FILL MANAGEMENT STUDY – PHASE II
INVESTIGATION AND DEVELOPMENT OF MARINE BORROW AREAS

EAST LAMMA CHANNEL BORROW AREA

SCOPED ENVIRONMENTAL ASSESSMENT

FINAL REPORT

JANUARY 1993

Binnie Consultants Limited

CIVIL ENGINEERING DEPARTMENT
GEOTECHNICAL ENGINEERING OFFICE

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EAST LAMMA CHANNEL BORROW AREA
SCOPED ENVIRONMENTAL ASSESSMENT
FINAL REPORT

EXECUTIVE SUMMARY

Introduction

A scoped assessment has been carried out of the potential environmental effects of developing a proposed borrow area located within East Lamma Channel (G.N. No. 2480 in Gazette No. 30, 19 July 1991). The study brief was agreed with the Environmental Study Management Group.

Scope of Assessment

The assessment involved a review of the planned project with respect to potential physical, socio-economic and ecological effects. The specific activities associated with dredging that were included in the assessment were seabed removal, sediment plumes, sediment deposition, vessel movements and noise generation. An assessment was made of the potential effects of these activities on the following aspects of the environment: water current flow, wave regime, marine traffic, utilities, anchorages, water quality, capture fisheries, mariculture, seawater intakes, Ocean Park, marine ecology (particularly coral and fish), conservation, marine parks, sound power levels and visual aesthetics.

The work included a literature review and analysis, interviews with Government departments and private companies. In addition, extensive computer modelling was undertaken to study the hydrodynamic regime, sediment transport regime and wave climate before and after the proposed dredging.

Field work included surveys and interviews with fish farmers at the mariculture zones, as well as underwater scuba surveys and photography of the both sides of the East Lamma Channel to a depth of 25 m.

Existing Conditions in the Area

The East Lamma Channel is Hong Kong's most important shipping lane.

The East Lamma Channel, of which the borrow area is part, serves as an inshore fishing ground that produces about 540 tonnes of fish worth $6 million annually. This accounts for about 3% of all Hong Kong inshore fish catch, 9% of shrimp catch and 5% of squid catch. The area may be a spawning and nursery ground for some commercial species. Fish fry collecting zones along the channel supply Lamma Island fish farms.

Two mariculture zones located next to the Channel produce about 500 tonnes of fish worth about $30 million annually.

The marine life along the southwestern side of East Lamma Channel is diverse and abundant, particularly in soft corals, sea whips and fans below a depth of 15 m. Hard corals are abundant and diverse in shallow water along the east side of Lamma to the south of Wong Chuk Kok. Marine life, including hard corals is much less abundant along the northeastern side of East Lamma Channel.

There are popular bathing beaches at Deep Water Bay and Repulse Bay, with others at South Bay and Chung Hom Kok.

Proposed marine parks are located at Cape D'Aguilar and at Sham Wan on the southern end of Lamma Island. The beach at Sham Wan is believed to be a turtle nesting ground.
Seawater intakes along the southern Hong Kong Island coast provide air conditioner cooling water, flushing water and water for exhibits of marine life at Ocean Park.

The 75 Mm^3 sand resource beneath the seabed in East Lamma Channel contains approximately 6% fine sediment and is considered to be one of the purest in the Territory.

Components of the Assumed Dredging Scenario

Layout of Proposed Dredging Pit

The initial stage of the assessment was based on an initial borrow pit design which maximized the use of the sand resource (Figure 1). Computer modelling of this initial pit configuration indicated that it would be likely to result in focusing of wave energy which, in turn, could have a significant impact on the long term stability of marine structures in the Aberdeen area and of beach sand in the Repulse Bay and Deep Water Bay areas. As a result, part way through the study, the pit layout was modified to a smaller pit shape ("TS" in Figure 1). A further sequence of computer modelling indicated that this modified pit would be unlikely to have a significant impact on marine structures or beaches.

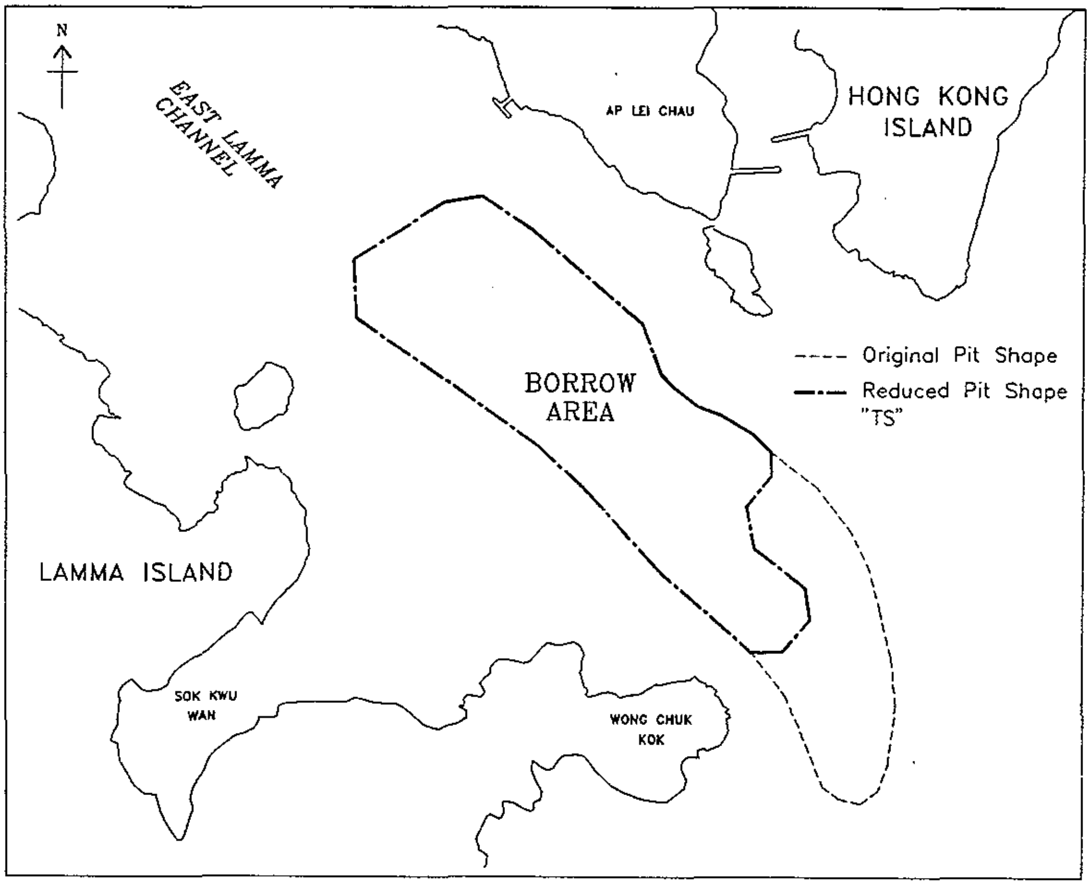


FIGURE 1 EAST LAMMA CHANNEL BORROW AREA.

Dredging Constraints

It was assumed in the study that overflow would be prohibited during dredging of mud overburden in the borrow pit.

Following early discussions with the Marine Department, it was also assumed that the use of stationary dredgers would be prohibited in the Traffic Separation Scheme, and that the dredging operation would only involve one mobile trailer dredger in the Traffic Separation Scheme at any one time.

Extent of Impacts

Seabed removal

The effect of seabed removal on the overall water flow in the area would be minor. As discussed above, the impact of the initial borrow pit design on wave energy focusing would have been significant but adoption of the modified pit design would eliminate this potential problem.

Seabed removal would probably not affect mariculture, but would preclude the operation of capture fisheries within the borrow area for the duration of the operation. Adult fish would be expected to migrate out of the affected area and would join nearby stocks; however, this could place them out of reach of inshore fishermen. Backfilling of the pit is unlikely, and therefore the increased water depth inside the pit would permanently preclude some types of fishing activities, such as shrimp trawling, due to limitations of fishing gear. A new benthic community would probably colonize the dredged area within two to three years, but it is not known if it would support commercial fisheries (due to the lack of data on deep water marine communities in Hong Kong).

Sedimentation

Because of the purity of the sand, approximately four times less fine sediment would be discharged into the sea during dredging of East Lamma Channel than has been the case during dredging of other Hong Kong marine borrow areas. In the area adjacent to the dredging, increased suspended sediment would be expected to reduce the abundance of wild fish fry during the dredging operations and for about one year following project completion. Fish farmers would therefore need to collect or buy additional fry from other areas during this period.

Sedimentation would be likely to cause a moderate reduction in fish catch in an area circumscribed by a line 1 km outside the borrow area margin. However, the majority of these fish would probably join stocks in other areas, although these might be beyond the reach of coastal fishing craft.

Visible sediment plumes that contain insufficient sediment to harm mariculture species would probably reach mariculture zones and could prompt fishermen to make complaints. Adult fish and fingerlings grown at the mariculture sites would not be expected to be killed by acute exposure to sediment plumes generated at the borrow area during dredging. However, infrequently, during severe storms, it is possible that dredging plume sediment which had already settled to the seabed could be resuspended. This could temporarily result in suspended sediment levels at the mariculture sites in excess of the 80 mg/l level which the Agriculture & Fisheries Department has adopted as the target level for water quality at mariculture sites. The bulk of scientific data suggests that long term (chronic) exposure to levels below 80 mg/l would not increase disease susceptibility or decrease growth rates.

Hard corals located near Wong Chuk Kok on Lamma Island would be expected to suffer up to about 25% loss. There would also be some loss of diversity. Other sensitive marine organisms in the same area could be harmed. Although low-lying patches of soft coral and sea fan communities located along East Lamma Channel would probably be buried by sediment and killed, most communities of these organisms are located in areas swept by strong currents and would not be damaged.

Neither of the proposed marine reserves in the area are likely to be damaged by the proposed dredging. Dredging would not be expected to affect the turtle nesting ground at Sham Wan, Lamma Island.

Light brown sediment plumes might be visible from the bathing beaches at Repulse Bay and Deep Water Bay during the summer months and, although harmless to bathers, could generate public complaints.

During the wet season, an increase of about 15 mg/l above average background levels of suspended sediment concentrations would be likely to occur regularly near the Ocean Park intake. During infrequent storms, and given appropriate weather conditions, increases above the 25 mg/l design specification for the Ocean Park seawater filter could occur, but this situation would not last for more than a single tidal cycle. An increase in the frequency of cleaning of the filtration system (at an estimated cost of $100 per cleaning) would be sufficient to prevent water quality problems within Ocean Park.

Noise

Noise levels created by the dredging are unlikely to be significantly above background levels.

Marine Traffic

Crossings of the Traffic Separation Scheme by trailer dredgers would require close co-operation between the dredgers and the Marine Department's Vessel Traffic Centre.

Mitigation Measures

The most effective mitigation measure against the impacts of dredging in the East Lamma Channel is to restrict the amount of dredging plant and its mode and area of operation. For this reason, the conclusions reached in the study are based on the assumptions that:

(a) the modified pit shape would be adopted,

(b) only a single trailer dredger would operate within the dredging area at any one time, and

(c) overflowing would not be permitted during the dredging of overburden.

If an alternative mode of dredging operation was envisaged, then the assessment would need to be revised and further analysis undertaken as necessary.

In addition to the above, there are a number of other possible measures which could be adopted to monitor impacts and possibly further reduce them. Principal among these measures are:

(a) To divide the borrow area in half and to dredge the two halves with respect to seasonal wind patterns; this would significantly reduce the chance of wind-driven sediment plumes reaching most sensitive receivers. This measure would not affect potential impacts to the hard coral and fry collection areas near Wong Chuk Kok and Sok Kwu Wan mariculture zone and would not reduce the potential impacts of tidal transport of sediment plumes.

(b) The automatic device used by dredgers to route low density material overboard (ALMOB) during overburden dredging could be prohibited by contract specification.

(c) A significant reduction in navigational risk could be achieved by establishing a Dredging Management Co-ordinator to work in close co-operation with the Marine Department Vessel Traffic Centre.

(d) A contractual Action Plan that provided for restricting the area of operation in response to specified exceedance levels in combination with an independent monitoring programme designed to rapidly determine the movement of sediment plumes towards sensitive receivers would lower the potential for environmental damage.

Silt curtains would not be feasible at the source and similarly would not be likely to be a viable option for controlling the dispersion of sediment around the mariculture sites and at beaches affected by strong currents or waves.

Postscript

This report has been prepared under the auspices of the Environmental Studies Management Group (ESMG). During the course of meetings with ESMG, some members expressed their views that the potential effects of the proposed dredging would be greater than estimates made in this report.

ENVIRONMENTAL ASSESSMENT
EAST LAMMA CHANNEL BORROW AREA

1 INTRODUCTION

Background to the Study

1.1 The East Lamma Channel Environmental Assessment was instructed by the Geotechnical Engineering Office (GEO) of the Civil Engineering Department under agreement No. CE 42/90, Fill Management Study - Phase II and was carried out by Binnie Consultants Limited (BCL), Hong Kong with mathematical modelling assistance from Binnie & Partners, UK.

1.2 The purpose of the study was to determine the environmental effects of the recovery of marine fill from a proposed borrow area in East Lamma Channel. The proposed borrow area is covered by Government Notice No. 2480 in Gazette No. 30 of 19 July 1991. An Environmental Review was endorsed by Government in February 1991 and a brief for this scoped study, or Environmental Assessment (EA) was compiled after discussions with the Environmental Studies Management Group. Work commenced on the agreed brief at the instruction of GEO in February 1992.

1.3 The main EA study area is shown in Figure 1.1 (hatched area). In addition, sensitive receivers and other important areas outside the main study area were included in the study as required. The grid boundaries shown in Figure 1.1 relate to the WAHMO tidal flow computer models which are discussed in detail in Section 4.

1.4 The seawater depth is shallow (<10 m) to the west of Lamma Island, deep (20-30 m) to the southeast of the study area; in the East Lamma Channel itself, the water depth reaches 40 m.

1.5 The proposed dredging area within East Lamma Channel, covers an area of approximately 3.0 km^2 (Figure 1.2), with recoverable sand resources of 75 Mm^3 reaching to depths greater than -60 mPD. A full description of the borrow area and its potential operation is given in the East Lamma Channel Borrow Area Assessment Report (BCL, 1992a). A revised, smaller dredging area (Figure 1.3) has been proposed, as a mitigation measure relating to wave climate (see Section 8).

Baseline Conditions

Weather and Tidal Currents

1.6 Lamma Channel is exposed to monsoonal weather patterns typical of Hong Kong and described in detail in BCL (1992b). The strength and intensity of winds at Lamma Island are shown in Figure 1.4. Some modification of local wind patterns is probably caused by the orientation of the channel with respect to topographic highs on surrounding land. In particular, bays on the Hong Kong side would be sheltered from northeast winds while those on the Lamma side would be sheltered from southwest winds.

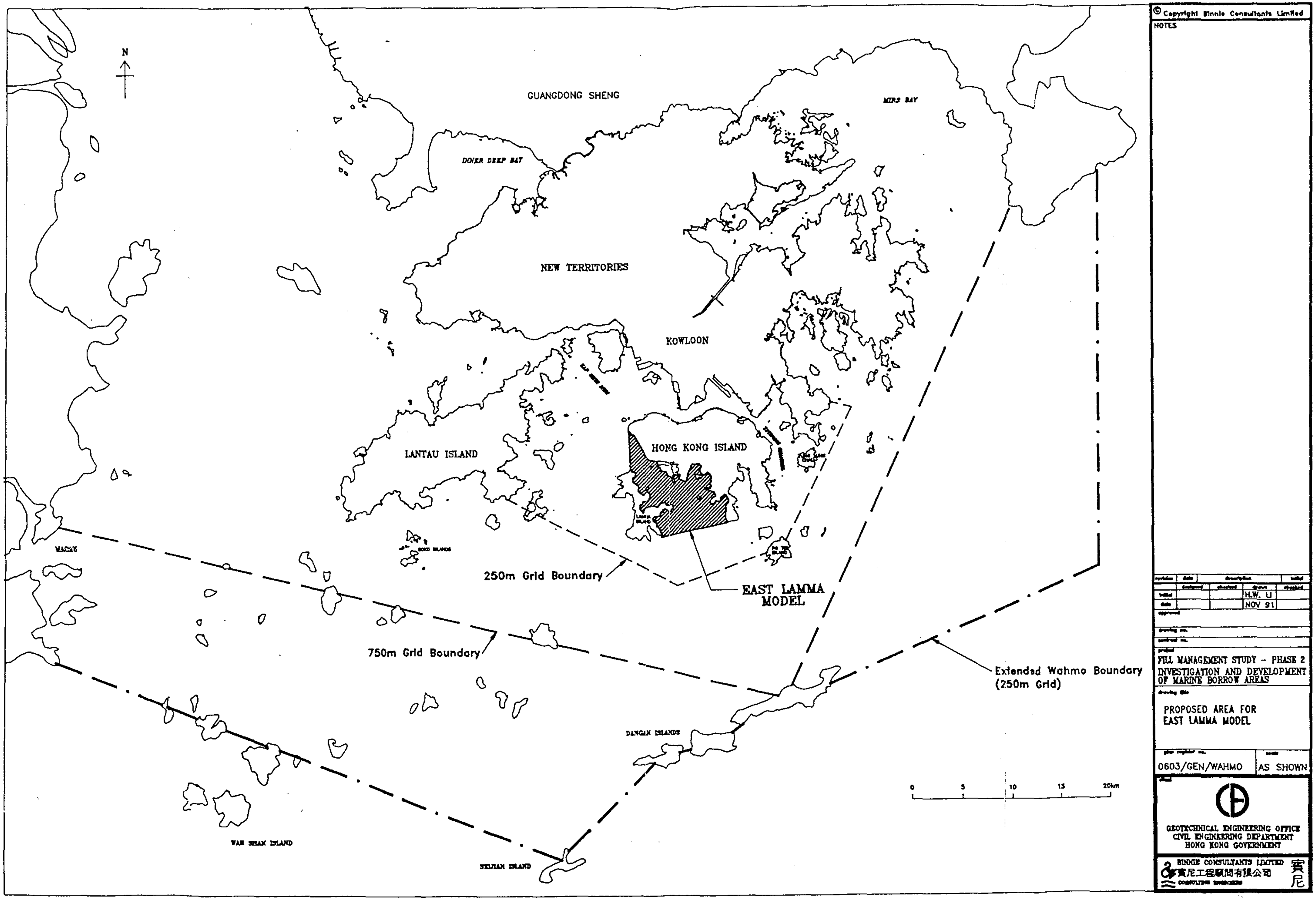


FIGURE 1.1 STUDY AREA

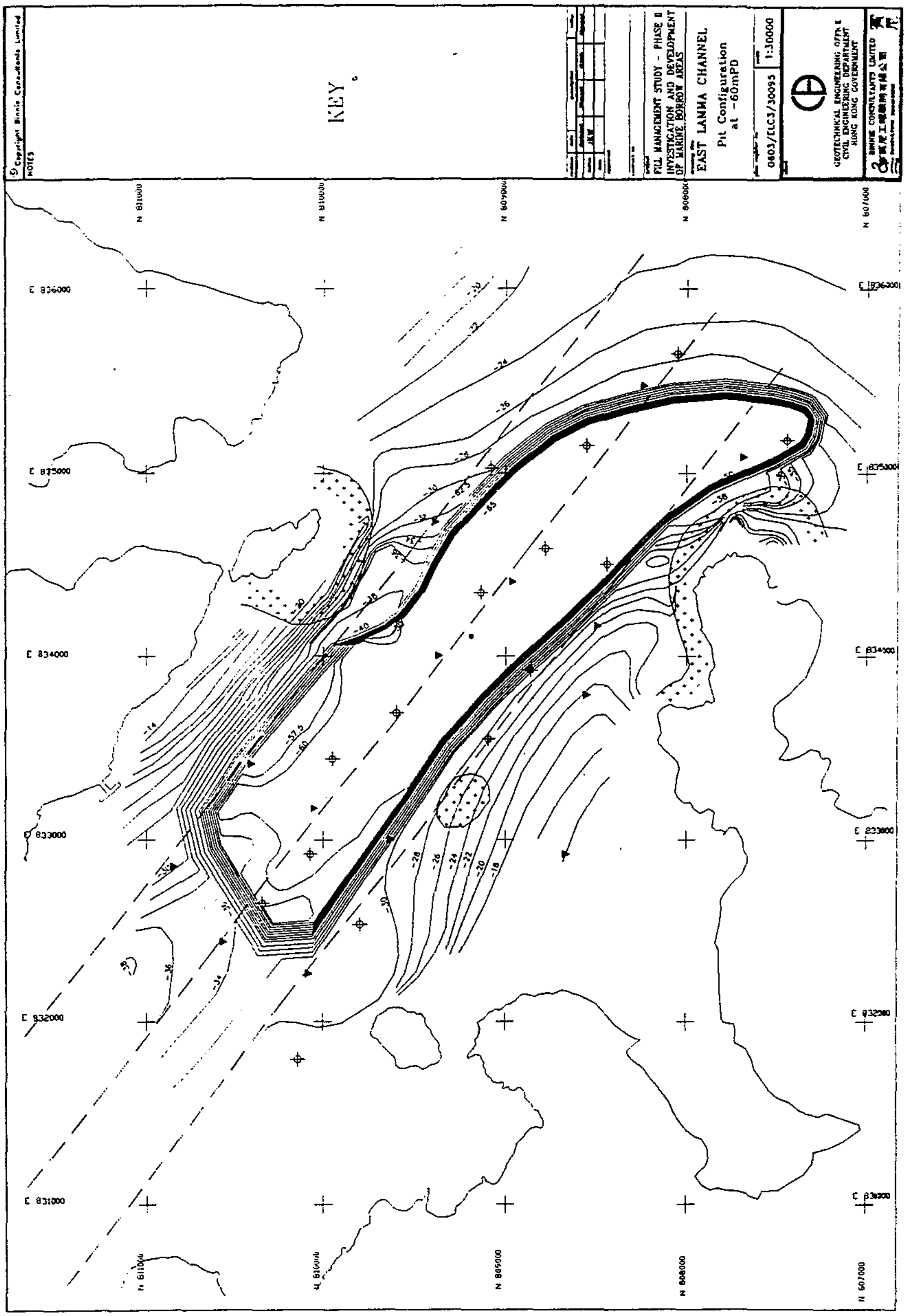


FIGURE 1.2 BORROW AREA - ORIGINAL DESIGN

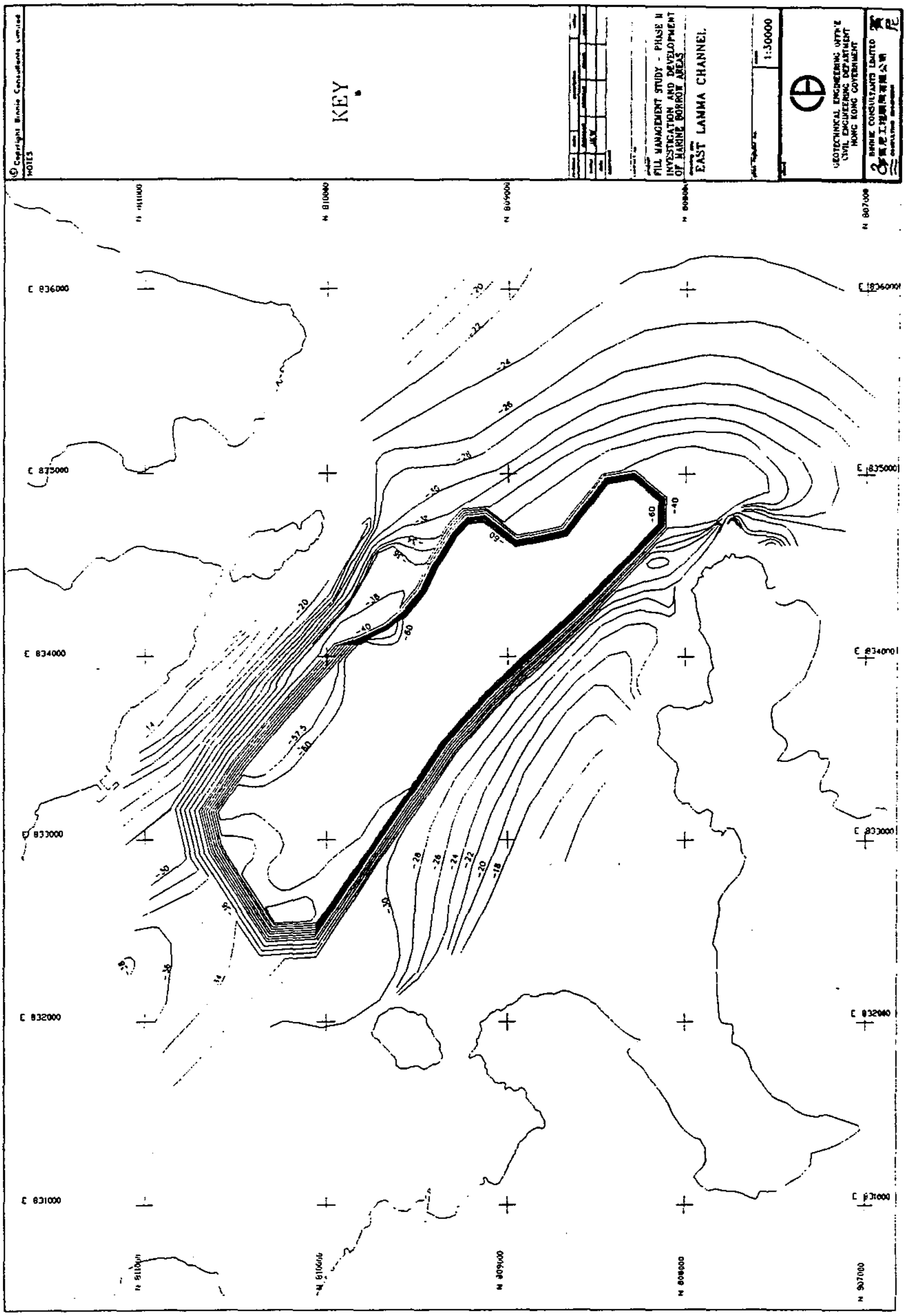


FIGURE 1.3 BORROW AREA - REDUCED WAVE IMPACT DESIGN

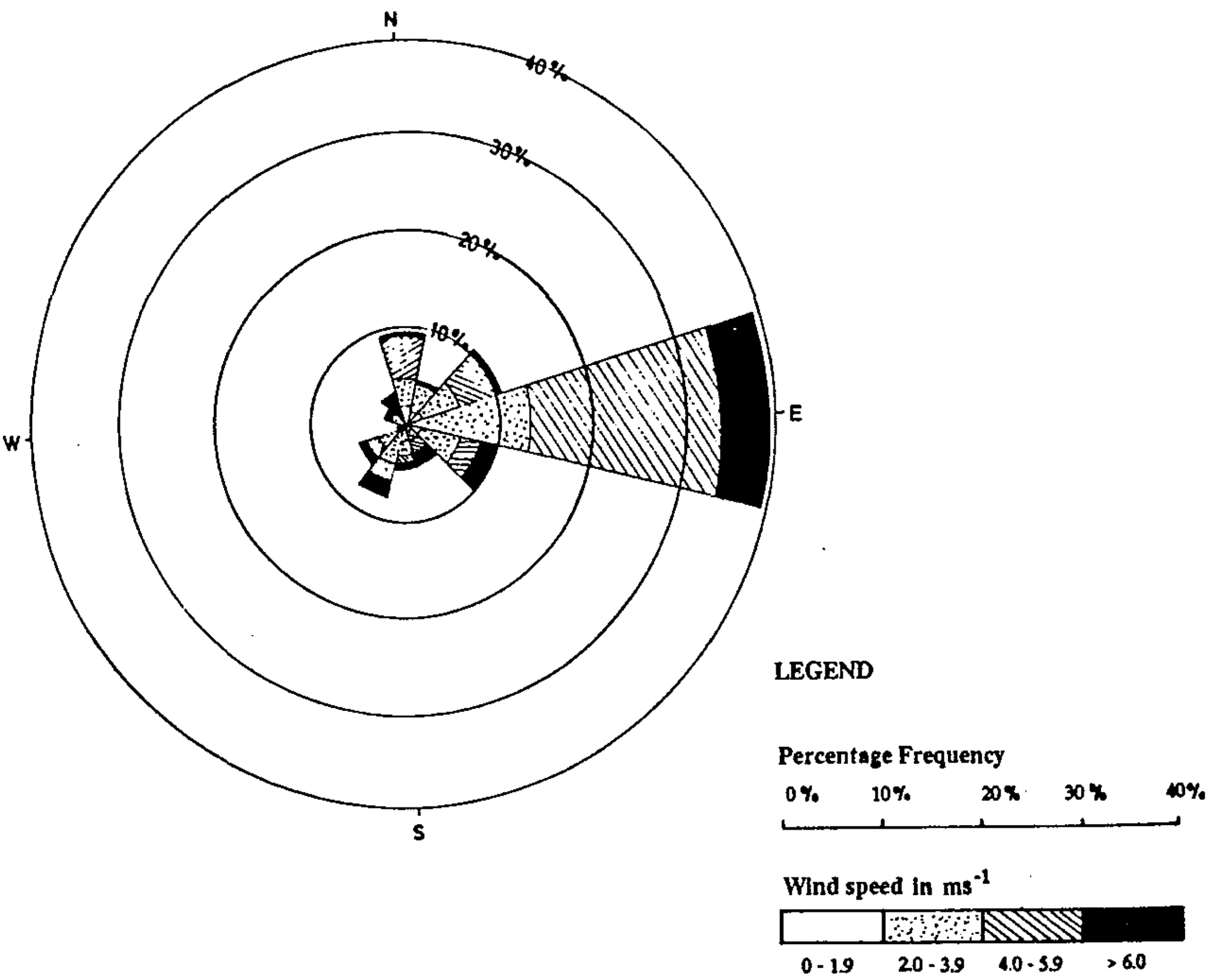


FIGURE 1.4 WIND ROSE - LAMMA ISLAND

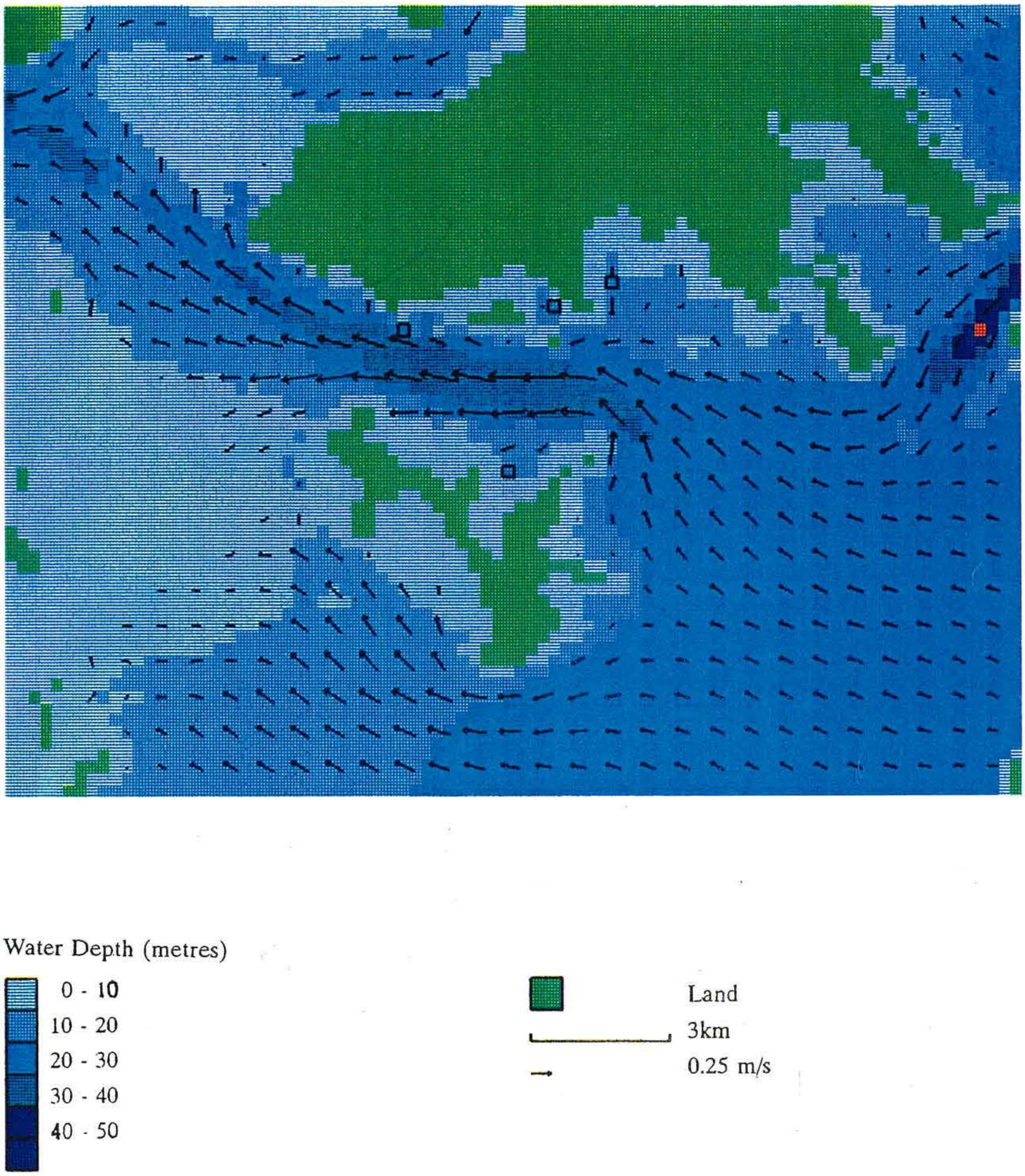
1.7 Tidal currents in East Lamma Channel reach 0.5 m/s. Plots of WAHMO model output for various tidal conditions before dredging are shown in Figures 1.5-1.14. The ebb tide flows southeast while the flood flows northwest. The pre- and post-dredging plots suggest that the creation of a pit would have little effect on the normal tidal flow patterns (Figures 1.15 and 1.16).

Water Quality and Sediments

1.8 The Environmental Protection Department (EPD) has six water quality sampling stations located within the study area (Figure 1.17a) and one for sediment sampling (Figure 1.17b). The water quality information reported by EPD for Hong Kong Island South are an average of data obtained at four individual stations (Sok Kwu Wan station is not included) and should be representative of the inshore areas of the Hong Kong side of East Lamma Channel (Table 1.1).

TABLE 1.1 WATER QUALITY - HONG KONG ISLAND SOUTH

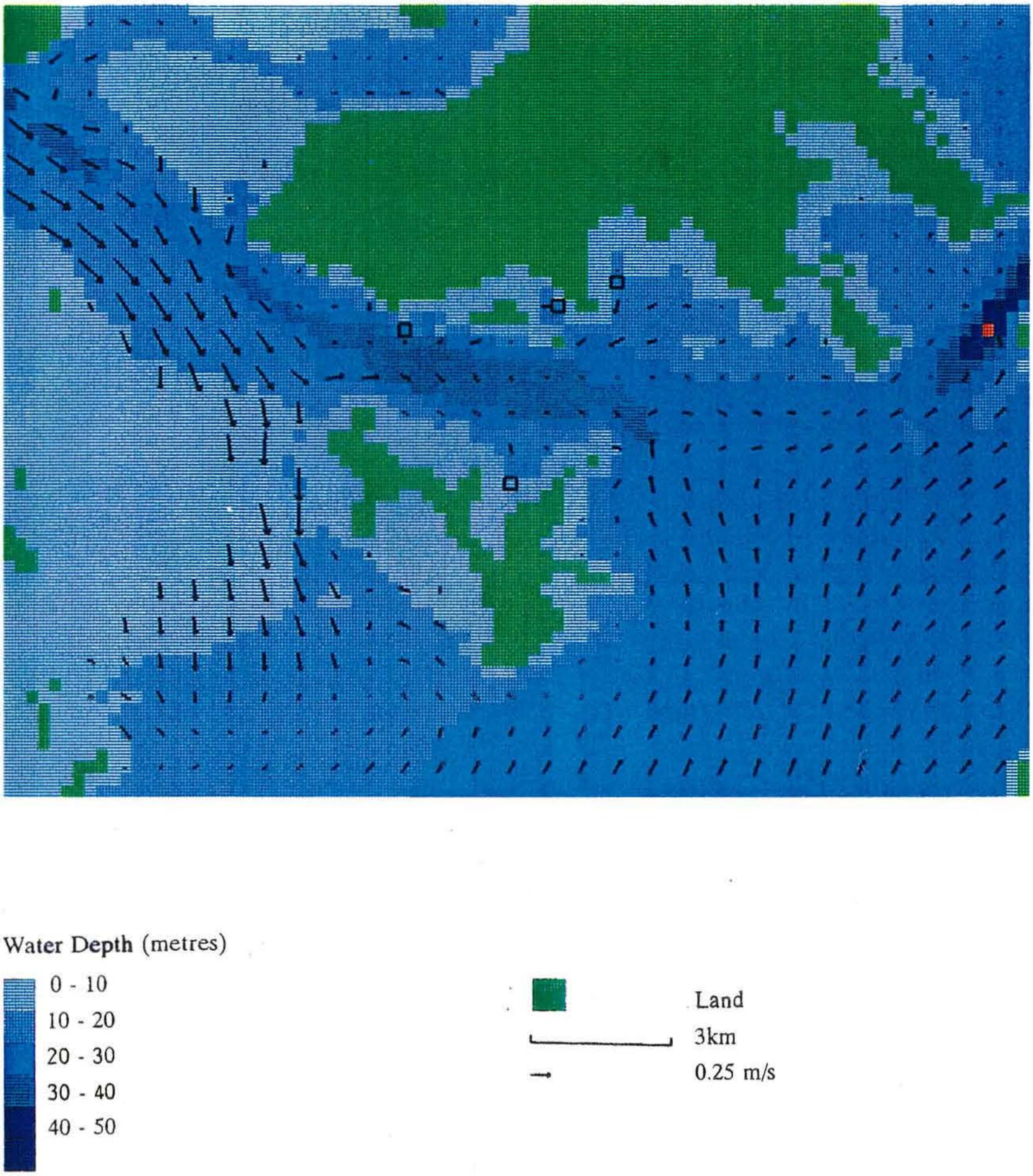
Measurement	Mean	Minimum	Maximum
Temperature (°C)			
Surface	23.4	16.1	29.4
Bottom	22.1	16.0	27.3
Salinity (ppt)			
Surface	31.3	29.1	32.9
Bottom	32.5	31.1	34.9
D.O. (% saturation)			
Surface	104.1	80.5	141.0
Bottom	80.4	56.5	113.1
pH	8.4	8.0	8.7
Secchi Disc (m)	2.5	1.5	4.0
Turbidity (NTU)	3.9	1.9	6.7
S.S. (mg/l)	2.9	0.5	9.3
BOD (mg/l)	0.68	0.27	1.36
Inorganic N (mg/l)	0.073	0.015	0.128
Total N (mg/l)	0.480	0.346	0.684
PO_4-P (mg/l)	0.007	0.002	0.021
TP (mg/l)	0.051	0.027	0.070
Chlorophyll-a (µg/l)	2.23	0.33	7.73
E. coli (#/100 ml)	41	1	179
Source : EPD, 1991			



