MBA; (iii) WN2 = NL & STY MBAs Scenario 2, LPD Cumulative & WSC MBA.
5. For Tung Wan Tsai, allowable increase is < 8.7mg/L (bottom water depth). For other SRs, allowable increase is < 5.7mg/L (depth-averaged).
6. * At Ma Wan fish culture zone (FCZ), a specific SS criterion of 50 mg/L is adopted (as based on *ex-gratia* arrangements for mariculturists).

Table 3.13 Summary of Predicted Elevations in Suspended Solids (mg/L) at Sensitive Receivers and Potential Cumulative Impacts with Further Mitigated Scenario for dredging works at Tang Lung Chau DGA

	Tung Wan Tsai	Tung Wan	Ma Wan FCZ	Anglers	Gemini	Lido	Hoi Mei Wan	Casam
Backfilling at North Lantau & South Tsing Yi MBAs								
Scenario 2 : WS	0	-	1	4	0	0	0	0
Scenario 4e : DS	1.4	-	2.9	1.5	2.9	2	1.8	4
West Sulphur Channel MBA								
WSC MBA (worst-case scenario)	0	0	0	-	-	-	-	-
Cumulative Scenario	0	0	0	-	-	-	-	-
Lantau Port Development – Stage 1 CT10 & CT11 Ancillary Works (Design)								
LPD Cumulative : WN	0.5 Ma Wan East	0.5	2.1	-	-	-	-	-
Penny's Bay Advance Works : DS/WN	- / <0.5 Ma Wan East	1.2 / -	<0.5 / 1.2	-	-	-	-	--
Tang Lung Chau DGA								
Dredging – further mitigated : DS/WN	4.4 / 1.9 (2.7/0.7)	-	1.4 / 1.1 (0.9/0.6)	0.2 / 0	0.1 / 0	0 / 0	0 / 0	0 / 0
Maximum Increase in SS Dredging : DS/WN1/WN2	5.8 / 2.4 / 2.4 (4.1 / 1.2 / 1.2)	-	4.8 / 3.3 / 4.2 (4.3 / 2.8 / 3.7)	1.7 / 4 / 4	3 / 0 / 0	2 / 0 /0	1.8 / 0 / 0	4 / 0 / 0
Exceedance of WQO for SS Exceedance of FCZ criterion	No	-	No No*	No	No	No	No	No

Notes:
1. Unit of SS concentration is mg/L. DS = Dry Season Spring Tide, WN = Wet Season Neap Tide.
2. At Tung Wan Tsai, the maximum predicted increase in SS concentrations during dredging works for the DGA occurs in layer 2, near the bed layer, for less than 1 hour in tidal cycle. Values given in brackets indicate the predicted depth-averaged SS concentrations where this is known (as based on modelling results).
3. For Maximum Increase in SS Dredging, following 3 "cumulative" scenarios considered: (i) DS = NL & STY MBAs Scenario 4e, PB Advance Works & WSC MBA; (ii) WN1 = NL & STY MBAs Scenario 2, Advance Works & WSC MBA; (iii) WN2 = NL & STY MBAs Scenario 2, LPD Cumulative & WSC MBA.
4. For Tung Wan Tsai, allowable increase is < 8.7mg/L (bottom water depth). For other SRs, allowable increase is < 5.7mg/L (depth-averaged).
5. At Ma Wan fish culture zone (FCZ), a specific SS criterion of 50 mg/L is adopted (as based on *ex-gratia* arrangements for mariculturists).

concurrent works indicates that the predicted maximum increases in SS concentrations during the mitigated dredging and sandfilling activities for the DGA construction are in compliance with the WQO for SS (Table 3.12). Therefore, as based on the available information, it is anticipated that the construction activities for the TLCDGA are unlikely to result in unacceptable impacts on water quality should there be marine-based works in progress near the study area for the Penny's Bay Reclamation and CT9.

Furthermore, with the adoption of the additional mitigation measure to restrict the number of grab dredgers at the DGA site to not more than two working at one time, the elevations in SS concentrations at the water sensitive receivers would be reduced through lowering the production rate for dredging works at the DGA. The resulting maximum increases in SS concentrations at Tung Wan Tsai and the Ma Wan Fish culture zone for the identified "cumulative scenarios" and the further mitigated dredging works for the DGA are shown in Table 3.13.

found to increase by up to 0.5 m/s on the flood tide because of the DGA constricting the flows. In the lee of the DGA on the ebb tide, speed decreases are shown with corresponding increases in speed around Tsing Yi and in the flow channel up to Green Island. Some speed increases were shown in Kap Shui Mun.

The DGA was found to alter the distribution of flows around Ma Wan by causing a reduction in flows through the Ma Wan Channel and an increase in flows through Kap Shui Mun. The simulations with the DGA showed an increase in flood flows through the Rambler Channel which reduced the imbalance between the food and ebb flows, the ebb previously being dominant by a large degree. The simulations showed a reduction in ebb flows through Victoria Harbour on the wet season tides, with a reduction of 4.88% on the wet season spring tide. It should be noted that 1.77% of this reduction through Victoria Harbour was previously found to be caused by the TWBFR, resulting in a net flow reduction of 3.11% due to the TLCDGA on the wet season spring tide. It is not anticipated, however, that the water quality in Victoria Harbour would deteriorate significantly during the operation of the DGA. This is because the predicted reduction in flow on the wet season tides would be compensated by the reduction of pollution loading into Victoria Harbour due to the implementation of the SSDS Stage 1. A full description of the results of the flow model simulations for the four representative tide types is provided in Section 2.4 of Appendix B.

As requested by EPD, a further model simulation (wet season spring tide) was undertaken of a revised elongated layout, in which the eastern and western breakwaters follow more closely to the original flow pattern. The results of the tidal flow modelling of this elongated layout, however, do not indicate a significant improvement in tidal flow through Victoria Harbour on comparison with the above simulations for the original DGA layout. Therefore, EPD confirmed in the 2nd ESMG meeting that the original layout of the DGA should be adopted for the purpose of this environmental assessment.

