5 WATER QUALITY

5.1 INTRODUCTION

This Section deals with the assessment of the impacts on water quality of the construction of the reclamation for the Lamma Extension project and the operation of the proposed 1800 MW gas-fired power station.

The construction phase assessment has considered changes in tidal current patterns resulting from the formation of the reclamation and the loss of fine sediment to suspension during dredging and filling activities for the reclamation. In order to assess these impacts computer modelling of hydrodynamics and sediment dispersion has been carried out.

The operational phase assessment has evaluated the impacts of the discharge of heated water and residual chlorine from the facility and the potential for the natural sediment erosion/deposition regime to be altered by the reclamation. Computer modelling of the dispersion of thermal and chlorine discharges from the new power station has been carried out. The assessment of possible changes to the sedimentation regime around the new power station was based on the results of the hydrodynamic modelling from the construction stage impacts.

The overall aim of the above assessment work was to determine the acceptability of any predicted impacts to water quality from the construction and operation of the power station. Predicted impacts have been assessed with reference to the relevant environmental legislation and standards, and suitable measures proposed to mitigate any potential adverse environmental impacts.

Cumulative impacts have also been assessed during the construction phase in terms of concurrent dredging and reclamation works which may overlap with the construction of the reclamation. Computer modelling simulations of the dispersion of sediment from these other projects has been undertaken and cumulative effects have been estimated. In addition, impacts from the new power station together with a reclamation for a new Waste to Energy Incineration Facility (WEIF) have been simulated together to determine cumulative impacts on tidal flows. Cumulative simulations of thermal and chlorine discharge from the WEIF and new power station have also been carried out.

5.2 LEGISLATION AND STANDARDS

The following legislation are applicable to the evaluation of water quality impacts associated with the construction and operation of the Lamma Extension project:

- *Environmental Impact Assessment Ordinance (Cap. 499. S.16)*, and the *Technical Memorandum on EIA Process* (*EIAO TM*), especially *Annexes 6* and *14;*

- *Water Pollution Control Ordinance* (WPCO); and

- *Technical Memorandum for Effluents Discharged into Drainage and Sewerage Systems, Inland and Coastal Waters.*

5.2.1 *Water Pollution Control Ordinance*

The WPCO is the primary legislation for the control of water pollution and water quality in Hong Kong. Under the WPCO Hong Kong waters are divided into 10 Water Control Zones (WCZs). Each WCZ has a designated set of statutory Water Quality Objectives (WQOs). The impacts from discharges during the construction and operation phases of the Lamma Extension power station will primarily fall within the Southern WCZ.

WQOs for the Southern WCZ are presented in *Annex B5-1*, and are applicable as evaluation criteria for assessing compliance of any discharges during the construction and operation of the Lamma Extension project.

5.2.2 *Technical Memorandum for Effluents*

All discharges during both the construction and operational phases of the project are required to comply with the *Technical Memorandum for Effluents Discharged into Drainage and Sewerage Systems, Inland and Coastal Waters* (TM) issued under Section 21 of the WPCO, which defines acceptable discharge limits to different types of receiving waters. Under the TM effluents discharged into the drainage and sewerage systems, inshore and coastal waters of the WCZs are subject to pollutant concentration standards for particular volumes of discharge. These are defined by EPD and specified in licence conditions for any new discharge within a WCZ. The Lamma Extension project will be required to comply in general with *Table 10b* of the TM. Specific licensing conditions for the existing power station discharge specify the following conditions:

- for units L1-L6 the maximum total daily discharge should be 6,510,000 m^3, with the maximum peak discharge of 4,550 $m^3\ min^{-1}$;
- for units L7-L8 the maximum total daily discharge should be 2,400,000 m^3, with the maximum peak discharge of 1,850 $m^3\ min^{-1}$;
- the discharge temperature should be no more than 10°C above the intake temperature;
- the effluent shall not cause the temperature of the sea at any depth outside 1,500 m from the point of discharge to raise more than 2°C above the ambient seawater temperature; and
- total residual chlorine within the discharge should be less than 0.5 mg l^{-1}.

5.3 Baseline Conditions

5.3.1 *Hydrodynamics*

The Lamma Extension site is on the southern side of the existing power station. This is located in an area of low tidal currents, less than 0.3 m s^{-1}, because it is sheltered to the north by the existing power station reclamation and to the south by the south west headland of Lamma Island. Immediately to the west of the site, out of the shelter of the existing power station, tidal current speeds on the ebb tide are higher with localised peak speed increases at the corner of the existing power station in excess of 0.5 m s^{-1}. During the dry season the water column is well mixed with little salinity and temperature stratification.

However, in the wet season, while temperature stratification is present, some salinity stratification may be observed, although it is weak due to the lower influence of the Pearl River Estuary discharge.

5.3.2 *Water Quality*

The site lies within the Southern WCZ and a number of routine EPD monitoring stations are in the vicinity of the extension site, the closest of which is some 2.5 km due south of the site. Water quality data for this site, SM5, and other nearby stations on the western side of Lamma Island is summarised in *Table 5.3a*. This data was monitored in 1996 and is the most up to date published information[(1)]. The locations of the stations are shown in *Figure 5.3a*.

Table 5.3a *EPD Routine Water Quality Monitoring in the Southern WCZ*

WQ Parameter	SM5	SM6	SM7
Temperature Surface (°C)	23.3 (16.5-28.4)	23.2 (16.6-28.2)	23.4 (16.6-28.3)
Temperature Bottom (°C)	22.3 (16.5-27.2)	22.0 (16.6-27.1)	22.3 (16.6-27.2)
DO Surface (mg l^{-1})	7.3 (6.4-9.7)	7.2 (5.9-8.5)	7.1 (6.3-8.7)
DO Bottom (mg l^{-1})	6.7 (3.7-8.8)	6.0 (3.3-7.3)	6.4 (5.1-7.2)
BOD (mg l^{-1})	0.4 (0.2-1.1)	0.4 (0.2-0.8)	0.4 (0.2-0.7)
SS (mg l^{-1})	9.5 (2.7-14.3)	5.4 (3.0-8.3)	9.4 (3.0-12.5)
TIN (mg l^{-1})	0.16 (0.03-0.44)	0.16 (0.04-0.37)	0.20 (0.05-0.47)
NH_4-N (mg l^{-1})	0.01 (<0.01-0.02)	0.02 (0.01-0.04)	0.03 (0.01-0.05)
Unionized ammoniacal nitrogen (mg l^{-1})	0.0005	0.001	0.0015
E.coli (cfu 100 ml^{-1})	3 (1-36)	5 (1-105)	14 (1-147)

Notes :
1. Data presented are depth-averaged, except as specified.
2. Data presented are annual arithmetic mean except for *E.coli* which are geometric means.
3. Data Enclosed in brackets indicate the ranges.
4. Unionized ammoniacal nitrogen is calculated based upon temperature, pH and salinity and based upon the EPD routine monitoring data may be taken as 5% of the NH_4-N.

The above data shows that water quality in the vicinity of the Lamma Extension is good, with compliance of WQOs for dissolved oxygen and unionized ammoniacal nitrogen being achieved. The data shows that the area is generally free from the influence of sewage discharges, as shown by the low BOD and *E.coli* values. The data for both temperature and dissolved oxygen show large variations which indicate seasonal changes. It is worth noting that there is no apparent impact on temperature from the discharges from the existing Lamma power station, as the recorded temperatures do not show any variation between the stations and the recorded values are within the expected seasonal fluctuations.

(1) EPD 1997. Marine Water Quality in Hong Kong for 1996.

5.4 CONSTRUCTION PHASE

Assessment of the construction phase has been split into two aspects, impacts to the hydrodynamic regime and the dispersion of fine sediment in suspension during the dredging and filling. Both of these areas have been assessed using computational modelling, which has been carried out by Delft Hydraulics.

5.4.1 *Hydrodynamic Assessment*

Assessment Methodology

The first phase of the modelling involved setting up a detailed hydrodynamic model of the area around Lamma Island[2]. The detailed model was nested within the "Upgraded Model" which had previously been set up and calibrated for the Hong Kong Government as a regional model of the whole of Hong Kong waters, the Pearl Estuary and Mirs Bay. This detailed model has considerably more active grid cells than the model which was used for the Stage I EIA. This model was designed to not only give a better representation of flows in the vicinity of the Lamma Extension site, but also to provide increased detail on the eastern side of Lamma Island. The extent of the detailed model is shown in *Figure 5.4a*, while the grid resolution around the site for the Lamma Extension is shown in *Figure 5.4b*. The performance of the detailed model was verified by comparison with the results of the "Upgrade Mode" and by comparison with field data measurements.

The detailed hydrodynamic model was used to simulate three tidal flow scenarios which are defined below. Each of the three scenarios was simulated for 15 day spring-neap tidal cycles in the wet and dry seasons:

- Scenario 1 - baseline case, corresponding to the current conditions with the existing Lamma Power Station;
- Scenario 2 - Lamma Extension case, including the reclamation for the Lamma Extension; and
- Scenario 3 - WEIF reclamation case, including the reclamations for both the Lamma Extension and the WEIF.

The changes to the tidal flow regime caused by the Lamma Extension reclamation extension alone were determined by comparing the results from Scenario 2 with Scenario 1. The cumulative impact of the Lamma Extension and the WEIF reclamation were determined by comparing the results of Scenario 3 with Scenario 1. *Figure 5.4c* shows the hydrodynamic model representation of these reclamations. The Lamma Extension reclamation covers an area of 22 ha, while the WEIF reclamation covers and area of 17 ha. There is a 200 m wide gap between the two reclamations, *Figure 5.4c*. The information relating to the siting of the WEIF reclamation was obtained from the engineering consultants for the WEIF, CDM, and is based on a dual 3,000 tpd unit.

The effects of the intake and release of cooling water on hydrodynamics has been taken into account by including a dedicated recirculation model in the hydrodynamic model. It has been assumed that the amount of water taken in is identical to the amount of water discharged. Also, it has been assumed that there

(2) WL | Delft Hydraulics 1998. Mathematical modelling for a new Hong Kong power station. Set up of Lamma Island detail model and upgrade of regional model.

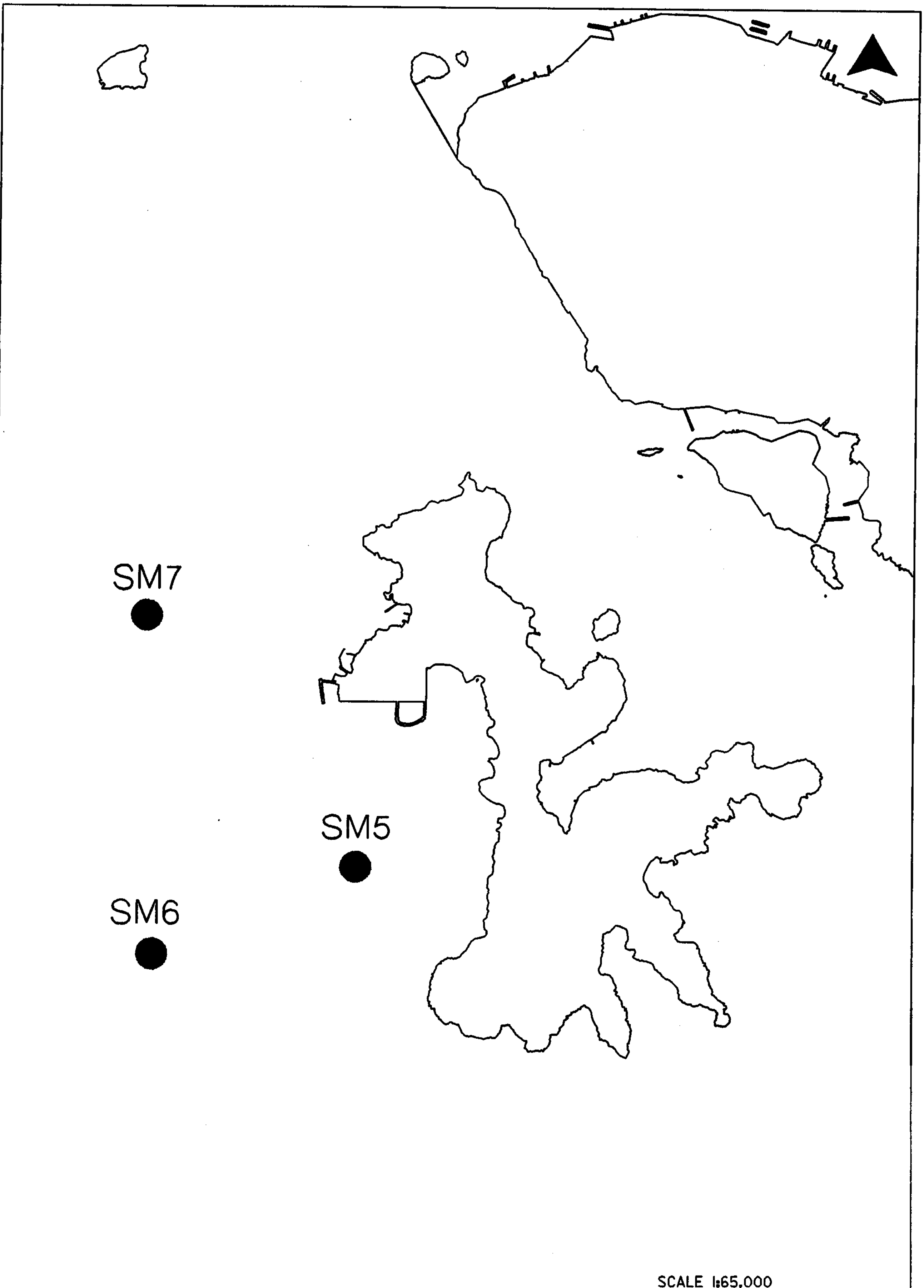

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FIGURE 5.3a

EPD ROUTINE MONITORING STATIONS

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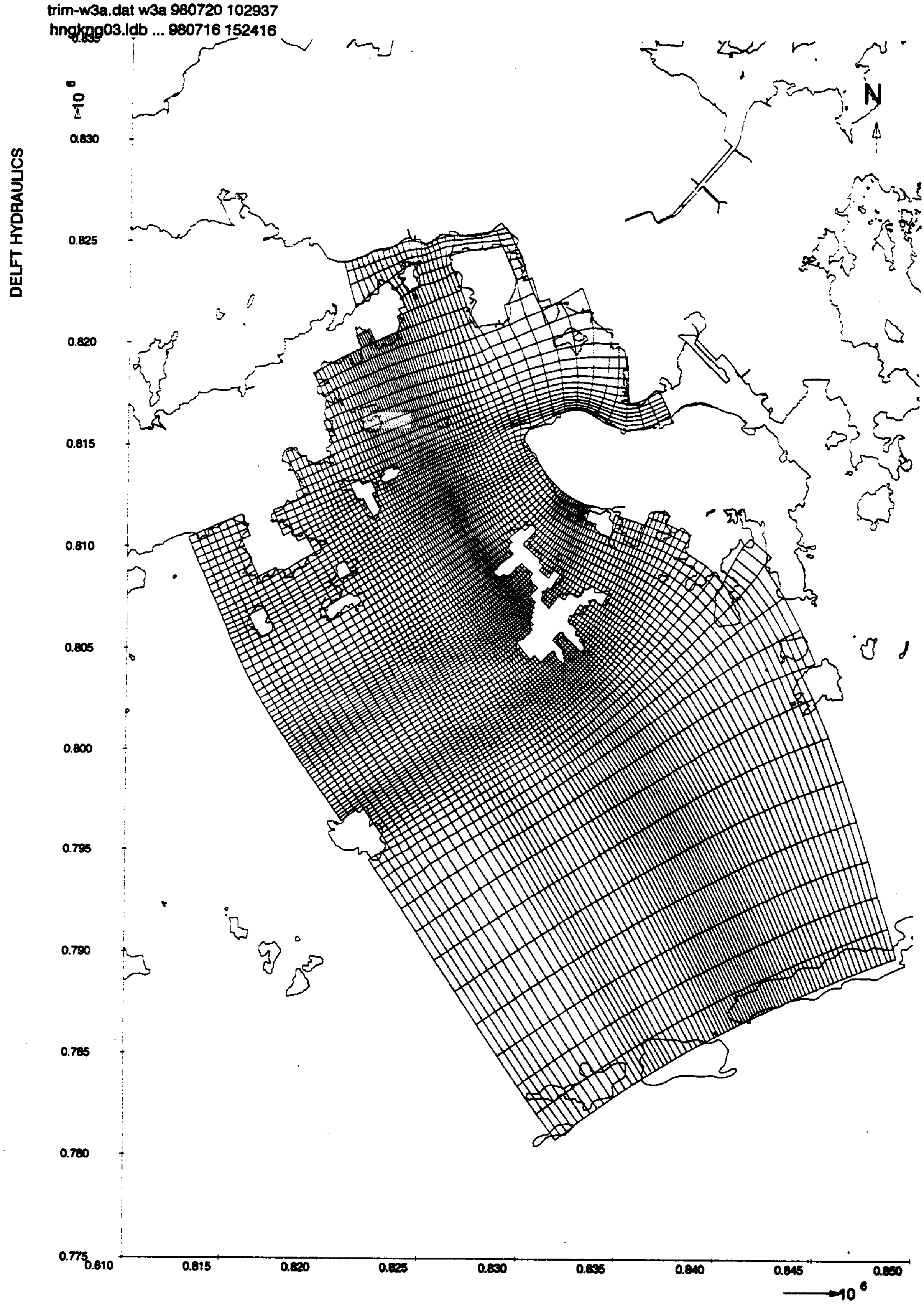

FIGURE 5.4a

EXTENT OF DETAILED MODEL

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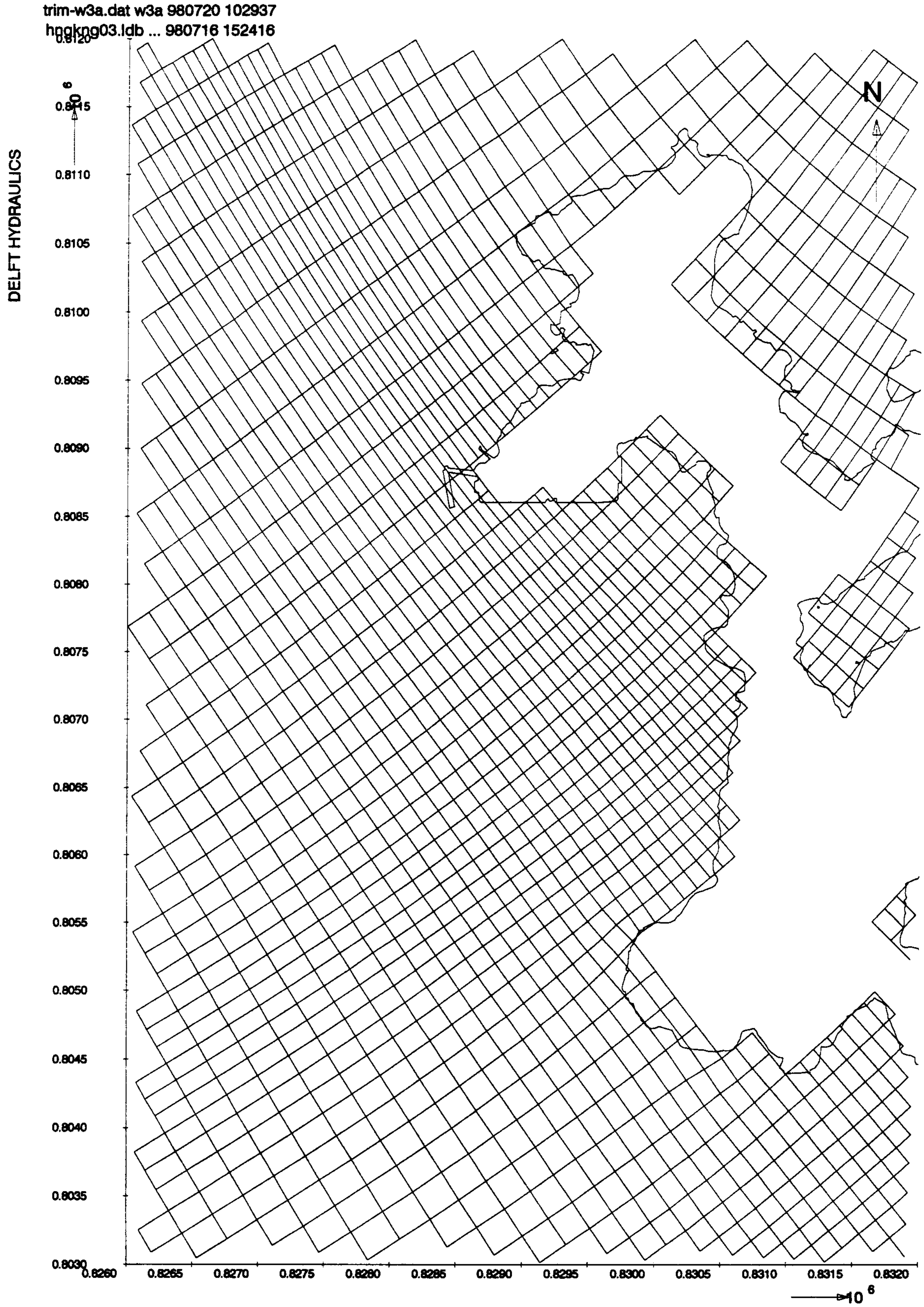

FIGURE 5.4b

DETAILED MODEL AND AROUND THE RECLAMATION SITE

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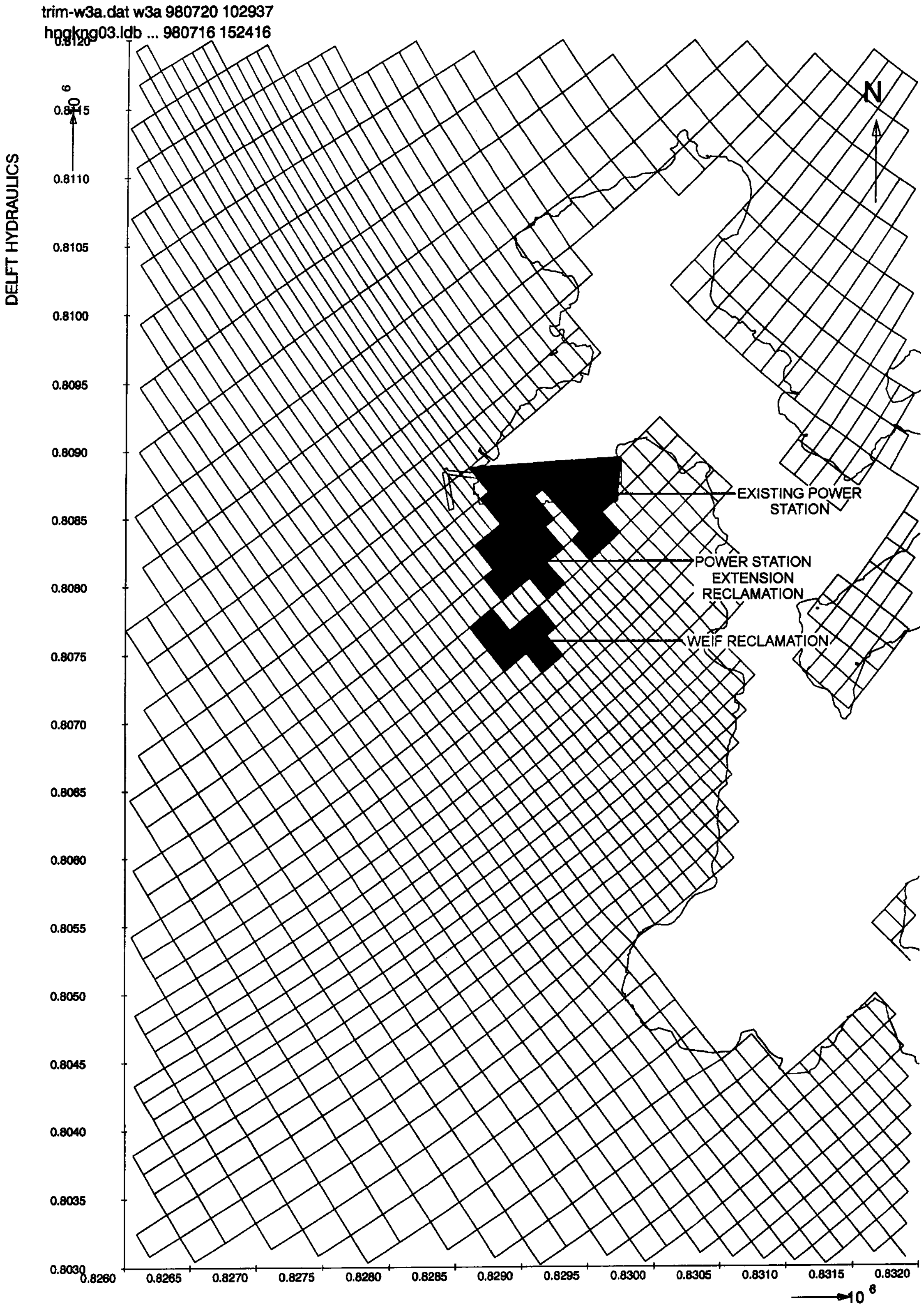

FIGURE 5.4C

MODEL REPRESENTATION OF RECLAMATION

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is no delay between the intake and discharge of water, which is reasonable because the time taken for water to pass through the current cooling system is 500 seconds.

