Annex E

Hydrodynamic and Sediment Plume Modelling for Reclamation at Yau Tong

TABLE OF CONTENTS

1 INTRODUCTION 1-1

2 HYDRODYNAMIC MODELLING OF YAU TONG BAY 2-1

3 HYDRODYNAMIC IMPACTS OF THE WESTERN COAST ROAD 3-1

3.1 Modelling results 3-1

3.2 On the effect of the culverts in the submerged reef 3-5

4 DEFINITION OF MARINE DREDGING AND FILLING SCENARIO 4-1

5 SIMULATION OF MARINE EARTHWORKS 5-1

6 IMPACTS FROM MARINE EARTHWORKS 6-1

7 REFERENCES 7-1

1 INTRODUCTION

The present document reports on the hydrodynamical impacts of the Western Coast Road (WCR), see Fig. 1.1, and the impacts of the marine earthworks in connection with construction of the Western Coast Road. The work has been carried out by the Danish Hydraulic Institute (DHI) under a subcontract dated 14 April 1998 with Maunsell Consultants Asia Limited (MCAL) for the Territory Development Department (TDD) of the Hong Kong Government.

The scope of the work was defined in a proposal from DHI faxed to ERM on 14 April 1998.

Results have been submitted to ERM during the course of the work. ERM is responsible for the Environmental Impact Assessment for the WCR.

The present report serves as final documentation of the simulations.

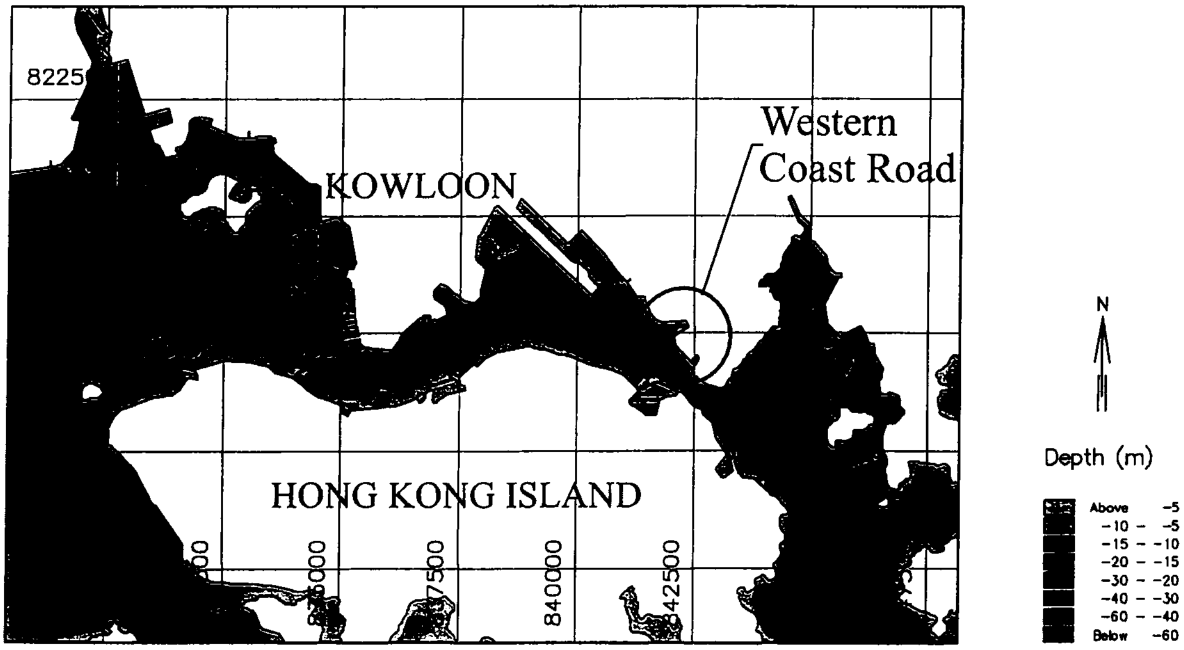


Fig. 1.1 *Western Coast Road project area. The dark green areas represent areas to be reclamed or that have been reclamed.*

2 HYDRODYNAMIC MODELLING OF YAU TONG BAY

The hydrodynamical impact of the planned design of the Western Coast Road is assessed using DHI's dynamically coupled 3-D model, MIKE 3 Nested HD. The nested model consists of a 75 m model covering the eastern approaches of Victoria Harbour, and a 25 m model in the area around Yau Tong Bay, see Figure 2.1. The assessment is based on model runs for two periods around spring and neap tide during the wet season. The two periods cover 3 days each which are preceded by warm-up periods of 1.5 days.

The model boundaries are supplied from a large 3-D nested model set-up consisting of a 675 m model, a 225 m model, and two 75 models. This set-up, which is shown in Fig. 2.2, was calibrated and used in the SEKDS, see ref. /1/. Thus, no further calibration has been necessary. In the SEKDS Cumulative Effects Study, ref. /5/, a set of development scenarios were considered. The scenario representing the expected situation in 2001, scenario 1 - Existing and Committed Projects, was chosen as a reference situation to gauge the effects of the WCR on the conditions in Yau Tong Bay.

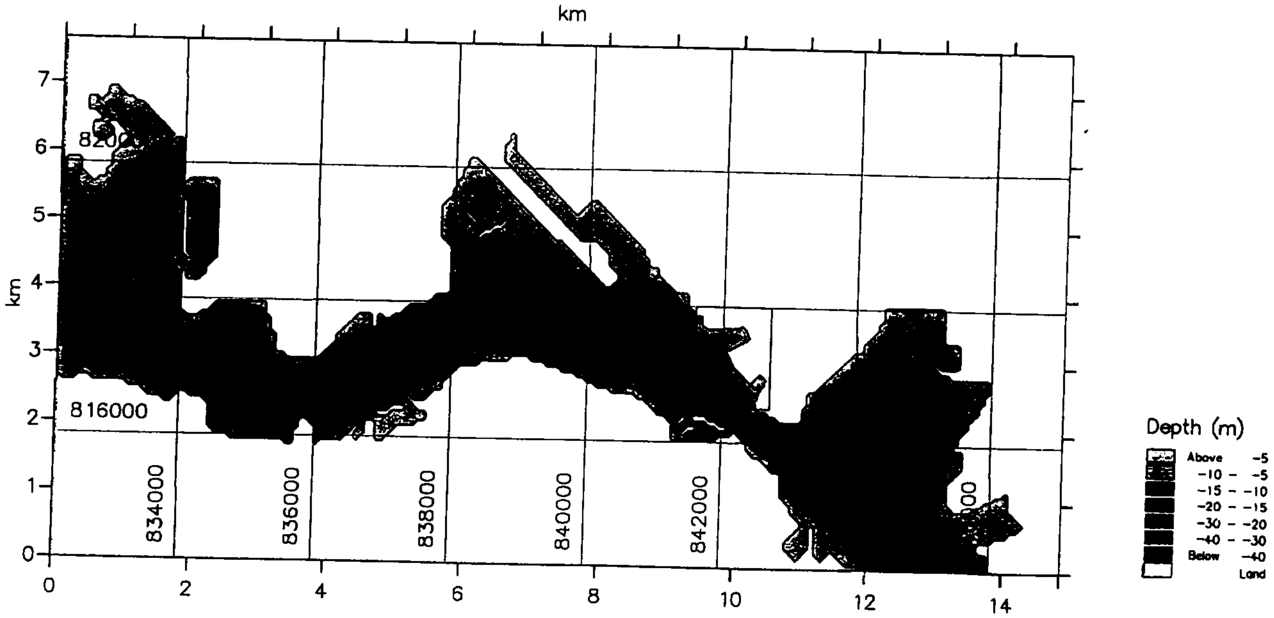


Fig. 2.1 Bathymetry of the coupled 75 m/25 m model used to assess the impact of the Western Coast Road on the water exchange from Yau Tong Bay.

