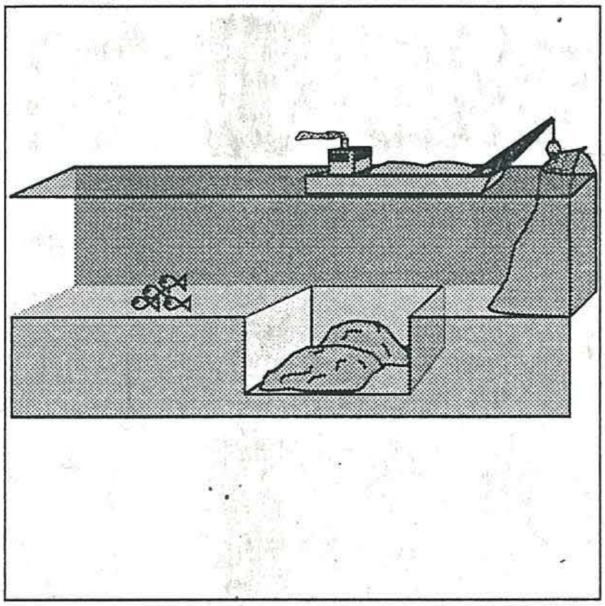
FINAL REPORT

Civil Engineering Department



Backfilling of South Tsing Yi and North of Lantau MBAs : Final *Environmental Impact Assessment*

November 1995

ERM HONG KONG
6/F Hecny Tower
9 Chatham Road, Tsimshatsui
Kowloon, Hong Kong
Telephone 722 9700
Facsimile 723 5660

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CONSULTING SERVICES BY ENVIRONMENTAL RESOURCES MANAGEMENT

FINAL REPORT

Civil Engineering Department

Backfilling of South Tsing Yi and North of Lantau MBAs : *Final Environmental Impact Assessment*

14 November 1995

Reference c1280/c1428

For and on behalf of ERM-Hong Kong, Ltd

Approved by: AM Laidlaw

Position: Deputy Managing Director

Date: 14th November 1995

CONTENTS:

1 INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Sand from Marine Borrow Areas (MBAs) south of Tsing Yi and north of Lantau has been excavated for various projects, including the North Lantau Expressway – Tai Ho Section. Since these sand resources have now been exhausted (see *Section* 2), in accordance with the policy of the Fill Management Committee (FMC), it is proposed to backfill the MBAs and restore the seabed to as close as possible to its pre-dredging condition without causing any unacceptable environmental impacts. This restoration is expected to produce several benefits including the potential reinstatement of the natural hydrodynamic regime, recolonization by a benthic community similar to that which existed prior to sand dredging, and provision of routine and emergency ship anchorage. Backfilling also provides additional disposal capacity, above the capacity supplied by the marine disposal sites at East of Ninepins and South Cheung Chau, for uncontaminated (Class A and B) fine marine sediments. The two MBAs proposed for backfilling are shown on *Figure 1.1a*.

This Feasibility and Environmental Impact Assessment (EIA) Study for the Backfilling of Marine Borrow Areas (MBAs), North of Lantau and South Tsing Yi, is prepared by ERM Hong Kong in association with Dredging Research Ltd, Electronic and Geophysical Services Ltd, Furano Environmental Consultants, Hydraulic and Water Research (Asia) Ltd and Scott Wilson Kirkpatrick.

1.2 OBJECTIVE OF FEASIBILITY STUDY/EIA

The objective of this Feasibility Study/EIA is to design an environmentally acceptable Operations Plan for the proposed backfilling at the South Tsing Yi and North of Lantau MBAs, and to provide information on the nature and extent of environmental impacts and cumulative effects arising from the backfilling projects and all related concurrent activities.

The findings of this Study will contribute to decisions on the overall acceptability of environmental impacts likely to arise as a result of the backfilling activities. The findings will determine operational conditions and requirements, including the optimum backfilling levels and rates for the MBAs, to minimise spoil loss and impacts to sensitive receivers. The Study also assesses the acceptability of residual impacts after the proposed mitigation measures are implemented.

The goal of the Study is to develop a practical approach to resolving key environmental issues, and to enable backfilling of dredged material at the MBAs to proceed within the proposed timeframe without unacceptable environmental impacts.

1.3 INITIAL ASSESSMENT REPORT (IAR) FINDINGS

An IAR for the proposed backfilling was released in December 1994. The overall purpose of the IAR was to review the environmental acceptability of the proposed backfilling operations at each MBA, and thereby provide a preliminary recommendation concerning the environmental feasibility of the backfilling and to determine if the projects should proceed to the detailed EIA stage.

The IAR described the existing environment within the study area, including baseline air, noise, water quality and marine ecological conditions. It provided an initial assessment and evaluation of the potential environmental impacts and internal cumulative effects (backfilling at both MBAs simultaneously) that may arise from the proposed backfilling projects. In order to achieve the objectives of the IAR, possible backfilling scenarios were agreed with CED/GEO and modelled. The IAR presented one backfilling approach for the North of Lantau MBA and three for the more complex South Tsing Yi MBA. The results of the modelling scenarios identified potential impacts requiring mitigation and indicated the general acceptability of these potential impacts.

The initial assessment of environmental consequences arising from the proposed backfilling activities at the two MBAs indicated that there are unlikely to be any insurmountable or unacceptable residual environmental impacts. Key issues during and after the backfilling activities warranting further assessment in the detailed EIA and potential cumulative impacts were identified. Where possible, practical and cost-effective mitigation measures and EM&A requirements necessary to minimize potential adverse environmental impacts were proposed. These included pollution, environmental disturbance and nuisance controls. The IAR proposed further analyses, such as field data collection, modelling studies and desktop assessments to address remaining data gaps, and to design an appropriate, environmentally-acceptable Operations Plan.

The IAR concluded that backfilling operations at the South Tsing Yi and North of Lantau MBAs were considered environmentally feasible and should be assessed further in the detailed EIA. At the Study Management Group (SMG) meeting held on 20 January 1995, the SMG agreed that the Feasibility Study/EIA should proceed to the detailed assessment stage and that the acceptability of the project would be evaluated through this process. The following points were raised for consideration in the detailed EIA: validation of WAHMO model, potential cumulative impacts with other projects in the surrounding area, incorporation of updated *Sousa* information from the AFD Dolphin Research Team, potential water quality impacts and impacts on capture fisheries.

1.4 *SCOPE OF EIA AND APPROACH*

This detailed EIA recommends an Operations Plan for the proposed backfilling projects which will maximise use of the MBAs and minimise environmental impacts by incorporating appropriate mitigation measures. The residual impacts resulting after the implementation of these mitigation measures are assessed and the project's overall environmental feasibility determined.

In this EIA, potential environmental impacts that may arise during and after the proposed backfilling activities are evaluated in terms of water quality and sediment transport, marine ecology, and noise and air quality. This approach involved the collection of field data and analysis of existing

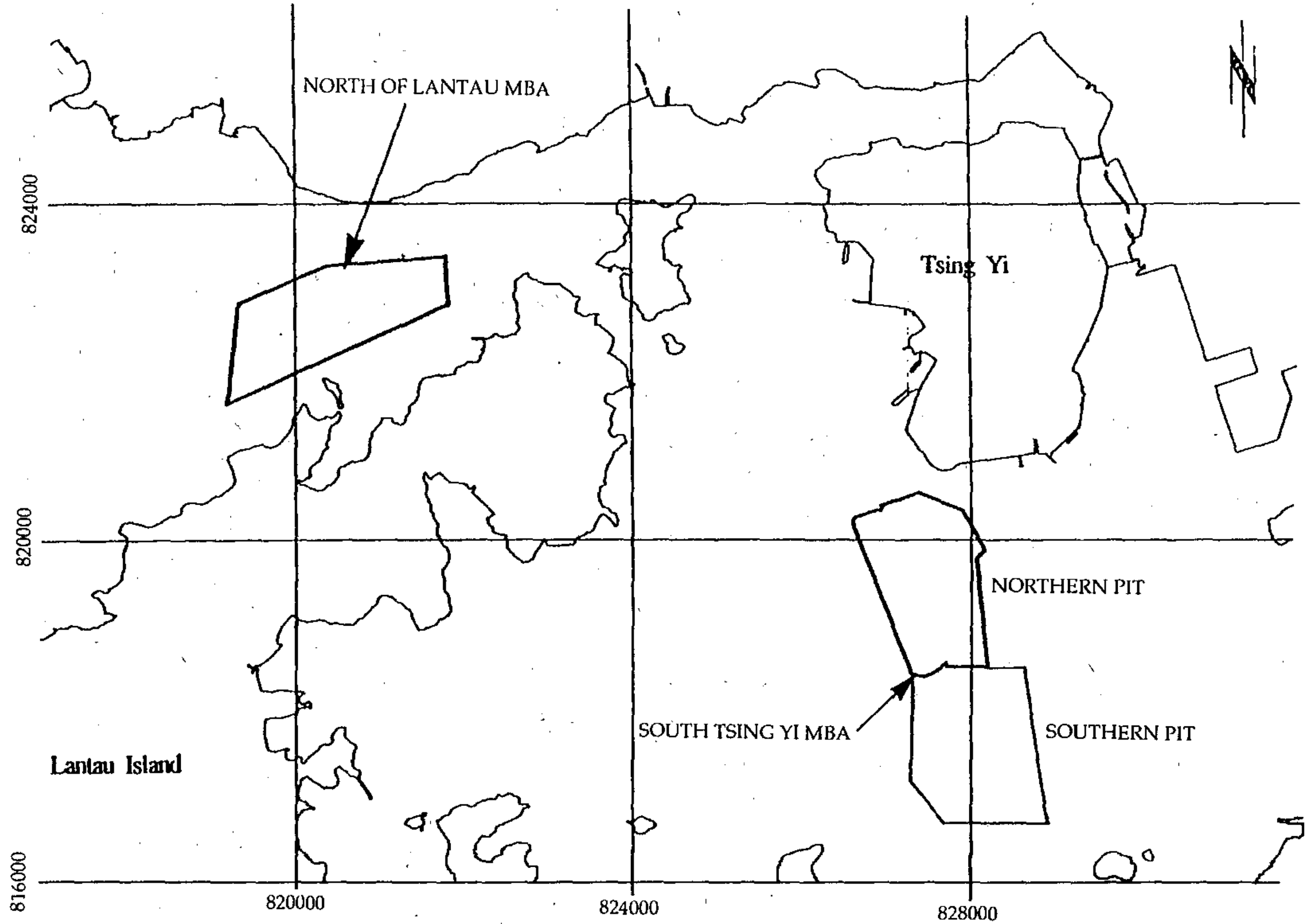

FIGURE 1.1a - LOCATION OF THE SOUTH TSING YI AND NORTH OF LANTAU MARINE BORROW AREAS (MBAs)

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baseline data. In order to provide a detailed assessment of the key issues identified in the IAR, modelling of sediment plumes, erosion/deposition, noise and air quality was performed and superimposed on baseline conditions. In addition, cumulative impacts were assessed through supplementary backfilling scenarios involving other dredging projects which may be operating simultaneously. Other detailed assessments conducted for the EIA include a greater range of possible backfilling scenarios to provide definition of operational design factors to minimise spoil loss.

Environmental monitoring and audit (EM&A) requirements necessary to ensure the implementation and effectiveness of the recommended mitigation measures and operational controls are identified within the EIA. Details of the proposed environmental monitoring and audit programmes during the operational and post-operational phases of the backfilling projects are given in the EM&A Manual (Environmental Schedule).

1.5 *NEW FEATURES OF THE FINAL EIA*

In response to comments received on the draft EIA (*Annex T*) several sections of the EIA have been revised and several new sections have been added. Additional changes have been made to the document in order to reflect comments and discussions on the Cumulative Effects Assessment Manual (CEAM) and the Environmental Monitoring and Audit (EM&A) Manual (*Annex U*).

Key changes to existing sections of the EIA include revisions to the evaluation of compliance with water quality objectives (WQOs) and specific water quality criteria (*Section 3.10*) and a revised, more conservative, rate of backfilling in the Operations Plan for the South Tsing Yi MBA (*Section 7.5.1*). A number of other sections have been revised in response to comments concerning modelling methodologies, engineering requirements and *ex gratia* issues.

New sections, added as a result of comments on the draft versions of the EIA, the CEAM and the EM&A Manual, include a discussion of mixing zones for the modelling scenarios (Section 3.9), an additional scenario to represent the revised Operations Plan (Scenario 4e in *Sections 3.8–3.10*), and an impacts summary table (*Section 7.7*).