Discharge of wastes inside the DGA

The results from the bacterial dispersion modelling were presented as graphs of bacterial concentrations in the surface layer at the nearby sensitive receivers and as contours of bacterial concentration in the surface layer at flood and ebb phases of the tidal cycle. [6]

The graphs of bacterial concentrations at the sensitive receivers (**Figures 3.2 - 3.5**) show that the maximum concentrations occur at Tung Wan Tsai for the dry season spring tide with values of up to 10 counts/100 ml (**Figure 3.2**). For this tide type, concentrations of almost 7 counts/100 ml occur at Tung Wan Beach and concentrations at the Ma Wan fish culture zone are almost undetectable. The predicted bacterial concentrations at these two bathing beaches and the Ma Wan fish culture zone are therefore well below the applicable WQO for *E. coli* concentrations at these subzones (Section 3.4).

The contours of bacterial concentrations show that the explanation for the very low impacts at the sensitive receivers is that minimal bacteria is transported outside of the DGA. The main transport out of the DGA is shown for the two spring tides. For the dry season spring tide on the flood phase of the tidal cycle bacteria is transported out of the northern entrance, with the majority of the bacteria impacting on the southern shoreline of Ma Wan and some bacteria impacting at Tung Wan Beach and Tung Wan Tsai.

During the ebb phase of the wet season spring tide bacteria is transported out of the northern entrance, past the Tsing Ma Bridge pier towards Tung Wan Tsai, but remaining offshore. The plume is caused by the reverse eddy which forms on the eastern side of Ma Wan during the ebb tide.

6 TELEMAC 3D Oil Spill And Bacterial Dispersion Modelling for Tang Lung Chau DGA, MCAL. July 1998.

3.7 Operational Phase Assessment

3.7.1 Potential Sources of Impacts

During the operation phase, major water quality issues include :

- effects on tidal flow due to the presence of the breakwaters for the DGA;
- overall effect of water quality due to the presence of the breakwaters for the DGA;
- local impacts related to the discharge of wastes from vessels inside the DGA;
- local impacts related to event of fuel spillage, inside or outside the DGA.

As the Ma Wan Channel and Kap Shui Mun are key water channels in Hong Kong, the effect of the DGA on tidal flows will be carefully studied. Changes in tidal flow may change the natural sedimentation or erosion pattern that affects seabed morphology. In the detailed hydraulic modelling carried out as part of the TWBFR Feasibility Study, changes in tidal flow due to the TLCDGA have been predicted.

A Cumulative Impact Study on Harbour Reclamation was carried out under the South East Kowloon Development Feasibility Study. Hydraulic and water quality modelling was carried out which indicated that the overall water quality impact related to TLCDGA is acceptable. Details of the modelling works and results are presented in Technical Note N10 *Cumulative Effects of Reclamation on Harbour Regime Final Report (June 1998)* for the South East Kowloon Development Feasibility Study.

For the current study, local water quality impacts are of higher interest, as the overall water quality related to TLCDGA has been found to be acceptable in the Cumulative Impact Study. Inside the breakwaters, water quality impacts may arise from the discharge of wastes from vessels, maintenance dredging and spillage of fuel. Pollutants generated inside the breakwaters, if transported outside, would also affect the water quality outside the breakwaters. These pollutants may potentially be transported by tidal action to outside the breakwaters through the entrances. It should be noted that as the TLCDGA will be located offshore in open waters, there will not be any landward sewage effluent nor stormwater outfall discharging into the DGA.

Outside the breakwater, water quality impacts may arise from the discharge of wastes from vessels. It would be difficult to carry out quantitative assessment regarding waste discharge outside the DGA. As the DGA would not affect the number of vessels using the channel, it is unlikely that there would be a significant increase of pollutants as compared to the existing situation. This is therefore not considered to be a key issue.

Impacts from the spillage of fuel on water quality, in and outside the DGA, will be described in Chapter 4 under Fuel Spillage. Records of fuel oil pollution incidents in Hong Kong waters indicate no cases between 1992 to 1997 at the TWDGA. Three minor fuel oil pollution incidents have been reported at the TWDGA last year (up to 2/9/98). Details of these minor pollution incidents are given in Section 4.4.

3.7.2 Prediction and Evaluation of Impacts

Tidal Flows

The results of the TELEMAC 3D tidal flow modelling show that the main effect of the TLCDGA on tidal current patterns is to alter the eddy which formed on the ebb tide to the east of Ma Wan Island. Peak ebb and flood currents in the main flow channel between Ma Wan and Tsing Yi Islands were

3.8 Mitigation of Adverse Impacts

3.8.1 Construction Phase

Dredging Works

It is important that appropriate measures be undertaken to ensure that potential impacts on water quality during construction can be kept to within acceptable levels as defined by the WQO. The proper selection of appropriate dredging methods will reduce the amount of sediment resuspension, and this in turn will minimize adverse impacts on water sensitive receivers. Based on the predicted impacts, low impact dredging techniques such as the closed grab dredger or trailing suction hopper dredger (THD), with no overflow nor ALMOB, are recommended. (The use of a THD is being retained as an option for the breakwater construction. The dredging method to be adopted will be agreed during the detailed design).

To further reduce the potential impact to the water sensitive receivers during the dredging and sandfilling works, particularly at the Ma Wan fish culture zone, the adoption of additional mitigation measures is recommended. These additional measures comprise restricting the number of closed grab dredgers to not more than two working at one time, and conducting one of the weekly water quality monitoring events for impact monitoring during night-time hours should there be dredging or sandfilling works at this time.

It is recommended that the maximum total daily dredging rate (i.e. for dredging of both contaminated and uncontaminated sediment) shall not exceed 9,524 m^3/day, as based on the reduced weekly production rate following adoption of the above additional mitigation measure on restricting the number of dredgers working at one time. For dredging of contaminated sediment alone, the maximum daily dredging rate shall not exceed 7,143 m^3/day, as based on the preliminary weekly production rate adopted in the water quality assessment of 50,000 m^3/week. Dredging works and sandfill placement for the breakwater foundations shall not be carried out concurrently. This restriction on there being no concurrent dredging and sandfilling works includes such works for different stages of the breakwater construction at one time.