Uncertainties in Assessment Methodology

Quantitative uncertainties in the hydrodynamic modelling should be considered when making an evaluation of the modelling predictions. For the hydrodynamic modelling these are considered to be negligible for the following reasons:

- the computational grid of the model is sufficiently refined to provide precise simulation results;
- the model has been calibrated and verified in order to provide reliable predictions for the study area; and
- the simulations comprise a sufficient warm up period of 10 days so that initial conditions do not affect the results.

Identification of Impacts

Impacts to the hydrodynamic regime have been assessed for the construction of the Lamma Extension and for the cumulative impacts of the Lamma Extension reclamation in conjunction with the WEIF reclamation.

Impacts to the hydrodynamic regime may be caused by the construction of the Lamma Extension altering the tidal currents in the vicinity of the reclamation. These changes may be in the form of increased current speeds in some areas and decreased current speeds in other areas. Impacts may also occur to the discharge rates through the region around the reclamation, including the East and West Lamma Channels. Such changes would be important in that they would indicate changes in the flushing capacity of the region which in turn could affect water quality. Another cause for concern could be the area to the east of the reclamation becoming poorly flushed because of a sheltering affect of the reclamations which could lead to reduced water quality in this area. This is an important consideration because of the presence of bathing beaches in this area.

In order to assess the above described potential impacts the following analyses have been carried out:

- instantaneous discharge rates through cross-sections;
- cumulative discharge rates through cross-sections;
- maximum and average discharge rates through cross-sections during the flood and phases of the tidal cycle;
- salinity fluxes through cross-sections;
- time histories of velocities and salinity at a number of stations; and
- flushing characteristics of the water to the east of the reclamation sites.

Cross-sections north, west and south of the existing Lamma Island power station and a cross-section in the East Lamma Channel have been defined (see *Figure 5.4d*). These four cross-sections together with land boundaries represent a closed area which means that the sum of the fluxes entering this area should be equal to the sum of the fluxes leaving the area. In order to assess the flushing characteristics in the near vicinity of the Lamma Extension, an additional cross-section from the south-east corner of the reclamation to the Lamma Island coast has been defined (*Figure 5.4e*). The four stations for the time histories are also shown in *Figure 5.4e*.

The flushing characteristics of the area to the east of the reclamations were modelled by computing the age of water. The age of water is defined as the difference in time between the actual time and the time at which the water entered the system through the boundary or from sources. The age of water from a specific source may be computed as follows:

$$age = - \frac{\ln \left[\frac{concentration\ conservative\ substance}{concentration\ decaying\ substance} \right]}{decay\ rate}$$

In the simulations two substances have therefore been added, a conservative substance and a substance that is subject to decay. A continuous source for the two substances of 5 $m^3\ s^{-1}$ was used, which represented the Hung Shing Ye river discharge into the area to the east of the reclamations.

Prediction and Evaluation of Impacts

A total of six simulations were carried out for the hydrodynamic modelling to investigate the impacts of the construction of the power station extension and the cumulative impacts of the WEIF reclamation on tidal flows. These simulations were Scenarios 1, 2 and 3 for the wet and dry seasons, as described above. The results from the hydrodynamic modelling are included in *Annex B5-2*, which contains a report on the hydrodynamic modelling prepared by Delft Hydraulics. Reference will be made to the results shown in *Annex B5-2* in this section during the discussion of the impacts.

At the four output locations, *Figure 5.4e*, the graphs of time variation of water level, current magnitudes, and salinity for both the wet and dry season show little variation between the three scenarios. *Figures 3.1.1* to *3.1.5* in *Annex B5-2* show the wet season results, while *Figures 3.2.1* to *3.2.5* show the dry season results. In the wet season the results show differences between the surface and bed layers which is a result of the wet season salinity stratification, and would be expected because of the influence of the freshwater discharge from the Pearl River Estuary. Some salinity stratification is shown for Stations B, C D in the dry season, because of the discharge from the Hung Shing Ye river, while at Station A there is no stratification.

Tables of cumulative, maximum and average discharges across the five cross-sections shown in *Figures 5.4d* and *5.4e* were produced. Discharges were calculated for each of the three scenarios and the changes between the Scenario 2 and Scenario 1 (the existing situation) and between Scenario 3 and Scenario 1 were made. In general, changes at the cross-section were found to be around 2 to 3%, which is a relatively small change. Large changes in the maximum discharge rate across the south east cross-section, 15.8%, are shown for Scenario 2 in the dry season, although this change reduces to 4.9% for Scenario 3. This apparent large

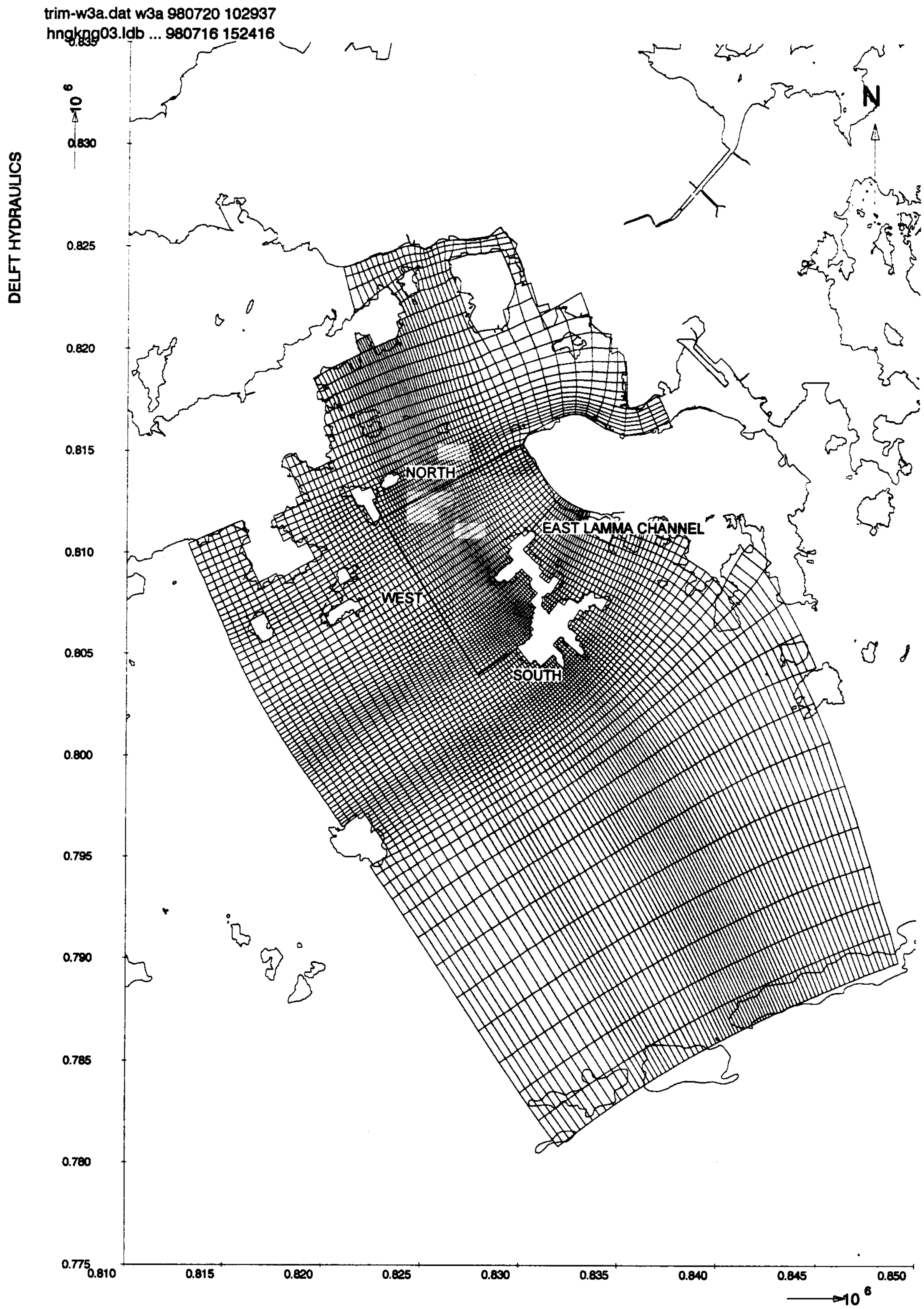

FIGURE 5.4d

LOCATIONS OF CROSS SECTIONS

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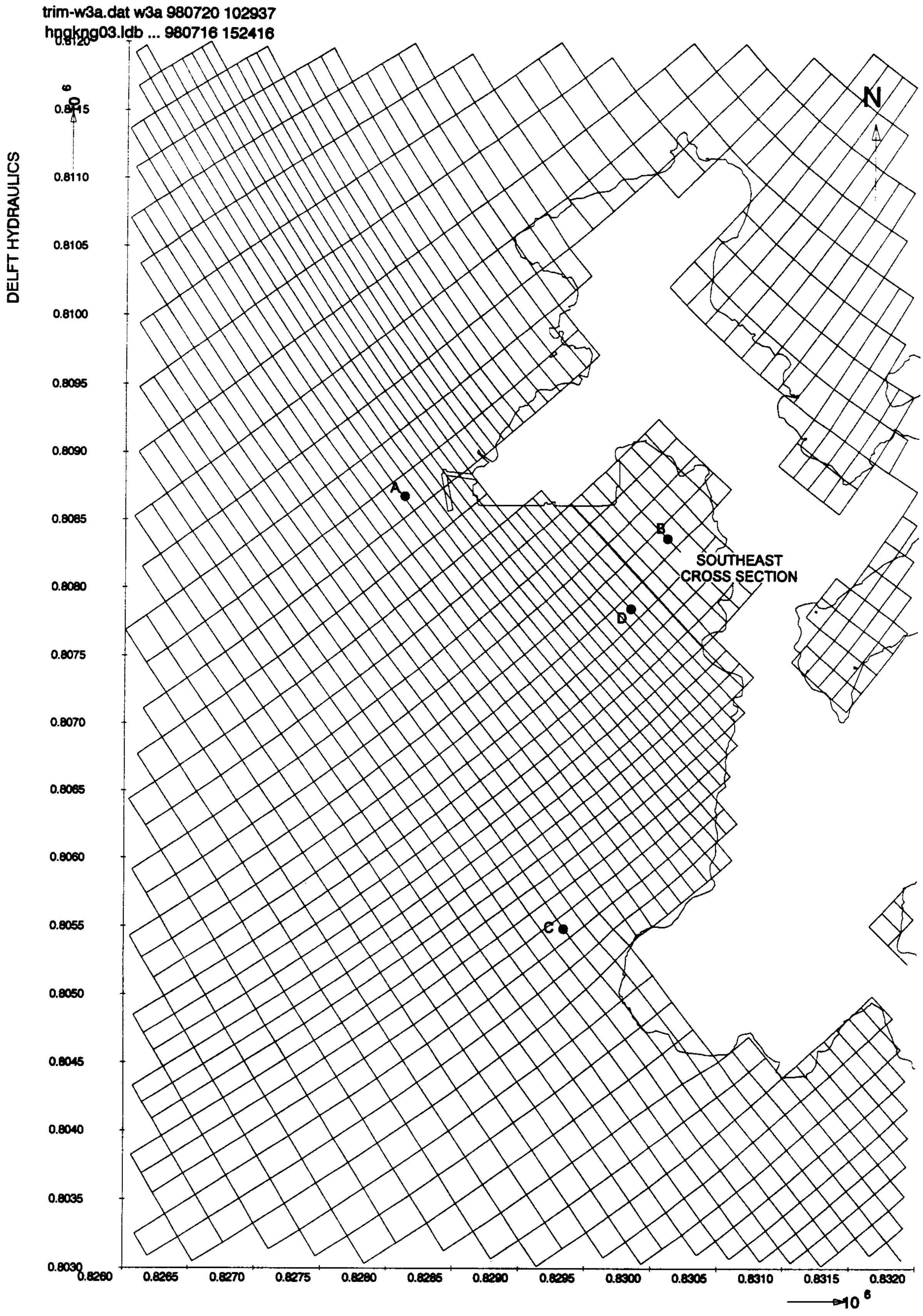

FIGURE 5.4e

LOCATIONS OF HYDRODYNAMIC OUTPUT POINTS AND SE CROSS SECTION

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reduction is shown for only for the maximum rate, as the average discharge rates change by only 2.0%. This shows that it is only at the instantaneous maximum where large changes occur and for the rest of the tide the changes are small. The results of the discharge analysis, even for the southeast cross section, show that the flushing characteristics of the area are not greatly affected by the inclusion of the two reclamations. This conclusion is also supported by graphs of the time varying discharge through the cross sections which also showed very small differences between the three scenarios (see *Figures 3.1.6* to *3.1.10* in Annex *B5-2* for the wet season and *Figures 3.2.6* to *3.2.10* for the dry season).

It should be noted that in *Figures 3.1.10* and *3.2.10* that there apparent maximum discharge rates through the southeast cross section are somewhat higher than those given in the tables of cumulative, maximum and average discharges. This is due to an apparent oscillation in the fluxes through this section, while the tables show average maximum discharges. The oscillation in the instantaneous discharges represents a change in current speeds of only 0.02 m s^{-1} which is very small. Also, the predicted changes in average discharge rates for this section represent average changes in current speed of 0.007 m s^{-1} which is extremely small. Therefore, any changes in the flushing rate of the section, which may be represented by large percentage changes, are in fact caused by extremely small changes in current speed and may give misleading results when trying to compare such changes between the three scenarios. Greater emphasis should thus be placed on the age of water analysis to determine the effects of the reclamations on the flushing characteristics of Hung Shing Ye Bay.

The age of water analysis for the area to the east of the reclamation showed that the reduction in concentrations of the introduced substance reduced at approximately the same rate for all three scenarios. This may be seen by comparing *Figures 3.1.13, 3.1.15* and *3.1.18* which show the age of water after 14 days for Scenarios 1, 2 and 3 in the wet season , while *Figures 3.2.11, 3.2.13* and *3.2.16* show the same results for the dry season. Small differences are shown in these figures which are consistent with the analysis of the tidal flux across the southeast cross section, as discussed in the previous paragraph. The differences relate to the extent of the 2 to 3 day age of water contour which is shown to not extend as far south following the construction of the reclamations. However, the extent of the 3 to 4 day age of water contour is similar which shows that the retention time of the bay has not greatly increased. This demonstrates that neither the Lamma Extension reclamation nor the combination of the Lamma Extension and WEIF reclamations significantly affected the flushing characteristics of the area to the east of the two reclamations, which includes the beaches at Lo So Shing and Hung Shing Ye. This means that the current water quality within this area is likely to be maintained with only a slight degradation.

The conclusion for the hydrodynamic modelling results is that the neither the Lamma Extension reclamation alone, nor the combined Lamma Extension and WEIF reclamations, significantly affected hydrodynamic conditions, in terms of water level, current speed, cumulative or instantaneous discharge, or flushing characteristics.

Mitigation of Environmental Impacts

The conclusion from the hydrodynamic assessment was that the reclamations for the Lamma Extension and the WEIF would not significantly alter hydrodynamic conditions, including the flushing of Hung Shing Ye Bay. This means that changes in water quality in Hung Shing Ye Bay would not be adversely affected due to reduced flushing rates and so no specific mitigation measures would be required. However, it is recommended that no pollutants be allowed to enter into the bay as a result of the construction and operational phases of the Lamma Extension reclamation and this may be achieved by preventing storm drain discharges to the eastern side of reclamation.

5.4.2 *Sediment Dispersion*

Assessment Methodology

- Description of Sediment Transport Model

Sediment transport was modelled with the Delft3D-WAQ module which simulates the process of sediment transport, deposition and erosion for plumes generated during dredging and filling activities. The basis of the model is the advection-diffusion transport. All sediment particles are transported by the flow (advection) and turbulent mixing (diffusion), and additional processes will be included for modelling various water quality parameters.

In the horizontal plane the computational grid of the model is exactly the same as the hydrodynamic model. In the vertical direction the model for the sediment dispersion uses 5 layers instead of the 10 layers hydrodynamic modelling. The required flow data are derived from the output of the hydrodynamic model by combining every two layers into one layer. The model is run for a period of 10 days, the first 8 days of which represent the 'spin up' period and the last 2 days are used for the results analysis. This process is repeated for both the spring and neap periods.

There are two processes governing sediment transport: settling of sediment particles and sediment exchange between the water column and the seabed. Settling of sediment particles is described by settling velocity. For the sediment exchange between the water column and the seabed, deposition and erosion are involved. Deposition only occurs when the bed shear stress is below a critical value of τ_d whereas erosion only occurs when the bed shear stress is above a critical value of τ_e.

$$D = W_s C_b (1 - \tau / \tau_d) \quad \text{for} \quad \tau < \tau_d$$

$$E = M (\tau / \tau_e - 1) \quad \text{for} \quad \tau > \tau_e$$

where

D	=	deposition rate
E	=	erosion rate
W_s	=	settling velocity = 2 m day^{-1}
C_b	=	suspended solid concentration in the bottom layer
τ_d	=	critical bed shear stress for deposition = 0.05 Pascal
M	=	erosion coefficient = 0.0002 kg m^{-2} s^{-1}
τ_e	=	critical bed shear stress for erosion = 0.4 Pascal

As short waves increase the bed shear stress only in relatively shallow water areas, their influence on sediment transport is neglected because the Study Area is covered by relatively deep water. Sediment release due to the dredging activities is assumed to be uniformly distributed over the water depth.

- Derivation of Scenarios

The construction of the reclamation will involve dredging of the existing marine mud and filling of the reclamation using sand. The programme for the construction of the reclamation is contained in *Figure 5.4f*. The programme indicates which areas are to be dredged and filled at any one time. The dredged mud will be disposed of at a suitable disposal site which will be determined in consultation with the Fill Management Committee. Sand fill will be sourced from outside of Hong Kong.

During the bulk dredging and sand filling a quantity of fine sediment will be lost to suspension which may be transported away from the works area, forming suspended sediment plumes. The formation and transport of such sediment plumes have been assessed using computer modelling of sediment dispersion.

Dredging works will be undertaken with either grab dredgers in isolation or with a combination of grab dredgers and trailer dredgers. The assumptions made with regards to modelling grab dredging operations are detailed below.

- Two sizes of dredger will be employed:

  - Large dredgers will have a production rate of 300,000 m^3 per month and operate for 25 days per month and 18 hours per day; this equates to a rate of 0.19 $m^3 s^{-1}$ during dredging operations.

  - Small dredgers will have a production rate of 200,000 m^3 per month and will operate for 25 days per month and 18 hours per day; this equates to a rate of 0.12 $m^3 s^{-1}$ during dredging operations.

- The amount of material lost to the water column will depend on the size of the dredger:

  - Large dredgers will lose 12 kg m^{-3} dredged which equates to a loss rate of 2.3 kg s^{-1}.

  - Small dredgers will lose 25 kg m^{-3} dredged which equates to a loss rate of 3.0 kg s^{-1}.

- For the purposes of modelling it will be assumed that the dredgers could potentially dredge for 24 hours per day at these rates.

- The material lost during grab dredging will be spread throughout the water column and this will be represented by spreading the sediment evenly over all 10 layers of the model.

- No more than 6 grab dredgers will operate on the site at any one time.

The assumptions made with regards to modelling trailer dredging operations are as follows:

- No more than one trailer dredger will operate on the site at any one time.

- No overflowing will be permitted during dredging.

- No Automatic Lean Mixture Overboard (ALMOB) will be permitted.

- Mud removal will be carried out using medium size trailing suction hopper dredgers.

- Each trailer will take 20 minutes to fill and will remove 800 m^3 of mud which equates to 0.67 $m^3 s^{-1}$.

- Approximately 4 kg of solids will be suspended for each cubic metre of mud removed which equates to 2.7 kg s^{-1} of material lost to suspension during trailer dredging operations.

- All material that is lost to suspension will enter the water column at the sediment-water interface and will be introduced into the bottom layer of the model which represents the bottom 10% of the water column.

- The dredging cycle, which will consist of dredging, travelling to the disposal site, disposal, and travelling back to the dredging site will have a duration of 2 hours.

Sand filling could be carried out by a range of plant but would most likely be either from trailer dredgers or by bottom dumping from barges. The assumptions made with regards to modelling sand filling are as follows:

- The maximum losses will occur during bulk filling during which time the contractor will need to place up to 400,000 m^3 of material per week.

- The quantities of sediment lost to suspension will be calculated on the basis that filling activities will be undertaken 24 hours per day six days per week, however, for the model simulations it will be assumed that the rate calculated on this basis could be applied continuously.

- The saturated density of sandfill is assumed to be 2.0 Mg m^{-3} and the dry density is assumed to be 1.6 Mg m^{-3}.

- The proportion of fines in the fill material will be 10 to 40% but for calculating the material released, 20% will be assumed as it is understood that this level could reasonably be achieved by fill providers.

- 5% of the fines will be lost during disposal operations.

- Filling will either be conducted using bottom dumping barges with a capacity of 1,500 m^3 or trailers with a capacity of 3,500 m^3.

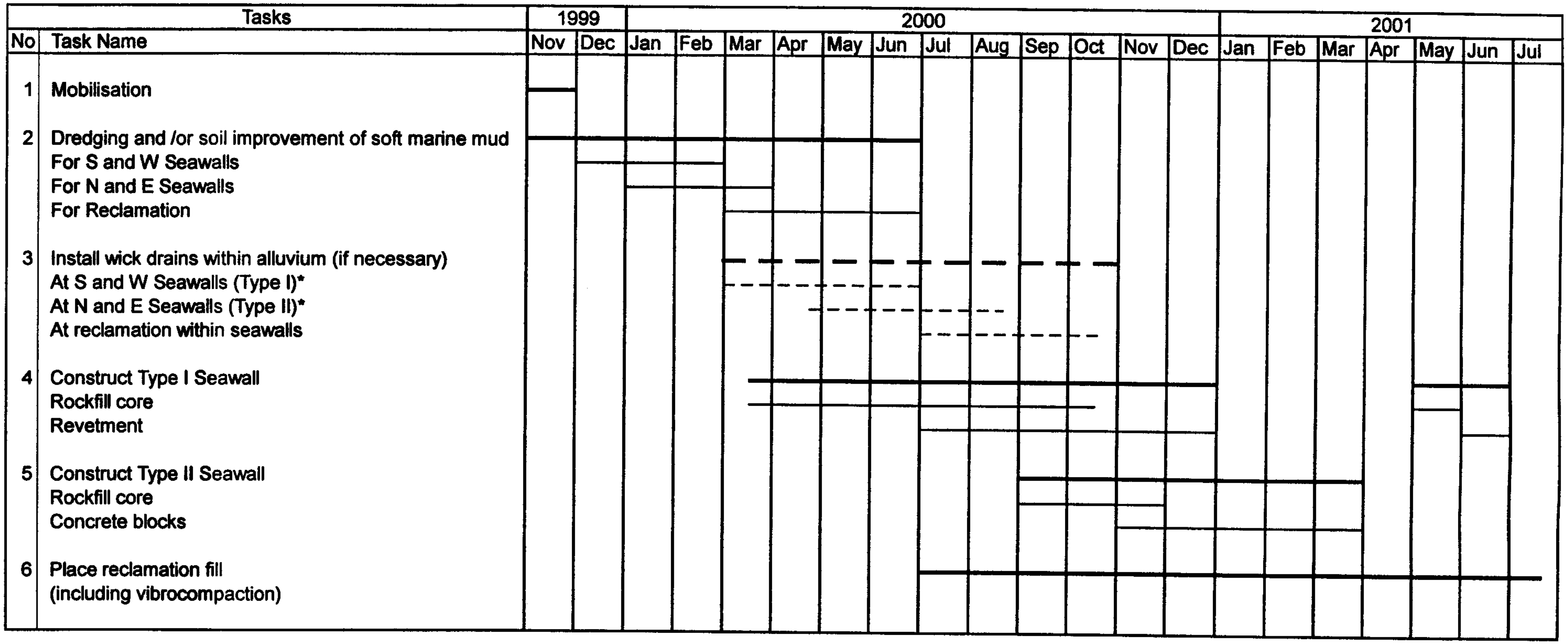
- The material lost during filling will be spread throughout the depth and this will be represented by the model by spreading the sediment evenly over all 10 layers of the model.

On the basis of the above the following loss rates have been calculated:

- either 44 barge disposals will occur each day (ie one every 32 minutes) during each of which 24 tonnes of sediment will be lost; and

- or 19 trailer disposals will occur each day (ie one every 76 minutes) during each of which 56 tonnes of sediment will be lost.

A range of scenarios simulating dredging using only grab dredgers and a combination of grab dredgers and trailer dredgers have been simulated. In addition, scenarios simulating combined dredging and filling have been carried



*Note : Type I Seawalls are rubble mound construction and Type II Seawalls are vertical blockwork construction

FIGURE 5.4f

PROGRAMME FOR THE CONSTRUCTION OF THE RECLAMATION

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out. The scenarios which have been simulated are summarised in *Table 5.4a* below.

Table 5.4a ***Summary of Sediment Dispersion Scenarios***

Scenario	Description	Losses
1	5 large grab dredgers 1 small grab dredger	11.0 kg s^{-1} (2.2 kg s^{-1} per dredger) 3.0 kg s^{-1}
2	3 large grab dredgers 1 small grab dredger	6.6 kg s^{-1} (2.2 kg s^{-1} per dredger) 3.0 kg s^{-1}
3	1 trailer dredger 2 large grab dredgers	2.7 kg s^{-1} for 20 minutes every 2 hours 4.4 kg s^{-1} (2.2 kg s^{-1} per dredger)
4	Sand filling by barge dumping 2 large grab dredgers	24 tonnes every 32 minutes 4.4 kg s^{-1} (2.2 kg s^{-1} per dredger)

Scenario 1 represents the highest possible dredging rate, based on site restrictions which limit the maximum number of dredgers to six. This scenario was simulated for the four representative tide types in Hong Kong (the wet and dry season spring and neap tides). The results from this scenario were used to determine which tide and season combination gave the worst impacts, termed the "worst case tide and season". Scenarios 2 and 3 were then simulated for this worst case tide and season. Scenario 2 represents a lower dredging rate using grab dredgers which may be used whilst still proceeding with the works according to programme, while Scenario 3 represents a combination of grab dredgers and trailer dredgers which may be used within the construction programme. Scenario 4 is representative of a possible combined filling and dredging rate using barge dumping. It was felt that, of the two options for dumping, barge dumping would be more severe in terms of impacts because the frequency of dumping was greater than that for trailer dumping. Scenario 4 was simulated for the wet season spring and neap tides, because the current construction programme indicates that these two activities may only overlap during the wet season, as shown in *Figure 5.4f*.