1.6 *STRUCTURE OF THE REPORT*

Following this introductory section, the EIA is organised as follows:

- *Section* 2 describes the locations of the MBAs at South Tsing Yi and North of Lantau, and the proposed project programme, including backfilling methods and engineering requirements, and the assumed parameters adopted for modelling;
- *Sections 3 through 6* define and assess potential environmental impacts which may arise during and after backfilling operations with respect to water quality and sediment transport (*Section 3*), marine ecology (*Section 4*), noise (*Section 5*) and air quality (*Section 6*). These sections also outline possible mitigation measures and environmental monitoring and audit requirements;

- *Section 7* summarises the findings of the EIA Study, including environmental monitoring and audit requirements, and presents an environmentally acceptable Operations Plan for backfilling the MBAs at South Tsing Yi and North of Lantau.

2 PROJECT DESCRIPTION

2.1 INTRODUCTION

The history and bathymetry of the two sites proposed for backfilling are different and therefore entail different engineering and project design requirements. This section describes the two sites and the associated backfilling methods. In addition, engineering features of the proposed backfilling operations are identified and discussed in relation to development of water quality modelling scenarios.

2.2 MARINE BORROW AREAS

South Tsing Yi MBA

The South Tsing Yi MBA is situated south of the south–eastern tip of Tsing Yi Island. It occupies an area of approximately 1 km x 2.7 km and lies in an area of strong tidal currents. This MBA can be broadly divided into northern and southern pits. There are still approximately 1.5 Mm^3 of sand resources remaining in the north–western portion of the northern pit, which is indicated as Area 1 in *Figure 2.2a*. The sand is not being dredged at present, however it is anticipated that it will be removed before backfilling encroaches on this area. The south–eastern area of the northern pit (Area 2 in *Figure 2.2a*) has been exhausted of sand and partially backfilled with uncontaminated (Class A and B) trailer–dredged material from the Chek Lap Kok Airport project. The south–western portion of the northern pit (Area 3 in *Figure 2.2a*) is already exhausted of sand and has been partially backfilled by dredged material generated from the Container Terminal 8 (CT8) project since mid–1992. The southern pit (see *Figure 1.1a*) has not yet been excavated, however the sand resources have been allocated to the Container Terminal 9 (CT9) project. The existing bathymetry of the area is presented in *Figure 2.2a*.

As a result of a previous focused EIA study [(1)], EPD agreed to backfilling of the northern pit of the MBA (Areas 2 and 3 in *Figure 2.2a*) at South Tsing Yi to a level of –34 mPD. In this focused EIA study, sediment plume modelling was performed for the disposal of material from the airport project. However, records have shown that the dumping rates actually adopted were substantially higher than the modelled rates. Recent bathymetric data [(2)] show that some parts of the northern pit of this MBA are still at a level of around –42 mPD. Under this Feasibility Study/EIA, it is proposed to extend the backfilling level from –34 mPD to –25 mPD.

A study has previously been undertaken by HWR to examine the stability and losses of dredged material disposed in the northern pit (Areas 1 to 3 in *Figure 2.2a*) of South Tsing Yi MBA [(3)]. In this assessment, these

(1) Greiner–Maunsell (1993) Focused EIA of Backfilling Operation at South Tsing Yi Marine Borrow Area.

(2) Electronic and Geophysical Services Ltd (1994) Surveying at South Tsing Yi Final Report.

(3) Hydraulics and Water Research (Asia) Ltd (1993) Disposal of Spoil at South Tsing Yi MBA: An Assessment of the Stability and Losses of Dumped Spoil Report HWR064.

hydrodynamic data are used to assess the fate of dredged material disposed either from trailer dredgers or from barges.

The South Tsing Yi MBA is located in an area with heavy marine traffic. For this reason, the Marine Department (MD) has indicated that potential interference with marine traffic in the vicinity of the South Tsing Yi MBA caused by towed barge dumping operations may be unacceptable.

North of Lantau MBA

Disposal of uncontaminated (Class A and B) dredged material is also proposed at the North of Lantau MBA. The North of Lantau MBA is well protected from extreme wave action and possible backfill levels may be less sensitive to local hydrodynamic conditions than the South Tsing Yi MBA. The largest waves at this MBA generally arrive from the west and the current speed is low due to tidal convergence. However, this MBA is closer to sensitive receivers such as the Ma Wan Fish Culture Zone and gazetted beaches along the Tsuen Wan and Tuen Mun coastline than the proposed South Tsing Yi MBA.

The North of Lantau MBA has been dredged to a maximum level of approximately -38 mPD and natural seabed levels along the northern margin are between -30 and -40 mPD. Since there is practically no backfill-retaining slope on the northern boundary of this MBA, hydraulically dredged material will not be contained within the MBA and for this reason the area can only be used for the disposal of uncontaminated (Class A and B) mechanically-dredged material. A recent bathymetric survey [4] for this MBA shows that the depth of the area varies from -12 mPD to -40 mPD. The bathymetry for this area is shown in *Figure 2.2b.*

2.3 PROJECT PROGRAMME

The programme for the backfilling operations will depend on those of the projects for which mud disposal is required. A list of projects, which are expected to commence within the period of January 1995 to December 1999, and which have unallocated dredged material disposal requirements is presented in *Annex A*. Since there is expected to be heavy demand for uncontaminated (Class A and B) dredged material disposal sites, it is particularly important to evaluate the environmental acceptability for the backfilling operations at the South Tsing Yi and North of Lantau MBAs in the present study.

The relative proportions of grab- to trailer-dredged material cannot be estimated for the above projects at this stage. It is reasonable to assume, however, that small inshore projects will use grab dredgers, whereas larger projects, ie, those over 200,000 m^3, may involve both grab dredgers and trailer dredgers.

(4) Electronic and Geophysical Services Ltd (1994) Bathymetric Surveying at North of Lantau Final Report.

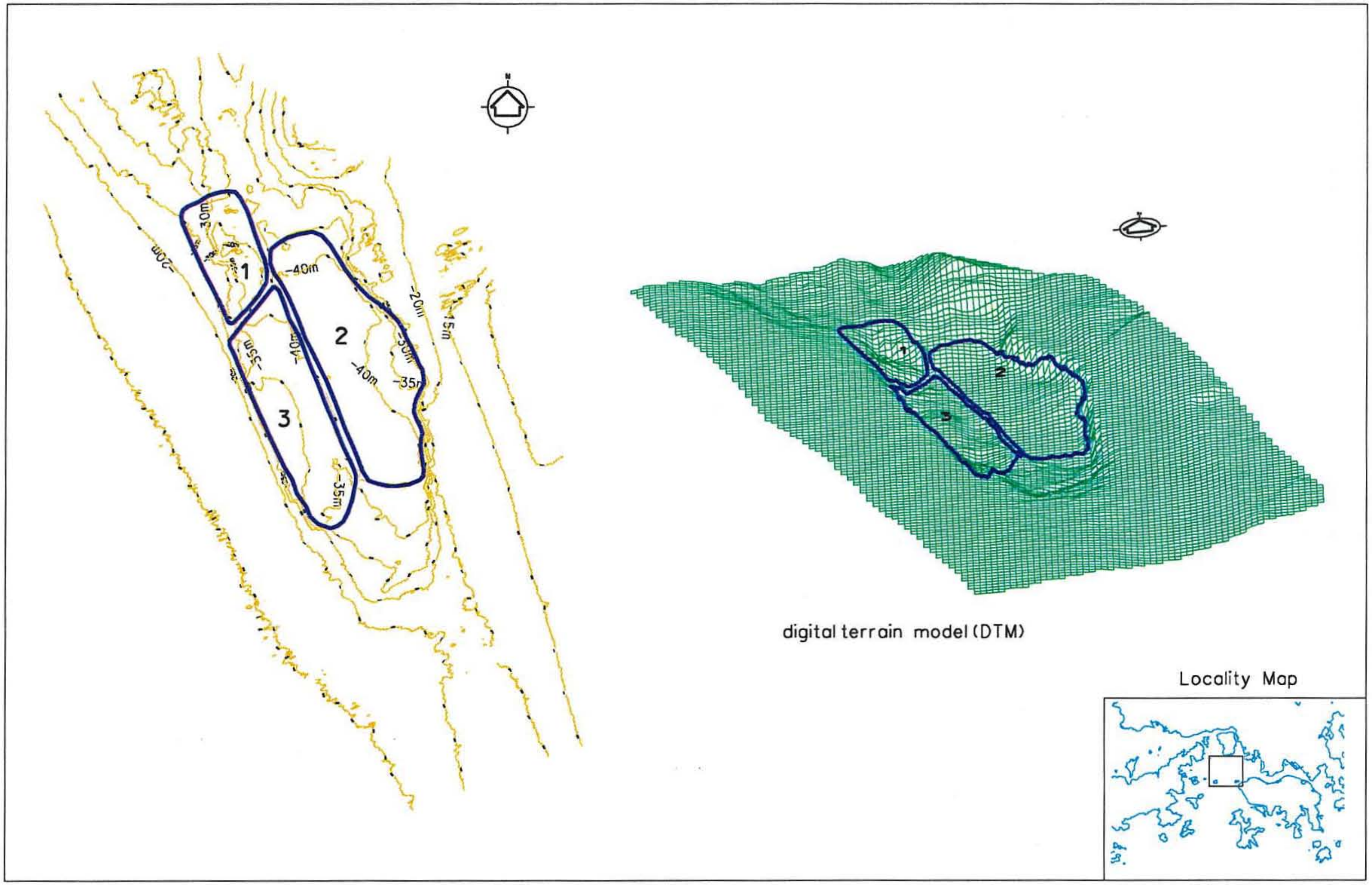

FIGURE 2.2 a Illustration of seabed bathymetry at the Northern South of Tsing Yi MBA

Date : 11 April 1995	Project No.: C 1280
Map drawn by GIS and Mapping, ERM	Base map from LANDS DEPT. 1:20k topo

KEY

3	Area boundary
	DTM grid
	Seabed contour

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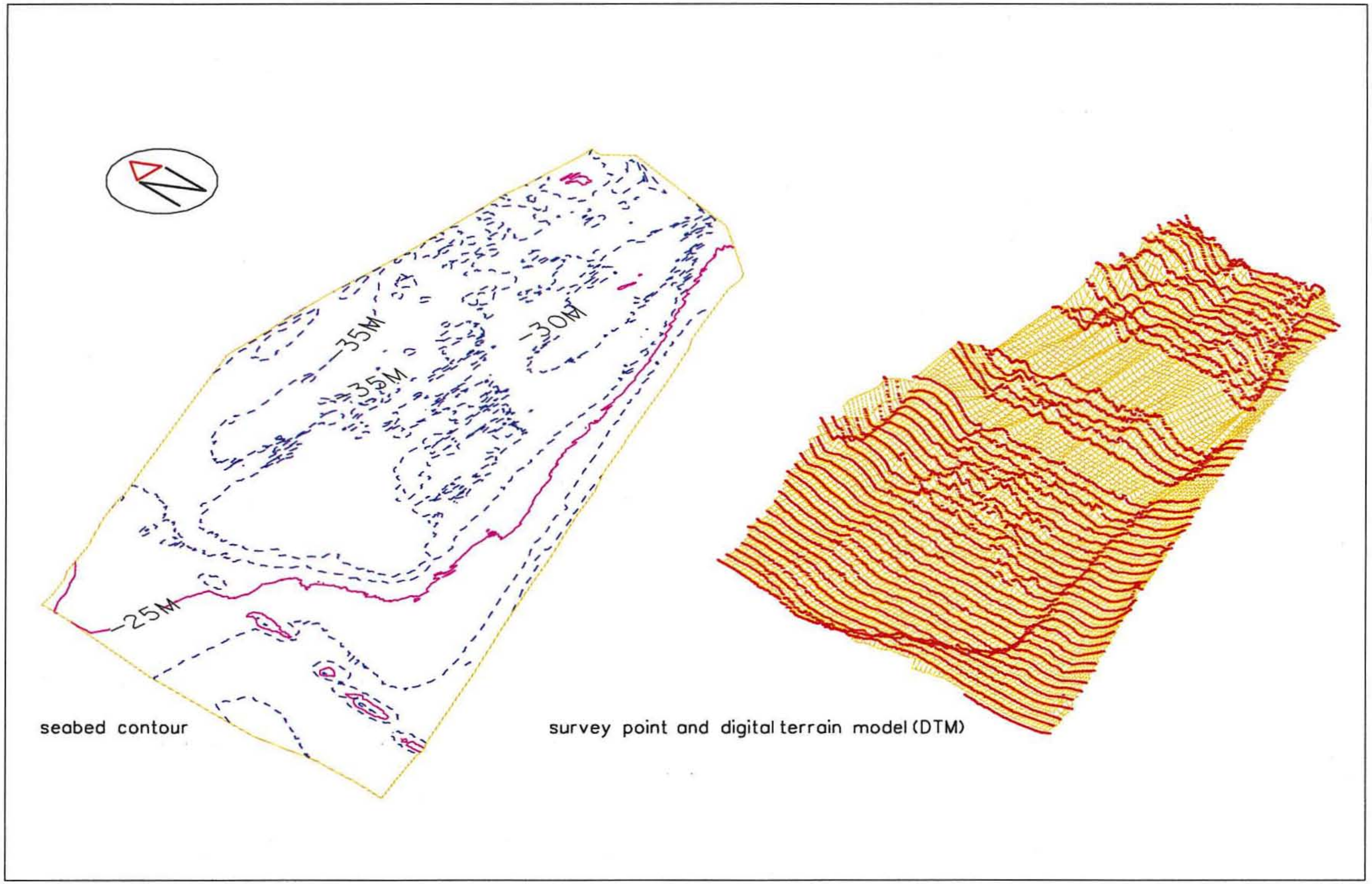

FIGURE 2.2 b Illustration of seabed bathymetry at the North of Lantau MBA	
Date : 11 April 1995	Project No.: C 1280
Map drawn by GIS and Mapping, ERM	Base map from LANDS DEPT. 1:20k topo

KEY

- Contour
- DTM grid
- Survey point

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2.4 *BACKFILLING METHODS AND ENGINEERING REQUIREMENTS*

2.4.1 *Backfilling Methods*

Dredged material may be transported to a disposal area by three methods:

- in a barge;
- in the hold of a trailing suction hopper dredger; and
- by pumping as a soil/water slurry through a pipeline.