Good Operational Practices

The contractor will be required to minimize potential adverse impacts on water quality resulting from dredging and dumping operations to within acceptable levels as defined by the WQO. To achieve these requirements the contractor should design and implement methods of working, to the maximum practicable extent, that:

- minimize disturbance to the seabed while dredging;
- minimize leakage of dredged material during lifting;
- prevent loss of material during transport of dredged material;
- prevent discharge of dredged material except at approved locations;
- dredging operations should involve leaving sediment in place whenever practicable; and
- ensure that the construction works will cause no visible foam, oil, grease, scum, litter or other objectionable matter to be present in the water within and adjacent to the site or dumping grounds.

Maintenance Dredging

The area of the TLCDGA must maintain a sufficient depth to allow for turning and manoeuvring of vessels anchoring within the DGA. Any sediments deposited through siltation must therefore be dredged to maintain this depth between the vessels and the seabed. A preliminary siltation assessment[7] has been carried out to assess the likely sediment deposition rate within the DGA. It should be noted that the siltation assessment study provides only an initial estimate of siltation effects for the purpose of providing a preliminary estimate of the likely maintenance dredging requirements. Reliable estimates of siltation and scouring effects would require 3D siltation modelling. The findings of the 3D siltation modelling would form the basis for determining maintenance dredging requirements.

Based on the estimated siltation rates within the DGA for calm and storm conditions, the average siltation rate is predicted to be less than 30,000 m^3/year[8], which is equivalent to a deposition depth of less than 50 mm/year (averaged over area of DGA). From these findings of the preliminary siltation study, two options are proposed for the maintenance dredging as shown in Table 3.14 below. The maintenance dredging will take place within the DGA. The proposed frequencies for maintenance dredging are based on the design life of the DGA breakwaters of 50 years.

Table 3.14 Proposed Options for Maintenance Dredging

Option	Frequency of dredging	Volume of dredged material (m^3)
Option 1	Initial dredging following completion of breakwater construction	9,850
Option 2	Initial dredging following completion of breakwater construction	600
	Once DGA operational, dredge at following periods from opening date:	
	• after 10 years	1,250
	• after 20 years	2,000
	• after 30 years	2,650
	• after 40 years	3,350

Due to the weak tidal currents within the DGA, sediment plumes will largely be contained by the breakwaters. Local elevations in suspended solids concentrations will result in the works area. However, in view of the fact that the dredging would take place within the breakwaters and there are no sensitive receivers in the immediate vicinity of the DGA (the nearest sensitive receiver of Tung Wan beach is located at a distance of approximately 1 km), it is not anticipated that any unacceptable impacts on water quality will arise at the sensitive receivers. Nevertheless, it is recommended that good operational practices be implemented during the dredging works to minimize potential impacts on water quality. As the predicted instantaneous release concentration of heavy metals in the marine waters is within the UK Water Quality Standards for the larger scale construction phase dredging, no adverse water quality impacts are anticipated during maintenance dredging from the potential release of heavy metals from any contaminated sediments.

7 Siltation Assessment for the Tang Lung Chau Dangerous Goods Anchorage, MCAL. October 1998.

8 The findings of the preliminary siltation study are that annual siltation rates within the TLCDGA would likely be in the range of 30,000 to 50,000 m^3/year (based on a dry density of 200 kg/m^3) and 12,000 to 20,000m^3/year (based on a dry density of 500 kg/m^3). Based on preliminary site investigation results the dry density of surface deposits is likely to be in the range of 500 kg/m^3 to 800 kg/m^3. The assumed siltation rate of 30,000 m^3/year is therefore a conservative estimate and is considered to be reasonable given the preliminary nature of the assessment.

accordance with the Dumping at Sea Ordinance. If the contaminated mud cannot be left in situ, it shall be dumped at East Sha Chau Contaminated Mud Disposal Pits (CMPs) or other disposal pits as may be approved for the purpose by the DEP. The Contractor shall be responsible for obtaining all necessary licences for these operations.

Notes: *The Engineer shall ensure that the Contractor has access to WBTC No. 22/92; EPD TC No. 1.1.92; and Fill Management Committee General Allocation Conditions for Marine Borrow Areas and Mud Disposal Sites.*

(b) When the Contractor dumps the contaminated mud at East Sha Chau CMPs, he shall place the contaminated mud at a location and in such a manner as directed by the Management Team of the Civil Engineering Department. The Contractor shall proceed with the disposal operation as instructed by the Management Team and in accordance with guidance notes which are issued by the Management Team. The Contractor shall not carry out any dumping without permission of the Management Team or when the Management Team is not in operation.

(c) The Contractor shall carry out the dumping operation in strict accordance with the method statement agreed by the DEP, any non-compliance with the agreed method shall be a breach of conditions of the relevant licence issued by the DEP and is an offence under the Dumping at Sea Ordinance.

(d) When dredging, transporting and disposing of designated contaminated marine mud, the Contractor shall implement additional special procedures for the avoidance of pollution which shall include, but not be limited to, the following:

(i) employ a grab dredger with a closed watertight grab for dredging of designated contaminated marine mud;

(ii) transport designated contaminated marine mud by split barge of not less than $750m^3$ capacity, well maintained and capable of rapid opening and discharge at the disposal site;

(iii) design properly and maintain carefully all operational plant so as to minimize the risk of sediments or other pollutants being released into the water column and deposited in the seabed other than designated locations. The Contractor's work shall cause no visible foam, oil, grease, scum, litter or other objectionable matter to be present in the water within the site;

(iv) fit all barges and hopper dredgers with tight fitting seals to their bottom openings to prevent leakage of material;

(v) release the mud rapidly and close the hoppers immediately; any material adhering to the sides of the hopper shall not be washed out of the hopper and the hopper shall remain closed until the barge next returns to the disposal site. The Contractor shall ensure that the dumping vessel shall be stationary throughout the dumping operation;

(vi) size all vessels such that adequate clearance is maintained between the seabed and vessels at all states of the tide, to ensure that undue turbidity is not generated by turbulence from vessel movement or propeller wash. Adequate freeboard shall be maintained on barges to ensure that decks are not washed by wave action;

The licensee should formulate his design and construction methods with these factors in mind, and provide specification in the tender submission.