The above scenarios simulated only dredging and filling at the power station extension reclamation site. However, there will be other concurrent dredging and filling projects which may impact the same areas as the works at the power station reclamation extension site. An analysis of projects which could occur at the same time as the power station extension reclamation has found that there will be three projects which could contribute to cumulative impacts. These projects are the Backfilling of South Tsing Yi Marine Borrow Area, dredging at the Container Terminal 9 reclamation site, and sand winning at the Southern South Tsing Yi Marine Borrow Area. The cumulative impacts from the first two concurrent projects were determined by computer simulations of the worst case tide for Scenario 1 plus the cumulative project. The assessment of cumulative impacts from the sand winning was carried out by summing the results of the worst case tide for Scenario 1 with the results of computer modelling of the sand winning from an earlier study[(3)].

In addition to the simulation of sediment dispersion, the Delft water quality model has been used to assess the effects of the sediment in suspension on water quality. The assessment included dissolved oxygen depletion and ammoniacal nitrogen release.

(3) Focussed Environmental Impact Assessment, West of Sulphur Channel Marine Borrow Area, Final Report, December 1994, under Agreement No CE 52/94 for Civil Engineering Department, Hong Kong Government.

Construction of the sea walls will also involve filling of the foundation trenches. Under the vertical sea walls, along the northern and eastern sides of the reclamation, the foundation trenches will be filled with rock material which means that there will be no loss of fines to suspension, and no impacts to water quality. Under the rubble mound sea walls, along the southern and western sides of the reclamation, the sea wall foundations will be filled with sand. The sand will be placed using controlled pumping down trailing suction hopper dredgers arms. The rate of placement will be restricted to 80,000 m^3 $week^{-1}$, with a total quantity of sand fill to be placed of 2,000,000 m^3. The loss of fines to suspension will be minimal because the filling will take place in the foundation trenches which are below the surrounding sea bed level, and because the head of the trailer arm will be places very close to the bed of the trench during filling. An indicative loss rate may be calculated as follows :

- The fines content of the sand fill is 20% and the dry density of the sand fill is 1,600 kg m^3.
- The trailer dredgers will working for 6 days per week, at a rate of 18 hours per day, which gives a rate of working of 740.7 m^3 $hour^{-1}$.
- The total quantity of fines lost to suspension is 5% of the total fines content of the sand fill.

The loss rate calculated on the above basis for the sand filling of the sea wall foundation trenches will be 3.3 kg s^{-1}. This rate of loss is similar to that simulated for the grab dredging operations. However, there will be significant differences in the manner in which the sediment is lost to suspension during controlled pumping down the trailer arm compared with grab dredging. The sediment will be lost to suspension close to the sea bed and in a trench which is below the surrounding sea bed level. This means that the sediment is likely to settle rapidly onto the sea bed within the trench and that there will be minimal possibility of the sediment being transported out of the trench. It is therefore considered that the impact of such operations will be minimal and as such no further assessment will be required.

Uncertainties in Assessment Methodology

Quantitative uncertainties in the sediment dispersion modelling should be considered when making an evaluation of the modelling predictions. Worst case conditions were adopted as model input in order to provide a conservative prediction of environmental impacts. It is therefore possible that the input data for the relevant parameters may cause an overestimation of the environmental impacts. Some examples of the conservative nature of the input parameters are given below:

- The simulations for generating flow data for the sediment dispersion modelling have been carried out with the pre-dredging bathymetry which will result in a greater amount of the sediment released during dredging remaining in suspension (use of the post-dredging bathymetry would mean that more sediment would deposit to the seabed, thus reducing plume extent and concentrations).
- The flow model simulations used for generating the flow data for the sediment dispersion modelling represent the baseline case without any

structure present which would result in a greater dispersion of suspended sediment than would occur during construction as sea walls are constructed.

- The settling velocity of SS of 2 m day^{-1} was derived from the recent calibration of the upgraded Hong Kong water model based on the Delft 3D system. During the calibration, settlement rates were varied to determine the sensitivity of model predictions to this factor and it was found that higher rates lead to an under-prediction of suspended sediment around Hong Kong Island. Therefore, the settling velocity in this Study is conservatively set at 2 m day^{-1} which is at the lower end of the wide range of values encountered in the general literature but represents the best available value in the absence of any more relevant field data.

Identification of Impacts

Impacts from the dispersion of fine sediment in suspension from the construction of new power station reclamation have been assessed using computer modelling.

- Suspended Sediment

Impacts from suspended sediment may be caused by sediment plumes being transported to sensitive areas, such as water intakes, bathing beaches and areas of high ecological value. A number of such areas have been defined as sensitive receivers in the areas likely to be affected by increased suspended sediment concentrations from the construction of the new power station extension. The locations of these sensitive receivers are shown in *Figure 5.4g*.

Any sediment plumes will cause the ambient suspended sediment concentrations to be elevated and the level of elevation will determine whether the impact is adverse or not. The determination of the acceptability of any elevations is based on the Water Quality Objectives. The WQO is defined as being an allowable elevation of 30% above the background. EPD maintains a flexible approach to the definition of ambient levels, preferring to allow definition on a case-by-case basis rather than designating a specific statistical parameter as representing ambient. As directed in a previous study of the environmental impacts of released suspended solids[(4)], the ambient value has been assumed to be represented by the 90th percentile of reported concentrations. EPD routine monitoring data has been used as the source of reported concentrations, with the station nearest to each of sensitive receivers being defined as representative of that station. EPD monitoring data and calculated WQOs are summarised in *Table 5.4b*.

(4) ERM-Hong Kong Ltd (1997). Environmental Impact Assessment for the Disposal of Contaminated Mud in the East Sha Chau Marine Borrow Pit. Final Report, under CED Contract No. CE 81/95, January 1997.

Table 5.4b ***Ambient and 30% Tolerance Levels for SS (mg l^{-1}) for Sensitive Receivers***

Sensitive Receiver (Relevant EPD Monitoring Station)	Depth	Dry Season		Wet Season	
		90th Percentile	30% Increase	90th Percentile	30% Increase
Hung Shing Ye Beach Lo So Shing Beach South Lamma Marine Park 1 South Lamma Marine Park 3 South Lamma Marine Park 4 (SM5)	Surface	13.0	3.9	5.8	1.7
	Middle	20.0	6.0	6.2	1.9
	Bottom	21.0	6.3	11.0	3.3
Shek Kok Tsui Pak Kok Wah Fu Estate Intake (WM1)	Surface	4.8	1.4	5.3	1.6
	Middle	7.7	2.3	5.2	1.6
	Bottom	7.5	2.3	8.6	2.6
Luk Chau Lo Tik Wan (SM3)	Surface	9.5	2.9	7.1	2.1
	Middle	11.5	3.5	4.7	1.4
	Bottom	15.5	4.7	8.7	2.6
Sok Kwu Wan (SM4)	Surface	7.5	2.3	5.7	1.7
	Middle	9.1	2.7	6.7	2.0
	Bottom	9.8	2.9	6.9	2.1
Queen Mary Hospital Intake Sha Wan Drive Intake (WM2)	Surface	9.7	2.9	2.9	0.9
	Middle	12.8	3.8	6.1	1.8
	Bottom	21.4	6.4	18.1	5.4
Kennedy Town WSD Intake (VM8)	Surface	11.9	3.6	11.0	3.3
	Middle	14.9	4.5	12.8	3.8
	Bottom	16.7	5.0	12.0	3.6
Kau Yi Chau (SM9)	Surface	9.1	2.7	20.3	6.1
	Middle	11.5	3.5	25.5	7.7
	Bottom	15.0	4.5	31.0	9.3

The WQO for a particular site corresponds to the 30% tolerance plus the ambient level. The predicted maximum values from the sediment dispersion modelling will be compared with the 30% tolerance values in the above table to determine acceptability of the impacts. It should be noted that the Sha Wan Drive Intake is very close to the Queen Mary Hospital Intake and that the modelling results for the Queen Mary Hospital Intake would be applicable to the Sha Wan Drive Intake. Only the Queen Mary Hospital Intake will be discussed in the following sections but the same assessment would apply equally to the Sha Wan Drive Intake.

In addition to the above criteria for suspended sediment, the water intakes which have been defined as sensitive receivers have specified SS criteria to protect abstraction systems and maintain appropriate water quality for the designated use. The SS concentrations at the cooling water intakes for the Lamma Power Station should be maintained below 100 mg l^{-1}, while at the Kennedy Town WSD intake a criterion of 10 mg l^{-1} total concentration is applied. In addition to these

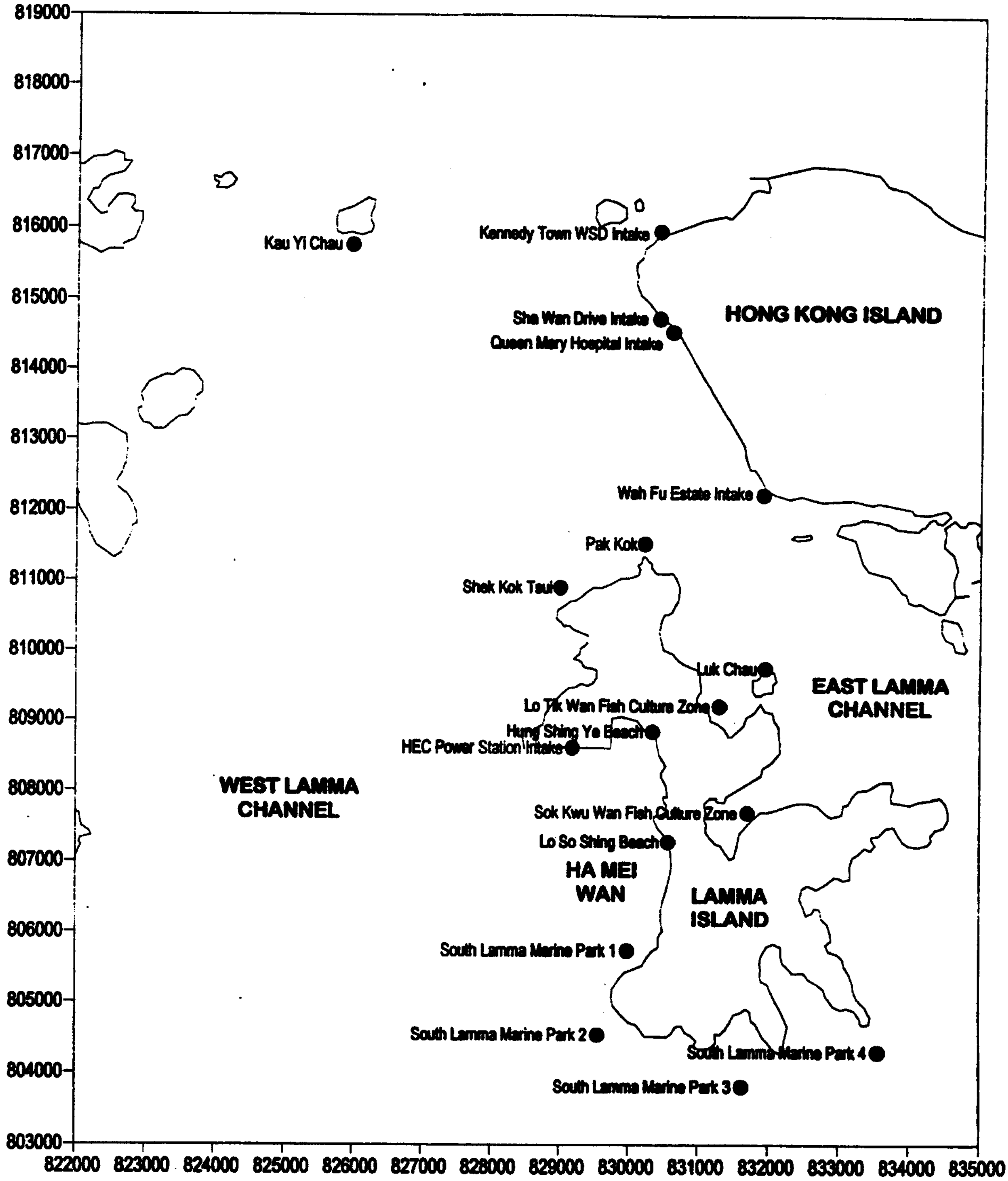

FIGURE 5.4g

LOCATIONS OF SENSITIVE RECEIVERS FOR RECLAMATION CONSTRUCTION AND OPERATION

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criteria a pragmatic approach of controlling SS concentrations to below 20 mg l^{-1} at flushing and cooling water intakes has been used on a number of other projects in and around Victoria Harbour. This approach was accepted by WSD and has most recently been adopted for the EIA for *Dredging an Area of Kellett Bank for Reprovisioning of Six Government Mooring Buoys*.

- Sediment Deposition

Impacts from the formation of sediment plumes may also be related to the settling of the sediment onto the sea bed and smothering any organisms present. A deposition rate of 0.2 kg m^{-2} day^{-1} has been determined as a level of concern for corals. Further discussion of the selection of this value is contained in *Section 10* of Part B of this Report, which discusses ecological impacts. The results from the sediment dispersion modelling have been analysed to show the rates of settlement onto the sea bed which may be assessed in terms of potential impacts, with reference to the above specified level of concern.

- Water Quality

The loss of sediment to suspension during dredging and filling may have chemical effects on the receiving waters. This is because the sediment may contain organic and chemical pollutants. As a part of this study laboratory testing of sediment samples was undertaken[(5)]. The testing found that the sediment was uncontaminated (Class A) in accordance with EPD's *Technical Circular No 1-1-92*, which means that the sediment contained low levels of heavy metals. There would therefore be minimal impact associated with the release of such substances during the dredging works. Further testing of sediment quality was undertaken[(6)] for organic contamination. The results of the sediment quality testing for organic contamination are summarised in *Table 5.4c* below.

Table 5.4c ***Summary of Sediment Quality Testing***

Testing Parameter	Average Level
Chemical oxygen demand (mg kg^{-1})	23000
Total carbon content (%)	1.16
Total organic carbon content (%)	0.17
Total inorganic carbon content (%)	1.02
Ammoniacal nitrogen content (mg kg^{-1})	9
Total Kjeldahl nitrogen (mg kg^{-1})	648

Dissolved oxygen impacts were assessed by calculating the differences between two water quality model simulations. The first simulation included the suspended sediment from the dredging activities, while the second did not include any of the suspended sediment and could be defined as the baseline simulation. The difference between the two runs showed the reductions in the dissolved oxygen concentrations which would occur as result of the dredging activities at the reclamation site. For each of the two runs a dissolved oxygen boundary concentration of 7.6 mg L^{-1} was applied to the model and the model was run until equilibrium was achieved. The discharge from the existing power station had already been included in the hydrodynamic simulations and for both

(5) ERM-Hong Kong Ltd (1998). Environmental Impact Assessment of a 1,800 MW Gas-fired Power Station at Lamma Extension: Sediment Quality Report. Working paper to Hongkong Electric Company, Ltd, September 1998.

(6) Bachy Soletanche (1998). Contract No. 98/8229. Lamma Power Station Extension Sediment Sampling and Testing. Final Laboratory Report. Volume III : Water Quality Assessment. Final report to Hongkong Electric Company Limited, August 1998.

the water quality runs it was assumed that the discharge had a dissolved oxygen concentration of zero. This meant that the minimum dissolved oxygen concentrations in the baseline simulation were 5.8 mg L^{-1} in the vicinity of the outfall, while the minimum concentrations in the vicinity of the dredging works was 7.4 mg L^{-1}. This meant that the background dissolved oxygen concentrations were below the saturation concentration which would mean that re-aeration would be enhanced in the areas with low dissolved oxygen simulations and could affect the results of the analysis of depletion from the suspended sediments released during dredging. To test whether the assumption of zero dissolved oxygen in the existing power station discharges would affect the results from the analysis of dissolved oxygen an additional sensitivity test was carried out. This sensitivity test assumed that the dissolved oxygen concentration in the power station discharge was 7.6 mg L^{-1}. The dissolved oxygen depletion from the suspended sediment using the assumption of 7.6 mg L^{-1} was compared with that assuming zero dissolved oxygen and found to be almost identical. This demonstrated that there was no significant effects from the assumption of zero dissolved oxygen in the existing power station discharge on the analysis of dissolved oxygen reduction due to the suspended sediments from the dredging works, and the analysis for all the scenarios was based on a zero dissolved oxygen assumption for the existing power station discharge. The above sediment characteristics of total organic carbon, total Kjeldahl nitrogen and ammonia were used as these are involved in oxidative processes, as was chemical oxygen demand which directly uses up dissolved oxygen.

The impacts on the ammoniacal nitrogen concentrations in the receiving waters are related to the release of ammoniacal nitrogen and organic nitrogen from the sediment. In the modelling it was assumed, conservatively, that all of the ammoniacal nitrogen and organic nitrogen was released from the sediment as it was lost to suspension. The two substances were then modelled separately from the sediment. No measurements of organic nitrogen within the sediment were made and it was assumed that all of the Kjeldahl nitrogen was in the form of organic nitrogen. Mineralisation of organic nitrogen produces ammonical nitrogen and so the resulting ammoniacal nitrogen concentrations in the water were generated from the combined effects of the release of ammoniacal nitrogen from the sediment and from the mineralisation of organic nitrogen. The model results were representative of the increase above background.

The results from the dissolved oxygen simulations were analysed to show the reduction in dissolved oxygen concentrations resulting from the suspension of sediment during dredging and filling. The reductions could then be compared with the ambient dissolved oxygen concentrations which were observed at Station SM5 from the EPD routine monitoring data, which gave minimum values of 6.4 mg L^{-1} in the surface layer and 3.7 mg L^{-1} in the bed layer, to determine whether breaches of the WQO would occur. The WQO states that depth averaged dissolved oxygen should be greater than 4 mg L^{-1} on 90% of occasions and greater than 2 mg L^{-1} within 2 metres of the sea bed on 90% of occasions. The results from the ammoniacal nitrogen simulations showed the elevations in concentrations above background. The background concentrations were determined from the EPD routine monitoring data at Station SM5 which gave mean depth-averaged concentrations of 0.01 mg L^{-1}. The unionized fraction of the monitored ammoniacal nitrogen may be calculated based on temperature, pH and salinity and in the vicinity of the Lamma Extension the average value is 5%, based on EPD routine water quality monitoring data. This gives a background unionized nitrogen concentration of 0.0005 mg L^{-1} and the compliance with the WQO could then be determined by adding the elevations from the dredging works to this background value. The results from the simulations will be presented as total ammoniacal nitrogen, of which 5% will be in the form of unionized ammoniacal nitrogen, as discussed above. The WQO for unionized ammoniacal nitrogen is a depth averaged annual mean of 0.021 mg L^{-1}.

Prediction and Evaluation of Impacts

A total of four sediment dispersion scenarios were modelled, as defined in *Table 5.4a,* which simulated dredging and filling at the power station extension reclamation site. A further two scenarios simulated the dispersion of sediment from the power station extension in combination with other projects. An additional cumulative analysis was carried out based on results of an earlier EIA for the West Sulphur Channel Marine Borrow Area[7].

The results from each scenario have been presented as contours of maximum depth-averaged suspended sediment concentrations above ambient, contours of average suspended sediment concentrations above ambient at the surface and bed, contours of average dissolved oxygen concentrations and as contours of average ammonia concentrations. These results are contained within *Annex B5-3* of this report. Maximum concentrations above ambient at each of the sensitive receivers (*Figure 5.4g*) have been produced for surface, middle and bed for comparison with the 30% tolerance limits. At water intakes the allowable total concentrations have been considered.

- Scenario 1

Scenario 1 simulated the maximum possible dredging rate which could occur at the reclamation site. This scenario was simulated for the four representative tide types which could occur in Hong Kong. The maximum concentrations which could occur at the sensitive receivers are shown in *Table 5.4d* for the dry season and *Table 5.4e* for the wet season.

(7) *Op cit.*

Table 5.4d ***Maximum Suspended Sediment Concentrations above Ambient (mg l^{-1}) at Sensitive Receivers for Scenario 1 - Dry Season***

Sensitive Receiver	WQO Tolerance			Tide Type					
				Dry Spring			Dry Neap		
	Surf	Mid	Bed	Sur f	Mid	Bed	Surf	Mid	Bed
HEC Power Station				22.5	27.5	29.0	25.0	30.0	37.0
Hung Sing Ye	3.9	6.0	6.3	12.5	12.5	12.5	13.8	13.8	13.8
Lo So Shing Beach	3.9	6.0	6.3	11.8	12.2	12.2	14.0	14.0	14.0
South Lamma MP1	3.9	6.0	6.3	11.3	11.3	11.3	15.0	13.8	12.2
South Lamma MP2	3.9	6.0	6.3	4.6	4.5	4.3	6.3	4.0	3.6
South Lamma MP3	3.9	6.0	6.3	2.0	2.0	1.8	1.3	1.4	0.6
South Lamma MP4	3.9	6.0	6.3	1.3	0.6	0.5	0.5	0.2	0.1
Shek Kok Tsui	1.4	2.3	2.3	5.0	7.0	9.0	6.3	7.2	11.4
Pak Kok	1.4	2.3	2.3	3.5	5.0	6.5	3.8	4.8	6.7
Luk Chau	2.9	3.5	4.7	2.4	3.3	3.3	2.1	2.2	1.5
Lo Tik Wan	2.9	3.5	4.7	2.3	2.3	2.1	1.5	1.5	1.4
Sok Kwu Wan	2.3	2.7	2.9	1.6	1.4	1.4	1.2	1.2	1.1
Wah Fu Estate Intake	1.4	2.3	2.3	1.4	1.3	1.2	1.3	0.9	0.7
Queen Mary Hospital	2.9	3.8	6.4	1.3	1.3	1.2	1.1	1.0	0.8
Kennedy Town Intake				1.3	1.3	1.2	1.0	0.9	0.7
Kau Yi Chau	2.7	3.5	4.5	1.3	1.3	1.3	0.8	0.8	0.9

Note : Shaded areas indicate exceedence of the WQOs

Table 5.4e ***Maximum Suspended Sediment Concentrations above Ambient (mg l^{-1}) at Sensitive Receivers for Scenario 1 - Wet Season***

Sensitive Receiver	WQO Tolerance			Tide Type					
				Wet Spring			Wet Neap		
	Surf	Mid	Bed	Surf	Mid	Bed	Surf	Mid	Bed
HEC Power Station				19.0	24.0	30.0	18.5	19.0	35.0
Hung Sing Ye	1.7	1.9	3.3	6.3	10.2	11.3	2.5	2.5	5.2
Lo So Shing Beach	1.7	1.9	3.3	7.5	12.5	11.0	3.1	3.8	8.0
South Lamma MP1	1.7	1.9	3.3	6.3	9.0	11.0	3.1	3.8	10.0
South Lamma MP2	1.7	1.9	3.3	3.5	4.3	2.5	2.2	3.5	1.4
South Lamma MP3	1.7	1.9	3.3	2.3	1.7	1.2	1.3	0.8	0.7
South Lamma MP4	1.7	1.9	3.3	1.1	0.4	0.5	0.9	0.7	0.2
Shek Kok Tsui	1.6	1.6	2.6	4.4	6.0	7.6	5.0	6.0	11.0
Pak Kok	1.6	1.6	2.6	3.1	3.6	4.9	2.5	4.5	5.1
Luk Chau	2.1	1.4	2.6	1.8	1.7	1.0	1.3	0.7	0.3
Lo Tik Wan	2.1	1.4	2.6	1.4	1.3	0.9	1.1	1.2	0.6
Sok Kwu Wan	1.7	2.0	2.1	0.8	0.7	0.6	0.6	0.6	0.5
Wah Fu Estate Intake	1.6	1.6	2.6	1.1	0.9	0.7	1.1	0.7	0.3
Queen Mary Hospital	0.9	1.8	5.4	0.9	1.0	0.8	0.7	1.1	0.6
Kennedy Town Intake				0.9	1.2	0.8	0.5	0.6	0.4
Kau Yi Chau	6.1	7.7	9.3	0.5	0.5	1.0	0.5	0.6	1.2

Note : Shaded areas indicate exceedence of the WQOs

The results shown in *Tables 5.4d* and *5.4e* show a large number of exceedences of the WQOs, in some cases by over 10 mg l^{-1}. The rate of dredging simulated in this scenario is not considered environmentally acceptable and a lower rate of dredging should be considered. No further assessment of the results from this scenario will be made in terms of acceptability.

- Evaluation of Worst Case Tide and Season

The results from this scenario have been used to assess the worst case tide type for further scenarios and a discussion of the selection is made here, which produced the dry season neap tide as the worst case tide and season combination.