PREDICTED FLOOD TIDE VELOCITY VECTORS
(LOWER LAYER) - WET SEASON, SPRING TIDE

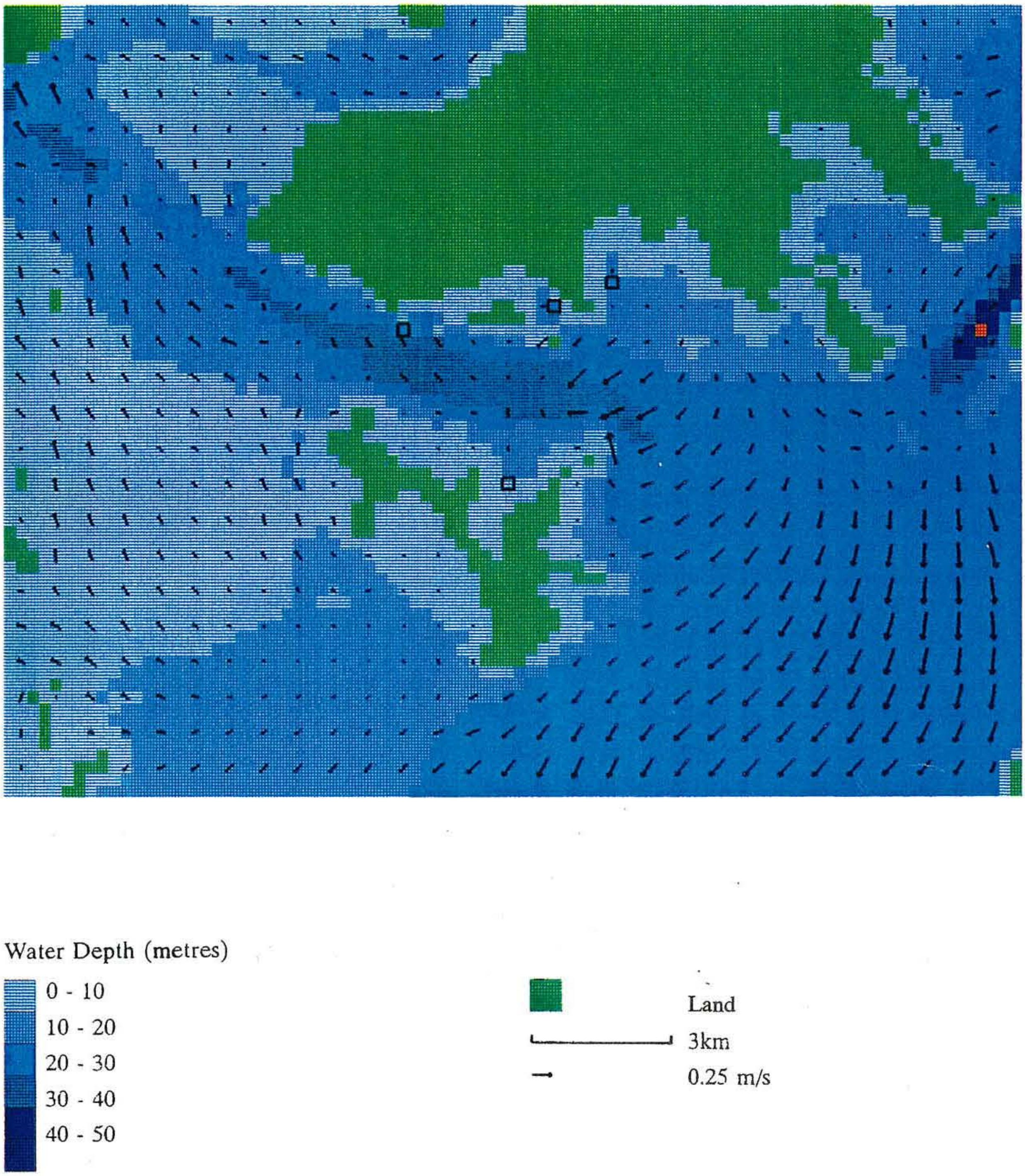
Figure 1.5

/D3983/250M/WET-SP-PIT/VELB.PIC>31/ 7/1992>HB



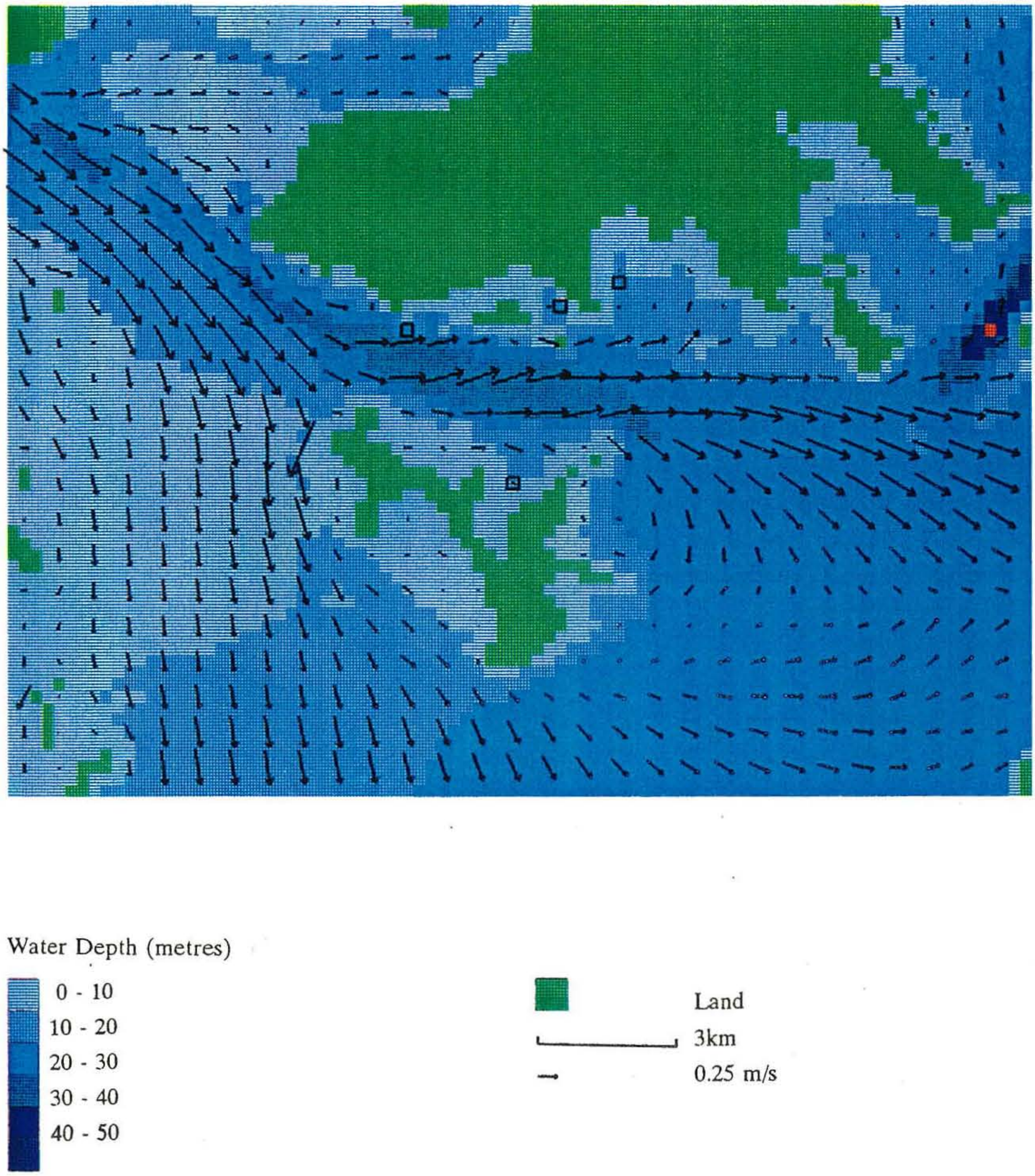
PREDICTED EBB TIDE VELOCITY VECTORS
(LOWER LAYER) - WET SEASON, SPRING TIDE

Figure 1.6



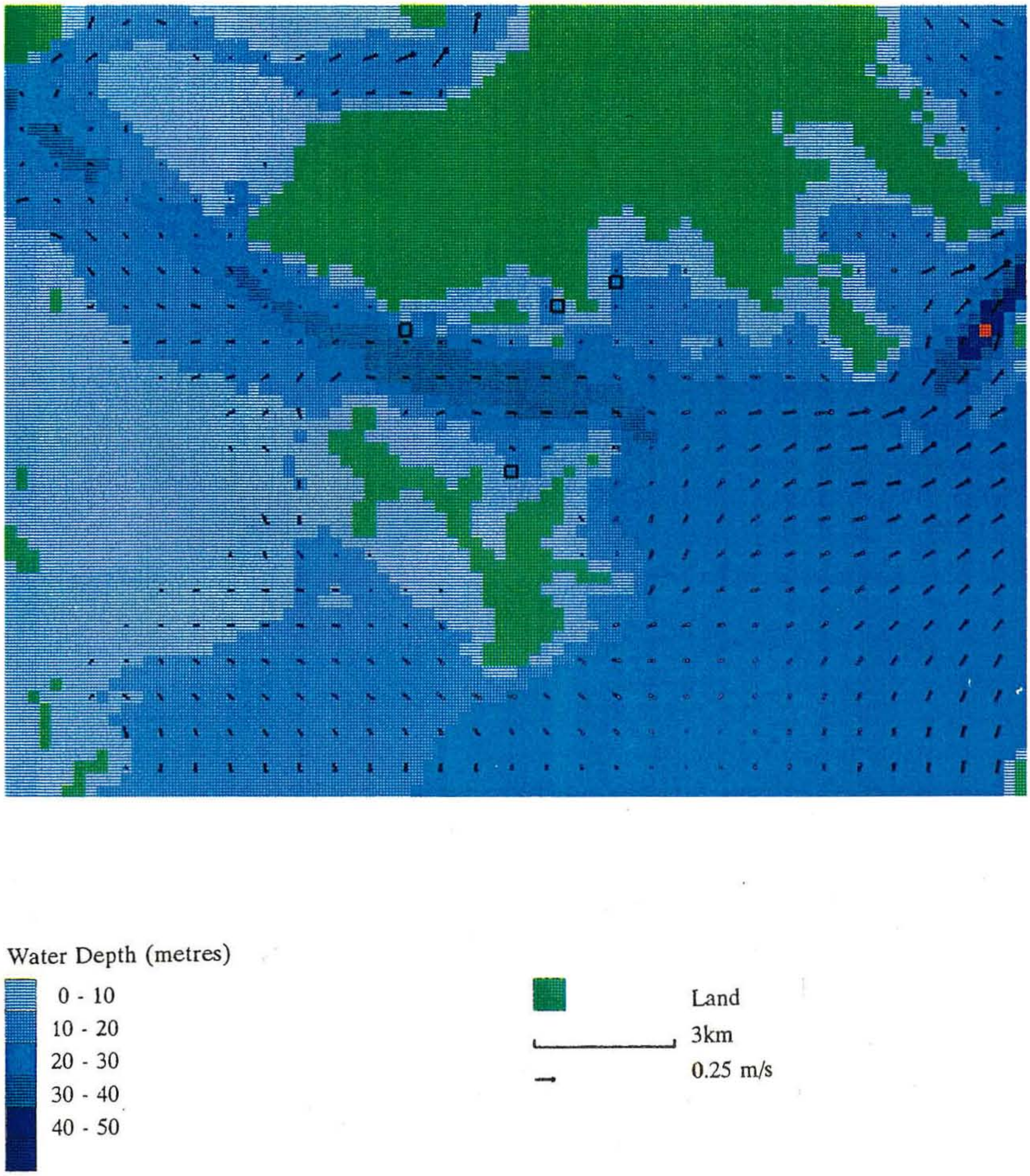
PREDICTED FLOOD TIDE VELOCITY VECTORS
(UPPER LAYER) - WET SEASON, SPRING TIDE

Figure 1.7



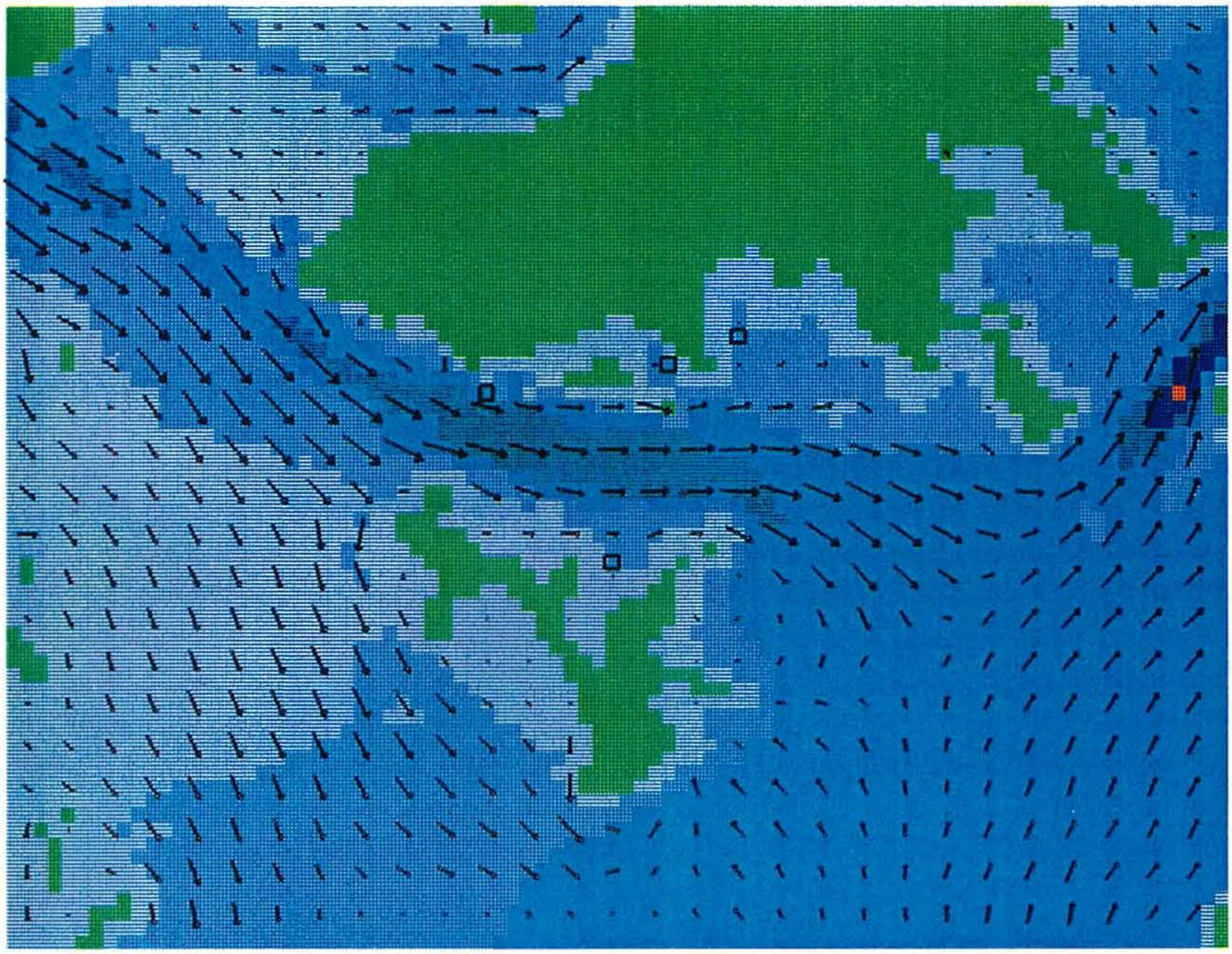
PREDICTED EBB TIDE VELOCITY VECTORS
(UPPER LAYER) - WET SEASON, SPRING TIDE

Figure 1.8



PREDICTED EBB TIDE VELOCITY VECTORS
(LOWER LAYER) - WET SEASON, NEAP TIDE

Figure 1.9



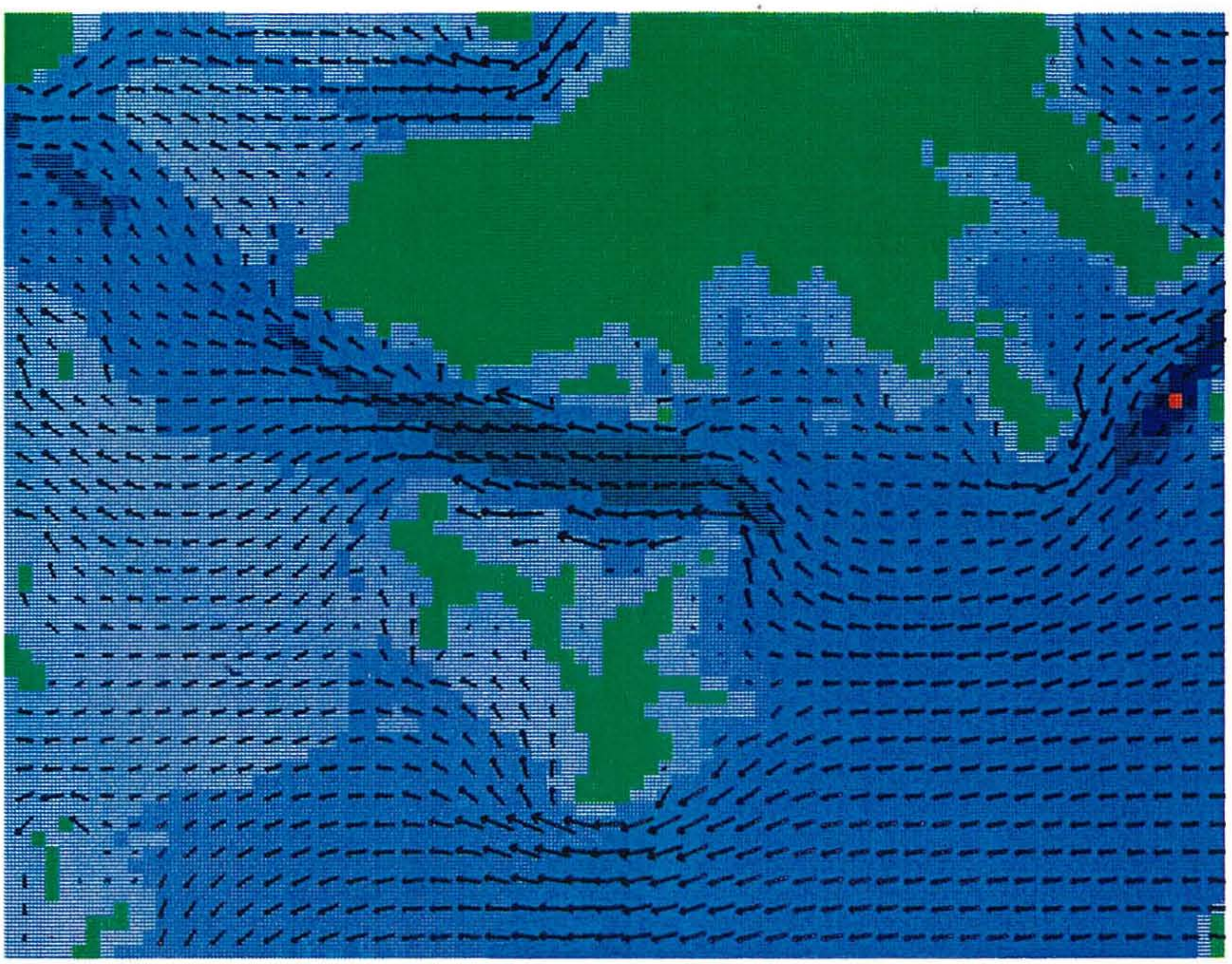
Water Depth (metres)

0 - 10
10 - 20
20 - 30
30 - 40
40 - 50

Land
3km
0.25 m/s

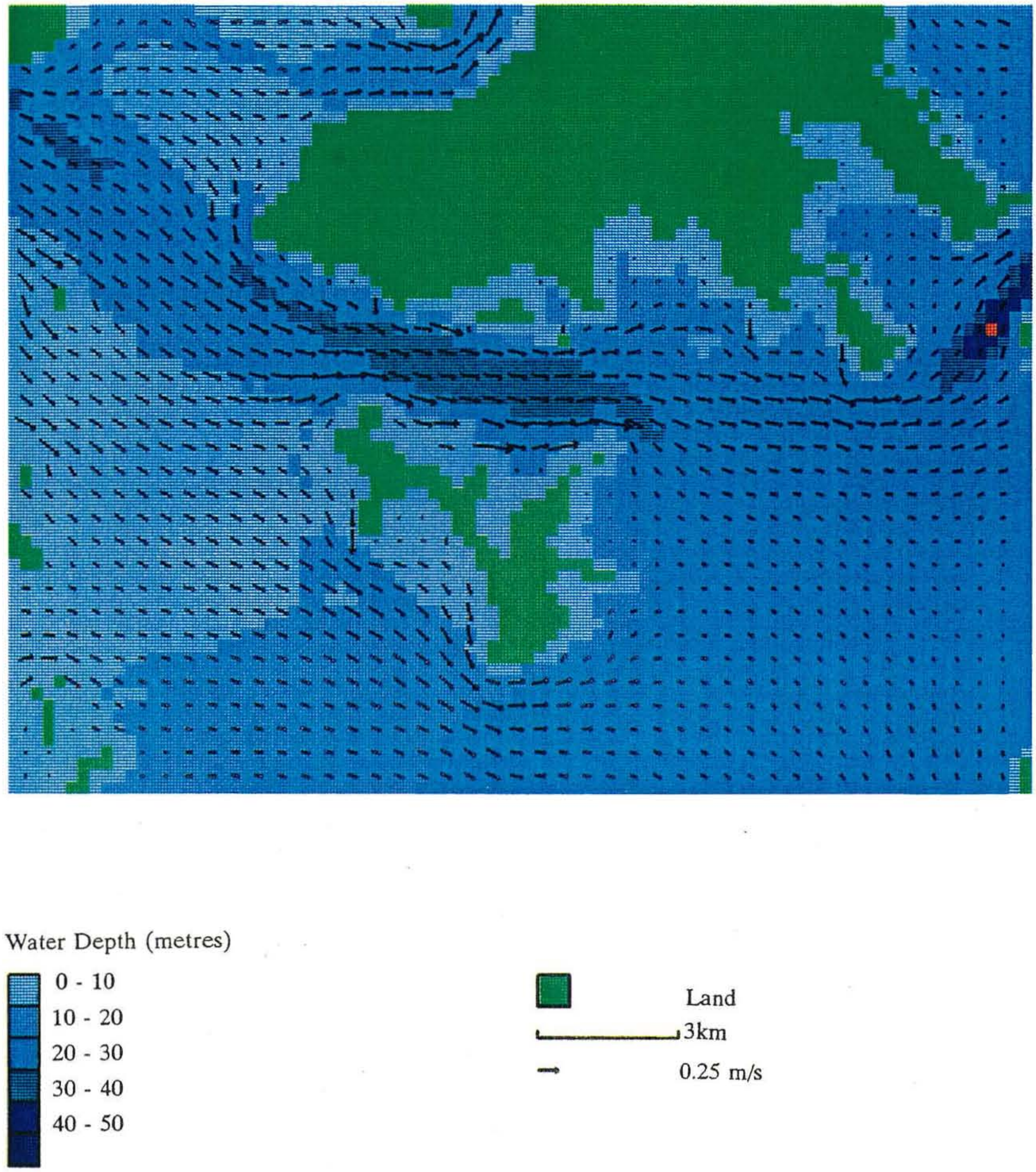
PREDICTED EBB TIDE VELOCITY VECTORS
(UPPER LAYER) - WET SEASON, NEAP TIDE

Figure 1.10



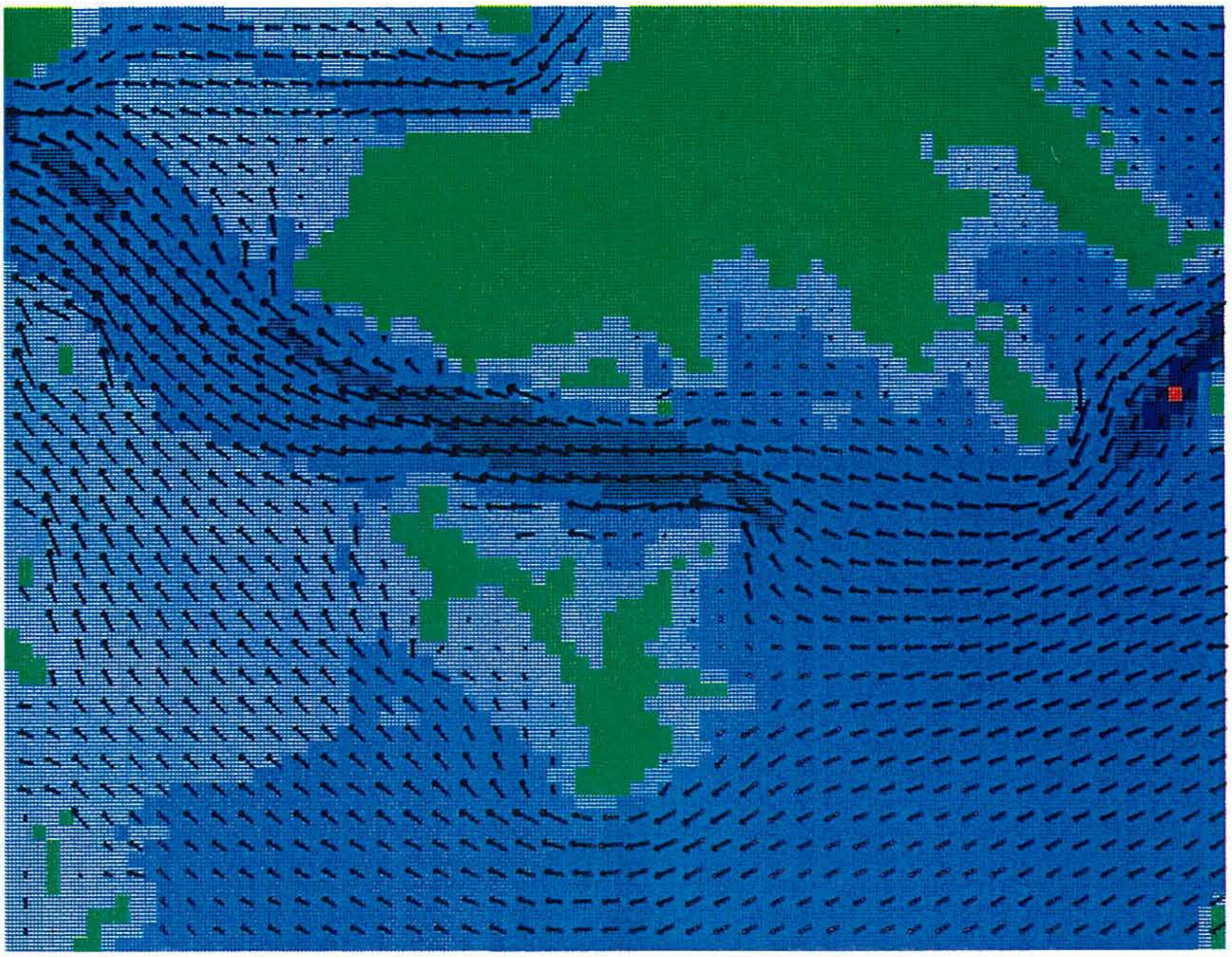
PREDICTED FLOOD TIDE VELOCITY VECTORS -
DRY SEASON, SPRING TIDE

Figure 1.11



PREDICTED EBB TIDE VELOCITY VECTORS -
DRY SEASON, SPRING TIDE

Figure 1.12



Water Depth (metres)

- 0 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50

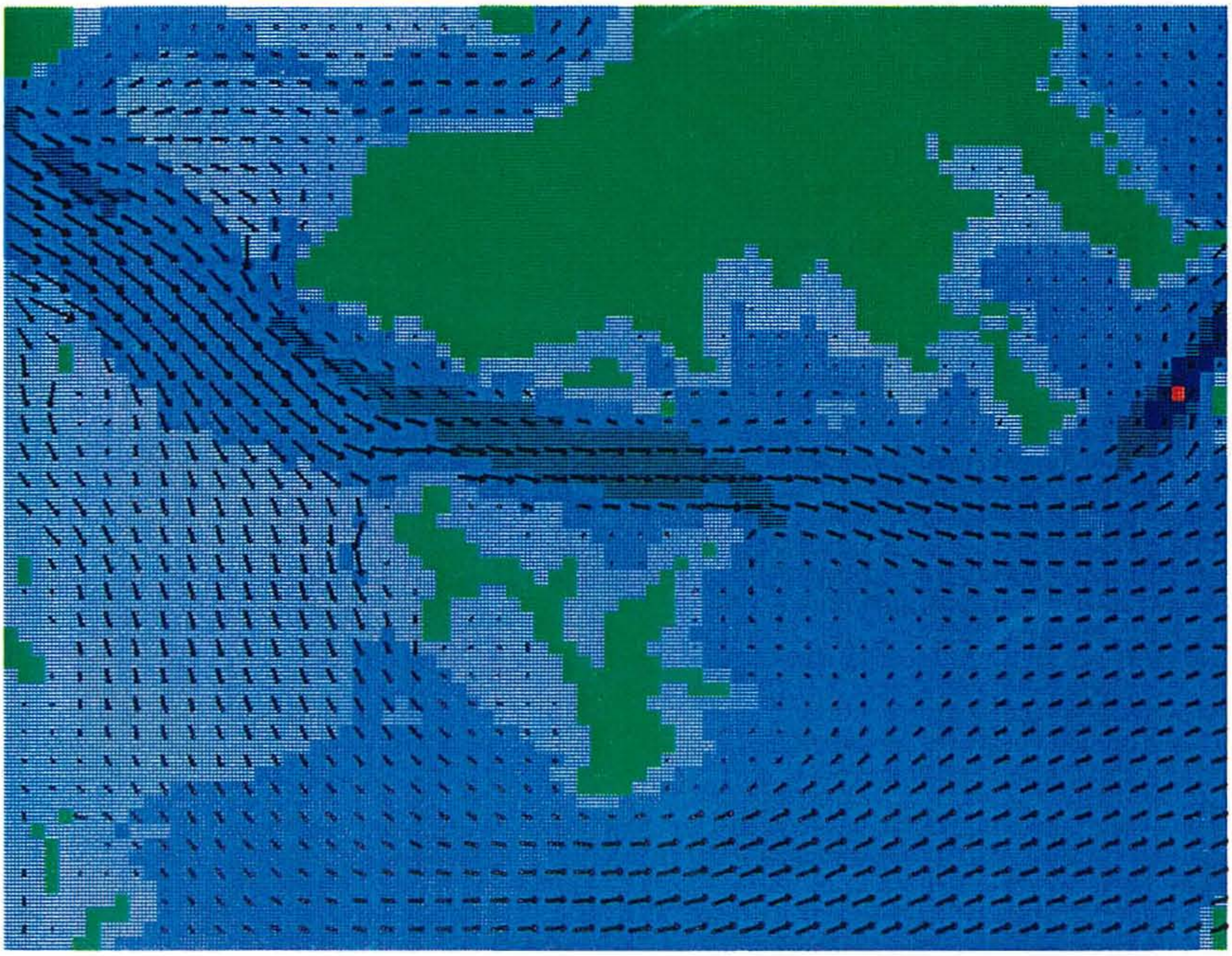
Land

3km

0.25 m/s

PREDICTED FLOOD TIDE VELOCITY VECTORS - DRY SEASON, NEAP TIDE

Figure 1.13



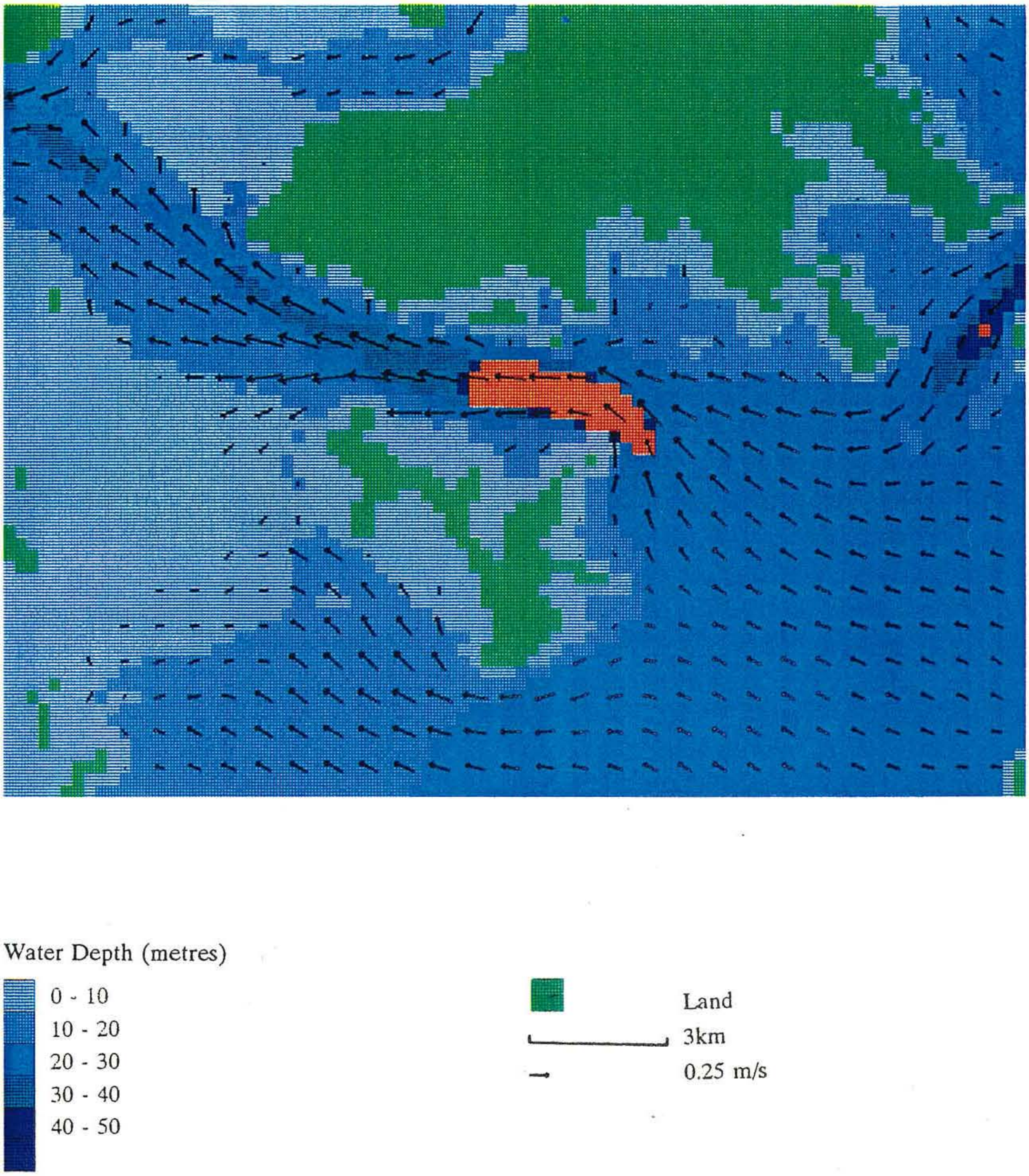
Water Depth (metres)

0 - 10
10 - 20
20 - 30
30 - 40
40 - 50

Land
3km
0.25 m/s

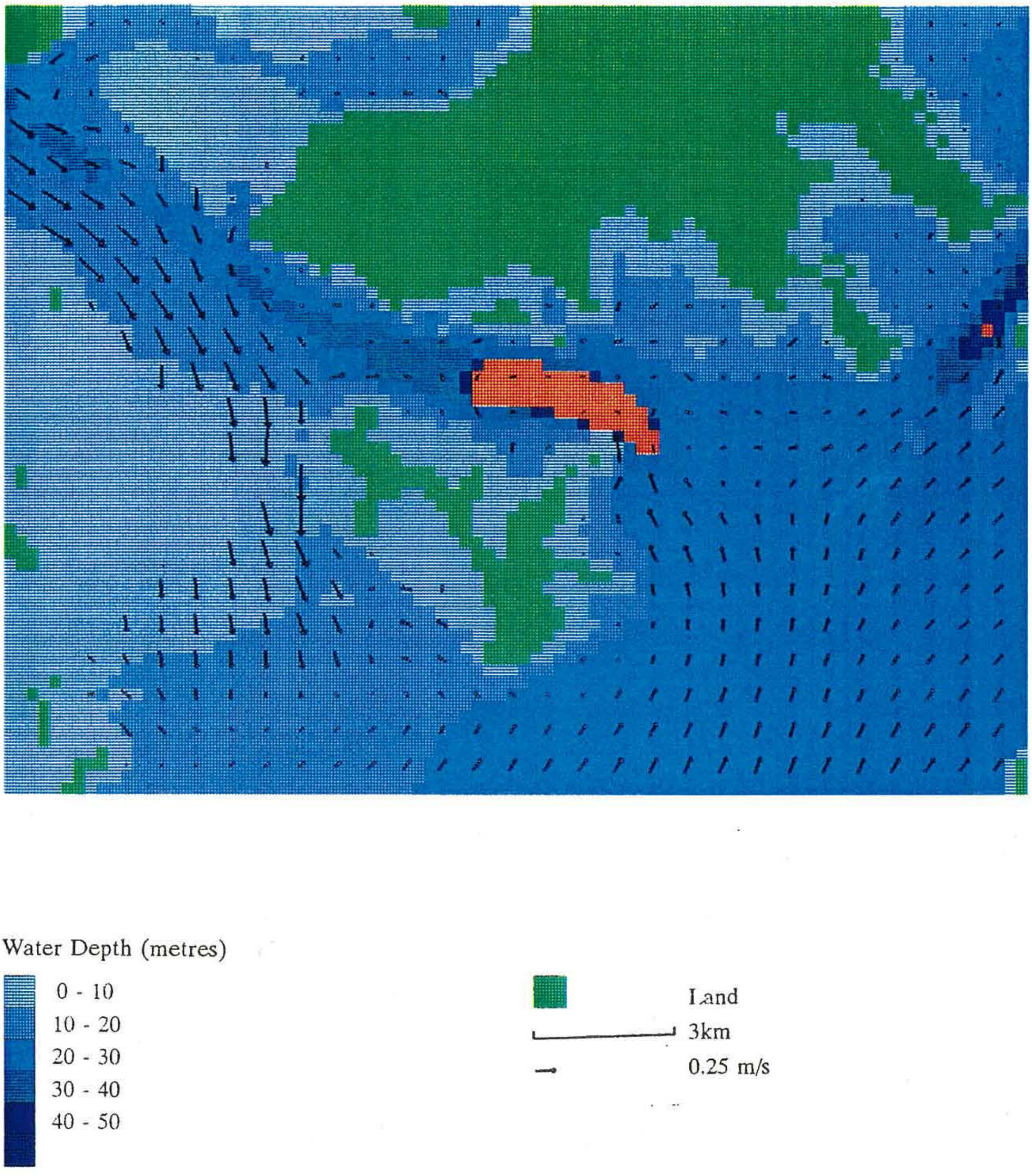
PREDICTED EBB TIDE VELOCITY VECTORS -
DRY SEASON, NEAP TIDE

Figure 1.14



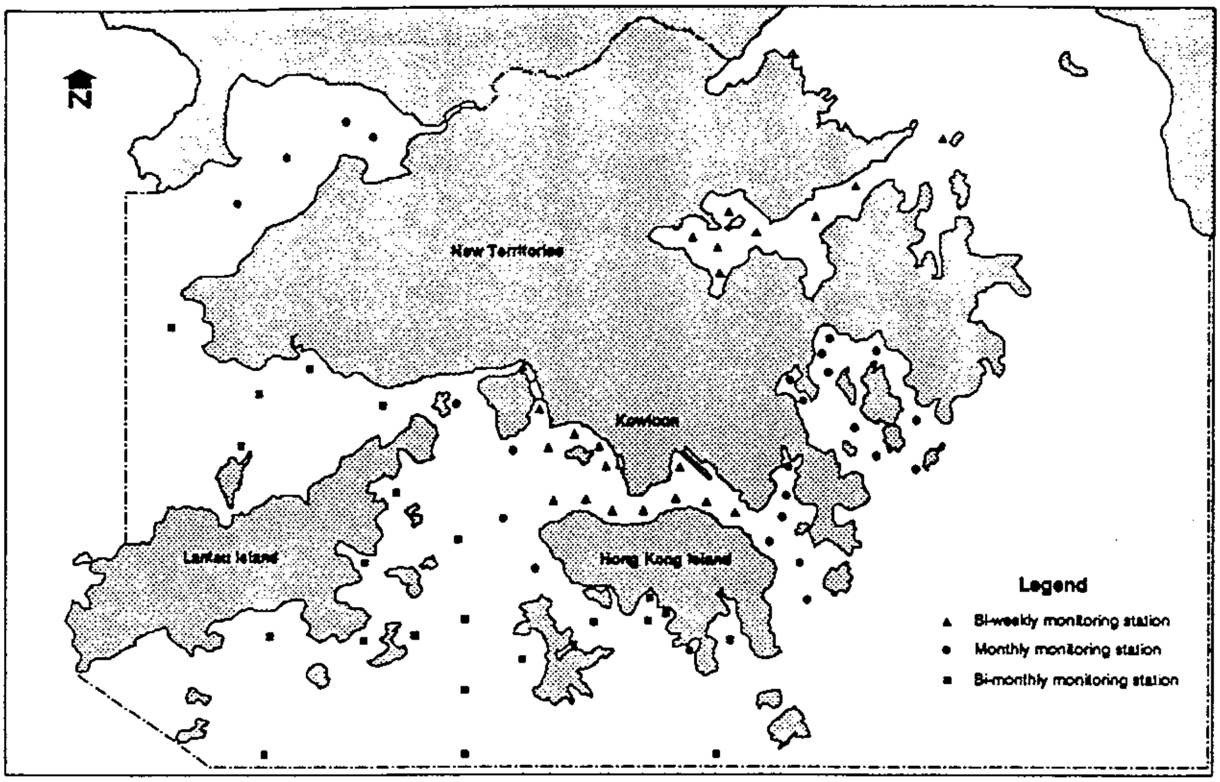
PREDICTED FLOOD TIDE VELOCITY VECTORS AFTER PIT EXCAVATION (LOWER LAYER) - WET SEASON, SPRING TIDE

Figure 1.15

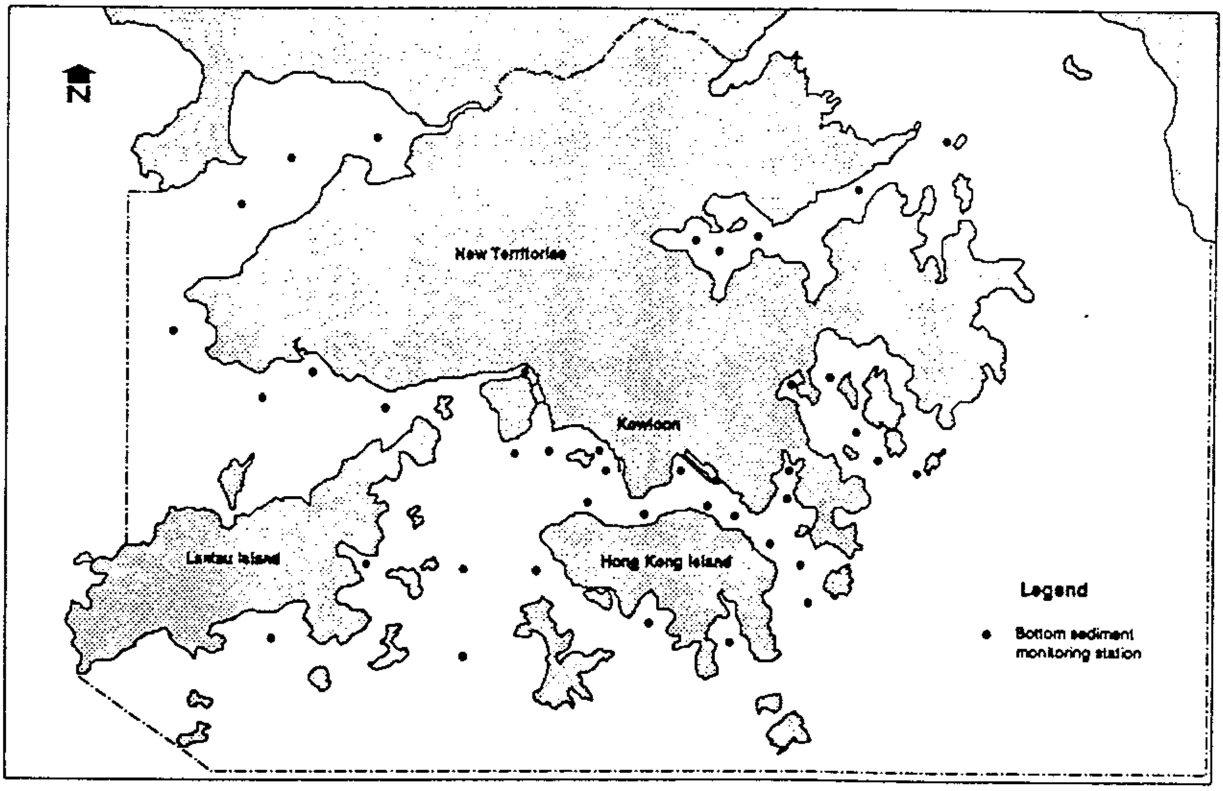


PREDICTED EBB TIDE VELOCITY VECTORS AFTER PIT EXCAVATION (LOWER LAYER) - WET SEASON, SPRING TIDE

Figure 1.16



A) WATER QUALITY



B) SEDIMENT

FIGURE 1.17 EPD SAMPLING STATIONS

1.9 The water quality data indicate that Hong Kong South waters are relatively clean. Oxygen saturation is relatively high and biochemical oxygen demand is low. Occasional elevated levels of nutrients and chlorophyll indicate that minor plankton blooms may be stimulated. The counts of coliform bacteria indicate a minor raw sewage problem. The suspended solids are confined to a narrow, low range while water transparency is intermediate between the clear eastern waters and the opaque western waters.

1.10 A summary of Agriculture and Fisheries Department (AFD) and EPD water quality monitoring at Sok Kwu Wan up to 1986 was given by Binnie & Partners (1988). The report concluded that water quality, particularly dissolved oxygen was marginal near the mariculture zone at the head of the bay (refer to Figure 2.1). This factor, along with high nutrient levels, was suggested as accounting for periodic fish kills at the site.

1.11 AFD water quality data for the mariculture areas in Sok Kwu Wan and nearby Lo Tik Wan (Figure 2.1) on 31 March and 23 June 1992 show an improvement in BOD and DO levels, although organic matter in the sediment remained high (Table 1.2).

TABLE 1.2 WATER AND SEDIMENT QUALITY - LO TIK WAN AND SOK KWU WAN MARICULTURE ZONES

Parameter	Sok Kwu Wan			Lo Tik Wan		
	Depth (m)			Depth (m)		
	0	2	4	0	5	9
Dissolved Oxygen(mg/l)	8.8	7.6	6.7	7.1	7.2	5.9
BOD (mg/l)	1.4	1.3	1.4	1.1	1.0	0.6
Sediment organic (%)	--	--	7.8	--	--	9.8

1.12 EPD results of sediment monitoring at the Hong Kong Island South station are given in Table 1.3.

TABLE 1.3 SEDIMENT QUALITY - HONG KONG ISLAND SOUTH

Total organic carbon (% dry weight)	<1.5
Electrochemical potential (mV)	-300 - 350
Total nitrogen (mg/kg)	800 - 1000
Total phosphorous (mg/kg)	1500 - 2000
Polychlorinated biphenyls (μg/kg)	<50
Heavy metals (mg/kg)	
Chromium	25 - 50
Copper	<50
Zinc	<100
Nickel	10 - 20
Lead	50 - 75
Mercury	<0.3
Source : EPD, 1991	

1.13 The sediment data indicate that Hong Kong Island South sediments, although showing some elevated levels of heavy metals and nutrients above background, are only marginally polluted. None of the heavy metal concentrations exceeds the action levels recommended in the Contaminated Spoil Management Study (Mott MacDonald, 1991).

2 MARINE BIOTA

2.1 Few ecological studies have been made of the marine ecology of East Lamma Channel. Data obtained from other areas combined with underwater surveys made by BCL give a general picture of the ecology (Figure 2.1). Intertidal fauna were studied by Wormald (1976) and Stirling (1977). Benthic infauna were sampled by Shin (1977) and Shin and Thompson (1982). Fish catch records have been examined by Richards (1980). Dr Chiu Sein Tuck of Baptist College has an ongoing marine sampling programme at Lamma sites including Lo Tik Wan. They have unpublished baseline data on water quality and benthic infauna collected over several years. Although the data were not available at the time of this report, they could prove useful for comparison with data collected during any future monitoring exercise.

2.2 The diversity and abundance of soft-bottom benthic invertebrates living between depths of 5 and 21 m have been sampled in the West Lamma Channel (Chilvers and Richards, 1974). It is likely that this community is similar to that in the same depth range in the East Lamma Channel. A maximum of 35 species were recorded including large numbers of crabs, shrimps, and molluscs. Biomass is estimated to be about 40 g/m^2. Below a depth of 21 m in East Lamma Channel, a different deep-water community would be expected. BCL underwater surveys were limited to a maximum depth of 25 m due to near-zero visibility below that depth. Preliminary surveys suggest that the number of invertebrate species found in the hard bottom communities of East Lamma Channel could total several hundred.

2.3 Within the channel itself, there are few hard corals, possibly due to the seasonal low salinity of the water reaching the coral depth range, however, soft corals, sea fans and whips are abundant and exhibit a high species diversity in areas with hard substratum, such as off Luk Chau (Figure 2.2). These non-reef building corals are found below about 15 m, while hard corals are restricted to a zone between 4 and 10 m depth. Hard corals are common along the eastern side of Lamma (south of Wong Chuk Kok), making this an area attractive to sport divers. Fish, particularly rabbit fish and grunts, are abundant at several sites. A summary of dive survey observations and photographs is given in Appendix A.

2.4 World Wide Fund for Nature (WWF) reports that turtles were sighted in 1987 building nests and laying eggs on a beach in Sham Wan on the south side of Lamma Island. Turtles born at a given beach will only nest on the same beach. Ridley, Green and Leather back marine turtles are considered endangered species under the Bonn Convention to which Hong Kong is a Party. WWF organised a turtle monitoring programme during August 1992 at Sham Wan on Lamma Island, however, no evidence of turtles returning to lay eggs was observed. Nonetheless, the site is still considered to be a turtle hatching ground.

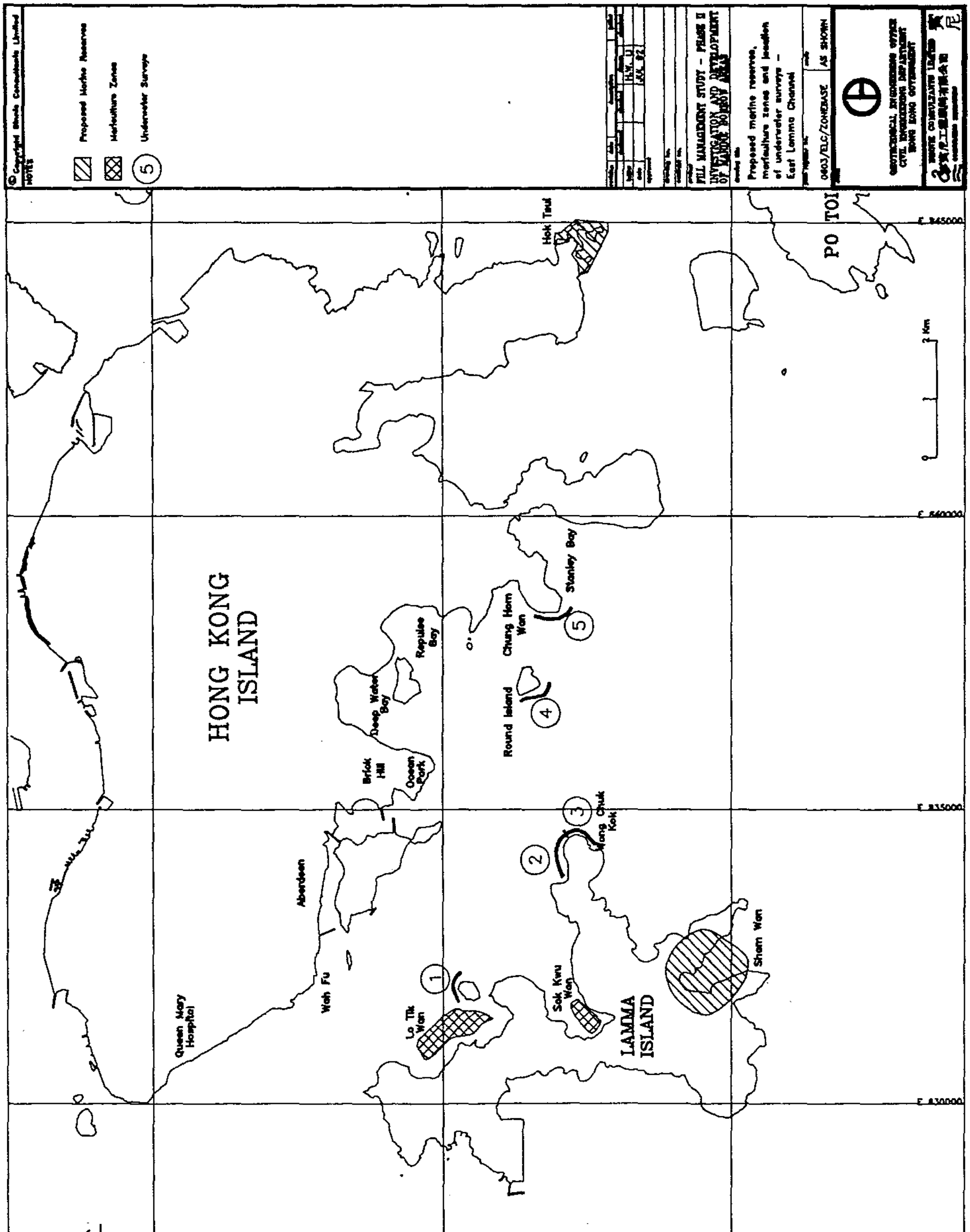


FIGURE 2.1 DIVE SURVEYS, MARINE RESERVES AND MARICULTURE ZONES

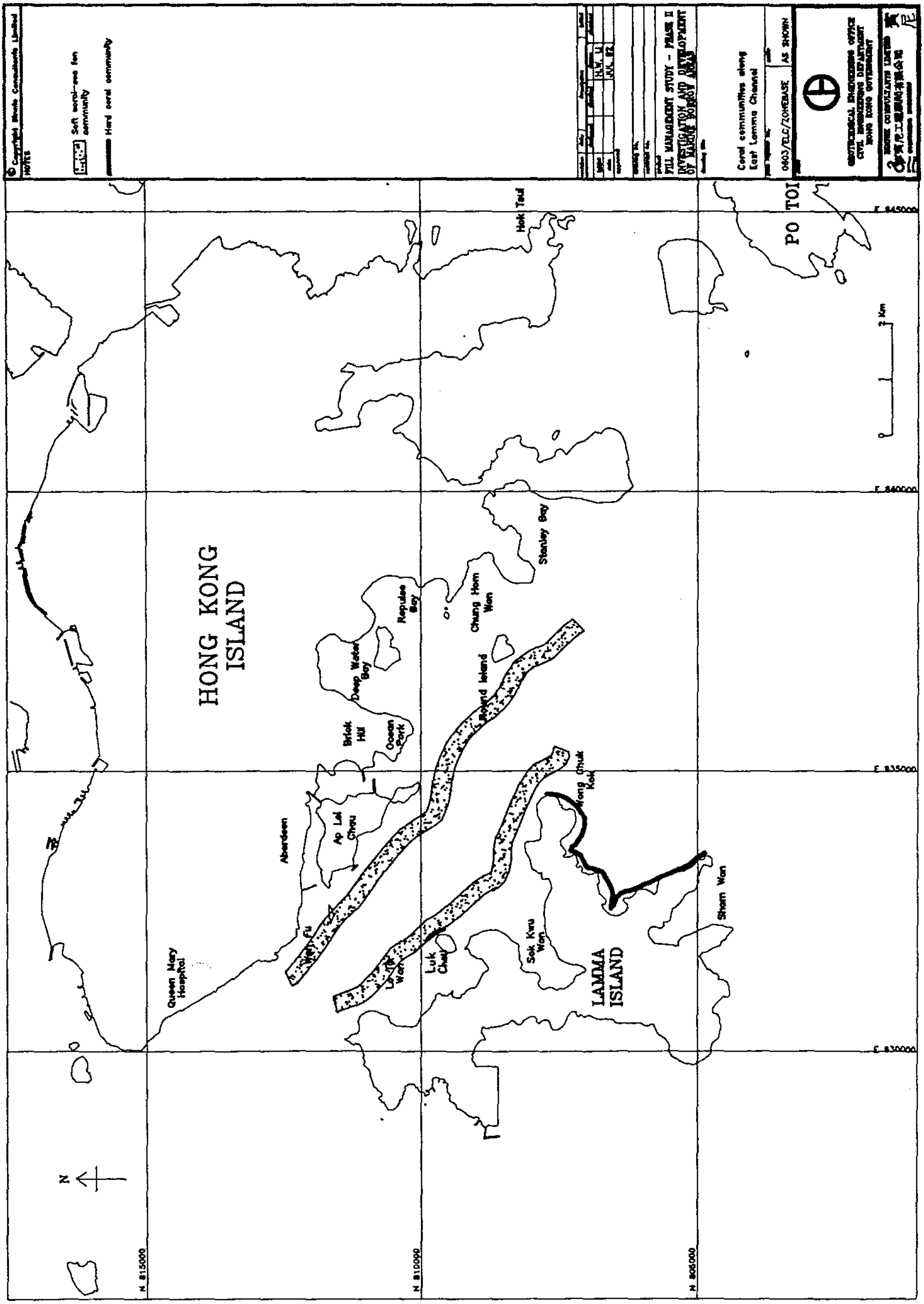


FIGURE 2.2 DISTRIBUTION OF HARD AND SOFT CORALS IN LAMMA CHANNEL

3 FISHERIES

Mariculture

3.1 The mariculture zones at Lo Tik Wan (Figure 3.1) and Sok Kwu Wan (Figure 3.2) are both gazetted. AFD reports that four major types of fish are farmed there; grouper (Areolated grouper, Green grouper (Epinephelus tauvina) and other species), purple amberjack (yellowtail), Russell's snapper (Lutjanus russelli) and Gold-lined sea bream (Rhabdosargus sarba). Other species, such as Chinese catfish, are grown for the farmers' own consumption. Data on the usage of the two fish culture zones are given in Table 3.1. Lo Tik Wan has grown in importance since 1979 when only 6 rafts were in use covering 180 m^2, while Sok Kwu Wan has increased by about 50 rafts since then (Richards, 1980).

TABLE 3.1 FISH CULTURE AT LAMMA ISLAND

	Lo Tik Wan	So Kwu Wan
Zone Area (m^2)	109,200	84,900
Licensees (n)	101	191
Rafts (n)	125	234
Licensed Area (m^2)	32,539	31,802
Production (tonnes)	256	254
Value ($'000)	15,042	14,700
Source : AFD, 1990; AFD, 1992		

3.2 Stocking density varies among farmers but averages about 3000 fish per cage. As they mature, the population is thinned. Feed is primarily "trash fish" bought for $1-2 per catty (0.6 kg/catty) and ground up on site. Feed conversion ratio is believed by AFD to be about 1:10. An AFD licence costs $3 per 1 m^2 of cage. Average annual production is 10 piculs per cage; maximum production is 26 piculs per cage (60.34 kg/picul).

3.3 According to the farmers interviewed, mortality is often 50%, and can reach 90% when diseases strike. Drug baths and drugs mixed with food (tetracycline) are used to combat these problems. Water quality is perceived to have declined in the past four years such that fish now require about one more month to grow to maturity than previously. Farmers consider Lo Tik Wan to be superior to Sok Kwu Wan for growing fish due to the cleaner water and faster currents found there. Although fish can still be profitably grown in Sok Kwu Wan, there is an increased risk of mortality due to disease.