In the first two cases, the usual method of discharge is to release the material through the bottom of the barge or trailer. This is termed 'bottom-dumping' and is the fastest and cheapest method of disposal or, in this case, backfilling. Inevitably, when dredged material is discharged in this manner, there is some loss of sediment to the water column. This loss of sediment is discussed in more detail in *Section 3*.

Alternative methods of unloading both barges and trailer dredgers are available which can, when properly carried out, reduce the loss of sediment. However, these methods require a longer period of time and, in some cases, additional equipment. Some trailer dredgers can discharge their load in a very controlled manner by lowering the suction pipe into the pit and slowly releasing the material through the suction pipe. Most dredgers with this capability can discharge through only one of their two suction pipes; a few can discharge through both of their two suction pipes at the same time. A variation on this method is to connect the dredger to a floating pipeline and to pump the dredged material to a nearby barge which delivers the material to the base of the pit through a vertical pipe which may terminate in a diffuser.

In the case of barges, it may be possible to moor the barge against an anchored pontoon equipped with a grab. The grab can unload the barge and place the material in a hopper which feeds into a vertical tremie pipe which carries the material to the base of the MBA. This method is not suitable for heavily trafficked areas.

Dredged material transport through a pipeline, with the exception of the methods described above, is almost invariably restricted to cases where the material is dredged using a cutter suction dredger. Cutter suction dredgers are often capable of pumping mud as a slurry over distances of several kilometres; the discharge end of the pipeline can be submerged, leading directly into the disposal area, or it can terminate in a diffuser barge similar to pipeline discharge from a trailer dredger.. However, material is very rarely dredged in Hong Kong using cutter suction dredgers and the inevitable restrictions on the use of long pipelines in the area under consideration (due to heavy marine traffic) renders this method of backfilling most unlikely. For the purposes of this EIA, it is therefore assumed that dredged material will only be delivered to the MBAs in barges and trailer dredgers.

South Tsing Yi MBA

Initial proposals are to backfill the South Tsing Yi MBA to a level of -25 mPD as previously agreed between FMC and MD.

Depending on the timing of the commencement of backfilling operations relative to the extraction of the sand which remains in the southern pit of the MBA, backfilling may proceed in one of two ways:

- if the sand in the southern pit of the MBA has not been extracted prior to the commencement of backfilling, it will be necessary to first reserve an area at approximately Hong Kong metric grid coordinates 819000N for mechanically-dredged uncontaminated (Class A and B) material. Such materials have a greater capacity to function as 'dams' to contain the more fluid trailer-dredged material and to prevent inundation of the southern pit's CT9 sand resource. Backfilling can then be undertaken, in the northern pit of the MBA, north of the area reserved for mechanically-dredged material using either mechanically-dredged or hydraulically-dredged uncontaminated (Class A and B) material.

- if the sand in the southern pit of the MBA has already been extracted when backfilling commences, then the entire MBA can be backfilled with either mechanically-dredged or hydraulically-dredged material.

At this stage, it is anticipated that backfilling will commence before the sand resources in the southern pit of the South Tsing Yi MBA have been exhausted.

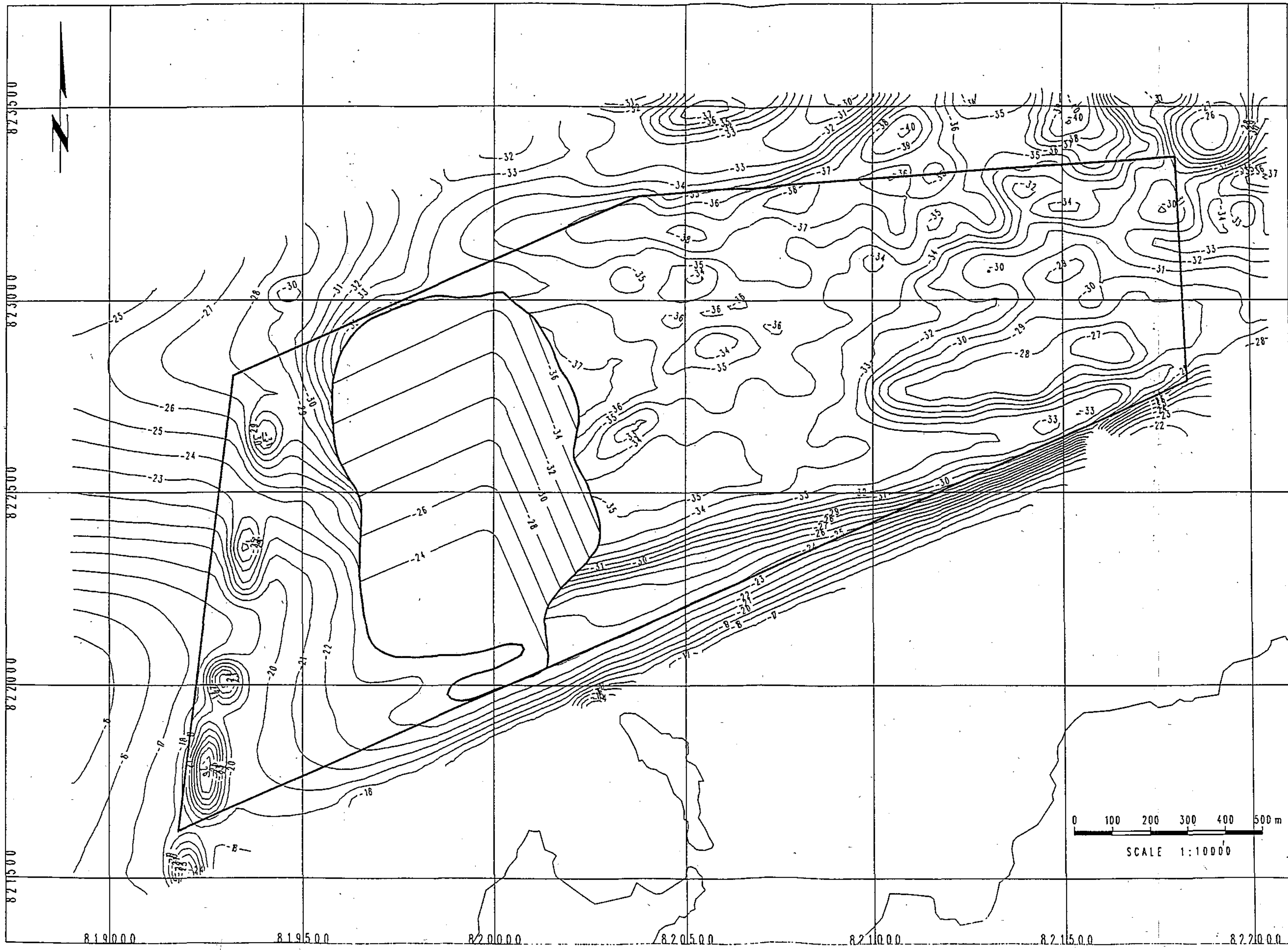
It will also be necessary to construct, from mechanically dredged uncontaminated (Class A and B) material, a separate small area of mechanically-dredged material at the northern end of the northern MBA to prevent movement of disposed material north toward the Ma Wan channel. *Section 2.4.2* provides more information on the engineering requirements for the proposed areas of grab-dredged material at the South Tsing Yi MBA.

Since the South Tsing Yi MBA is situated in an area with heavy marine traffic, the MD has indicated concerns with the potential interference of the proposed backfilling operations with other marine traffic. Marine traffic constraints are described in more detail in *Section 2.5.1*.

North of Lantau MBA

Owing to bathymetric restrictions, the North of Lantau MBA cannot be used to dispose of hydraulically-dredged (trailer) material unless mechanically-dredged (grab) material is first dumped along the northern margin to retain it. However, discussions with CED/GEO indicate that, at present, it is envisaged that there will be no requirement to use this area for backfilling with trailer-dredged material and thus backfilling from barges with mechanically-dredged material at a rate of 10,000 m^3/day was assumed for the modelling included in this EIA. The overall objective, if this is found to be environmentally acceptable, is to restore the original seabed profile at the North of Lantau MBA.

In order to promote recolonization of the seabed in the North of Lantau MBA backfilling will occur in phases, with backfilling initially confined to an area covering approximately 20% of the western portion of the site (*Figure 2.4a*). It is estimated that 2.2 Mm^3 of grab spoil will be required to achieve the proposed initial backfill profile in the western part of the site. Assuming a dumping rate of 50,000 m^3 per week, this initial phase of operation will require approximately 11 months. After completion of the



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TITLE **FIGURE 2.4a**

NORTH OF LANTAU - PROPOSED INITIAL BACKFILL PROFILE

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FILE NO.	
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DRAWN BY	M.C. Yeung
DRAWING NO. FMC/302/3	SCALE 1:10000
OFFICE FILL MANAGEMENT DIVISION Geotechnical Engineering Office	

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initial phase, backfilling will proceed sequentially to the east, allowing progressive recolonisation from the west (*Figure 2.4b*). No more than 20% of the gazetted area will be affected by backfilling operations at any one time.

There are no special marine traffic restrictions as yet on dumping in this area, however MD have indicated that all dumping activities must comply with the *General Allocation Conditions for Marine Borrow Areas and Mud Disposal Sites*.

2.4.2 *Engineering Requirements*

The northern pit of the South Tsing Yi MBA leads, both to the north and south, into deeper water. In the case of the northern margin there is a natural deepening towards Ma Wan, while to the south the MBA has been partially dredged and will be dredged further for the exploitation of as yet unused sand reserves. During backfilling operations, it will be necessary to ensure that as little as possible of the dumped material escapes the dumping area to avoid inundation of the southern sand reserves and general loss to the environment towards Ma Wan. In order to achieve this, it will be necessary to form slopes with the dumped material.

Areas of grab–dredged material have not previously been used in MBAs in Hong Kong to contain trailer–dredged materials. However, recent surveys of the South Cheung Chau disposal site confirm that areas of grab–dredged materials are effective in containing more fluid materials. These areas of grab–dredged material have been observed to stand with sideslopes of approximately 1:25. Subareas within the disposal site are specified and regularly relocated through the EPD License and Black Box system. Similar procedures will be used to construct physical barriers to fluid mud flow at the South Tsing Yi MBA, and it is envisaged that areas of grab dredged materials would be maintained to exceed the height of trailer–dredged materials by at least 1 meter.

Mound formation by disposal

Dredging and disposal, which will be described in *Section 3*, give rise to two different types of material. Material dredged and disposed using hydraulic trailer dredgers comprises small lumps of remoulded mud in a fluid mud slurry, whereas material dredged by grabs and dumped from barges comprises mainly large lumps of softened material with only a subsidiary slurrified component. These two materials may be expected to behave differently in terms of the maximum geotechnically stable slope which can be formed.

In order to form the required stable slope at the MBAs it will be necessary:

- to use material which is capable of sustaining the slope; and
- to place the material in such a manner that the slope can be formed.

Mechanically grab–dredged material clearly has better engineering characteristics than hydraulically trailer dredged material in so far as it contains a far greater proportion of large lumps. In addition, the generally smaller loads involved in barge dumping (typically 750 – 1,000 m^3 in the case of Hong Kong barges) compared to those involved in trailer dumping (typically 6,000 – 10,000 m^3), combined with the characteristics of the material, cause barge-disposed material to be carried a shorter distance by disposal-induced bottom density surges than trailer dredged mud.

The properties of dumped material in Hong Kong have been reviewed from both theoretical and observational standpoints. [5] Surveys at the South Cheung Chau disposal site showed that two types of slope were common:

- transient slopes at a maximum gradient of 5.7° (1:10); and
- more persistent slopes with gradients between 0.46° - 0.23° (1:125 and 1:250), which were mainly found around the periphery of the area.