Pollution Avoidance Measures During Dredging and Dumping

Pollution avoidance measures shall include, but not be limited to, the following:

- mechanical grabs shall be designed and maintained to avoid spillage and shall seal tightly while being lifted (closed-grab dredgers);
- where trailing suction hopper dredgers are in use, overflow from the dredger and the operation of automatic lean mixture overboard (ALMOB) systems shall not be permitted;
- 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;
- all pipe leakages shall be repaired promptly and plant shall not be operated with leaking pipes;
- 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 ensure that decks are not washed by wave action;
- all barges and hopper dredgers shall be fitted with tight fitting seals to their bottom openings to prevent leakage of material; and
- loading of barges and hoppers shall be controlled to prevent splashing of dredged material to the surrounding water, and barges or hoppers shall not be filled to a level which will cause the overflow of materials or polluted water during loading or transportation.

Contaminated Marine Sediments

Additional provisions will be required where marine sediments are contaminated. Preliminary sediment analyses indicate that the marine sediments along the south-west breakwater (vibrocore locations VC2, VC3 and VC4) are seriously contaminated (Class C). Further to the sediment sampling undertaken during this EIA Study, which is indicative of the sediment contamination levels within the area of the DGA, the successful Tenderer (detailed design stage) would be required to undertake a detailed sediment quality assessment to identify precisely the location and extent of any contamination and to present the findings within a Sediment Quality Report.

Once determined, the locations and depths of any areas of contaminated marine sediments shall be indicated in the construction contract. The contractor shall ensure that contaminated marine sediments, if present, are dredged, transported and placed in approved special dumping grounds in accordance with the *EPD Technical Circular No. 1-1-92 Classification of Dredged Sediments for Marine Disposal, Works Branch Technical Circular (WBTC) No. 22/92 Marine Disposal of Dredged Mud* and *WBTC No. 6/92 Fill Management*. Special EPD procedures for the avoidance of pollution during the dredging, transportation and disposal of designated contaminated marine sediment are listed below:

(a) Uncontaminated mud shall not be dumped other than in dumping grounds as may be approved for the purpose by the Director of Environmental Protection (DEP) and in

Oil Spillage

Mitigation measure requirements to minimize impacts on water quality in the event of oil spillage are discussed in Section 4 under Oil Spillage.

3.8.3 Environmental Monitoring and Auditing Requirements

It is recommended that environmental monitoring and auditing (EM&A) of marine water quality be carried out at the Ma Wan fish culture zone and near Tung Wan and Tung Wan Tsai beaches during the construction phase, in particular during dredging and sandfilling activities for the breakwaters foundation. This EM&A programme will be required to ensure the implementation of the recommended water quality mitigation measures and to assess the effectiveness of these measures during the construction works. Details of the EM&A procedures are presented in Section 10.2. If monitoring results indicate that the dredging and/or sandfilling works have caused an adverse impact on water quality at the above sensitive receivers, the construction programme should be carefully reviewed so as to slow down the rate of dredging or sandfilling such that the water quality at these sensitive receivers is in compliance with the water quality criteria.

Based on the findings of the preliminary siltation study carried out to give an initial estimate of the likely sediment deposition rate within the DGA, the volume of maintenance dredging required within the DGA is minor in scale on comparison to the construction phase dredging. As described in Section 3.7.2, no unacceptable impacts on water quality are anticipated to result at the sensitive receivers during maintenance dredging and thus it is considered that EM&A of marine water quality during these dredging works will not be necessary.

3.9 Definition and Evaluation of Residual Impacts

With the full and strict implementation of the recommended mitigation measures for the construction and operational phases of the TLCDGA, no unacceptable residual impacts on marine water quality are anticipated to arise. In addition, it is considered that no adverse environmental effects will result from the employment of the recommended water quality mitigation measures for the construction and operational phases of the DGA, as described in Section 3.8.

3.10 Conclusions

Sediment plume modelling of the effects on water quality of fine sediment lost to suspension during dredging works for TLCDGA breakwaters was conducted. A worst-case scenario was assumed for the sediment plume modelling, with loss rates for fine particles based on three open grab dredgers working concurrently without the employment of silt curtains.

The maximum predicted increases in suspended sediment (SS) concentrations occur at Tung Wan Tsai during the dry season spring tide. As the predicted increase above ambient levels is in exceedance of the stipulated WQO for SS, the full implementation of the recommended mitigation measures will be necessary to reduce impacts resulting from the dredging works to within acceptable levels. These measures include the use of the closed grab dredger or trailing suction hopper dredger (with no overflow nor ALMOB) for construction, the specification of an upper limit on the dredging rate to be employed, and no concurrent dredging and sandfilling works. At the Ma Wan fish culture zone, the predicted maximum increases in SS concentrations comply with the WQO.

Adverse impacts on water quality arising from the release of heavy metals from contaminated sediment are not anticipated during the dredging works. A quantification of the release of heavy metals from the sediment pore water indicates that the predicted instantaneous concentrations in the marine waters surrounding the dredging site will not exceed the UK Water Quality Standards. As the

(vii) employ only barges equipped with automatic self-monitoring devices for the dumping operation, and shall co-operate with and facilitate the DEP to inspect the device and retrieve the record stored in the device on a regular basis;

(viii) provide experienced full time personnel on board all dumping vessels and provide suitable training to ensure that appropriate methods to minimize pollution are implemented. Records shall be maintained to satisfy the DEP that there is no short dumping or dumping outside the Designated Dumping Area. The Contractor shall also make available to the DEP and the secretary of Fill Management Committee (S/FMC), Civil Engineering Department, at any time upon the written request of the DEP, all information and records relevant to the dredging and mud disposal operation. This information shall include, but not be limited to, all data on the plant used by the Contractor, up-to-date periodic data on production rates and record copies of Notification of Dumping which have been sent to the Management Team, etc.

Sandfilling Activities

The recommended method for sandfilling of the breakwater foundations is the use of a trailing suction hopper dredger (THD), or other suitable vessel, with sandfill placement by discharging through a pipeline. It is recommended that the sandfilling placement rate shall not exceed 2,500 m^3 over one hour.

This method would require the vessel to hook up to a floating pipeline leading to a diffuser pontoon stationed over the breakwater trench. The diffuser pipe would enable sandfill to be discharged relatively close to the seabed level thus minimizing the loss of fines in the middle and upper parts of the water column. The position of the diffuser pontoon would need to be adjusted during discharge and this would be possible using either a self powered pontoon or a separate craft. Adjustments to the elevation of the diffuser to suit the seabed levels along the breakwater trenches could be made prior to periods of sandfill discharge.