3.4 No data are available regarding the profit of the fish farmers. The average family size of the fish farmers was 5 persons in 1989. Assuming one licence per family, an estimate of the population supported by the mariculture operations would be 1500 people.

3.5 More details regarding the culture of the four most common species are given below.

Grouper

3.6 Grouper are obtained from Thailand and the Philippines as fingerlings (juveniles) of 7-20 cm in length at a cost of HK$10-15 each. Growth to marketable size (400 g) takes 2 years.

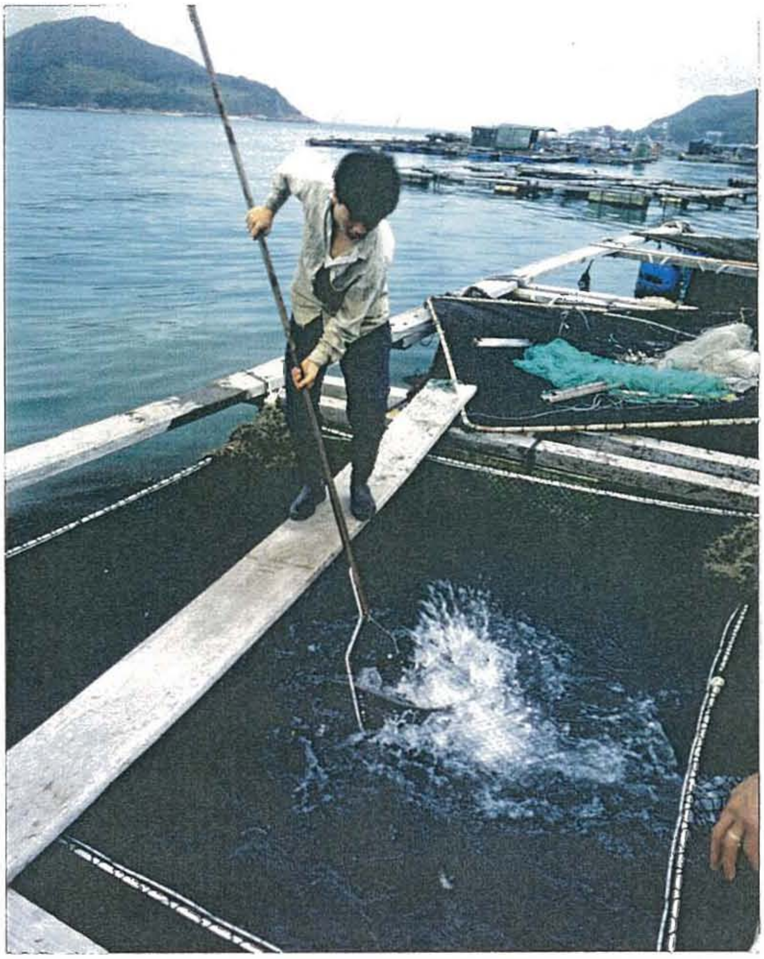


FIGURE 3.1a AMBERJACK AT LO TIK WAN

FIGURE 3.1b LO TIK WAN MARICULTURE ZONE

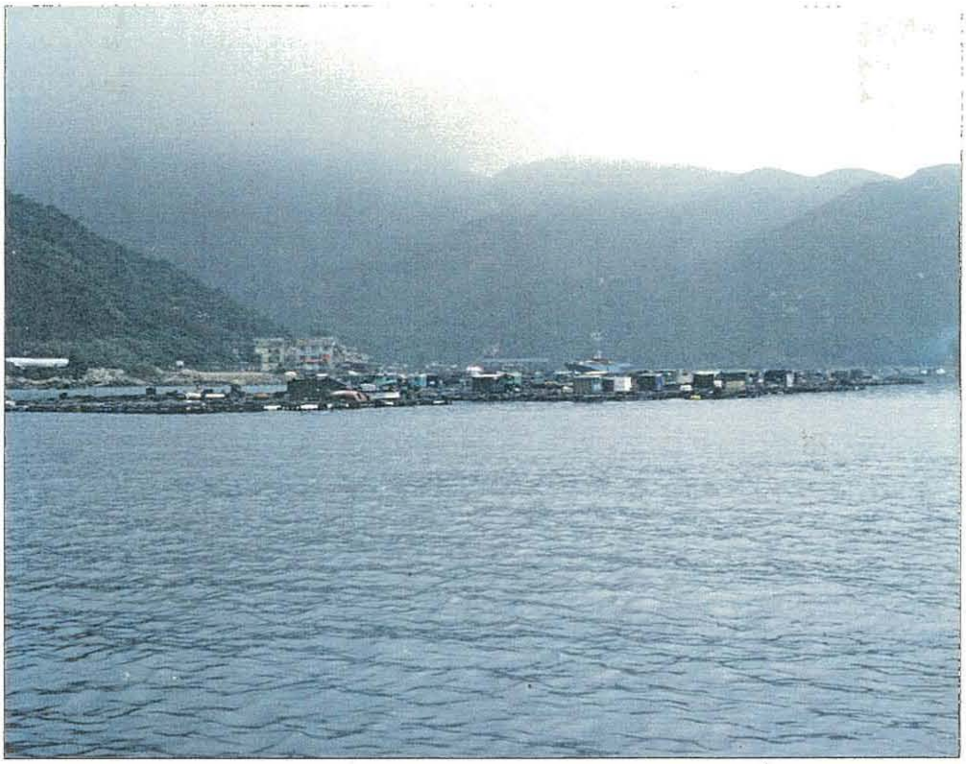


FIGURE 3.2 SOK KWU WAN MARICULTURE ZONE

Grunt

3.7 Fingerlings of 2-9 cm are obtained from China at $3-6 each. Growth to marketable size (500-1000 g) takes 2 years.

Sea Bream

3.8 Sea bream fingerlings can be caught along unpolluted shores throughout the territory. Fingerlings as small as 1 cm are caught locally along the shores of Lamma during January and February or can be bought for $3-6 each (3-4 cm size) from collectors. Seabream accounts for 10% of total production at Sok Kwu Wan and 20% at Lo Tik Wan.

Amberjack

3.9 Fingerlings as small as 1 cm are bought for $3-6 each. Obtained from the South China Sea. Growth to a marketable size of 2-5 kg takes two to three years (consumption is for sashimi).

Capture Fisheries

3.10 AFD estimates 250 vessels (less than 25 m length) operate in East Lamma waters producing an annual catch of 540 tonnes of fish valued at HK$6 million. This is about 3% of the fish catch for inshore (small vessel catch) Hong Kong waters. No recent catch data are available for vessels larger than 15 m such as shrimp trawlers. The latest analysis of fish catch in Hong Kong by zone (Figure 3.3) was carried out over a decade ago (Richards, 1980). These data indicate that about 9% of Hong Kong's shrimp catch and 5% of the squid catch came from the Lamma Channel and Tsin Shui Wan (Zone 5, subzones 3,4,5, 6 and 7).

Fry Collection Zones--Lamma

3.11 AFD reports that gravid adult fish of a variety of species have been caught in East Lamma Channel indicating the areas possible significance as a spawning zone. No detailed data are available.

3.12 Although fry are used in the mariculture industry, they are considered part of the capture fisheries industry because they are caught from wild stocks. According to Richards (1980) and BCL interviews with local fishermen, the East Lamma Channel side of Lamma Island, particularly Luk Chau Wan, is used as a fry collection area. Available information suggests that sea bream fry are initially available beginning in November and December, and by January are large enough to be caught by fishermen using fine-mesh nets.

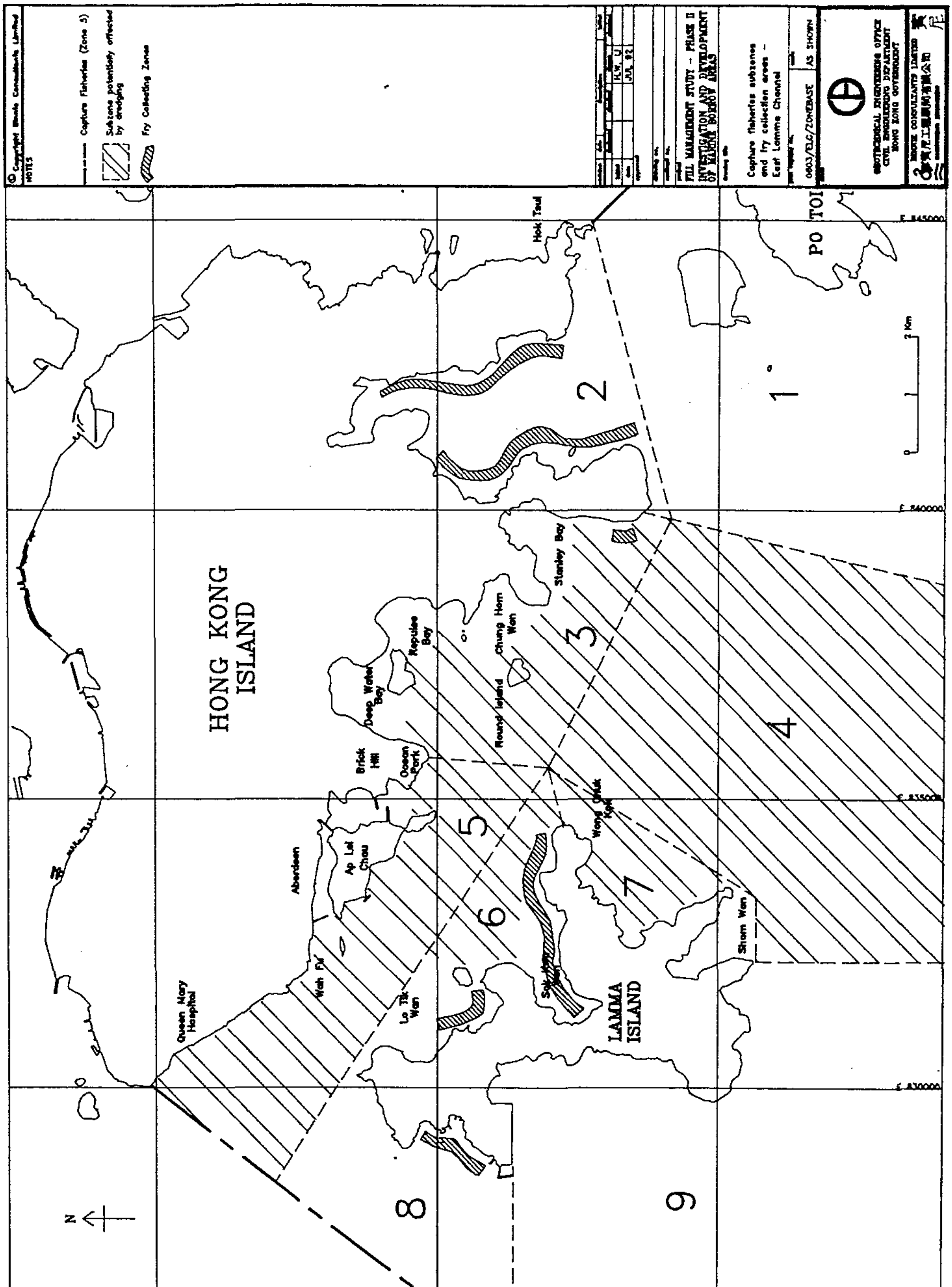


FIGURE 3 . 3 EAST LAMMA CHANNEL FISHERIES SUB-ZONES (ZONE 5)

4 SEDIMENT TRANSPORT AND DEPOSITION

Techniques

4.1 Estimates of sediment transport and deposition were made with the assistance of two modelling techniques, computer modelling and hand calculations. This section covers computer modelling. Modelling of sediment transport is a highly complex exercise based on a large number of dynamic variables. The computer modelling was carried out to assess the results of an input scenario that is believed to represent the most likely dredging programme. If the actual dredging programme differs greatly from that used here, it is possible that the actual distribution of suspended sediment and sediment deposition would not be the same as predicted in this report.

4.2 Hand calculations were carried out as a check on the computer results and as a method of assessing the impacts of intermittent events, such as wave driven sediment resuspension, that were not included in the computer work. The results of the hand calculations are given in Section 5.

Computer Modelling

4.3 The overall objective of the sediment studies is to quantify the amounts and distribution of sediment predicted to be lost during dredging of the proposed borrow area.

4.4 The specific objectives of the sediment studies are:

- to determine the increase in concentration of suspended sediment in the East Lamma Channel and adjacent waters as a result of the proposed dredging activities, and
- to determine the amount of sediment that will be deposited on the sea bed of the East Lamma Channel and adjacent waters as a result of the dredging.

Input Parameters and Model Assumptions

4.5 It was assumed that dredging of East Lamma Channel would be carried out using trailer dredgers; maritime constraints within the East Lamma Channel would limit the operation to one dredger at a time. There would be two phases to the dredging; the first would involve dredging of overburden (mud) for disposal while the second would involve sand dredging (production of fill).

4.6 The study has assumed that two 8,000 m^3 trailers will be dredging alternately such that one dredger is always in operation, while the other is travelling to and from the borrow area. The result will be essentially a continuous dredging operation.

Overburden dredging

4.7 As will be discussed in detail in the Mitigation section, no overflow would be allowed during dredging of overburden, as is consistent with Hong Kong practice. Despite this limitation, sediment losses due to normal operation of the Automatic Lean Mixture Overboard System (ALMOB) would be about 4000 tonnes/week, equivalent to 6% of the overflow losses generated during sand dredging. It is not expected that sand and mud dredging would occur simultaneously, so the sediment plumes created would not be additive. The only additive effect would be deposition. Since the major allowable losses of concern will occur during sand dredging, the modelling has focused on the effects of overflow losses during sand dredging.

Sand dredging

4.8 When a trailer dredger is operating, the hopper is allowed to overflow in order to discharge fine sediment. The East Lamma Channel sand resource contains about 6% fine sediments that will make up the bulk of the sediment discharged during overflow. By comparison, the fines content found at most other potential borrow areas in Hong Kong waters ranges between 20 to 30%. Therefore the East Lamma Channel resource is consider to be relatively "clean."

4.9 Overflow waters are denser than seawater, due to the high concentration of sediment, and descend rapidly toward the seabed leaving a relatively small fraction of material in suspension in the water column. For the computer runs the assumption has been made that 33,700 tonnes/week of sediment would be released from each 8000 m^3 capacity trailer dredger working the East Lamma Channel resource.

Dredging Scenario

4.10 We have assumed that the two trailers would discharge 67,400 tonnes of sediment per week, at an average discharge of 6.69 t/min. While each dredger was on station, it would discharge 9.3 t/min of sediment into the channel and would travel at 2 m/s relative to the water. The dredging speed is an important input parameter as it affects the initial dilution of sediment. The speed chosen is considered intermediate.

4.11 We have assumed that the sediment discharged from the trailer is divided into three components.

10%	remains within the surface layer
9%	goes directly into suspension
81%	falls fairly rapidly to the sea bed and can be resuspended only if bed shear stresses are sufficiently high.

4.12 The latter assumptions regarding sediment plume dynamics take into account the results of suspended sediment monitoring trials using the Acoustic Doppler Current Profiler (ADCP). These trials (BCL, in prep.), which were undertaken during calm sea conditions near the Ninepin Island group, have documented a pattern whereby a high percentage of sediment discharged with dredger overflow descends to a depth of 20 m within about 30 minutes. ADCP equipment is not capable of measuring sediment concentrations in the water column less than 3 m deep.

4.13 Overflow losses during sand dredging at Ninepins were approximately four times the predicted losses for sand dredging in East Lamma Channel. So the effects at the East Lamma Channel will be correspondingly lower. However, the general patterns of sediment plumes monitored by ADCP at Ninepins may be indicative of what might be expected at Lamma, albeit with lower absolute concentrations.

Fate of Sediments Released From the Dredger

4.14 The 10% of sediment that remains on the surface of the sea is assumed to move under the combined action of tidal currents and wind assisted currents. It is assumed that the sediment is discharged into a surface plume, 50 m wide and 2 m deep. With a dredger moving at 2 m/s, the initial concentration in this surface plume will be 77.5 mg/l. This initial concentration is consistent with plume concentrations measured in Hong Kong within 30 to 40 minutes of plume creation. The surface plume will be convected by the tidal and wind generated currents and will gradually disperse laterally under the influence of local turbulence. The sediment in this plume will also slowly sink.

4.15 Calculations of the movement of this plume under the combined action of wind and tide have been made by adding the wind driven component of current to the tidal component. The wind driven component is assumed to be 3% of the surface wind speed in the direction to which the wind is blowing. This is opposite to the wind direction so that a south west wind blows the plume towards the north east. The tidal movement has been calculated using the velocity data predicted by the WAHMO hydrodynamic model (Binnie and Partners, 1989).

4.16 The 81% of sediment that falls directly to the seabed in the density current associated with the dredger overflow is deposited on the seabed beneath the dredger. The model allows this material to be eroded whenever the shear stress exceeds 0.04 N/m^2. The eroded material is added to the sediment already in suspension in the lower layer of the model.

4.17 The critical shear stress for erosion of this material is determined from the assumption that the dry density of the sediment in the density current would be in the range 20 to 25 kg/m^3. The full equations for calculation of erosion stress are given in Appendix C.

4.18 The remaining 9% of sediment which remains in suspension is assumed to be uniformly distributed over the entire depth of water at the location of the dredger. In the wet season, when the flow is stratified, the proportion of material placed in each layer is determined by the relative depth of each layer.

4.19 The sediment in suspension is convected by the tidal currents and allowed to move from upper to lower layer and vice versa in accordance with the vertical movement of water computed within the hydrodynamic model to preserve continuity.

4.20 The sediment in the lower layer is allowed to settle at times when the shear stress in this layer is below a threshold value 0.1 N/m^2. The material that settles in this way may be subsequently eroded if the shear stress exceeds 0.3 N/m^2 at some later time. The value of 0.3 N/m^2, adopted for the present study, was used during previous studies for Hong Kong coastal water (Hydraulics Research, 1988).

4.21 The full equations for erosion and deposition of this material are given in Appendix C and are based on the recommendations contained in Delo (1988).

Choice of Sediment Models

4.22 The convection and deposition of sediment was carried out using a sediment model based on the equations set out in Appendix C. This model was limited to a single layer for dry season tests but incorporated two layers for wet season tests. The sediment model utilised the solution to the convection dispersion equation developed for the DIVAST model by Falconer (1981).

4.23 The velocities and water levels used in the sediment model were derived from the output of the WAHMO hydrodynamic model provided by Civil Engineering Services Department.

4.24 Sediment plume modelling was based on the output from the hydrodynamic model, modified by the wind driven component of current. The dispersion of the plume was predicted using a Brooks two sided plume model (Brooks, 1960) with a lateral dispersion coefficient proportional to depth and shear velocity as suggested by Fischer et al (1979).

Choice of Hydrodynamic Model

4.25 Hydrodynamic modelling of Hong Kong waters is available on a 250 m grid from the WAHMO model which has subsequently been enhanced and extended to include the waters to the south of Lamma Island (Figure 1.1). A more detailed model of the East Lamma Channel and Western Harbour area with a 100 m grid has recently been developed as part of the Port and Airport Development Studies.

4.26 To help establish the hydrodynamic regime in the study area, CESD supplied us with WAHMO data from both the 250 m grid and 100 grid models with and without the dredged pit. These data include velocity and water surface elevations at each grid cell at 20 minute intervals throughout a typical 25 hour spring tide and typical 12.5 hour neap tide.

4.27 The 100 m model provided much greater detail of bathymetry in the East Lamma Channel, but the model boundary is situated at the south end of Hong Kong Island. The proposed dredged pit was inside the limit of this model but very close to its boundary. Thus most of the sediment entrained on the ebb tide passed out of the model and its subsequent movement could not be accounted for in this model. The western limit of this model was chosen to be at the west end of Hong Kong Island for practical reasons. This also allowed considerable quantities of sediment to leave on the flood tide.

4.28 The difficulty of defining model boundaries sufficiently remote from the dredged pit prevented the use of the 100 m model for sediment dispersion studies. The proximity of the pit to the 100 m model boundary in East Lamma Channel meant that predictions using this model were likely to be less reliable than those using the more extensive 250 m grid model in the region of greatest interest along the shores of the East Lamma Channel. All sediment model studies in this report have therefore been based on the 250 m extended WAHMO model predictions.

Model Study Area

4.29 The part of the 250 m model used for sediment modelling is shown in Figure 1.1. This area extends from Tsing Yi in the north west to the Po Toi islands in the south east. The sediment model includes the majority of the western harbour, all the coastline of Lamma Island and the southern and western coastline of Hong Kong Island.

4.30 The existing bathymetry shows that the water depth is shallow (<10 m) in the west of the modelled area, but deep (20-30 m) in the east of the model area, and particularly deep in the East Lamma Channel where water depths of 30-40 m occur.

4.31 The proposed dredging pit is located in the centre of the East Lamma Channel. It was initially proposed to excavate approximately 3.0 km^2 of the sea bed to a water depth of 60 m. Subsequent proposals have limited the southern extent of the pit to avoid wave refraction problems. The smaller pit has not been tested in the sediment models but the consequences of limiting the pit size are examined.

Water Velocities

4.32 Water velocities predicted by the 250 m extended WAHMO model are shown in Figures 1.5-1.16 for typical flood and ebb conditions during spring and neap tides for wet and dry season conditions. These figures indicate the velocity patterns predicted by the extended WAHMO model for the existing bathymetry.

4.33 In the wet season (Figures 1.5-1.10), the currents in the lower more saline layer are stronger on the flood tide than the ebb tide. In the upper less saline layer, ebb tide currents, which carry brackish water seaward from the Pearl River estuary, are much stronger than flood tide currents.

4.34 On the neap tide, with its slower tidal currents, there is an almost constant outflow of brackish water in the surface layer. Currents on the flood neap tide are very weak in both layers in the East Lamma Channel and are therefore not shown.

4.35 In the dry season (Figures 1.11-1.14) the currents on the ebb and flood are more evenly balanced. The differences between neap and spring tides are also rather smaller.

4.36 The presence of the pit causes relatively small changes in local velocities. The velocities on a spring tide in the lower layer are shown in Figures 1.15 (flood) and 1.16 (ebb) which may be directly compared with the velocities before pit excavation shown in Figures 1.5 and 1.6. The velocities within the pit area itself decline and the vectors around the side of the pit are drawn slightly towards the pit to increase the flow through the deep water of the pit.

Sedimentation Predictions

4.37 The movement of suspended sediment caused by dredging operations was modelled with the existing bathymetry and with a fully excavated pit. The results of these cases were deemed to represent the effects incurred at the beginning and end of pit excavation respectively. Although simultaneous studies of wave action in the area showed that the extent of the pit should be limited, it was not possible to incorporate the modifications during the period of the present study. The conditions likely to occur during both spring and neap tides were examined. Model runs were made for both wet and dry seasons.

4.38 Two types of computer models were used to assess the increase in suspended sediment and the changes in sediment deposited on the seabed throughout the area of the study, a convection-dispersion model and a sediment plume model. The convection-dispersion model was used primarily to assess tidal transport while the plume model was used to assess wind-driven transport of surface plumes.

Convection-dispersion model

4.39 This model used hydrodynamic data from the 250 m WAHMO model. Sediment transport estimates were made using the convection dispersion equations from the Bradford University DIVAST model. During dry season tests, flows and sediment transport characteristics were averaged over the entire depth of water. During the wet season, a similar approach was adopted, although two-layer modelling was used to account for the layered effects caused by the large influx of freshwater from the Pearl River.

4.40 In this model, two alternative methods were employed to represent the sediment load from the dredger. The first of these, the 'line source' was used to represent the most severe effects likely to occur along a coastline, when a dredger repeatedly passes close by. The second method of representing sediment load, the 'area source', was used to model the cumulative effects of multiple passes of the dredger along different areas of the excavation zone, over a prolonged period of time.

4.41 The model was also used to estimate the deposition of overspill from dredging on the seabed. In the two layer model, deposition was permitted only in the bed layer, which due to the system used in the WAHMO models does not extend to the coast in most areas. Therefore, during the wet season, the model underestimates sediment deposition close to the coast.

Sediment plume model

4.42 The sediment plume model was based on Brooks' method for plume dispersion. The movement of the plume centreline was also estimated using hydrodynamic data from the 250 m WAHMO model. Calculations were performed by estimating paths of particles released at various stages during the dredger's transit of the excavation area. At each release position, overspill from the dredger was represented by a point source of sediment, which subsequently dispersed. As a conservative assumption, settlement of this surface sediment was not permitted by the model.

4.43 Generally, the convection-dispersion model was used to predict typical conditions, with plume modelling used to assess the effects that could occur locally before full mixing of the sediment throughout the water column takes place.

Results of Sedimentation Model Runs

Wet Season - Spring Tide

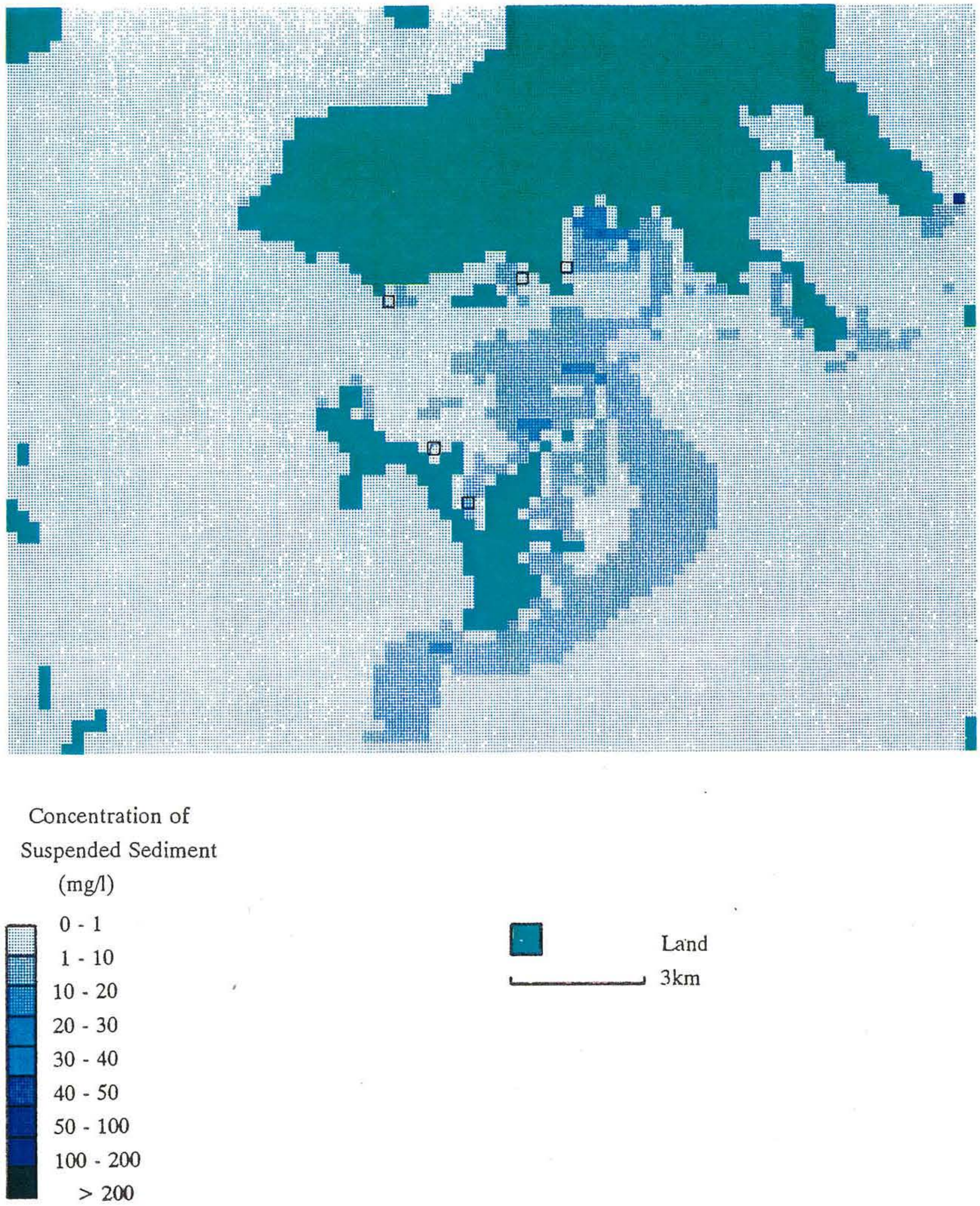
4.44 Figures 4.1 and 4.2 show the estimated average increase in concentration of suspended sediment during spring tides due to the proposed dredging operations. On the figures, the small black squares indicate the locations of important sensitive receivers. The results presented were estimated using the convection-dispersion model, using the existing bathymetry. Figure 4.1 shows the average distribution of suspended sediment in the surface layer. Figure 4.2 shows the corresponding distribution in the bed layer.

4.45 In the surface layer, the estimated average increase in suspended sediment concentration is typically less than 10 mg/l, with the northern part of the East Lamma Channel remaining virtually unaffected. There are small areas where concentrations range between 10 and 20 mg/l. The most important of these is an area extending over more than 0.5 km^2, where the water is shallow. The average increase in concentration of suspended sediment in the surface layer is estimated to remain below 10 mg/l at the seawater intakes at Wah Fu, Brick Hill and Ocean Park, and in the fish farming areas in Sok Kwu Wan and Lo Tik Wan, on the north eastern coast of Lamma Island. The average increase in the surface layer above the Ocean Park intake is estimated to be approximately 2 mg/l during these conditions. As shown in Figure 4.1, little transport of suspended material in a northerly direction is likely to occur. This is primarily due to the south easterly flow which dominates in the surface layers throughout the tide.

4.46 In the bed layer, suspended sediment concentrations are likely to show more widespread increases throughout the modelled area. Figure 4.2 illustrates the estimated distribution of suspended sediment. The increase in concentration of suspended sediments at the Brick Hill and Ocean Park intakes is likely to remain below 1 mg/l.

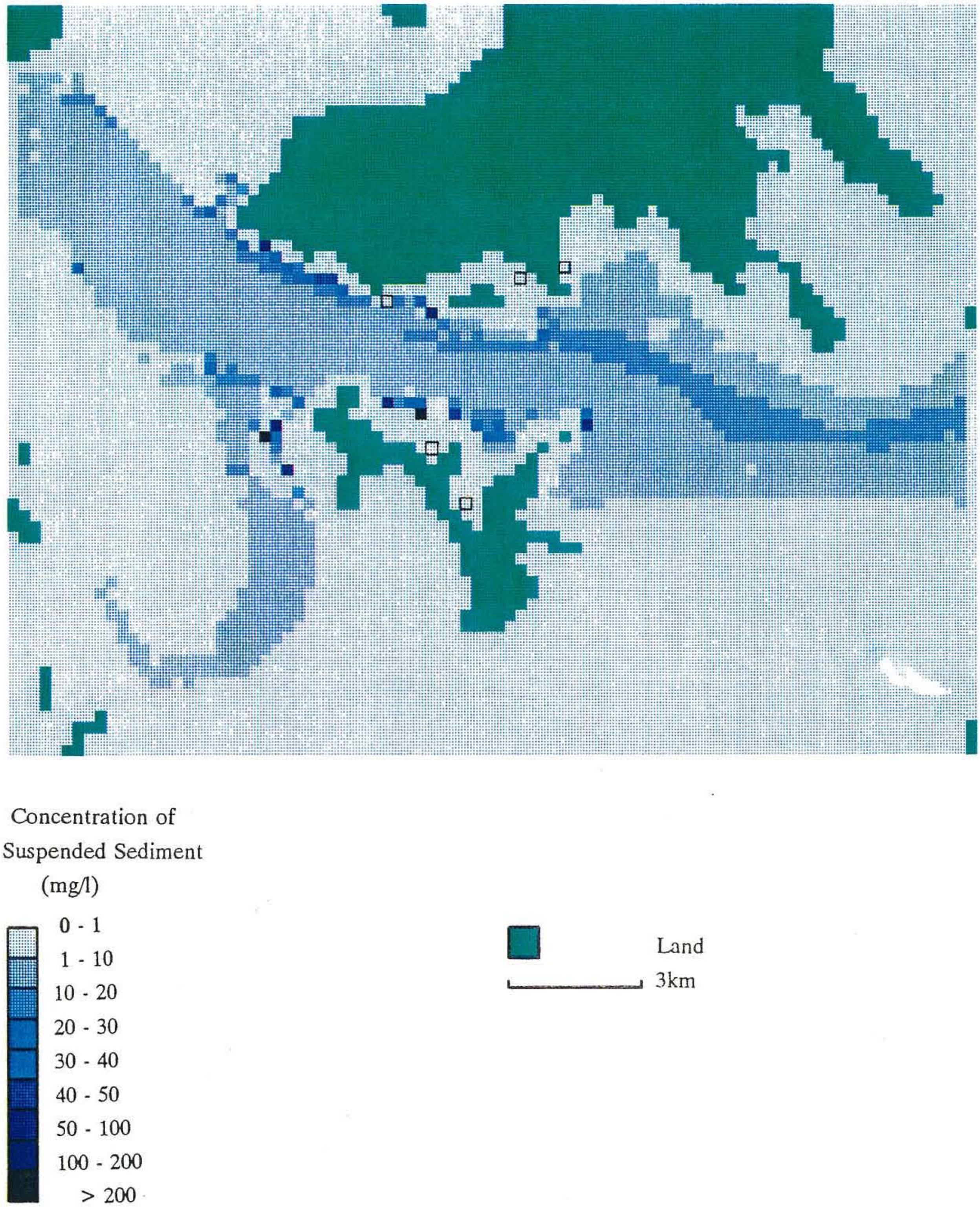
4.47 The Wah Fu intake lies close to a zone of higher concentration. However, as the intake is thought to be located close to the surface, it is not likely to be subject to the increases in concentration between 10 and 20 mg/l estimated at lower levels. On the Lamma Island side of the Channel, the fish farming areas are likely to experience a similar increase in suspended sediment in the lower layers. Typical increases in suspended sediment concentrations in the central region of the East Lamma Channel are likely to be less than 10 mg/l. These raised concentrations are estimated to extend well beyond the limits of the East Lamma Channel in both directions during spring tides in the wet season, but are likely to be confined to the lower saline layer.

4.48 The model output includes both average and maximum values of suspended sediment. The average values are depth-averaged and averaged over the multiple tidal cycle period used. The maximum values represent the maximum depth-averaged level reached during the multiple tidal cycle period used. Figures 4.3 and 4.4 show the estimated maximum increase in suspended sediment during spring tides, and reflect a similar pattern to the corresponding average distributions. Figure 4.3, which shows the maximum concentration in the surface layer confirms that sediment is predominantly transported to the south and west in this layer. Figure 4.4 illustrates the more widespread effects likely to occur in the lower layer.



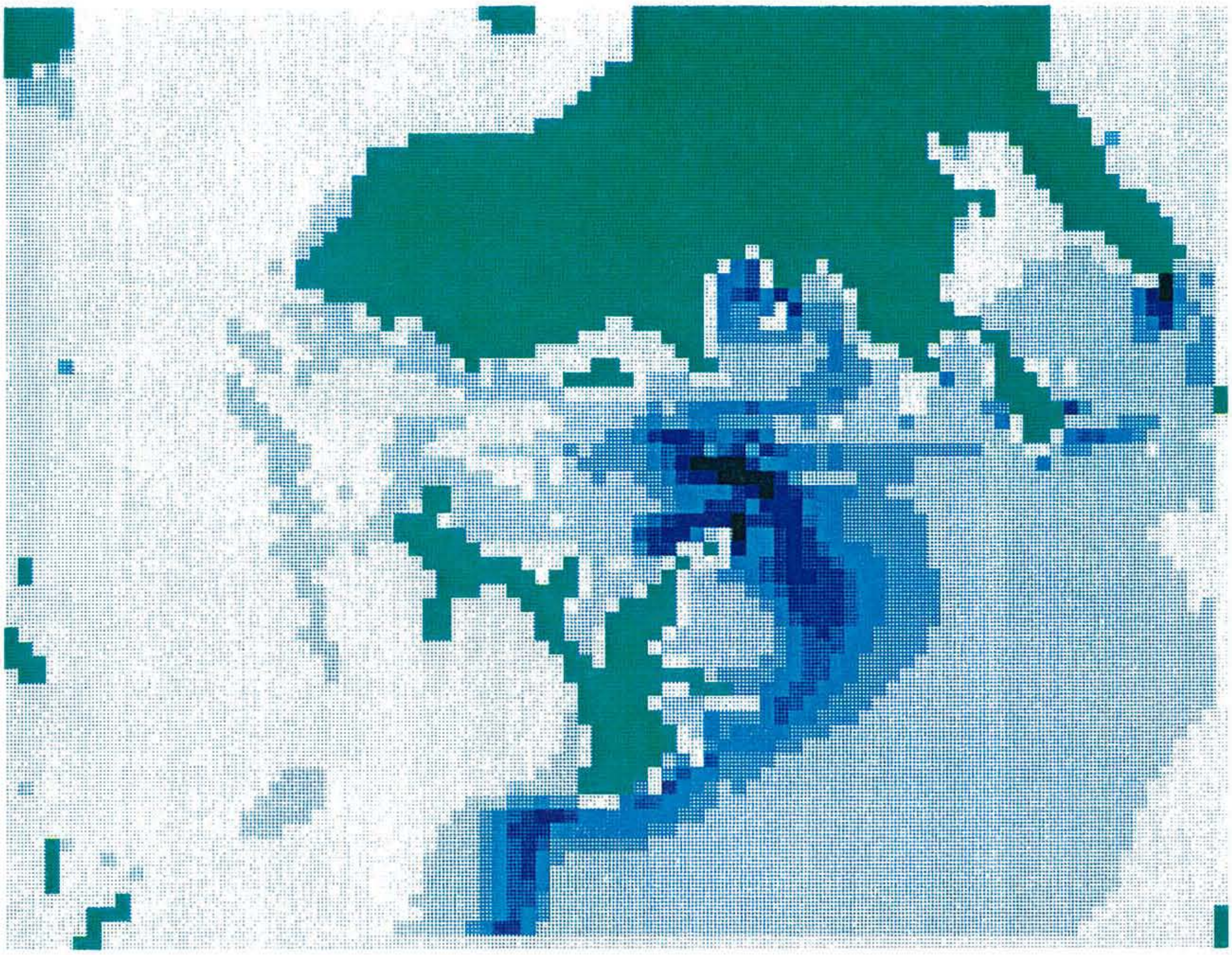
UPPER LAYER AVERAGE CONCENTRATION -
WET SEASON, SPRING TIDE (250m MODEL)

Figure 4.1



LOWER LAYER AVERAGE CONCENTRATION - WET SEASON, SPRING TIDE (250m MODEL)

Figure 4.2



Concentration of
Suspended Sediment
(mg/l)

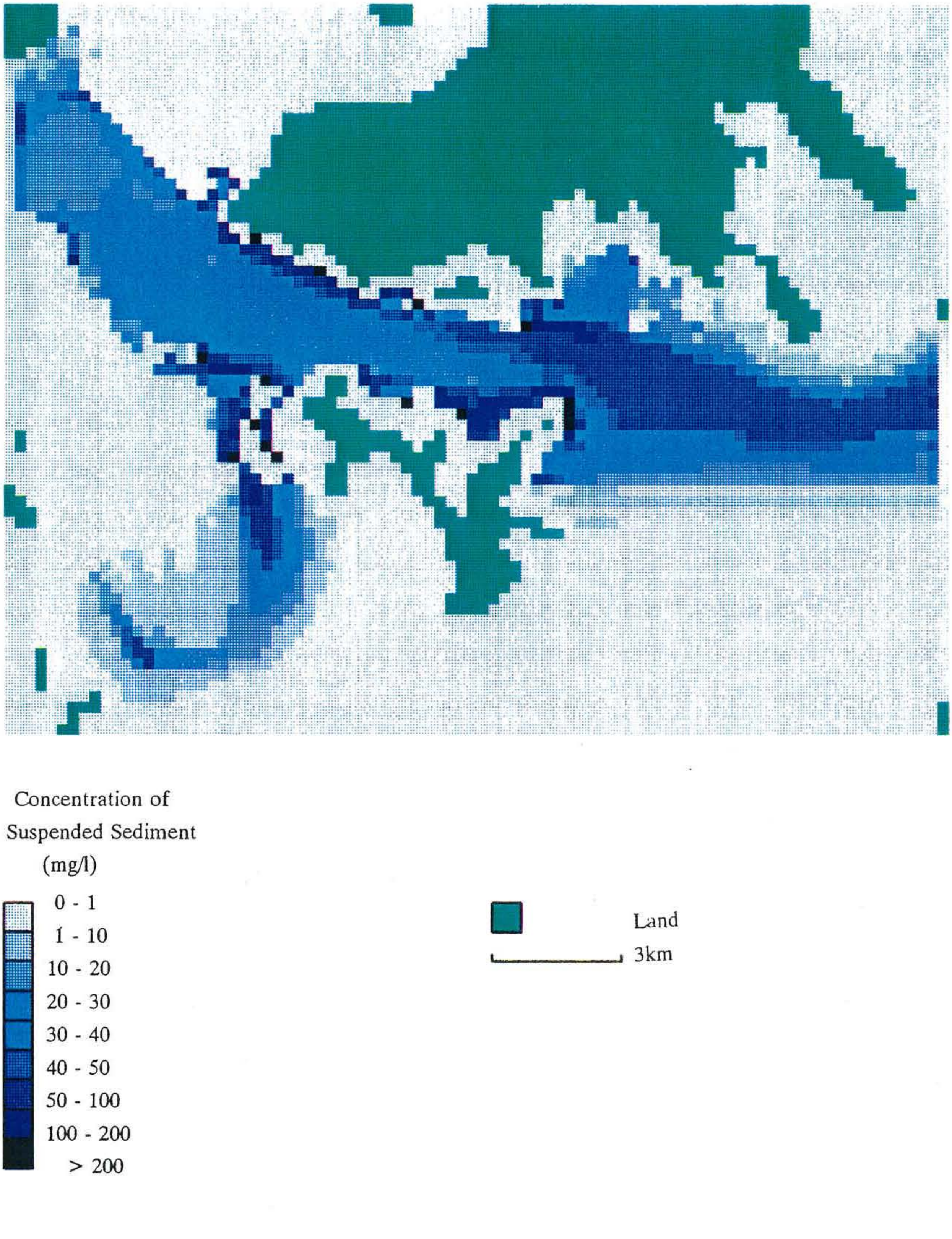
- 0 - 1
- 1 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 100
- 100 - 200
- > 200

Land

3km

SURFACE LAYER MAXIMUM CONCENTRATION -
WET SEASON, SPRING TIDE

Figure 4.3



BED LAYER MAXIMUM CONCENTRATION -
WET SEASON, SPRING TIDE

Figure 4.4

4.49 In the area surrounding the Ocean Park intake, the peak increase in concentration of suspended sediment estimated to occur is approximately 13 mg/l. This is likely to be confined within the surface layer above the level of the intake. Surface layer concentrations in excess of 10 mg/l are likely to persist for a period of less than 2 hours during the flood tide. For approximately 70 percent of the 25 hour spring tide, no increase in concentration is expected to occur in the surface water above the Ocean Park intake. The increase in concentration of suspended sediment in the lower layer, at the level of the intake, is estimated to be negligible throughout the spring tide.

4.50 The model results suggest that during spring tides in the wet season, the intake at Brick Hill will remain unaffected by increases in suspended sediment due to the proposed dredging operation in East Lamma Channel.

4.51 Of the three intakes examined, the Wah Fu intake is likely to experience the worst effects during spring tides in the wet season. Although the surface layers in which the intake is thought to be located are likely to be unaffected, the peak increase in concentration in the bed layer could reach values in excess of 40 mg/l for a period of several hours.

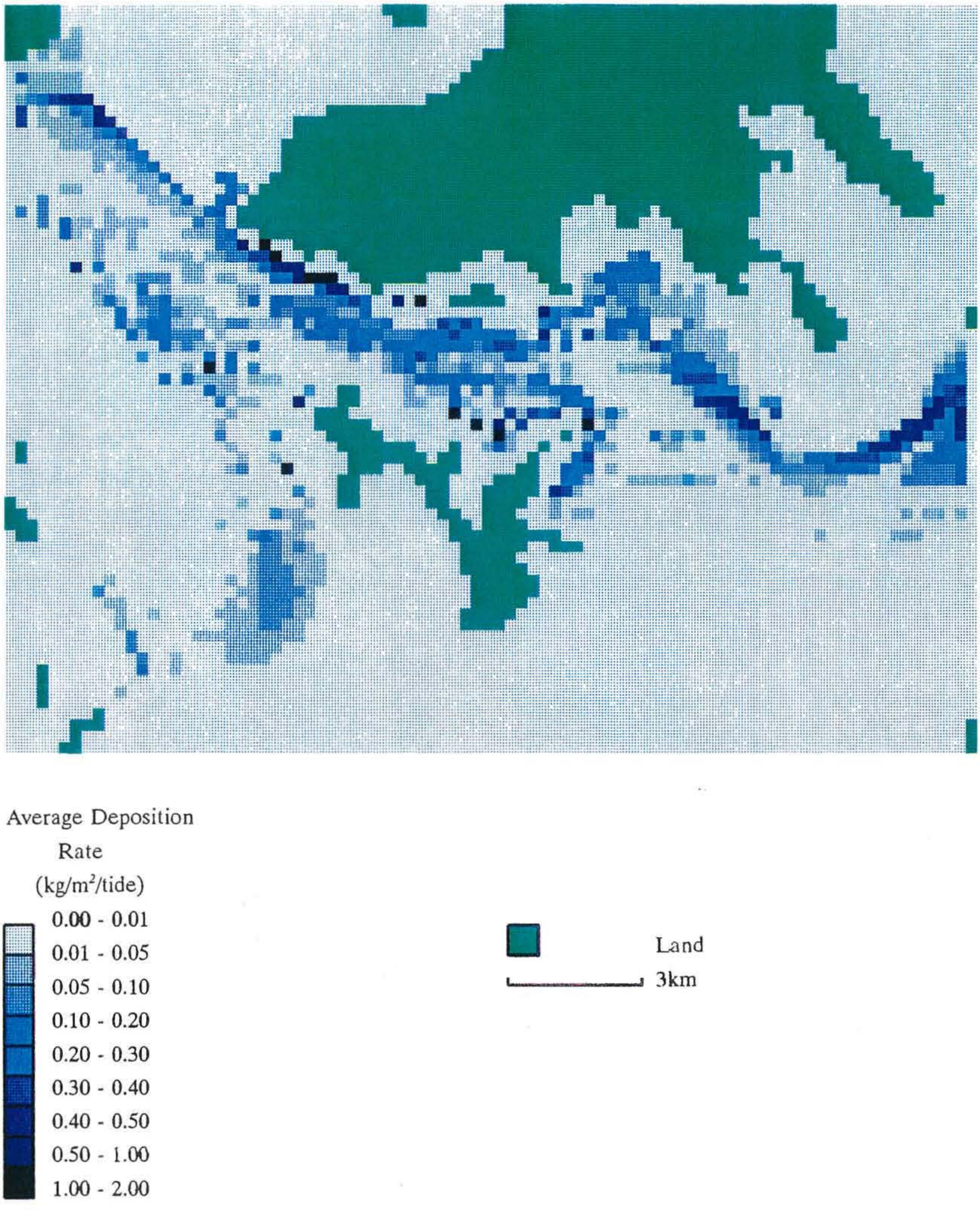
4.52 Figures 4.3 and 4.4 show that the areas most severely affected by dredging are towards the south eastern end of the East Lamma Channel, where peak increases in suspended sediment concentrations reach values of around 100 mg/l in both the surface and bed layers. These peak values are however likely to persist for a short period only and generally occur at a distance of more than one kilometre from the coast. There is also a tendency for a band of settlement along both sides of the channel.

4.53 The estimated deposition of sediments during spring tides is illustrated in Figure 4.5. The average deposition rate is typically of the order of 0.10 to 0.20 kg/m^2/tide in the central region of the channel. Higher deposition rates are estimated to occur over small areas, notably along the west side of Hong Kong Island. Settlement rates occasionally reach values around 1.00 kg/m^2/tide.