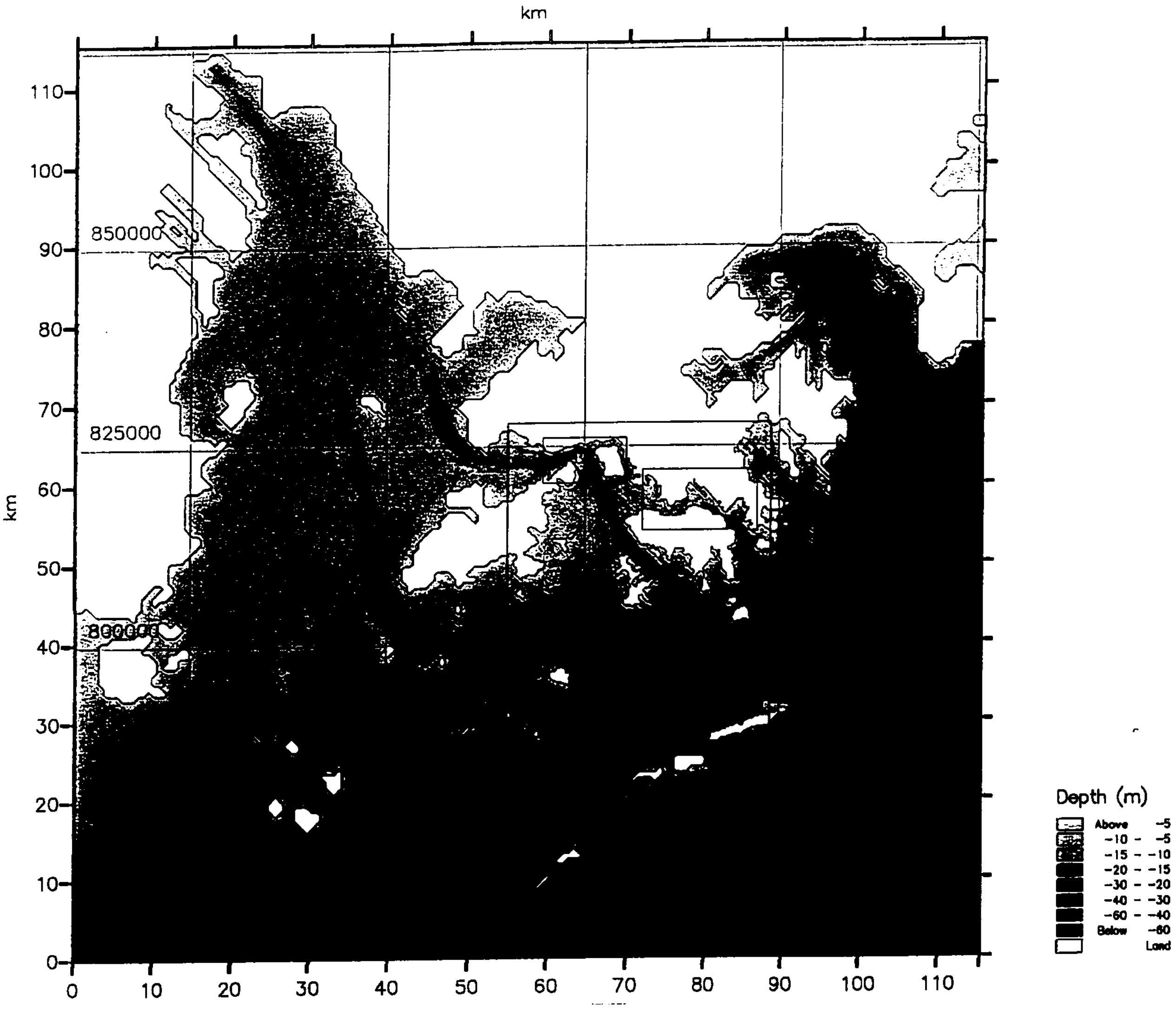


Fig. 2.2 The large 3-D nested model set-up (675 m/225 m/two 75 m models) that has provided boundary conditions for the model set-up around Yau Tong Bay.

The effect of the Western Coast Road is assessed in terms of the change of the water exchange from Yau Tong Bay as the planned design is implemented in the 25 m model. The planned design consists of the following elements:

- a reclaimed area of approximately 800 m by 100 m along the dock from Yau Tong Bay to the north to the Sam Ka Tsuen Ferry Pier to the south,
- a submerged reef extending about 200 m towards north-east from the outer edge of the reclaimed area. A total of 14 pipe culverts with a diameter of 2.5 m are set 15 m apart across the reef to increase the water exchange,
- bridge piers across the outer part of Yau Tong Bay, and an about 400 m long line of protective dolphins located between the submerged reef and the bridge alignment.

Some of these features are shown in Fig. 2.3.

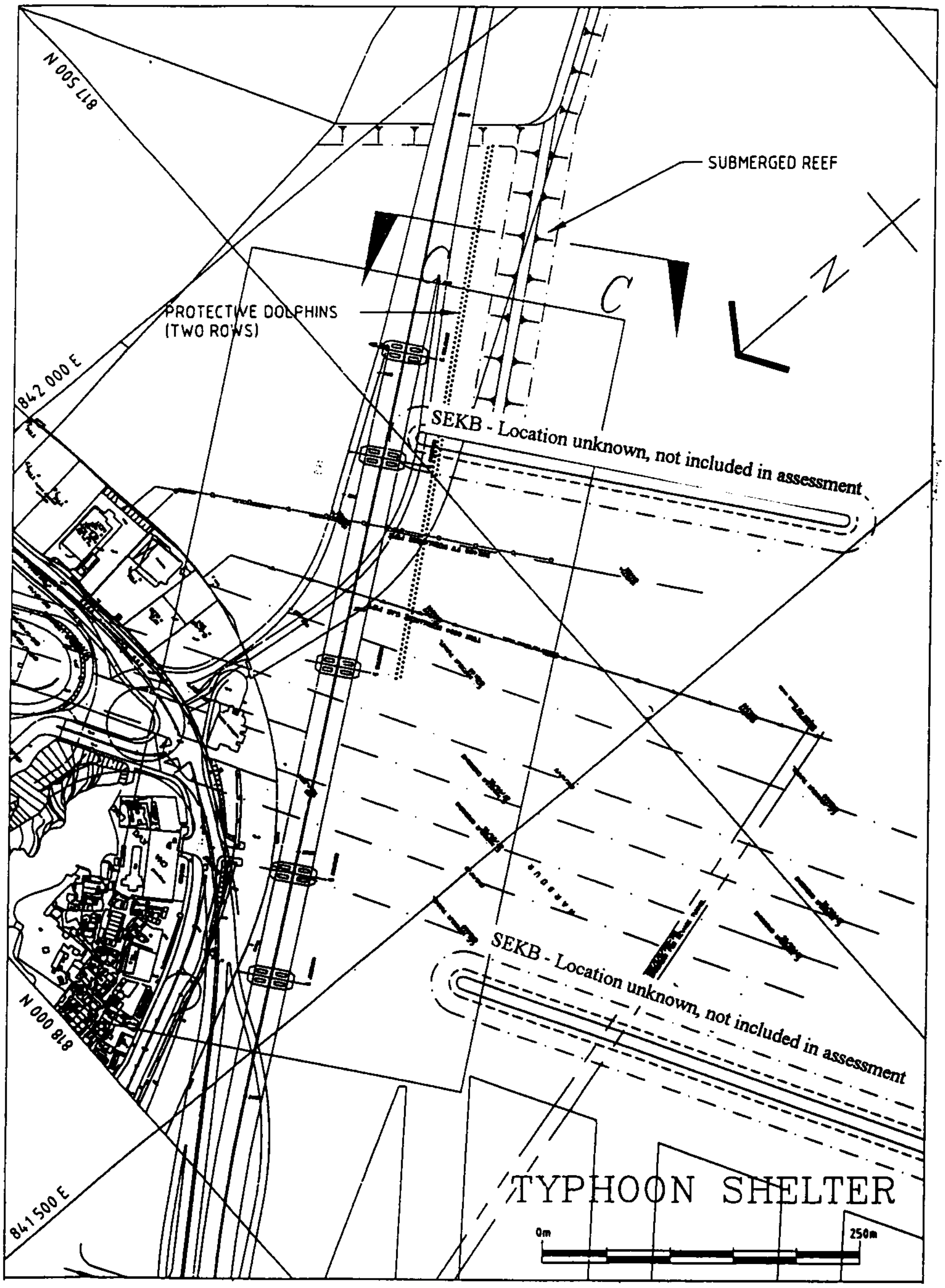


Fig. 2.3 Sketch showing the planned design of the Western Coast Road.