As described earlier for the sub-section *Dredging Works*, sandfill placement for the breakwater foundations shall not be carried out concurrently with dredging. This restriction includes sandfilling and dredging works for different stages of the breakwater construction at one time.

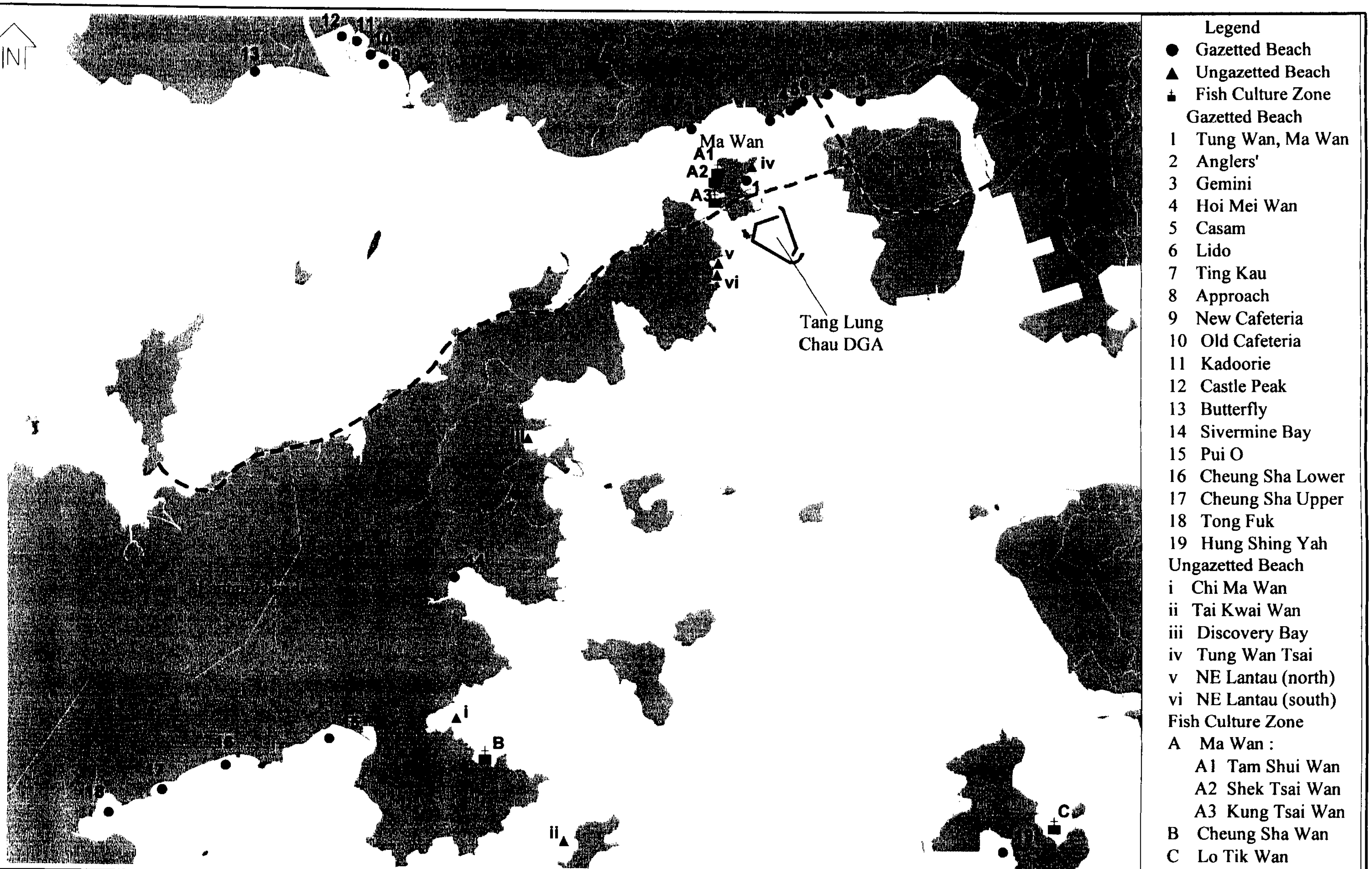
Placement of Sediment within DGA

It is recommended that the dumping of filling materials in the necessary areas within the DGA, so as to make up the required thickness of soft material cover at the mooring anchorages, be undertaken after the completion of the breakwaters construction. With this works method, sediment plumes generated from the dumping of mud will largely be contained by the breakwaters.

3.8.2 Operation Phase

Maintenance Dredging

It is anticipated that the potential for adverse impacts on water quality may be minimized with the observation of good operational practice and general pollution avoidance measures. These mitigation measures recommended to minimize potential impacts arising from maintenance dredging are as discussed above for dredging works during the construction phase.



LOCATIONS OF MARINE WATER QUALITY SENSITIVE RECEIVERS

FIGURE	3.1
SCALE	1 : 120000

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proposed DGA site is located offshore and there are no sewage effluent discharges in the area, it is not anticipated that nutrient levels in the sediment will be of concern. Similarly, as the proposed DGA site is located away from the industrial areas of Tsing Yi and Tsuen Wan, it is anticipated that the levels of organic pollutants and trace organics in the sediment will be less than the values recorded in Tsuen Wan Bay and thus these potential pollutants will not be of concern.

In view of the predicted high SS concentrations at the sensitive receivers during sandfilling by bottom dumping, it is recommended that a pipeline be used to discharge the sandfill relatively close to the breakwater trench and thereby reduce the loss of fines to the water column. For the proposed mitigated method of sandfill placement, the maximum elevation in SS concentrations occurs at Tung Wan Tsai in the dry season spring tide and is within the allowable increase stipulated by the WQO for SS. The mitigated sandfilling works are not anticipated to result in unacceptable impacts on water quality at the Ma Wan fish culture zone as the predicted maximum SS concentrations do not exceed the WQO.