Wet Season - Neap Tide

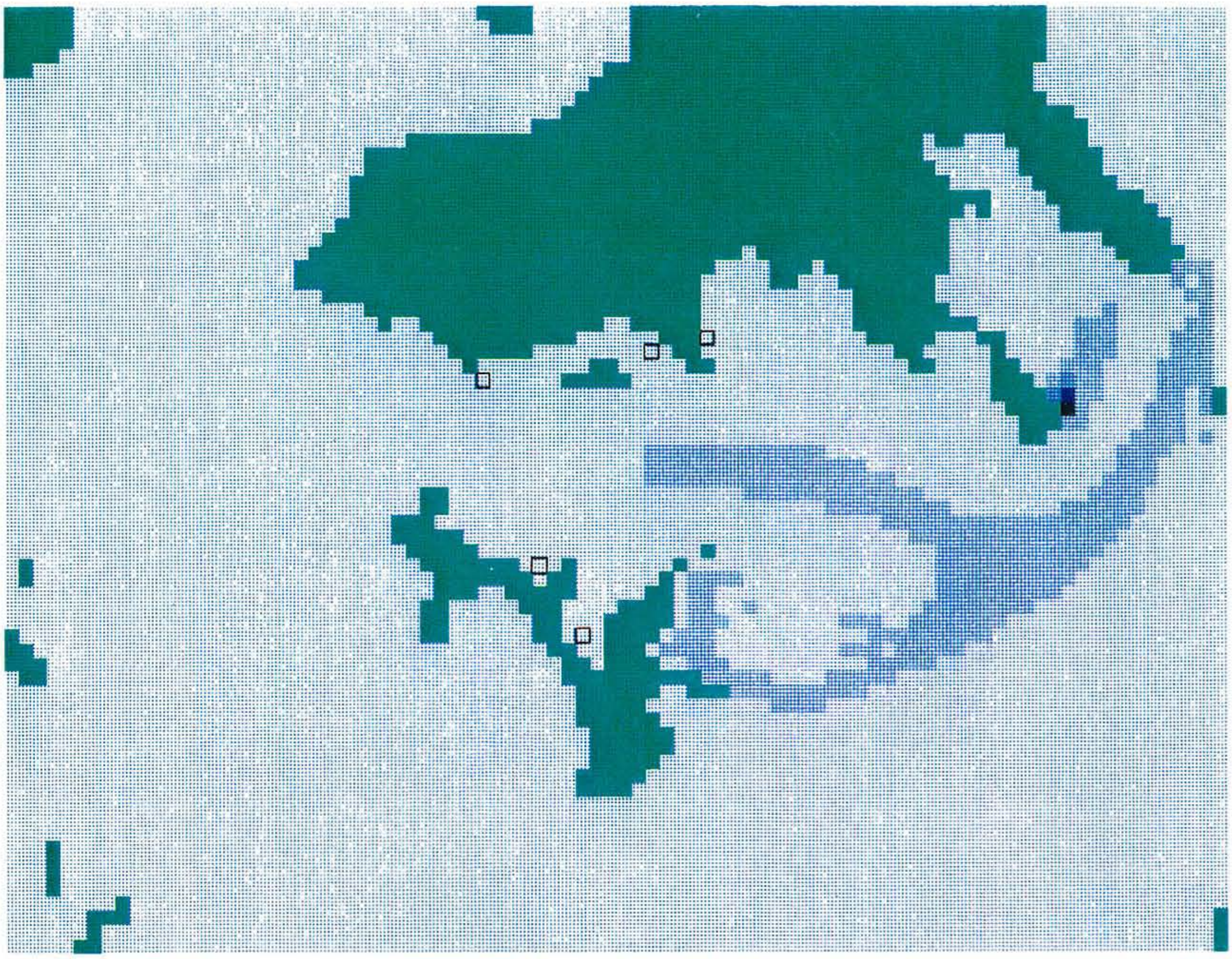
4.54 Figures 4.6 and 4.7 illustrate the estimated distribution of suspended sediments due to dredging on neap tides in the wet season. For both the upper and lower layers, the average increase in concentration is seen to remain below 10 mg/l in virtually all areas. The extent over which the average increase would be detectable is smaller than on spring tides. For both the upper and lower layers, the net movement of sediment in suspension is in a south-easterly direction. This is primarily due to the influence of freshwater flow from the Pearl River during the wet season.

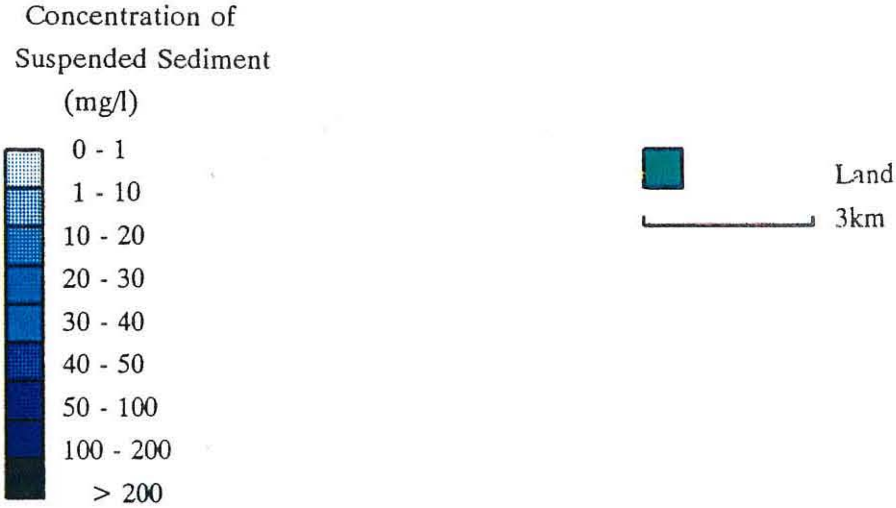
4.55 The seawater intakes at Wah Fu, Brick Hill and Ocean Park are unlikely to experience any increase in suspended sediments during these conditions. The fish farming area off the north eastern coast of Lamma Island would also remain free from any significant increase. The southeastern shore of Lamma Island is likely to experience increased sediment concentrations averaging between 1 and 10 mg/l throughout the tide.



AVERAGE DEPOSITION RATE -
WET SEASON, SPRING TIDE (250m MODEL)

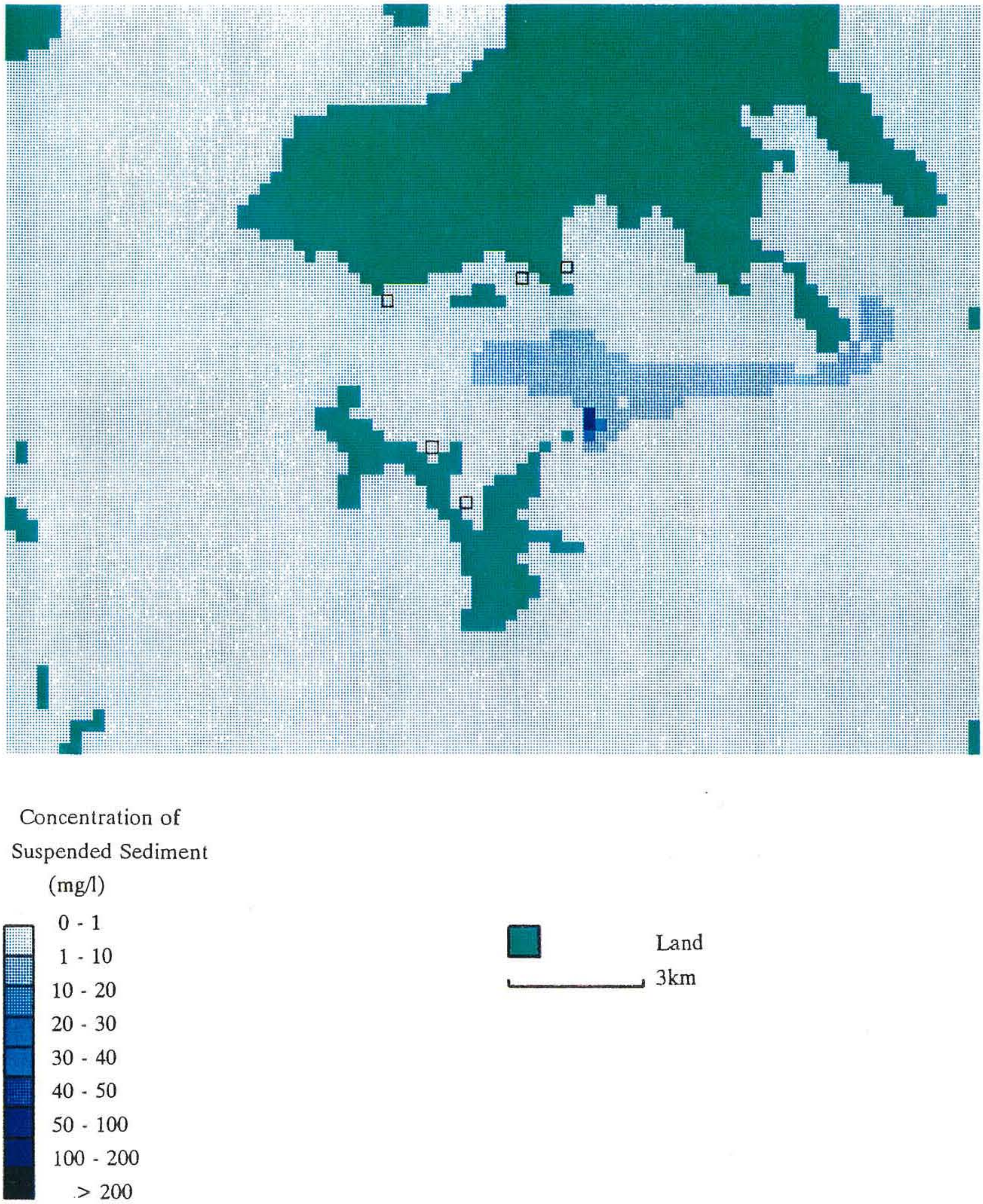
Figure 4.5





UPPER LAYER AVERAGE CONCENTRATION - WET SEASON, NEAP TIDE (250m MODEL)

Figure 4.6



LOWER LAYER AVERAGE CONCENTRATION -
WET SEASON, NEAP TIDE (250m MODEL)

Figure 4.7

4.56 The average rate of deposition of dredged overspill on neap tides is shown in Figure 4.8. The influence of the freshwater flow in transporting sediment south-eastward before deposition is quite pronounced. The pattern of south-easterly movement is much better defined than on spring tides. The area affected by deposits from dredging extends eastward from half way along the East Lamma Channel to Sheung Sz Mun, the strait between Stanley and Beaufort Island. Within the East Lamma Channel, the affected area spans a width of approximately 2 kilometres, reducing to one kilometre beyond Round Island. The average rate of deposition over most of this area is likely to be between 0.01 and 0.05 kg/m^2/tide, with values reaching 0.1-0.2 kg/m^2/tide over an area of one square kilometre between the eastern tip of Lamma Island and Round Island. The area affected by bed deposits is much smaller on neap tides than on spring tides and does not approach any of the seawater intakes or fish farming areas under consideration in this study.

Dry Season - Spring Tide

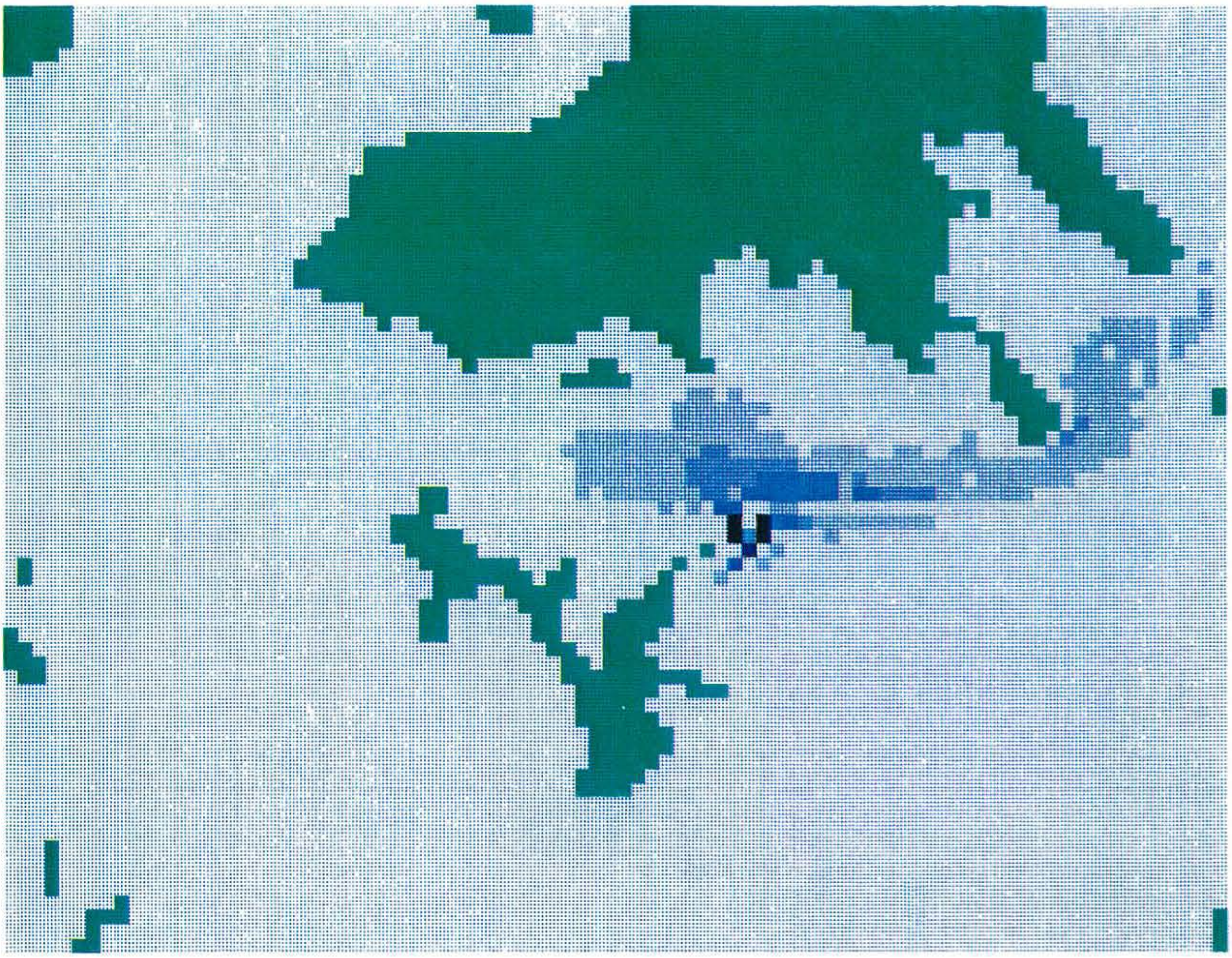
4.57 During the dry season, the average suspended sediment concentrations due to dredging operations are likely to remain below 10 mg/l in all areas. As illustrated in Figure 4.9, the average increase in suspended sediment is estimated to remain below 1 mg/l in virtually all coastal areas. Despite the reduction in freshwater flow during the dry season, the net transport of suspended sediment is still estimated to be in a south-easterly direction. The seawater intakes at Wah Fu, Brick Hill and Ocean Park are unlikely to be affected by any significant increase in suspended sediment. Likewise, the fish farming areas in Sok Kwu Wan and Lo Tik Wan off Lamma Island are not likely to experience any significant sediment increases during these conditions.

4.58 As shown in Figure 4.10, the region affected by increased bed deposits covers a similar area to that affected by increased suspended sediments. The average deposition rate is estimated to remain between 0.01 and 0.05 kg/m^2/tide in all areas, except on the shore of Round Island, where low velocities will tend to result in deposition rates around 0.10 kg/m^2/tide.

Dry Season - Neap Tide

4.59 The model estimates show that, in contrast to the distribution of suspended sediments on spring tides, a significant quantity of material is transported in a north-westerly direction on neap tides. The results estimated by the model for these conditions are shown in Figure 4.11. The increase in concentration remains similar to that for spring tides, at less than 10 mg/l over the area affected. The region affected covers a similar area but extends from Round Island in the south-east to approximately 4 km off Green Island, close to the western tip of Hong Kong Island.

4.60 In this case, the average concentration of suspended sediment at the Wah Fu intake could potentially rise above 1 mg/1, but is likely to remain near this level throughout the tide. The model estimates that no significant increase in average suspended sediment will be experienced at the Brick Hill and Ocean Park intakes. During neap tides, the fish farming areas in Sok Kwu Wan and Lo Tik Wan are likely to be unaffected by increases in suspended sediments due to dredging in the East Lamma Channel.



Average Deposition Rate (kg/m²/tide)

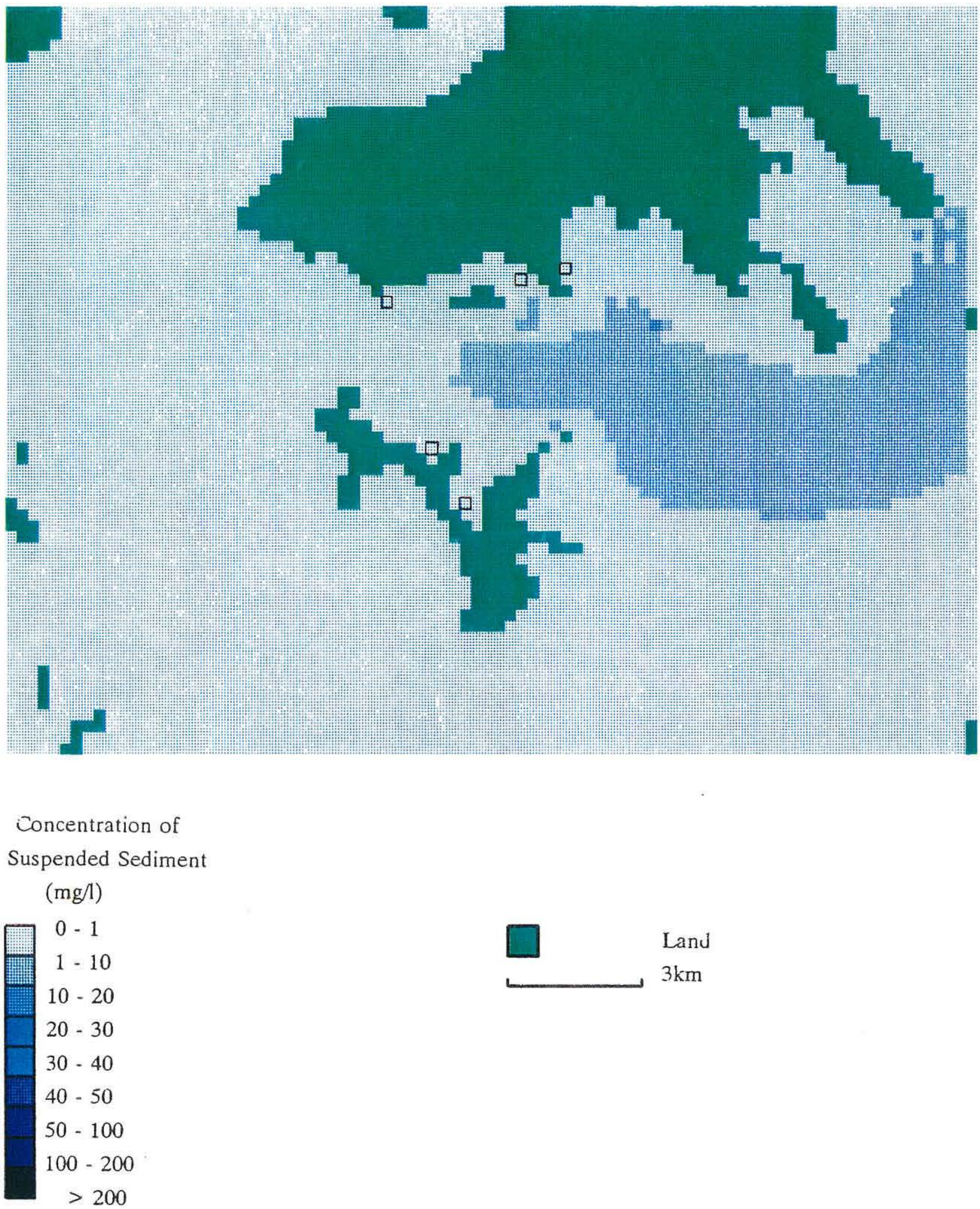
- 0.00 - 0.01
- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.30
- 0.30 - 0.40
- 0.40 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00

Land

3km

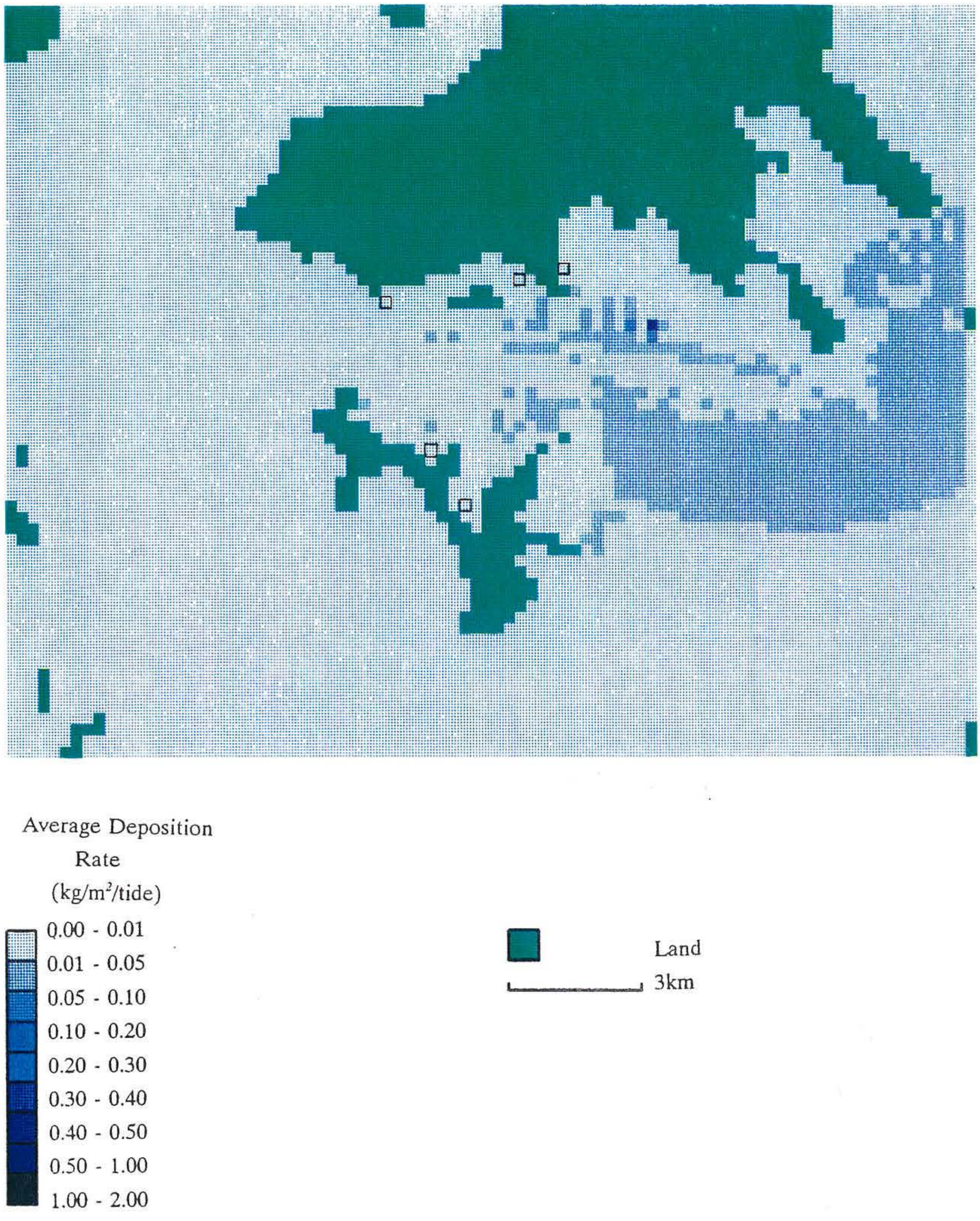
AVERAGE DEPOSITION RATE - WET SEASON, NEAP (250m MODEL)

Figure 4.8



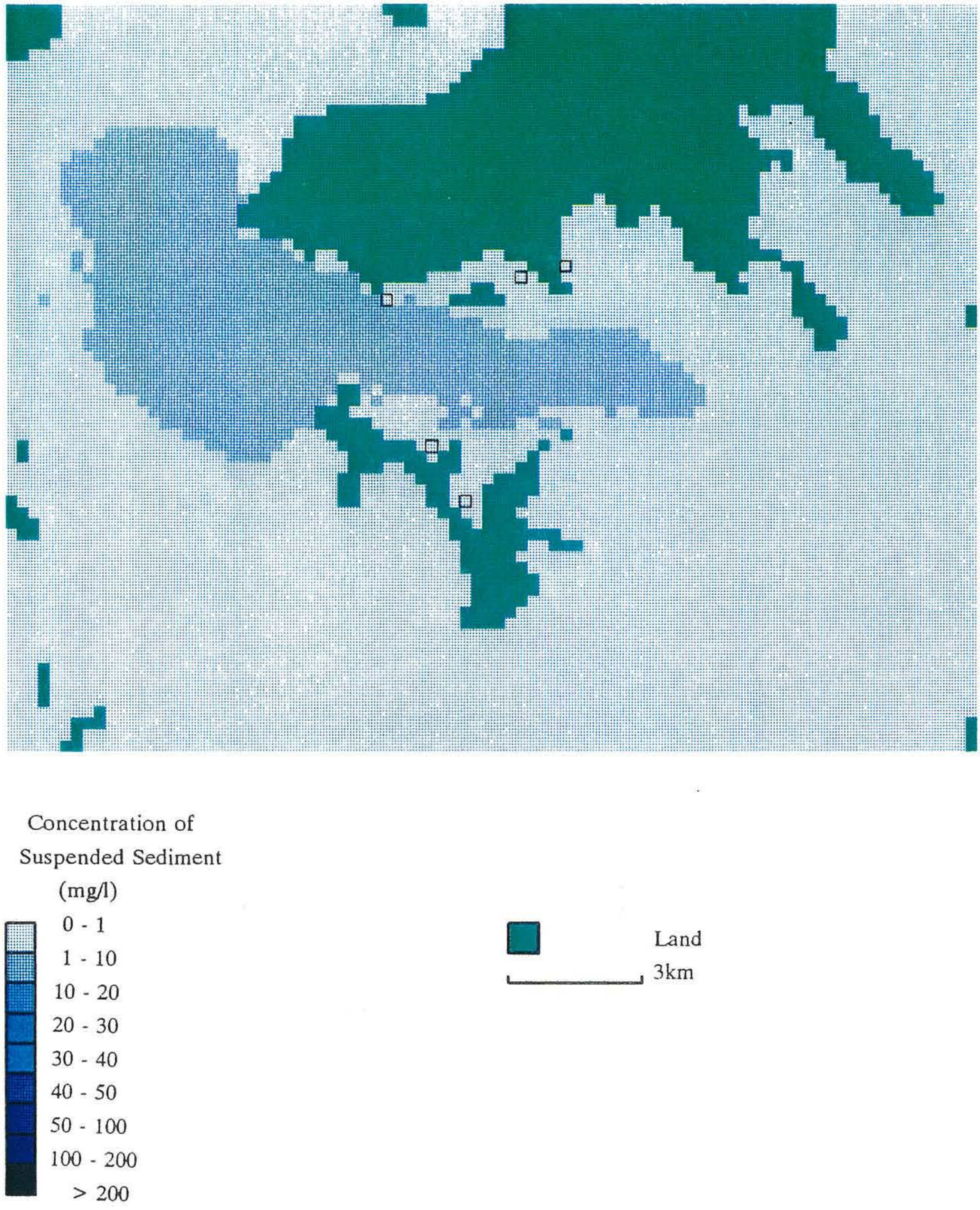
AVERAGE CONCENTRATION -
DRY SEASON, SPRING TIDE (250m MODEL)

Figure 4.9



AVERAGE DEPOSITION RATE -
DRY SEASON, SPRING TIDE (250m MODEL)

Figure 4.10



AVERAGE CONCENTRATION -
DRY SEASON, NEAP TIDE (250m MODEL)

Figure 4.11

4.61 The estimated deposition rate during dry season neap tides is shown in Figure 4.12. It is estimated that during neap tides, sediment will be deposited over an area of East Lamma Channel extending from Round Island to Green Island. In all affected areas, the average rate of deposition throughout a tide is unlikely to exceed 0.05 kg/m^2.

4.62 The plots show that, in general, deposition will occur more than 0.5 km from the coast at Lamma Island. Similarly, no coastal deposition is expected to occur at Brick Hill or Ocean Park. Some deposition is likely to occur along the western coast of Hong Kong Island from Wah Fu to Green Island.

Annual Deposition of Sediment

4.63 The annual rate of deposition of sediments due to the proposed dredging was quantified by combining the estimated effects during individual tides. Calculations were carried out using the assumption that the spring tide tested occurs 15 times per month and the tested neap tide occurs 30 times in a month. The wet season lasts for approximately 4 months of the year. The computed annual deposition rate is shown in Figure 4.13. This estimated distribution indicates that bed deposits in the central area of the East Lamma Channel will generally accumulate at a rate of 10-20 kg/m^2/year. At the north western end of the channel, deposition at a rate of 5-10 kg/m^2/year is likely to extend up to 8 km beyond the northern limit of Lamma Island. The width of the deposition zone is estimated as 4 km at the northern limit of the island, reducing to 1.5 km wide off the western tip of Hong Kong Island. The deposition zone is also estimated to extend south-east of Lamma Island, with deposition rates of 5-10 kg/m^2/year estimated to occur up to 9 km south-east of Lamma Island, at the limit of the modelled area.

4.64 Significant zones of increased deposition are estimated to occur along the west coast of Hong Kong Island between Ap Lei Chau and Green Island; in the central region of the East Lamma Channel; near Wong Chuk Kok; at the boundary between deep and shallow water, at the entrance to Sok Kwu Wan; and in the deep water area west of Beaufort Island. In some of these areas, sediment accumulation could reach a thickness of 1.2 m per year.

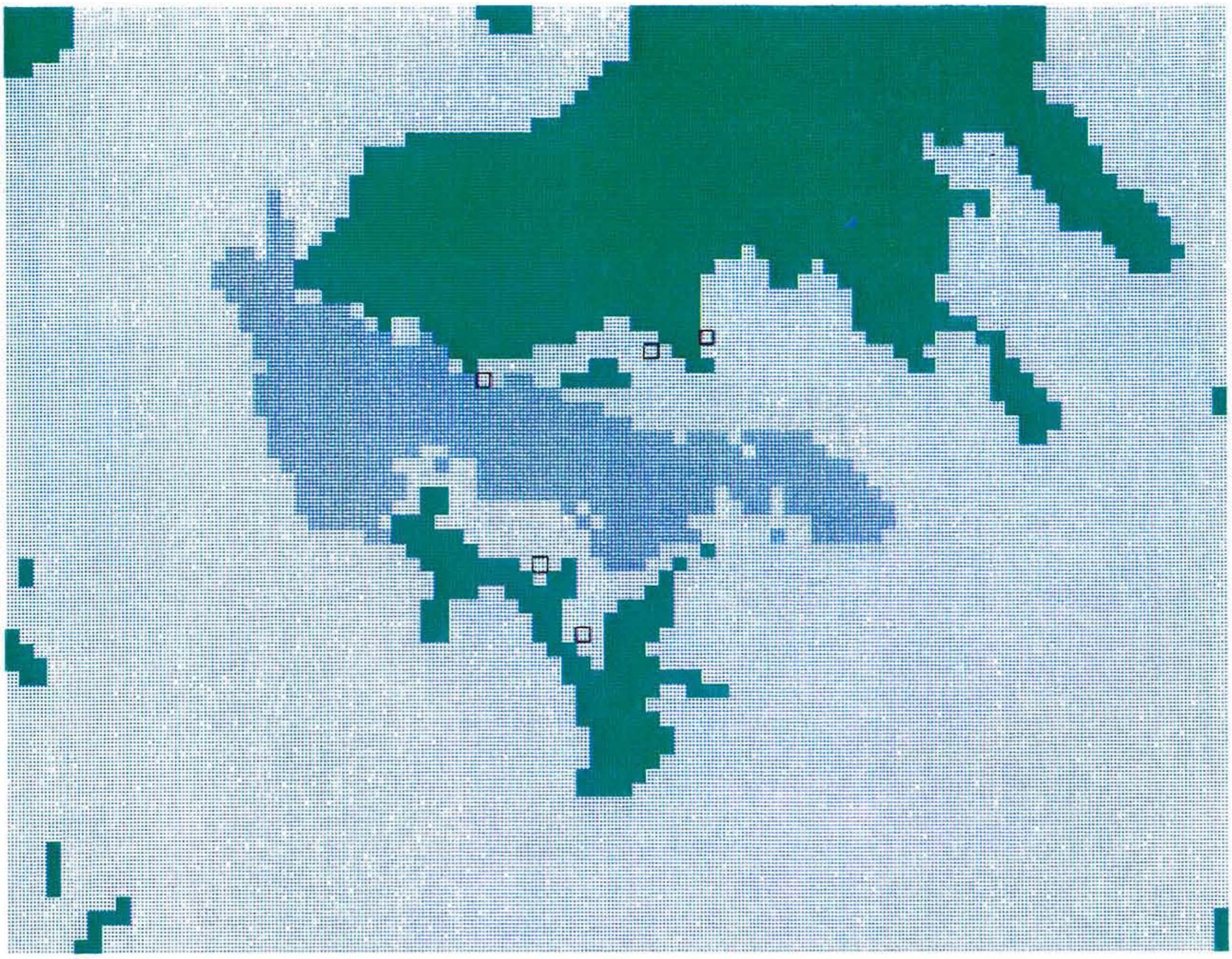
4.65 Of the three seawater intakes investigated, estimations relating to bed deposits indicate that only the Wah Fu intake could potentially be affected by bed deposits. The depth of the intake at Wah Fu is assumed to be similar to that at Brick Hill. At 1-2 metres below Chart Datum, the depth of the intake suggests that operation of the intake is not likely to suffer significant effects due to increased deposition of sediment on the seabed.

Estimates Based On Plume Model Output

4.66 The sediment plume model was used to assess the local effects of plume transport due to the combined effects of wind-driven and tidally driven currents. Selective tests were carried out, based on the results estimated by the convection-dispersion model. The behaviour of sediment plumes was investigated under the following conditions:

(i) wet season, spring tide, surface layer;
(ii) dry season, neap tide.

4.67 These cases were deemed to represent the most likely conditions during which plumes would approach the Ocean Park intake in Deep Water Bay and the fish farming areas off Lamma Island.



Average Deposition Rate (kg/m²/tide)

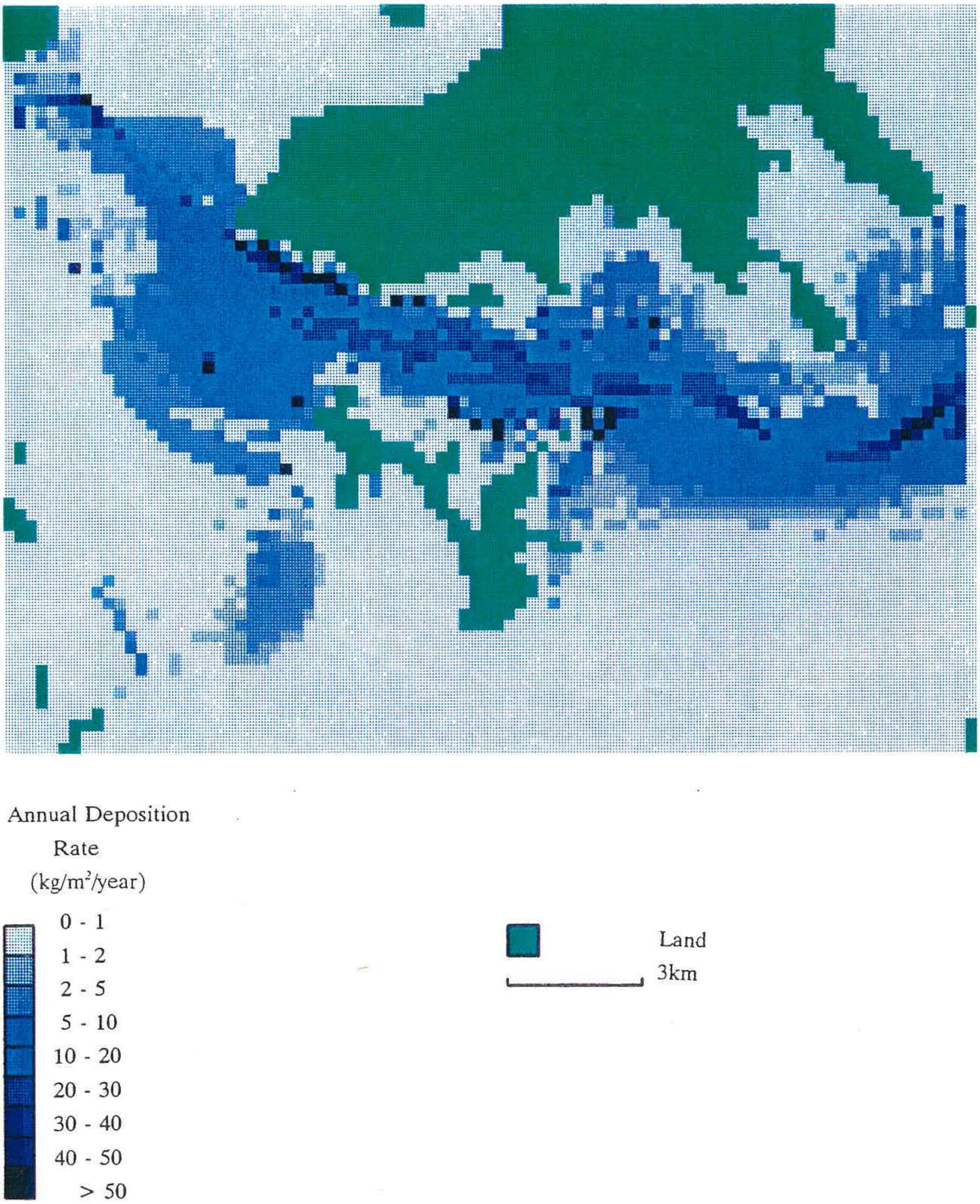
- 0.00 - 0.01
- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.30
- 0.30 - 0.40
- 0.40 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00

Land

3km

AVERAGE DEPOSITION RATE - DRY SEASON, NEAP TIDE (250m MODEL)

Figure 4.12



ANNUAL DEPOSITION RATE (250m MODEL)

Figure 4.13

4.68 Tests were carried out by simulating the release of drogues using hydrodynamic data from the 250 m model. Particles were released at six locations along a dredging line that followed the appropriate edge of the proposed excavation. Particles were released at a frequency of 5 per hour, allowing the different paths of the plume throughout the tide to be monitored.

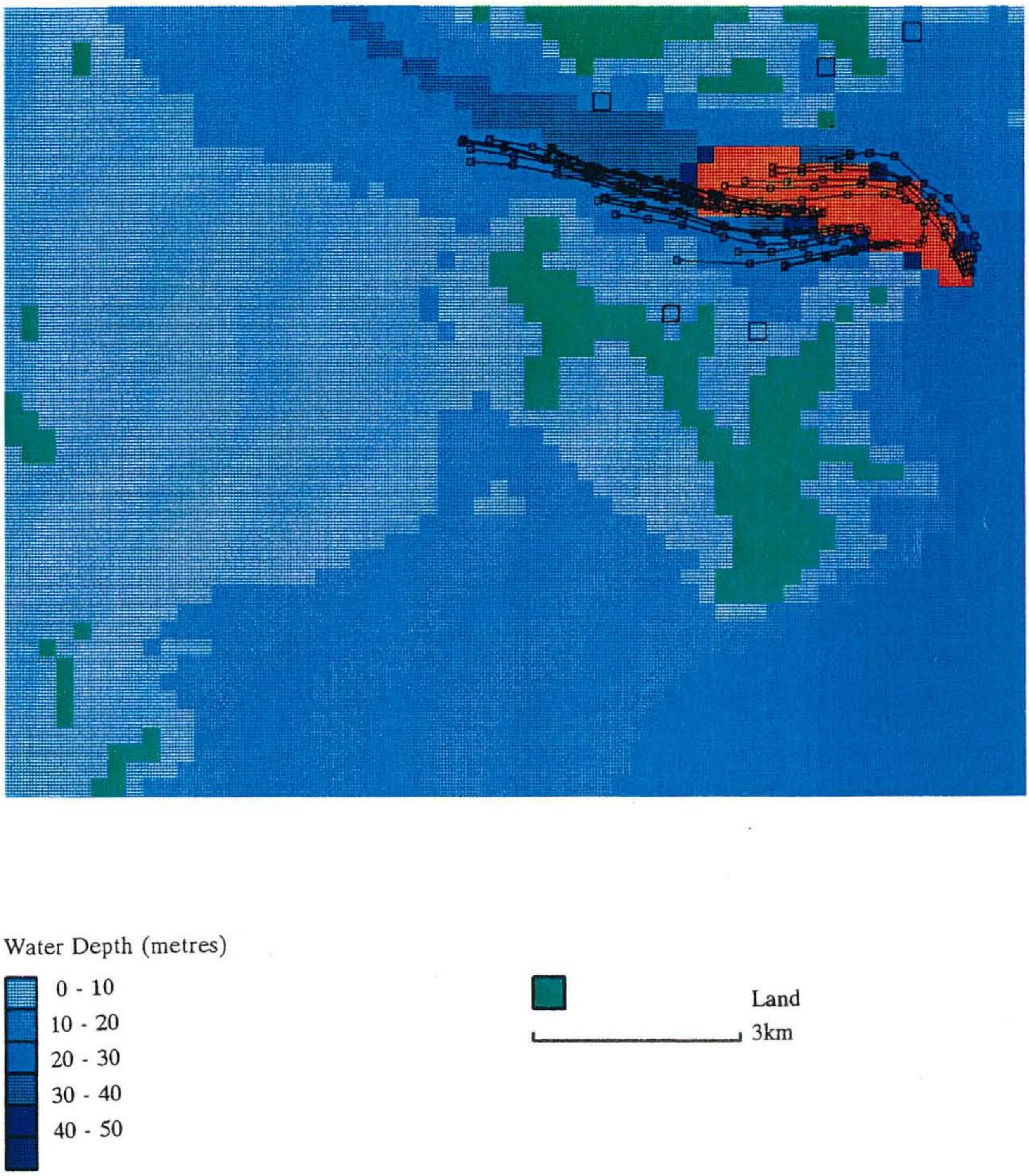
Predicted Plume Paths

4.69 Tests carried out under calm conditions showed that a sediment plume caused by dredging along the southern limit of the pit is unlikely to enter Sok Kwu Wan. The estimated plume paths are presented in Figure 4.14. The strong tidal currents will tend to transport the dispersing plume along the East Lamma Channel, away from the fish farming area.

4.70 Further tests were carried out to assess the behaviour of the plume under wind conditions that would carry plumes toward sensitive receivers. The paths of the plume at various stages in the tide were modified to account for the effect of a 4 m/s easterly wind. This was considered to represent the most likely condition for plume transport into the mariculture zones. The results of the model runs are shown in Figure 4.15. Despite the influence of the easterly wind the plume is estimated to remain outside Sok Kwu Wan. However, the tests indicate that under these conditions, the sediment plume could be driven towards Lo Tik Wan. By the time the plume would reach this area, sediment concentrations would have reduced to around 20-25 mg/l due to dispersion. The area within the bay would also be protected from the sediment plume to some extent by the island of Luk Chau, which was not included in the model.

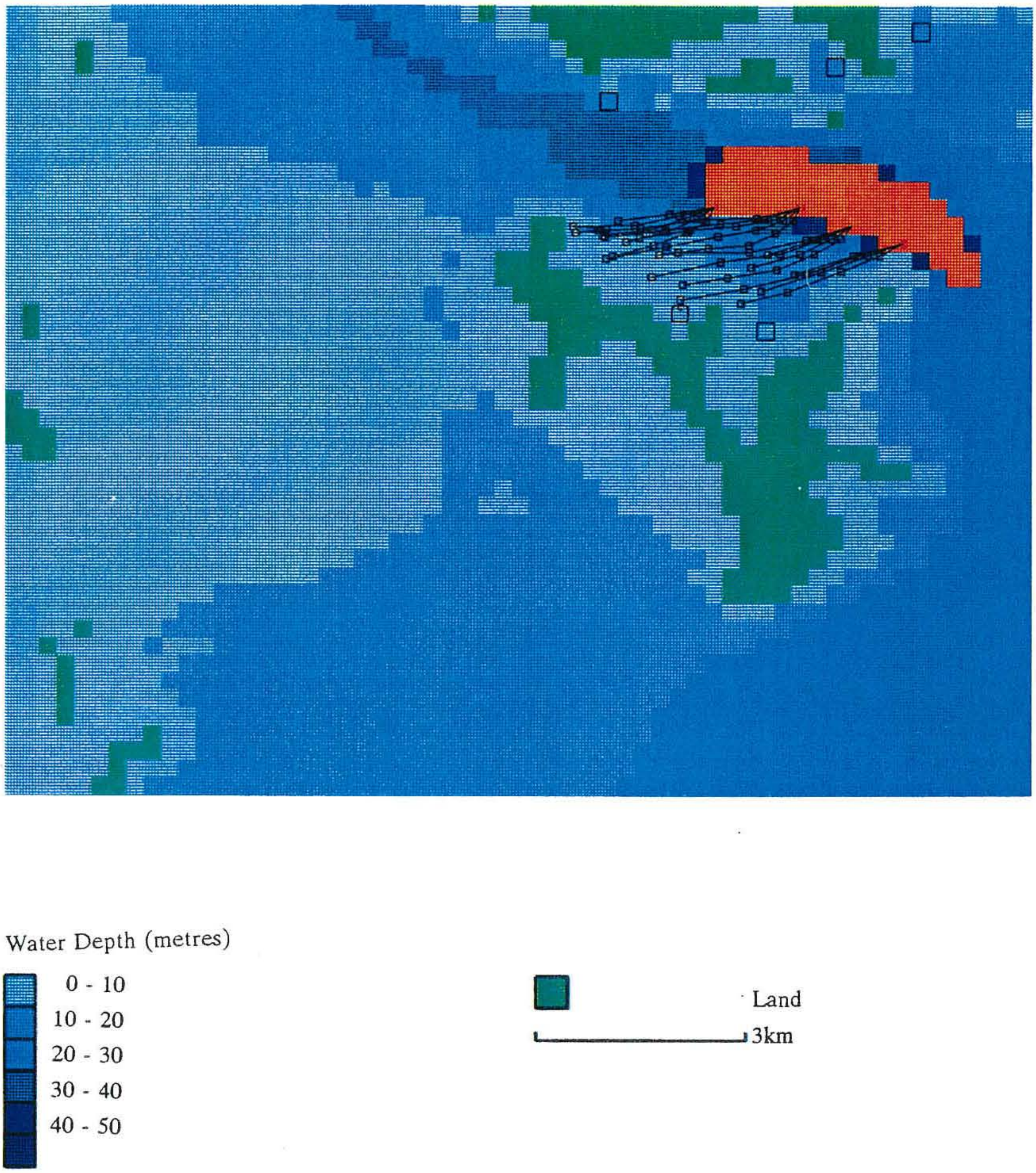
4.71 Initial tests representing calm weather conditions in the wet season showed that a plume produced by dredging along the eastern side of the pit is unlikely to be transported into Deep Water Bay. Figure 4.16 shows the estimated path of particles during the ebb tide. Further tests were carried out, with the effect of a 4 m/s south westerly wind included. The results are illustrated in Figure 4.17. This represents a severe condition, which only occasionally occurs during the wet season. The estimated paths of sediment plumes indicate that, under these conditions, the sediment plume may be driven towards Deep Water Bay.

4.72 The results suggest that sediment concentrations would decrease by a factor of 6-8 between the release location and the point at which it passes the Ocean Park intake. The resulting concentrations are therefore likely to be approximately 10-15 mg/l. These concentrations would not be experienced frequently, but only during dredging of a short length of the east side of the pit on the ebb tide with a south westerly wind. The sediment plume will have been in the water for around an hour before passing the Ocean Park intake. In order for the plume to be driven by the wind, it would have to remain close to the surface, and initially would be above the intake situated 10 m down, in the lower stratified layer.