The two former elements are implemented in the model by changing the bathymetry. Bridge piers and dolphins are implemented via descriptions that parameterize their resistances as functions of flow speed and alignment relative to the current. Appropriate friction factors, c_D, have been taking from ref. /2/.

However, due to the horizontal and the vertical gridspacings of the model it is not possible to include the culverts into the model directly. Therefore, the effects of including the culverts are discussed separately in Section 3.2.

The bathymetry of the 25 m model around Yau Tong Bay is shown in Fig. 2.4; panel a and b show the situation before and after implementing the planned design of the Western Coast Road.

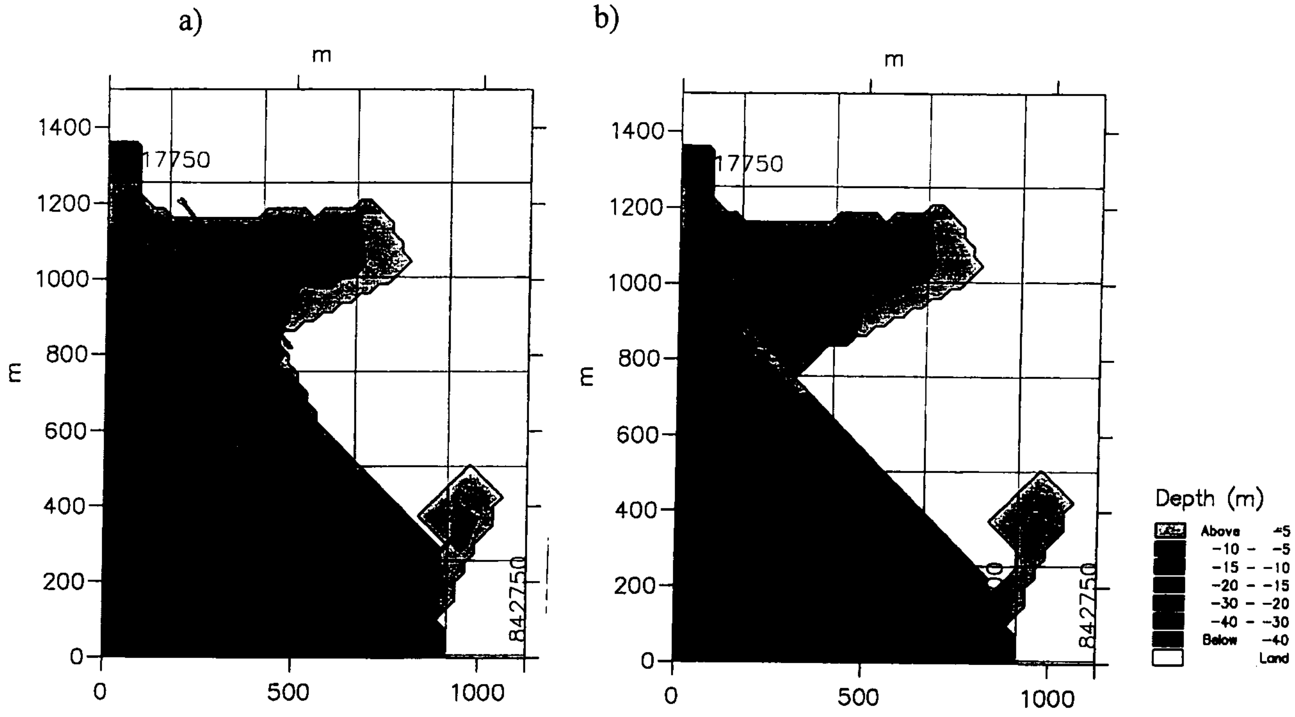


Fig. 2.4 *The bathymetry of the 25 m model around Yau Tong Bay a) before and b) after implementing the planned design of the Western Coast Road. The cross section through which the discharge has been calculated is shown in a).*

3 HYDRODYNAMIC IMPACTS OF THE WESTERN COAST ROAD

The hydrodynamical impact of the Western Coast Road is assessed in terms of the water exchange through a cross section along the outer edge of Yau Tong Bay, see Fig. 2.4.

3.1 Modelling results

The results for the spring time period and neap time period are shown in Figs. 3.1 and 3.2, respectively; the black curves show the computed discharge in the reference situation whereas the red curves show the discharge when the planned design of the Western Coast Road has been implemented in the model. Positive values indicate flow out of Yau Tong Bay.

From Figs. 3.1 and 3.2 it appears how the strong tidal flow in the harbour is well reflected in the water exchange of Yau Tong Bay. Because of the small extent of the bay the maximum discharge occurs when the tidal wave is either rising or falling abruptly. Accordingly, the tidally induced flows in the harbour are almost at their maximum when the discharge out of Yau Tong Bay is close to zero.

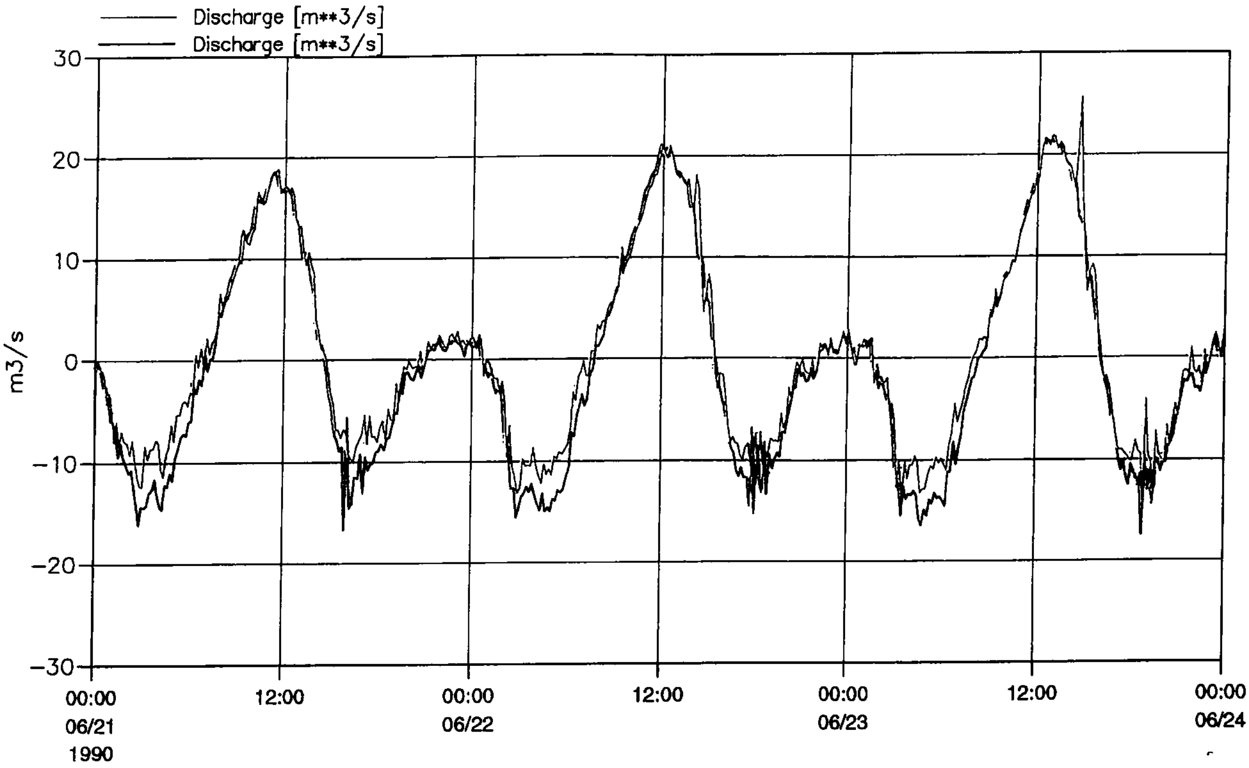


Fig. 3.1 *Computed discharge to and from Yau Tong Bay during spring tide. Positive values indicate flow out of the bay. The black curve shows the discharge in the reference situation, whereas the red curve is the discharge when the planned Western Coast Road design is implemented in the model.*