The steeper slopes are interpreted in the above-mentioned review[5] to be formed from a mixture of grab- and trailer-dredged material, representing the lump fraction of that material. The shallower peripheral slopes were interpreted to be formed from the slurry fraction, principally derived from trailer-dredged material. A theoretical review [6] of slope stability based on the measured properties of dredged marine dumped in the Urmston Road borrow pits [7] suggested that the initial slope of `core' (ie. lumpy) material under static conditions should be of the order of 5.8° (1:10), remarkably similar to slopes observed at South Cheung Chau, and that the slope of the slurrified material might be of the order of 0.2° (1:286).

Under dynamic conditions (eg tidal currents, wave loading and wave-induced currents, and seismic forces), these slopes would be expected to degrade. Evans (1992) calculated that, for a significant wave height of 5 m, all slopes on the mound at South Cheung Chau would be destabilised. However, for a wave height of 1.35 m, which is more typical of the normal maximum in the Western Harbour (except in typhoon conditions), slopes of up to 3.6° (1:16) should remain stable in water depths as shallow as 11 m. The water depth at the proposed maximum backfilling level for each MBA will be approximately 25 m and it therefore seems likely that such slopes could be maintained.

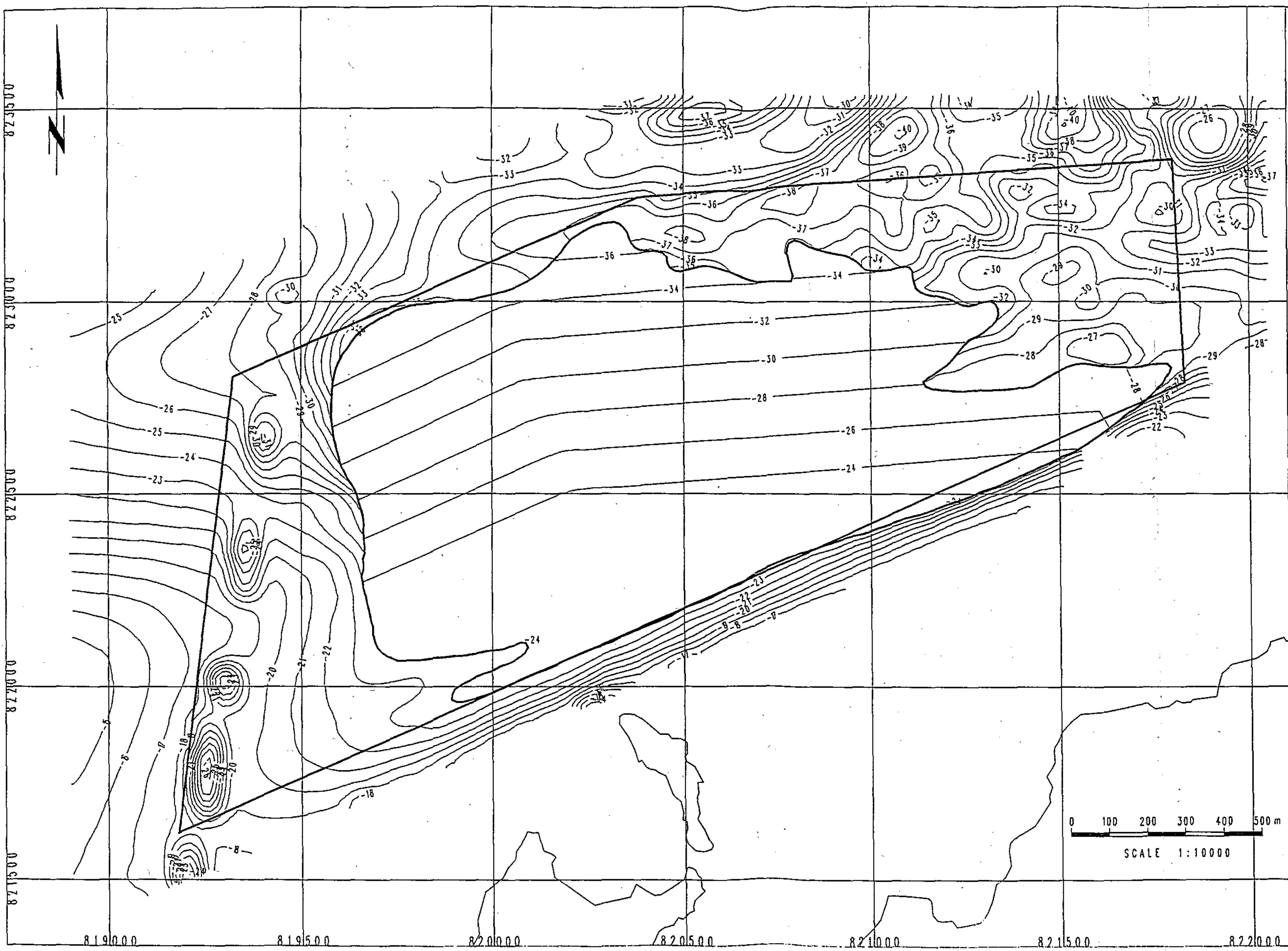
More recent data from South Cheung Chau generally confirms the conclusions made by Evans (1992). In 1993, a very prominent mound of material was formed in an area where only grab-dredged material was being dumped from barges. The mound reached an elevation of approximately -4.5 mPD (ie. a water depth of approximately 5.5 metres) before dumping ceased. Since then, no further dumping has taken place in that area. In June 1993, an Acoustic Doppler Current Profiler survey [8] (Dredging Research Ltd., 1993) showed very clearly that material was being slowly eroded from the mound by tidal currents, even during good weather and sea conditions. This was interpreted to be derived from the exposed slurry fraction.

(5) Evans N C (1992) Geotechnical Aspects of Mud Dredging and Dumping. Special Project Report SPR 13/92, Geotechnical Engineering Office, Civil Engineering Department, Hong Kong.

(6) Ibid.

(7) Maunsell Consultants Asia Ltd (1990) BMAT: Backfilled Mud Anchor Trials Study, Discussion Paper No. 6, Geotechnical Review. Report to the Geotechnical Engineering Office, Civil Engineering Department, Hong Kong (Agreement CE 34/89).

(8) Dredging Research Limited (1993) Draft Report on Initial Survey at South Cheung Chau (June 1993). Report prepared for the Geotechnical Engineering Office, Civil Engineering Department, Hong Kong.



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TITLE **FIGURE 2.4b**

NORTH OF LANTAU - PROPOSED FINAL BACKFILL PROFILE

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DRAWN BY	W.C. Yeung
DRAWING NO.	FMC/302/2
SCALE	1:10000
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A bathymetric survey carried out during May to June 1993 [9] showed the main mound to have slopes in the range 2.8° - 1.4° (1:20 - 1:40). A survey undertaken in August 1994 [10] revealed broadly similar slopes except on the western side where the slope was at around 0.9° (1:65) and a marked change in mound shape suggests a large-scale failure. However, the mound had reduced in height by some 2 metres. The mound had been impacted for approximately 1 year by storms and erosion and by tidal currents, and it seems likely that degradation of the slopes would be less marked if they were in deeper and/or more sheltered water.

Slope formation at South Tsing Yi

As described above, the areas of grab-dredged materials are likely to be highly effective in containing trailer-dredged materials. It appears that relatively slurrified trailer-dredged material could be prevented from flowing out of the backfilling area into the southern pit of the MBA and northward towards Ma Wan, by ensuring that the southern and northern margins of the area are backfilled only with grab-dredged material dumped from barges. Such grab-dredged material should be put in place in advance of backfilling the remainder of the area with trailer-dredged material. The predicted loss of fluid muds without this mitigation measure has not been calculated since backfilling with trailer-dredged materials will not take place unless the areas of grab-dredged materials are in place (see *Section 7.5*). A staged approach could be adopted in which the backfill in the barge-dumping areas is maintained at a higher level than in the trailer-dumping area, thus permitting both types of material to be dumped at the same time, after the initial raising of levels in the barge-dumping areas.

It is estimated that disposal of grab-dredged material can result in slopes of up to 2.9° (1:20) and this is deemed sufficient for the purposes of containing mechanically-dredged material within the South Tsing Yi MBA. In order to achieve these slopes, considerable care will need to be taken with the barge-dumping operations. Barges will need to be directed to each dumping location as part of a managed dumping plan and frequent bathymetric surveys will be required to monitor the formation of the slopes. Even with careful placement techniques, it must be recognised that a small proportion of grab-dredged material will likely flow down the outside edge of the slopes and beyond the limits of the MBA. If the surveys showed that the required slopes were not being formed or maintained, then the `design' slope and, consequently, the management of the dumping operations would need to be modified to reduce material losses. Such modifications are anticipated to comprise limiting backfilling operations to grab-dredged materials only until sand dredging has been completed in the southern portion of the South Tsing Yi MBA.

(9) Electronic and Geophysical Services Ltd (1993) Contract No. GC/91/01 South Cheung Chau Bathymetric and Geophysical Surveys. Final Report to the Geotechnical Engineering Office, Civil Engineering Department, Hong Kong.

(10) Electronic and Geophysical Services Ltd (1994) Contract No. GE/93/05 Bathymetric Surveying at South Cheung Chau. Final Report to the Geotechnical Engineering Office, Civil Engineering Department, Hong Kong.

2.5 ASSUMED PARAMETERS FOR MODELLING

2.5.1 *Marine Traffic Constraints*

Marine Traffic Constraints at South Tsing Yi

Discussions with the MD suggest that they view dumping operations at Tsing Yi using towed barges as unfavourable because of potential interference with other marine traffic, although prohibition of barge dumping operations is not, at this stage, contemplated. However, they have indicated a requirement to use only highly manoeuvrable, self-propelled barges. For the purposes of modelling the effects of backfilling, we have assumed that both trailer dredgers and barges will be permitted to dump at the South Tsing Yi MBA on the basis that further discussions between CED and MD will take place to resolve the barge dumping issue, possibly resulting in the adoption of special measures such as the pushing, rather than towing, of barges.

MD have indicated that the following limitations may be applied to dumping from trailer dredgers:

- no more than 2 trailers or barges will be operating at any one time in the MBA (ie. including possible future sand dredging operations in the southern pit of the MBA),

- only one dredging or disposal vessel will be permitted to work in the fairway at any one time.

MD have indicated that there will be a general requirement that all dumping vessels must be moving whilst dumping. As the water quality modelling must specify a particular speed, MD's requirement has been interpreted as a speed during disposal of 2 - 3 knots. All dumping activities must comply with the *General Allocation Conditions for Marine Borrow Areas and Mud Disposal Sites.*

Marine Traffic Constraints at North of Lantau

There are no special restrictions on dumping as yet in this area, however MD have indicated that all dumping activities must comply with the *General Allocation Conditions for Marine Borrow Areas and Mud Disposal Sites.*

2.5.2 *Dumping From Trailers*

Dumping has been assumed to take place using 8,000 m^3 trailer dredgers. These are representative of the larger type of trailer working in Hong Kong. Typically, the *in situ* bulk density of marine mud is approximately 1.4 - 1.45 Mg/m^3 at the surface and rises to approximately 1.6 Mg/m^3 at a depth of 10 metres below surface. An average *in situ* density of 1.5 Mg/m^3 is therefore assumed. The hopper density which can be achieved in the case of trailer dredgers working in reasonably unrestricted dredging areas is usually of the order of 1.35 Mg/m^3. Lower hopper densities will be attained if the dredger is working in restricted areas; slightly higher densities may be achieved when working under very favourable conditions. Assuming an average hopper density of 1.35 Mg/m^3 gives a bulking factor of 1.43. If the particle specific gravity is assumed to be 2.7, the total mass of dry solids which will be released per dumping event is 4,450 Mg and a 5% solids loss (222.5 Mg) has been assumed for the purposes of modelling.

During this EIA, models have been run for the South Tsing Yi MBA using dumping rates of 50,000, 100,000, 150,000 and 200,000 m^3 of *in situ* trailer-dredged material per day. Allowing for bulking, these figures give rise to the bulked volumes, dumping frequencies and daily solids losses set out in *Table 2.5a* below.

Table 2.5a *Assumed Model Input Parameters: Backfilling with Trailers at the South Tsing Yi MBA*

Nominal dredged volume, m^3/day	Dumped volume, allowing for bulking, m^3/day	Number of dumping events per day	Daily sediment release assuming 5% of total dry load, Mg
200,000	286,000	35.7	7,943
150,000	214,500	26.8	5,933
100,000	143,000	17.8	3,972
50,000	71,500	8.9	1,978

Backfilling using trailers has only been modelled for the South Tsing Yi area, as CED/GEO have indicated that there is no intention to backfill using trailers in the North of Lantau area.