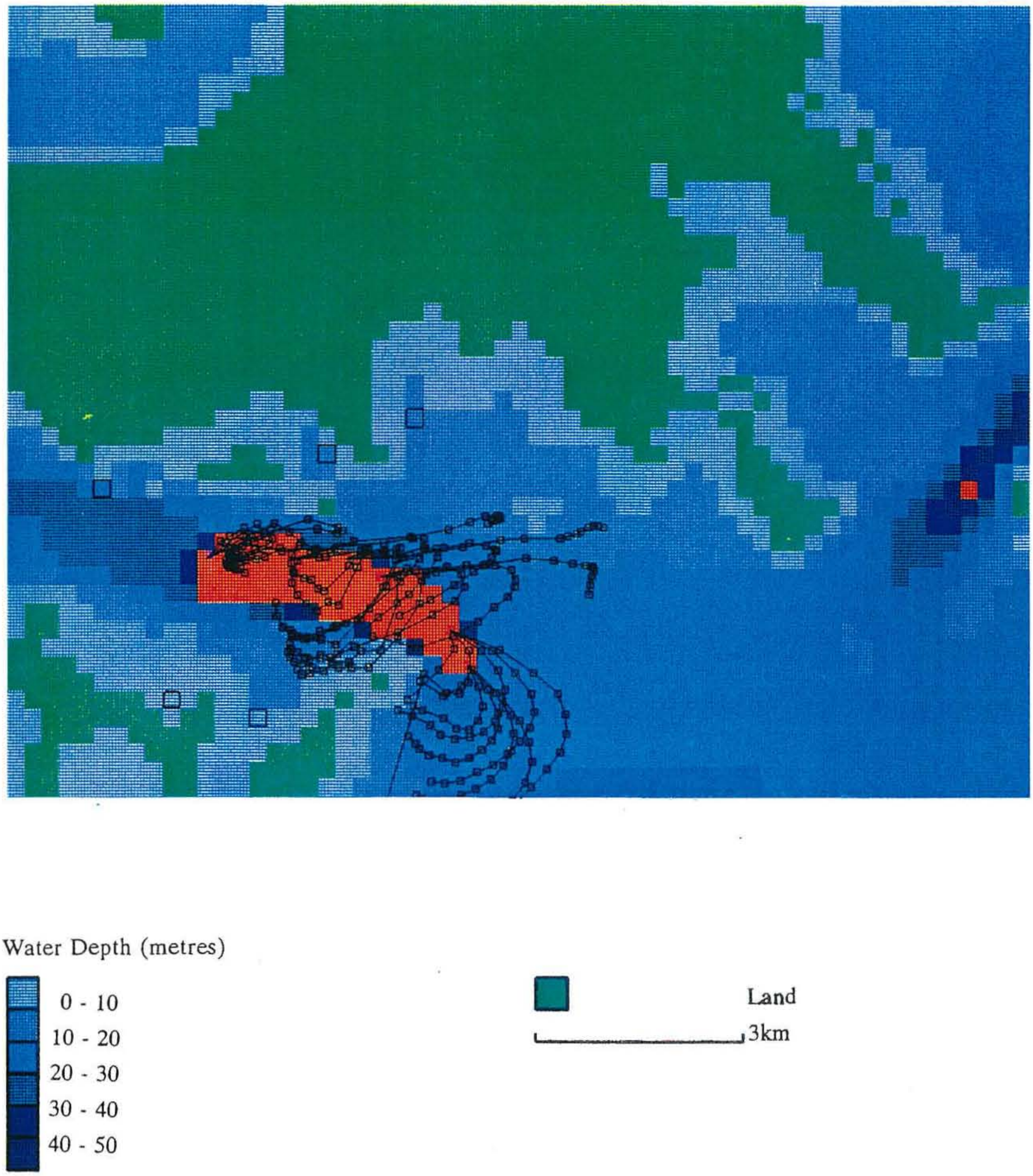
PREDICTED PLUME PATHS -
DRY SEASON, NEAP TIDE (NO WIND)

Figure 4.14



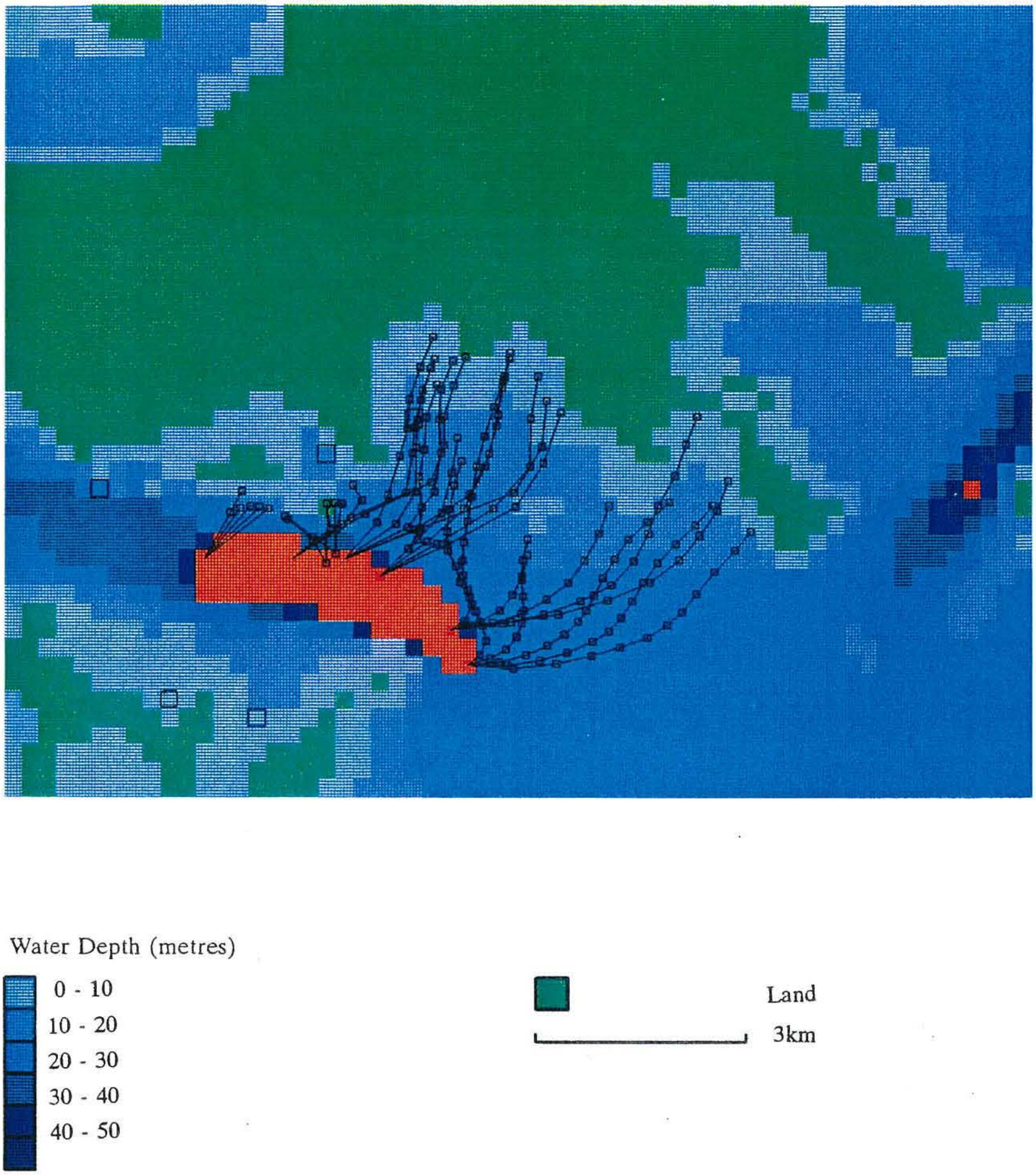
PREDICTED PLUME PATHS -
DRY SEASON, NEAP TIDE (EASTERLY WIND)

Figure 4.15



PREDICTED PLUME PATHS - WET SEASON, SPRING TIDE (NO WIND)

Figure 4.16



PREDICTED PLUME PATHS - WET SEASON, SPRING TIDE (SOUTH WESTERLY WIND)

Figure 4.17

Conclusions of Computer Modelling

4.73 Sediment transport models were used to assess the potential impact of sediment dispersion due to dredging in the East Lamma Channel. Specifically, the models were used to estimate the potential increase in suspended sediment concentration and sediment deposition in the area. Particular attention was paid to the effect of dredging on seawater in the vicinity of intakes at Wah Fu, Brick Hill and Ocean Park, on Hong Kong Island, and in the mariculture zones in Sok Kwu Wan and Lo Tik Wan, Lamma Island.

4.74 Given the assumptions of the model, the following conclusions have been drawn:

(i) With the exception of spring tides during the wet season, the average increase in suspended sediment concentration is likely to remain below 10 mg/l in virtually all areas. On spring tides during the wet season, values between 10 and 20 mg/l are likely to occur in the lower layers along the Hong Kong side of the East Lamma Channel, spreading south-eastward more than 9 km beyond the end of the channel.

(ii) Deposition of sediments on the seabed is likely to be most widespread during wet season spring tides, with large variations estimated across the modelled area during these conditions. On neap tides during the wet season, the area affected is smaller, but the local rate is relatively high, particularly around the eastern tip of Lamma Island. During the dry season, deposition is estimated to occur at lower rates. The size of the area affected is more consistent between spring and neap tides.

(iii) The seawater intake at Brick Hill is unlikely to experience any significant increase from the proposed dredging in the East Lamma Channel.

(iv) The mariculture zone in Sok Kwu Wan is unlikely to experience any significant change in either suspended sediments or bed deposits, except on spring tides during the wet season, when the concentration of suspended sediments in the bed layer more than 7 m below the water surface could reach a peak value of 30 mg/l. During these conditions the average value is likely to be between 10 and 20 mg/l.

(v) The mariculture zone in Lo Tik Wan in unlikely to experience any significant change in either suspended sediments or bed deposits due to tidal transport. It may experience a rise in suspended sediments of up to 25 mg/l in the surface layer during easterly winds. These effects would most likely be experienced if dredging of the west side of the pit is permitted during these conditions. The island of Luk Chau will provide some protection, particularly for the inner part of the bay.

(vi) The seawater intake at Wah Fu is unlikely to be affected by significant increases in suspended sediment. The model runs carried out indicate that water in the upper layer, at the level of the intake, would remain unaffected by dredging operations. On spring tides during the wet season, an increase in suspended sediment is expected in the saline layer in this region. However, this is unlikely to affect the water abstracted from the surface layers. Likewise, the increase in bed deposits estimated, particularly on neap tides in the dry season, is unlikely to have any effect on operation of the intake.

(vii) In the area of the Ocean Park intake, increases in suspended sediment concentrations are likely to be small, except on spring tides during the wet season. Under these conditions increased concentrations of <10 mg/l are likely to be confined within the brackish water of the surface layer, which typically represents the top 7 m of water. At a depth of 10 m, the intake is influenced mainly by changes in the saline water of the bed layer. In the area of the Ocean Park intake, sediment deposition rates are not expected to be affected by the proposed dredging operations.

(viii) Studies were carried out to assess the local effects which might occur when dredging takes place on the Hong Kong side of the excavation. Studies of plume movement and dispersion confirmed that under calm weather conditions, the area around the Ocean Park Intake would not be affected by a dispersing sediment plume. During the unusual adverse conditions of a south westerly wind coinciding with a wet season spring tide, a plume could potentially be driven toward the intake for a short period during the ebb tide. However, calculations suggest that the sediment concentration would be reduced to 10-15 mg/l by the time the plume passed offshore of Ocean Park. Most of this sediment would remain in the surface layer, particularly as movement between the layers is restricted by the freshwater/seawater interface. As a result, even under these circumstances the probability of a significant increase in suspended sediment at the level of the seawater intake is low.

Sensitivity of the Model Input Parameters

4.75 As stated previously, the input parameters were chosen to represent the most realistic scenario that is likely to occur if dredging proceeds in East Lamma Channel. There are a large number of input parameters which have been used to generate the model output. Although no formal sensitivity analysis has been carried out, clearly the model output would be sensitive to several of these parameters including the number of dredgers, the discharge rate, plume depth, and dredger speed.

4.76 Changes in key input parameters could alter the results. For example, if more than one dredger were to be operating at a time, the discharge rate would be effectively doubled and this could result in a doubling of plume concentrations in areas where plumes overlapped. If several input parameters are changed, it can also alter the results. For example, by reducing the assumed velocity of the dredger from 2 to 1 m/s, reducing the initial depth of the plume from 2 to 1 m, and reducing the discharge rate from 9.3 to 6.7 tonnes per minute, the initial plume concentration would increase from 77.5 mg/l to 222.3 mg/l. Under the latter conditions, a wind-driven plume might contain a maximum of 60 mg/l suspended sediment by the time it reached Lo Tik Wan. In addition, other factors such as wind-mixing, which reduce the trapping effect of the low salinity surface water during the wet season, could alter the distribution and concentration of sediment.

4.77 If changes are proposed in the actual dredging programme such that it differs greatly from that modelled, additional model runs would be required to assess the effect of the altered input parameters on the model output.

5 POTENTIAL IMPACTS OF DREDGING ON MARINE ECOLOGY OF LAMMA CHANNEL

Types of Impact and Assumptions

5.1 Two types of impacts on the marine ecology of Lamma Channel and surrounding areas due to dredging operations are considered in this report--direct and indirect. The direct effect is due to sea bed removal. Organisms living within the sea bed would be removed with the overburden; other organisms that are dependent on the habitat would be adversely affected. An indirect effect of dredging would be the creation of sediment plumes which could be transported away from the site and deposited elsewhere. Effects on non-living resources are considered in Section 6. The potential impacts considered here relate to dredging carried out without the proposed mitigation measures. If implemented, the mitigation measures proposed in Section 7 could significantly reduce many of the potential impacts discussed below.

5.2 Sediment plumes and sediment deposition could potentially affect wild stocks of marine organisms, including those that are the target of capture fisheries, as well as endemic and exotic fish that are cultured. The impact on wild stocks with no commercial value is considered an effect on the conservation and possibly recreation value of East Lamma Channel. The potential impacts on species with commercial value are considered under effects on the mariculture and capture fisheries industries.

5.3 The assessment of potential impacts is based on the assumptions given in the previous section, i.e. continuous operation of a single 8,000 m^3 trailer dredger and sediment losses of 67,400 tonnes/week. During dredging, as soon as one dredger is full, another would take its place.

5.4 Computer generated estimates of suspended sediment and sediment deposition rates have been given in the previous section. The potential impacts of these changes are considered here. In addition, estimates based on hand calculations of sediment transport are also considered.

Water Quality Regulations

5.5 East Lamma Channel falls mainly within the Southern WCZ. Water quality guidelines have been designated by Government for Hong Kong waters, however, there are no statutes covering sediment plumes generated by dredging. In general, the guideline used is that increases in suspended sediments should not exceed 30% above ambient. The water quality guidelines have not been established with respect to the sediment tolerance of Hong Kong organisms.

Tolerance Thresholds of Marine Organisms

5.6 The information available on sedimentation tolerance of marine organisms was reviewed in the South Mirs Bay Borrow Area Initial Assessment Report (BCL, 1992b). Although comprehensive data are available on the effects of sediment on hard corals found in Hong Kong, no data are available on the sediment tolerance of other Hong Kong invertebrates and fish. There is an extensive database regarding the effects of sediment on temperate freshwater species, with limited data on tropical marine species.

5.7 In the absence of relevant data on the sediment tolerance of species in Hong Kong, we have made use of data in the international scientific literature. Two reviews of the literature were particularly useful; a chapter in a book entitled "Water Quality Criteria for Freshwater Fish" by Alabaster and Lloyd (1984), and a paper by Peddicord et al. (1975).

5.8 The results of the tests of sedimentation tolerance show that there is a large variation among species. All stages of invertebrates and vertebrates can be injured by sediment and, in general, susceptibility decreases with age, with eggs being the most, and adults the least sensitive to injury from sedimentation (eggs > larvae > juveniles > adults). The exposure time to sediment is important in determining the effect. We suggest defining continuous exposures that last over 24 h as "chronic" and those that last less than 24 h as "acute."

5.9 Since sedimentation is a natural phenomenon, organisms have evolved adaptations to protect themselves from deleterious effects. Organisms that live in habitats with a naturally high level of suspended sediment and sediment deposition, such as a muddy seabed, will tend to have a high resistance to suspended sediment and sediment deposition. Much of the East Lamma Channel ecosystem consists of such habitats.

5.10 Of the organisms subjected to sediment resistance tests, many were found to be able to withstand levels of 1 to 10 g/l for long periods. Levels of suspended sediment above 1 g/l are unusual in nature. This suggests that sediment tolerance is much higher than might be expected based on measurements of natural sediment levels.

Corals

5.11 Species of hard corals found in Hong Kong cover a wide range of sediment tolerance. Some species with small polyps such as *Acropora candelabrum*, are highly susceptible to damage by sedimentation (Hodgson, 1990; Rogers, 1990). Other species with large polyps, such as *Turbinaria peltata* are highly resistant. For the purpose of this report, we suggest that suspended sediment levels above 100 mg/l and deposition rates above 0.2 kg/m^2/d (20 mg/cm^2/d) are considered the tolerance limits for corals exposed for more than 24 hours. Since all corals can survive 24 h burial in sediment, there is no acute tolerance limit for corals, only a chronic limit.

5.12 *Other Invertebrates*

As mentioned above, the most sensitive life stages of animals are eggs and larvae. Injuries range from improper development to infections. Available data suggest that the lowest suspended sediment concentration that causes chronic sub-lethal effects on invertebrate eggs and larvae is around 100 mg/l (Peddicord et al., 1975). Acute lethal effects are generally found above several hundred mg/l. For the purpose of this study 100 mg/l is chosen as the chronic tolerance limit for invertebrates other than corals and 200 mg/l is chosen as the acute limit for the same group.

5.13 *Fish*

Fish, like invertebrates, show a wide range of sediment tolerance. Injury and death appear to be mainly due to gill clogging and an increased susceptibility to disease. A few examples of the tolerance limits of fish taken from Alabaster and Lloyd (1984) are given below.

5.14 The tropical aquarium fish, *Rasbora heteromorpha*, survived for one week in 6000 mg/l of bentonite clay. We classify this as a test of chronic elevation of suspended sediment; no sub-lethal effects were noted.

5.15 Resuspended harbour sediment at concentrations up to 28,000 mg/l had no observable effects on the stickleback (*Gasterosteus aculeatus*) over a four day exposure in California, USA.

5.16 There were no deaths of rainbow trout during 8 months exposure to 100 and 50 mg/l spruce fibre or coal washery waste solids (Herbert and Richards, 1963) and no significant increase over control mortality among the same species in 30 mg/l kaolin or diatomaceous earth (Herbert and Merkens, 1961).

5.17 The growth (and survival) of larval lake herring (*Coregonus artedii*) were not affected during exposure for 62 days to a concentration of red clay of up to 28 mg/l (Swenson and Matson, 1976).

5.18 Alabaster and Lloyd conclude that, "In the majority of reported cases, however, death rates in 100 mg/l and less have been little or no higher than among control fish in clean water." The authors summarise their literature review by stating (p16), "In laboratory tests the lowest concentration known to have reduced the expectation of life of fish is 90 mg/l, and the lowest concentration known to have increased susceptibility to disease is 100 mg/l."

5.19 Recently, AFD has used 80 mg/l of suspended sediment to define the limit for Hong Kong marine fish culture, based in part on tentative criteria for freshwater fisheries presented by Alabaster and Lloyd (1984). AFD has not yet adopted suspended sediment limits for wild stocks of fish or for different life stages of fish.

5.20 For the purpose of this report, we chose 125 mg/l as the acute limit for fish larvae and 250 mg/l for one hour as the acute lethal limit for adult fish. No limit was chosen for juveniles due to a lack of data. We believe that these limits are conservative estimates for mariculture and wild marine fish in Hong Kong.

5.21 The difference between the two sets of limits applies only to mariculture fish and would only affect the outcome of this report's estimates with respect to infrequent weather conditions when resuspension could create suspended sediment values above 80 mg/l but below 125 mg/l.

5.22 We have not attempted to define "chronic" tolerance levels for adult Hong Kong fish and do not believe that there is sufficient scientific information to do so. In general, Hong Kong fish species that are adapted to living in turbid waters on soft unconsolidated substrata would be expected to have high suspended sediment thresholds. Hong Kong fish species adapted to living in rock or coral reef habitats would be expected to have the lowest tolerance thresholds. Mariculture species are a mix of local and exotic species. The exotic species are reef fish that would be expected to have a low tolerance of suspended sediment.

Potential Impact on Mariculture

5.23 Seabed removal in Lamma should not have a significant direct impact on mariculture activities. The primary potential threat to mariculture activities due to dredging would be the transport of sediment plumes into mariculture areas. If the concentration of suspended sediments increases above the tolerance thresholds of any life stage of the cultured species, losses of fish stocks could occur. In general, the most sensitive life stages would be larvae and juveniles. Since three of the four major cultured species are obtained as juveniles, larval tolerance levels are not an issue for them. For sea bream, which are collected locally, the issue of larval tolerance should be considered. Wild stocks of sea bream larvae would be subject to the effects of sediment plumes. It is understood that larvae collected for mariculture are not held in the sea, but are cultured in aquaria until they attain a juvenile (fingerling) size. Therefore following capture, fry would be unaffected by dredging until they reached a juvenile stage. For this reason, the direct effects of sediment plumes on fry of mariculture species is not considered here. This subject is considered under the Capture Fisheries section.

Lo Tik Wan

5.24 The mariculture zone closest to the borrow area is Lo Tik Wan. During ebb tides throughout the year, the majority of sediment generated near the zone is likely to be flushed out through the channel to the southeast. Inspection of the tidal vector plots shows that during incoming tides with little or no wind effects, both submerged and surface sediment plumes could enter Lo Tik Wan. At its closest, the distance from the margin of the borrow area to the mariculture rafts is less than 1 km. The results of the computer modelling suggest that a high proportion of suspended sediment will have settled before the reaching Lo Tik Wan and concentrations are unlikely to exceed tolerance thresholds for larvae.

5.25 Regardless of the actual biological effects of sediment plumes on mariculture, a more important effect may be caused by visible plumes. A small amount of fine suspended sediment can create a bright discolouration of the water. Due to the presence of fine sediments in overflow, plumes transported to Lo Tik Wan by tidal flow are likely to be visible and strong protests can be expected from the fish farmers.

<u>Wind Effects</u>

5.26 Winds from the east (70 to 110°E) may increase the speed with which surface layer sediment plumes are transported to the mariculture zone. The wind will increase water turbulence, thus maintaining sediment in suspension, and will push the surface layer toward Lo Tik Wan. Winds are from the 70 to 110° eastern sector during almost 40% of the year and usually range in velocity between 4 to 6 m/s (Binnie & Partners, 1988). If a wind-assisted flood-tide water current achieved a velocity of 0.4 m/s, it could bring sediment laden water into Lo Tik Wan in less than one hour.

5.27 The results of the plume modelling suggest that suspended sediment concentrations would not be expected to exceed 25 mg/l under such conditions. In the event that the input parameters were changed (as given in section 4.75), the maximum level of suspended sediment estimated to temporarily enter the zone is 60 mg/l, well below the tolerance of the larvae and adult fish cultured there. Due to continuous settlement of the suspended sediment, it is unlikely that sediment concentrations would be increased after reaching Lo Tik Wan. In the relative calm there, it is highly likely that the sediment concentration would decrease with time.

Build-up of Bottom Sediment

5.28 Sediment deposition in shallow water and the potential resuspension of bottom deposits by wave action were not covered by the computer model, therefore an empirical desk-top model was used to estimate the likely effects of this scenario.

5.29 Underwater observations during dredging near the Ninepin Islands revealed a pattern wherein fine sediment built up on the sloping seabed from 5 to 20 m below the surface. Given the East Lamma Channel bathymetry and the predominant northeast monsoon winds, it is likely that sediment transported toward Lo Tik Wan would be deposited on the nearby sea bed in less than 10 m of water, adding to the mud which is already there. During severe storms, it is likely that some of this new sediment would be resuspended by wave action along with sediment already in place. Because of the large number of variables involved, it is difficult to estimate the characteristics of a plume so created, however, it is possible that concentrations would temporarily exceed acute tolerance thresholds of adults of some fish species during such storms. It should be emphasized that these circumstances are likely to be infrequent and of relatively short duration, generally less than two days.

5.30 Observations at Ninepin Islands have shown that mud initially deposited in shallow water was later washed out by storm action. It is likely therefore that following storms, most resuspended fine sediments would be carried away from Lo Tik Wan by currents, reducing the potential for long-term repeated impacts.

Sok Kwu Wan

5.31 The distance of Sok Kwu Wan mariculture zone from the borrow area tends to limit the sediment concentration that could reach there. The results of the computer modelling indicate that during wet season spring tides, sediment plumes could enter Sok Kwu Wan with a maximum concentration of 30 mg/l, well below the tolerance limits of mariculture species. The results also suggested that wind-driven plumes would not enter the mariculture zone. Therefore, with the exception of possible long-term seabed build up and then resuspension during storms, suspended sediment tolerance levels of cultured species are not expected to be exceeded during the dredging period.

Potential Impact on Capture Fisheries

Seabed Removal

5.32 Seabed removal will directly reduce the habitat of demersal and benthic fish stocks in the Lamma area but will not affect pelagic species. We estimate that the majority of fish would be able to escape this disturbance and would move to other locations. The effect of the migration on fish catch would depend on both biological and socio-economic factors.

5.33 The socio-economic factor relates to access to fishing grounds of small vessel fishermen. If the migration resulted in fish moving to locations inaccessible to small vessel fishermen (e.g. open sea), stocks would be effectively removed from small vessel fisheries.

5.34 The biological factor relates to the population dynamics of multi-species fish stocks. There is no quantitative data on the status of East Lamma Channel fish stocks, however, underwater surveys by BCL indicate that with the exception of two species, fish stocks are heavily overfished in East Lamma Channel. The effect of migration on fish catch in East Lamma Channel and surrounding areas can be estimated from a theoretical standpoint.

5.35 Based on the available evidence, we assume that most species of inshore commercial importance are depleted and populations are thus below equilibrium level. If fish moving out of the borrow area enter a zone of depleted stocks, then it is plausible that the net loss in habitat within the borrow area would not lead to a net loss in fish stocks. If the surrounding areas are not overfished for the species in question, they still may be able to sustain a higher biomass by undergoing an equilibrium shift. If food or other resources are limited, then an equilibrium shift would be unlikely. If fishing pressure remains constant, then a net loss could occur. AFD has suggested that the latter scenario is likely. We believe that because most inshore fish stocks appear to be depleted, migrating fish should be able to join fish stocks outside of East Lamma Channel, however, it is not known if this would place them out of economical reach of inshore fishermen.

5.36 It appears that much of the commercial fishing done in East Lamma Channel is by small inshore fishing boats. Many of these boats are not equipped to trawl below 30 m. Since much of the seabed to be dredged is below 30 m depth, this would tend to reduce the direct impact of seabed removal on inshore fisheries.

5.37 Seabed removal will also reduce the amount of food available at the base of the food chain and will thus have an indirect negative effect on the area's fisheries.

5.38 Backfilling of the pit is unlikely to be viable, therefore the effects of seabed removal are likely to be permanent. Some recolonization of the seabed at the bottom of the pit by marine organisms is likely, however, it is not possible to assess what type of fish the deep benthic community could support or whether it could be commercially exploited. The depth of the pit would tend to limit the types of fishing gear which could be profitably used there.

Sedimentation and Sediment Deposition

Adults

5.39 Due to sediment deposition outside the borrow area, a portion of the seabed will be rendered uninhabitable for adults of some fish species during dredging.

5.40 Scientific studies have clearly demonstrated that adult fish are capable of detecting sediment plumes and swimming away from them (Peddicord et al, 1975). With the exception of benthic species, it is expected that wild stocks of fish would be able to avoid sediment plumes in East Lamma Channel by swimming to other areas. This would decrease the inshore fisheries catch from the area. Benthic species living in the vicinity of the borrow area would be reluctant to leave their burrows and would be subject to sedimentation, however, these species would tend to be tolerant of high sedimentation levels since they live in a constantly shifting muddy environment.

Fry collection

5.41 Wild fry (fish larvae) are found along the coast of East Lamma Channel, including in Lo Tik Wan and Sok Kwu Wan as shown in Figure 3.1. The results of the computer modelling suggest that plumes reaching these areas as a result of tidal or wind-driven currents would usually not exceed 30 mg/l. The result of reducing one model input parameter (dredging speed) by half increased the estimated suspended sediment level at Lo Tik Wan to 60 mg/l. Both of these levels are below the 125 mg/l tolerance limit of fry.

5.42 Under conditions not examined with the computer model, however, it appears likely that portions of the fry collection zones could experience temporary increases in suspended sediment above the larval tolerance level of 125 mg/l. These conditions would include the build-up of sediment in shallow water along the seabed in front of Lo Tik Wan, followed by wave driven resuspension, tidal and wind-driven transport. The other fry collecting area potentially affected by such plumes would be the East Lamma Channel side of Wong Chuk Kok. The prevailing easterly winds during the fry season would tend to push surface plumes into these fry collecting zones.

5.43 The duration of the exposure would depend on the type of tide occurring at the time. Based on a 2 m/s dredging speed, as many as three plumes per hour could be transported in this way, depending on the actual route of the dredger. The maximum duration of the exposure would be one tidal cycle, approximately 6 hours, after which the outgoing tide would flush the plume out of the area.

5.44 Based on the assumed dredging plan, suspended sediment concentration would be expected to exceed the larval tolerance limit several times per year at Wong Chuk Kok, but only once or twice per year at Lo Tik Wan.

5.45 Individual sediment plumes are unlikely to kill fish larvae, however, repeated exposure to the plumes would be expected to reduce their availability. Mariculture operators would thus need to collect from other areas or to buy a larger proportion of their seabream fry and fingerlings. The reduced availability of sea bream fry would not be expected to last for longer than one year after the cessation of dredging. This is because the larvae gather in shallow waters from which accumulated sediment is likely to be removed by wind waves within one year.

Potential Impact on Other Marine Biota

5.46 Suspended sediment concentrations along the Lamma Channel coast are likely to exceed the tolerance of larvae of invertebrates such as shrimp, crabs and squid. Without data on the distribution of these larvae, it is difficult to assess the likely impacts. In general, larvae closest to the borrow area and which spend time close to the seabed would be most likely to be affected. Since many of these species breed seasonally, the effect would also be seasonal. Reductions in the number of larvae over several years eventually could reduce adult populations.

5.47 The coastal area closest to the borrow pit is the eastern point of Lamma Island (Wong Chuk Kok). In this specific area, the intertidal and subtidal communities there would be exposed to relatively high concentrations of suspended sediment. During calm periods, and close inshore, sediment deposition could be high enough to kill susceptible slow moving organisms such as gastropods, and sessile organisms such as some hard corals, and injure others. Organisms tolerant of high sediment concentrations normally would survive.

5.48 The computer plots of water currents and sediment deposition patterns suggest that during ebb tides, water flow will curve south around Wong Chuk Kok and back towards the Lamma coast. This phenomenon would extend the reach of the deleterious effects of the suspended sediment, and during calm periods, of sediment deposition.

5.49 As discussed above, hard corals show a wide range of sedimentation tolerance; the major impact would be from sediment deposition rather than from exposure to suspended sediment. Based on sediment deposition rates and distribution calculated by the computer model, we estimate that the cover of living hard coral could be reduced by about 25% along the eastern coast of Wong Chuk Kok. Smaller reductions of coral cover would be expected in the neighbouring bay (Tung O Wan). These deleterious effects should not extend past the point (Yuen Kok) at the southern end of Tung O Wan.

5.50 The marine communities along the Lamma Channel coast of Hong Kong Island are diverse, however, abundance of individual species is generally low. Occasionally, areas such as Ap Lei Chau and Round Island are likely to be exposed to levels of suspended sediment and sediment deposition that are above tolerance levels of some species. As a result, a decrease in diversity and abundance of marine organisms would be expected.

5.51 One community that is abundant and diverse is the sea fan, sea whip and soft coral community (gorgonians and alcyonarians). No data are available on tolerance levels of these organisms, however, their ecology is well-known. In addition, observations made during dive surveys and during monitoring work at the Ninepin Islands provide an insight into their likely susceptibility. In Hong Kong, these organisms often live in a highly turbid environments. Some are adapted to colonizing soft substrata. Because they have flexible skeletons, they move back and forth with water movements, preventing sediment from settling on their surfaces. Only when they are buried are they injured and killed.

5.52 We estimate that low-lying patches of the soft coral and gorgonian community would be buried and killed by sediment deposition. A high proportion of those colonies that are not buried are likely to survive high suspended sediment concentrations due to their flexible skeletons and the cleansing action of relatively fast water currents in the channel.

Turtles

5.53 Sediment plumes are not expected to reach the beach inside Sham Wan on Lamma, so dredging is not expected to have an impact on potential turtle nesting grounds there. There is no evidence to suggest that suspended sediment would injure turtles; however, a reduction in their algal food supply by sediment deposition could have an indirect effect. No turtles were seen during dive surveys around Lamma Island. A factor known to confuse turtles attempting to locate their nesting beaches is strong lighting. Given the considerable marine traffic transiting East Lamma Channel, the additional lights associated with the dredging traffic should not be significant.

Marine Parks, Reserves and SSSIs

5.54 Two of seven sites selected by the Marine Parks and Reserves Working Group (Hong Kong Country Parks Board, 1990) as potential marine parks are linked by water flows with the East Lamma Channel; these sites, which are already gazetted as Sites of Special Scientific Interest, are South Lamma and Cape D'Aguilar (Figure 2.1).

5.55 Legislation is currently under preparation to support the designation of the marine parks and reserves. It is the stated intention of AFD to carry through with the gazetting of these areas starting with Hoi Ha Wan and Cape D'Aguilar. The proposed marine park at South Lamma is more than 5 km away from the proposed borrow area and Cape D'Aguilar is even farther away, therefore, it appears unlikely that dredging plumes would carry sufficient sediment from Lamma Channel to affect these potential park areas.

Post-dredging Recovery

5.56 Shallow intertidal and subtidal communities would be expected to recover within a one to two years after most sediment was flushed out of these areas. The exception to this would be the hard coral community at Wong Chuk Kok, which is likely to take at least one decade of recruitment and growth to return to its present condition.

5.57 During the year following the termination of dredging, fine sediments deposited in water less than 10 m deep could be subject to resuspension by wave action. Within one year of the termination of dredging, most of this sediment would have been shifted to deeper water where it would no longer be subject to resuspension.

5.58 Deep water soft coral and gorgonian communities, along the western side of the proposed borrow pit, that may be buried under sediment and would not be expected to recover. They would be transformed into lower diversity soft-bottom communities within a period of one to two years.

5.59 Recolonization of dredged sea bed by deep-water benthic organisms would be expected to take several years. The final community is likely to be different from the one currently inhabiting the area.

6 ADDITIONAL IMPACTS

6.1 Several beaches and seawater intakes located along the southern shores of Hong Kong Island could potentially be affected by dredging plumes (Figure 6.1).

Beaches

Baseline conditions

6.2 The water quality monitoring stations designated by EPD for Hong Kong Island South are located about halfway between the Ocean Park headland and Round Island. In 1990, the maximum suspended solids level measured there by EPD was 9.3 mg/l, with an average of about 3 mg/l (Table 1.1). Due to the combined effects of terrestrial runoff during rainy periods and conditions of frequent wave surge, it is probable that the maximum suspended sediment load near the popular bathing beaches is higher than those measured at the EPD station. During storms, such as Tropical Storm Faye (July 18, 1992) the water becomes brown and suspended sediment is probably increased significantly. During much of the summer, however, the water appears relatively clean and has a translucent green colour.

Water discolouration

6.3 Discolouration and turbidity are affected to a greater extent by the mineralogy of the suspended sediment than by the concentration (Ekern, 1976; Campbell & Sprinrad, 1987). The mineralogy of Lamma Channel sediment has not been investigated, however, the Sand Resource is largely a reworked alluvial material and the overflow is likely to be light brown or grey, and much lighter in colour and hence more visible than overflow in other areas of Hong Kong.

Tidal currents

6.4 Computer modelling suggests that tidal flow alone could increase the surface layer sediment concentration in one part of Deep Water Bay by up to 30 mg/l above background during wet season spring tides. Under the same conditions, the model predicts that sediment transport from the dredging area could increase the suspended sediment concentration over most of Repulse Bay by up to 10 mg/l. It is likely that this would result in some visible water discolouration.

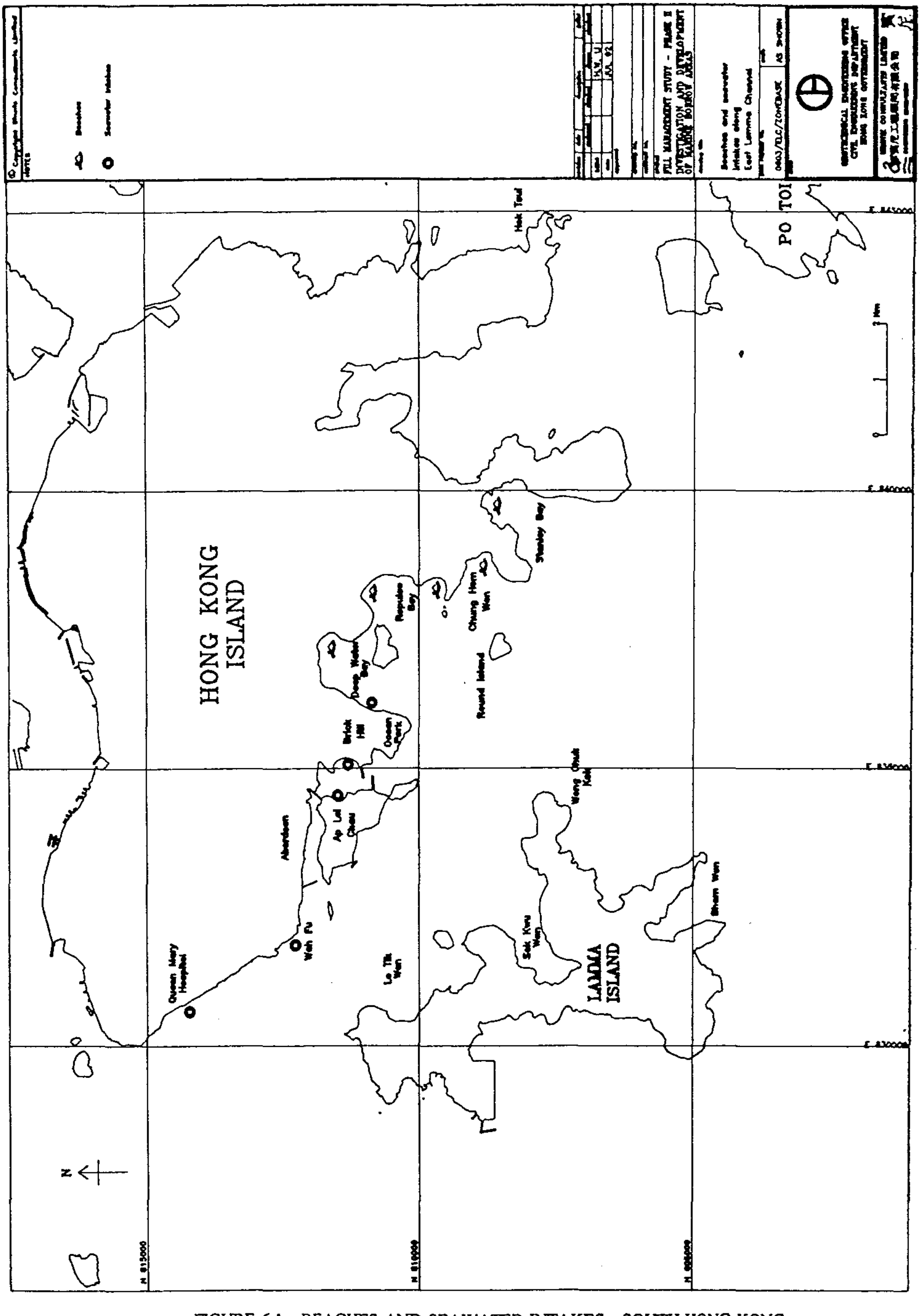


FIGURE 6.1 BEACHES AND SEAWATER INTAKES - SOUTH HONG KONG

Wind driven plumes

6.5 The results of plume modelling indicate that southwest winds could push surface plumes into Deep Water Bay or Repulse Bay. This would be expected to cause discolouration. During the summer months when sediment plumes are most likely to approach swimming beaches, public complaints could be expected regarding turbid water. Since the dredging activities will be obvious to the public, even turbidity increases not actually caused by dredging could generate complaints from the public and might decrease beach usage.

Ocean Park Seawater Intake

Pumping and Filtration System Design

6.6 The seawater pumping and filtration system at Ocean Park takes in water at an intake pipe located at a depth of 10 m inside the headland for nine hours daily (8:00 am to 5:00 pm). The water is gravity fed through three sand and gravel filters and then is pumped up to the headland where it is stored in a one million gallon reservoir. Approximately 90% of the water is used each day.

Filter Tolerance

6.7 According to design specifications, suspended solids should not exceed 25 mg/l in the intake water. If suspended sediment specifications are exceeded, the filter systems would be expected to clog more rapidly than given in the design. According to Ocean Park, the sea water intake pumping has been halted in the past due to poor water quality and a shut-down of more than two days would expose aquarium animals to declining water quality that could affect their health.

6.8 The results of computer modelling suggest that tidal and wind-driven plumes would not exceed the design specification. It is likely, however, that some sediment would be deposited at the entrance to Deep Water Bay near the Ocean Park headland. If after a year or more of dredging, this material were to be resuspended by a stormy period with south to southeast winds lasting for several days, there is the possibility that the suspended sediment concentration at the Ocean Park intake would remain well above design specification for the duration of the storm.

Filter Cleaning

6.9 The current cycle of seawater intake and the frequency of filter cleaning has been determined by Ocean Park through trial and error to be the minimum necessary to achieve the required water quality. In the event that design specifications would be exceeded, Ocean Park could prevent deleterious effects by increasing the pump backflushing frequency above the current once per two weeks at a cost of about $100 per backflush.

6.10 Given the intermittent timing of predicted sediment load increases, it appears likely that coordination of Ocean Park intake pumping with respect to tides, weather conditions and dredger location would prevent the filters from becoming overloaded with sediment.

Other Seawater Intakes

6.11 Other seawater intakes have been identified along the shores potentially affected by dredging plumes (Figure 6.1). These are flushing water intakes at Brick Hill and Wah Fu, and intakes for air conditioning cooling water for Yue On Court and Queen Mary Hospital.

6.12 The results of computer modelling suggest that design specifications would not be exceeded during dredging. The intake of turbid water should not affect cooling water systems, but could have a detrimental effect on the appearance of flushing water. The extent of this effect would depend on the length of time the flushing water is allowed to stand before use.

Noise

6.13 A noise assessment was carried out (Appendix B) based on day and night time readings taken at the Noise Sensitive Receivers (NSR) and using conservative predicted noise levels from the dredging operation.

6.14 The estimated sound pressure levels at each NSR due to the proposed dredging operation are lower than the recorded background noise levels. The estimated noise levels are only marginally higher than the background noise levels at the NSR sites. The potential noise impact on sensitive receivers due to the proposed dredging in East Lamma Channel is therefore considered to be insignificant.

7 MITIGATION, MONITORING AND AUDIT

Mitigation Measures for Sedimentation

7.1 A variety of possible mitigation measures are discussed here. None have been taken into account when assessing the potential impacts discussed above. A brief analysis is made of the potential effectiveness of the proposed mitigation measures, however, this analysis must be considered tentative until a more precise dredging plan becomes available.

Dredger Type

7.2 The use of stationary dredgers must be ruled out because the proposed borrow area lies wholly within the East Lamma Channel Traffic Separation Scheme (TSS) where an anchored dredger would pose an unreasonable maritime risk. Semi-stationary dynamically positioned trailer dredgers would create concentrated sediment plumes which would pose a risk to the environment, and therefore should be ruled out. The dredgers of choice are therefore fully mobile trailers.

Silt Curtains

7.3 Where water currents are slow, silt curtains could be used to limit the flow of sediment plumes into fish culture zones and bathing beaches. At mariculture zones, however, they might create water quality problems by restricting water circulation. Water circulation is necessary to maintain dissolved oxygen levels and to flush wastes from the culture zones. Wave action could also limit the effectiveness of the silt curtains at beaches.

Seasonal Restrictions

7.4 A significant reduction in the potential impact of sedimentation could be afforded sensitive receivers by dividing the Borrow Area into two halves and by dredging alternate halves on a seasonal basis. The dividing line would be perpendicular to the long axis of the borrow area. This mitigation plan would distance dredging operations from some sensitive receivers during the period when prevailing winds were blowing toward them. A seasonal restriction would have the negative impact of increasing the rate of channel crossing by the dredger and would slightly decrease the production rate due to the increased frequency of turns.

<u>November - April</u>

7.5 If the southeastern half of the Borrow Area could be worked only during the northeast monsoon (November-April), this would minimise the chances of sediment plumes reaching the Ocean Park intake. This would also maximise the distance between dredging operations and Lo Tik Wan during the period when prevailing east winds would normally push sediment plumes in that direction. This measure would not mitigate potential impacts on the fry collection area, the coral area at Wong Chuk Kok or the Sok Kwu Wan mariculture zone.

<u>May - October</u>

7.6 Working the northwest half of the Borrow Area during the southwest monsoon (May-October) would decrease the chances of sediment plumes reaching Lo Tik Wan and would maximise the distance between dredging operations and Ocean Park during the season when wind direction posed the greatest risk of transporting sediment plumes in that direction.

Operational Restrictions

7.7 A number of possible restrictions on dredging operations could be included in the dredging contract to limit the potential for damage caused by sediment plumes. All restrictions will raise the cost of sand production and some, such as a complete stoppage of work, are considered to be too costly because they could make Government liable for large claims.

7.8 Several possible operational restrictions are listed below:

- limit overflow density
- limit filling rate
- restrict minimum dredging speed
- limit number of hours of dredging per day
- restrict proximity to sensitive receivers by reducing size of borrow area
- restricting area of operation based on monitoring results
- limit number of dredgers operating simultaneously

7.9 Of the six restrictions listed, only the last two would possibly be acceptable to Government and Contractors. The others would be considered too costly by Government and difficult or impossible to abide by Contractors.

Restricting Area of Operation

7.10 A good monitoring programme and close communication with Contractors could allow dredging to be restricted to a specified area of operation if monitoring at a sensitive receiver showed an exceedance of a predetermined suspended solids limit. It is doubtful, however, that Contractors would agree to this system, and given the 24 h operations of dredgers, it would be difficult to implement and enforce. It would also make Government liable for potential claims if Contractors were temporarily excluded from what they believe are areas rich in sand.

Limiting Number of Dredgers

7.11 By contractually limiting the number of dredgers allowed to operate simultaneously, the potential impacts can be kept to the minimum, however, this would limit the production rate. Although careful planning could allow this restriction to be feasible, in practice, not all future periods of high demand for fill can be predicted. During periods of high demand, this restriction could cause potentially costly delays to development projects.

Mitigation Measures to Limit Maritime Risk

7.12 The operation of large dredgers, no matter how manoeuvrable, within a major shipping lane, presents a risk of collision. The major risk is caused by dredgers crossing the TSS.

7.13 There is a need for centralised monitoring and management of a dredging operation of this magnitude as identified in the Borrow Area Assessment Report. Marine Department are in a unique position of being equipped through the services of the Vessel Traffic Centre (VTC), with state-of-the-art monitoring facilities, which also present a complete overview of port traffic control. These facilities are essential to Marine Department's role in the management of the port and maritime safety, and would be used by them to monitor dredging of East Lamma Channel within the limits of their responsibilities.

7.14 In addition to the Masters of the dredging vessels taking all of the necessary precautions to prevent incidents or collisions, there is considerable merit to the dredging Contractor being required to provide a separate Dredging Management Co-ordinator to oversee the dredging operation and coordinate dredging operations with the Marine Department.

Monitoring

7.15 It would be useful to establish a regular system of monitoring of turbidity and sediment load at specified time intervals and stations. Given the above problems with controlling dredging operations, the major use of the monitoring data will be to track the potential effects and to compare predicted with actual impacts. In the unlikely case that a 'restricted area of operations programme' based on monitoring results can be implemented, then specific Action Plans should be designed that specify what areal restriction should be required when the specified Trigger, Action and Target levels are exceeded. A method of enforcing these provisions would also be required.

7.16 If it is possible to include the above restrictions in the dredging contract, the results of the monitoring could be used, for example, to introduce quite simple temporary changes in the operation of the trailer dredgers including reduction of the loading area either by early turns or by bias towards one or other sides of the shipping lane to distance the operation from any threatened sensitive receivers, until such time as the adverse effects of wind and tide have passed.

7.17 The type and extent of monitoring required would depend on final decisions regarding dredging plant, exact Borrow Area location and dimensions and production rate requirements. Monitoring recommendations are given assuming that the final choice will be the continuous trailer-dredging scenario presented above. A plume monitoring programme could be established as set out below.

7.18 A turbidity problem could be created if trailer dredgers were to indiscriminately use Automatic Lean Mixture Overboard (ALMOB) during overburden dredging. This would be particularly easy to disguise at night. In locations where flushing by water currents is minimal, this would be self-defeating because much of the overburden would be re-deposited in the pits. But in Lamma Channel, where flushing is quite good, indiscriminate ALMOB use, which is essentially a form of agitation dredging, is a conceivable method of overburden removal.

7.19 Without actually stationing an observer on each vessel, it would be very difficult to monitor the use of ALMOB. The most effective monitoring programme would concentrate on observing plume characteristics using semi-permanent automatic silt meters and possibly the ADCP near the sensitive receivers identified above. In practice, a 24 hour capability to carry out monitoring and to implement an Action Plan would be needed. The ADCP has the advantage of being able to indicate the total amount of sediment in a given plume even at night. If ALMOB abuse is suspected, spot inspections of the plume characteristics could be made, with special attention to suspended sediment concentration or turbidity. These inspections should not necessarily be limited to daylight hours. A record of dredger movements would be available from the VTC. If suspended sediment levels exceed the contract specifications, the contract conditions should be invoked whereby the contractor is required to modify the dredging pattern, timing and dredging rates, until such time as continuously acceptable suspended solids levels are restored.

7.20 In addition to monitoring sediment levels at sensitive receivers, it would be important to monitor potential effects on sensitive organisms. The hard corals located at Wong Chuk Kok are sensitive to sedimentation; hard coral abundance, diversity and evidence of injury (bleaching and tissue loss) should be monitored. In addition, the catch of fish fry along the coast of Lamma Island could be monitored. The results of this monitoring would be useful for predicting the potential effects of future dredging work and as documentary evidence in case claims are made against Government.

7.21 The environmental audit system is designed to methodically check that the activities of a project are in compliance with previously defined environmental requirements and predictions, and that the necessary remedial measures are identified to remedy any unacceptable or unforeseen environmental impacts. Environmental auditing is seen as a check to reassure management and regulatory agencies, that activities are being carried out in an environmentally acceptable manner. It also enables a post project analysis to be carried out to examine the accuracy of the original environmental impact assessment.

The Environmental Auditor

7.22 The audit may best be carried out by an independent body having the necessary expertise to review the method and philosophy behind the monitoring programme.

Auditing Frequency

7.23 Auditing frequency will be related to a number of factors, such as rate of data collection and dredging. We suggest that audits be carried out at monthly intervals for the first six months and thereafter at six monthly intervals so that the monitoring programme can be updated to take account of any changing environmental impacts. This frequency could be reviewed and revised as necessary as part of the audit process until full recovery has been established.

7.24 Environmental auditing should be considered as a long term exercise, but we suggest that the monitoring and auditing system be dispensed with when all the monitored environmental effects are within acceptable limits and are stable or decreasing.

Scope of the Audit

7.25 The auditors should be familiar with the philosophy behind the dredging operations, environmental impacts and control procedures. The audit should:

- check that the approved sampling procedures and analytical techniques were used to access the quality of the collected data.
- consider tidal, wind and weather conditions where appropriate at the time of sampling.
- ascertain whether any extraneous activities, unrelated to dredging, may have influenced the data. Factors such as terrestrial runoff, for example, adjacent to monitoring sites should be considered.
- review the collected data, in the light of the preceding information, to identify any events which did not comply with the acceptance criteria, and why they did not comply.