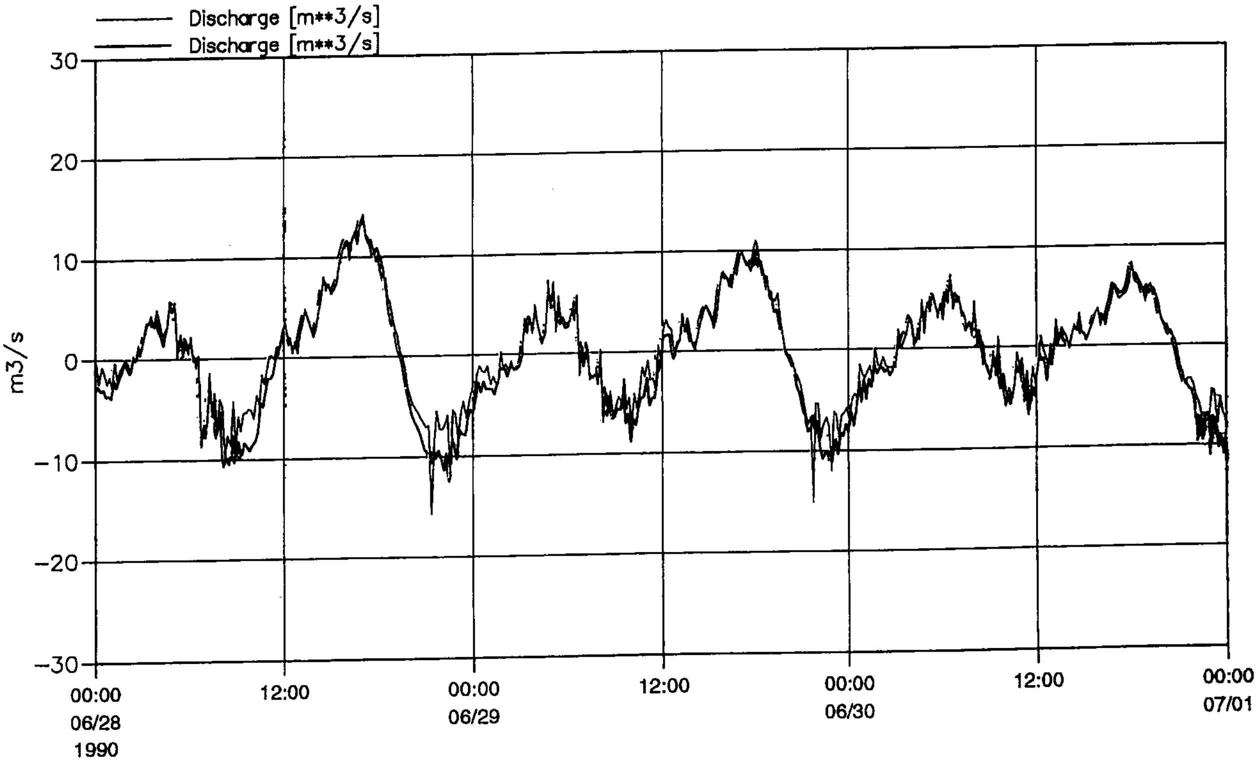
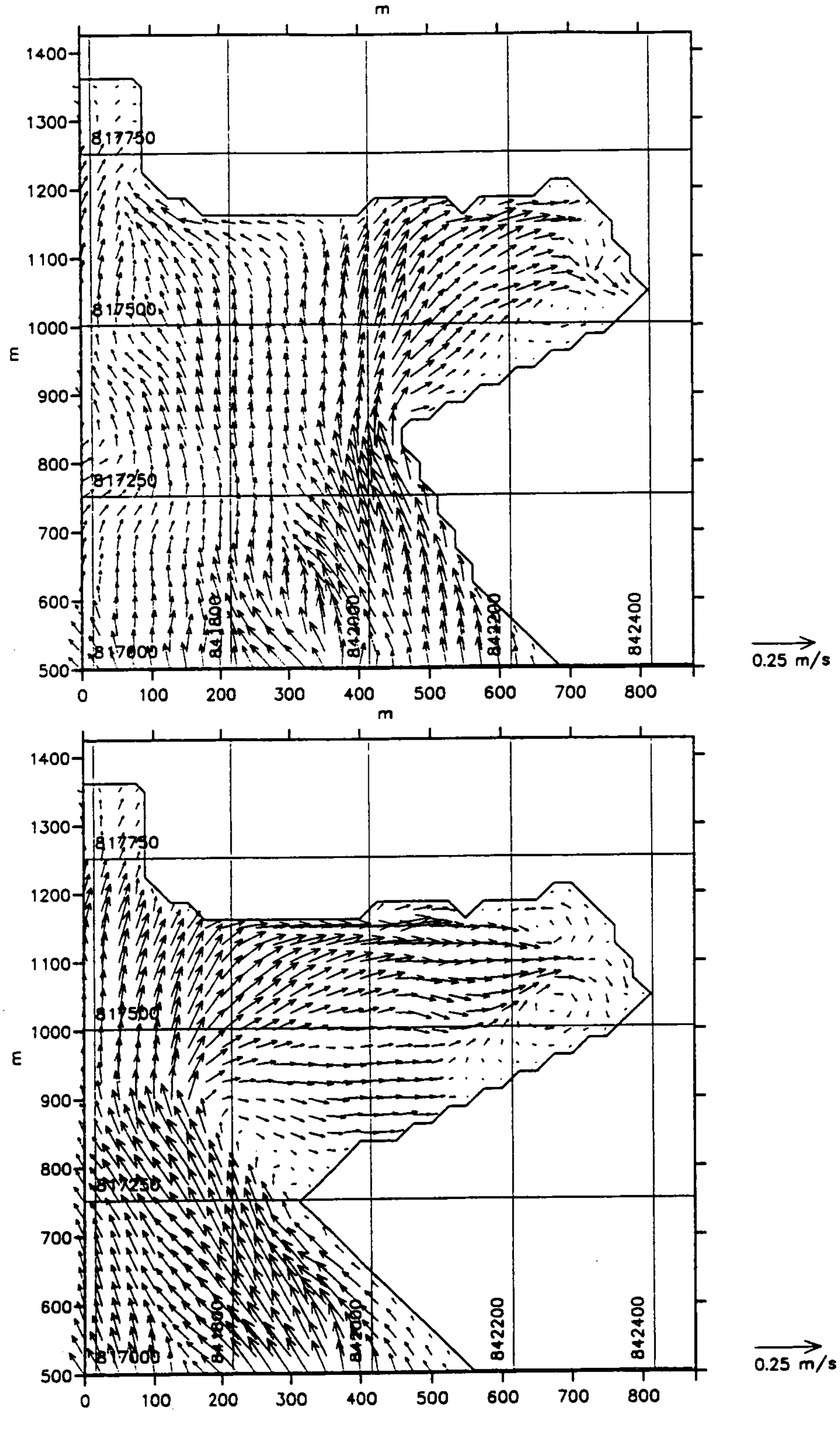


Fig. 3.2 *Computed discharge to and from Yau Tong Bay during neap tide. See also caption of Fig. 3.1.*

It also appears how the flow to and from Yau Tong Bay is associated with fairly large fluctuations on a small temporal scale; this applies to the situation before as well as after inclusion of the Western Coast Road design. These fluctuations are caused by eddies at the outer edge of the bay. It is seen that the fluctuations are somewhat larger when the Western Coast Road design is implemented, and this shows that the eddy field is changed by the constructions. There are mainly two reasons for this: The reclaimed area is responsible for higher velocities just outside the bay; and the presence of the submerged reef and the long row of protective dolphins have a tendency to concentrate the exchange of water to the northern part of the bay. These circumstances can be seen in Fig. 3.3, which shows an example of the instantaneous flow field without and with the Western Coast Road design.