The results in *Tables 5.4d* and *5.4e* demonstrate that the dry season tides produce higher impacts at all of the sensitive receivers than the wet season tides. It should be noted that although the wet season tides produce a greater number of exceedences of the WQOs than the dry season tides, the magnitudes of the exceedences for the dry season tides is greater than the wet season tides. Of the two dry season tides, the neap tide generally gives higher impacts than the spring tide, especially at the sensitive receivers closer to the works area where concentrations of greater than 10 mg l^{-1} are shown. At South Lamma MP3 the impacts are shown to be slightly higher for the spring tide than the neap tide, 0.7 mg l^{-1} in the surface layer. However, at this site the overall impact is low, less than 5 mg l^{-1}, and so should not be considered critical to the analysis of the worst case tide type.

The contours of suspended sediment concentrations, shown in *Annex B5-3*, at the surface and bed generally show that the maximum extent of the sediment plumes are similar in both layers. In particular, for the dry season tides the difference between the layers is small. For the wet season tides the bed plumes show a greater spread in a northern direction than the surface plumes because of the residual northward bed current resulting from the density stratification in the wet season. The contours of suspended sediment show that a larger area is impacted at higher concentrations for the dry season tides than for the wet season tides, which supports the conclusion from the graphs that the dry season tides are the worst case.

Comparing the dry season spring tide with the dry season neap tide shows that an increased area is covered at the lowest significant contour band, 1 to 5 mg l^{-1}, for the dry season spring tide. However, the increased area does not cover any sensitive receivers. Closer to the works area, where most of the sensitive receivers are located, the contours of higher concentration, greater than 10 mg l^{-1}, cover a larger area for the dry season neap tide than for the spring tide. These differences between the spring and neap tide are because the higher currents on the tide result in a greater dispersion of sediment and hence lower concentrations. Again, this supports the conclusion that the dry season neap tide is worse than the dry season spring tide.

- Scenario 2

A lower rate of dredging was simulated in Scenario 2 (see *Table 5.4a*) for the worst case tide type, the dry season neap tide. The maximum concentrations at sensitive receivers is shown in *Table 5.4f*.

Table 5.4f ***Maximum Suspended Sediment Concentrations above Ambient (mg l^{-1}) at Sensitive Receivers for Scenario 2 - Dry Season Neap Tide***

Sensitive Receiver	WQO Tolerance			Concentration		
	Surf	Mid	Bed	Surf	Mid	Bed
HEC Power Station				18.0	25.0	32.0
Hung Sing Ye	3.9	6.0	6.3	7.9	7.9	7.9
Lo So Shing Beach	3.9	6.0	6.3	8.0	8.0	8.0
South Lamma MP1	3.9	6.0	6.3	8.7	8.0	7.5
South Lamma MP2	3.9	6.0	6.3	3.5	2.8	2.6
South Lamma MP3	3.9	6.0	6.3	0.7	0.9	0.4
South Lamma MP4	3.9	6.0	6.3	0.4	0.2	0.1
Shek Kok Tsui	1.4	2.3	2.3	4.8	5.4	7.8
Pak Kok	1.4	2.3	2.3	2.4	3.4	4.7
Luk Chau	2.9	3.5	4.7	1.4	1.5	1.1
Lo Tik Wan	2.9	3.5	4.7	1.1	1.1	1.0
Sok Kwu Wan	2.3	2.7	2.9	0.8	0.8	0.7
Wah Fu Estate Intake	1.4	2.3	2.3	0.9	0.7	0.5
Queen Mary Hospital	2.9	3.8	6.4	0.8	0.7	0.6
Kennedy Town Intake				0.7	0.6	0.5
Kau Yi Chau	2.7	3.5	4.5	0.6	0.6	0.6

Note : Shaded areas indicate exceedence of the WQOs

The results shown in the above table still show exceedences of the WQOs at five stations. Graphs of the time varying suspended sediment concentrations at the five sensitive receivers which have exceedences of the WQOs are shown in *Figure 5.4h*. At Shek Kok Tsui, Pak Kok and South Lamma MP1 the graphs show that the exceedences occur for only short periods of time, less than 1 hour for each instance of exceedence. At Lo So Shing and Hung Shing Ye beaches the graphs of suspended sediment concentrations do not show such variations and the concentrations are relatively constant. For these sensitive receivers it is therefore recommended that mitigation measures be employed because of the exceedences of the WQO. Silt curtains should be deployed around the eastern and southern portions of the reclamation site and at north western side, along the existing HEC jetty to prevent the transport of suspended sediments to the sensitive receivers. The deployment of silt curtains would reduce the quantity of suspended sediment transported from the dredging area by a factor of 2.5. The resulting suspended sediment concentrations at the five senstive receivers showing exceedences of the WQO are shown in *Table 5.4g*. It should be noted that it is likely that suspended sediment concentrations will be reduced at other sensitive receivers but by lesser factors than for the five sensitive receivers presented below because the silt curtains are positioned to optimally trap the sediments being transported towards these sensitive receivers. No further analysis on the other sensitive receivers has been undertaken as these already comply with the WQO.

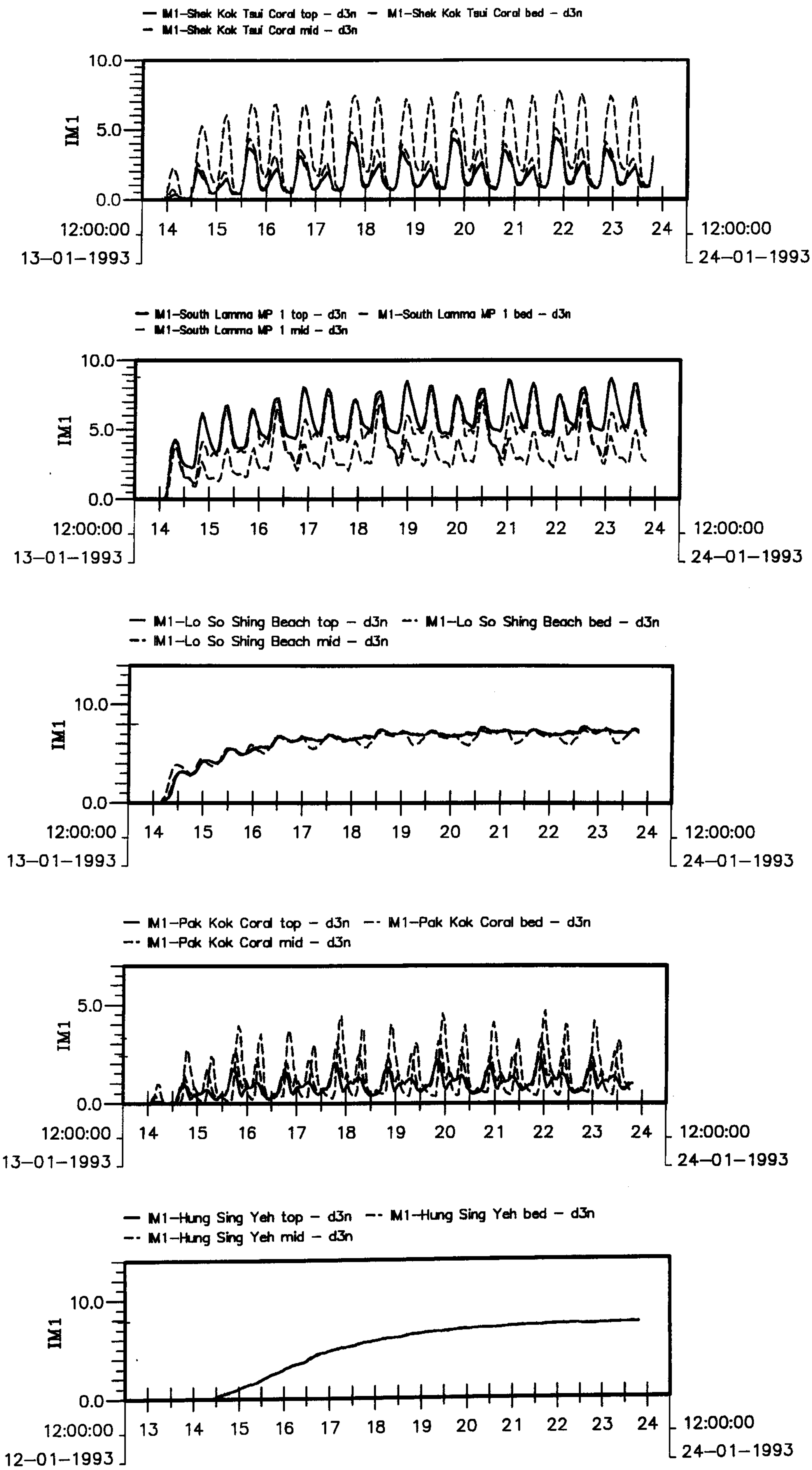

FIGURE 5.4h

GRAPHS OF SUSPENDED SEDIMENT CONCENTRATIONS AT SENSITIVE RECEIVERS - SCENARIO 2

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Table 5.4g ***Resulting Maximum Suspended Sediment Concentrations above Ambient (mg l^{-1}) at Sensitive Receievers following the Implementation of Silt Curtains***

Sensitive Receiver	WQO Tolerance			Concentration		
	Surf	Mid	Bed	Surf	Mid	Bed
Hung Sing Ye	3.9	6.0	6.3	3.2	3.2	3.2
Lo So Shing Beach	3.9	6.0	6.3	3.2	3.2	3.2
South Lamma MP1	3.9	6.0	6.3	3.5	3.2	3.0
Shek Kok Tsui	1.4	2.3	2.3	1.9	2.2	3.1
Pak Kok	1.4	2.3	2.3	1.0	1.4	1.9

Note : Shaded areas indicate exceedence of the WQOs

The above table shows that the only exceedences of the WQO are at Shek Kok Tsui in the surface and bed layers. The impacts at these two stations will be caused by suspended sediment being transported to the north on the flood tide. In order to mitigate the impacts along the northern shore of Lamma Island it is recommended that the dredging rate be reduced on the flood phase of the tidal cycle. This would be achieved by one of the large grab dredgers stopping work while the current direction was to the north. This would reduce the total quantity of sediment lost to suspension by 23% and it may be assumed that the suspended sediment concentrations on the northern shore of Lamma Island will be rduced by a similar amount. The resulting suspended sediment concentrations are shown in *Table 5.4h.*

Table 5.4h ***Resulting Maximum Suspended Sediment Concentrations above Ambient (mg l^{-1}) at Sensitive Receievers following the Implementation of Reduced Dredging on the Flood Tide***

Sensitive Receiver	WQO Tolerance			Concentration		
	Surf	Mid	Bed	Surf	Mid	Bed
Shek Kok Tsui	1.4	2.3	2.3	1.4	1.7	2.3
Pak Kok	1.4	2.3	2.3	0.8	1.1	1.5

Note : Shaded areas indicate exceedence of the WQOs

The suspended sediment concentrations are now compliant with the water quality objective. It is worth noting that the suspended sediment concentrations at the other stations on the flood side of the reclamation will also reduce by the same amount. However, no further discussion of these other stations will be carried out as they have low suspended sediment concentrations which are below the WQO.

The allowable criterion for the Kennedy Town WSD and Lamma Power Station intakes will now be considered. At Kennedy Town WSD Intake an allowable, total concentration of 10 mg l^{-1} has been specified. The predicted concentrations from the dredging at the power station site would contribute less than 10% to this value. An analysis of data from EPD Routine Monitoring Station VM8 for the period January 1996 to December 1997, as shown in *Table 5.4b*, showed that 90th percentile mid-depth values were 15 mg l^{-1}, which demonstrates that periodic exceedences of the allowable value do occur. The 90th percentile mid-depth value was used because the allowable value is based on instantaneous concentrations, not mean values, and the mid-depth position is closest to the position of the intake. The increase from the dredging at the power station reclamation would contribute negligibly to the recorded levels. It should be noted that the total concentrations would be below the pragmatic level of 20 mg l^{-1} for WSD water intakes in Victoria Harbour. At the Lamma power station intakes a maximum level of 100 mg l^{-1} has been specified. Maximum concentrations at EPD Station SM5 were recorded as 14.3 mg l^{-1}, which when combined with the levels predicted here would give a total concentration of between 32.3 and 46.3 mg l^{-1}. This value is below the allowable level and so would be acceptable for the HEC intakes.

Consideration is given here to the mixing zone. The mixing zone is defined as the area within which exceedence of the water quality objective occurs. Analysis of the EPD monitoring data at Station SM5 has shown that the 90th percentile depth averaged suspended sediment concentration is 16.7 mg l^{-1}, which gives a limit of exceedence of 5.0 mg l^{-1}. The comparison may be made with the 5 mg l^{-1} contour in *Figure 21* in *Annex B5-3*. This figure shows the envelope of maximum depth averaged concentrations, which means the values on this figure are those maxima which occur at any time during the model simulation. The area covered by the WQO contour includes the western side of Lamma Island and a portion of the northern shore. This envelope covers a number of sensitive receivers. However, with the deployment of silt curtains, as described above, the size of the 5 mg l^{-1} contour would reduce significantly and would not cover any sensitive receivers on either the western or northern sides of Lamma Island.

The predicted rates of deposition are shown in *Figure 25* in *Annex B5-3*. The area covered by sediment deposition is shown to be the western and northern coasts of Lamma Island. The maximum rates of deposition, without the implementation of silt curtains, along the western side of Lamma Island, in the vicinity of the two beaches, is less than 0.001 kg m^{-2} day^{-1} and along the northern coast of Lamma Island is less than 0.0007 kg m^{-2} day^{-1}. These values are well below any level of concern, even without the implementation of silt curtains. The use of silt curtains would reduce these rates of deposition by the same factor as the suspended sediment concentrations, which is 2.5. The above rates of deposition would reduce to 0.0004 kg m^{-2} and 0.00028 kg m^{-2} at the western side of Lamma Island and along the northern coast of Lamma Island respectively.

The analysis of the impact of the release of suspended sediments during dredging on dissolved oxygen and ammonia has been carried out and the results are presented in *Figures 23* and *24* respectively in *Annex B5-3*. These results show the dissolved oxygen and nutrient concentrations without the implementation of silt curtains. Maximum decreases in dissolved oxygen were found to be less than 0.05 mg L^{-1} in the surface layer and 0.05 mg L^{-1} in the bed layer. These decreases would result in total dissolved oxygen concentrations of 6.35 mg L^{-1} in the surface layer and 3.65 mg L^{-1} in the bed layer, based on the observed background concentrations in the surface and bed layers of 6.4 mg L^{-1} and 3.7 mg L^{-1} respectively. These concentrations would be in compliance with the WQO for dissolved oxygen. Maximum increases in tidal average ammonia concentrations were found to be 0.1 mg L^{-1} over a small area close to the existing power station intakes. This corresponds to an unionized ammonia concentration of 0.005 mg L^{-1}. When added to the background concentration of 0.0005 mg L^{-1} this would give a total concentration of 0.0055 mg L^{-1} which is below the WQO of 0.021 mg L^{-1}. Impacts at nearby sensitive areas, such as South Lamma and the bathing beaches are less than this value and so breaches of the WQO would not occur for unionized ammonia. It is worth noting that these impacts would be significantly reduced by the trapping of suspended sediment by the silt curtains.

Based on the above assessment it is concluded that the dredging assessed in Scenario 2 is likely to be environmentally acceptable provided that silt curtains are installed on the eastern, southern and north-western protions of the reclamation site and that the number of large dredgers in operation on the flood tide is reduced by one.

- Scenario 3

In Scenario 3 a combination of trailer and grab dredgers was simulated (see *Table 5.4a*) for the worst case tide type, the dry season neap tide. The maximum concentrations at sensitive receivers is shown in *Table 5.4i.*

Table 5.4i ***Maximum Suspended Sediment Concentrations above Ambient (mg l^{-1}) at Sensitive Receivers for Scenario 3 - Dry Season Neap Tide***

Sensitive Receiver	WQO Tolerance			Concentration		
	Surf	Mid	Bed	Surf	Mid	Bed
HEC Power Station				12.5	16.5	18.8
Hung Sing Ye	3.9	6.0	6.3	4.5	4.5	4.5
Lo So Shing Beach	3.9	6.0	6.3	4.7	4.7	4.7
South Lamma MP1	3.9	6.0	6.3	4.6	3.7	3.5
South Lamma MP2	3.9	6.0	6.3	1.7	1.4	1.2
South Lamma MP3	3.9	6.0	6.3	0.3	0.5	0.2
South Lamma MP4	3.9	6.0	6.3	0.2	0.1	0.0
Shek Kok Tsui	1.4	2.3	2.3	2.5	4.3	2.9
Pak Kok	1.4	2.3	2.3	1.3	2.6	1.7
Luk Chau	2.9	3.5	4.7	0.8	0.8	0.7
Lo Tik Wan	2.9	3.5	4.7	0.6	0.5	0.5
Sok Kwu Wan	2.3	2.7	2.9	0.4	0.4	0.4
Wah Fu Estate Intake	1.4	2.3	2.3	0.5	0.4	0.3
Queen Mary Hospital	2.9	3.8	6.4	0.5	0.4	0.3
Kennedy Town Intake				0.4	0.4	0.3
Kau Yi Chau	2.7	3.5	4.5	0.4	0.4	0.4

Note : Shaded areas indicate exceedence of the WQOs

The above table shows fewer exceedences of the WQOs than does Scenario 2, *Table 5.4f*, and the suspended sediment concentrations are much lower. At Hung Shing Ye, Lo So Shing and South Lamma MP1 exceedences are only shown for the surface, while the mid-depth and bed concentrations are within the WQO. At Shek Kok Tsui exceedences are shown for all layers, while at Pak Kok the exceedences are only for the mid-depth layer. Graphs of the time varying suspended sediment concentrations at the five sensitive receivers which have exceedences of the WQOs are shown in *Figure 5.4i*. At Shek Kok Tsui, Pak Kok and South Lamma MP1 the graphs show that the exceedences occur for only short periods of time, less than 1 hour for each instance of exceedence. At Lo So Shing and Hung Shing Ye beaches the graphs of suspended sediment concentrations do not show such variations and the concentrations are relatively constant. As for Scenario 2, silt curtains should be deployed around the eastern, southern and north western sides of the reclamation to prevent the transport of suspended sediment to the sensitive receivers. Silt curtains would reduce the concentrations at the beaches by a factor of 2.5. The resulting concentrations at the five sensitive receivers showing exceedences of the WQO are shown in *Table 5.4j*.

Table 5.4j ***Resulting Maximum Suspended Sediment Concentrations above Ambient (mg l^{-1}) at Sensitive Receievers following the Implementation of Silt Curtains***

Sensitive Receiver	WQO Tolerance			Concentration		
	Surf	Mid	Bed	Surf	Mid	Bed
Hung Sing Ye	3.9	6.0	6.3	1.8	1.8	1.8
Lo So Shing Beach	3.9	6.0	6.3	1.9	1.9	1.9
South Lamma MP1	3.9	6.0	6.3	1.8	1.5	1.4
Shek Kok Tsui	1.4	2.3	2.3	1.0	1.7	1.2
Pak Kok	1.4	2.3	2.3	0.5	1.0	0.7

Note : Shaded areas indicate exceedence of the WQOs

The above table shows that all of the concentrations will now comply with the WQO.

The predicted concentrations at the Kennedy Town WSD Intake and the Lamma Power Station intake are lower than those for Scenario 2 (see above) and so the same conclusion may be drawn that the predicted concentrations are acceptable.

The same WQO tolerance for calculation of the mixing zone, 5.0 mg l^{-1}, has been used as for Scenario 2. The corresponding sediment dispersion results are shown in *Figure 26* in *Annex B5-3*. The figure shows that the 5 mg l^{-1} contour does not touch the coastline and does not impact on any sensitive receivers, even without considering the reduction due to the implementation of silt curtains which would further reduce the size of the mixing zone.

The predicted rates of deposition are shown in *Figure 30* in *Annex B5-3*. The area covered by sediment deposition is shown to be the western and northern coasts of Lamma Island. The maximum rate of deposition along the western side of Lamma Island, in the vicinity of the two beaches, is less than 0.0007 kg m^{-2} day^{-1} and the maximum rate along the northern coast of Lamma Island is less than 0.0004 kg m^{-2} day^{-1}. These values are well below any level of concern, even without considering the reductions from the implmentation of silt curtains. These would reduce the deposition rates along the northern shore of Lamma Island to 0.00016 kg m^{-2} day^{-1} and along the western side of Lamma Island to 0.00028 kg m^{-2} day^{-1}.

The contours of dissolved oxygen and ammonia are shown in *Figures 28* and *29* in *Annex B5-3*. The contours of dissolved oxygen are similar to those for Scenario 2 and so the conclusion from Scenario 2 that the oxygen depletion from the suspended sediment would not cause a breach of the WQO remains valid. The contours of ammonia show the maximum increase in concentration to be 0.005 mg L^{-1}, which gives an unionized ammoniacal nitrogen concentration of 0.00025 mg L^{-1}, and would not cause a breach of the WQO when added to the background concentration of 0.0005 mg L^{-1}. These results are presented without the implementation of silt curtains which would further reduce the impacts on dissolved oxygen and ammonia.

Based on the above discussion it is concluded that the dredging for Scenario 3 is environmentally acceptable provided that silt curtains are installed on the eastern, southern and north-western sides of the reclamation.

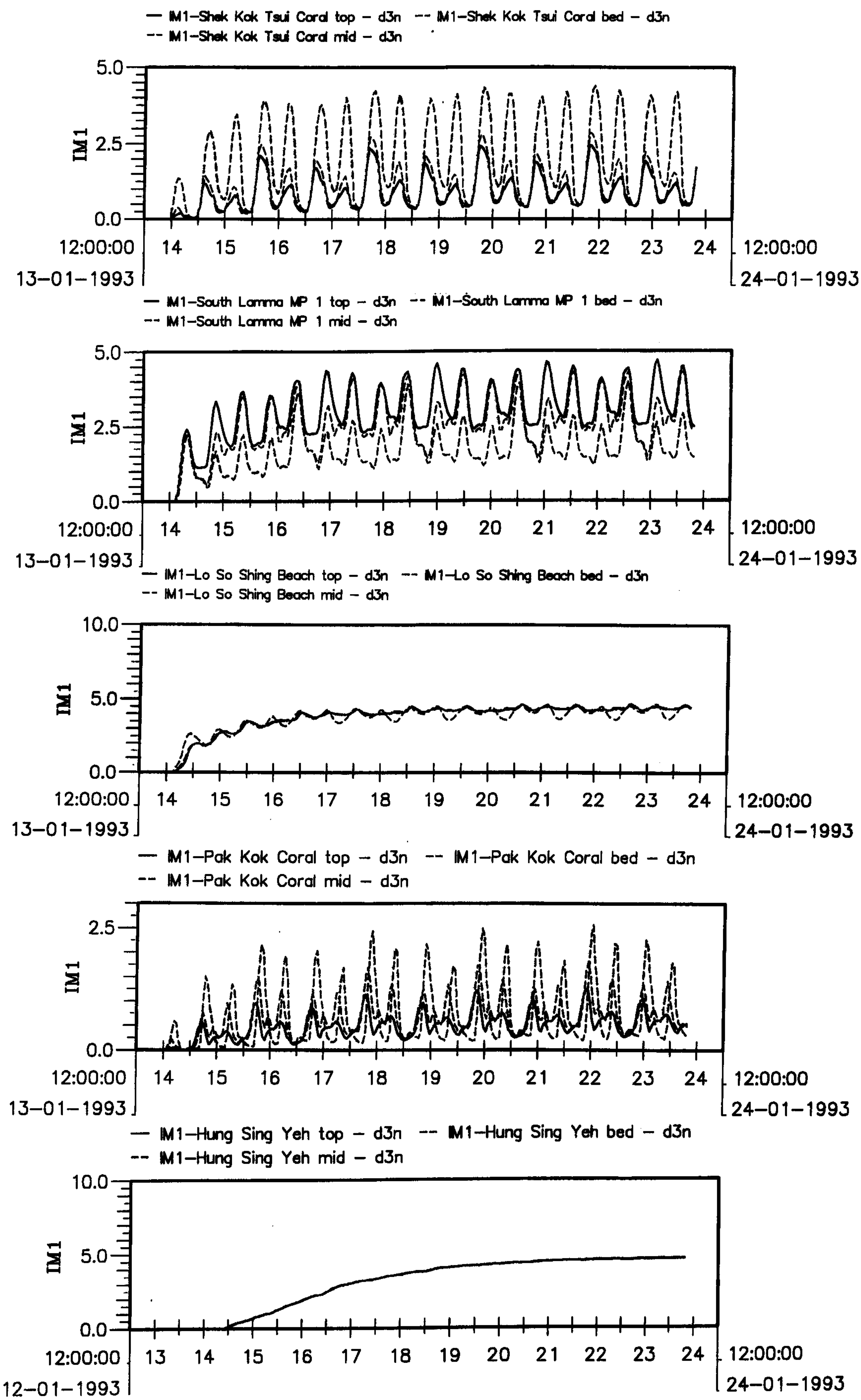

FIGURE 5.4i

GRAPHS OF SUSPENDED SEDIMENT CONCENTRATIONS AT SENSITIVE RECEIVERS - SCENARIO 3

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- Scenario 4

In Scenario 4 combined dredging and filling was simulated (see *Table 5.4a*) for the wet season spring and neap tides. The maximum concentrations at sensitive receivers is shown in *Table 5.4k*.