2.5.3 *Dumping From Barges*

It is assumed that only material which has been dredged using mechanical dredgers, rather than hydraulic dredgers, will be dumped from barges. No detailed measurements have ever been undertaken in Hong Kong of the average density of grab dredged mud in barges, however bulking factors are generally accepted to be small. We have therefore assumed an overall bulking factor of 1.1. This yields a density in the barge of 1.455 Mg/m^3 if an average *in situ* density of 1.5 Mg/m^3 is adopted. Barges are taken to have a nominal capacity of 800 m^3 and are assumed to be loaded to 90% of that capacity, ie. 720 m^3. The total dry solids released per dump is 520 Mg. A 5% loss of material is thus 26 Mg.

During this EIA, a dumping rate of 10,000 m^3 (*in situ* dredged volume) per day has been modelled for barge dumping at both the South Tsing Yi and North of Lantau MBAs. Allowing for bulking during dredging, these figures give rise to the volumes and dumping frequencies in *Table 2.5b.*

Table 2.5b *Assumed Model Input Parameters: Backfilling with Barges at the South Tsing Yi and North of Lantau MBAs*

Nominal dredged volume, m^3/day	Dumped volume, allowing for bulking, m^3/day	Number of dumping events per day	Daily sediment release assuming 5% of total dry load, Mg
10,000	11,000	15.4	400

2.5.4 *Sediment Release From Other Dredging Operations*

In order to investigate the cumulative impacts arising from the proposed backfilling operations when dredging or disposal is in progress in other parts of the Western and Victoria Harbours, sediment release rates have been estimated for a range of concurrent operations. Modelling scenarios designed to address cumulative impacts have focused on backfilling in conjunction with sand dredging at the southern pit of the South Tsing Yi MBA (presently allocated to CT9) and from the West Sulphur Channel MBA including dredging and reclamation at Green Island. The release rates for the West Sulphur Channel MBA (609 kg/s) have been estimated by DEMAS, consultants to CED/GEO.

The release of sediment from dredging and reclamation operations at CT10 and CT11 (32 kg/s), CT9 (< or ≅32kg/s), Stonecutters Island (2.9 kg/s), Central Reclamation Phase III (< or ≅32 kg/s) and Kowloon Point (≅32 kg/s) was considered but was not modelled because the sediment loss rate is extremely low when compared with sediment loss during dredging at West Sulphur Channel. Potential cumulative impacts other than those modelled in this EIA are assessed in detail in the Cumulative Effects Assessment Manual (CEAM) which is issued as a separate document.

2.5.5 *Modelling Scenarios*

As a result of the above assumptions and considerations, the following modelling runs have been formulated:

Scenario 1

Disposal of 150,000 m^3 day^{-1} of trailer-dredged material at the South Tsing Yi MBA and concurrent disposal of 10,000 m^3 day^{-1} of mechanically-dredged material at the North of Lantau MBA. The number of dumping events per day was assumed to be 26.8 at the South Tsing Yi MBA and 15.4 at the North of Lantau MBA.

Scenario 2

Disposal of 50,000 m^3 day^{-1} of trailer-dredged material at the South Tsing Yi MBA and concurrent disposal of 10,000 m^3 day^{-1} of mechanically-dredged material at the North of Lantau MBA. The number of dumping events per day was assumed to be 8.9 at the South Tsing Yi MBA and 15.4 at the North of Lantau MBA.

Scenario 3

Disposal of 10,000 m^3 day^{-1} of mechanically-dredged material at the South of Tsing Yi MBA and concurrent disposal of 10,000 m^3 day^{-1} of mechanically-dredged material at the North of Lantau MBA. The number of dumping events per day was assumed to be 15.4 at both MBAs.

Scenario 4

Disposal of 200,000 m^3 day^{-1} of trailer dredged material at the South of Tsing Yi MBA plus 10,000 m^3 day^{-1} of mechanically-dredged material at the North of Lantau MBA. The following tidal conditions were considered:

- *4a.* dry season spring tide
- *4b.* dry season neap tide
- *4c.* wet season spring tide
- *4d.* wet season neap tide

The number of dumping events per day was assumed to be 35.7 at the South Tsing Yi MBA and 15.4 at the North of Lantau MBA. (This scenario determined that the dry season spring tide represented the worst case and so was used for all subsequent scenarios).

Scenario 4e

Scenario 4e was designed to represent the backfilling operation proposed under the Operations Plan, ie 100,000 m^3 day^{-1} of trailer dredged material at the South Tsing Yi MBA and 10,000 m^3 day^{-1} of mechanically dredged material at the North of Lantau MBA on the worst case tide (dry season spring tide). The number of dumping events per day was assumed to be 17.9 at the South Tsing Yi MBA and 15.4 at the North of Lantau MBA.

Scenario 5

Scenario 4a plus dredging of surface marine sands from the South Tsing Yi MBA at a rate of 2.4 Mm^3 $month^{-1}$ (ie a sediment loss rate of 65,814 tonnes day^{-1}).

Scenario 6

Scenario 4a plus dredging of bottom alluvial sands from the South Tsing Yi MBA at a rate of 2.4 Mm^3 $month^{-1}$ (ie a sediment loss rate of 2,938 tonnes day^{-1}).

Scenario 7

Scenario 5 plus dredging in West Sulphur Channel and dredging and reclamation at Green Island assuming a sediment release rate of 200 – 800 kg sec^{-1} (ie a sediment loss rate of 19,995 tonnes day^{-1}).

Scenario 8

Scenario 6 plus dredging in West Sulphur Channel and dredging and reclamation at Green Island assuming a sediment release rate of 200 – 800 kg sec^{-1} (ie a sediment loss rate of 19,995 tonnes day^{-1}).

Scenario 9

Modelling was conducted with maximum backfilling rates at the South Tsing Yi MBA (Scenario 4) plus simulated sediment input from dredging and filling activities at Chek Lap Kok airport. Predicted concentrations from the model were compared to actual field data collected as part of the project's environment monitoring and assessment programme.

3 WATER QUALITY AND SEDIMENT TRANSPORT

3.1 INTRODUCTION

This section presents the detailed assessment of potential water quality impacts associated with proposed backfilling operations at North of Lantau and South Tsing Yi Marine Borrow Areas (MBAs). In order to examine a comprehensive range of potential impacts, scenarios were developed and subjected to WAHMO sediment plume and erosion/ deposition modelling on various tidal states.

Impacts investigated include those associated with potential increases in suspended solid concentrations, decreases in dissolved oxygen concentrations, nutrient increases within the water column, and bed deposition/erosion effects. The environmental acceptability of these predicted impacts is assessed, with a view to identifying appropriate operational mitigation measures where necessary to reduce them to acceptable levels.

3.2 STATUTORY REQUIREMENTS AND EVALUATION CRITERIA

3.2.1 *Water Quality Control Zones*

Under the Water Pollution Control Ordinance, Hong Kong waters are subdivided into 10 Water Control Zones (WCZ). Each WCZ has a designated set of statutory Water Quality Objectives (WQO). The two MBAs proposed for backfilling are situated within the following two WCZs:

- South of Tsing Yi MBA – Western Buffer Water Control Zone (WBWCZ) declared in 1993. This site is also located near the boundary of the Victoria Harbour Water Control Zone (VHWCZ) which has not yet been declared.
- North of Lantau MBA – North Western Water Control Zone (NWWCZ) declared in 1992.

3.2.2 *Sediment Quality Criteria*

The material used to backfill the MBAs will be uncontaminated marine mud, as detailed by the Environmental Protection Department (EPD). Therefore the sediments will be of Class A and Class B as stipulated in the EPD Technical Circular No. 1-1-92, Classification of Dredged Sediments for Marine Disposal. Definition of the classification is as follows:

- Class A: Uncontaminated material, for which no special dredging, transport or disposal methods are required beyond those which would normally be applied for the purpose of ensuring compliance with EPD's Water Quality Objectives, or for protection of sensitive receivers near the dredging or disposal areas.
- Class B: Moderately contaminated material, which requires special care during dredging and transport, and which must be disposed of in a

manner which minimizes the loss of pollutants either into solution or by resuspension.

3.2.3 *Water Quality Objectives*

Since sediment disposed in backfilling operations will meet EPD criteria for uncontaminated material, suspended solids (SS), dissolved oxygen (DO) and nutrient WQOs will be of greatest relevance in assessing compliance with statutory requirements. These criteria are as follows:

- *Suspended Solids*: Human activities must not raise the natural ambient SS level by 30% nor cause the accumulation of SS which may adversely affect aquatic communities;
- *Dissolved Oxygen*: DO within 2 m of the bottom should not be less than 2 mg l^{-1} for 90% of the samples. Depth averaged DO should not be less than 4 mg l^{-1} for 90% of the samples (not less than 5 mg l^{-1} for fish culture zones).
- *Nutrients*: Nutrients must not be present in quantities that cause excessive algal growth.
- *Inorganic Nitrogen*: Annual mean depth averaged inorganic nitrogen must not exceed 0.5 mg l^{-1} in North Western WCZ and 0.4 mg l^{-1} in Western Waters WCZ.

It is understood that EPD do not necessarily consider the Water Quality Objectives for SS concentrations to be appropriate as the sole assessment criteria for temporary dredging or backfilling projects. Nevertheless, it is important to calculate predicted compliance or noncompliance with SS WQOs as an initial screening of the acceptability of environmental impacts. Details on the calculation and application of SS, DO and nutrient WQOs is provided in *Sections 3.8.1, 3.8.2* and *3.8.3*, respectively. In addition to these WQOs, some sensitive receivers (eg mariculture zones and cooling water intakes) have specific criteria with which the backfilling operations must comply. These are detailed in *Section 3.5*.

3.3 HYDRODYNAMIC CONDITIONS

3.3.1 *Circulation and Mixing*

The hydrodynamic characteristics of the Study Area are determined primarily by the influence of tidal currents and flows from the Pearl River delta. Approximately 80% of the water discharged annually from the Pearl River occurs during the summer months, depositing several million tonnes of sediment and organic material into Hong Kong Territorial Waters. Subsequent changes in silt and pollutant loads create seasonal variations in water quality. In addition, the marine waters become highly stratified as the large influx of freshwater creates a layer of brackish water overlying the denser, more saline oceanic waters near the sea bed. During the dry winter months the water column is well mixed as oceanic waters move northwards into the Pearl River estuary, as the influx of freshwater from the Pearl River is greatly reduced.

3.3.2 *Tidal Flows and Currents*

In order to assess the impact of backfilling operations upon marine water quality it is necessary to determine the tidal flows and current speeds which will act upon the dredged material, within the water column and at the sea bed. These vary according to seasonal, monthly and diurnal cycles. Spring and neap tides have been investigated, during both the wet and dry season. In addition the daily tidal state, flood or ebb, may influence the degree of potential impact upon water quality.

On a daily cycle, ebb tides in the vicinity of the Study Area flow down through the Urmston Road, bifurcate north west of Chek Lap Kok to flow south down the west coast of Lantau, southeast around the north and south of Chek Lap Kok island, and east along the southern Tuen Mun shoreline. This flow pattern reverses during the flood tides and has been confirmed by field surveys of currents in the study area (28 November 1994 - 4 December 1994). These circulation patterns cause predictable seasonal patterns in water mixing as indicated on *Figure 3.3a*.

Tidal divergence and convergence in the study area north of Lantau results in current flows which vary with season and depth in addition to tidal and Pearl River flows. In the wet season, horizontal density gradients result as a denser layer of oceanic water pushes landward near the sea bed, and water currents near the sea bed are often slow on both the rising and falling tides. The fastest water current velocities have been found to occur during the dry season spring tide, when the oceanic waters have intruded into the Pearl Estuary and well mixed conditions result, as mentioned above. This results in relatively high water velocities over the whole depth of the water column [(1)]. Peak surface water velocities of 1 m s^{-1} at South Tsing Yi MBA and 1.4 m s^{-1} at North of Lantau MBA have previously been observed during the dry season spring tide (December 1994). Both wet and dry season neap tide water velocities are much lower for most of the tidal cycle, while the wet season spring tide water velocities vary with tidal state (ebb or flood) and are intermediate between 0.3 - 0.7 m s^{-1} in the surface layer. These differences in water velocities of various tidal states have been taken into account in the water quality modelling simulations.

3.4 FUTURE CONDITIONS

It is anticipated that, with the progressive implementation of the various pollution control schemes by the Hong Kong Government, the water quality within the area of the two MBAs will improve. These controls include the enforcement of the Livestock Waste Control Scheme, the Sewage Master Plan for Tuen Mun, Tsuen Wan, Kwai Chung and Tsing Yi, and the declaration of the Victoria Harbour WCZ. However, pollutant loads transported by the Pearl River, which are likely to equal or exceed loadings originating in Hong Kong, will continue to affect water quality in the MBAs.

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(1) EGS Field Data Report. Backfilling of Marine Borrow Pits. North Lantau and South Tsing Yi Feasibility Study and EIA. Current Meter and Related Measurements. Final Report, January 1995, Report No. HK87594

3.5 *SENSITIVE RECEIVERS*

As identified in the IAR, there are a number of sensitive receivers which may be affected by the changes in water quality resulting from backfilling activities. These are indicated on *Figure 3.5a* and have been listed below in accordance with the HKPSG, which provides guidelines for identifying environmental factors influencing development planning.