1990/06/29 21:40:00

Fig.3.3 Instantaneous picture of velocity vectors in and around Yau Tong Bay during neap flood. Panel a) is the reference situation, whereas b) shows the effect of implementing the planned design of the Western Coast Road.

The results of the simulations are summarized in Table 3.1; this gives integrated values over the simulation periods of the absolute discharge in or out of Yau Tong Bay. It appears that the Western Coast Road reduces the integrated discharge by 11.4 % during spring tide and 12.9 % during neap tide.

Table 3.1 Integrated values over the whole simulation periods of the absolute discharge in or out of Yau Tong Bay, and the change caused by the Western Coast Road.

	Spring period	Neap period
SEKDS Scenario A1 (m^3)	2,203,812	1,215,103
SEKDS A1 with WCR (m^3)	1,951,889	1,058,833
Change (%)	- 11.4	- 12.9

The results of the simulations show that the planned Western Coast Road design has an effect on the local hydrodynamics in terms of the local flow pattern as well as the water exchange of Yau Tong Bay.

3.2 On the effect of the culverts in the submerged reef

Because of the horizontal and the vertical gridspacings of the model it has not been possible to include the culverts directly. Therefore, the modelling results discussed in Section 3.1 do not reflect the exchange of water through the culverts. Furthermore, due to the fact that the culverts will change the pressure conditions locally around the reef, it is not possible to use the modelling results to assess the effect of the culverts. However, an order of magnitude estimate of the effects of the culverts can be obtained by considering the ratio of the cross-sectional area of the culverts to the total cross-sectional flow area.

With the planned design of the Western Coast Road the cross-sectional flow area between Yau Tong Bay and the harbour outside amounts to roughly 2,500 m^2. The cross-sectional flow area of the culverts is 69 m^2 or just under 3 % of the total flow area. However, as the flow through the culverts will experience a relatively high friction this part of the flow will constitute significantly less than 3 % of the total flow. The high friction in the culverts is caused by the narrowness of the pipes and the fact that developing boundary layers will be a prominent part of the flow pattern in the pipes.

The above estimate of the distribution of flow is made under the assumption of steady flow conditions. In case of highly variable flows as the ones actually taking place in the tidally influenced harbour, a reduced amplitude of velocity as well as a phase shift must be expected. These circumstances imply that the expectations of the effect of the culverts on the water exchange should be reduced.

Furthermore, it should be noted that the exact design of the culverts in the submerged reef will be of importance for the throughflow. E.g., it is possible that flow adjustments around the mouths of the pipes will induce local pressure changes that will draw or push water through the pipes depending on the flow in the harbour. Therefore, the magnitude of the culvert flow given above can only be taken as a rough estimate.

Although the estimate of the culvert flow arrives at a value which is significantly less than 3 % of the total flow, it should be stressed that a good measure can only be obtained by physical model tests. Such tests will be able to take into account the actual design of the project as well as the complicated small-scale flow patterns. Accordingly, the above calculations cannot be used to design details of the culvert solution.

4 DEFINITION OF MARINE DREDGING AND FILLING SCENARIO

The construction of the planned design of the Western Coast Road is associated with marine earthworks that potentially will cause suspended sediments to spread in the harbour. The worst case scenario is assumed to be the concurrent dredging and filling of the seawall trench, prior to the formation of the seawall; this is because the lack of seawall protection offers the greatest potential for sediment plume dispersal. Based on the assumption that the sediment spill for the two operations amounts to 1.8 %, the sediment sources are as follows:

Dredging for seawall trench	
Volume to be removed	227,050 m^3
Completion time	4 months
Daily rate	1,892 m^3/day
Dry density of harbour mud	1400 kg/m^3
Spill rate during dredging	0.828 kg/s
Filling of seawall trench	
Volume to be installed	162,010 m^3
Completion time	6 months
Daily rate	900 m^3/s
Dry density of filling sand	1800 kg/m^3
Spill rate during filling	0.506 kg/s

Sediment characteristics from a previous study (ref. /3/) have been used. Furthermore, it is assumed that the work takes place 16 hours per day, and that it is carried out using grab dredgers. The latter implies that the spill during dredging and filling takes place at a continuous rate.

5 SIMULATION OF MARINE EARTHWORKS

A nested version of the MIKE 3 Particle Model, ref. /4/, has been used for simulation of suspended sediment plumes arising from the marine earthwork operations described in Chapter 4. The Particle Model used a MIKE 3 Nested 225 m/75 m model set-up which has been run for the same two periods as described in Chapter 2. Boundary conditions for this model set-up was provided by the large model set-up shown in Fig. 2.2. The simulation periods which cover spring and neap tide have durations of 3 days, and they are preceded by 1.5 days of warming up.

The MIKE 3 Particle Model is based on an Lagrangian approach, where the dispersed matter is represented by a large number of small particles which are released at the working sites over time. The movement of each particle is affected by the hydraulic processes described in the underlaying hydrodynamic model.

Once the particles are released in the water body, their discrete path and mass are followed and recorded as function of time relative to the reference grid system fixed in space. The density distribution of the particles then represents the concentration of the dispersed matter.

The advection of surface matter is caused by the combined effects of surface current and wind drag. The advection of subsurface matter follows the movement of the subsurface flow. The particles diffuse randomly in the horizontal and vertical directions.

Particles representing suspended material settles with a specified gravitational settling velocity which is affected by ambient turbulence in the water.

A particle which has settled on the seabed may be resuspended, if the flow velocity and the accompanying bed shear stress is larger than the bed shear strength.

The use of the nested version of the MIKE 3 Particle Model reduced the loss of sediment through the model boundaries to a minimum.

Based on a well calibrated hydrodynamic current model, the MIKE 3 Particle Model is able to simulate the fate of dredging spoils, taking an average fall velocity of the suspended sediment particles into account.

The main coefficients govering the physical process rates in the Particle Model are the dispersion coefficients and bottom roughness. These coefficients, which completely define the dispersion of matter and consequently the simulated results, have been taken from similar work carried out as a part of the SEKDS, ref. /3/. It is emphasized that the quality of the current fields, the hydrodynamic HD basis, is of primary importance to the suspended sediment plumes; calibration and validation of the present HD basis can be found in ref. /1/.

To simulate the marine earthworks described in Chapter 4 the sediments have been released at a location at about the middle of the area to be reclaimed.

6 IMPACTS FROM MARINE EARTHWORKS

The results of the sediment plume modelling are presented in Figs. 6.1 and 6.2 which give the depth-averaged concentration of suspended sediment at three locations in and around Yau Tong Bay. The black and red curves show the conditions at two locations in Yau Tong Bay; these are Dairy Ice Farm Factory Seawater Intake and Cha Kwo Ling Saltwater Pumping Station Intake, respectively. The green curves show the conditions at Yau Tong WSD Saltwater Pumping Station Intake which is located at about the middle of the area to be reclaimed in connection with construction of the Western Coast Road. These three locations are shown in Fig. 6.3. Units of concentration of suspended sediment are kg/m^3 which equals 10^3 mg/l.