Table 5.4k ***Maximum Suspended Sediment Concentrations above Ambient (mg l^{-1}) at Sensitive Receivers for Scenario 4 - Wet Season Spring and Neap Tides.***

Sensitive Receiver	WQO Tolerance			Tide Type					
				Wet Spring			Wet Neap		
	Surf	Mid	Bed	Surf	Mid	Bed	Surf	Mid	Bed
HEC Power Station				104.0	118.0	170.0	68.0	88.0	188.0
Hung Sing Ye	1.7	1.9	3.3	17.0	27.0	23.0	5.0	5.8	13.8
Lo So Shing Beach	1.7	1.9	3.3	34.0	43.0	33.0	8.3	9.4	21.8
South Lamma MP1	1.7	1.9	3.3	23.0	21.0	31.0	8.6	10.0	24.0
South Lamma MP2	1.7	1.9	3.3	7.6	9.3	4.6	6.4	7.5	3.2
South Lamma MP3	1.7	1.9	3.3	6.0	4.0	3.0	3.7	1.8	1.6
South Lamma MP4	1.7	1.9	3.3	2.8	1.0	1.2	2.7	2.2	0.5
Shek Kok Tsui	1.6	1.6	2.6	15.6	22.4	21.6	19.0	22.5	32.5
Pak Kok	1.6	1.6	2.6	10.3	12.0	13.4	10.0	15.8	15.8
Luk Chau	2.1	1.4	2.6	6.5	5.2	2.9	4.7	2.5	0.9
Lo Tik Wan	2.1	1.4	2.6	4.5	4.3	2.8	3.5	3.6	1.9
Sok Kwu Wan	1.7	2.0	2.1	2.4	2.2	1.8	1.9	2.0	1.5
Wah Fu Estate Intake	1.6	1.6	2.6	3.7	2.8	2.3	3.5	2.4	1.2
Queen Mary Hospital	0.9	1.8	5.4	4.0	3.5	2.5	2.0	3.5	1.7
Kennedy Town Intake				2.7	3.6	2.8	1.7	2.0	1.2
Kau Yi Chau	6.1	7.7	9.3	1.4	1.5	2.8	1.3	1.6	3.5

Note : Shaded areas indicate exceedence of the WQOs

The results shown in *Table 5.4k* show a majority of the stations exceeding the WQOs. The combined dredging and filling shown in this scenario is clearly environmentally unacceptable. If the programme were to slip and combined dredging and filling could occur in the dry season, this scenario would also be environmentally unacceptable. In fact the impacts would be likely to be higher in the dry season, which is demonstrated above in the assessment for Scenario 1. Combined bulk dredging and filling would therefore not be allowed to occur at any time.

The above scenario assumed, conservatively, that there would no sea walls in place to retain the fill material. It is clear that the fill material will have to be retained during sand filling to prevent loss of the fines content to the water column. This means that sea walls should be in place, behind which sand filling will take place.

- Cumulative Scenarios

Following assessment of the above scenarios, which simulated the construction of the power station extension reclamation in isolation, cumulative assessment scenarios were undertaken for two cases of the combined construction of the power station extension reclamation and other reclamation and disposal projects. The two cumulative projects which were simulated were the Backfilling of South Tsing Yi at a rate of 100,000 m^3 day^{-1} and the mud dredging at the Container Terminal 9 reclamation. The simulation of mud dredging at Container terminal 9 assumed six grab dredgers and one trailer dredger working simultaneously. The grab dredgers were assumed to have rates of working of 50,000 $m^3 week^{-1}$ each, while the trailer dredger was assumed to load for 15 minutes at intervals of 185 minutes. These two projects were simulated in combination with Scenario 1 for the dry season neap tide, the worst case tide type.

However, Scenario 1 had previously been found to be unacceptable and so the assessment of cumulative impacts has been made based on Scenario 2, which gave the highest acceptable suspended sediment concentrations at sensitive receivers. This was achieved by subtracting the concentrations given by Scenario 1 from the cumulative concentrations and then adding the concentrations from Scenario 2 alone. The concentrations used for Scenario represented the mitigated scenario using silt curtains. This methodology would give an estimation of the likely cumulative impacts which would give indicative values.

The results of this analysis for the combined Scenario 2 and Backfilling South Tsing Yi are shown in Table 5.4l.

Table 5.4l ***Maximum Suspended Sediment Concentrations above Ambient ($mg\ l^{-1}$) at Sensitive Receivers for the Combined Scenario 2 and Backfilling at South Tsing Yi***

Sensitive Receiver	WQO Tolerance			Scenario					
				Scenario 2 + South Tsing Yi			Scenario 2		
	Surf	Mid	Bed	Surf	Mid	Bed	Surf	Mid	Bed
HEC Power Station				25.5	32.5	40.0	18.0	25.0	32.0
Hung Sing Ye	3.9	6.0	6.3	9.4	9.4	9.4	3.2*	3.2*	3.2*
Lo So Shing Beach	3.9	6.0	6.3	9.2	9.2	9.2	3.2*	3.2*	3.2*
South Lamma MP1	3.9	6.0	6.3	11.0	10.7	9.6	3.5*	3.2*	3.0*
South Lamma MP2	3.9	6.0	6.3	9.2	9.8	8.0	3.5	2.8	2.6
South Lamma MP3	3.9	6.0	6.3	3.4	3.3	1.6	0.7	0.9	0.4
South Lamma MP4	3.9	6.0	6.3	4.9	3.0	1.0	0.4	0.2	0.1
Shek Kok Tsui	1.4	2.3	2.3	29.1	28.5	24.9	1.4**	1.7**	2.3**
Pak Kok	1.4	2.3	2.3	34.5	33.8	32.3	0.8**	1.1**	1.5**
Luk Chau	2.9	3.5	4.7	28.3	16.8	12.1	1.4	1.5	1.1
Lo Tik Wan	2.9	3.5	4.7	17.6	17.6	14.6	1.1	1.1	1.0
Sok Kwu Wan	2.3	2.7	2.9	13.6	13.6	11.6	0.8	0.8	0.7
Wah Fu Estate Intake	1.4	2.3	2.3	22.1	14.8	9.8	0.9	0.7	0.5
Queen Mary Hospital	2.9	3.8	6.4	21.0	19.7	18.7	0.8	0.7	0.6
Kennedy Town Intake				21.5	19.7	19.6	0.7	0.6	0.5
Kau Yi Chau	2.7	3.5	4.5	27.3	27.3	27.2	0.6	0.6	0.6

Notes : Shaded areas indicate exceedence of the WQOs
* Impacts mitigated by the use of silt curtains
** Impacts mitigated by the use of silt curtains and by a reduction in dredging rate on the flood tide

It can be seen from *Table 5.4l* that for the cumulative scenario the majority of the sensitive receivers have exceedences of the WQO. The highest suspended sediment concentrations are shown along the northern shore of Lamma Island, at Pak Kok and Shek Kok Tsui, where the contribution from the power station dredging is less than 10%. At the water intakes on Hong Kong Island the contribution from the power station dredging is again less than 10%, while the majority of results are less than 40%. At the beaches, the contributions to suspended sediment concentrations are 25% from the dredging at the reclamation and 75% from the backfilling at South Tsing Yi.

The backfilling at South Tsing Yi alone is predicted to cause exceedences of the WQOs at the sensitive receivers on Hong Kong Island and along the northern and eastern sides of Lamma Island. Should such impacts occur during the backfilling operations then mitigation measures would be taken to reduce the concentrations to below acceptable levels. Such measures would then be likely to reduce the cumulative impacts from the Lamma Extension reclamation and the backfilling at South Tsing Yi to acceptable levels. Should this not be the case then additional mitigation would need to be applied at the Lamma Extension site. Such measures could include reducing dredging rates.

The predicted rates of deposition are shown in *Figure 45* in *Annex B5-3*. The area covered by sediment deposition is shown to be the whole of the Western Harbour from Lamma Island up to Ma Wan. However, the area of deposition covered by the reclamation works at the power station extension reclamation is around the western and northern shores of Lamma Island and only these areas will be considered. The maximum rate of deposition along the western and northern coasts of Lamma Island is less than 0.002 kg m^{-2} day^{-1}. Even though the higher rate of dredging at the reclamation and the higher rate of dumping at South Tsing Yi has been simulated, these values are well below any level of concern and as such are considered environmentally acceptable.

The predicted reduction in concentrations of dissolved oxygen in *Figure 43* in *Annex B5-3* show reductions in concentration along the northen coastline of Lamma Island, which is where the plumes from the Lamma Extension and the backfilling at South Tsing Yi overlap, of less than 0.3 mg L^{-1}. This would not be sufficient to cause any breaches of the WQO when subtracted from the background concentrations of 6.4 mg L^{-1} in the surface layer and 3.7 mg L^{-1} in the bed layer. This assessment is the case even though the rate of dredging at the power station extension reclamation represents Scenario 1 not the mitigated Scenario 2 which would cause smaller impacts. The maximum increases in ammonia concentrations (see *Figure 44*) is shown to be around 0.1 mg L^{-1}, which corresponds to an unionized ammoniacal nitrogen concentration of 0.005 mg L^{-1}. This would not cause a breach of the WQO as the total concentration, increase plus background, would be 0.0055 mg L^{-1}, which is less than objective of 0.021 mg L^{-1}. Elsewhere in the areas covered by the Lamma Extension dredging plumes the ammonia concentration increases are less than 0.005 mg L^{-1} which would not cause a breach of the WQO.

Based on the above discussion the cumulative scenario of Backfilling at South Tsing Yi and dredging at the power station reclamation has been found to be environmentally acceptable under certain conditions. These conditions relate to the implementation of mitigation measures at South Tsing Yi which may be necessary to reduce suspended sediment concentrations at sensitive receivers. If, following the implementation of such mitigation measures and confirmation from monitoring that it is the Lamma Extension construction that is causing any unacceptable impacts at sensitive receivers, then mitigation measures at the reclamation site would be required.

The same procedure has been adopted to analyse the cumulative impacts from Scenario 2 and the mud dredging at the CT9 reclamation site. The results of the analysis are shown in *Table 5.4m*.

Table 5.4m ***Maximum Suspended Sediment Concentrations above Ambient ($mg\ l^{-1}$) at Sensitive Receivers for the Combined Scenario 2 and Mud Dredging at CT9***

Sensitive Receiver	WQO			Scenario					
				Scenario 2 + CT9			Scenario 2		
	Surf	Mid	Bed	Surf	Mid	Bed	Surf	Mid	Bed
HEC Power Station				18.0	25.0	32.5	18.0	25.0	32.0
Hung Sing Ye	3.9	6.0	6.3	3.4	3.4	3.4	3.2*	3.2*	3.2*
Lo So Shing Beach	3.9	6.0	6.3	3.2	3.2	3.2	3.2*	3.2*	3.2*
South Lamma MP1	3.9	6.0	6.3	4.5	4.4	3.8	3.5*	3.2*	3.0*
South Lamma MP2	3.9	6.0	6.3	3.7	3.8	3.5	3.5	2.8	2.6
South Lamma MP3	3.9	6.0	6.3	0.8	1.2	0.5	0.7	0.9	0.4
South Lamma MP4	3.9	6.0	6.3	0.9	0.4	0.2	0.4	0.2	0.1
Shek Kok Tsui	1.4	2.3	2.3	4.1	4.5	3.9	1.4**	1.7**	2.3**
Pak Kok	1.4	2.3	2.3	3.5	3.3	3.8	0.8**	1.1**	1.5**
Luk Chau	2.9	3.5	4.7	4.3	2.8	2.1	1.4	1.5	1.1
Lo Tik Wan	2.9	3.5	4.7	3.1	3.1	2.6	1.1	1.1	1.0
Sok Kwu Wan	2.3	2.7	2.9	2.4	2.4	1.9	0.8	0.8	0.7
Wah Fu Estate Intake	1.4	2.3	2.3	3.9	2.8	1.8	0.9	0.7	0.5
Queen Mary Hospital	2.9	3.8	6.4	4.2	4.0	2.3	0.8	0.7	0.6
Kennedy Town Intake				8.2	8.2	8.3	0.7	0.6	0.5
Kau Yi Chau	2.7	3.5	4.5	4.3	4.3	4.2	0.6	0.6	0.6

Notes: Shaded areas indicate exceedence of the WQOs
* Impacts mitigated by the use of silt curtains
**Impacts mitigated by the use of silt curtains and by a reduction in dredging rate on the flood tide

Table 5.4m shows exceedences of the water quality objectives at a number of stations. The greatest exceedences of the water quality objectives occur along the northern coast of Lamma Island, at Pak Kok and Shek Kok Tsui. At South Lamma MP1, the majority of the impacts occur as a result of the new power station reclamation. Exceedences are also shown on the eastern side of Lamma Island, from Luk Chau to Sok Kwu Wan, where for Scenario 2 alone none were predicted.

The predicted increases in suspended sediment concentrations at the Lamma Power Stations intakes, 25 $mg\ l^{-1}$ at mid-depth, plus background concentrations would not result in exceedence of the 100 $mg\ l^{-1}$ allowable limit. At the Kennedy Town WSD intake increases in suspended sediment concentrations are predicted to be 8.2 $mg\ l^{-1}$, of which only 0.7 $mg\ l^{-1}$ is contributed from the dredging at the power station extension reclamation. However, the background concentration at this site was found to be 15 $mg\ l^{-1}$, making the total concentration 23.2 $mg\ l^{-1}$, which is in excess of the 20 $mg\ l^{-1}$ pragmatic limit. It should be noted that the majority of the contribution comes from the dredging at CT9, which alone would cause exceedence of the limit and that, even if there was no contribution from the Lamma Extension reclamation, there would still be exceedences of the pragmatic limit. At Queen Mary Hospital and Wah Fu Estate Intake the total concentrations, background plus the elevation from the cumulative impacts would not breach the 20 mg l^{-1} pragmatic limit. It will therefore be incumbent upon the CT9 project to employ suitable mitigation measures to reduce the concentrations to acceptable levels and that further mitigation of the Lamma Extension reclamation would not reduce the suspended sediment concentrations to acceptable levels.

The predicted rates of deposition are shown in *Figure 50* in *Annex B5-3*. The area covered by sediment deposition is shown to be the majority of the Western Harbour from Lamma Island up to Ma Wan. However, the area of deposition covered by the reclamation works at the power station extension reclamation is around the western and northern shores of Lamma Island and only these areas will be considered. The maximum rate of deposition along the western and northern coasts of Lamma Island is less than 0.001 kg m^{-2} day^{-1}. Even though the higher rate of dredging at the reclamation has been simulated, these values are well below any level of concern and as such are considered environmentally acceptable.

The contours of dissolved oxygen and ammonia concentrations in *Figures 48* and *49* show the largest changes in concentrations in the immediate vicinity of the CT9 works in the Rambler Channel. This is in an area where no impacts from the dredging at the power station extension reclamation are found. At the Lamma Extension reclamation the changes in these parameters are similar to those of Scenario 2 which showed no breaches of either the dissolved oxygen WQO or the unionized ammoniacal nitrogen WQO.

Based on the above assessment it is concluded that the cumulative impacts arising from the Scenario 2 dredging and the CT9 dredging are environmentally acceptable. This conclusion is based on the assumption that mitigation measures will be applied at the CT9 works to reduce the unacceptable impacts which are primarily caused by that project. Such an assumption will be confirmed by monitoring during the construction programme.

The cumulative assessment of sand dredging for CT9 at the Southern South Tsing Yi Marine Borrow Area was carried out by considering results from a previous EIA for the works[8]. The results for the worst case tide type for this project, the dry season neap tide, gave concentrations at Kennedy Town WSD Intake of 1 mg l^{-1} which, when combined with the results from this Study, would give a total elevation in concentration of 1.6 mg l^{-1} which would not cause exceedence of the allowable limit of 20 mg l^{-1}, as the maximum background is 15 mg l^{-1}. Along the East Lamma Channel, including the sensitive receivers along the western coast of Hong Kong Island and along the eastern coast of Lamma Island, concentrations from the sand dredging would include 14 mg l^{-1} at Lo Tik Wan and 20 mg l^{-1} at Queen Mary Hospital Intake. These concentrations alone would give exceedences of the WQOs. The sand dredging would cause increases in concentration along the northern and western sides of Lamma Island of less than 1 mg l^{-1}.

For the cumulative scenario of sand dredging for CT9 unacceptable suspended sediment increases would primarily be observed along the East Lamma Channel, where the majority of the impacts would be from the sand dredging and not the reclamation construction at the new power station extension reclamation. Given these circumstances further mitigation of the power station extension

(8) Focussed Environmental Impact Assessment, West of Sulphur Channel Marine Borrow Area, Final Report, December 1994, under Agreement No CE 52/94 for Civil Engineering Department, Hong Kong Government.

reclamation construction would not reduce these concentrations to below acceptable levels.

Mitigation of Environmental Impacts

During construction of the reclamation all storm drains at the site should be diverted to avoid the eastern side of the reclamation site. This condition also applies to the operation of the Lamma Extension power station. This measure will prevent any discharges from the power station entering Hung Shing Ye Bay.

Mitigation for the dredging and filling for the reclamation will take two main forms: operational constraints and general plant maintenance and working methods. Both types of mitigation measures are discussed below. The implications of potential concurrent projects for mitigation of dredging and filling at the reclamation site are also discussed.

A number of options were simulated for dredging at the reclamation site which were based on site constraints and the proposed construction programme. Two of the three dredging scenarios gave rise to environmentally acceptable impacts and these are as follows:

- 3 large grab dredgers and 1 small grab dredger operating concurrently, each with rates of working of 300,000 m^3 $month^{-1}$ and 200,000 m^3 $month^{-1}$ respectively, which equates to daily working rates of 12,000 m^3 and 8,000 m^3 respectively. These working rates were simulated as Scenario 2; and

- 1 trailer dredger with a rate of working of 200,000 m^3 $month^{-1}$, and 2 large grab dredgers, each with rates of working of 300,000 m^3 $month^{-1}$, which equates to daily working rates of 8,000 m^3 and 12,000 m^3. These working rates were simulated as Scenario 3.

For both of the above rates of working silt curtains will be required to be deployed along the eastern, southern and north western sides of the reclamation to prevent the transport of suspended sediments towards the identified sensitive receivers which include the two gazetted beaches at Lo So Shing and Hung Shing Ye, the northern shore of Lamma Island and the area to the south of the reclamation. For Scenario 2 (3 large grab dredgers and 1 small grab dredger) it will be necessary to reduce the number of large dredgers by one on the flood phase of the tidal cycle to protect the sensitive receivers along the northern coastline of Lamma Island.

Either of the above described rates of working may be adopted at any one time, provided that the mitigation measures described above are implemented, during the bulk dredging for the reclamation site which will be adopted as a requisite operational constraint.

Combined dredging and bulk filling of the site platform was also simulated. The impacts from this operation were found to be environmentally unacceptable and the following operational constraints will be adopted:

- concurrent bulk dredging and filling of the site platform will not be permitted; and

- sand filling of the site platform must be conducted behind constructed sea walls which pierce the water surface to prevent the migration of fines from the works area.

Additionally, sand filling for the rubble mound seawall foundations on the southern and western sides of the reclamation should be placed using controlled pumping down the trailing suction hopper dredger arms.

To augment the operational constraints (mitigation measures) given above, additional constraints may be applied as further mitigation measures should unacceptable impacts be detected by the EM&A programme during the course of the project. Potential additional mitigation measures, to be implemented through the EM&A programme would include the following and would be applied so that the recorded suspended sediment concentrations reduced to below acceptable levels.

- reducing the number of dredgers working at any one time;
- reducing the rate of working of the dredgers;
- temporary suspension of operations;

The following general plant maintenance and working methods shall be applied to supplement the operational constraints (operationally-based mitigation measures) and to minimise further sediment release:

- fully-enclosed, watertight grabs should be used to minimise loss of sediment during the raising of loaded grabs through the water column;
- the descent speed of grabs should be controlled to minimise the seabed impact speed and to reduce the volume of over dredging;
- barges should be loaded carefully to avoid splashing of material;
- all barges used for the transport of dredged materials should be fitted with tight bottom seals in order to prevent leakage of material during loading and transport;
- all barges should be filled to a level which ensures that material does not spill over during loading and transport to the disposal site and that adequate freeboard is maintained to ensure that the decks are not washed by wave action;
- the speed of trailer dredgers should be controlled to prevent propeller wash from stirring up the sea bed sediments;
- "rainbowing" sand fill from trailer dredgers will not be permitted; and
- the works shall cause no visible foam, oil, grease or litter or other objectionable matter to be present in the water within and adjacent to the dredging site and along the route to the disposal site.

With implementation of these operationally-based and general plant maintenance and working methods as mitigation measures, potential water quality impacts associated with proposed reclamation construction operations at the power station reclamation will be minimised to levels that are not predicted to cause unacceptable impacts to identified sensitive receivers.

Cumulative impacts have also been assessed. However, for the majority of the impacts which were predicted mitigation of the Lamma Extension construction would not lead to acceptable concentrations at the sensitive receivers. It would therefore be the responsibility of the other project to employ mitigation measures. The responsibility for employing mitigation measures will be determined through monitoring and the implementation of such measures would be determined through coordination between the different concurrent projects. Potential mitigation measures for the Lamma Extension site are the same as those discussed above.

The EM&A programme, outlined below in *Section 5.6*, is designed to determine whether unacceptable impacts are occurring and to determine whether these impacts are attributable to the power station extension reclamation construction. This attribution is achieved through the location of control stations to account for potential external contributions from other projects to observed impacts and through the specification of Action and Limit Levels with reference to control station values. The EM&A programme thus provides the mechanism for determining whether the Lamma Extension construction is contributing to cumulative impacts at sensitive receivers.

Should unacceptable impacts be observed in the EM&A programme, and these impacts be attributable (solely or partially) to the reclamation, the operationally-based mitigation measures described above should be implemented in accordance with the Event and Action Plan in the EM&A Manual. It is recommended that in the case of cumulative impacts arising from the power station extension reclamation and another project, the party responsible for the other project be consulted to coordinate implementation of joint or compatible mitigation measures. As described in the EM&A Manual's Event and Action Plan, the effectiveness of the implemented mitigation measures for the power station extension reclamation construction should be assessed and adjusted if necessary.

5.5 *OPERATIONAL PHASE*

The assessment of the operational aspects of the Lamma Extension project has been divided into three aspects, which are the discharge of heated water, the discharge of residual chlorine from the cooling system, and the potential for changes to occur in the natural sedimentation regime around the reclamation. The discharge of heated water and chlorine have been simulated using computational modelling by Delft Hydraulics. The assessment of sedimentation changes has been based on a desk top assessment based on the results from the hydrodynamic modelling for the construction phase assessment (see *Section 5.4.1)*.

5.5.1 *Thermal Discharge*

Assessment Methodology

A model of thermal discharge has been set up as part of this project using the same grid as the detailed hydrodynamic model, which provided the tidal flow data for this modelling exercise. The thermal model has been used to simulate three scenarios for the discharge of cooling water:

- Scenario 1 - the discharge from the existing power station;

- Scenario 2 - the combined discharge from the existing power station and the Lamma Extension; and

- Scenario 3 - the combined discharge from the existing power station and the Lamma Extension together with the discharge from the WEIF.

The first two scenarios allow a comparison to be made between the existing discharges and those when the Lamma Extension project is in operation. The third scenario provides an assessment of the cumulative impacts of the Lamma Extension and the WEIF. All of the above scenarios were simulated for a 15 day spring-neap tidal cycle in the wet and dry seasons.

The locations of the outfalls and intakes for the three scenarios are given in *Table 5.5a* below and shown in *Figure 5.5a*.