- review impacts that cannot be quantified and for which there are no absolute acceptance criteria such as visual impact.

- consider any complaints or reactions from the general public relating to dredging operations. If appropriate, recommend suitable actions which could be taken.

- review the overall monitoring philosophy, in terms of sampling location, frequency, parameters measured, test methods, acceptance criteria and control procedures. Revise if necessary.

- revise the scope and frequency of the auditing system to reflect changes in environmental impacts and dredging procedures.

- carry out a post project analysis to compare the environmental impacts predicted in the EA, with actual impacts. Comment on any discrepancies and make recommendations as appropriate.

Reporting Procedures

7.26 A report should be produced by the auditors after each inspection. The report should provide Contractors and EPD with information about compliance status of dredging and should review the earlier stages of the Environmental Assessment. It should, in addition, indicate any operational changes which should be made to monitoring and control procedures.

8 WAVE STUDIES -- COMPUTER MODELLING

8.1 This section covers wave modelling studies and sets out the main issues identified, their probable impact, and possible mitigation measures.

The Borrow Area Site

8.2 The existing sea bed in the proposed borrow area is at a depth in excess of 30 m below Principal Datum (PD) (which is approximately 0.15 m above Chart Datum (CD). Figures 8.1 and 8.2 show the borrow area before and after the proposed excavation. Because of potential wave impacts caused by the original pit shape, it two alternative pit shapes were proposed; a stepped shape (S) and a smaller trimmed and stepped shape (TS). These revised designs are discussed in Sections 8.60 and 8.61.

Objectives of the Wave Studies

8.3 The overall objective of the wave studies is to identify the potential impact, in regional and local terms, of dredging at the proposed borrow area. The specific objectives of the wave studies are summarized below:

- To determine the extent of the modification of the existing wave climate, due to dredging in the proposed borrow area, at sea defence structures, gazetted beaches, typhoon shelters and mariculture areas in the vicinity of the East Lamma Channel;

- To determine the extent of the modification of the existing wave climate in the East Lamma Channel navigation lanes and in the inshore navigation areas.

Components of Inshore Waves

8.4 Waves in an inshore location such as the East Lamma Channel may consist of two main components:

- Oceanic swell -- defined as low frequency, long period waves generated far offshore generally by winds blowing for long periods over a long fetch.

- Local wind waves -- defined as high frequency, short period waves (or seas) generated within a few kilometres of shore.

8.5 The potential for wave impacts depends on wave energy which is proportional to wave height. Since local wind waves tend to be relatively small, their potential effects in the absence of swell are of less concern than those of oceanic swell. Oceanic swell reaching Hong Kong may typically have been generated by distant typhoons or by monsoonal winds in the South China Sea.

8.6 As waves move inshore and they reach a water depth that is less than half their wave-length, the waves are said to "feel" the seabed. The seabed begins to affect the characteristics of the waves. Waves with wave-lengths greater than about 40 m would be affected by the seabed as they approach East Lamma Channel.

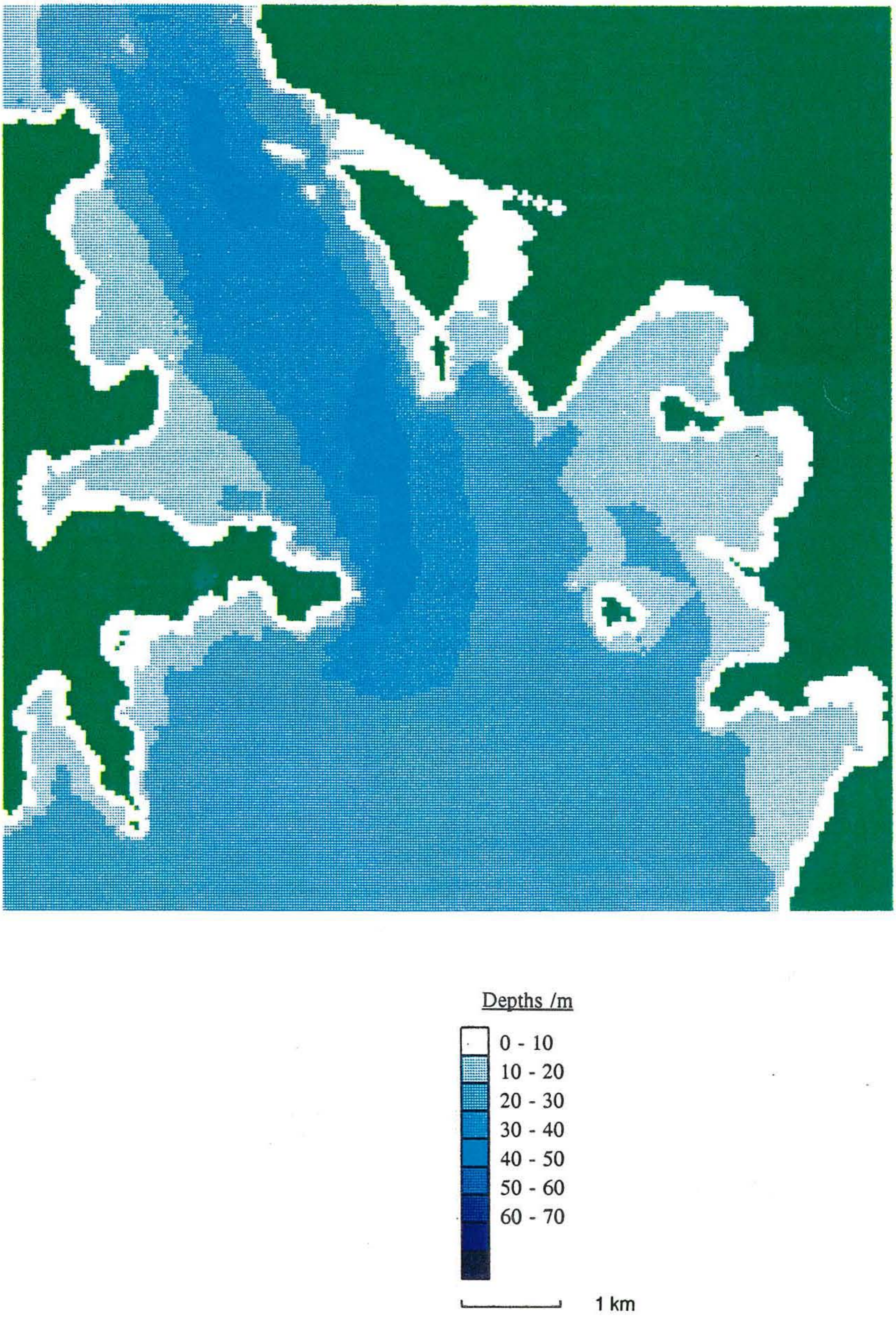


FIGURE 8.1 NATURAL BATHYMETRY (10 M CONTOURS)

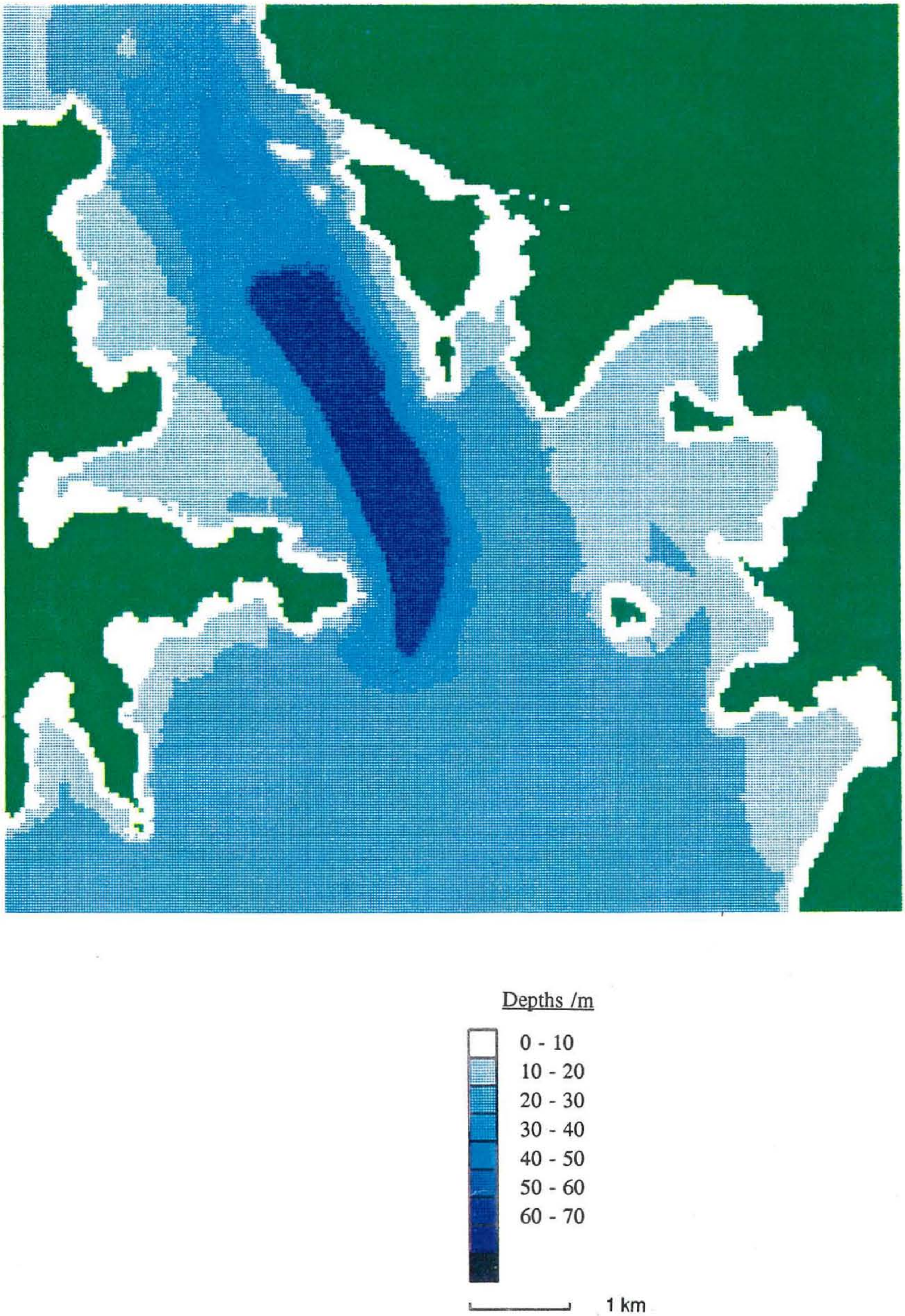


FIGURE 8.2 ORIGINAL BORROW PIT SHAPE (10 M DEPTH CONTOURS)

Factors Affecting Inshore Wave Energy and Direction

8.7 The fundamental physical processes that modify waves travelling from deep to shallow water are wave reflection, refraction and diffraction. A shoaling seabed affects waves mainly through seabed friction. These processes are defined below.

Seabed Friction

8.8 Seabed friction which, together with seabed percolation, causes a loss of wave energy as a wave travels over a shoaling sea bed. By reducing the velocity of waves, seabed friction affects several of the processes noted above. High waves are reduced in height by this process to a greater extent than small waves;

Wave Refraction

8.9 Wave refraction causes wave crests to bend as they approach the shoreline. Sections of a wave crest passing shallow water will lag behind such that the wave crest progressively conforms to the contours of the shoaling sea bed. Refraction may also result in local variation of wave energy and wave height.

Wave Diffraction

8.10 Wave diffraction occurs when the path of a wave train is partially blocked by a barrier, such as a steep headland, or by a breakwater. Diffraction causes waves to turn into the sheltered area behind the barrier. The effect is to transmit wave energy laterally along a wave crest.

Wave Reflection

8.11 Wave reflection occurs when wave trains propagate towards cliffs, breakwaters, beaches, or underwater slopes and then then change direction.

8.12 When waves enter shallow water, two additional processes can occur; wave shoaling and breaking.

Wave Shoaling

8.13 Wave shoaling is a gradual increase in wave height and concentration of wave energy that occurs as a wave moves into shallow water.

Wave Breaking

8.14 Wave breaking can occur when wave steepness (wave height divided by length) has become too great or when the forward velocity of the wave crest has exceeded the velocity of the lower portion of the wave.

Combined Effects

8.15 When long period (and wavelength) waves approach and cross a dredged pit, the combined effects of refraction and diffraction can cause the waves to change direction. Depending on the wave period, and on the depth of water inside and outside the pit, the wave may bend back towards the shallower side. This may focus wave energy due to the interaction of these waves with waves refracted by existing seabed contours outside the pit. Such a focusing may lead to higher waves than under existing conditions.

8.16 The changes in wave climate under various return period wave conditions due to imposed changes in sea bed bathometry can be studied analytically, using numerical modelling techniques, or with a physical model. The former is considerably quicker and less costly, and is normally employed.

Wave Model

8.17 The wave model used for the wave studies, WC2D, is a finite difference numerical model which, in addition to modelling the processes by which waves propagating from deep water to inshore areas are modified in height, period, and direction, is used to calculate wave-current interactions and inshore circulation.

8.18 The theory and original model were developed in the Department of Civil Engineering, University of Liverpool, UK, by D.H. Yoo in the early 1980's. The present model was further developed by K.S. Lee and by N.J. MacDonald of the University of Liverpool in 1990-1992.

Wave Processes Covered by the Model

8.19 The model WC2D covers the following wave modification processes:

- refraction (including refraction due to currents);
- diffraction;
- shoaling;
- breaking;
- seabed friction.

It does not include wave reflection, or energy gain due to local winds.

8.20 The WC2D model therefore includes additional wave modification processes to the OUTDIF wave model developed recently by Hydraulics Research Ltd (HRL) from their OUTRAY wave model, which formed one of the WAHMO suite of models. OUTDIF, which was used by CED to establish the inshore wave climate at a number of points in the approaches to the Western Harbour for the Lantau Port and Western Harbour Development Studies (LAPHS), and for the seaward boundary conditions for the present East Lamma wave study, does not include the effects of refraction due to currents, of seabed friction, or of wave breaking.

Limitations of the Model

8.21 A limitation of the model relates to diffraction around headlands or other barriers where waves are diffracted more than 90°. This problem can be overcome by running the model over the affected areas in stages, effectively breaking down the diffraction process around barriers where the problem occurs into two consecutive processes.

Extent of the Model

8.22 The WC2D wave model, which has a 50 m by 50 m grid, extends from the seaward boundary, which is a line roughly north-northeast/south-southwest between Stanley Peninsula and south of Tai Kok at the southern extremity of Lamma Island, to the landward boundary, roughly between Telegraph Bay and north of Pak Kok at the northern extremity of Lamma Island. It thus includes Repulse Bay, Deep Water Bay, Aberdeen Harbour and typhoon shelters, Sok Kwu Wan, and Luk Chau Wan.

8.23 The orientation of the grid is chosen to give the best representation of the borrow area and its side slopes. The y-axis of the model is 20° west of True North.

Wave Model Input Data

8.24 To run the WC2D model wave data are input along the seaward boundary. The wave data comprise wave height, period and direction. Wave period must be constant along the boundary, but the input wave heights and directions can vary along the boundary.

8.25 The present depth of water in which the proposed borrow area is situated, around 30 m below Principal Datum (PD), and the proposed depths to which the borrow area will be dredged, 60 m below PD are such that only longer waves, e.g. swell from deep water offshore, will be significantly modified in height and direction by the proposed borrow area. The analysis has therefore concentrated on swell, rather locally-generated waves whose wavelengths, even in extreme conditions, will not exceed those of frequently occurring swell.

Source of Input Wave Data Used

8.26 The source of wave data used as input at the seaward boundary of the WC2D model has been output data from the OUTDIF model, run by CED for LAPHS, which in turn used as input data voluntary observations from ships (VOS) data updated to 1990, and the results of work carried out by Hong Kong Polytechnic for LAPHS on typhoon waves.

8.27 The output data for three points: Point 1, Point 2 and Point 3, on the seaward boundary of the WC2D model were obtained from CED for the 50 times a year, 1 in 1 year and 1 in 50 years conditions.

Source of Input Current Data Used

8.28 The source of current data used (when relevant) as input at the nodes of the WC2D grid was the 100 m grid WAHMO model. This data was supplied by CED.

Source of Water Level Data Used

8.29 For the OUTDIFF wave modelling by CED, a water level of +2.0 m Chart Datum (CD) (approximately +1.9 m PD) was used for the 50 times a year, 1 in 1 year, and 1 in 50 years conditions. This corresponds roughly to a mean high water condition.

8.30 For the WC2D wave modelling, it was decided to use the +0.2m CD level for the 50 times a year and 1 in 1 year conditions, and to use a level of +3.4m CD for the 1 in 50 years wave condition. The latter corresponds to about a 1 in 15 years water level at North Point/Quarry Bay, and is considered appropriate.

8.31 In practice, the wave modification is not very sensitive to small differences in water level, since the existing (and future) water depths are relatively large.

Wave Studies

8.32 The programme of wave studies carried out has been designed to make a comparison between the existing conditions and conditions after dredging the borrow area. For this, the studies have concentrated on the 50 times a year conditions, and on the 1 in 50 years conditions. The former represent moderately rough 'normal' conditions; the latter represent extreme typhoon conditions in the approaches to Hong Kong.

8.33 The programme of wave studies carried out is set out in Table 8.1. In general, these cover offshore (seaward of the Lamma Islands) wave directions of 120°N, 150°N and 180°N which are the directions most likely to result in significant modification by the proposed borrow area.

8.34 The majority of runs were made without tidal currents. The effect of adding tidal currents is to shorten the wavelength during the ebb (currents in opposite direction to waves), and to lengthen the wavelength during the flood (currents in same direction as waves). The lengthening of the wavelength leads to greater refraction and diffraction, and thus in general to a great divergency of wave energy either side of the main channel; the shortening of the wavelength leads to less refraction and diffraction, and thus to less divergence of the wave energy on either side of the main channel. This effect is more marked for waves of smaller period.

8.35 In practice, with the tidal currents prevailing under the conditions studied, the change in wave height between conditions with and without tidal currents is only of the order of 10%. The greatest relative effect on wave height of tidal currents is with waves of around 8s period, which just begin to "feel the bottom" with the prevailing water depths, and in which the shortening or lengthening effect of the current is still significant.

8.36 Runs were also carried out to check sensitively to wave period, (e.g. Run I001), to current (e.g. Runs J001 and K001), and to current and borrow area (e.g. Runs L001 and M001).

8.37 Further runs were required to model the modified pit shapes TS (trimmed and stepped) and S (stepped), to compare the amount of focusing taking place during extreme events.

Comparative Wave Conditions Before and After Dredging

8.38 The purpose of the comparison of wave conditions before and after dredging is primarily to determine whether or not wave heights are increased in 'sensitive' areas due to the focusing of wave energy as a result of changes to the sea bed bathometry. Absolute wave heights in the 'before' and 'after' situation, although significant, are not as important as the relative concentration of wave energy when the two scenarios are compared. A summary of the comparative conditions is given in Table 8.1.

8.39 a) 50 times a year wave conditions

Since the wavelength of the waves in these conditions is relatively short (around 6.0s peak period), and the water depths relatively deep, the amount of refraction and diffraction is small, even for the existing situation. Figures 8.3 and 8.4 show that in general, wave energy focusing is not much modified by dredging in the borrow pit.

Table 8.1 Programme of WC2D wave model runs carried out. 3983/200

Natural Bathymetry - Before Excavation

	Height (m)	Period(s)	Dir.	Currents	Event	Results
A001	.90	6.0	120°	None	50/yr	Energy not impinging on Lamma Island, passing up Lamma Channel with some divergence on either side.
A002	.66	6.0	150°	None	50/yr	Energy not impinging on Lamma Island, waves passing up Lamma Channel or breaking on Ap Lei Chau.
B001	5.00	13.7	120°	None	1/50 yrs	Some focusing on Ap Leu Chau, and on part of Sham Shui Kok.
B002	5.00	13.7	150°	None	1/50 yrs	Marked focusing on Sham Shui Kok and behind Ngan Chau.
B003	5.00	13.7	180°	None	1/50 yrs	Marked focusing behind Ngan Chau on Tong Po Chau.
B004	5.00	13.7	210°	None	1/50 yrs	Marked focusing behind Ngan Chau onto the headland east of Repulse Bay. Considerable wave heights in Repulse Bay.
C001	.90	6.0	120°	Flood	50/yr	Energy not impinging on Lamma Island, passing up Lamma Channel with some divergence on either side - little change from A001.
D001	.90	6.0	120°	Ebb	50/yr	Similar to cases A001 or C001, but marginally less energy passing up to case M001.
L001	3.24	8.0	120°	None	Curr. /area sensitivity	The bathymetry of the main channel causes no focusing at this wave period (unlike B001.) Some focusing behind Ngan Chau occurs.
M001	3.24	8.0	120°	Ebb	Curr. /are sensitivity	Wave heights around Wong Chok Kok increase slightly (about 10%) relative to case M001.

After Dredging - Original Pit Shape F

	Height (m)	Period(s)	Dir.	Currents	Event	Results
E001	.90	6.0	120°	None	50/yr	Similar to A001, C001 or D001, but marginally more energy being spread away from the channel onto Lamma and Hong Kong Islands.
E002	.66	6.0	150°	None	50/yr	Virtually identical to case A002.
F001	5.00	13.7	120°	None	1/50 yrs	Intense focusing in southern approaches of Aberdeen Harbour. Shift in position of focusing behind Ngan Chau (as compared to B001).
F002	5.00	13.7	150°	None	1/50 yrs	More intense focusing on Sham Shui Kok, focusing behind Ngan Chau as in existing code (B002)
F003	5.00	13.7	180°	None	1/50 yrs	More wave energy reaching Repulse Bay area, focusing behind Ngan Chau is shifted from Middle Island (in case B003) into Repulse Bay.
G001	.90	6.0	120°	Flood	50/yr	Little difference from case C001.
H001	.90	6.0	120°	Ebb	50/yr	Little difference from case D001.
I001	5.00	12.00	120°	None	Period sensitivity	Considerable focusing in southern approaches of Aberdeen Harbour. Not too different from case F001.
J001	3.24	8.0	120°	None	Current sensitivity	8s waves most sensitive to current - slight focusing towards Ap Lei Chau beginning.
K001	3.24	8.0	120°	Ebb	Current sensitivity	Wave heights around Wong Chok Kok increase slightly (about 10%) relative to case J001.
P001	2.10	10.0	120°	None	1/1 yr	Similar results to B001, although the focusing is less intense.
P002	2.10	10.0	150°	None	1/1 yr	Similar results to B002, although the focusing is less intense.
P003	2.10	10.0	180°	None	1/1 yr	Similar results to B003, although the focusing is less intense.

Table 8.1 continued **Programme of WC2D wave-model runs carried out.** 3983/200

After Dredging - Modified Pit Shape TS

	Height (m)	Period (s)	Dir.	Currents	Event	Results
X001	5.00	13.7	120°	None	1/50 yrs	Some focusing of wave energy onto Ap Lei Chau, wave heights on the coast of Hong Kong island are changed by about 1 m.
X002	5.00	13.7	150°	None	1/50 yrs	Focusing onto Sham Shui Kok, similar to case B002 (before excavation).
X003	5.00	13.7	180°	None	1/50 yrs	Focusing on Tong Po Chau, considerable wave energy in Repulse Bay.
X004	5.00	13.7	210°	None	1/50 yrs	Similar to case B004 (before), but with slightly more energy in Repulse Bay.

After Dredging - Modified Pit Shape S

Y001	5.00	13.7	120°	None	1/50 yrs	Intense focusing onto west side of Aberdeen Harbour approach, similar to case F001 (original pit shape).
Y002	5.00	13.7	120°	None	1/50 yrs	Intense focusing onto Sham Shui Kok, similar to case F002. (original pit shape)
Y003	5.00	13.7	180°	None	1/50 yrs	Intense focusing onto Tong Po Chau.

All these run results have been plotted and examples are included in this report.

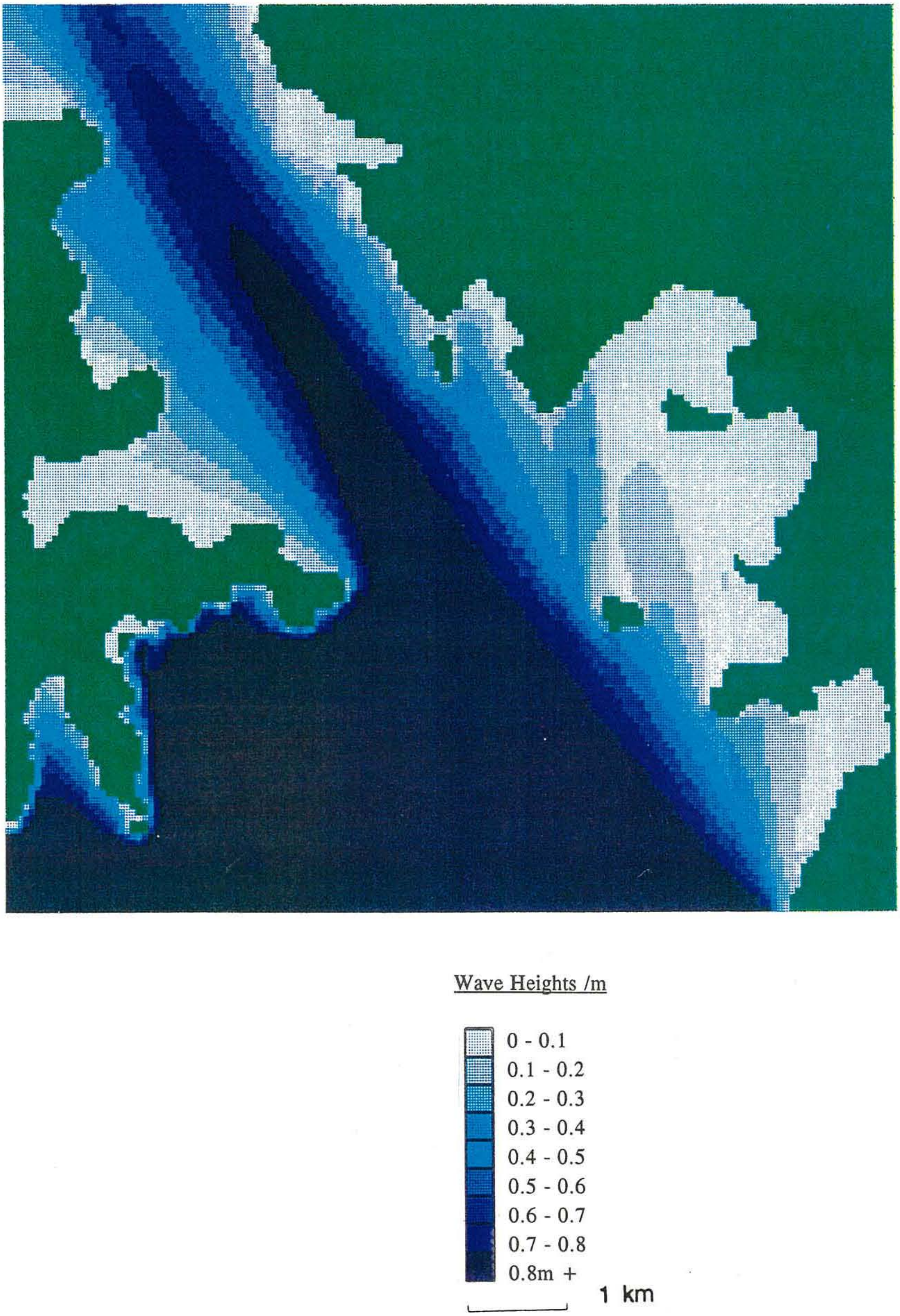


FIGURE 8.3 PRE-DREDGING WAVE REGIME; 50 TIMES PER YEAR, SWELL HEIGHT 0.9 M, FROM 120°, 6 S PERIOD

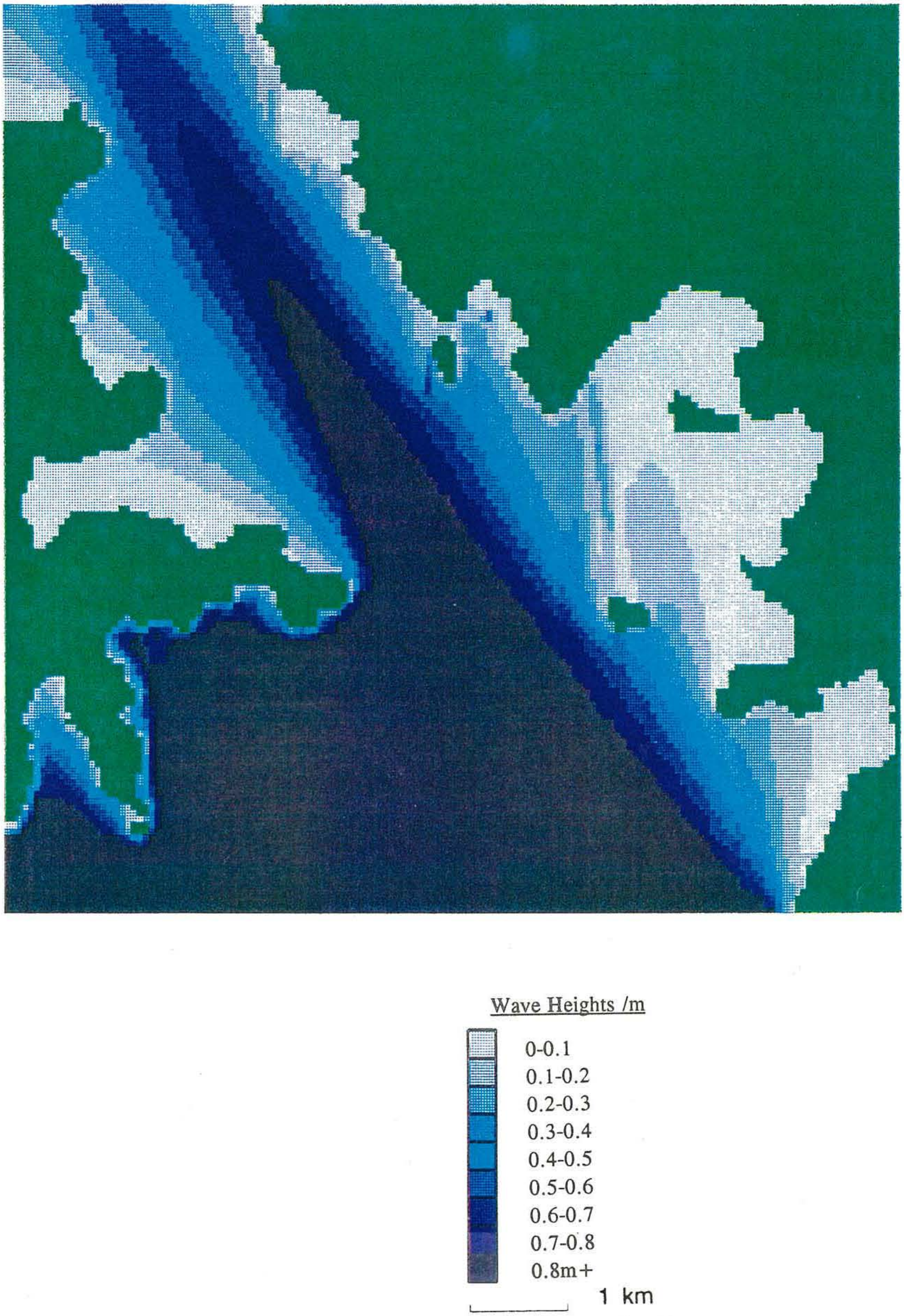


FIGURE 8.4 POST-DREDGING WAVE REGIME, ORIGINAL PIT SHAPE; 50 TIMES PER YEAR, SWELL HEIGHT 0.9 M, FROM 120°,6 S PERIOD

8.40 b) 1 in 1 year wave conditions

It is with swell of reasonable length (around 10.0s peak period) that the focusing of wave energy due to the borrow area configuration starts to become more marked. Model runs carried out for the 'after dredging' scenario suggest that waves with an offshore direction of around 135°N could be focused in the southern approaches to Aberdeen Harbour, as shown in Figure 8.5.

8.41 c) 1 in 50 years wave conditions

Due to the longer wavelength of the swell under these conditions, the refraction and diffraction effects are significantly greater under both scenarios. Under existing conditions there is a noticeable degree of wave energy focusing on the headlands and towards lengths of coastline most exposed to the directions 120°, 150° and 180° (Figures 8.6, 8.7 and 8.8). It can be deduced that for an offshore wave direction of around 135°N, there could be a marked degree of focusing in the southern approaches to Aberdeen Harbour under the existing conditions.

8.42 After dredging, however, with the original proposed borrow area configuration, there is a significant increase in the extent and degree of wave energy focusing, mainly due to the configuration of the seaward end of the dredging area, on the north eastern side, which could adversely affect the typhoon shelter breakwater in the southern approaches to Aberdeen Harbour, and beach stability in Deep Bay and Repulse Bay during typhoon conditions (see Figures 8.9, 8.10 and 8.11).

8.43 There is also a slight increase in the focusing of wave energy, following dredging of the borrow area, in the vicinity of Luk Chau Tsuen.

Environmental Impacts Due to Potential Wave Climate Changes

8.44 The main effect of the modification of the inshore wave climate due to dredging in the borrow pit is likely to be to redistribute the wave energy of longer waves in the vicinity of the borrow area, which may lead to the focusing, or increased focusing compared to existing conditions, of wave energy in certain locations; these locations may vary depending on the direction of approach of the swell offshore. At the same time, there is likely to be a corresponding decrease in wave energy in other locations.

8.45 An increase in wave energy will result in higher wave heights than would otherwise occur under existing conditions. Table 8.2 shows likely wave heights in sensitive areas for 1 in 50 year conditions with the different pit shapes.

8.46 Waves with below about 8s peak period, and locally-generated waves, are unlikely to be significantly affected by the presence of the borrow pit, and the present distribution of wave energy within the East Lamma Channel and along the shores of Hong Kong Island and Lamma Island is unlikely to be significantly affected.

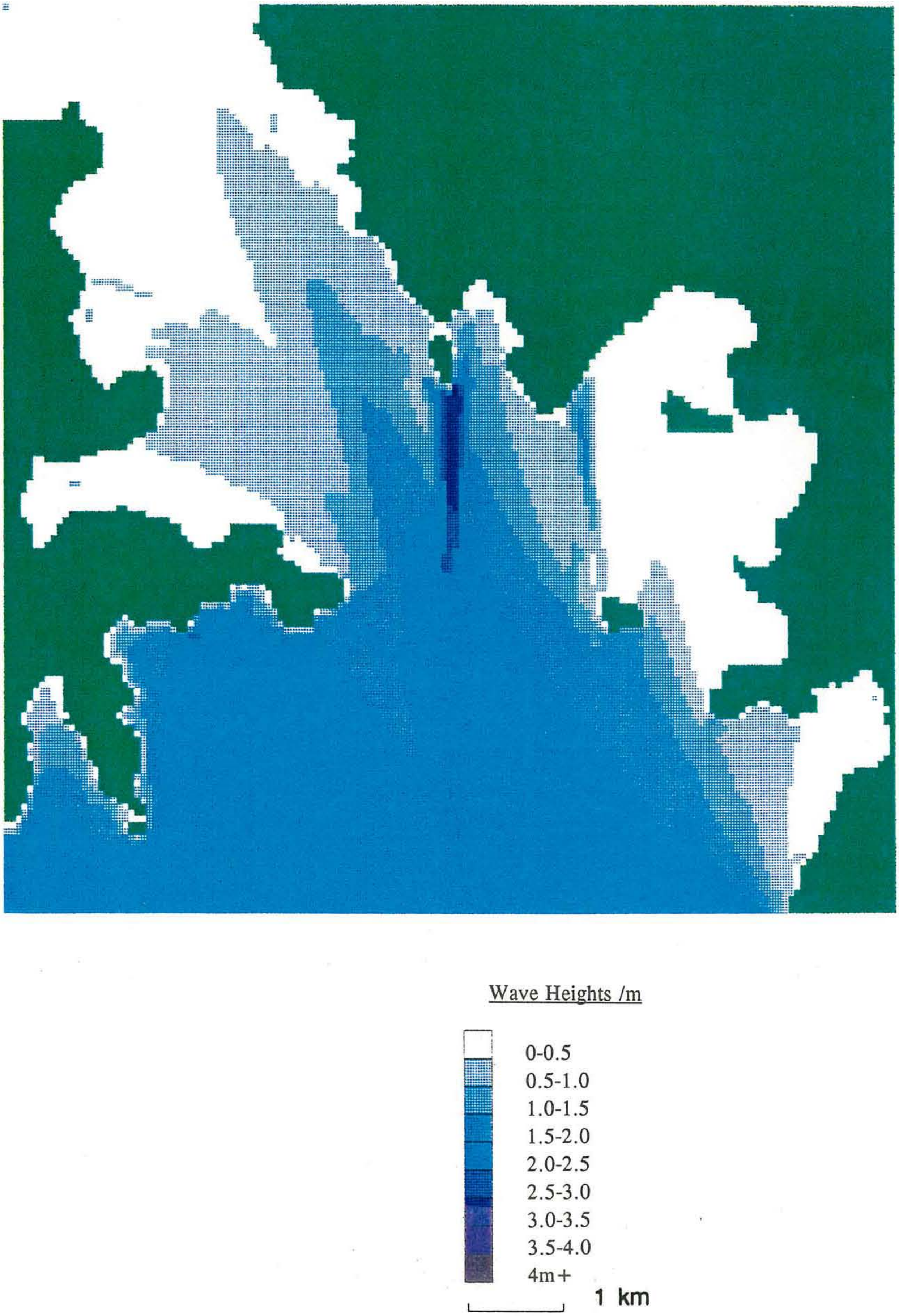


FIGURE 8.5 POST-DREDGING WAVE REGIME, ORIGINAL PIT SHAPE; 1 TIME PER YEAR EVENT, SWELL HEIGHT 2.1 M, FROM 120°, 10 S PERIOD

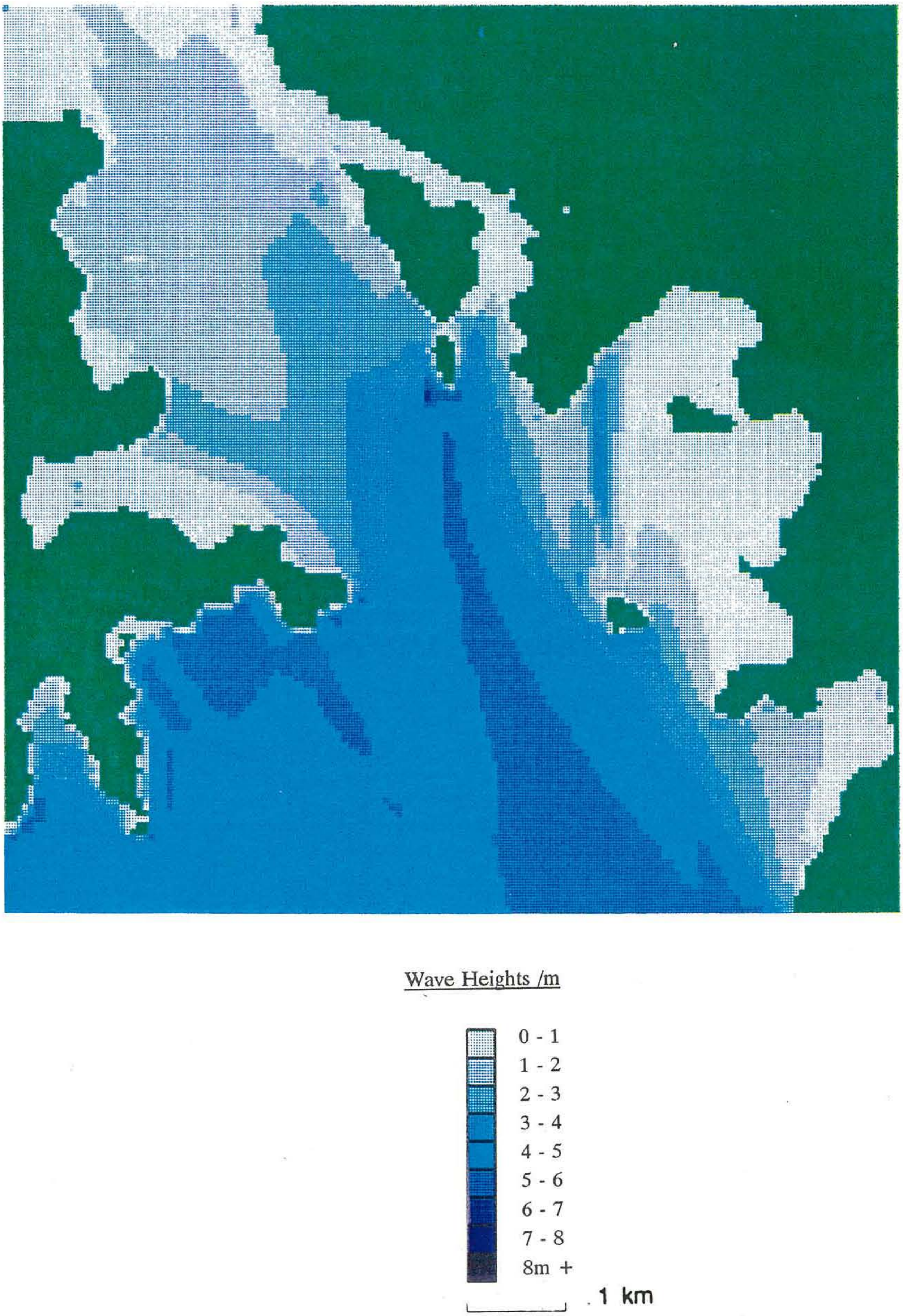


FIGURE 8.6 PRE-DREDGING WAVE REGIME; 1 PER 50 YEAR EVENT, SWELL HEIGHT 5.0 M, FROM 120°,13.7 S PERIOD

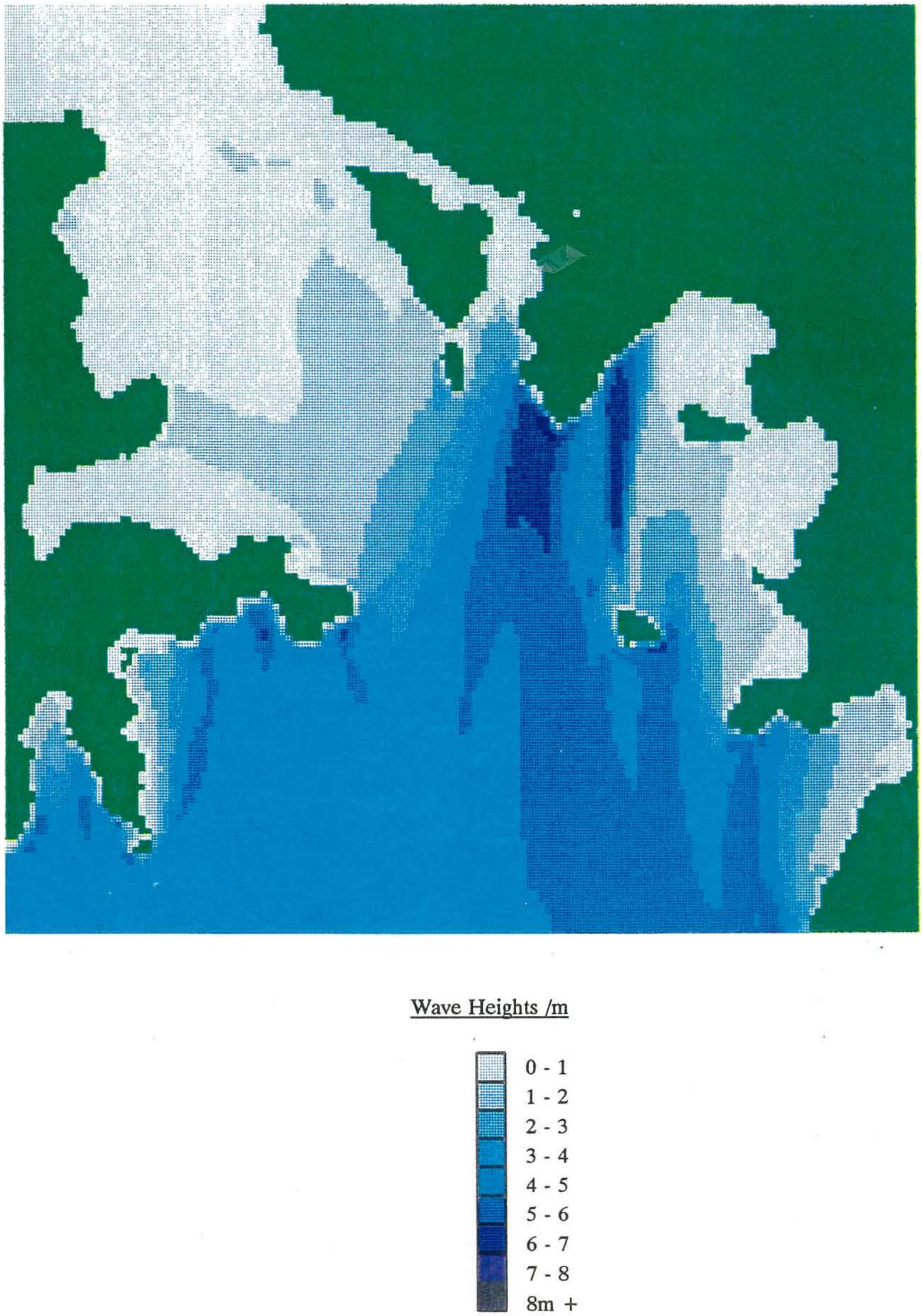


FIGURE 8.7 PRE-DREDGING WAVE REGIME; 1 PER 50 YEAR EVENT, SWELL HEIGHT 5.0 M, FROM 150°, 13.7 S PERIOD

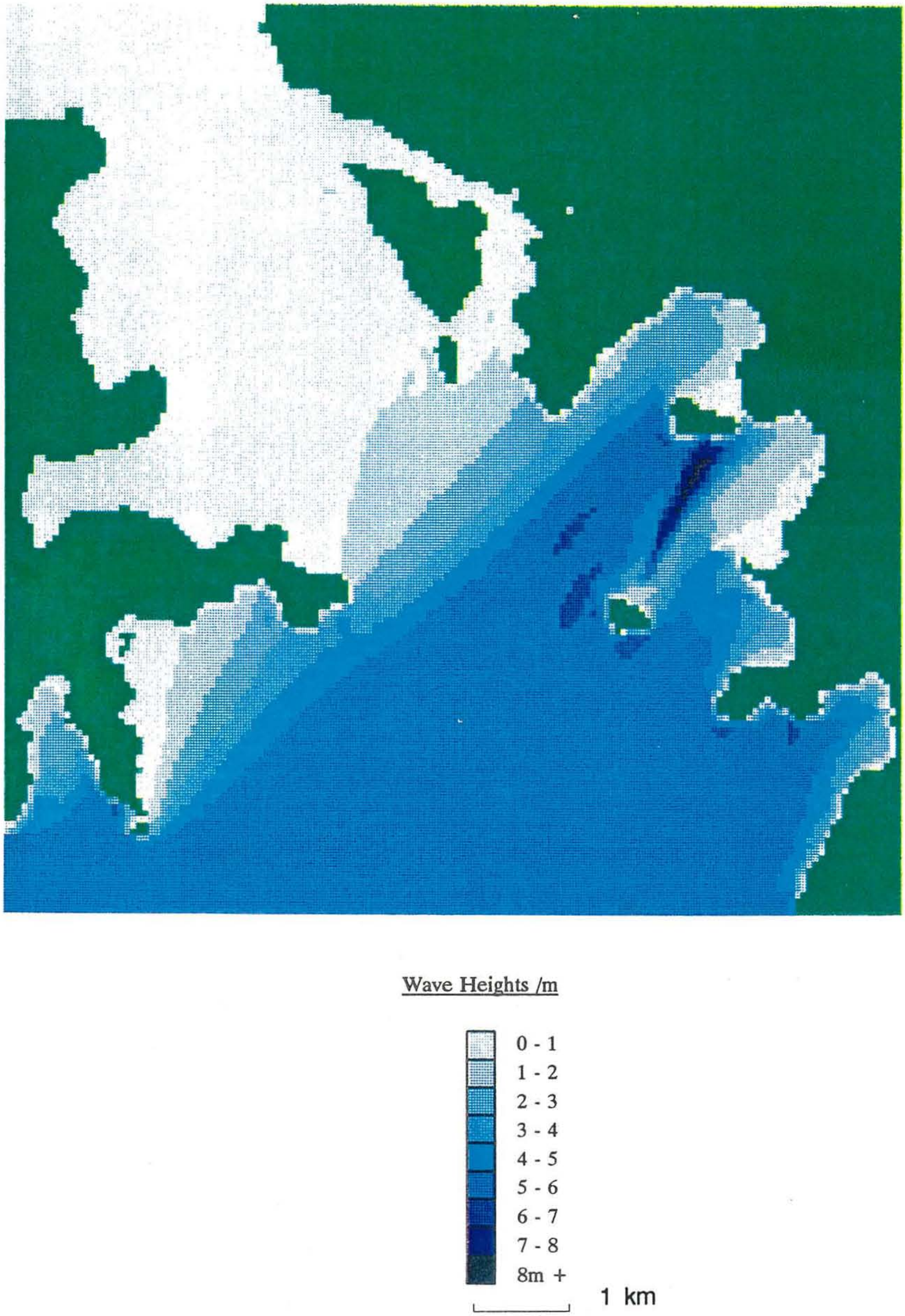


FIGURE 8.8 PRE-DREDGING WAVE REGIME; 1 PER 50 YEAR EVENT, SWELL HEIGHT 5.0 M, FROM 180°, 13.7 S PERIOD

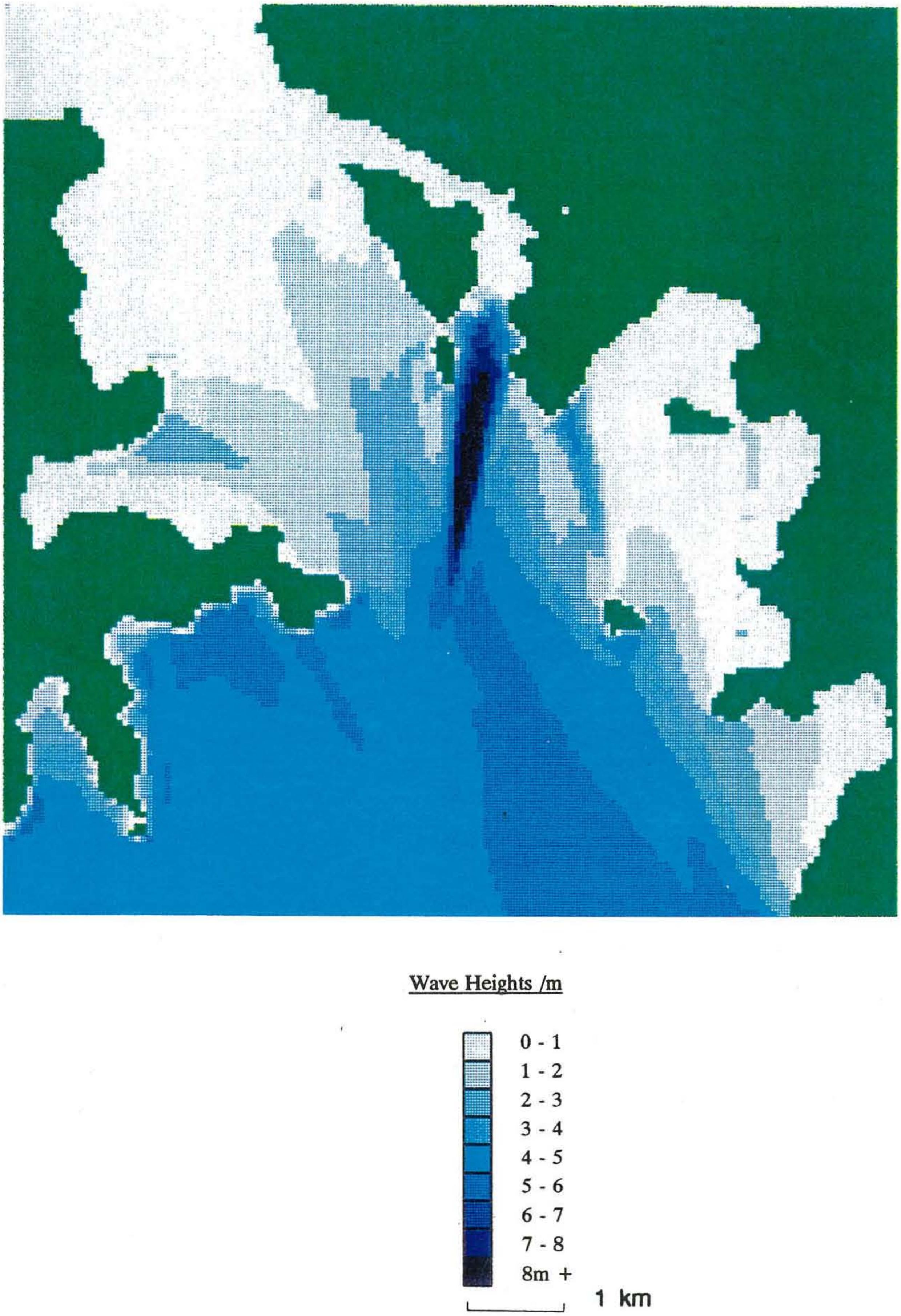


FIGURE 8.9 POST-DREDGING WAVE REGIME, ORIGINAL PIT SHAPE; 1 PER 50 YEAR EVENT, SWELL HEIGHT 5.0 M, FROM 120°, 13.7 S PERIOD