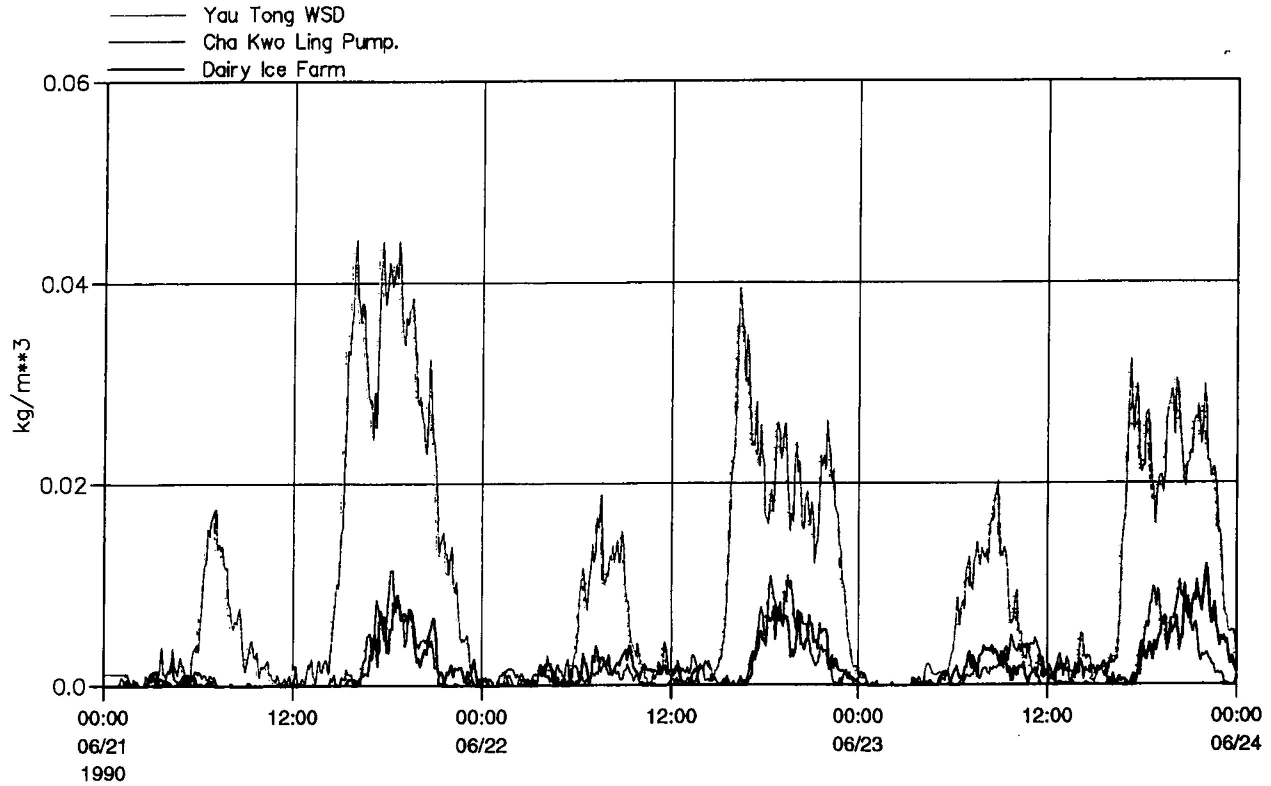


Fig. 6.1 *Computed depth-averaged concentrations of suspended sediment from the marine earthworks during spring tide. The black and red curves indicate the concentrations at two locations in Yau Tong Bay; these are Dairy Ice Farm Factory Seawater Intake and Cha Kwo Ling Saltwater Pumping Station Intake, respectively. The green curve shows the conditions at Yau Tong WSD Saltwater Pumping Station Intake.*

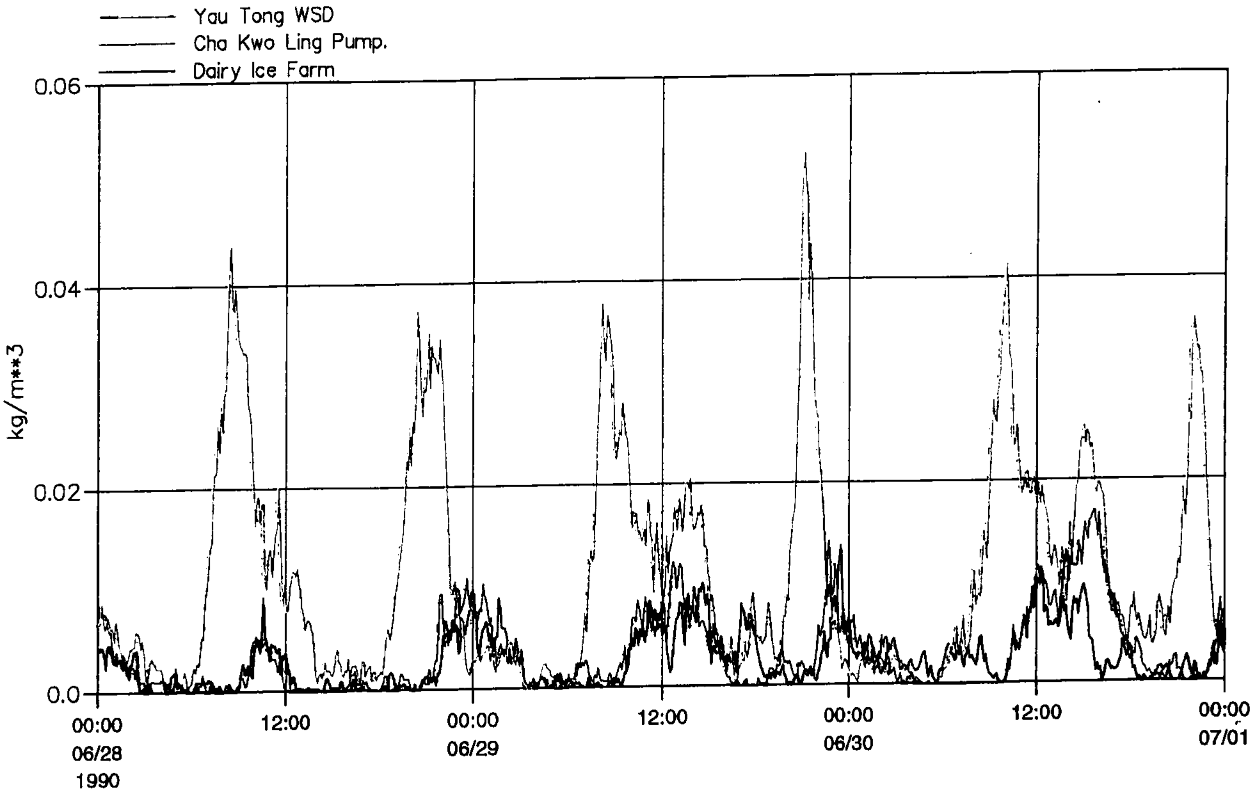


Fig. 6.2 *Computed depth-averaged concentrations of suspended sediment from the marine earthworks during neap tide. See also caption of Fig. 6.1.*