Bathing Beaches: A number of gazetted bathing beaches which may be affected by water quality impacts are located along the Tsuen Wan and Tuen Mun coastline. These include Anglers, Butterfly, Gemini, Hoi Mei Wan, Casam, Lido, and Cafeteria beaches. Other potentially affected gazetted and non-gazetted beaches include Sha Chau, Discovery Bay, and Silvermine Bay beaches.

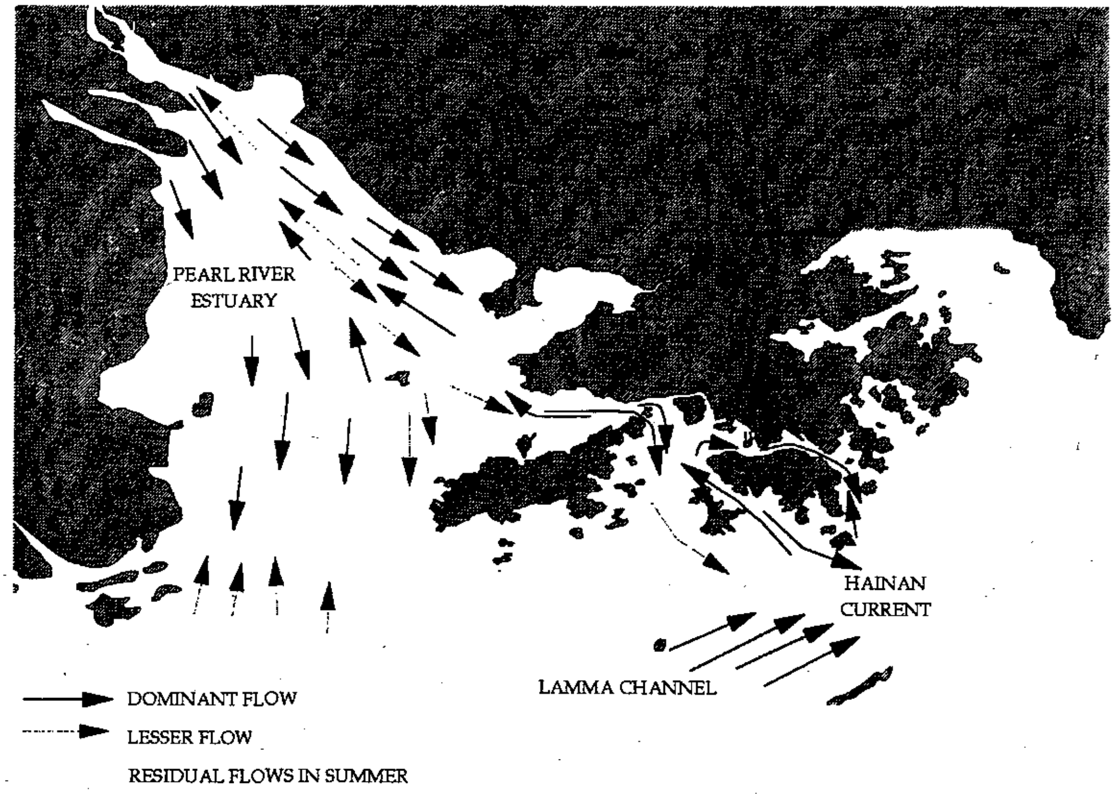
Power Stations: Power stations in the area also have criteria for SS levels in cooling water intake since increased particulate matter in the seawater supply could block filters and damage cooling water intake pumps. The Castle Peak Power Station has a 5 km radius within which the water quality must be maintained below 150 mg l^{-1} of SS. The Black Point Power Station which is scheduled to be commissioned in 1996 is expected to have similar requirements. The Lamma Power Station cooling water intake criteria is 140 mg l^{-1}, as is that of the Tsing Yi Power Station, which is currently in standby mode.

Other Cooling and Flushing Water Intakes: There are a number of additional cooling water and flushing water intakes in the vicinity of the study area. Each of these have specific criteria with which the backfilling operations must comply, namely the Kennedy Town, Tsing Yi, Tsuen Wan and Tuen Mun WSD Intakes (which have a target limit of 10 mg l^{-1}), Queen Mary Hospital Intake (140 mg l^{-1}) and Wah Fu Estate Intake (140 mg l^{-1}).

Fisheries and Mariculture: The sensitive receivers include several fisheries and mariculture areas close to the study area with individual criteria. These are Ma Wan Fishery, Ma Wan Fish Culture Zone (FCZ), Kau Yi Chau Fishery, Pennys Bay Fishery, Tung Wan Tsai Fishery, Tai Pak Wan Fishery, Lo Tik Wan FCZ, Silvermine Bay Fishery and Sok Kwu Wan FCZ. According to new *ex-gratia* arrangements for mariculturists, at any one time the SS concentration must not exceed 50 mg l^{-1} or exceed by 100% the highest level recorded at the fish culture zone during the five years before commencement of works in the vicinity. If these levels are exceeded the mariculturists may opt for *ex-gratia* payments.

There are also a number of sensitive water bodies which may be affected by backfilling at the MBAs. Those are East Tung Chung Bay, Rambler Channel and Chek Lap Kok Sea Channel.

Each of these identified sensitive receivers has been plotted in the WAHMO sediment plume simulations, except for East Tung Chung Bay, Rambler Channel, and the Tsing Yi, Tsuen Wan and Tuen Mun WSD Intakes, which are not affected by any of the modelled scenarios. The plotted sensitive receivers are shown on *Figure 3.5a*. Other points which do not represent sensitive receivers (eg North of Lamma, West Green Island, Mid Western Harbour, West of Tsing Yi and West of Ma) are plotted for reference only for some the modelling scenarios. Results of the modelling scenarios are discussed in *Section 3.8*.



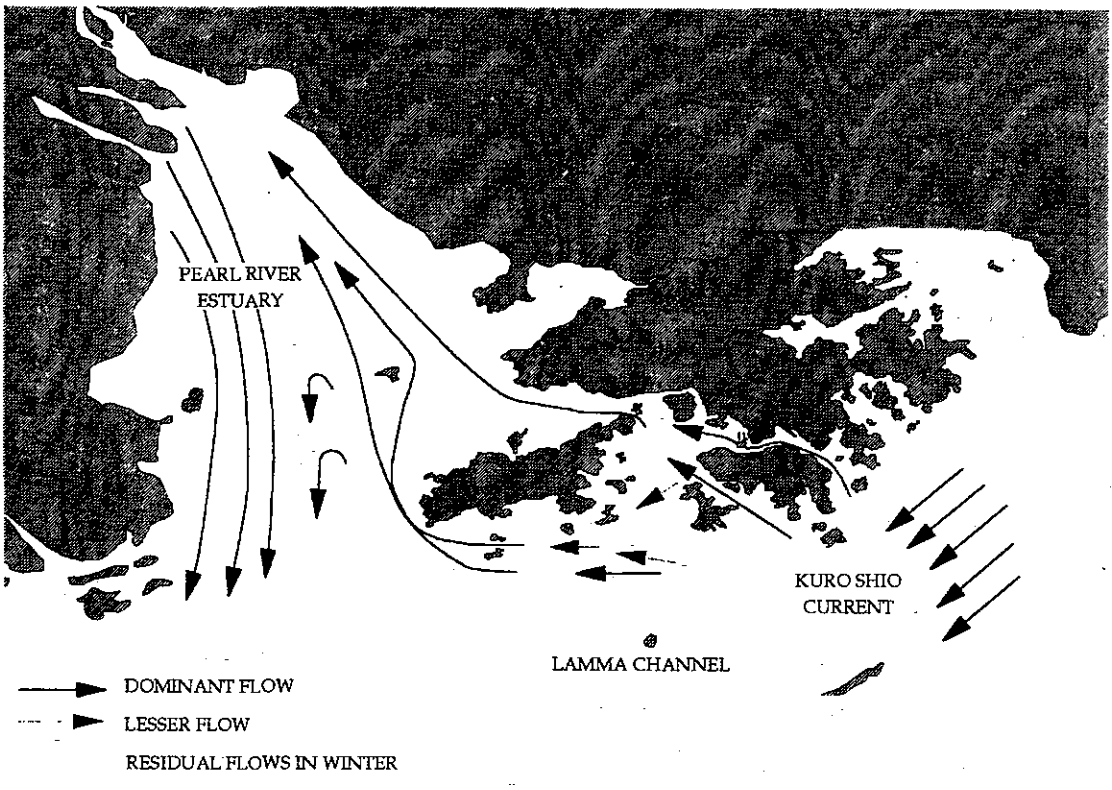


FIGURE 3.3a - RESIDUAL SEASONAL WATER FLOWS IN THE REGION

ERM Hong Kong, Ltd
6th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

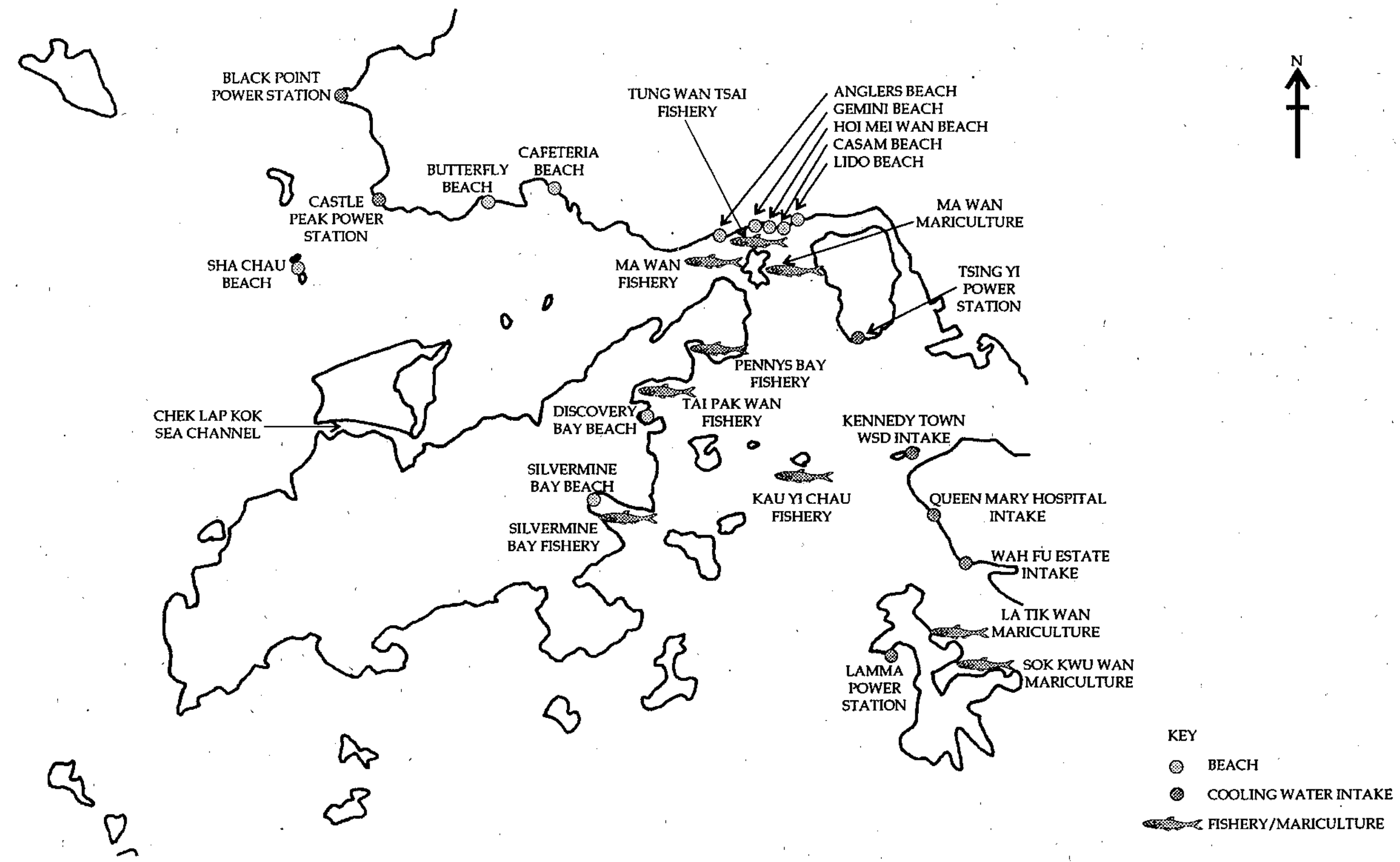


FIGURE 3.5a - WATER SENSITIVE RECEIVERS

ERM Hong Kong

6th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

ERM

3.6 *General Impact Processes*

The extent of potential water quality impacts, resulting from backfilling activities at the MBAs, will be highly dependent upon a number of factors. These include:

- the physical and chemical nature of the dumped spoil;
- the dispersion characteristics of the receiving waterbody at the MBA;
- the rate of backfilling operations ie the quantity of spoil to be dumped per day; and
- the number, nature and proximity of the sensitive receivers.