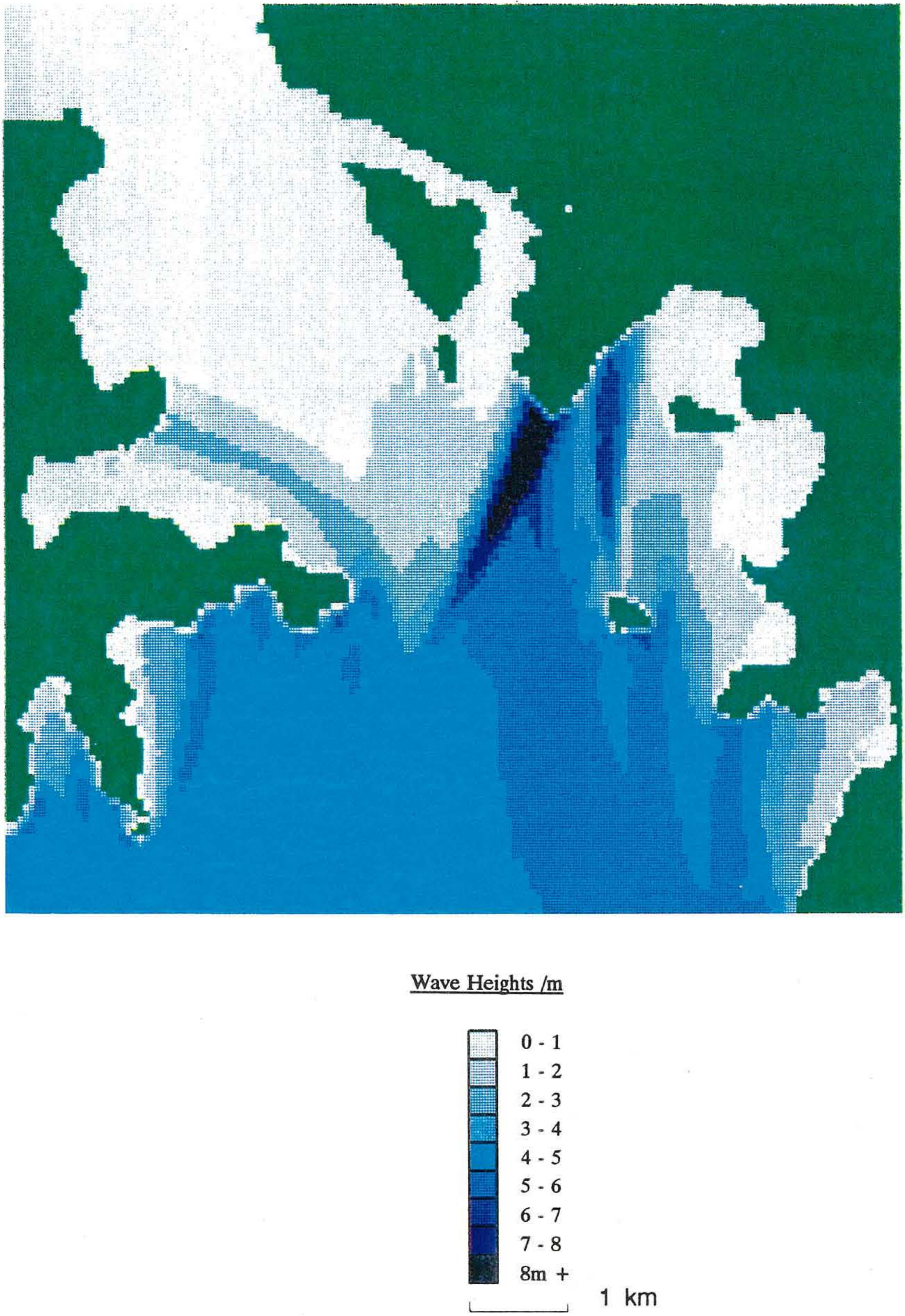


FIGURE 8.10 POST-DREDGING WAVE REGIME, ORIGINAL PIT SHAPE; 1 PER 50 YEAR EVENT, SWELL HEIGHT 5.0 M, FROM 150°, 13.7 S PERIOD

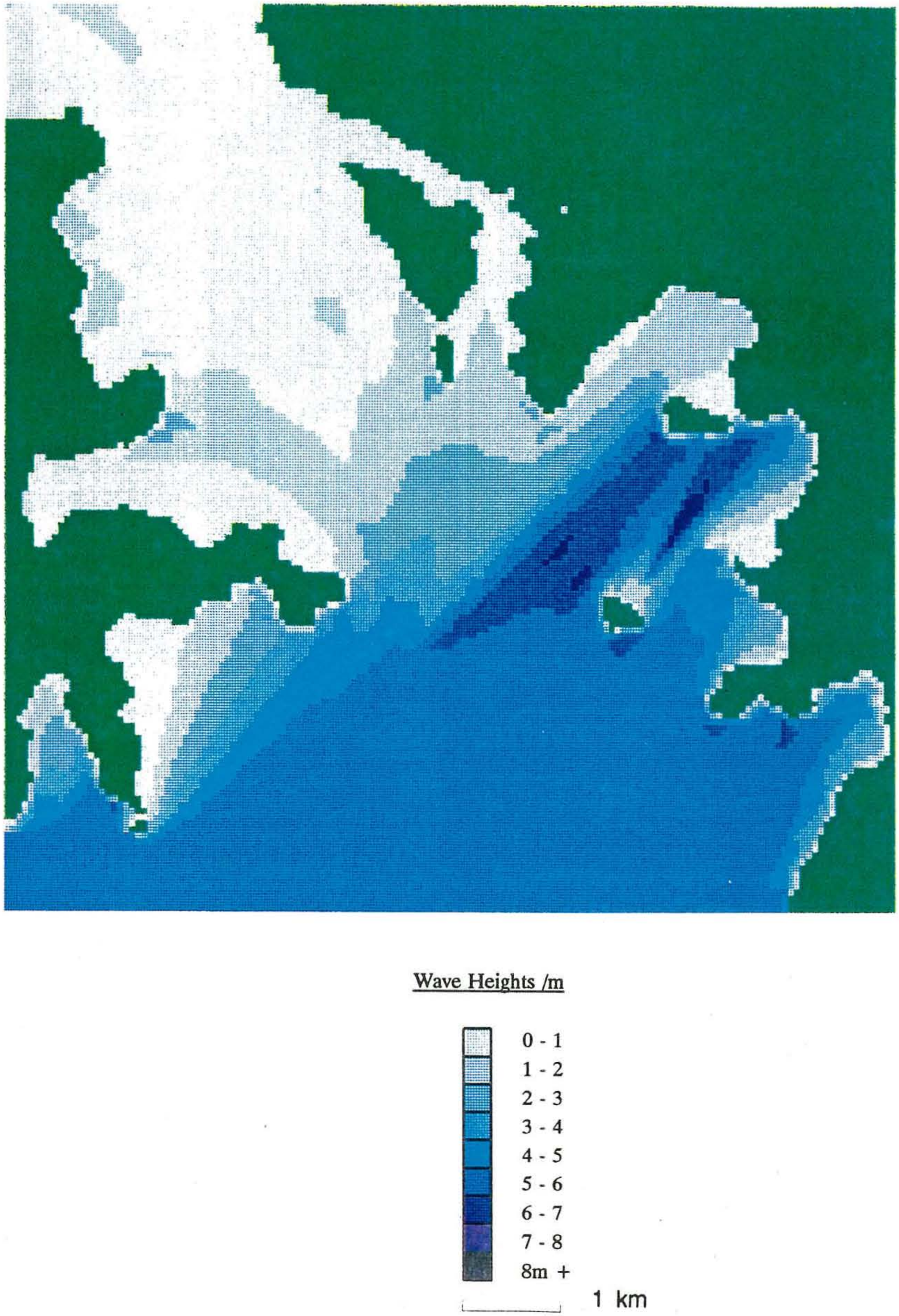


FIGURE 8.11 POST-DREDGING WAVE REGIME, ORIGINAL PIT SHAPE; 1 PER 50 YEAR EVENT, SWELL HEIGHT 5.0 M, FROM 180°, 13.7 S PERIOD

Table 8.2
Hong Kong Fill Management
Wave Modelling - WC2D model results.
Inshore waves of 5 m height, 13.7s period. (1 in 50 year typhoon.)

Wave heights in metres in sensitive areas.

	Aberdeen Harbour (next to island)		Sham Shui Kok (off headland)		Deep Water Bay (centre of bay)		Repulse Bay (centre of bay)		Luk Chan Tsuen (off headland)
	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Natural bathymetry (Case B)									
Max Height:- 6.98									
Wave Direction									
120°	3.60	3.20	2.00	1.60	.18	.18	.20	.16	2.50
150°	3.10	2.40	6.98	5.20	.30	.24	.50	.40	1.20
180°	.98	.90	3.26	3.00	2.30	2.20	1.20	1.00	.72
210°	.60	.50	1.50	1.00	1.00	.80	3.20	2.50	.50
Original pit shape (Case F)									
Volume of fill extracted approximately 79M m3									
Max height:- 10.04									
Wave Direction									
120°	8.00	6.00	4.16	1.80	.14	.10	.30	.20	3.10
150°	.70	.60	10.04	6.00	.32	.26	.52	.40	2.20
180°	1.26	1.00	2.30	1.90	1.50	1.32	4.80	4.00	1.62
Small pit shape (TS)									
Volume of fill extracted approximately 59M m3									
Max height:- 6.00									
Wave Direction									
120°	3.46	3.00	3.40	2.00	.12	.08	.44	.20	3.26
150°	3.40	2.80	6.00	5.00	.28	.24	.50	.46	2.36
180°	1.22	1.00	2.60	2.40	1.78	1.20	4.26	3.90	1.42
210°	.66	.44	1.50	1.20	1.00	.80	2.90	2.60	.70
Large, stepped pit shape (S)									
Volume of fill extracted approximately 73M m3									
Max height:- 8.00									
Wave Direction									
120°	6.08	5.40	3.20	2.00	.16	.12	.20	.16	2.48
150°	1.60	1.20	8.00	6.00	.30	.24	.50	.40	2.00
180°	1.60	1.20	2.62	2.50	1.50	1.20	4.00	2.00	1.44

The maximum height in a sensitive area is given for each pit shape.

Heights of up to 8m are reached for pit shapes S and TS, but occur off Ap Lei Pai Island with 120° inshore wave directions.

For Deep Water Bay and Repulse Bay the wave heights in the central area of the bay are shown. Larger wave heights could occur on one side of the bay if wave energy is being focused onto a headland - see the plots for details.

8.47 Wave studies to date, which have examined the effect of the proposed borrow pit configuration and depth, have indicated some potential beneficial impacts and some impacts which may give rise to concern.

8.48 a) East Lamma Channel main navigation lanes

The indications are that following dredging of the borrow pit, wave energy is likely to be directed more to either side of the East Lamma Channel, particularly to the Hong Kong Island side. This will result in somewhat lower wave heights in the main navigation lanes, and more significantly, less wave energy passing up the Channel into the Western Harbour. This will have a marginally beneficial effect on shipping and on port facilities at the proposed Lantau Port.

8.49 b) Mariculture and port facilities in Sok Kwu Wan

In general, the proposed borrow pit appears unlikely to affect the limited amount of wave energy reaching Sok Kwu Wan, which is well protected from swell from the open sea. Under extreme conditions, with swell from certain directions, there may be slightly more wave energy focused on Luk Chau Tsuen at the northern entrance to Sok Kwu Wan, increasing typical wave heights in the centre of the entrance of Sok Kwu Wan from about 0.70 to 1.40 m. Wave heights on the northern side of the bay increase more than those on the south side. This is unlikely to affect vessels at the cement jetty on the northern side of the bay but may adversely affect fish farms and mariculture in the area.

8.50 c) Ap Lei Chau and Ap Lei Pai

The proposed borrow pit appears unlikely to affect wave energy reaching Ap Lei Chau, but there is a tendency for the energy of longer waves to be focused somewhat more on Ap Lei Pai. Since Ap Lei Pai is a rocky islet, this is unlikely to be an issue.

8.51 d) Aberdeen Harbour and typhoon shelter

The wave studies indicate that under existing conditions, there is a tendency for wave energy under fairly extreme annual wave conditions (probably associated with a typhoon) and under less frequent extreme conditions to be focused on the southern approaches to Aberdeen Harbour. The borrow pit would aggravate these conditions, which might lead to damage to the typhoon shelter breakwater. Damage has already occurred to these breakwaters during the passage of Typhoon Ellen.

8.52 e) Sham Shui Kok

Due to the existing seabed bathymetry, there is a tendency for longer swell waves to be focused on Sham Shui Kok. Dredging of the borrow pit would aggravate these conditions, and during annual extreme wave conditions and during less frequent typhoon events. Since Sham Shui Kok is a predominantly rocky headland, the impacts would not constitute a serious issue. However, design wave conditions for nearshore structures such as the Ocean Park sea water intake may become more severe.

8.53 f) Deep Water Bay (Sham Shui Wan)

Here again, there is a tendency for longer swell waves to concentrate wave energy towards this Bay due to existing bathometry, when waves offshore approach from certain directions. The effect of the borrow pit will be to aggravate this focusing of wave energy. The main effect of this could be to draw down beach material during a typhoon if waves approach from the relevant direction offshore. Provided that the material was not drawn down too far, more normal swell conditions could be expected gradually to restore the beach.

8.54 g) Middle Island (Tong Po Chau)

The existing bathymetry, together with diffraction/refraction around Ngan Chau, some 2 km south of Middle Island, combine to focus the energy of longer swell on Middle Island under certain offshore directional conditions. The borrow pit appears to intensify this focusing, but the seaward side of the island, being rocky, would not be unduly affected.

8.55 d) Repulse Bay (Tsin Shui Wan)

Although existing bathymetry, combined with diffraction/refraction around Ngan Chau, can focus wave energy towards Repulse Bay (whose beach has recently been recharged), the wave studies indicate that for offshore wave directions to the west of south, this focusing could be intensified, with consequences similar to those discussed in f) above.

8.56 i) Other shore lengths

South of Repulse Bay, and south of Wong Chuk Kok on Lamma Island, the proposed borrow pit configuration would not affect the distribution of wave energy reaching these shores (e.g. Chung Hom Kok and St. Stephen's beaches).

8.57 It must be borne in mind that the probable environmental impacts discussed in a) to i) above are likely to be restricted to wave conditions recurring relatively infrequently, with return periods of the order of 5 or less times a year. The more severe impacts would only occur under relatively extreme typhoon conditions, with return periods of the order of 1 in 10 years or less frequently.

Modified Pit Shapes

8.58 Due to the considerable amount of wave focusing taking place with the original pit shape, BCL proposed modified pit shapes (shown on Figures 8.12 and 8.13) with the intention of reducing wave heights in sensitive areas.

8.59 Two new pit shapes were tested. The pit depth remains as before, at 60 m below PD, and the gradient of the side slopes was not changed.

Pit Shape S (Stepped)

8.60 The southern boundary of Pit S, (Figure 8.13), is stepped, but the pit is only slightly smaller than the original, extending just as far south. A similar amount of fill could be excavated as originally planned if this shape proved effective in preventing the focusing wave energy.

Pit Shape TS (Trimmed and Stepped)

8.61 Pit shape TS (Figure 8.12), is considerably smaller than the original one, with a substantial loss of fill. The southern boundary has been moved north of Wong Chuk Kok, to shelter it from waves from south-westerly directions which had previously been focused into Repulse Bay. The southern boundary of the pit is now stepped, with the intention of spreading waves refracted off it over a larger area.

Model Runs Carried Out on the New Pit Shapes

8.62 The design (1 in 50 year) wave conditions, from a range of directions, were modelled for both pits. These were the conditions that had caused focusing of wave energy with the original pit, and changes in the sea bed configuration would be most marked with these long period waves. The same wave and water level input data were used as before, enabling a direct comparison with previous runs (B1 - B4, F1 - F3) to be made (see Table 8.1).

Pit Shape TS

8.63 With pit shape TS, far less focusing of wave energy occurs than with the original pit. With waves from 120° (Figure 8.14) there is focusing onto Ap Lei Pai, with an increase of about 1 m in wave height. Elsewhere on the coast of Hong Kong Island reductions in wave height of this size could take place.

8.64 With waves from other directions (for example, see Fig 8.15) the degree of focusing is anticipated to decrease (as compared to the natural case) and the peak wave heights at many points on the coast should decrease slightly. However, the pit still causes rather more wave energy to be refracted clockwise towards Hong Kong Island than occurs at present. This moves to the south the positions where wave energy concentrations presently occur with the particular offshore wave directions used for the tests. However similar focusing would probably have occurred with the existing bathymetry if the offshore wave direction had been a few degrees more westerly.

Pit Shape S

8.65 Despite the changes in the shape of the southern edge of the pit, a large amount of wave energy focusing still occurs (Figure 8.16). The focusing is not as intense as with the original pit shape. Wave heights of over 6 m can occur during typhoon conditions in Aberdeen Harbour approaches and off Sham Shui Kok.

8.66 Wave heights in Sok Kwu Wan will increase, but only by a maximum of 80 cm at Luk Chau Tsuen.

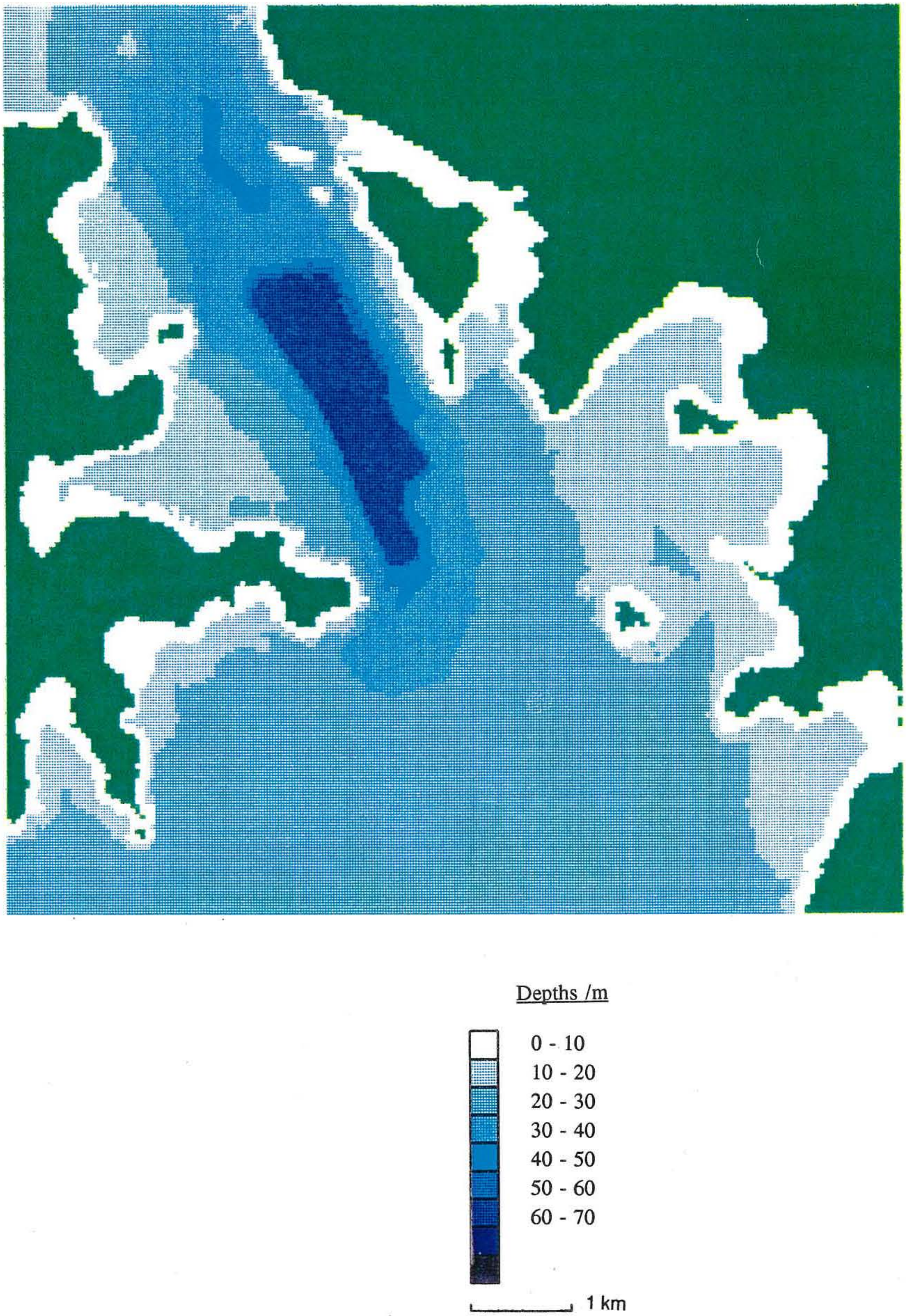


FIGURE 8.12 PIT SHAPE "TS"; TRIMMED AND STEPPED

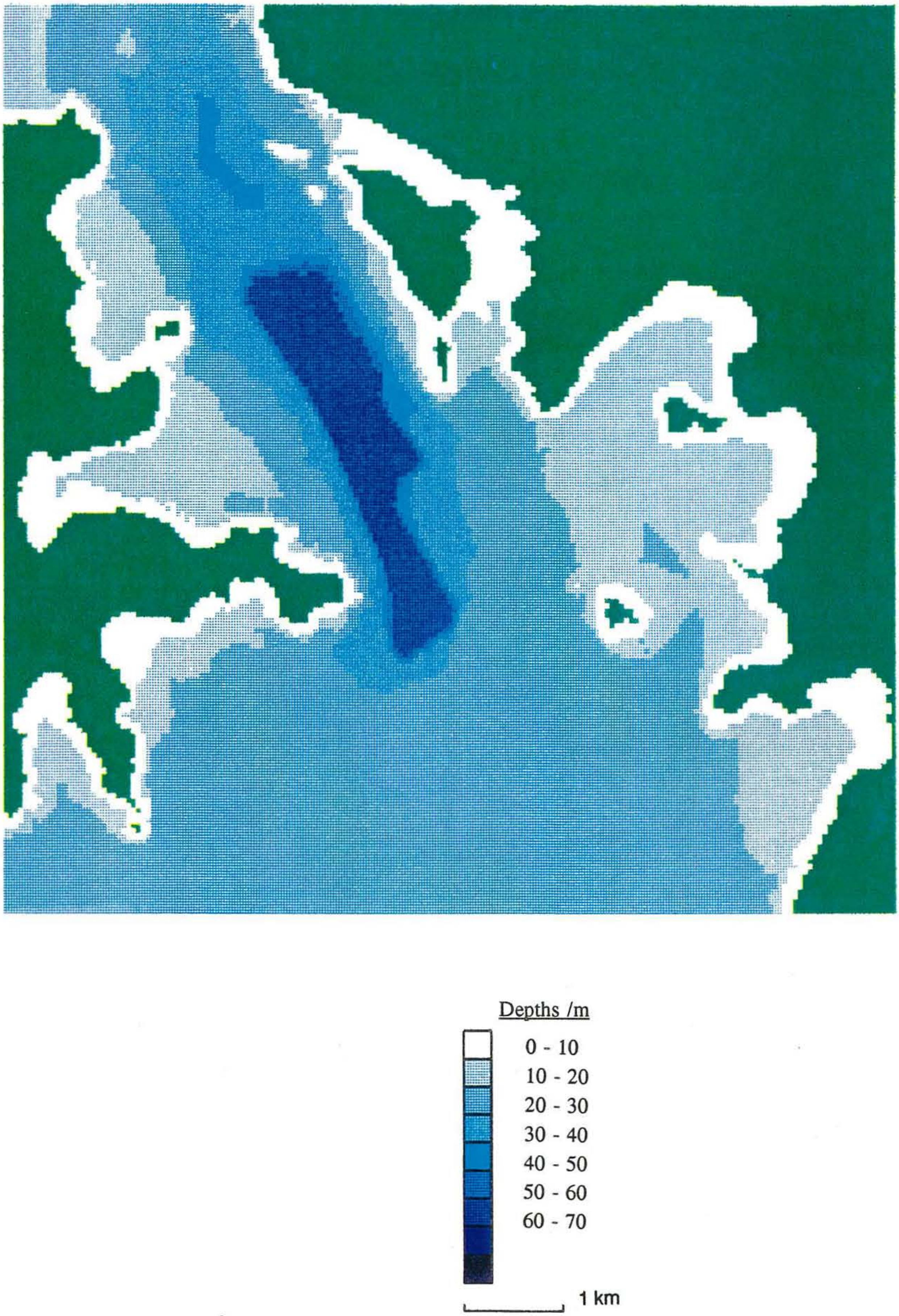


FIGURE 8.13 PIT SHAPE "S"; STEPPED

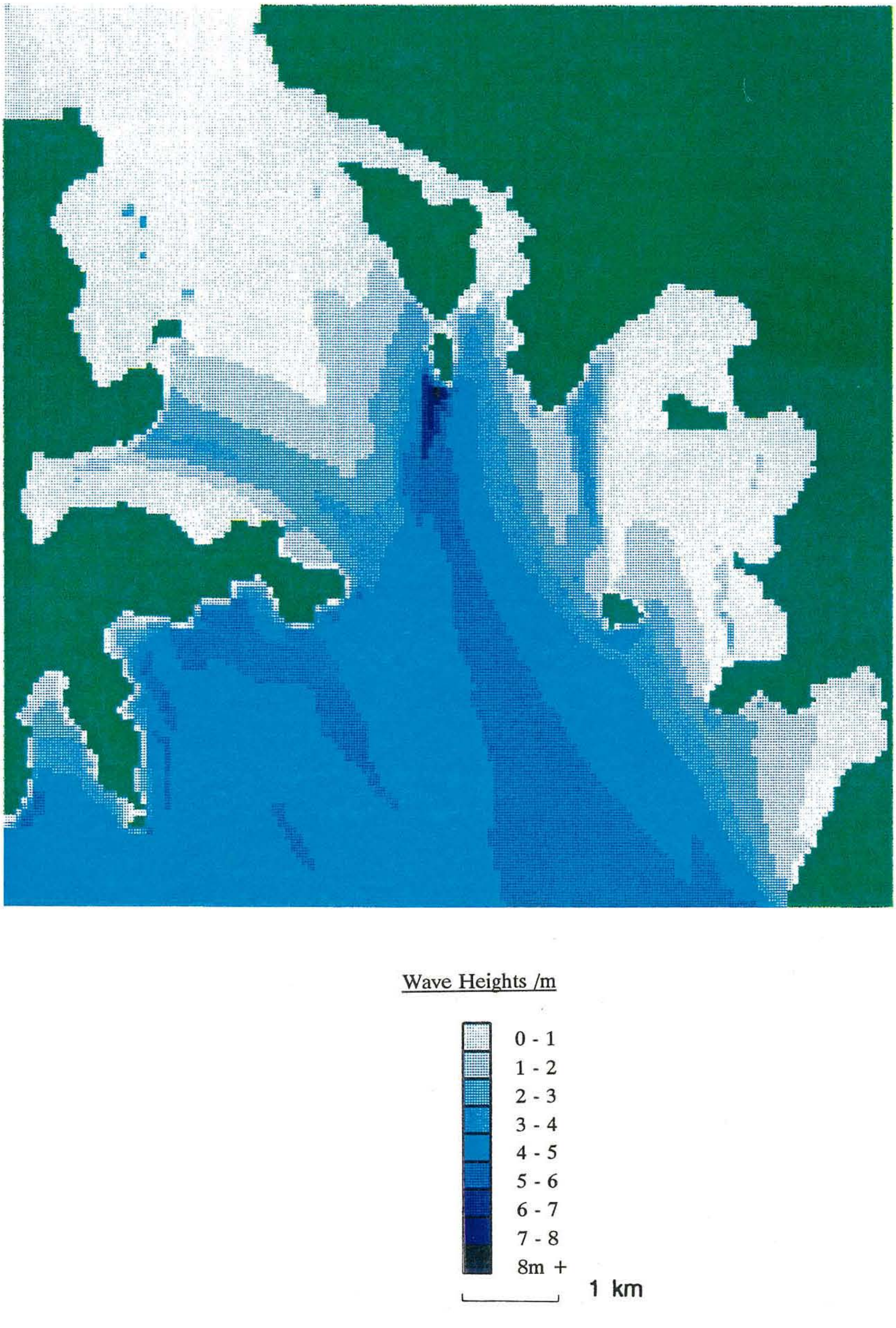


FIGURE 8.14 POST-DREDGING WAVE REGIME, PIT SHAPE "TS"; 1 PER 50 YEAR EVENT, SWELL HEIGHT 5.0 M, FROM 120°, 13.7 S PERIOD

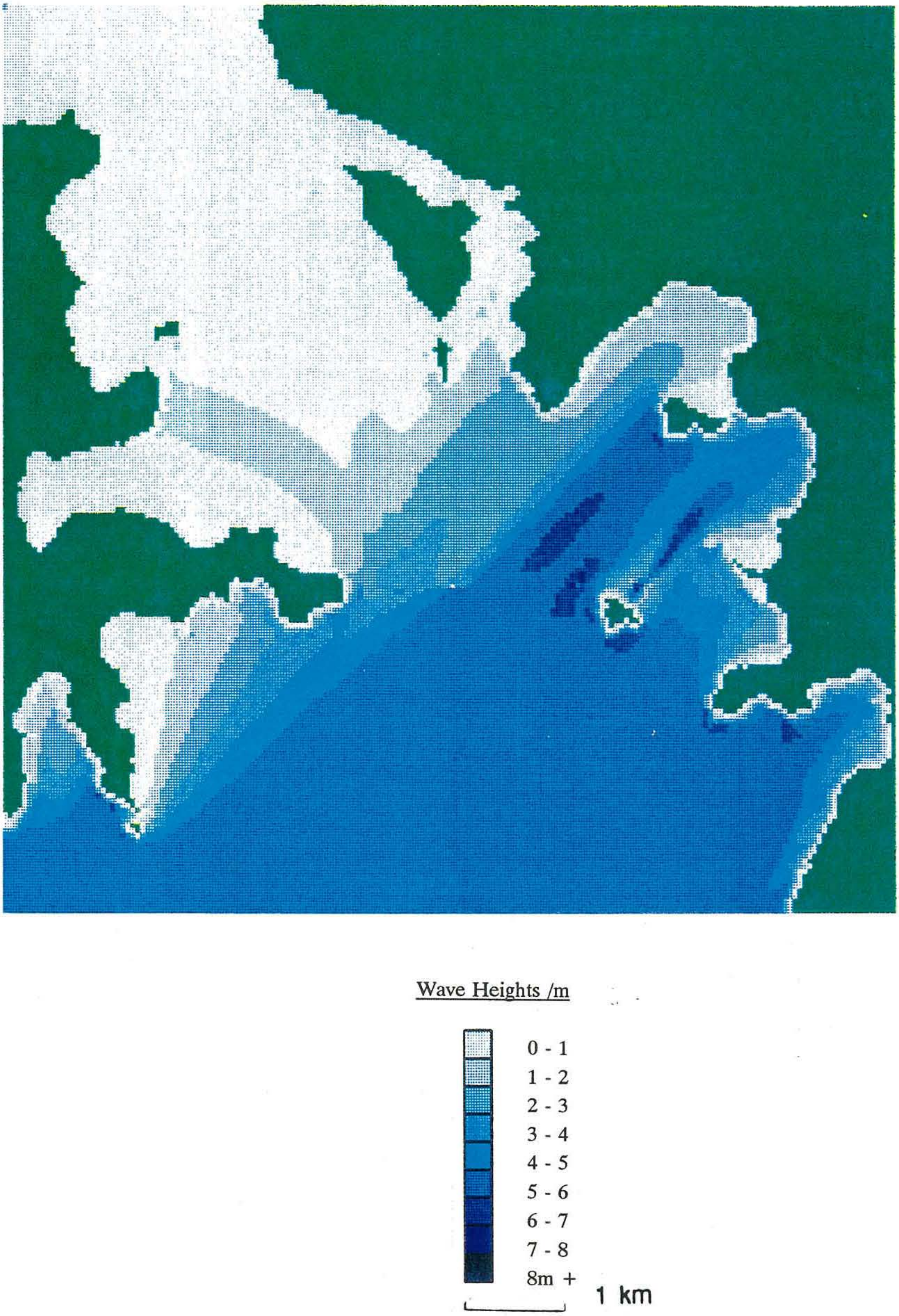


FIGURE 8.15 POST-DREDGING WAVE REGIME, PIT SHAPE "TS"; 1 PER 50 YEAR EVENT, SWELL HEIGHT 5.0 M, FROM 180°, 13.7 S PERIOD

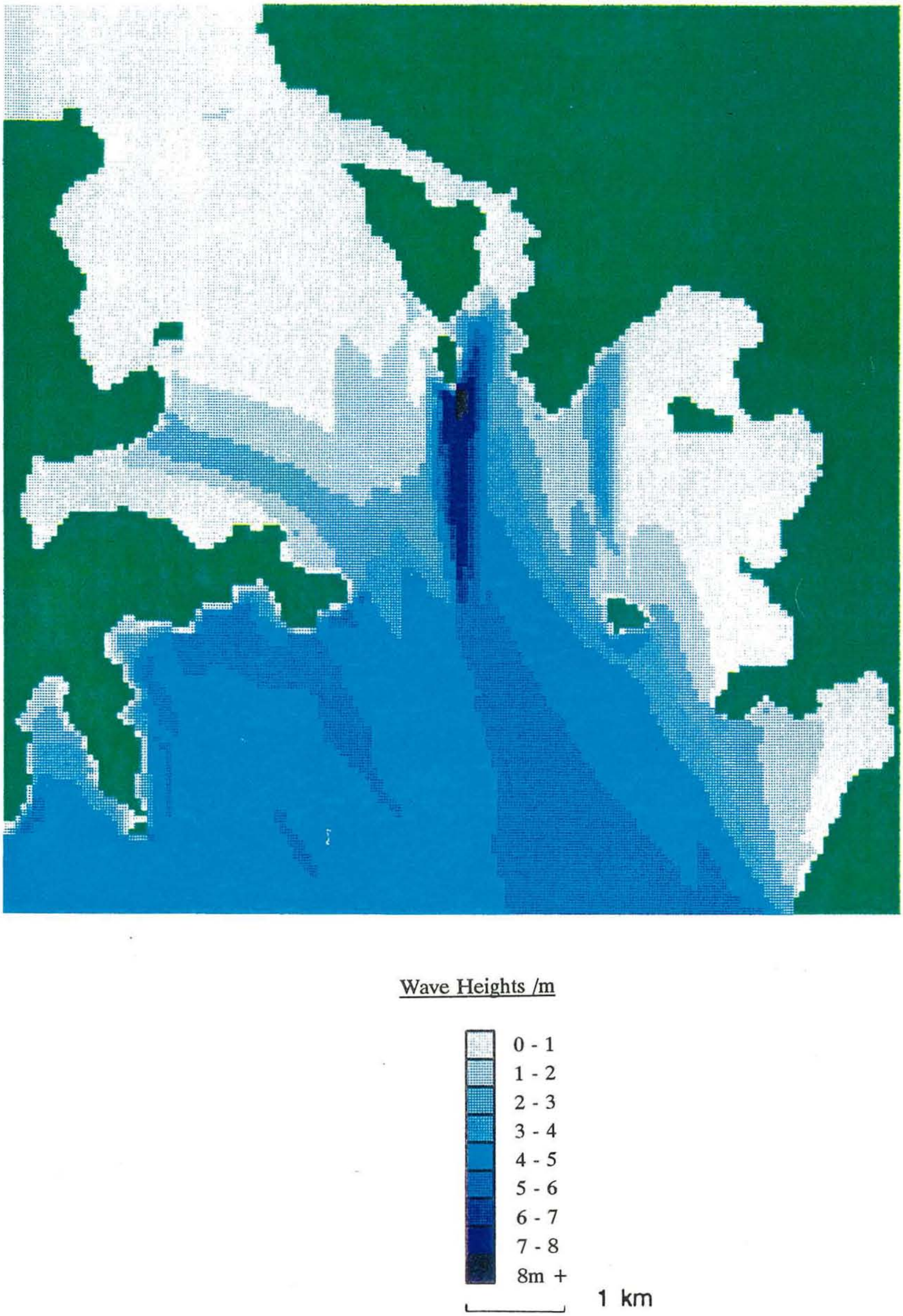


FIGURE 8.16 POST-DREDGING WAVE REGIME, PIT SHAPE "S"; 1 PER 50 YEAR EVENT, SWELL HEIGHT 5.0 M, FROM 120°, 13.7 S PERIOD

8.67 Although most waves pass over the southern boundary of the pit, many then hit the side slope and these are refracted back onto unaffected waves, resulting in focusing.

Conclusions of Wave Modelling

8.68 Table 8.2 compares wave heights for the various pit shapes and the natural sea bottom. It would appear that pits extending south of Wong Chuk Kok will cause considerable focusing of wave energy onto Hong Kong Island. This effect is still apparent even with the smaller pit shape (TS), but is mitigated by the fact that the wave energy has started to diverge before hitting the southern edge of the pit (Figure 8.17). Because only smaller waves reach the pit, less energy is focused by the pit and wave heights on the Hong Kong Island coast do not increase so much.

8.69 The smaller pit shape substantially reduces the amount of focusing of wave energy, and, for the directions studied, the wave heights in sensitive areas are similar to those occurring naturally. Pit shape S is only marginally better than the original pit shape and is therefore probably unacceptable.

8.70 The probable result of any excavation in the East Lamma Channel is to refract wave energy further around towards the coast of Hong Kong Island. A wave direction of 160° approaching the East Lamma Channel, after excavation, could produce a similar wave regime on the coast as that which occurred naturally with waves approaching from perhaps 170°. So long as the excavation does not cause more energy to be focused onto one point than would occur naturally from a different direction, the presence of the pit will not significantly change the long term wave climate on the coast.

8.71 It is understood that CED has carried out an independent check of the alternative pit designs.

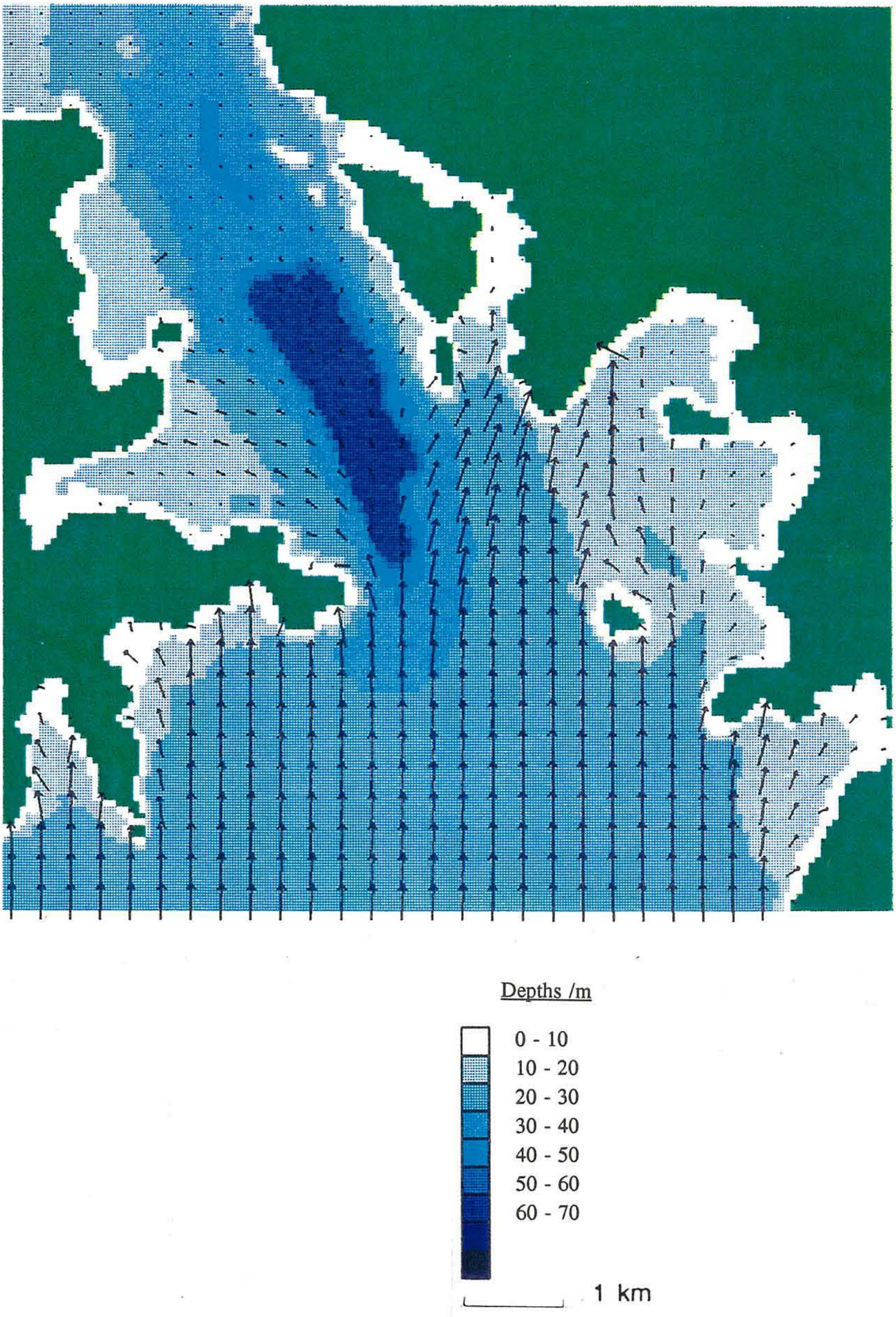


FIGURE 8.17 POST-DREDGING WAVE ORTHOGONALS, PIT SHAPE "TS"; 1 PER 50 YEAR EVENT, SWELL HEIGHT 5.0 M, FROM 150°, PERIOD 13.7 S

9 CONCLUSIONS

9.1 An assessment has been made of the potential environmental effects of developing a proposed borrow area located within East Lamma Channel (Government Notice No. 2480 in Gazette No. 30 19 July 1991).

Socio-economic and Environmental Importance of the Site

9.2 The 75 Mm^3 sand resource in East Lamma Channel contains approximately 6% fine sediment and is considered to be one of the cleanest in the Territory. Approximately four times less fine sediment would be discharged into the sea during dredging of East Lamma Channel than has been the case during dredging of other Hong Kong borrow areas.

9.3 The East Lamma Channel is an important shipping lane.

9.4 The East Lamma Channel, including the borrow area, serves as an inshore fishing ground that produces 540 tonnes of fish worth $6 million annually. This accounts for about 3% of all Hong Kong inshore fish catch, 9% of shrimp catch and 5% of squid catch. The area may be a spawning and nursery ground for some commercial species. Fish fry collecting zones along the channel supply Lamma Island fish farms.

9.5 Two mariculture zones located next to the Channel produce about 500 tonnes of fish worth about $30 million annually.

9.6 The marine life along the southwestern side of East Lamma Channel is diverse and abundant, particularly in soft corals, sea whips and fans below a depth of 15 m. Hard corals are abundant and diverse in shallow water along the east side of Lamma to the south of Wong Chuk Kok. Marine life including hard corals, is much less abundant along the northeastern side of East Lamma Channel.

9.7 Bathing beaches are found at Deep Water Bay and Repulse Bay to a lesser extent South Bay and Chung Hom Kok.

9.8 Proposed marine parks are located at Cape D'Aguilar and at Sham Wan on south Lamma Island. The beach at Sham Wan is believed to be a turtle nesting ground.

9.9 Seawater intakes along the southern Hong Kong Island coast provide air conditioner cooling water, flushing water and water for exhibits of marine life at Ocean Park.

Potential Impacts

9.10 A summary ranking of potential impacts of dredging is given in Table 9.1.

Seabed removal

9.11 The impact of seabed removal on water flow would be minor. The impact of the original borrow pit design on wave energy focusing would be significant; however, a redesign of the pit to a stepped and trimmed shape would eliminate this potential problem.

9.12 Seabed removal would not be expected to affect mariculture, but would preclude capture fisheries within the borrow area for the duration of the operation. Adult fish would be expected to migrate out of the affected area and would join nearby stocks; however, this could place them out of reach of inshore fishermen. Backfilling of the pit is unlikely, therefore upon completion of the project, the increased water depth inside the pit would permanently preclude some types of fishing activities, e.g. shrimp trawling, due to limitations of fishing gear. A new benthic community would be expected to colonize the pit within two to three years, but it is not known if it would support a commercial fisheries (due to the lack of data on deep water marine communities in Hong Kong).

Sedimentation

9.13 Increased suspended sediment would be expected to reduce the abundance of wild fish fry in fry collection zones off Lamma Island during the dredging operations and for about one year following project completion. Fish farmers would need to collect or buy additional fry from other areas during this period.

9.14 A stated above, removal of seabed is expected to preclude capture fisheries within the borrow area and cause the emigration of adult fish stocks. In addition, sedimentation would be expected to cause a moderate reduction in fish catch in an area circumscribed by a line 1 km outside the borrow area margin; however, the majority of these fish also would be expected to join depleted stocks in other areas. The newly enhanced stocks may be beyond the reach of coastal fishing craft.

9.15 Adult fish and fingerlings grown at the mariculture sites are not expected to be killed by acute exposure to sediment plumes generated at the borrow area during dredging. Infrequently (during severe storms), sediment generated during dredging and deposited over many months near mariculture zones, could be resuspended and could temporarily exceed the acute tolerance limit of some adult fish. The bulk of scientific data suggests that long term (chronic) exposure to levels below 80 mg/l would not increase disease susceptibility or decrease growth rates.