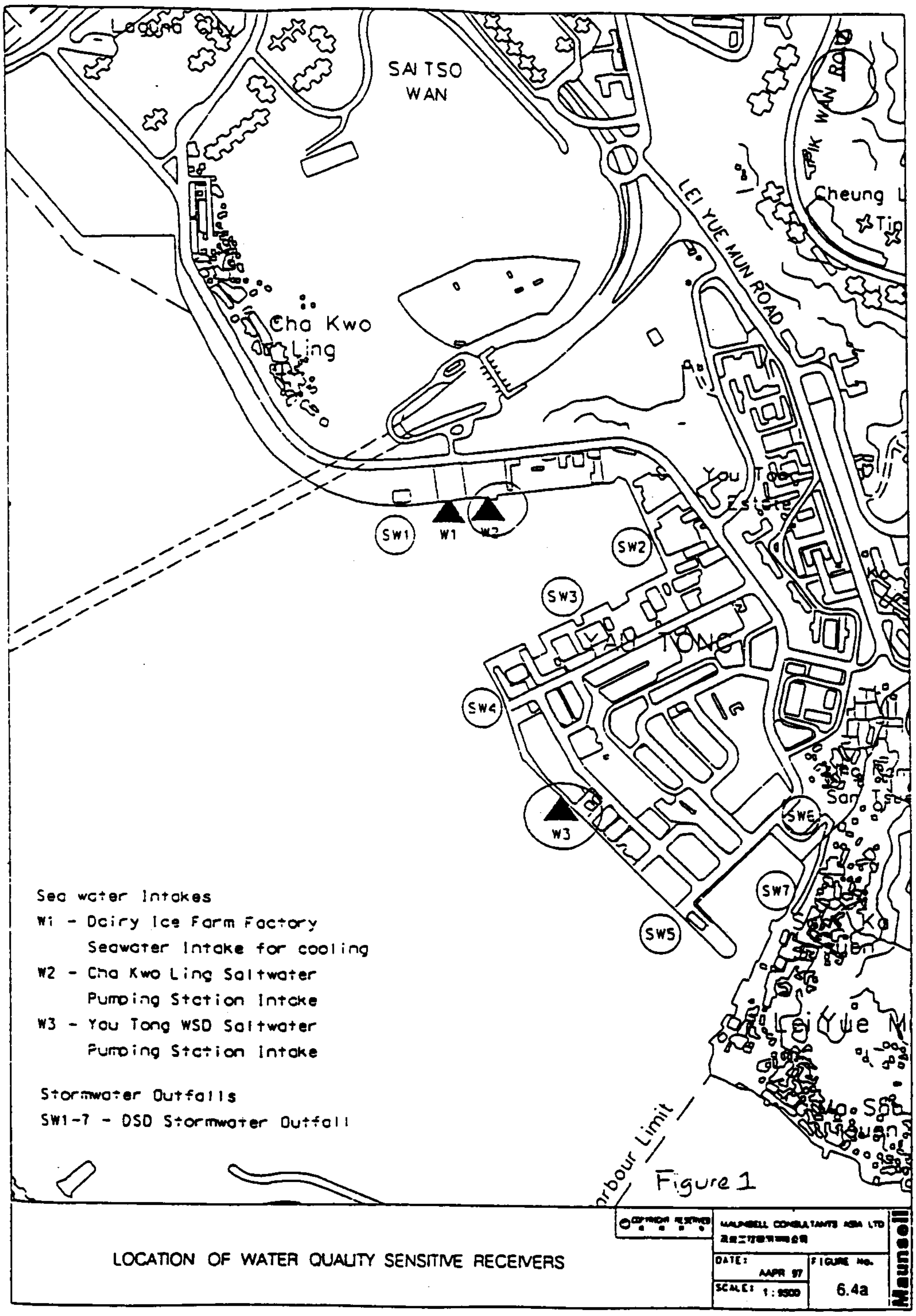


Fig. 6.3 Sketch showing the locations of the three sea water intakes in and around Yau Tong Bay.

It should be noted that the results give the concentration of suspended sediment from the dredged and filled materials only. To obtain values as they are actually observed one has to add the background concentration of suspended sediment which is in the range from 1 to 25 mg/l during the wet season (ref. /3/).

From the results it appears how the incidents of high sediment concentrations are connected to the course of the tidal flows in the harbour. I.e., when the tidal wave is rising, the sediment is carried towards north-west giving high concentrations at the three study sites. Accordingly, sediment concentrations are low when the tidal flow is towards south-east. These conditions apply to the periods around spring as well as neap tide.

However, during spring tide the peaks of sediment concentration appear to be a little lower than what is seen during neap tide. This is attributed to the fact that higher velocities during spring tide provide a faster spreading of the sediment from the work areas. Accordingly, the spring tide is associated with relative high sediment concentrations for longer periods than what is the case for neap tide.

The results of the sediment plume modelling are summarized in Table 6.1 which gives the mean and the maximum concentrations of suspended sediments at three sea water intakes.

Table 6.1 Mean and maximum concentrations of suspended sediments at the three sea water intakes. Background concentrations are not included.

Location	Spring period		Neap period	
	Mean (mg/l)	Max (mg/l)	Mean (mg/l)	Max (mg/l)
Dairy Ice Farm Factory Seawater Intake	1.6	11.8	2.6	13.7
Cha Kwo Ling Saltwater Pumping Station Intake	1.7	11.4	3.1	17.0
Yau Tong WSD Saltwater Pumping Station Intake	9.9	44.3	11.0	52.4

The spreading of sediment from the working area is illustrated in Fig. 6.4 which gives a snapshot of the depth-averaged concentration of suspended sediment. The figure gives a good impression of the extent of the sediment plume in connection with a peak of the spring tidal flow in the harbour.

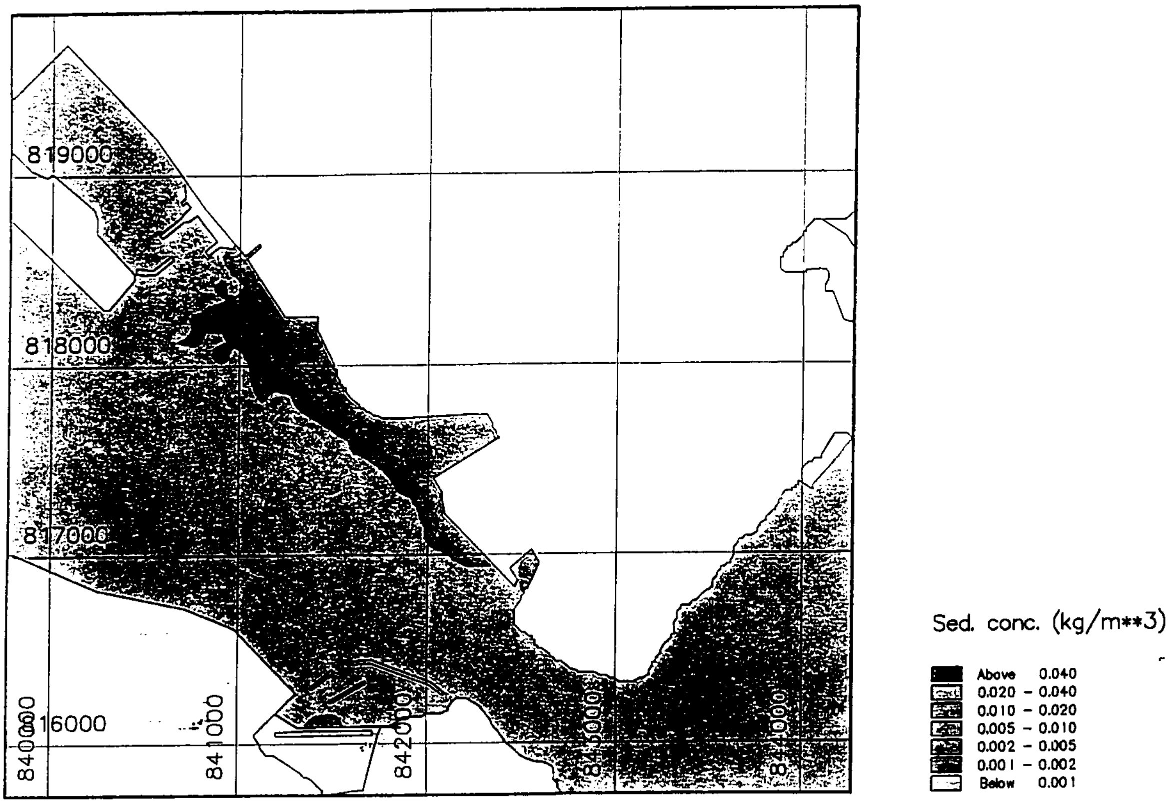


Fig. 6.4 *Instantaneous picture of the depth-averaged concentration of suspended sediment during peak flow of spring flood.*