Discussions of the physical and chemical effects of spoil disposal, as well as factors affecting spoil loss to suspension or erosion are provided below.

3.6.1 *Physical Effects*

Water quality impacts resulting from marine backfilling arise directly from the increased concentration of SS in the water column. This leads to a reduction in light penetration and increased heat retention. Physical effects can also occur in the form of smothering of marine organisms through obstruction or irritation of gill filaments and other membranes. The extent of physical effects will depend on the amount of material put into suspension during the backfilling operations, and the dispersive forces acting on the suspended material.

3.6.2 *Chemical Effects*

Since it is anticipated that material disposed of at the MBAs will be uncontaminated mud, resulting chemical effects are expected to be confined to dissolved oxygen impacts, and those associated with increases in nutrient concentrations.

Material with high oxygen demand can interact with conditions caused by high levels of SS, to cause substantial declines in DO. An increase in solids in the water column reduces light penetration, and subsequently diminishes photosynthesis except in the immediate surface layer. This, therefore, reduces the rate at which oxygen is produced in the water column. The effects of SS on temperature, as described above, also act to reduce DO levels since the solubility of oxygen in water decreases with increasing temperature.

In addition, increased concentrations of nutrients released from backfilling activities may promote algal growth in the upper layers of the water column (ie, in the upper water layers receiving sufficient light to enable photosynthesis). Increased algal growth can lead to algal blooms, which have the potential to cause eutrophication. This is a condition which results as algal blooms die and enter the lower water column, where they create a substrate with high oxygen demand, and promote oxidation by marine organisms. Anoxic conditions may result if DO concentrations cannot accommodate increased oxidation, or are not replenished.

The extent of chemical effects associated with proposed backfilling operations will depend on the oxygen demand and nutrient content of the disposed material and the degree of interaction with the physical effects described above.

3.7 *SPOIL LOSSES*

The cause of spoil losses, which could lead to the above impacts, can be divided into two distinct stages:

i) losses to suspension during and immediately following dumping (ie, caused by entrainment into the water column as the spoil descends to the seabed and as a result of the generation of an impact cloud as the spoil hits the sea bed and previously dumped spoil); and

ii) in the longer term, losses as dumped spoil is reworked by tidal and wave induced currents, and eroded and transported from the MBA.

The effects of each of these stages are discussed in detail below. Predictions of spoil losses and evaluation of impacts for backfilling of the North of Lantau and South Tsing Yi MBAs are presented in *Section 3.8*.

3.7.1 *Suspension Effects*

Spoil loss during backfilling operations will be determined by factors influencing sediment entrainment in the water column and those forces acting to transport these entrained sediments. The loss of sediment to the water column during the dumping process occurs in two stages:

- material lost due to 'stripping' of fine sediment from the sediment mass as it descends through the water column (this effect is distributed throughout the water column);
- material lost due to stripping from the top of the radially–expanding bottom density surge after impacting the seabed as detailed below.

The actual volume of spoil loss due to suspension will depend on the density and composition of the spoil, and the rate of dumping. Other factors, such as dilution will influence the proportion of material lost during a particular dumping event. Dredged material undergoes considerable dilution during dumping from both trailer–dredgers and barges. The degree of dilution is a function of the size of the barge openings, the speed of discharge and the water depth. The dilution decreases as the size of the hopper or barge openings increases and as the speed of discharge increases.

The characteristics of spoil material, and hence the efficacy of the suspension processes detailed above, will vary according to the original extraction method used.

3.7.2 *Effects of Dredging Properties on Spoil*

The effects of two types of dredging method have been considered:

1) hydraulic dredging using trailing suction hopper dredgers
2) mechanical dredging using grab–dredgers.

These two methods account for the overwhelming majority of mud dredged in Hong Kong. A small amount of mud has been dredged in the past (eg. North Lantau Expressway) using bucket ladder dredgers and the effects of this method are similar to those caused by grab dredging. Some mud was also dredged at the Chek Lap Kok Airport site using cutter suction dredgers, which pumped the mud to a rehandling pit where it was subsequently re-dredged using trailers, for transport to the disposal area. The use of cutters to load directly into barges is most unlikely because of the dilution which takes place during dredging which would result in an uneconomic volume increase for transport. The two types of dredging process which have been considered thus adequately reflect the methods which are relevant to this EIA.

Dredging with Trailing Suction Hopper Dredgers

During dredging by hydraulic methods, such as that employed by trailing suction hopper dredgers, mud undergoes a degree of dilution due to limitations of the pumping system. In extremely soft, semi fluid mud the density of the material delivered to the hopper may be close to that of the material *in situ* but, as the cohesive properties and *in situ* density of the mud increases, so too does the degree of dilution.

In addition, the nature of the area which is being dredged also affects the hopper densities which can be achieved. In cases where the dredger is working in large unconfined areas where frequent turning is not required, relatively high hopper densities can be achieved. When working in confined areas, frequent turning and the need to raise the dragheads from the seabed when turning leads to increased entrainment of water and lower hopper densities.

Limited and somewhat crude measurements undertaken during dredging operations in the Black Point MBA during overburden stripping operations in connection with the Tin Shui Wai land formation project (Engineering Geology Ltd., 1988) [2], showed that during dredging by trailer–dredgers, the mud is reduced to a lumpy slurry comprising approximately 10% softened lumps of greater than 35 mm size. Approximately 80% of the material was greater than 2 mm in diameter. The remainder comprised smaller lumps and fluid mud.

Dredging with Grab–dredgers

Mechanical dredging methods, eg. grab dredging, involve much less remoulding and dilution of the mud. The dredged mud comprises large lumps ($\geq 1m^3$) of remoulded but generally intact material with a relatively small amount of slurry. Much higher barge densities and lower bulking factors can be achieved than is usual with hydraulic dredging methods.

3.7.3 *Effects of Dumping on Spoil Properties*

Processes operating during dumping

The hydrodynamic conditions at the backfilling site, as well as the characteristics of the backfill material, will determine the forces acting upon SS released into the water column during dumping. The impact of SS on sensitive receivers will be based on factors influencing sediment transport and the formation of sediment plumes.

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(2) Engineering Geology Ltd., (1988). *Tin Shui Wai Development, Hong Kong. Bottom–dumping of borrow area overburden: Report and assessment of the Wiesbaden Dumping Trials (16th June, 1988).* Report to Bilfinger + Berger Dredging BV, Amsterdam.

There are a large number of published accounts detailing the effects of dumping on dredged material, both theoretical and observational. The majority of these are the results of research undertaken in the United States (mainly by the Corps of Engineers). In addition, Japanese studies (eg. Nakai, 1978) [3] provide useful data, and a limited amount of work has also been undertaken in Hong Kong (eg. Engineering Geology, 1989 [4]; Binnie Consultants Ltd, 1993) [5].

The basic processes which operate during dumping can be divided into three stages (Pequegnat *et al.*, 1978) [6] as follows:

- convective descent;
- impact (or dynamic collapse); and
- passive diffusion.

Upon release from the barge or trailer–dredger, the material descends rapidly as a well–defined turbulent jet, at a speed far in excess of the natural settling velocity of the component soil particles. Transit sonar measurements of descent speed during dumping from a 4,000 m^3 trailer–dredger in Hong Kong (Engineering Geology, 1988) [7] showed that the average descent speed, in about 20 m of water, was 3 – 4 m s^{-1} and that the seabed impact speed was between 5 – 6 m s^{-1}.

During descent, the material undergoes considerable dilution as a result of axial spreading of the jet and entrainment of ambient water. Two types of dilution can be distinguished:

- In the case of slurrified dredged material (eg, the slurry component of trailer–dredger mud), the dilution is a true dilution of the slurry.

- In the case of mechanically–dredged material, which comprises large softened lumps of mud with a relatively small slurry component, the dilution is principally one where the lump fraction spreads out during descent.

A proportion of the slurrified material is stripped from the descending jet and remains as a turbid cloud in the main part of the water column. Depending on water depth and hydrodynamic conditions at the dump site, this material may be transported considerable distances by water currents.

In deep water, the dilution of the jet eventually reaches the stage where dynamic collapse occurs. The density of the jet is reduced to a density

(3) Nakai, O., (1978). Turbidity generated by dredging projects. Management of bottom sediments containing toxic substances: Proceedings of the Third U.S./Japan Experts Meeting, EPA–600/3–78–084, U.S. Environmental Protection Agency, Washington D.C.

(4) Engineering Geology Ltd., (1989). *Tin Shui Wai Development, Hong Kong. Bottom–dumping of borrow area overburden: Report and assessment of the Wiesbaden Dumping Trials (1st December, 1988).* Report to Bilfinger + Berger Dredging BV, Amsterdam.

(5) Binnie Consultants Ltd., (1993). *Report on surveys and dumping experiments undertaken in the redundant marine borrow pits off Black Point in Urmston Road.* Final Report to the Geotechnical Engineering Office, Civil Engineering Department, Hong Kong.

(6) Pequegnat, W.E., Smith, D.D, Darnell, R.M., Presley, B.J. and Reid, R.O., (1978). An assessment of the potential impact of dredged material disposal in the open ocean. Technical report D–78–2, US Waterways Experiment Station, Vicksburg, Ms.

(7) Engineering Geology, (1988) op. cit.

similar to that of the surrounding seawater, and the material becomes subject to passive diffusion processes with the individual soil particles, or lumps, settling at a terminal speed appropriate to their size, shape and density. The theoretical settling speed may be reduced slightly in turbulent waters. However, in Hong Kong the water is not deep enough for dynamic collapse to occur and the jet will always impact the seabed at considerable speed. The only possible exception to this may arise if very small barges (eg less than 200 m^3), were used to slowly discharge highly slurrified material.

Detailed analysis of the data from the second Wiesbaden dumping trial (Engineering Geology, 1989) [8] determined that, after impacting upon the seabed, the diluted, low-density material eroded a considerable amount of original seabed (or previously dumped) material and rapidly increased in density as a result of entrainment of this material. The dumped material spread laterally as a radially-expanding bottom density surge. During the first 30 m of the initial spreading of this surge, net erosion of the seabed enabled the surge to increase in density; this was accompanied by an increase in thickness of the surge until dynamic equilibrium (between density, thickness and propagation velocity) occurred. After this stage had been reached, the result was net deposition on the seabed and the bottom surge decayed. The surge travelled up to a distance of about 150 m from the impact point before it effectively came to a halt.

During radial spreading, some material is stripped from the top of the density surge in a manner broadly similar to the stripping of material from the descending jet. As before, this material can be advected from the dump site by water currents. The remainder of the material settles to the seabed; a proportion of this material might be eroded again by tidal currents and carried out of the area.

Bokuniewicz and Gordon (1980) [9] studied the effects of dumping on the lump fraction of the original discharged material. They concluded that lumps do not undergo any marked degree of degradation during descent or impact. Some additional softening and remoulding occurs, particularly during impact, but the lumps remain essentially intact and settle on the seabed close to the impact point.

It is understood that EPD have, in the past, accepted a figure of 5% as being representative of the immediate loss of solids during dumping operations, independent of whether the dumped material is hydraulically or mechanically dredged, and that EPD consider the loss should be assumed to take place in the upper part of the water column. Available data from measurements undertaken in Hong Kong and elsewhere, suggest this scenario to be very conservative and that losses are generally lower in percentage terms and are distributed throughout the water column rather than confined to the near-surface zone.

The most relevant data stems from experiments conducted in the redundant MBA in Urmston Road, near Black Point, during the Fill Management Study

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(8) Engineering Geology 1989 op. cit.

(9) Bokuniewicz *et al.*, (1978). *Field study of the mechanics of the placement of dredged material at open-water sites.* Technical Report D-78-7, prepared by Yale University for the US Army Waterways Experiment Station, Vicksburg, Miss., U.S.A.

Phase II (Binnie Consultants Ltd., 1993). [10] The Geopodes IX, a 6,400 m^3 trailer–dredger dumped two loads of marine mud, dredged from the site of Chek Lap Kok Airport, into approximately 27 m of water. The losses were measured using Acoustic Doppler Current Profilers. An analysis of two dumping events indicated that about 6% of the material passed through a line 300 m downcurrent of the dump site and about 3% passed through a line 600 m downcurrent of the dump site. The trials did show, however, that the majority of the material was transported in the lower part of the water column. These data should be viewed in the context of the relatively fast currents in the area where the experiment was undertaken and the fact that the site was at the edge of a rather poorly–defined pit. Dumping into a better–defined pit with slower water currents might have resulted in much lower losses.