Table 5.5a ***Locations of Outfalls and Intakes***

	Outfalls		Intakes	
	Easting	**Northing**	**Easting**	**Northing**
Existing Power Station				
Outfall 1/Intake Units 1-6	828651	808909	828983	808650
			829215	808650
Outfall 2/Intake Units 7-8	828679	808991	829306	808650
Lamma Extension				
Outfall 3	828690	808455	829240	808312
Outfall 4	828690	808283		
WEIF	Mid-point of western side		Mid-point of eastern side	

Different discharge rates were used which reflected the existing situation, the case with the Lamma Extension project when the power station will be operating as a combined cycle and the WEIF discharge. The discharges which were used in the model are defined in *Tables 5.5b, 5.5c* and *5.5d.*

Table 5.5b *Discharge Rates for the Existing Situation*

Hour	Wet Season			Dry Season		
	Heat Rejection (Gcal hour^{-1})	Discharge Rate ($m^3 s^{-1}$)	Temperature Rise (°C)	Heat Rejection (Gcal hour^{-1})	Discharge Rate ($m^3 s^{-1}$)	Temperature Rise (°C)
0	1,746.6	77.2	6.3	1,006.1	53.2	5.3
1	1,536.2	77.2	5.5	917.5	53.2	4.8
2	1,444.2	77.2	5.2	857.6	53.2	4.5
3	1,394.5	77.2	5.0	819.2	53.2	4.3
4	1,358.9	77.2	4.9	802.7	53.2	4.2
5	1,347.4	77.2	4.8	803.8	53.2	4.2
6	1,371.9	77.2	4.9	863.0	53.2	4.5
7	1,592.0	77.2	5.7	1,100.6	53.2	5.8
8	2,075.4	87.6	6.6	1,567.0	66.8	6.5
9	2,417.9	98.0	6.9	1,904.7	87.6	6.9
10	2,517.4	98.0	7.1	2,162.3	87.6	6.9
11	2,590.7	98.0	7.3	2,147.4	87.6	6.8
12	2,590.7	98.0	7.3	2,203.6	87.6	7.0
13	2,590.7	98.0	7.3	2,153.7	87.6	6.8
14	2,590.7	98.0	7.3	2,180.5	87.6	6.9
15	2,590.7	98.0	7.3	2,119.0	87.6	6.7
16	2,590.7	98.0	7.3	2,082.1	87.6	6.6
17	2,590.7	98.0	7.3	2,086.5	87.6	6.6
18	2,506.6	98.0	7.1	2,082.7	87.6	6.6
19	2,468.3	98.0	7.0	1,880.9	77.2	6.8
20	2,389.8	98.0	6.8	1,616.3	66.8	6.7
21	2,350.1	98.0	6.7	1,501.3	66.8	6.2
22	2,168.8	87.6	6.9	1,374.9	66.8	5.7
23	2,000.9	87.6	6.3	1,189.2	53.2	6.2
Mean	2,117.6	89.8	6.5	1,559.3	70.8	6.0

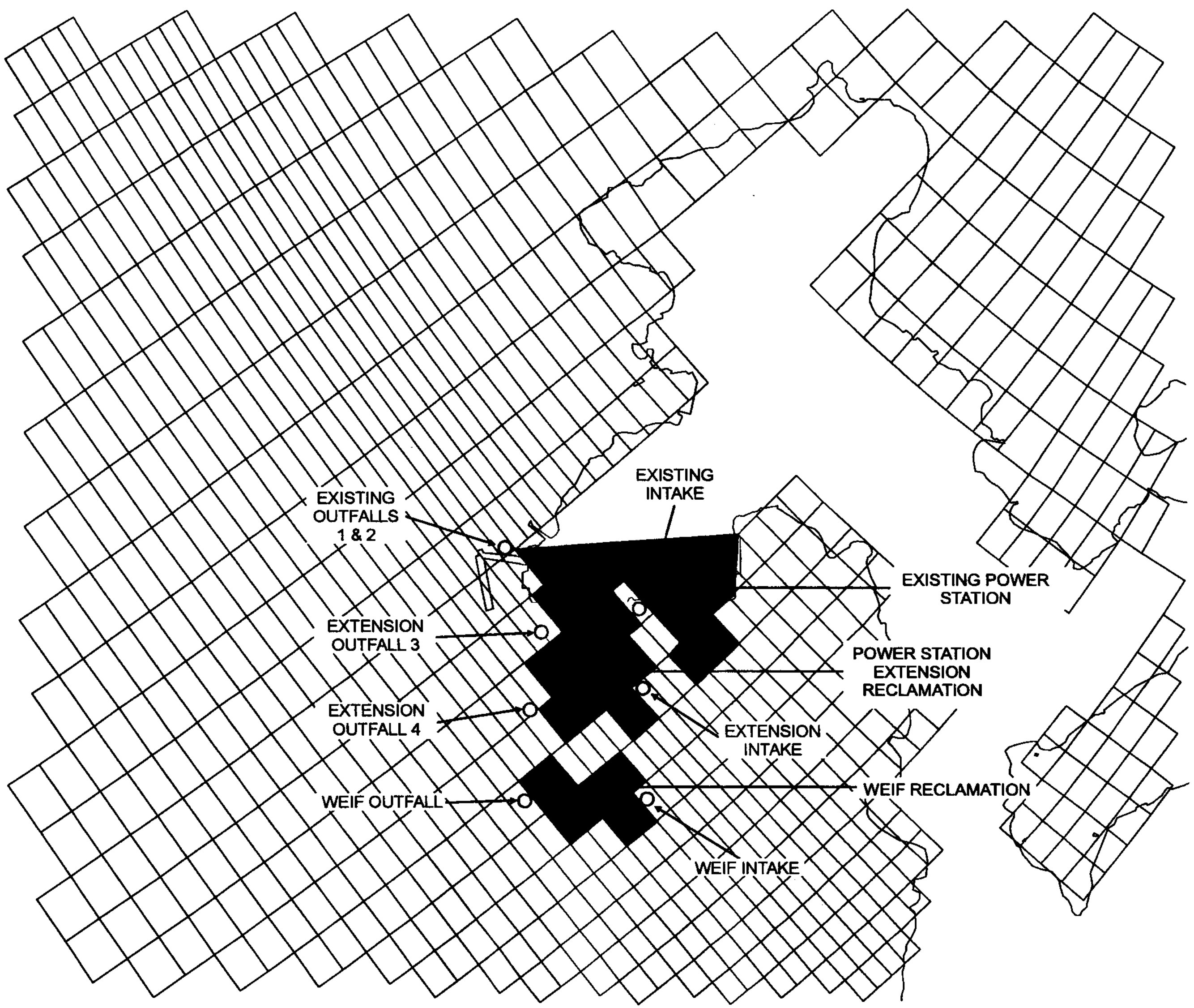

FIGURE 5.5a

LOCATIONS OF OUTFALLS & INTAKES

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Environmental Resources Management

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Table 5.5c ***Discharge Rates for the Lamma Extension Project Operating with Combined Cycle Technology and the Existing Power Station for the Wet Season***

Hour	Heat Rejection (Gcal hour^{-1})			Discharge Rate ($m^3 s^{-1}$)	Temperature Rise (°C)
	Total	Existing	New[(a)]		
0	1,440.3	578.0	862.3	58.8	6.8
1	1,161.4	305.2	856.2	58.8	5.5
2	1,098.2	305.2	793.0	58.8	5.2
3	1,065.5	305.2	760.3	58.8	5.0
4	1,043.8	305.2	738.6	58.8	4.9
5	1,036.7	305.2	732.5	58.8	4.9
6	1,051.2	305.2	746.0	58.8	5.0
7	1,230.9	368.6	862.3	58.8	5.8
8	1,941.2	1,078.9	862.3	86.2	6.3
9	2,467.6	1,605.3	862.3	99.8	6.9
10	2,858.2	1,995.9	862.3	120.6	6.6
11	2,963.7	2,101.4	862.3	120.6	6.8
12	3,056.3	2,194.0	862.3	120.6	7.0
13	2,979.2	2,116.9	862.3	120.6	6.9
14	2,985.6	2,123.3	862.3	120.6	6.9
15	3,004.3	2,142.0	862.3	120.6	6.9
16	2,969.1	2,106.8	862.3	120.6	6.8
17	2,955.2	2,092.9	862.3	120.6	6.8
18	2,844.3	1,982.0	862.3	120.6	6.6
19	2,650.3	1,788.0	862.3	110.2	6.7
20	2,430.2	1,567.9	862.3	99.8	6.8
21	2,285.3	1,423.0	862.3	99.8	6.4
22	2,068.6	1,206.3	862.3	86.2	6.7
23	1,796.3	934.0	862.3	72.5	6.9
Mean	2,141.0	1,301.5	839.5	92.1	6.3

Note :
(a) New discharge is evenly distributed over the new outfalls 3 and 4.

Table 5.5d ***Discharge Rates for the Lamma Extension Project Operating with Combined Cycle Technology and the Existing Power Station for the Dry Season***

Hour	Heat Rejection (Gcal $hour^{-1}$)			Discharge Rate ($m^3 s^{-1}$)	Temperature Rise (°C)
	Total	Existing	New[(a)]		
0	639.4	0.0	639.4	27.5	6.5
1	584.8	0.0	584.8	27.5	5.9
2	551.6	0.0	551.6	27.5	5.6
3	531.5	0.0	531.5	27.5	5.4
4	523.1	0.0	523.1	27.5	5.3
5	523.8	0.0	523.8	27.5	5.3
6	554.3	0.0	554.3	27.5	5.6
7	719.9	0.0	719.9	33.0	6.1
8	1,231.7	369.4	862.3	58.8	5.8
9	1,699.4	837.1	862.3	72.5	6.5
10	2,021.8	1,159.5	862.3	86.2	6.5
11	2,090.7	1,228.4	862.3	86.2	6.7
12	2,162.2	1,299.9	862.3	86.2	7.0
13	2,099.8	1,237.5	862.3	86.2	6.8
14	2,047.2	1,184.9	862.3	86.2	6.6
15	1,961.8	1,099.5	862.3	86.2	6.3
16	1,911.6	1,049.3	862.3	86.2	6.2
17	1,917.8	1,055.5	862.3	86.2	6.2
18	1,913.4	1,051.1	862.3	86.2	6.2
19	1,666.1	803.8	862.3	72.5	6.4
20	1,298.8	436.5	862.3	58.8	6.1
21	1,154.5	305.2	849.3	58.8	5.5
22	970.7	152.6	818.1	45.9	5.9
23	775.5	0.0	775.5	33.0	6.5
Mean	1,314.6	552.9	761.7	58.4	6.1

Note :
(a) New discharge is evenly distributed over the new sets of outfalls 3 and 4.

Table 5.5e ***Discharge Rates for WEIF***

Hour	Wet Season		Dry Season	
	Discharge Rate ($m^3 s^{-1}$)	Temperature Rise (°C)	Discharge Rate ($m^3 s^{-1}$)	Temperature Rise (°C)
Continuous	14.8	6.0	14.8	6.0

The discharge rates in *Table 5.5b* were used to simulate the existing situation (Scenario 1), while the discharge rates in *Tables 5.5c* and *5.5d* were used to simulate the combined operation of the Lamma Extension and the existing power station (Scenario 2). It is worth noting that in the wet season average flows are increased for the Lamma Extension project and average temperatures decrease and in the dry season averaged flows decreased and there is a slight increase in temperatures. The WEIF discharges in *Table 5.5e* were added to the discharges in *Tables 5.5c* and *5.5d* to simulate the cumulative discharge from the WEIF and the combined Lamma Extension and existing power stations (Scenario 3).

The primary fuel for the Lamma Extension power station will be natural gas which will be transported to the power station via a submarine pipeline from the LNG terminal in Shenzhen. If, for any reason, the supply of gas is interrupted the Lamma Extension power station has a backup supply of light gas oil which would last for a period of seven days. In the event of burning the light gas oil the discharge of cooling water and residual chlorine from the power station would be no different from when natural gas was burned. The data presented in *Tables 5.5c* and *5.5d* is thus applicable for both fuels and the results of the cooling water dispersion may be taken to represent either use of natural gas or light gas oil as the fuel for the power station.

In the Stage I EIA a comprehensive assessment of the initial rise of the buoyant plumes from the existing power station cooling water outfalls was made[9]. The aim of this assessment was to determine the plume geometry and dilution characteristics within the initial mixing zone. The results of the previous study found that the discharge of buoyant heated water would lead to a surface plume. The heated water was thus put into the top three layers of the model, which represented 30% of the water depth. The same approach has been used in this study.

Uncertainties in Assessment Methodology

Quantitative uncertainties in the thermal discharge modelling should be considered when making an evaluation of the modelling predictions. Worst case conditions were adopted as model input in order to provide a conservative prediction of environmental impacts. It is therefore possible that the input data for the relevant parameters may cause an overestimation of the environmental impacts. Some examples of the conservative nature of the input parameters are given below:

- the maximum discharge rates of the cooling water were assumed; and
- the assumption of a near surface input to the model means that the heated water will be concentrated near the sea surface resulting in higher temperatures than if better vertical mixing had been assumed.

Identification of Impacts

The dispersion of cooling water from the Lamma Extension project has been assessed for the power station operating with combined cycle technology and with the existing power station, and for the combined case of discharge from the Lamma Extension project and the WEIF.

(9) Delft Hydraulics 1997. Expanded Site Search for a New Hong Kong Power Station. Thermal Modelling Report

The impacts from the thermal discharge are caused by increases in temperature in the receiving waters above the ambient values. The WQO for the Southern WCZ states that the variation in temperature from human activity should not exceed 2°C. However, it is likely that this level will be exceeded within a certain distance of the discharge point. The assessment of the impact has been to determine the size of the area within which 2°C is exceeded, the "mixing zone", and that any area of more than 2°C temperature rise does not include any sensitive regions. These sensitive regions have been defined as a selection of the sensitive receivers shown in *Figure 5.4g*, and have been limited to those along the western side of Lamma Island. The background temperatures in the wet and dry seasons were assumed to be 28°C and 17°C respectively, thus the resulting temperatures of concern were 30°C and 19°C.

For all of the scenarios it was found that the buoyancy of the thermal plumes coupled with the near surface discharge meant that there was no temperature rise in the lower part of the water column. Therefore results from the thermal dispersion modelling have been assessed for the top 40% of the water column which corresponds to the upper 4 layers in the model.

Prediction and Evaluation of Impacts

A total of six simulations were carried out of thermal discharge from the existing power station, the existing power station and combined cycle operation of the and Lamma Extension project, and the cumulative discharge from the Lamma Extension and existing power stations together with the WEIF discharge. These simulations were Scenarios 1, 2 and 3 for the wet and dry seasons, as described above. The results from the thermal discharge modelling are included in *Annex B5-4*, which contains a report on the thermal modelling prepared by Delft Hydraulics. Reference will be made to the results shown in *Annex B5-4* in discussing the predicted impacts.

Results from the thermal discharge modelling for all three scenarios were analysed to determine the plan area of the contours of temperature rise. The results of this analysis are presented in *Tables 5.5f* and *5.5g* for the wet and dry seasons.

Table 5.5f ***Plan Area Sizes of Temperature Rise Zones in the Wet Season (km^2)***

Scenario	Tide	1°C	2°C	3°C	4°C
1	Neap	22.7	7.6	2.5	1.0
	Spring	31.1	10.1	3.1	1.3
2	Neap	16.4	5.7	2.2	0.3
	Spring	24.1	7.8	3.1	1.3
3	Neap	19.6	7.6	2.8	1.3
	Spring	34.1	10.2	3.6	1.4

Table 5.5g ***Plan Area Sizes of Temperature Rise Zones in the Dry Season (km^2)***

Scenario	Tide	1°C	2°C	3°C	4°C
1	Neap	28.1	9.5	3.1	0.6
	Spring	30.1	10.2	3.1	0.7
2	Neap	20.8	5.1	1.1	0.2
	Spring	23.0	5.5	1.2	0.2
3	Neap	19.1	3.9	0.6	0.4
	Spring	23.5	4.7	0.8	0.4

In the above tables the size of the 2°C temperature rise zone is critical because this corresponds to the WQO.

The above tables show that the temperature rise zones are larger for the spring tides than for the neap tides. For Scenario 2 in both seasons the plan areas sizes of all temperature rise zones, including the 2°C zone, are smaller than Scenario 1. This is a reflection of the lower heat rejection rates for the combined cycle operation following the construction of the Lamma Extension compared with the existing power station for the dry season. In the wet season the combination of a different discharge pattern coupled with the tidal conditions has resulted in the smaller heat rise zones. In the wet season the size of the temperature rise zone in Scenario 3 is similar to that for Scenario 1 which is because the additional discharge from the WEIF has increased the temperature discharge in Scenario 2 to similar levels as Scenario 1. In the dry season the temperature rise zones for Scenario 3 are smaller than for Scenario 2 which is surprising given the increased thermal output from the WEIF. This is because the inclusion of the WEIF reclamation has altered the local tidal current patterns, thereby affecting the thermal plume dispersion.

Graphs of temperature at the sensitive receiver stations, shown in *Figure 5.4g*, have been produced. At all of these stations the total temperature is less than 2°C above the ambient temperature for all three scenarios in both the wet and dry seasons. These results are shown in *Figures 3.1.3* to *3.1.10, 3.2.3* to *3.2.10*, and *3.3.3* to *3.3.10* in *Annex B5-4* for Scenarios 1,2 and 3 respectively in the wet season and *Figures 4.1.3* to *4.1.10, 4.2.3* to *4.2.10, 4.3.3* to *4.3.10* for Scenarios 1,2 and 3 respectively in the dry season. These results show compliance with the WQO.

Contours of maximum temperature have been produced for all six simulations. In Scenario 1 for the wet season the 2°C temperature rise (30°C total temperature) contour is shown to be localised for the neap tide (*Figure 3.1.1* of the Annex), while for the spring tide the contour extends south and east from the power station, almost reaching the coast of Lamma Island just below Hung Shing Ye (*Figure 3.1.2*). For Scenario 2 on the neap tide the 2°C rise contour is narrower and extends further south than in Scenario 1, but remains some distance offshore of the coast of Lamma Island and just extends level with the south western tip of the Island (*Figure 3.2.1*). For the spring tide the 2°C contour extends into the large bay area between the power station and the south western tip of Lamma Island but remains offshore of the coast (*Figure 3.2.2*). In Scenario 3, for the spring and neap tides, the 2°C contour is larger than for Scenario 2 but remains further offshore (*Figures 3.3.1* and *3.3.2*). In the dry season for Scenario 1 the contours of 2°C (19°C total temperature) covers areas further to the north and less to the south than in the wet season (*Figures 4.1.1* and *4.1.2*). The contours are shown to remain offshore of the coastline of Lantau Island. For Scenario 2 the 2°C contour is much smaller than for Scenario 1 with the areas covered being quite local to the power station (*Figures 4.2.1* and 4.2.2). In Scenario 3 the 2°C contour is even smaller than in Scenario 2 (*Figures 4.3.1* and 4.3.2). This may be explained by the fact that the dominant direction of travel of the plumes is in the flood direction and the WEIF reclamation provides shelter on the flood tide.

Based on the above assessment it is concluded that the planned thermal discharge from the Lamma Extension alone are environmentally acceptable. In both the wet and dry seasons the area which is predicted to exceed the WQO of 2°C is reduced by at least 23%. The cumulative impact from the Lamma Extension combined with the WEIF is not predicted increase the size of area of the receiving waters exceeding 2°C in the wet season, while in the dry season the area is predicted to substantially decrease. In both cases, for the Lamma Extension alone and the cumulative impact of the Lamma Extension and WEIF, the thermal plumes are predicted to remain further offshore at present and are not predicted to impact upon any sensitive receivers at temperatures above 2°C.

Mitigation of Environmental Impacts

No adverse environmental impacts were predicted to occur as a result of the thermal discharges from the Lamma Extension project. As such no mitigation measures are considered necessary. Predicted impacts will be verified during Environmental Monitoring and Audit of the operational stage.

5.5.2 *Chlorine Dispersion*

Assessment Methodology

It is common practice in coastal power stations worldwide where sea water is used for plant cooling that chlorine, in the form of sodium hypochlorite solution produced through electrolysis of sea water, is used an anti-fouling agent. This is the standard and proven means for marine fouling control and Hongkong Electric has been adopting this practice for decades. At present, Hongkong Electric is not aware that other biocide alternatives have been adopted for power station applications in any other places in the world, although there are some smaller scale applications in a few industrial facilities. Since the cooling water system is so vital to the operation of the power station it is vital that more experience and trial tests on other biocide alternatives are required before they can be regarded as reliable and effective as supplementary or replacement agents for chlorine. For the purpose of assessment the worst case scenario, assuming that the Lamma Extension and the WEIF, if sea water is employed for plant cooling, will adopt chlorine or hypochlorite dosing, has been assumed so that the cumulative impact of residual chlorine dispersion from the outfalls of the existing and new facilities can be evaluated.

The dispersion of residual chlorine from the power station discharges was simulated using computer modelling. Only the combined case of the Lamma Extension and WEIF discharges was simulated, which corresponded to Scenario 3 in the thermal simulations. This scenario would be the worst case in terms of future conditions because of the higher discharge rates of this combined case compared with the Lamma Extension alone.

In setting the concentration of the residual chlorine in the existing and new outfall discharges for assessment, it is noted that the current licence limit is 0.5 mg L^{-1}, but depending on seasonal variation of the Lamma sea water in respect of marine growth HEC's experience over the past years shows that there are times, especially during winter seasons, when a concentration of less than 0.5 mg L^{-1} is sufficient to prevent marine fouling in the sea water system. HEC has been conducting actual field tests to find out the minimum residual chlorine level for effective suppression of marine growth in the sea water system of the power station. Initial results indicated that an average residual chlorine level of not less than 0.3 mg/l is the lowest in order to limit any marine growth. More field tests will be conducted to ascertain whether this level can be further lowered. In the design planning for additional generating facilities, which will only be in operation in 2003, it is Hongkong Electric's intention to limit the dosing of chlorine as much as possible. Whilst seeking for a balance point between minimum environmental impact and good integrity of the cooling water system, Hongkong Electric is now working with a local marine biologist (Professor Rudolph Wu of City University of Hong Kong) to determine the required minimum level of residual chlorine to prevent encristing by marine organisms, which is the prime threat to the integrity of the cooling water system in the power station. The initial target is to lower the residual chlorine level to 0.3 mg L^{-1} and, if practicable, further lower the concentration to 0.2 mg L^{-1}. A strategic chlorination regime of the whole power station will also be investigated with the aim of reducing the overall loading of residual chlorine. Meanwhile, supplementary dosing of other biocide alternatives, such as *1.3-propylene diamine* and *(Alkyl Amino)-3 Aminopropane* will be explored. Actual field tests on the minimum effective concentrations of these two biocides and the combined dosing regime with chlorine will need to be carried out before adopting an optimum scheme for marine fouling control for the new power plant. Other feasible mechanical cleaning systems, such as Tapprogge on-line ball cleaning system for condensers and heat exchangers, will also be pursued to enhance fouling control.

Residual chlorine is known to decay rapidly in the marine environment as the chlorine demand of the receiving waters is likely to be high. Hongkong Electric have monitored residual chlorine within the cooling system pipes from the point of dosing to the outfall. The locations of the monitoring points are shown in *Figure 5.5b*. The residual chlorine monitoring data is summarised in *Table 5.5h*.

Table 5.5h ***Residual Chlorine Concentrations in the Existing Power Station Cooling Water System***

Time from Dosing (s)	Concentration
1 (point of dosing)	1.2
98	0.5
596 (outfall)	0.3

The above data was used to determine a decay rate for the residual chlorine following discharge to the receiving waters. This was because it was the only data available at the time for making such a determination. A literature search found no useful quantitative information, only qualitative statements that residual chlorine concentrations decay rapidly in the marine environment.

The initial time period, from 1 to 98 seconds, represents the chlorine demand of the system. The period from 98 to 596 seconds represents the decay of the residual chlorine. This data was plotted on a graph of residual chlorine against time, *Figure 5.5c*. The curve was then extrapolated to the time at which concentrations would reach 0.03 mg L^{-1}. This time was found to be at 2,396 seconds after release, which would be 1,800 seconds after the discharge time to the marine environment. An exponential decay rate curve was then applied to the concentration decay from 0.3 mg L^{-1} to 0.03 mg L^{-1}, as shown in *Figure 5.5c*. This decay term was then applied to the discharged residual chlorine, which used a T_{90} value for the decay from the discharge point of 1,800 seconds. This would give a conservative simulation because the chlorine demand of the receiving waters would be high due to reactions with organic matter, dissolved gases and inorganic salts and residual chlorine concentrations would initially decay much more rapidly.

Following the determination of the chlorine decay rate, as described above, laboratory tests were carried out by HEC's HOKLAS accredited laboratory to obtain data to validate the assumed decay rate. The test procedure may be summarised as follows.

- An ambient seawater sample of approximately 10 litres was collected in the vicinity of Hung Shing Ye beach where the residual chlorine concentrations are very low. The water sample was then immediately sent back to the HEC laboratory for analysis.

- The temperature of the collected sample was controlled to 30°C in order to simulate the thermal effects of the cooling water discharges in the vicinity of the outfalls (the cooling water temperature is raised by 8-10°C after passing through the condenser).

- The sample was manually stirred in a gentle manner throughout the test.

- Sodium hypochlorite was dosed into the water sample. Immediately after injection of the hypochlorite solution the total residual chlorine in the sample was measured. The initial residual chlorine was set to 0.3 mg L^{-1} to simulate the current discharge concentration.

- At four minute intervals a sub-sample (25 cc) was taken out of the sample for measurement of the total residual chlorine. A total of five sub-samples were taken and analysed. In the fifth analysis, 20 minutes after initial sodium hypochlorite dosing, the residual chlorine concentration was found to have dropped below 0.05 mg L^{-1}, which was below the confidence limit of the detection method.

- The measurements of residual chlorine were made using the Hach (total residual chlorine) colorimetric method using the Hach chemical and spectrophotometer DR 2000. The measuring range is specified as being 0-2 mg L^{-1}. There is no available information on the accuracy of the text from Hach but it is stipulated in the manual that the precision of testing is defined by the testing of a 1.0 mg L^{-1} chlorine standard having a standard deviation of 0.012 mg L^{-1}.

The results from this testing are shown in *Figure 5.5c*, together with an exponential curve which was applied through the data points. This curve was plotted on the same graph as the decay curve applied for the modelling and it clearly shows that the measured decay curve is more rapid than that applied for the modelling. This, therefore, gives confidence that the modelling results will be conservative.