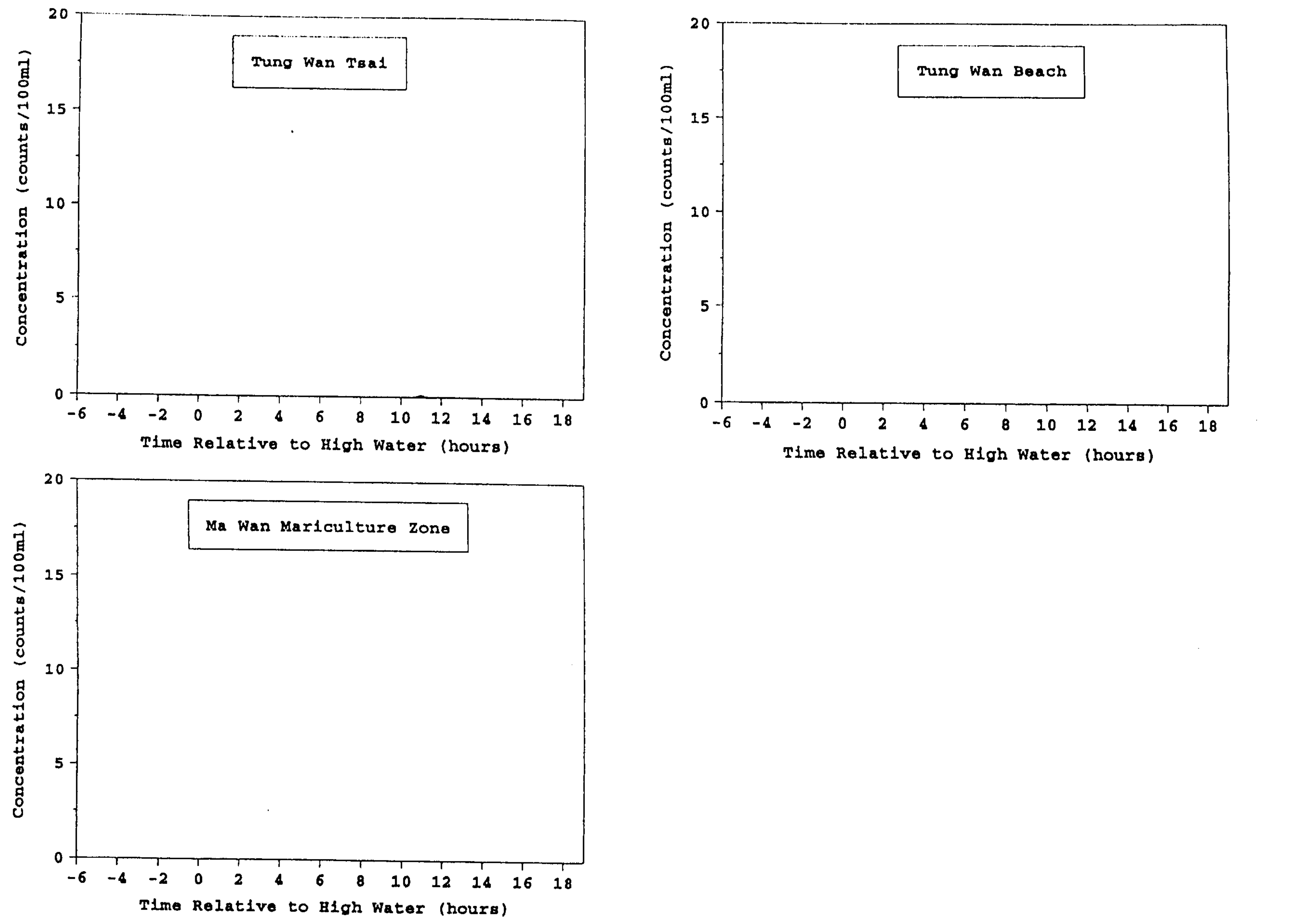
To further reduce the potential impact to the water sensitive receivers during the dredging and sandfilling works, particularly at the Ma Wan fish culture zone, the adoption of additional mitigation measures is recommended. These additional measures comprise restricting the number of closed grab dredgers to not more than two working at one time, and conducting one of the weekly water quality monitoring events during night-time hours should there be dredging or sandfilling works at this time.

Based on the available information, the potential has been identified for construction activities for the DGA to be concurrent with dredging and filling works for the Penny's Bay Reclamation and CT9 (including associated works at the West Sulphur Channel MBA and South Tsing Yi MBA). An assessment of potential cumulative impacts on water quality resulting from these concurrent works indicates that the predicted maximum increases in SS concentrations during the mitigated dredging and sandfilling works for the DGA are in compliance with the WQO for SS. Therefore, as based on the available information, it is anticipated that the construction activities for the TLCDGA are unlikely to result in unacceptable impacts on water quality should there be marine-based works in progress near the study area for the Penny's Bay Reclamation and CT9.

The TELEMAC 3D bacterial plume model has been used to simulate the dispersion of bacteria generated from sewage discharged by vessels moored within the DGA. The results show that only minimal *E. coli* concentrations occur at Tung Wan Tsai and Tung Wan beach under the two spring tides. Bacterial concentrations at the Ma Wan fish culture zone are almost undetectable.