9.16 Visible sediment plumes that contain insufficient sediment to harm mariculture species would be expected to reach mariculture zones and could stimulate fishermen to make complaints.

9.17 Hard corals located near Wong Chuk Kok on Lamma Island would be expected to suffer up to a 25% loss of cover and some loss of diversity. Other sensitive marine organisms in the same area could be harmed. Low-lying patches of soft coral and sea fan communities located along East Lamma Channel would be buried by sediment and killed; most communities of these organisms are located in areas swept by strong currents and would not be damaged.

9.18 Neither of the SSSIs and proposed marine reserves in the area are expected to be damaged by the proposed dredging. Dredging is not expected to affect the turtle nesting ground at Sham Wan, Lamma Island.

9.19 Light brown or grey sediment plumes may be visible from the bathing beaches at Repulse Bay and Deep Water Bay during the summer months and could generate public complaints. The "seasonal split" mitigation measure could reduce the potential for this problem (see 9.23 below).

9.20 During the wet season, an increase of 15 mg/l above average background levels of suspended sediment concentrations would be expected regularly near the Ocean Park intake. During infrequent storms, increases above the 25 mg/l design specification for the Ocean Park seawater filter could occur, given appropriate weather conditions, but would not last for more than a single tidal cycle. An increase in the frequency of cleaning of the filtration system would prevent water quality problems within the facility, at an estimated cost of $100 per cleaning.

Noise

9.21 Noise levels created by the dredger are not expected to be significantly above background levels.

Marine Traffic

A significant increase in cross TSS traffic would be generated by trailer dredging. Mitigation measures have been proposed to provide an additional margin of safety for the operations.

Mitigation

9.22 A summary and ranking of the effectiveness of mitigation measures is given in Table 9.1. Many potential mitigation measures are impractical or would be unacceptable to Government or to Contractors.

9.23 The most effective mitigation measure would be to divide the borrow area in half and to dredge the two halves with respect to seasonal wind patterns. This mitigation measure would significantly reduce the chance of wind-driven sediment plumes reaching most sensitive receivers. This measure would not affect potential impacts to the hard coral and fry collection areas near Wong Chuk Kok and Sok Kwu Wan mariculture zone and would not reduce the potential impacts of tidal transport of sediment plumes.

9.24 A contractual Action Plan that provides for restricting the area of operation in response to specified exceedance levels in combination with an independent monitoring programme designed to rapidly determine the movement of sediment plumes towards sensitive receivers would lower the risk of environmental damage.

9.25 If the contract specifies that only one dredger is allowed to operate at a time, this would restrict potential impacts to those covered in this report. If more than one dredger is allowed to operate simultaneously, the potential impacts could be greater than those estimated here.

9.26 The indiscriminate use of ALMOB should be prohibited by contract specification.

9.27 Silt curtains are not feasible at the source and similarly are not likely to be a viable option for controlling the dispersion of sediment around the mariculture sites and at beaches affected by strong currents or waves.

9.28 A significant reduction in maritime and environmental risk could be achieved by establishing a Dredging Management Co-ordinator to work in close co-operation with Marine Department Vessel Traffic Centre (VTC).

TABLE 9.1 POTENTIAL EFFECTS OF DREDGING AND MITIGATION

Aspects of the Environment		Actions: Dredging Effects			Mitigation Measures				
		Sediment Plumes	Seabed Removal	Sediment Deposition	Dredging Co-ordinator	Silt Curtain	Seasonal Plan	Trimming Borrow Area	Trigger, Action Levels
Current flow		-	**	*	-	-	-	*	-
Wave regime		-	**	O*	-	-	-	***	-
Water quality	BOD	*	O	O	*	-	*	*	*
	Nutrients	*	O	O	*	-	*	*	*
	Heavy metals	*	O	O	*	-	*	*	*
Benthic verts	adults	*	**	**	***	-	O	*	***
	larvae	**	***	**	***	-	O	*	***
Benthic inverts	adults	**	**	**	***	-	O	*	***
	larvae	***	*	*	***	-	O	*	***
Pelagic verts	adults	*	*	*	*	-	O	*	*
	larvae	**	*	*	**	-	O	*	**
Pelagic inverts	adults	**	-	***	**	-	O	*	**
	larvae	***	-	***	***	-	O	*	***
SSSI/Marine Park		*	O	O	***	-	*	*	***
Capture fisheries	Fry	**	**	*	***	-	***	*	***
	Adult	*	***	*	**	-	*	*	**
Mariculture	Lo Tik Wan	**	O	*	***	-	***	*	***
	So Kwu Wan	*	O	*	***	-	*	*	***
Marine traffic		-	-	-	***	-	*	*	-
Anchorages		O	O	O	***	-	-	*	-
Recreation (beaches etc)		**	*	*	***	*	***	*	***
Noise		-	*	-	*	-	*	*	-
Visual aesthetics		**	O	O	***	*	***	*	**
Seawater intakes		**	O	*	***	***	***	*	***

No effect O   Minimal Effect *   Moderate Effect **   Strong Effect ***   Not applicable -

Postscript

9.29 This report has been prepared under the auspices of the Environmental Studies Management Group (ESMG). During the course of meetings with ESMG, some members expressed their views that the potential effects of sediment plumes would be greater than estimates made in this report.

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11 APPENDICES

APPENDIX A
DIVE RECORDS - LAMMA CHANNEL

Dive 1: Lamma Island--NE side Luk Chau (George's island)

Date	: 23rd April 1992
Time	: 11:00 pm - 11:30 pm
Underwater visibility	: 0.5 m
Max Depth	: 25 m

General

Steep slope boulder and sand. Little marine life until reaching 15 m, then profuse diversity of non-reef building corals, soft corals, sea fans and whips. Boulders and sand/silt bottom (Figure A.1).

Zones and Organisms

0-15 m Bare boulders--barnacles, mussels, oysters, urchins, coralline algae.

16-25 m Highest diversity of soft corals and gorgonians in Hong Kong as well as high abundance.

Dive 2: Lamma Island--Channel side Wong Chuk Kok (NE tip Lamma)

Date	: 23rd April 1992
Time	: 12:00 pm - 12:30 pm
Underwater visibility	: 0.5 m
Max Depth	: 6 m
Photos	

General

Semi-exposed zone with boulders and sand, patches of hard coral.

Zones and Organisms

0-5 m Bare boulders--barnacles, mussels, oysters, urchins, coralline algae. Coarse sand.

6 m Few gorgonians and sea cucumbers.

Dive 3: Lamma Island--East side Wong Chuk Kok (NE tip Lamma)

Date	: 23rd April 1992
Time	: 2:30 pm - 3:00 pm
Underwater visibility	: 2 m
Max Depth	: 16 m
Photos	

General

Exposed zone with boulders and sand, numerous encrusting hard corals (Figure A.2).

Zones and Organisms

0-5 m	Bare boulders--barnacles, mussels, oysters, urchins, coralline algae. Coarse sand.
6-10 m	Huge boulders and many caves with sweepers, apogonids. Numerous hard corals--encrusting faviids. Few gorgonians and sea cucumbers, urchins.
10-16 m	Silt cover of 0.5 cm on bottom over sand. Some soft corals and gorgonians.

Dive 4: Ngan Chau (Round Island)--off Chung Hom Wan, S Hong Kong

Date : 24th April 1992

Conditions :

Wind	: 5-10 knots NE
Swell	: 0 m
Current	: 1 knot
Tides	: 1:34 pm 1.9 10:55 pm 0.9
Time	: 10:00 - 11:00 am
Underwater visibility	: 5 m
Max Depth	: 20 m
Photos	

General

Marine life shows moderate diversity above 10 m depth, with a high diversity and cover of gorgonians below this depth and increasing to 20 m (Figures A.3 and A.4). Few hard corals, fish abundant. Silt layer below 10 m.

Zones and Organisms

0-5 m	Large boulders--barnacles, mussels, oysters.
6-15 m	Large boulders--small anemones, gastropods, sparse hard corals, coralline algae.
16-20 m	Large boulders tumbled from above, about 2.5 cm of light silt lying on sand at slope base. Very high diversity of non-reef building corals and gorgonians, some soft corals. Three species of Tubastrea. Barnacles, holothurians, some Diadema. Schools of Chromis, scad and individual large apogonids. Two colonies of Dendrophyllia (30 cm) under rock.

Dive 5: Chung Hom Kok (Kok = Cape), South Hong Kong

Date	: 24th April 1992
Conditions :	
Wind	: 5-10 knots NE
Swell	: 0 m
Current	: 1 knot
Tides	: 1:34 pm 1.9 10:55 pm 0.9
Time	: 11:30 - 12:30 am
Underwater visibility	: 3 m
Max Depth	: 16 m
Photos	

General

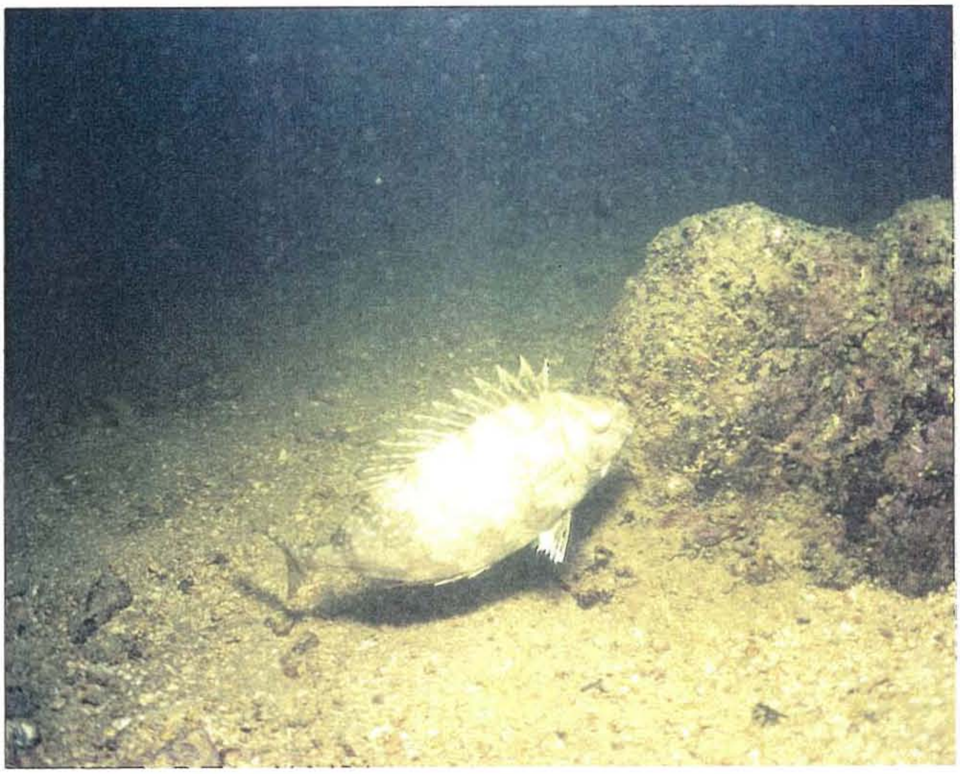
Benthic diversity increases moving from inside Chong Hom Wan out into Lamma Channel. Marine life shows moderate diversity between 5 and 10 m depth, with a high diversity and cover of gorgonians below this depth and increasing to 16m. Few hard corals, fish abundant. Silt/sand bottom below 10 m. Many oysters have been collected from this area leaving white scars.

Zones and Organisms

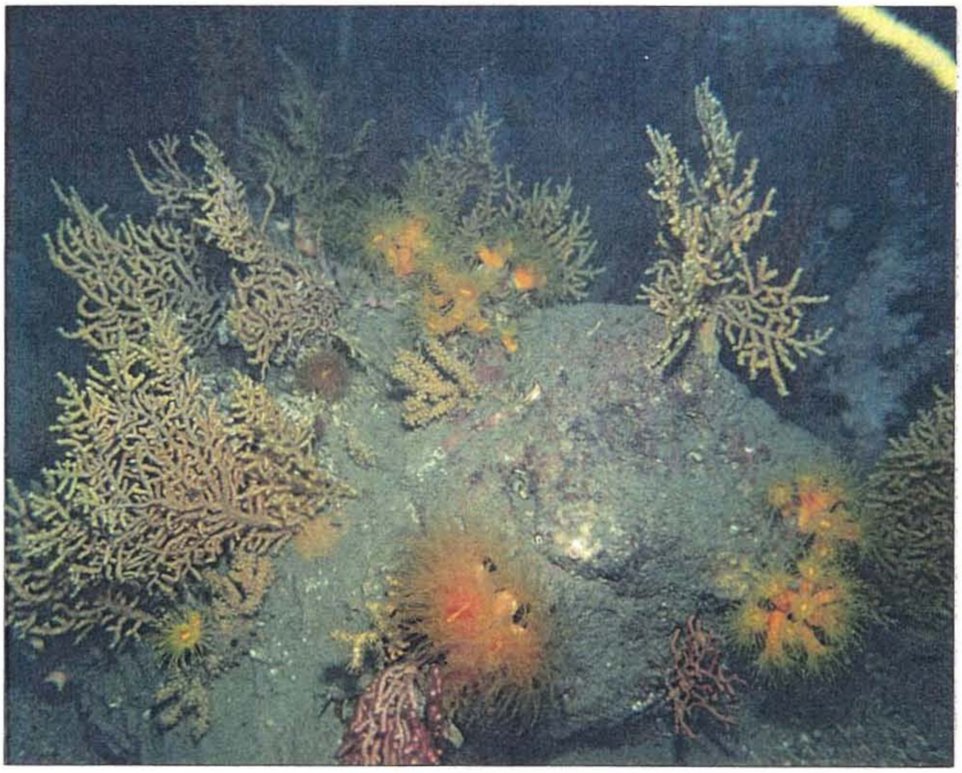
0-5 m Vertical wall--barnacles, mussels, oysters.

6-10 m Wall and boulders--very little growth--sparse anemones, gastropods, hard corals, coralline algae, urchins.

11-16 m Inside Chong Hom Wan, flat silt/sand bottom. Meiofauna but little visible. Around point out towards the channel, increasing numbers of gorgonians and some soft corals, but not as abundant as at Ngan Chau. Schools of grunt 30 cm long, Chromis, and rabbit fish (siganids) 20 cm long. Silt/sand bottom gentle slope.

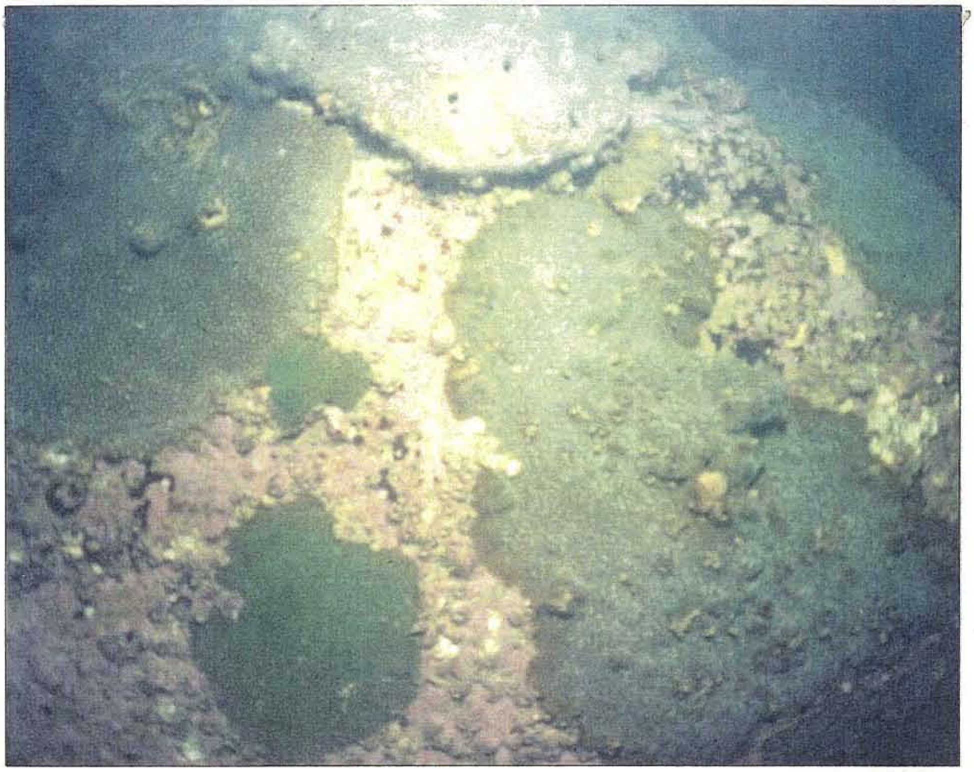


a) SAND BOTTOM WITH RABBITFISH (DEPTH 5 M)

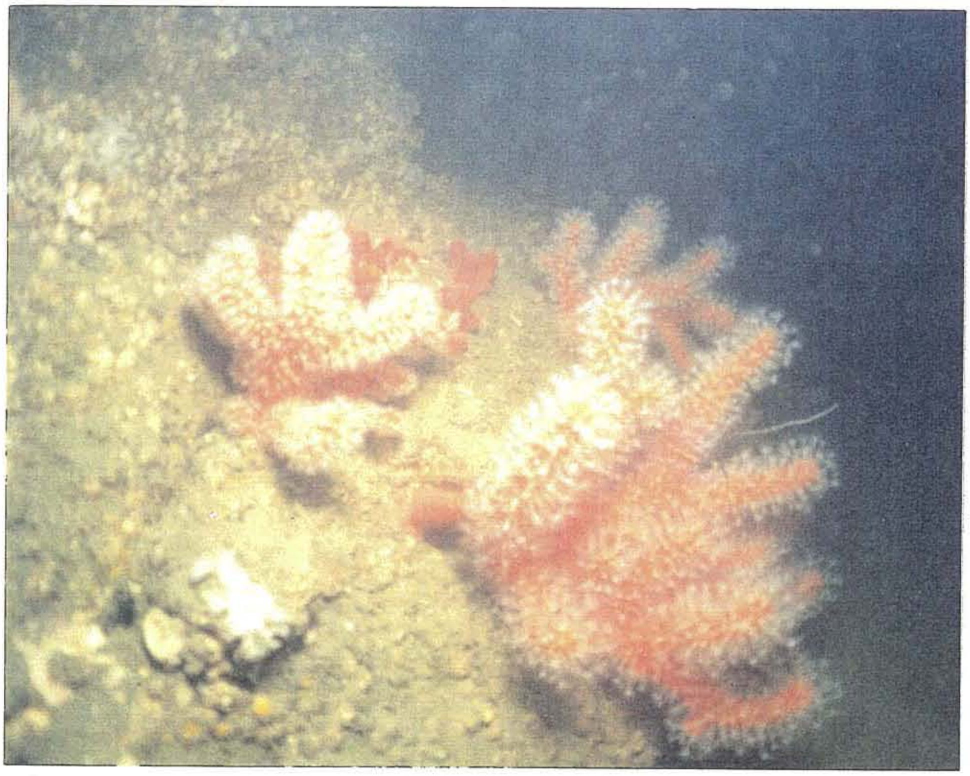


b) SEA FAN GARDEN (DEPTH 20 M)

FIGURE A.1 LUK CHAU

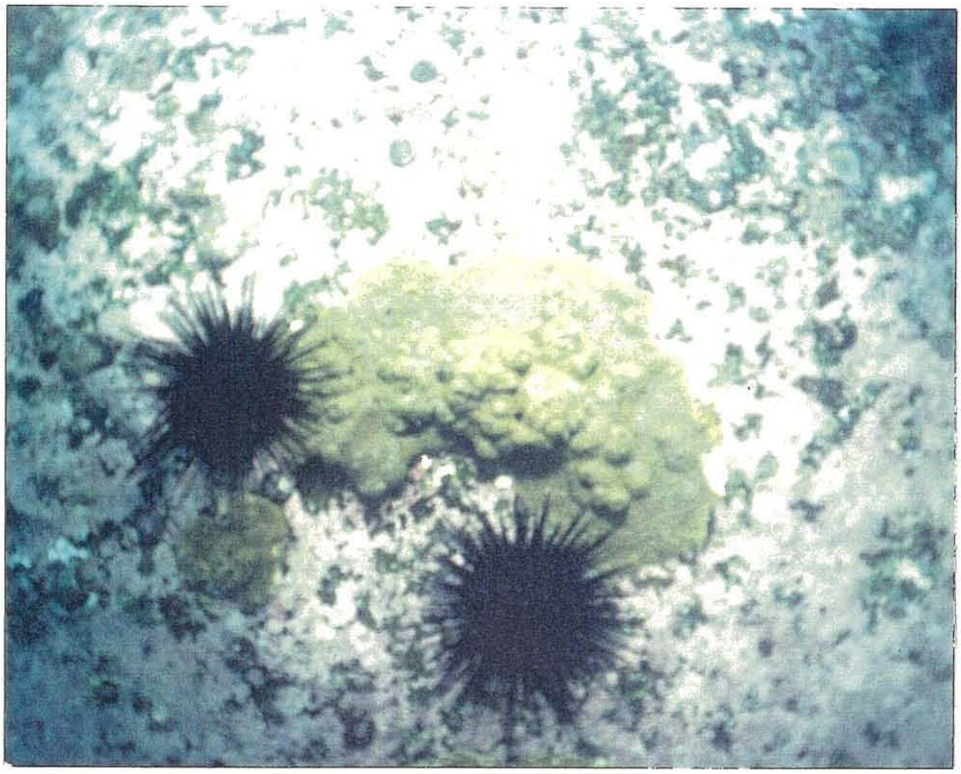


a) HARD CORALS (DEPTH 5 M)

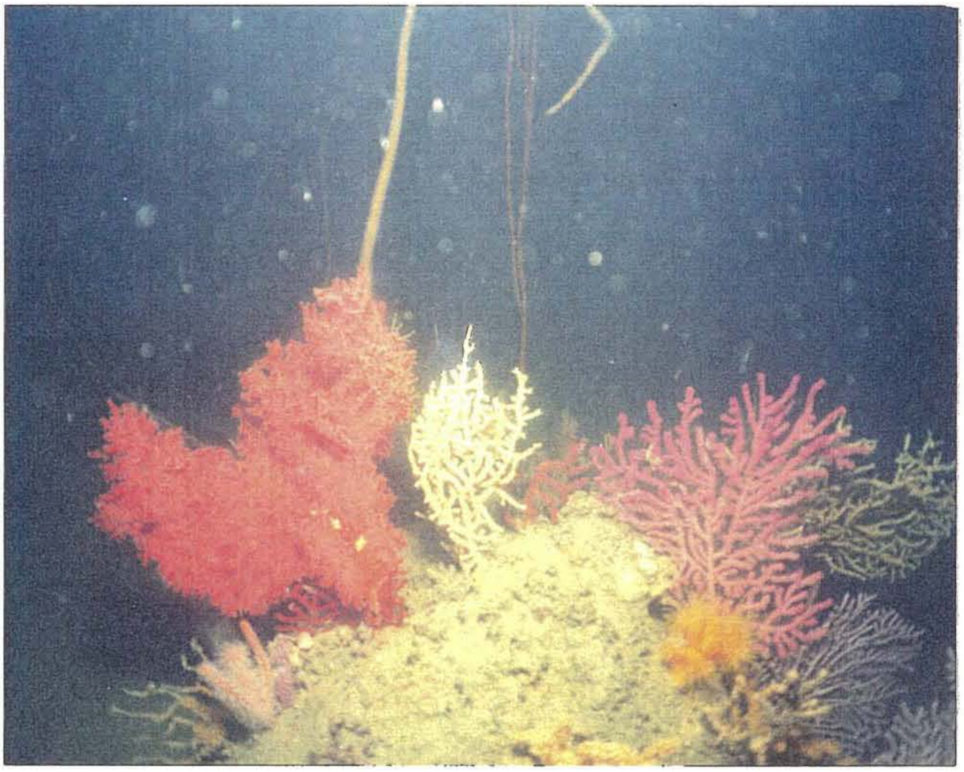


b) SOFT CORALS (DEPTH 18 M)

FIGURE A.2 WONG CHUK KOK

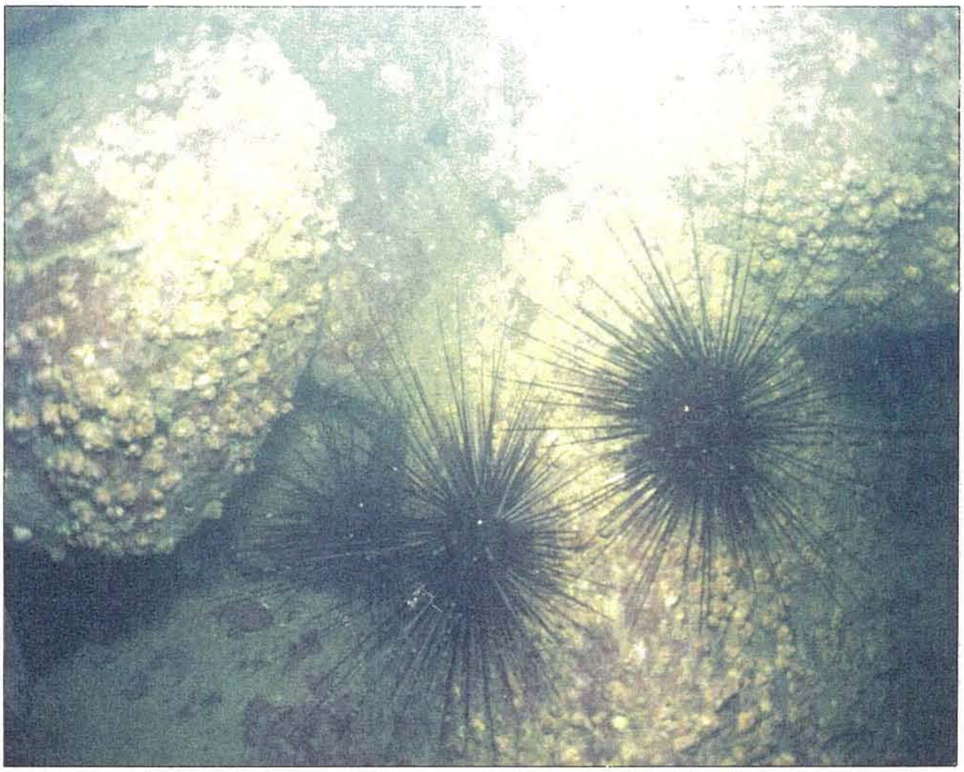


a) HARD CORAL WITH SEA URCHINS (5 M)

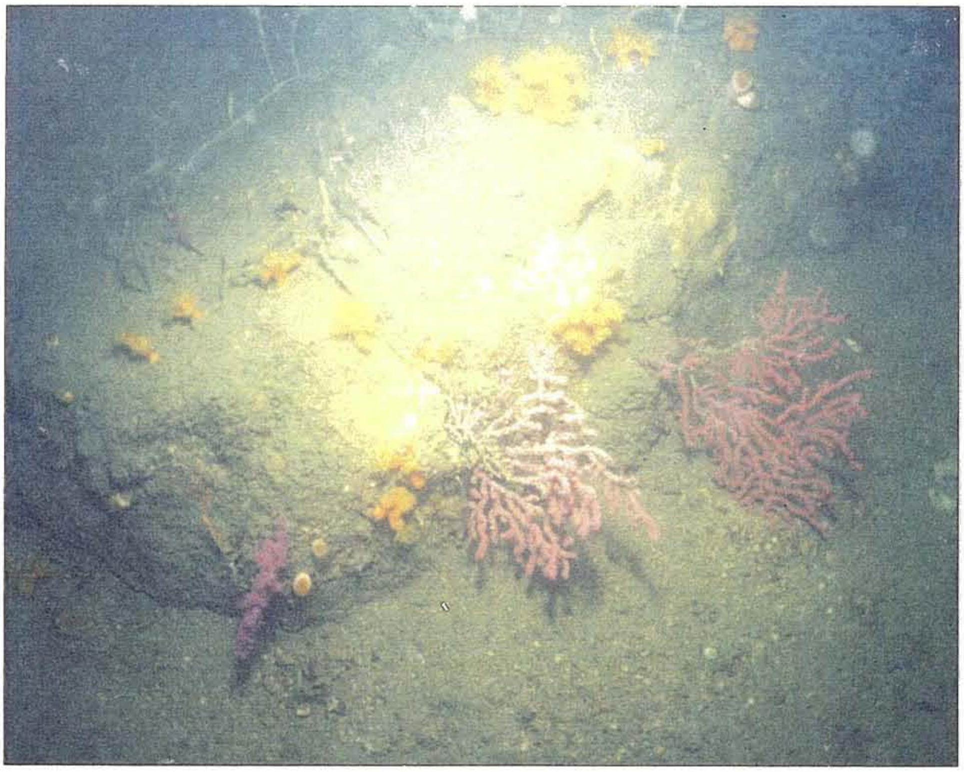


b) SEA FANS (20 M)

FIGURE A.3 ROUND ISLAND



a) BARNACLES AND URCHINS ON ROCK (5 M)



b) SEA FANS AND SMALL CORALS (15 M)

FIGURE A.4 CHUNG HOM KOK

APPENDIX B

NOISE IMPACT ASSESSMENT

As recommended in the East Lamma Channel Borrow Area Assessment Report, the preferred method of extraction and transportation of sand from the borrow area is by large trailing suction hopper dredgers (trailers). In order to ensure safe shipping in the Traffic Separation Scheme (TSS) on East Lamma Channel, Marine Department requires that only one trailer dredger may work within the TSS at any time. The noise generated from the operation of the trailer dredger will be the dominant source of noise in the proposed dredging operation.

Noise Sensitive Receivers (NSR)

An initial calculation was made to establish the 30 dB(A) envelope resulting from the proposed dredging operation. Urban premises within this envelope and rural settlements facing the borrow area were examined for identification of NSRs.

Figure B-1 illustrates the location of the proposed borrow pit which lies along the length of East Lamma Channel between Luk Chau and Wong Chuk Kok of Lamma Island. Villages (Lo Tik Wan, Luk Chau Tsuen, So Kwu Wan and Mo Tat Wan) on the northeast coast of Lamma Island are considered NSRs.

The high rise residential blocks of Lei Tung Estate on Ap Lei Chau facing the East Lamma Channel and the Ap Lei Chau Kai Fong Primary School adjacent to Lei Tung Estate are also considered as NSRs. Tung Yip House is closest to the edge of the proposed borrow pit and was chosen as the background noise measurement station. The primary school is considered to be affected during daytime only.

A phased housing development (South Horizon) is in progress at the western tip of Ap Lei Chau. Phases I and II (18 blocks) of the development were completed and occupation was started in mid 1991. Phases III and IV (16 blocks) of the development are under construction at the time of writing this report (July 1992). The site is also considered a NSR. Blocks in the Phase III construction site were considered most exposed with respect to the proposed borrow pit and a background noise measurement station was chosen in the area.

Oil storage tanks, a sewage treatment plant and an industrial area are located along the south coast of Ap Lei Chau. There are no domestic premises in this area.

Residential areas on the north side of Ap Lei Chau and at Aberdeen are shielded from the proposed borrow area by the topography.

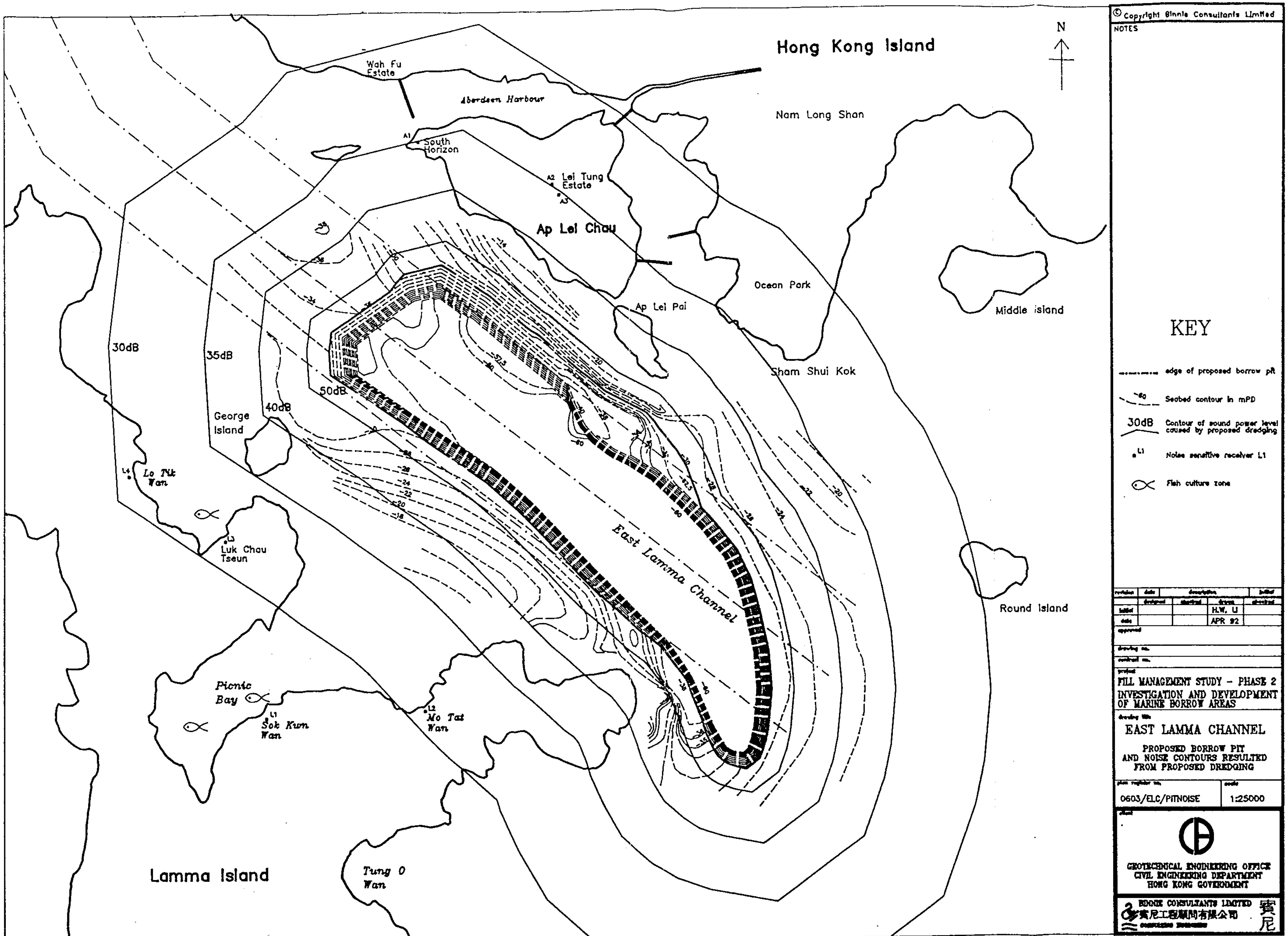


FIGURE B.1 NOISE CONTOURS

Background Noise Measurement

Background noise measurements were carried out during the day (0700 hrs to 1900 hrs) at all NSRs identified above, except Lo Tik Wan, to establish the basis for assessing the impact of noise generated from the proposed works. It was not possible to cover the four NSRs on Lamma Island on foot in one day. Sound levels at Lo Tik Wan are assumed to be similar to those at Luk Chau Tsuen.

Night-time (2300 hrs to 0700 hrs) measurements were also taken at stations at Lei Tung Estate and South Horizon at Ap Lei Chau.

Night-time measurements were not taken at stations on Lamma Island after considering the relatively high daytime noise level recorded and the considerable distance from the edge of the proposed borrow pit (over 1 km). It should also be noted that night-time visits for noise measurement at villages on Lamma Island would invite continuous dog barking which would render the readings unrepresentative. In the absence of a true receiver, a measuring point was chosen on the southern coastal slope of Ap Lei Chau facing the proposed borrow area. The night-time background noise level reading taken at this point is assumed to be similar to that on the East coast of Lamma Island. Subsequent calculation has shown that the villages on Lamma are only likely to be subject to a very small increase in noise level as a result of the proposed dredging.

The measurements were carried out using a calibrated Rion NL-11 sound level meter mounted 1 m above the ground on tripod. Average 'A'-weighted sound pressure level over 30 minutes was obtained at each station. Occasional high noise levels such as the passage of trucks and motor boats and dog barking were noted to obtain a comprehensive picture of the make up of the measured noise levels. The results are summarised in Table 1 below.

TABLE 1 BACKGROUND NOISE LEVEL

Noise Sensitive Receiver		Background Noise Level Leq_{30} dB(A)		Remarks
		Day-Time	Night-Time	
A1	South Horizon*	68.6	52.0	Construction works in progress during day-time, occasional motor boat passings during night-time
A2	Tung Yip House, Lei Tung Estate	60.4	46.0	
A3	Ap Lei Chau Kai Fong Primary School	61.0	-	
L1	So Kwu Wan	59.8	44.0#	Continuous waves and occasional dog's barks during day-time
L2	Mo Tat Wan	52.6	44.0#	
L3	Luk Chau Tsuen	54.0	44.0#	
L4	Lo Tik Wan**	54.0	44.0#	

N.B. * *Phase III site of South Horizon is not accessible during day-time due to the on-going construction activities, day-time measurement taken at Hoi Ling Court, Phase III of South Horizon*

** *Assume similar to Luk Chau Tsuen (L3)*

Assume similar to measurement taken on a platform on southern slopes on Ap Lei Chau facing East Lamma Channel

Predicted Noise Level for Dredging

Trailer dredgers, with the pumps and other equipment housed in the hull, are considered one of the quieter types of dredger. Sound power level measurement was carried out for the trailer dredger (Wiesbaden) used in the Tin Shui Wai Development Land Formation Contract and an 'A'-weighted sound power level (L_{wA}) of 102 dB(A) was reported (Wimpey Lab. Limited, 1988). This value is taken as representative and used as the sound power level of the noise source for the purpose of this assessment.

The maximum sound pressure level at the NSRs can be calculated as follows:

$$L_{PA} = L_{WA} - 20 \log d - 8 \text{ dB(A)}$$

where d is the closest distance of dredger to NSR in m.

The result of the calculation is summarised in Table 2. A noise contour map is also prepared (see Figure 1) to show the maximum predicted sound pressure level in the area resulting from the proposed dredging.

TABLE 2 MAXIMUM PREDICTED NOISE LEVELS

Noise Sensitive Receiver		Acceptable Noise Levels ANL dB(A)	Background Noise Level Leq_{30}, dB(A)	Maximum Predicted Noise Level due to Dredging L_{PA} dB(A)	Resultant Noise Level Leq dB(A)	Increase Over Background dB(A)
South Horizon	day night	65 50	68.6 52.0	34.5 35.2	68.6 52.1	0.0 0.1
Lei Tung Estate	day night	65 50	60.4 46.0	34.9 34.9	60.4 46.3	0.0 0.3
Kai Fong P. School	day	65	61.0	36.5	61.0	0.0
So Kwu Wan	day night	60 45	59.8 44.0*	25.6	60.0 44.1	0.0 0.1
Mo Tat Wan	day night	60 45	52.6 44.0*	31.2	52.6 44.2	0.0 0.2
Luk Chau Wan	day night	60 45	54.0 44.0*	30.6	54.0 44.2	0.0 0.2
Lo Tik Wan	day night	60 45	54.0* 44.0*	29.9	54.0 44.2	0.0 0.2

* assumed values

Assessment of Noise Impact

The predicted sound pressure levels at each NSR due to the proposed dredging operation are much less than the recorded background noise levels. The resultant noise levels are only marginally higher than the background noise levels at these NSR sites. The potential noise impact on sensitive receivers due to the proposed dredging in East Lamma Channel is therefore considered insignificant.

The dredging is likely to be carried out on a 24 hours basis. The Contractor working in the borrow area will be required to obtain a Construction Noise Permit (CNP) under the Noise Control Ordinance (Cap 400) for working at night time hours of the weekdays and any time on general holidays (including Sundays). The acceptable noise levels (ANL) for the NSRs obtained in accordance with the Technical Memorandum on Noise from Construction Work Other Than Percussive Piling are also listed in Table 2. The noise levels at respective NSRs generated by the trailer dredger are lower than the corresponding ANLs by a margin of more than 5 dB and should therefore qualify for a CNP. Also, noise created by trailer dredgers fall below limits noted in Clause 4.2.13 of the Environmental Guidelines for Planning in Hong Kong (EPD, 1991) and as such do not present a noise problem which requires mitigatory measures.

APPENDIX C

DESCRIPTION OF THE SEDIMENT MODEL

The governing equations used in sediment transport model can be written as follows:

Surface Layer

$$\frac{\partial dc}{\partial t} + \frac{\partial udc}{\partial x} + \frac{\partial vdc}{\partial y} - (w - w_s)\ \bar{c} - \frac{\partial}{\partial_s}\left(D_s d\ \frac{\partial c}{\partial_s}\right)$$

$$-\frac{\partial}{\partial n}\left(D_n d\ \frac{\partial c}{\partial n}\right) + l_c\ l_m \left| \frac{\partial \sqrt{(u^2 + v^2)}}{\partial z} \right| \frac{\partial c}{\partial z} = 0$$

Bed Layer

$$\frac{\partial z_B c}{\partial t} + \frac{\partial u z_B c}{\partial x} + \frac{\partial v z_B c}{\partial y} + (w - w_s)\ \bar{c} - \frac{\partial}{\partial S}\left(D_s z_B\ \frac{\partial c}{\partial S}\right)$$

where

d	=	surface layer depth (m)
z_B	=	bed layer depth (m)
u,v	=	x,y - direction velocities (m/s)
W	=	the vertical velocity at the layer interface (m/s)
t	=	time
s,n	=	intrinsic co-ordinates
D_s	=	longitudinal dispersion coefficient (m^2/s)
D_n	=	lateral diffusion coefficient (m^2/s)
c	=	suspended mud concentration (kg/m^3)
l_m	=	momentum mixing length (m)
l_c	=	solute mixing length (m)
w_s	=	settling velocity (m/s)
L_{mud}	=	sediment load (kg/m^2/s)

$\bar{c}$ = suspended solids concentration in upper layer if $(w - w_s) \leq 0$ (kg/m^3)

or $\bar{c}$ = suspended solids concentration in lower layer if $(w - w_s) \geq 0$ (kg/m^3)

deposition

$$\frac{dm}{dt} = w_s c \left(1 - \frac{\tau_b}{\tau_d}\right) \quad when\ \tau_b \leq \tau_d$$

erosion

$$\frac{dm}{dt} = M\ (\tau_b - \tau_e) \quad when\ \tau_b \geq \tau_e$$

where

τ_b = bed stress (N/m^2)

τ_d = critical stress for deposition (N/m^2)

τ_e = critical stress for erosion (N/m^2)

M = empirical erosion constant (kg/s/n)

w_s = settling velocity (m/s)

Sedimentation Processes

a) Erosion

In the present model, two critical shear stresses for erosion have been defined, one is for the dredging materials, called "mud" and the other is for the bed materials, defined as "bed mud". In order to model the two sorts of materials correctly different critical erosion stresses were used.

For the bed materials, in accordance with Hydraulics Research (1988), a typical value of shear stress for erosion of 0.3 N/m^2 has been employed in the model.

For the mud (dredging materials), the relationship between the erosion shear stress and the dry density can be written as, (Delo, 1988):

$$\tau_e = 0.0005\ \rho_h^{1.4}$$

in which

τ_e = erosion stress (N/m^2)
ρ_h = dry density (kg/m^3)

using ρ_h = 25, 50, 80 kg/m^3 to calculate τ_e:

$$\tau_e = 0.0005\ \rho_h^{1.4} \quad \begin{cases} 0.0453 & (\rho_h = 25) \\ 0.1195 & (\rho_h = 50) \\ 0.2308 & (\rho_h = 80) \end{cases}$$

A dry density of 20-25 kg/m^3 has been assumed for the dredging materials, resulting in a value of τ_e = 0.04 in the model.

The erosion rate is given by the following equation:

$$\frac{dm}{dt} = M\ (\tau_b - \tau_e) \quad kg/m^2/s$$

in which M is an empirical erosion constant. A value of M = 0.0015 kg/N/s has been adopted from Hydraulics Research (1988).

b) Settling

It is assumed that the average diameter of the particles is 0.02 mm and the settling velocity has been found from Vanoni (1977).

W_s = 0.0004 m/s.

c) Deposition

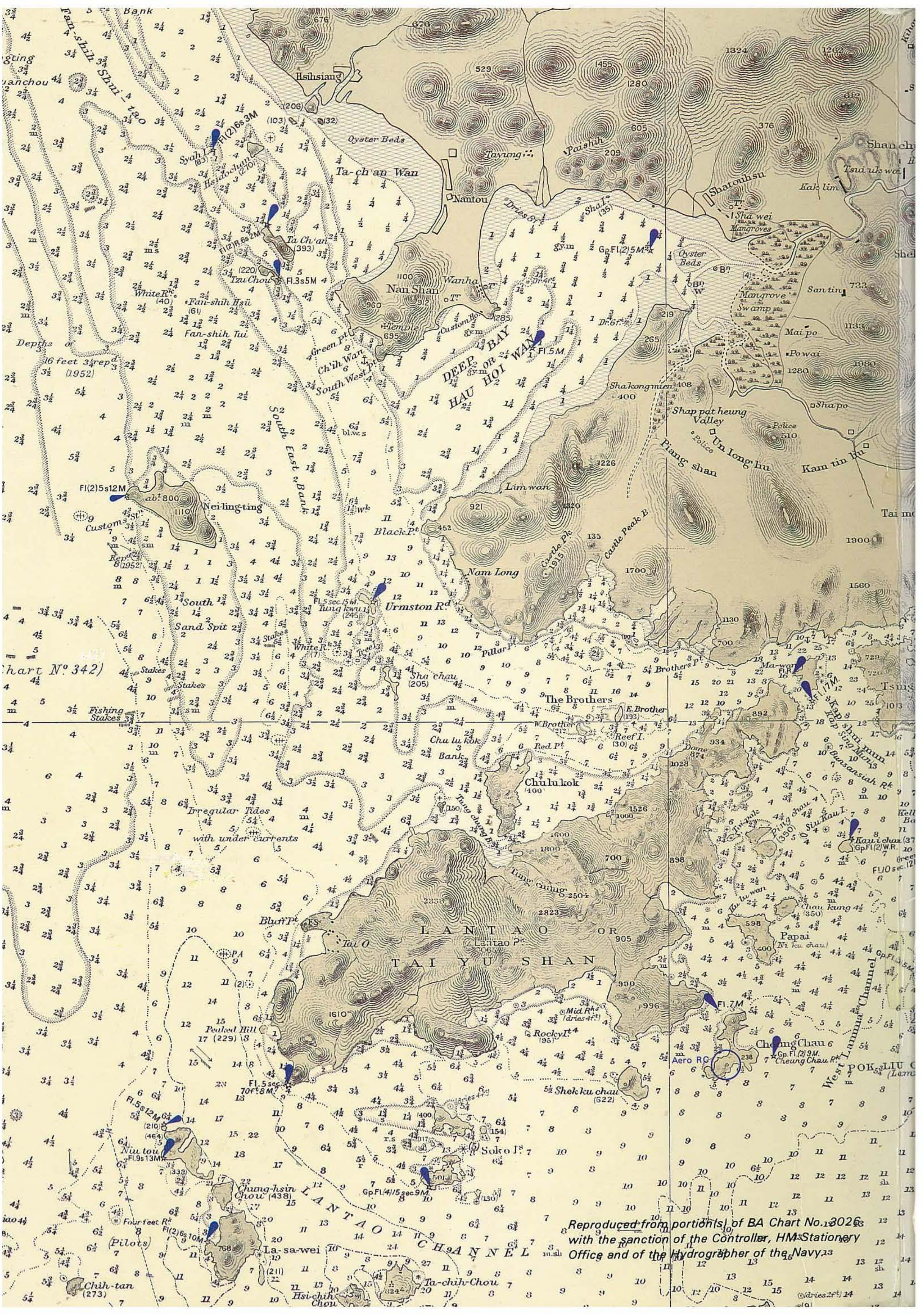
It is assumed in the model that if the bottom shear stress is less than the critical stress (ρ_d) then deposition occurs.

The deposition rate

$$\frac{dm}{dt} = W_s C\ (\ - \tau_b/\tau_d) \quad kg/m^2/s$$

in which: W_s = settling velocity (m/s)
C = concentration (kg/m^3_
τ_b = bottom shear stress (N/m^2)
τ_d = deposition critical stress (N/m^2)

The deposition critical stress of 0.1 N/m^2 has been adopted from Hydraulics Research (1988).


Ta-ch'an Wan
Nantou
Hsihsiang
Oyster Beds
Nan Shan
Wanha
Deep Bay or Hau Hoi Wan
Sharouhsu
Mangroves
Mangrove Swamp
San tin
Mai po
Powai
Sha po
Shap pat heung Valley
Un long hu
Kam tin hu
Piang shan
Castle Peak
Lim wan
Nam Long
Black Pt.
Urmston Rd.
Pillar Pt.
Sha chau
Neil-ing-ting
Fan-shih Shui
Fan-shih Tui
South East Bank
South Sand Spit
Tung kwu I.
White Rk.
The Brothers
E. Brother
W. Brother
Chu lu kok Bank
Chulukok
Red Pt.
Ma-wan
Kap shui mun
Ping chau
Lantao or Tai Yu Shan
Tai O
Tung chung
Peaked Hill
Irregular Tides with under currents
Lantao Channel
Shek ku chau
Soko Is.
Cheung Chau
West Lamma Channel
Papai
Chau kung
Niu tou
Chung-hsin Chou
La-sa-wei
Chih-tan
Ta-chih-Chou
Hsi-chih Chou
Kau i chau
Aero RC
Chart No. 342)
Fishing Stakes
Customs
Pilots