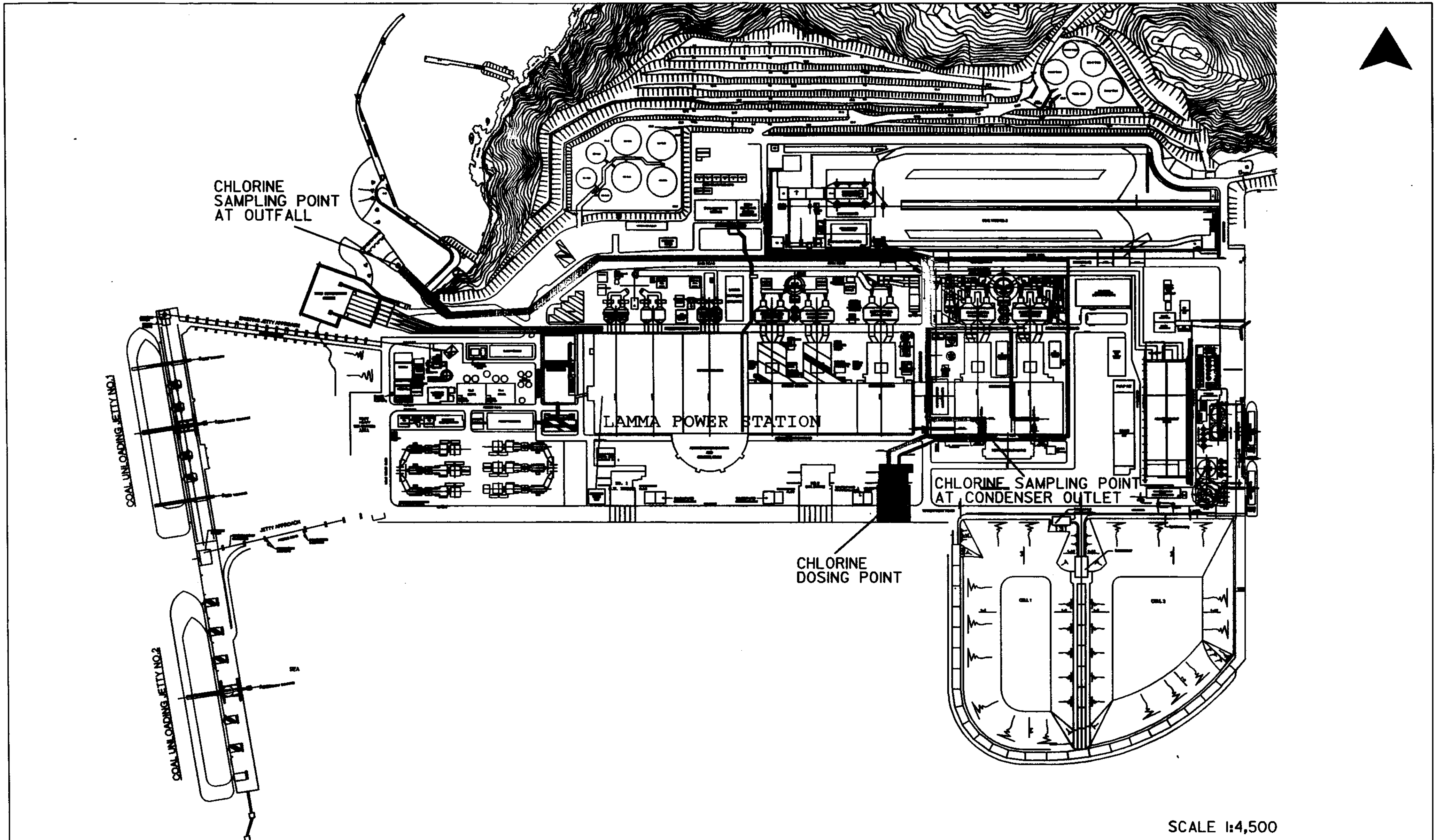

FIGURE 5.5b

LOCATIONS OF CHLORINE MONITORING POINTS WITHIN THE COOLING WATER SYSTEM

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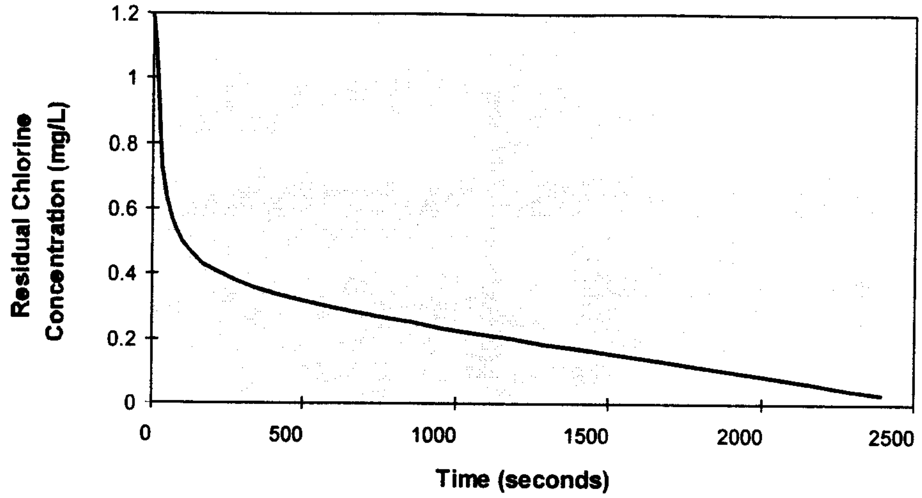
Concentration of Residual Chlorine in the Cooling System against Time



Applied Exponential Decay of Residual Chlorine compared with Laboratory Data

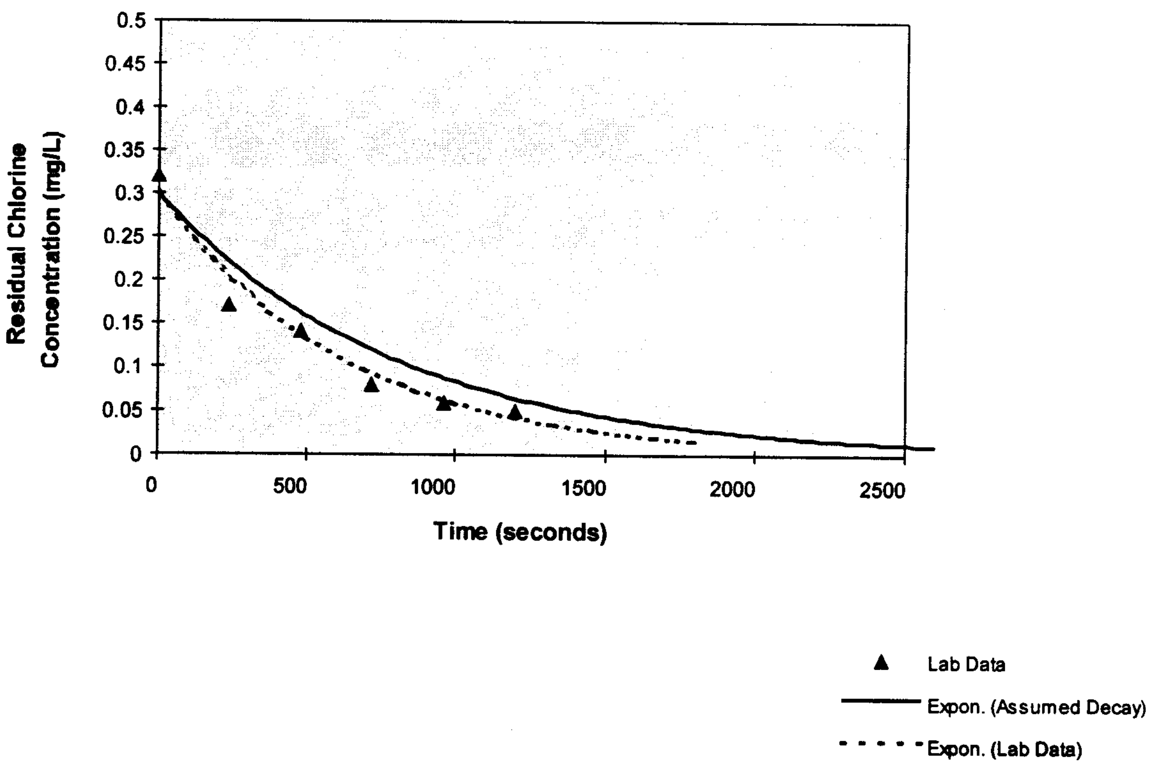


FIGURE 5.5c

DERIVATION OF RESIDUAL CHLORINE DECAY RATE

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Concern has also been expressed as to the potential for the formation of foam during to discharge of cooling water. This aspect of the discharge from the Lamma Extension, which is associated with the discharge of residual chlorine, has been assessed in a qualitative manner.

Uncertainties in Assessment Methodology

Quantitative uncertainties in the chlorine dispersion modelling should be considered when making an evaluation of the modelling predictions. Worst case conditions were adopted as model input in order to provide a conservative prediction of environmental impacts. It is therefore possible that the input data for the relevant parameters may cause an overestimation of the environmental impacts. Some examples of the conservative nature of the input parameters are given below:

- the highest discharge rates were used in conjunction with the chlorine discharge; and
- the exponential decay curve applied for the modelling has been shown to be less rapid than measurements made in the laboratory which suggests that the applied decay curve is conservative.

Identification of Impacts

Residual chlorine in the marine environment is harmful to marine organisms if concentration levels exceed a certain value. It has been found that harmful effects begin to occur at concentrations above 0.02 mg l^{-1} [(10)], while EPD have expressed concern at levels of residual chlorine as low as 0.01 mg l^{-1}. There is no value specified in the WQOs for the Southern WCZ, nor for any other WCZ, and so the lower value of 0.01 mg l^{-1} has been chosen as the criteria against which to assess the results from the computer modelling of chlorine dispersion.

Foam may be produced on the surface of the sea in the immediate vicinity of the cooling water outfalls due to the aeration of the decaying protein from dead marine organisms resulting from the use of chlorine and other anti-fouling agents. Nevertheless it is not considered that the foam as generated will have either detrimental nor harmful impact to the marine environment.

Prediction and Evaluation of Impacts

The results from the chlorine simulations are presented as contour plots of maximum chlorine concentrations for the spring and neap tidal periods in the wet and dry seasons. The contour plots are contained in *Annex B5-5*. The results for the residual chlorine discharge at 0.3 mg L^{-1} for the Lamma Extension and WEIF are presented in *Figures 1* to *8*, while the results for the discharge at 0.2 mg L^{-1} are presented in *Figures 9* to *16*. For both scenarios the discharge concentration of residual chlorine from the existing power station was 0.3 mg L^{-1}.

The contour plots for the 0.3 mg L^{-1} discharge generally show that the chlorine plumes are smaller in the dry season, *Figures 1* to *4*, compared with the wet season, *Figures 5* to *8*. This is due to the higher total discharge rates in the wet season compared with the dry season. For all of the results the majority of the chlorine is contained within the top 40%, the upper 4 model layers, of the water column which is because the release of the chlorine is near to the water surface

(10) T E Langford 1983. Electricity Generation and the Ecology of Natural Waters.

and the buoyancy of the heated water, in which the chlorine is discharged, ensures that there is weak vertical mixing. In all of the plots the highest concentrations of chlorine occur in the immediate vicinity of the outfalls, which are evident as discrete areas in the upper contour band. The highest concentrations are found for the wet season neap tide, *Figure 7*. In this plot the largest area covered by the 0.01 mg L^{-1} occurs in the vicinity of the outfalls for the existing power station and the extension. The area is shown to extend some 700 metres offshore of the existing power station outfalls and along the western face of the existing power station and the extension reclamation which represents a distance of 1,500 metres. The offshore distance of the plume reduces to less than 500 metres at the outfalls for the power station extension. A much smaller area, 250 metres by 250 metres, is shown exceeding the 0.01 mg L^{-1} contour around the WEIF outfall.

The results for the 0.2 mg L^{-1} chlorine discharge (*Figures 9* to *16*) show similar patterns to those which were shown for the 0.3 mg L^{-1} discharge, although the extents of the chlorine plumes are reduced. The largest plume is again shown in Layers 1 to 4 for the wet season neap tide (*Figure 15*). The extent of the chlorine plume from the existing power station at concentration over 0.1 mg L^{-1} is the same as that for the 0.3 mg L^{-1} which is because the discharge concentration from the existing power station is the same for both scenarios. This also shows that the Lamma Extension does not contribute cumulatively to the discharge plume from the existing power station. The main difference between the two scenarios is that there is longer a continuous area exceeding the 0.01 mg L^{-1} contour extending from the existing power station along the face of the Lamma Extension reclamation. The discharge from the Lamma Extension has become discrete from the existing power station discharge, although the distance offshore which is impacted at 0.01 mg L^{-1} is only slightly reduced. The discharge plume from the WEIF has reduced in size compared to the 0.3 mg L^{-1} scenario.

The results from the chlorine simulations with a 0.3 mg L^{-1} discharge concentration for the Lamma Extension and WEIF predicted that areas immediately adjacent to the outfalls, extending approximately 700 metres offshore and 1,500 metres along the western shore of the power stations, in the worst case, will experience residual chlorine concentrations in excess of 0.01 mg L^{-1}. This area would be defined as the 'mixing zone' and its small extent, and the fact that no sensitive areas are impacted, would mean that the impacts from residual chlorine discharge would not cause unacceptable environmental impacts. The results from the 0.2 mg L^{-1} discharge showed the same maximum extent for the 0.01 mg L^{-1} contour from the existing power station, while the total size of the area impacted at 0.01 mg L^{-1} reduced in size slightly because the plumes from the Lamma Extension and the existing power station did not merge to form a continuous band along the western seaward face of the two reclamations. The distance offshore from the Lamma Extension outfalls for the 0.01 mg L^{-1} contour was only slightly reduced for the 0.2 mg L^{-1} discharge compared with the 0.3 mg L^{-1} discharge.

As previously discussed, there is the potential for foam to be formed on the surface of the water adjacent to the cooling water outfalls. Such foam would breach the WQO which states that no scum or discolouration should be allowed to form. The potential for foam formation from the Lamma Extension cooling water outfalls may be minimised by appropriate design measures which are discussed in the following section. If this measure is found to unable to prevent the formation of foam, then further measures will be required to contain the foam which are discussed below.

Mitigation of Environmental Impacts

The modelling of the dispersion of chlorine from the power station extension combined with the WEIF predicted that an area extending approximately 700 m offshore from the discharge point of the existing power station would experience residual chlorine concentrations in excess of 0.01 mg L^{-1}. The localised nature of the predicted elevations in chlorine concentrations would mean that the discharge would not cause unacceptable environmental impacts as no sensitive areas would be impacted and so no mitigation measures would be required. The modelling predictions will be confirmed during EM&A, which will monitor residual chlorine.

Notwithstanding the above discussion of the results of the chlorine dispersion modelling, HEC will commit to exploring the possibility of lowering the residual chlorine discharge concentration and of the potential for using alternative biocides.

Associated with dosing of chlorine or other anti-fouling agents, foam may be formed as a result of aeration of the decaying protein from dead marine organisms. In the detailed design of the new power plant the following measures will be adopted, where appropriate, to limit the formation of foam and restrict its escape from the immediate vicinity of the outfalls to the open sea.

- Adopting a lower discharge velocity to reduce turbulence at the outfall;
- Avoiding air entrainment in the discharging water, as far as practicable; and
- Installing a suitable foam barrier or containment system in the outfall vicinity to restrict any foam from escaping into the sea.

5.5.3 Sedimentation Changes

Assessment Methodology

The potential for the Lamma Extension and the WEIF reclamations to affect sea bed erosion and deposition has been assessed in a qualitative manner. The assessment was based on the hydrodynamic modelling in the construction phase impact assessment which predicted tidal flow patterns in the vicinity of the reclamation, as described in *Section 5.4.1*. Any changes in the tidal currents around the reclamations could cause changes in the form of increased erosion and deposition.

Identification of Impacts

Sediment changes following the construction of reclamations can occur as a result of changes in tidal currents around the reclamations. Should current speeds increase then erosion may occur if the speed increases are sufficiently high, and should current speeds decrease then deposition may occur if speeds decrease sufficiently. Areas of speed increases and decreases around the reclamations for the Lamma Extension and WEIF have been identified from the hydrodynamic modelling in *Section 5.4.1*, and the potential for either erosion or deposition assessed.

Prediction and Evaluation of Impacts

The hydrodynamic modelling predicted that the neither the Lamma Extension reclamation nor the WEIF reclamation would significantly alter the tidal currents around the site, as shown in *Figures 3.1.2, 3.1.3, 3.2.2* and *3.2.3* in *Annex B5-2*. This is primarily because the site for the new power station is sheltered from the main tidal current streams by the existing power station to the north (ebb current sheltering) and by the south western tip of Lamma Island to the south (flood current sheltering). There would not be any localised tidal current speed increases due to the reclamation decreasing the size of a flow path and as such the potential for localised erosion would not exist. Similarly, there would not be speed decreases, except in the area to the east of the reclamation. This area was predicted not to experience appreciable decreases in flushing capacity following the construction of the reclamation and as such the tidal currents in this area would not reduce significantly. However, it is to be expected that the tidal currents would reduce to a certain extent but the potential for deposition would be low. This is primarily because of the low suspended sediment concentrations in the area, which means that the quantities of sediment available for deposition would not be high.

Mitigation of Environmental Impacts

It was concluded that no changes to the sedimentation regime would occur as a result of the construction of either the Lamma Extension reclamation or the WEIF reclamation and so no mitigation measures are required.

5.6 EM&A REQUIREMENTS

5.6.1 Construction Phase

Introduction

This section presents technical requirements for monitoring water quality during the construction of the power station extension. The monitoring programme and its technical requirements will be subject to review depending on the results of the environmental monitoring. To ensure timely data gathering / retrieval and presentation in a consistent and efficient format, an electronic environmental monitoring and auditing system will be implemented to manage the EM&A process. An *Initial Review Report* will be submitted after the first three months of monitoring or on an appropriate agreed date. The EM&A Consultants will discuss the adequacy of the monitoring programme and provide recommendations on how to improve the monitoring programme, if required.

Water quality monitoring results will be compared to Action and Limit levels to determine whether impacts associated with dredging are acceptable. An Event and Action Plan provides procedures to be undertaken when monitoring results exceed Action or Limit levels. The procedures are designed to ensure that if any significant exceedances occur (either accidentally or through inadequate implementation of mitigation measures on the part of the Contractor), the cause is quickly identified and remedied, and that the risk of a similar event re-occurring is reduced.

Action and Limit levels will be used to determine whether modifications to dredging operations are required. Action and Limit levels are environmental quality standards chosen such that their exceedance indicates potential deterioration of the environment. Exceedance of Action levels can result in an increase in the frequency of environmental monitoring, modification of dredging operations and implementation of the proposed mitigation measures. Exceedance of Limit levels indicates a greater potential deterioration in environmental conditions and may require the cessation of works unless appropriate remedial actions, including a critical review of plant and working methods, are undertaken.

Water Quality Monitoring

The objectives of the water quality monitoring programme are as follows:

- to determine the effectiveness of the operational controls and mitigation measures employed, and the need for supplementary mitigation measures;
- to check compliance with relevant WQOs; and
- to verify the predictions of the sediment plume modelling.

The WQOs for the Southern WCZ (SWCZ), in which the reclamation site is located, are as follows:

- *Suspended Solids (SS)*: SS should not be raised above ambient levels by an excess of 30% nor cause the accumulation of SS which may adversely affect aquatic communities.
- *Dissolved Oxygen (DO)*: DO within 2 m of the bottom should not be less than 2 mg l^{-1} for 90% of the samples; depth averaged DO should not be less than 4 mg l^{-1} for 90% of the samples during the whole year.
- *Ammonia (NH_3-N)*: The unionized ammoniacal nitrogen level should not be more than 0.021 mg L^{-1}, calculated as the annual average (arithmetic mean).
- *Nutrients (TIN)*: TIN should not exceed 0.1 mg L^{-1}, expressed as annual water column average.

The water quality monitoring stations are shown in *Figure 5.6a*. Seven Sensitive Receiver (SR) Stations are chosen on the basis of their proximity to the dredging and filling operations and thus the greatest potential for water quality impacts. These SR Stations are situated along the western and northern sides of Lamma Island which were predicted in the EIA to experience suspended sediment concentrations above ambient levels during some periods. The seven Sensitive Receiver monitoring locations are:

- SR1 representing the sub tidal assemblages at Pak Kok (north Lamma coastline);
- SR2 representing the sub tidal assemblages at Shek Kok Tsui (north west Lamma coastline);
- SR3 representing the existing power station intakes;
- SR4 representing Hung Shing Ye beach;
- SR5 representing Lo So Shing beach;
- SR6 representing the north western part of the proposed South Lamma Marine Park; and
- SR7 representing Ha Mei Tsui in the proposed South Lamma Marine Park.

These monitoring locations are sited in order to represent as closely as possible the water quality conditions at the Sensitive Receivers, however, the stations are located away from activities (eg piers, areas of high ship traffic) which may confound monitoring results. Due to their proximity to the mixing zone, SR4, SR5 and SR6 also serve to assess whether the mixing zone predictions in the EIA were accurate.

Five Control Stations are chosen to facilitate comparison of the water quality of SR Stations with ambient water quality. Three Control Stations C1, C2 and C3 are designated to monitor the ambient water quality in relation to other activities with potential water quality impacts in the Study Area (ie CT9 sand dredging, backfilling of the South Tsing Yi borrow area and CT9 mud dredging). The other Control Stations, C4 and C5, are located in areas not affected by other projects and which lie within the path of water body movements affecting the SRs but are outside the predicted influence of the reclamation works. Monitoring data from these Control Stations can be used as upstream and downstream controls for the SR stations. Locations of control stations shall be subject to change depending on the location and timing of dredging and other marine works projects in the Study Area. Any proposal for changes to the locations of control/impact stations shall be subject to EPD approval.

Water quality monitoring shall be undertaken by suitably qualified members of the EM&A Consultant. Water quality monitoring results from both Control Stations and SR Stations will be compared with EPD's WQOs. Control Stations are used to determine ambient water quality. SR Stations are in the immediate vicinity of the dredging site and expected to experience elevated suspended sediment concentrations during the reclamation construction activities.

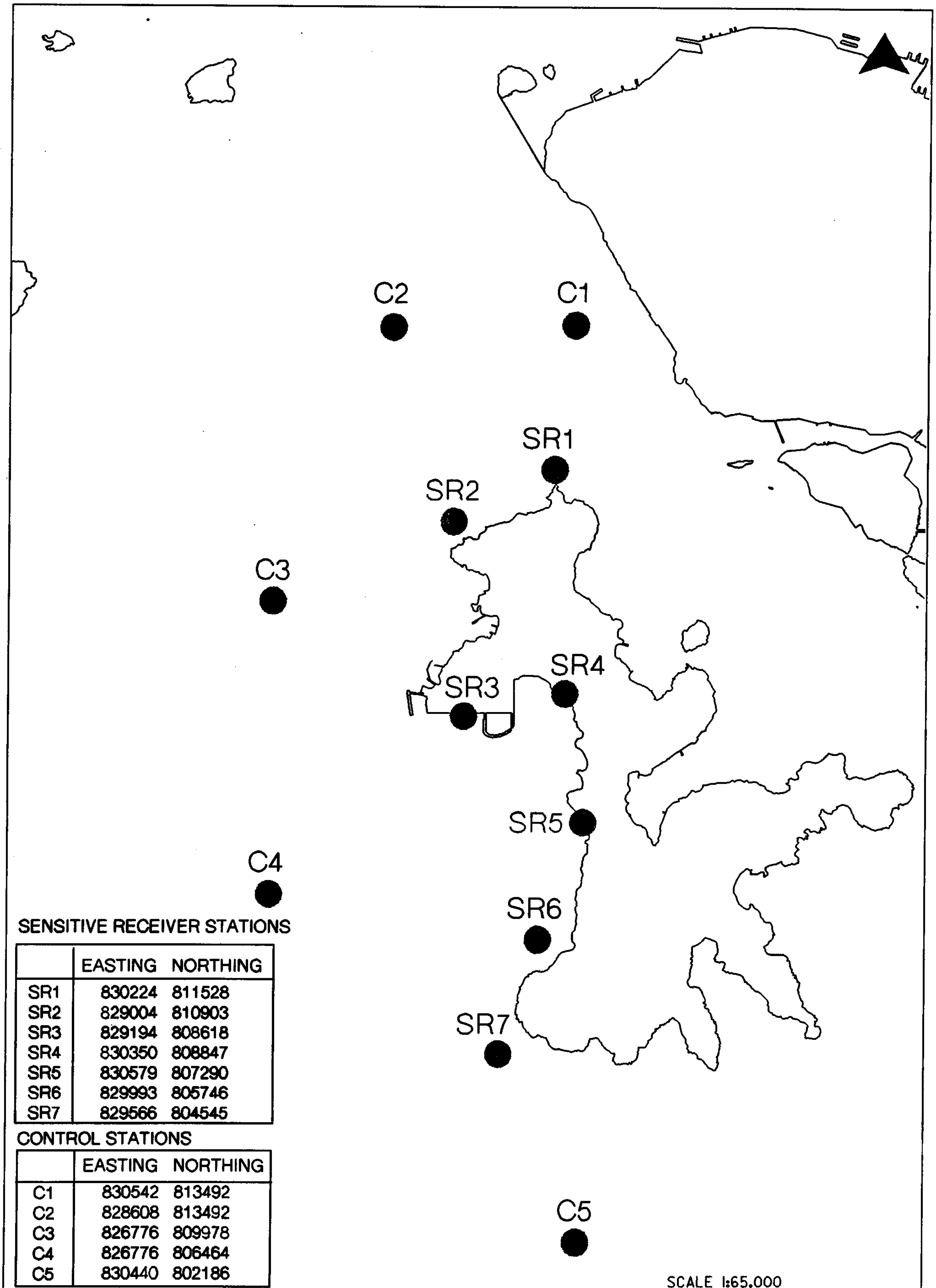
Baseline conditions for water quality shall be established and agreed with EPD prior to the commencement of reclamation construction works. The purposes of the baseline monitoring are to establish ambient conditions prior to the commencement of the works and to demonstrate the suitability of the proposed Control and SR Stations. The baseline conditions shall normally be established by measuring the water quality parameters specified *below*. The measurements shall be taken at all Control and SR Stations, 3 days per week, at mid-flood and mid-ebb tides, for at least four weeks prior to the commencement of construction works.

During the course of the dredging operations, monitoring shall be undertaken three days per week, at mid-flood and mid-ebb tides, with sampling and measurement at the designated monitoring stations. The interval between two sets of monitoring shall not be less than 36 hours except where there are exceedances of Action and/or Limit levels, in which case the monitoring frequency will be increased.

Upon completion of all dredging activities, a post project monitoring exercise on water quality shall be carried out for four weeks in the same manner as the impact monitoring.