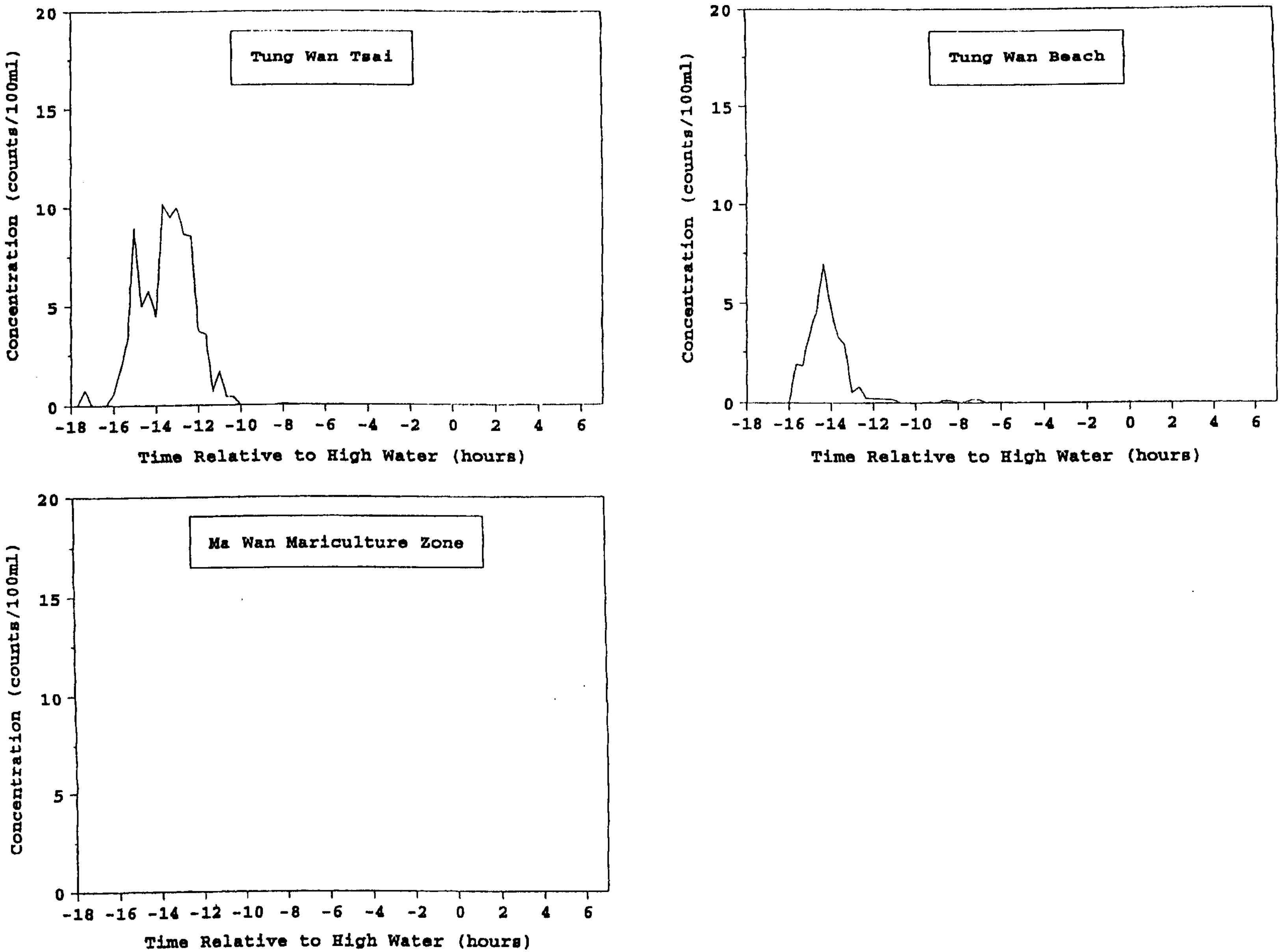
Detailed tidal flow modelling was conducted using the TELEMAC 3D tidal flow model to determine the impact of the completed TLCDGA on tidal current patterns. Despite the predicted net reduction in flow of 3.11% through Victoria Harbour on the wet season spring tide, it is not anticipated that the water quality in Victoria Harbour would deteriorate significantly. This is because the predicted flow reduction through Victoria Harbour on the wet season ebb tides would be compensated by the reduction of pollution loading into Victoria Harbour from the implementation of the SSDS Stage 1.

Based on the findings of the preliminary siltation study carried out to give an initial estimate of the likely sediment deposition rate within the DGA, the volume of maintenance dredging required within the DGA is minor in scale on comparison to the construction phase dredging. Sediment plumes generated during dredging will largely be contained by the breakwaters, due to the weak tidal currents within the DGA, and therefore no unacceptable impacts on water quality are anticipated to result at the sensitive receivers. Nevertheless, it is recommended that good operational practices be observed during maintenance dredging to minimize potential impacts on water quality. EM&A will be required to monitor and audit the implementation and efficacy of measures to mitigate any impacts on water quality resulting from construction of the DGA, as detailed in Section 10.2.



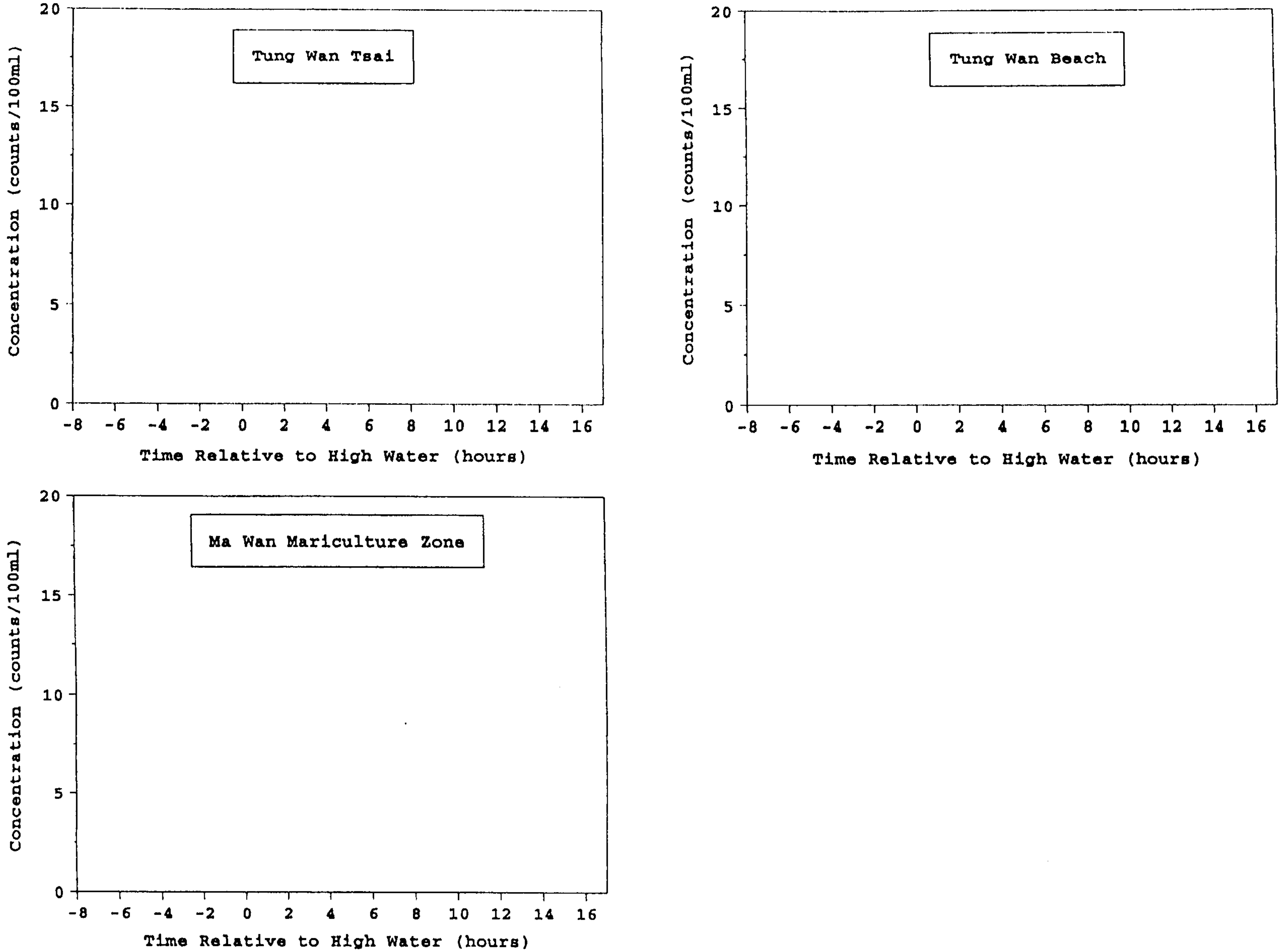
TANG LUNG CHAU DGA
SURFACE BACTERIAL CONCENTRATIONS AT SENSITIVE RECEIVERS, DRY SEASON NEAP TIDE