7 REFERENCES

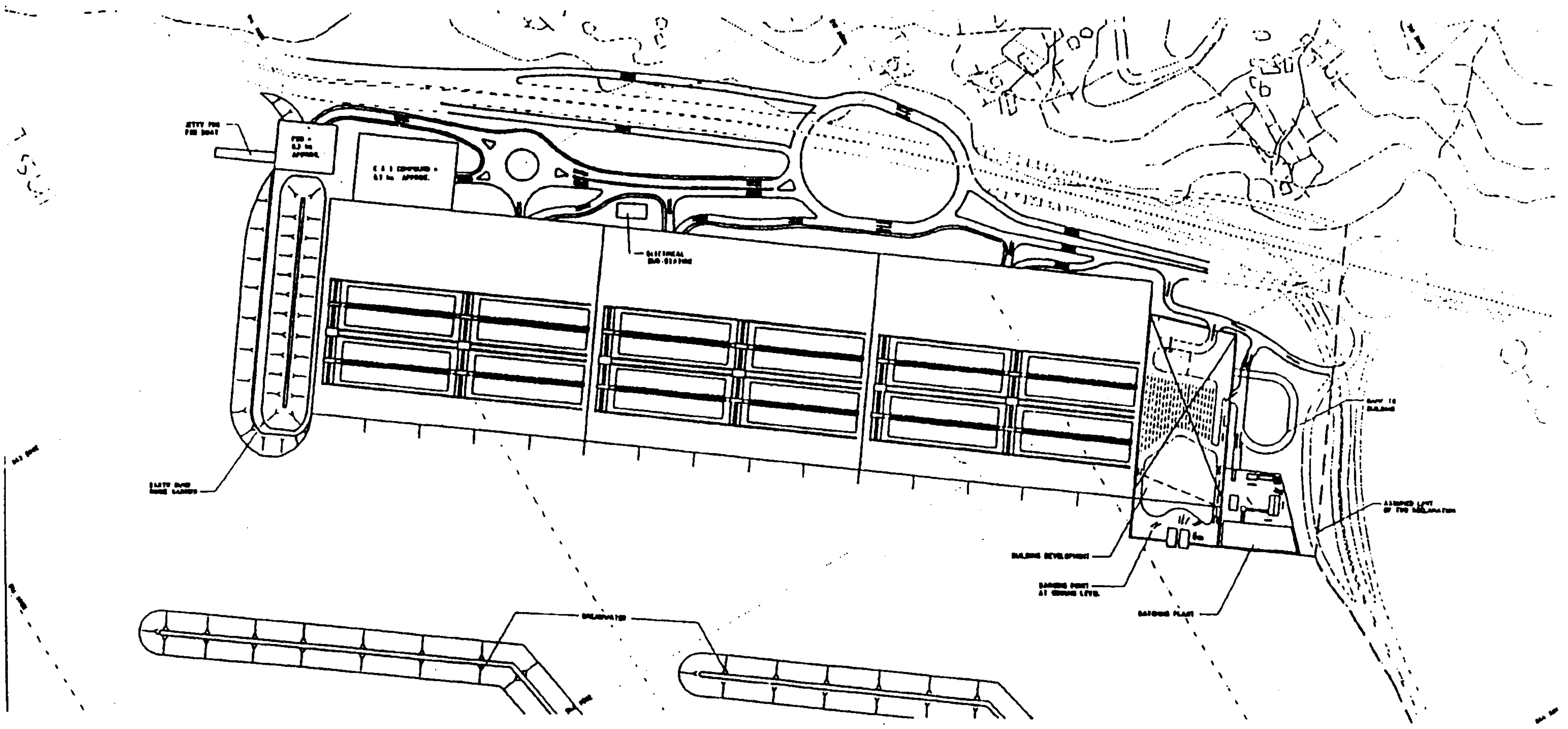
/1/ Feasibility Study for South East Kowloon Development. Technical Note N11. Additional Hydraulic Studies. Wet Season Calibration. Final Report. Maunsell Consultants Asia Ltd., Oct. 97.

/2/ Blevins, R. D., Applied Fluid Dynamics Handbook, Van Nostrand Reinhold, 1984.

/3/ Feasibility Study for South East Kowloon Development. Technical Note N12. Modelling of Marine Dredging Operations. Draft Final Report. Maunsell Consultants Asia Ltd., Nov. 97.

/4/ Danish Hydraulic Institute: MIKE 3 Sediment Transport Modelling, MIKE 3 Particle Module, Edition 1.0, January 1997.

/5/ Feasibility Study for South East Kowloon Development. Technical Note N10. Cummulative Effects of Reclamation on Harbour Regime. Maunsell Consultants Asia Ltd., Sept. 1997.



TKO AREA 131 RECLAMATION LAYOUT

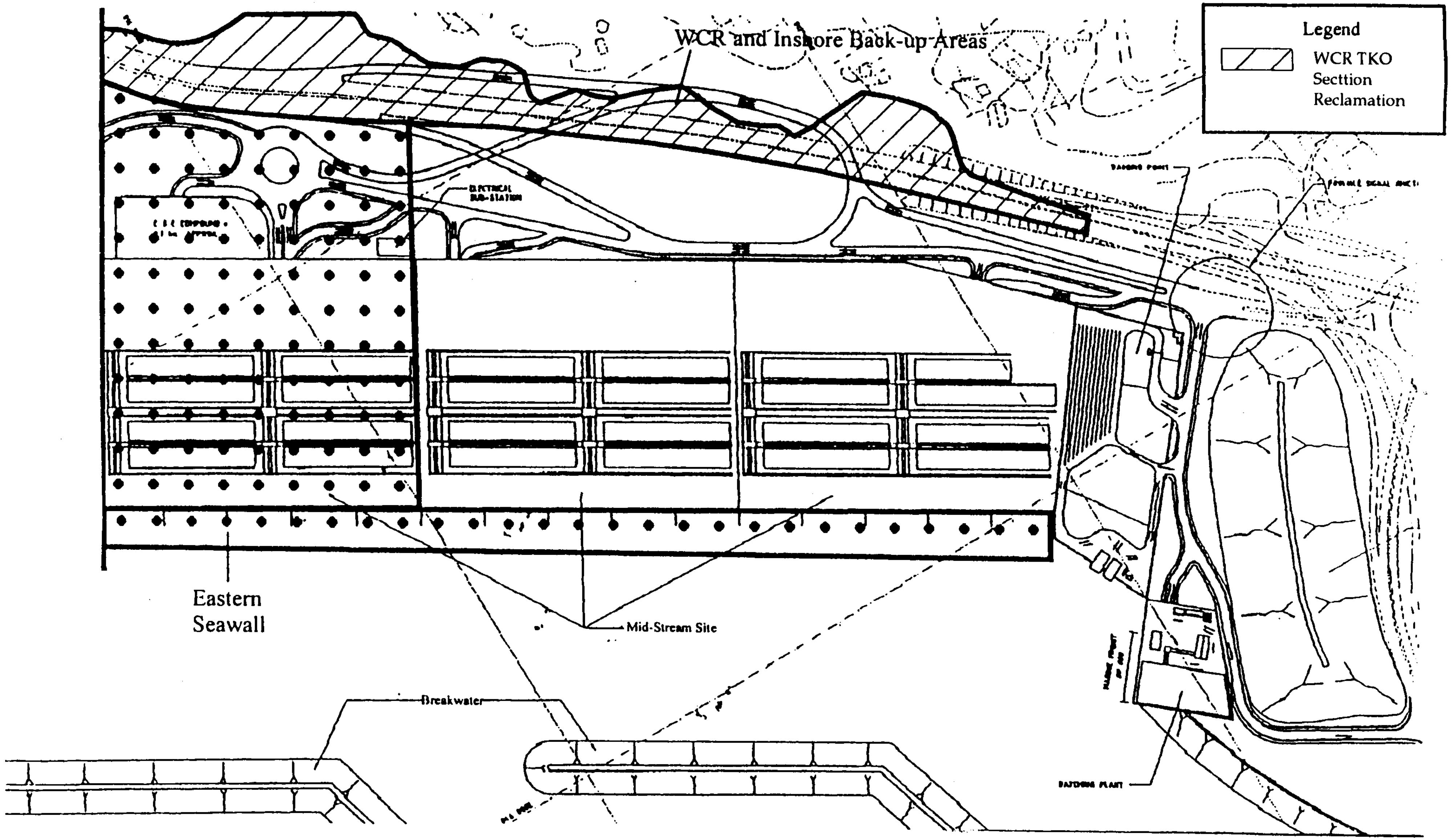
Source : *Feasibility Study for Tseung Kwan O Port Development at Area 131*, Draft Environmental Impact Assessment Report, East Territories East Development Office, Territory Development Department, May 1998.

FIGURE No.
A1.5a

SCALE:

DATE:
OCT 98

Maunsell



WCR TKO SECTION RECLAMATION

Source : *Feasibility Study for Tseung Kwan O Port Development at Area 131*, Draft Environmental Impact Assessment Report, East Territories East Development Office, Territory Development Department, May 1998.

FIGURE No. A1.5b	
SCALE:	DATE: OCT 98

Maunsell