Water Quality Monitoring Methodology

The values of turbidity, dissolved oxygen (DO) and suspended solids (SS) will be determined at each designated monitoring stations. Two measurements of DO concentration (mg l^{-1}), DO saturation (%) and turbidity (NTU) will be taken *in situ* at Control and SR Stations at 1 metre below surface, mid-depth and 1 metre above sea bed. The monitoring probes must be removed from the water after the



SENSITIVE RECEIVER STATIONS

	EASTING	NORTHING
SR1	830224	811528
SR2	829004	810903
SR3	829194	808618
SR4	830350	808847
SR5	830579	807290
SR6	829993	805746
SR7	829566	804545

CONTROL STATIONS

	EASTING	NORTHING
C1	830542	813492
C2	828608	813492
C3	826776	809978
C4	826776	806464
C5	830440	802186

FIGURE 5.6a LOCATIONS OF WATER QUALITY MONITORING STATIONS

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first measurement and redeployed for the second measurement. Where the difference in value between the first and second measurement of DO or turbidity parameters is more than 25% of the value of the first reading, the readings will be discarded and further readings will be taken. Water samples for SS (mg l^{-1}), NH_3-N (mg l^{-1}) and TIN (mg l^{-1}) measurements shall be collected at the same three depths. As for the *in situ* measurements, duplicates will be taken at both Control and SR Stations.

In addition to the above *in-situ* measurements temperature, salinity and pH will be determined at all control and monitoring stations at the same three depths, as specified above.

For the purpose of evaluating water quality, the values obtained from individual water depths (ie surface, middle, bottom) will be assessed individually against the specified WQOs criteria. Note that in addition to the monitoring location/position, time, water depth, water temperature, salinity, weather conditions, sea conditions, tidal stage, and any special phenomena and work underway at the dredging site should be recorded.

Water samples for all monitoring parameters shall be collected, stored, preserved and analysed according to the Standard Methods, APHA 17 ed, and/or methods agreed by the Director of Environmental Protection (DEP).

All *in-situ* monitoring instruments shall be checked, calibrated and certified by a laboratory accredited under HOKLAS or any other international accreditation scheme before use, and subsequently re-calibrated at 3-monthly intervals throughout all stages of the water quality monitoring. Responses of sensors and electrodes shall be checked with certified standard solutions before each use. Wet bulb calibration for a DO meter shall be carried out before measurement at each monitoring station. The turbidity meter shall be calibrated to establish the relationship between turbidity readings (in NTU) and levels of suspended solids (in mg l^{-1}) where possible.

For the on-site calibration of field equipment, the BS 127:1993 *Guide to field and on-site test methods for the analysis of waters* shall be observed. Sufficient stock of spare parts shall be maintained for replacement when necessary. Backup monitoring equipment shall also be made available so that monitoring can proceed uninterrupted even when some equipment is under maintenance, calibration, etc.

Analysis of SS, NH_3-N and TIN shall be carried out in a HOKLAS or other international accredited laboratory. Water samples of about 1000ml shall be collected at the monitoring and control stations for carrying out the laboratory determinations. The determination work shall start within 24 hours after collection of the water samples. The determination work shall follow APHA 19 ed 2540D for suspended solids, 4500-NH_3 G for ammoniacal nitrogen and 4500-N_{org}/NO_3 for total nitrogen or equivalent methods subject to approval of DEP.

For the each of the testing methods detailed testing methods, pre-treatment procedures, instrument use, Quality Assurance/Quality Control (QA/QC) details (such as blank, spike recovery, number of duplicate samples per batch, etc), detection limits and accuracy shall be submitted to DEP for approval prior to the commencement of monitoring programme. The QA/QC shall be in accordance with requirement of HOKLAS or international accredited scheme. The QA/QC results shall be reported. EPD may also request the laboratory to carry out analysis of known standards provided by EPD for quality assurance. Additional duplicate samples may be required by EPD for inter-laboratory calibration. Remaining samples after analysis shall be kept by the laboratory for

3 months in case repeat analysis is required. If in-house or non-standard methods are proposed, details of the method verification may also be required to submit to DEP. In any circumstance, the sample testing shall have comprehensive quality assurance and quality control programmes. The laboratory shall prepare to demonstrate the programmes to DEP or his representatives when requested.

Compliance Assessment

Water quality monitoring results will be evaluated against Action and Limit levels as shown in *Table 5.6a*. Exceedence of the Action and Limit Level will result in changes to the monitoring and dredging operations, potentially involving increased monitoring and implementation of mitigation measures.

Table 5.6a ***Action and Limit Levels for Water Quality***

Parameters	Action	Limit
Do in mg l^{-1} (surface, Middle & Bottom	Surface & Middle 5th percentile of baseline data for surface and middle layer Bottom 5th percentile of baseline data for bottom layer	Surface & Middle 4 mg l^{-1} or 1%-ile of baseline data for surface and middle layer Bottom 2 mg l^{-1} or 1%-ile of baseline data for bottom layer
SS in mg l^{-1} (depth averaged)	95th percentile of baseline data or 120% upstream control stations's SS at the same tide of the same day[5]	99th percentile of baseline data or 130% of upstream control station's SS at the same tide of the same day[5]
Turbidity (Tby) in NTU (depth averaged)	95th percentile of baseline data or 120% upstream control station's turbidity at the same tide of the same day	99th percentile of baseline data or 130% of upstream control station's turbidity at the same tide of the same day
NH_3-N in mg l^{-1} (depth averaged)	95th percentile of baseline data	99th percentile of baseline data or 0.021 mg l^{-1} for unionized ammoniacal nitrogen, whichever is greater
TIN in mg l^{-1} (depth averaged)	95th percentile of baseline data	99th percentile of baseline data or 0.1 mg l^{-1}, whichever is greater

Notes:
1. Depth-averaged is calculated by taking the arithmetic mean of all three depths.
2. For DO, non-compliance of the water quality limits occurs when monitoring result is lower then the limits.
3. For SS and Tby, non-compliance of the water quality limits occurs when monitoring result is higher than the limits.
4. All the figures given in the table are used for reference only and the EPD may amend the figures whenever it is considered necessary.
5. Whichever of the two criteria is greater shall be used as the Action and Limit levels, subject to approval by the EPD.
6. Unionized ammoniacal nitrogen shall be calculated from the monitored ammoniacal nitrogen based on temperature, pH and salinity which are routinely monitored.

Water Quality Mitigation Measures

The Contractor shall be responsible for the design and implementation of the water quality control and mitigation measures recommended for the construction phase in *Section 5.4.2*.

If the above measures are not sufficient to restore the water quality to an acceptable level upon the advice of the EM&A Consultants, the Contractor shall liaise with the EM&A Consultants on other mitigation measures, propose these to Independent Checker (Environmental) and Engineer's Representative for approval, and carry out the mitigation measures.

5.6.2 *Operational Phase*

Introduction

This sub-section provides details of the environmental monitoring programme and presents technical requirements for monitoring water quality during the operation of the power station extension. The programme and the requirements will be subject to review depending on the results of the environmental monitoring. An *Initial Review Report* will be submitted after the first three months of monitoring or on an agreed suitable date. The EM&A Consultant will discuss the adequacy of the monitoring programme and provide recommendations on how to improve the monitoring programme, if required.

Water Quality Monitoring

The objectives of the water quality monitoring programme are as follows:

- to determine the size of the 2°C mixing zone, that is the area within which the water temperature is greater than 2°C above ambient;
- to determine the extent of the detectable chlorine concentrations; and
- to verify the predictions of the thermal and chlorine dispersion modelling.

The WQOs for the Southorn Water Control Zone (WCZ), in which the reclamation site is located, are as follows:

- human activity shall not cause the natural daily temperature range to change by more than 2°C.

It should be noted that there is currently no standard for residual chlorine concentrations in marine waters. The concentration used for assessment purposes in the chlorine dispersion modelling was taken to be 0.01 mg l^{-1}, which was based on ecotoxicity data. However, it is not possible to detect residual chlorine at this concentration in marine waters. A detection limit of 0.04 mg l^{-1} is achievable under optimal conditions. If alternative biocides are to be used then monitoring of the concentrations of such biocides should be carried out and the extent of detectable concentrations be determined with reference to any available ecotoxicity data.

Monitoring of water quality, in terms of temperature and residual chlorine, or alternative biocide, concentrations, will be undertaken within the area (exact area of monitoring will be agreed with EPD prior to the commencement of measurements) shown on *Figure 5.6b*.

The location of the monitoring area is chosen to cover the area predicted by the computer modelling to experience elevated temperatures and residual chlorine concentrations. Control, or background, values will be determined from measurements made on the outer edges of the monitoring area, which will not be influenced by the discharges from the power station.

Baseline conditions shall be established prior to the commencement of the discharges from the power station. The purposes of the baseline monitoring are to establish conditions prior to the commissioning of the power station extension. The baseline conditions shall normally be established by measuring temperature and residual chlorine, or alternative biocide, concentrations, as specified below. The measurements shall be taken over the whole of the monitoring area, over a spring tide and a neap tide in both the wet and dry seasons.

During the course of the operation of the power station extension, monitoring shall be undertaken for complete spring and neap tidal cycles in the wet and dry seasons.

Water Quality Monitoring Methodology

The value of temperature will be determined at each designated monitoring point within the monitoring area *in situ*. Measurements will be made at 2 metre intervals over the whole water column. Water samples for residual chlorine, or alternative biocide, measurement will be collected at each designated monitoring point within the monitoring area. The water samples will be collected at the same depths as the temperature measurements.

For the purposes of evaluation, measurements at each of the depths and stations will be combined to form contours of temperature and residual chlorine, or alternative biocide. This will enable a determination of the areal extent of different contour bands. Note that in addition to the monitoring location/position, time water depth, salinity, weather conditions, sea conditions, tidal stage and any special phenomena and work underway within the monitoring area shall be recorded.

Compliance Assessment

The results of the monitoring for temperature and residual chlorine, or alternative biocide, will be compiled to show contours of excess temperature and residual chlorine. This will then enable the size of the mixing zone, predicted during the modelling assessment, to be verified for both temperature and residual chlorine. The acceptability of the measured sizes of the mixing zones will be determined in consultation with the EPD.

5.7 SUMMARY AND CONCLUSIONS

The assessment of the impacts to water quality of the Lamma Extension project has been carried out for the construction and operational phases.

5.7.1 Construction Phase

The aspects of the construction of the reclamation which have been considered in the assessment are as follows:

- changes to the hydrodynamic regime upon completion of the reclamation; and
- the dispersion of sediment in suspension during dredging and filling operations.

Both of these aspects of the construction phase assessment have been carried out using computer modelling.

Hydrodynamic Assessment

The assessment of the hydrodynamic regime impacts concluded that there would be only small changes in the tidal flows upon completion of the reclamation. It was therefore determined that no mitigation measures would be necessary.

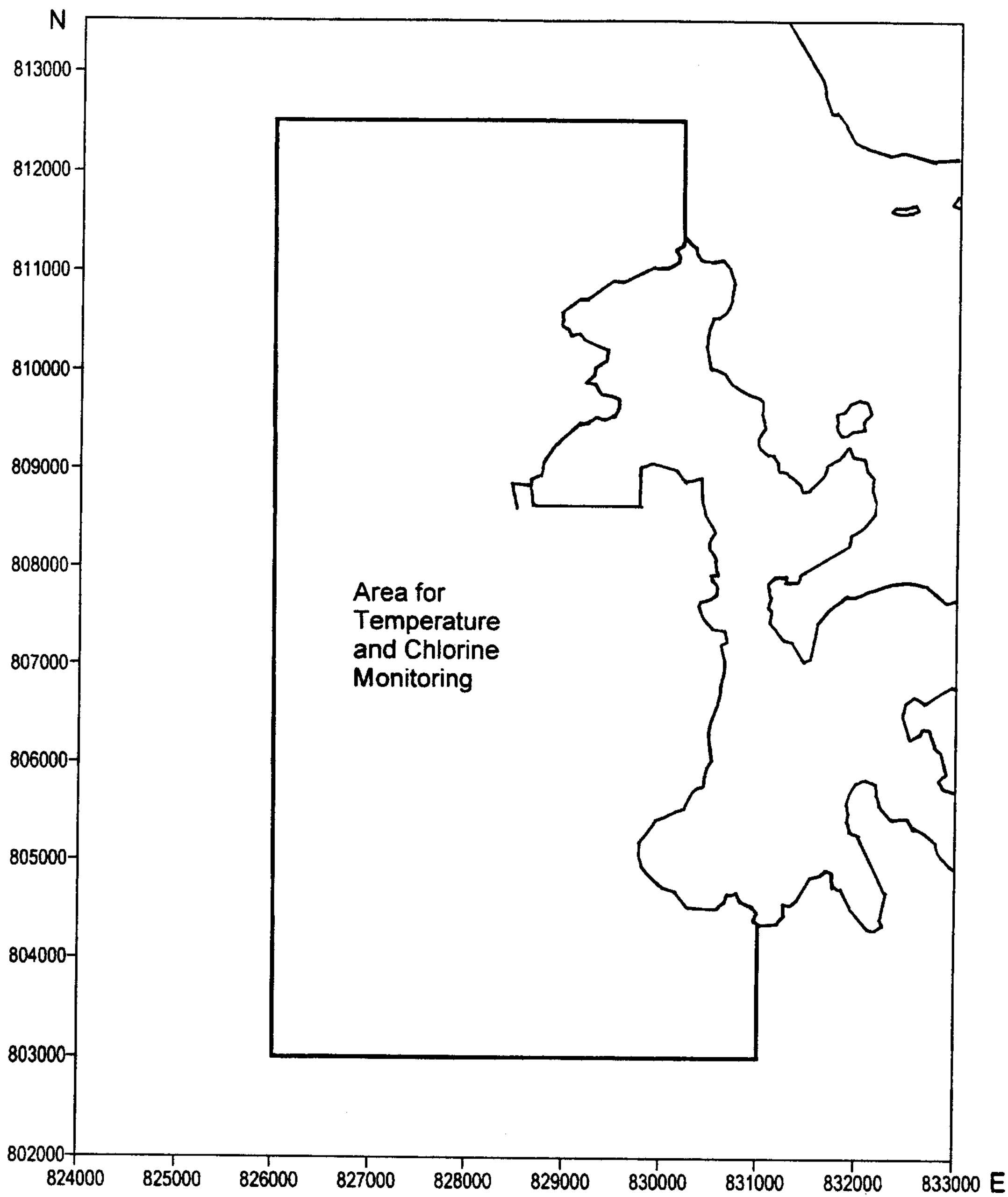

FIGURE 5.6b

LOCATION OF THE AREA FOR TEMPERATURE AND CHLORINE MONITORING

FILE: C1830/C1830Z9
DATE: 28/10/98

Environmental Resources Management

ERM

Cumulative impacts on the hydrodynamic regime were also considered from the construction of the WEIF reclamation, 200 m to the south of the Lamma Extension. The assessment concluded that there would again be only small changes to the hydrodynamic regime upon completion of both the Lamma Extension and the WEIF reclamations. An assessment of the flushing of the area to the east of the reclamation was also carried out for this cumulative case. It was found that there would be very little change to the retention of the water in this sheltered area and that adequate flushing would be maintained in the area. It was therefore determined that no mitigation measures would be necessary. However, it was recommended that all storm drains from the reclamation be diverted away from the eastern side of the reclamation to prevent discharge into the Hung Shing Ye Bay.

Sediment Dispersion

The assessment of the dispersion of suspended sediment during the construction phase found that the following rates of dredging would be environmentally acceptable:

- three large grab dredgers and one small grab dredger operating concurrently, each with rates of working of 300,000 m^3 $month^{-1}$ and 200,000 m^3 $month^{-1}$ respectively, which equates to daily working rates of 12,000 m^3 and 8,000 m^3 respectively. These working rates were simulated as Scenario 2; and

- 1 trailer dredger with a rate of working of 200,000 m^3 $month^{-1}$, and 2 large grab dredgers, each with rates of working of 300,000 m^3 $month^{-1}$, which equates to daily working rates of 8,000 m^3 and 12,000 m^3. These working rates were simulated as Scenario 3.

At these rates of dredging it was found that there would be short term exceedences of the WQO for suspended sediment concentrations at some of the sensitive receivers and at the two nearby bathing beaches where the concentrations of suspended sediments were not predicted to vary greatly throughout the tidal cycle. For this reason it was required that silt curtains be installed on the eastern, southern and north western sides of the reclamation to reduce the suspended sediment concentrations at the sensitive receivers to acceptable levels. An additional requirement was specified to protect the sensitive receivers along the northern shore of Lamma Island. This measure was to reduce by one the number of large dredgers working on the flood phase of the tidal cycle for Scenario 2 (3 large grab dredgers and 1 small grab dredger).

Combined dredging and filling of the site platform was also assessed. The impacts from these operations were found to be environmentally unacceptable and the following operational constraints were recommended:

- concurrent bulk dredging and filling of the site platform will not be permitted; and

- sand filling of the site platform must be conducted behind constructed sea walls which pierce the water surface to prevent the migration of fines from the works area.

In additional to the above operational constraints, mitigation measures in terms of good working practice were specified.

Cumulative impacts from the reclamation construction and a number of other projects which could occur concurrently were also assessed. The other projects were as follows:

- backfilling at the South Tsing Yi Marine Borrow Area;
- mud dredging at the CT9 reclamation site; and
- sand dredging at the Southern South Tsing Yi Marine Borrow Area.

The assessment of cumulative impacts found that unacceptable impacts would be caused by the backfilling at South Tsing Yi and the mud dredging at CT9 alone and that, at many of the impacted sensitive receivers, mitigation of the Lamma Extension reclamation construction would not reduce the impacts to below acceptable levels. Mitigation of the Lamma Extension reclamation was found to be only necessary if the monitoring programme was able to attribute any exceedences of the WQOs to the reclamation construction, and not to the cumulative projects.

Mitigation of Environmental Impacts

The conclusion from the hydrodynamic assessment was that the reclamations for the Lamma Extension and the WEIF would not significantly alter hydrodynamic conditions, including the flushing of Hung Shing Ye Bay. This means that changes in water quality in Hung Shing Ye Bay would not be adversely affected due to reduced flushing rates and so no specific mitigation measures would be required. However, it is recommended that no pollutants be allowed to enter into the bay as a result of the construction of the Lamma Extension reclamation and this may be achieved by diverting all storm drains to the western side of reclamation. This measure should be enforced during both the construction and operation phases of the Lamma Extension.

Mitigation for the dredging and filling for the reclamation will take two main forms: operational constraints and general plant maintenance and working methods. Operational constraints are discussed above, which specify the maximum rates of working and the potential concurrent activities which may be allowed.

To augment the operational constraints (mitigation measures) given above, additional constraints may be applied as further mitigation measures should unacceptable impacts be detected by the EM&A programme during the course of the project. Potential additional mitigation measures, to be implemented through the EM&A programme represent general plant maintenance and working methods and are detailed in *Section 5.4.2*.

With implementation of the operationally-based and general plant maintenance and working methods as mitigation measures, potential water quality impacts associated with proposed reclamation construction operations at the power station reclamation will be minimised to levels that are not predicted to cause unacceptable impacts to identified sensitive receivers.

Cumulative impacts have also been assessed. However, for the majority of the impacts which were predicted mitigation of the Lamma Extension construction would not lead to acceptable concentrations at the sensitive receivers. It would therefore be the responsibility of the other project to employ mitigation measures. The responsibility for employing mitigation measures will be determined through monitoring and the implementation of such measures would be determined through coordination between the different concurrent projects. Potential mitigation measures for the Lamma Extension site are the same as those discussed above.

The EM&A programme, outlined below in *Section 5.6*, is designed to determine whether unacceptable impacts are occurring and to determine whether these impacts are attributable to the power station extension reclamation construction. This attribution is achieved through the location of control stations to account for potential external contributions from other projects to observed impacts and through the specification of Action and Limit Levels with reference to control station values. The EM&A programme thus provides the mechanism for determining whether the Lamma Extension construction is contributing to cumulative impacts at sensitive receivers.

Should unacceptable impacts be observed in the EM&A programme, and these impacts be attributable (solely or partially) to the reclamation, the operationally-based mitigation measures described above should be implemented in accordance with the Event and Action Plan in the EM&A Manual. It is recommended that in the case of cumulative impacts arising from the power station extension reclamation and another project, the party responsible for the other project be consulted to coordinate implementation of joint or compatible mitigation measures. As described in the EM&A Manual's Event and Action Plan, the effectiveness of the implemented mitigation measures for the power station extension reclamation construction should be assessed and adjusted if necessary.

Environmental Monitoring and Audit

An Environmental Monitoring and Audit programme has been specified to monitor and control the impacts from the construction of the power station extension reclamation. Part of the Environmental Monitoring and Audit programme involves the implementation of mitigation measures to control any unacceptable impacts.

5.7.2 *Operational Phase*

The aspects of the operation of the power station extension which have been considered in the water quality assessment are as follows:

- the dispersion of heated water from the cooling system;
- the dispersion of residual chlorine in the cooling water discharge; and
- the potential for changes to occur to the sedimentation regime of the area around the power station extension.

The dispersion of heated water and residual chlorine were assessed using computer modelling. The potential for changes to the sedimentation regime was assessed qualitatively, using the results of the hydrodynamic modelling from the construction phase assessment.

Thermal Discharge

The thermal discharge from the existing power station, Scenario 1, and from the combined cycle operation of the new power station, Scenario 2, were modelled. In the dry season it was found that the size of the plume of heated water would reduce in the dry season. In the wet season it was found that the size of the plume decreased from Scenario 1 and that the plume was positioned further offshore of the coast of Lamma Island. It was further found that the thermal plume for Scenario 2 did not touch the coast of Lamma Island. The thermal discharge from the new power station extension was assessed to be environmentally acceptable.

Cumulative impacts arising from the thermal discharge from the WEIF were also considered. In the dry season the results from this showed a smaller thermal plume than for Scenario 2, which was likely due to small changes in the tidal currents patterns caused by the WEIF reclamation. In the wet season the size of the plume was similar to that for Scenario 1 but was positioned even further offshore than the plume for Scenario 2. The impacts from this cumulative scenario were also found to be environmentally acceptable.

Chlorine Dispersion

The dispersion of residual chlorine from the new power station and the WEIF was simulated using computer modelling. A discharge concentration for residual chlorine of 0.3 mg L^{-1} was originally selected for the Lamma Extension and WEIF as this concentration has been identified as the lowest value which can currently be achieved. A further simulation using a discharge concentration of 0.2 mg L^{-1} was also simulated to examine the sensitivity of the results to the discharge concentration and represented a concentration which may achieved in the future, subject to performance verification by HEC. The discharge for the existing power station was set to 0.3 mg L^{-1} which represented the lowest concentration which could be effectively maintained. It should be noted that this concentration is less than the allowable discharge concentration of 0.5 mg L^{-1}.

The computer modelling used the conservative assumption that the residual chlorine would decay at the same rate as was measured in the cooling water system which in reality would not be the case due to the high chlorine demand of the receiving waters because of reactions with organic matter, dissolved gases and inorganic salts. The assumed decay rate was indeed found to be conservative when compared with a decay rate measured in HEC's HOKLAS laboratory. An assessment value of 0.01 mg L^{-1} was used and this value represented the level which EPD consider to be a cause for concern in the marine environment.

The chlorine dispersion modelling for the 0.3 mg L^{-1} chlorine discharge from the Lamma Extension and WEIF predicted that within an area approximately 700 metres seaward of the existing outfall and extending southwards 1,500 metres to the southern Lamma Extension outfall the concentrations of residual chlorine would reduce to below 0.01 mg L^{-1}. The impacts to water quality would thus be localised to the outfalls and not impact upon any sensitive areas and as such were determined to be environmentally acceptable. The results from the simulations with discharges for 0.2 mg L^{-1} for the Lamma Extension and WEIF showed the same plume at 0.01 mg L^{-1} from the existing power station extending 700 metres offshore because the discharge was the same for both scenarios. The extent of the plume from the Lamma Extension and WEIF was only slightly reduced. Overall the impacts with a discharge concentration of 0.2 mg L^{-1} for the Lamma Extension and WEIF showed only small reduction in the size of the area impacted by the 0.01 mg L^{-1} contour when compared the simulation for a discharge of 0.3 mg L^{-1}.

Sedimentation Assessment

A qualitative assessment of the likely impacts of the power station operation on sediment erosion and deposition was carried out. The assessment concluded that the power station operation would not cause the natural patterns of erosion and deposition of the sea bed to change.

Mitigation of Environmental Impacts

No adverse environmental impacts were predicted to occur as a result of the thermal discharges from the Lamma Extension project. As such no mitigation measures are considered necessary. Predicted impacts will be verified during Environmental Monitoring and Audit of the operational stage.

As stated above, the Lamma Extension cooling water outfalls will be designed to minimise foam formation. If foam is till found to form then additional measures would be taken to prevent the foam spreading beyond the immediate vicinity of the outfalls. Such measures would involve the use of floating booms, similar to those used to contain oil spills.

The modelling of the dispersion of chlorine from the power station extension combined with the WEIF predicted that an area extending approximately 700 m offshore from the discharge point of the existing power station would experience residual chlorine concentrations in excess of 0.01 mg L^{-1}. The localised nature of the predicted elevations in chlorine concentrations would mean that the discharge would not cause unacceptable environmental impacts as no sensitive areas would be impacted and so no mitigation measures would be required. The modelling predictions will be confirmed during EM&A, which will monitor residual chlorine.

It was concluded that no changes to the sedimentation regime would occur as a result of the construction of either the Lamma Extension reclamation or the WEIF reclamation and so no mitigation measures are required.

Environmental Monitoring and Audit

An Environmental Monitoring and Audit programme was devised to measure water temperature and residual chlorine and determine the exact size of the thermal and chlorine plumes during operation of the power station extension.