FIGURE 3.3



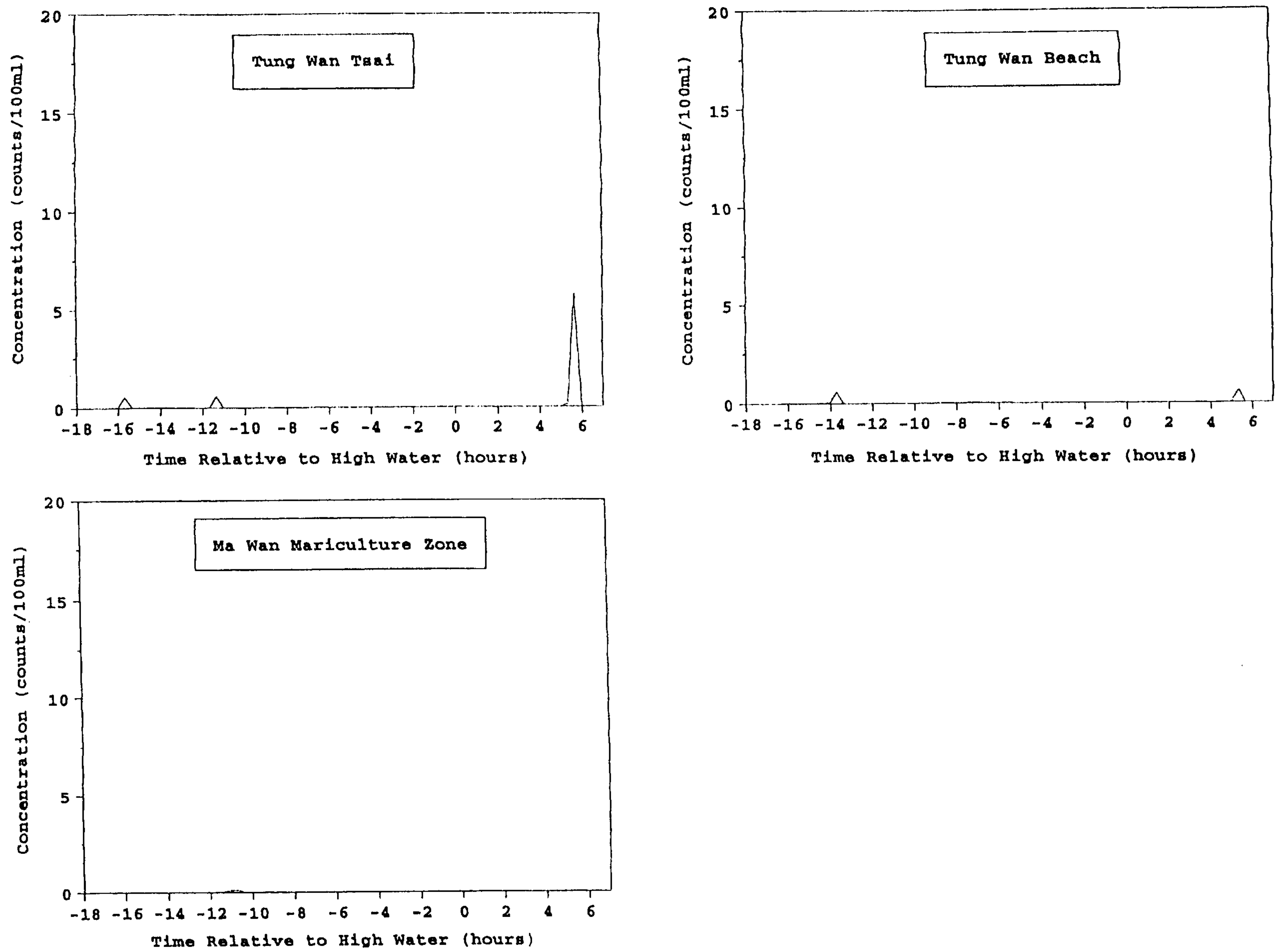
TANG LUNG CHAU DGA
SURFACE BACTERIAL CONCENTRATIONS AT SENSITIVE RECEIVERS, DRY SEASON SPRING TIDE

FIGURE 3.2



TANG LUNG CHAU DGA
SURFACE BACTERIAL CONCENTRATIONS AT SENSITIVE RECEIVERS, WET SEASON NEAP TIDE

FIGURE 3.5



TANG LUNG CHAU DGA
SURFACE BACTERIAL CONCENTRATIONS AT SENSITIVE RECEIVERS, WET SEASON SPRING TIDE

FIGURE 3.4