Nakai (1978) [11] summarised observational data from several dump sites in Japan. Full details of soil type, trailer size and hydrodynamic conditions are not provided but the data can be used at an indicative level. These data are summarised in *Table 3.7a*. The Turbidity Generation Unit (TGU) shown in *Table 3.7a* is the estimated loss of sediment from the immediate area of the dump. The data are insufficient to convert the TGU figures given in the table to percentage losses since the conversion will vary considerably depending upon the soil characteristics and the density of the material in the barges. However, at an indicative level, if a hopper or barge density of 1.455 Mg m^{-3} is assumed, a 5% loss would equate with a TGU of about 36 kg m^{-3}. Therefore, *Table 3.7a* shows that for most of the vessels and most of the material types, losses would be well under 5%.

Table 3.7a *Observed dumping losses from projects in Japan (after Nakai, 1978)*

Dump vessel	Volume or power	Type of material			TGU, kg m^{-3}
		Classification	% < 5 microns	% <74 microns	
Barge	500 m^3	Silty loam	36.5	36.5	14.9
		Silty loam	10.0	21.5	15.8
		Silty clay loam	15.0	20.5	10.6
	180 m^3	Sand	-	2.7	0.02
		Silty clay loam	27.5	57.7	8.3
	120 m^3	Sandy loam	-	22.7	3.8
		Silty loam	6.8	19.1	143.5
Trailer dredger	2,400 HP	Silty loam	19.4	68.6	22.7
	1,800 HP	Clay	33.4	82.2	123.4

More published observations are available from the United States and these have been summarised by Truitt (1986) [12]. *Table 3.7b* is adapted from this summary.

(10) Binnie Consultants (1993) op. cit.

(11) Nakai (1978) op. cit.

(12) Truitt, C.L., (1986). *Fate of dredged material during open–water disposal.* Environmental Effects of Dredging, Technical Notes, EEDP-01-2, US Army Waterways Experiment Station, Vicksburg, Miss., U.S.A.

Table 3.7b *Summary of dumping loss observations in the U.S.A. (after Truitt, 1986b).*

Data source	Water depth (m)	Bottom current	Material	Dredger	Dumping vessel	Volume, m^3	Sediment in upper water column, %
1	18.3 – 19.8	0.06 – 0.3	Silt–clay	Grab	Barge	920 – 2,300	1
4	51.8	0.21 – 0.7	Marine silt	Grab	Barge	1,150	1
4	67.0	0 – 0.21	Sandy silt	Grab	Barge	380 – 535	1
5	15.8 – 24.4		Silt and Clay	Grab	Barge	1,380 – 3,060	3.7
3	19.8 – 21.3	0.06	Silt–clay	Grab	Barge	840	2 – 4
2	13.7	0.09 – 0.25	Silt–clay	Trailer	Trailer	995	1 – 5
4	14.9 – 18.0	0 – 0.21	Sandy silt	Trailer	Trailer	690	1
4	25.9	0.06 – 0.24	Marine silt	Trailer	Trailer	6,120	1
4	16.8 – 45.7	0 – 0.21	River silt	Trailer	Trailer	690	1

Data Sources: 1. Gordon, 1974 2. Sustar and Wakeman, 1977 3. Truitt, 1986a 4. Bokuniewicz *et al.* 1978 5. Tavolaro 1982

The work of Gordon (1974) [13] focused on maintenance dredging materials with 60 – 90% of the material falling within the silt/clay size range, ie. broadly similar to Hong Kong marine mud. It was calculated that about 1% of the dumped material was stripped from the descending jet and remained in the main part of the water column. The remainder was transported along the bed as a density surge, 3.5 - 4.5 m thick; 80% was deposited within a radius of 30 m, and 90% was deposited within a radius of 120 m.

Sustar and Wakeman's (1977) [14] work at three sites in the San Francisco area determined that:

1) dumping resulted in the creation of a well–defined bottom–surge with a thickness of about three metres and in which concentrations exceeded 300 mg l^{-1},

2) between 1 and 5% of the material dumped remained in the main part of the water column above the bottom surge, and

3) that the cause of most of the main sediment plume was due to spillage from the dredger as the vessel turned in the disposal site and from disturbance by the vessel itself of the released jet of material.

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(13) Gordon, R.B., (1974). *Dispersion of dredged spoil dumped in near–shore waters.* Estuarine and Coastal Mar. Sci., Vol. 2, pp 349–358.

(14) Sustar, J. and Wakeman, T., (1977). *Dredge Material Study, San Francisco Bay and Estuary – Main Report.* U.S. Army Engineer District, San Francisco, Calif.

The amount which could be attributed solely to stripping from the descending jet was not established but might be inferred to be much less than the upper-bound estimate of 5% loss. In addition, they studied a site in 180 m of water where they concluded that 'most' of the material could be identified as having come to rest in an area of about 150 x 300 m.

Bokuniewicz *et al.* (1978) [15] studied seven sites and concluded that in most cases less than 1% of the dumped material contributed to the sediment loss in the upper part of the water column. Significant solids concentrations were only found in a 'well-defined bottom layer'.

Tavolaro's (1982) [16] work is unique both because it represents the combined observations of 229 barge loads of material amounting to a total of ≈ 600 000 m^3 , and because the results are based on a detailed mass-balance assessment. This contrasts with the work described in the preceding paragraphs which was undertaken by measuring solids concentrations using siltmeters and gravimetric methods. The mass balance approach combines detailed geotechnical data about the dumped material, both in the barges and after deposition on the bed, with precision bathymetric surveying, to establish the total loss of solids. Tavolaro [17] concluded that approximately 3.7% of the dumped material mass could not be accounted for. However, it should be noted that a proportion of this loss may have been due to erosion after dumping rather than stripping during descent of the dumped material and during the radial expansion of the bottom surge.

Truitt's (1986a) [18] work was undertaken in the Duwamish Waterway in Seattle, and combined mass balance analysis with siltmeter and gravimetric observations, thus resulting in two independent estimates of loss. The total flux of solids, including the bottom surge, at a radius of 30 m was estimated to be between 7 and 14%. The amount lost to the water column above the bottom layer was estimated to be in the range 2 to 4%. Virtually no effects were noted in the near-surface zone.

The data presented here suggests that losses during dumping, from both barges and trailer-dredgers are often less than 5%. Losses are more typically approximately 1-2%, and sediment transport at the dump site is dominated by a near-bed density surge. There is no information to suggest that large amounts of material are lost to the upper part of the water column. Since modelling undertaken for this EIA has assumed a 5% loss at the surface, it is therefore considered to be conservative.

3.7.4 *Properties of Spoil Affecting Erosion and Resuspension*

The following two sections describe theoretical aspects of erosion and resuspension processes. Actual predictions of erosion and resuspension for backfilling of the North of Lantau and South Tsing Yi MBAs is discussed in *Section 3.11*.

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(15) Bokuniewicz *et al.* op. cit.

(16) Tavolaro, J.F., (1982). *Sediment budget study for clamshell dredging and disposal activities.* U.S. Army Engineer District, New York, U.S.A.

(17) Ibid

(18) Truitt, C.L., (1986a). *The Duwamish Waterway capping demonstration project: Engineering analysis and results of physical monitoring.* Technical report D-86-2, US Army Waterways Experiment Station, Vicksburg, Miss., U.S.A.

Muds which have been dredged by trailer or grab–dredgers and then dumped, will comprise two components;

- lumps of remoulded and softened mud; and
- a fluid or semi–fluid slurry component.

In both cases, the dumping process will lead to slight degradation of the lump fraction but, as shown by Bokuniewicz and Gordon (1980) [19], this is not expected to be significant. The fluid component of both types of dredged material will increase in volume during dumping as a result of entrainment of ambient water.

The lump fraction of grab–dredged material will comprise much larger lumps than those resulting from trailer dredging, and are likely to be carried a shorter distance from the impact point. Therefore the resulting deposit may have slightly greater stability than those resulting from smaller trailer–dredged lumps. However, both types of deposit can be expected to be broadly similar in terms of their resistance to erosion by water currents. Therefore, the most important difference between grab and trailer–dredged material, in the context of this EIA, concerns the relative proportions of the lump and slurry components.

Recent measurements undertaken at the South Cheung Chau disposal site and the East Sha Chau contaminated mud disposal pits (CMPs) provide useful data concerning the properties of dumped dredged material. The general characteristics of the dumped material are described by Selby and Foley (in press, 1994) [20]. Based on the results of chirp acoustic profiling in the East Sha Chau Pits, they have identified three types of material resulting from the dumping of mechanically–dredged materials:

- Fluid mud suspensions;

- Extremely soft mud with a shear strength of < 2 kPa and bulk densities in the range 1.1 – 1.45 Mg m^{-3}; and

- Soft muds representing the lump fraction of the dumped material, with shear strengths lying between the remoulded strength and the undisturbed strength of the original material prior to dredging.

Fluid mud suspensions appear to grade vertically into extremely soft mud, and both tend to form ponds in the depressions on the surface of the main mound of soft mud and around the mound adjacent to the sides of the pit. It was found that the extremely soft mud can be eroded to form mobile suspensions under the action of strong tidal and wave–induced currents. One of the objectives of the active management policy at the East Sha Chau CMPs was to minimise the occurrence of fluid mud suspensions and extremely soft mud, and particularly the formation of large ponds. This is reported to have been achieved by dumping evenly over the whole area of the pit rather than focusing the dumping operations at the centre of the pit.

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(19) Bokuniewicz and Gordon (1980), op. cit.

(20) Selby, I. and Foley, M. (In press, 1994). *An application of chirp acoustic profiling: Monitoring dumped muds at sea bed disposal sites in Hong Kong*. Journal. Mar. Environmental Eng.

Measurements undertaken in East Sha Chau Pit 1 by HR Wallingford Ltd in June and July 1993 [21] using a nuclear transmission gauge and an ultrasonic density meter, showed a broadly similar situation. Fluid mud layers were encountered with densities in the range 1.1 – 1.3 Mg m^{-3} and up to 4 m thick.

The above data relate to the properties of grab-dredged mud, dumped from barges. No recent data has been obtained concerning the properties of trailer-dredged mud. Some data was obtained during the BMAT study (Maunsell Consultants, 1990) [22] in the Urmston Road pits which were backfilled with a mixture of grab-dredged and trailer-dredged marine muds, and alluvial silts and clays. The data are difficult to interpret with confidence due to the mixed soil types and the fact that grab-dredged and trailer-dredged materials were often dumped in the same areas. Evans (1992) [23] reviewed these data and concluded that trailer-dredged materials had wet densities which were lower than grab-dredged materials. However, the investigations were not undertaken in a manner which enabled an assessment of the volume and properties of the fluid and semi-fluid components of the dumped materials, and it is these which are of primary importance in the estimation of possible erosion losses from dumped materials.

It is anticipated that dumping trailer-dredged muds, will generate a larger proportion of easily eroded fluid muds, than dumping grab-dredged materials. The measurements made by Engineering Geology Ltd (1988) [24] of trailer-dredged mud suggest that about 80% of the material comprises lumps greater than 2 mm diameter. If it is assumed that the lump fraction does not disaggregate during dumping, this suggests that fluid and semi-fluid muds are unlikely to comprise more than 20% of the dumped material. Dilution during descent will inevitably increase the volume, but not the solids mass, of this material. In contrast, it seems unlikely that more than about 5% of grab-dredged and dumped material will form low density, easily eroded materials.

3.7.5 *Long Term Erosion of Spoil*

Once the spoil has been dumped, water quality impacts may arise due to erosion of the newly deposited spoil from the seabed. After disposal, spoil consolidation will be a slow process which can be hindered by tidal and wave-induced 'bed shear stresses'. The greater the bed shear stress, the more likely it is that the dumped spoil will be eroded and moved across the seabed as described for suspended material above. As is the case with suspension, the probability of erosion is largely dependent on material characteristics. Soft or fluid mud, such as that dredged by a trailer hopper dredger can be easily eroded given sufficient bed shear stresses.

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(21) Contract Number GC 91/01, Fill Management Study, Phase III: Mud Management, Bed Density Profiles, EGS Report No. HK 72393, July 1993

(22) Maunsell Consultants Asia Ltd., (1990). *BMAT: Backfilled Mud Anchor Trials Study, Discussion Paper No. 6, Geotechnical Review.* Report to the Geotechnical Engineering Office, Civil Engineering Department, Hong Kong (Agreement CE 34/89)

(23) Evans, N.C., (1992). *Geotechnical aspects of mud dredging and dumping.* Special Project Report SPR 13/92, Geotechnical Engineering Office, Civil Engineering Department, Hong Kong.

(24) Engineering Geology (1988) op. cit.

Previous studies of spoil stability in MBAs have indicated that, for backfill levels below natural local bed levels, spoil with densities close to naturally occurring *in situ* densities is unlikely to be eroded by commonly occurring hydraulic conditions. The erosion of soft material from the MBAs will be sensitive to backfill levels and whether tidal flows generate a velocity profile which extends sufficiently deeply into the pit to erode the soft material. The velocity profile in the pit is of major importance and will depend on the local tidal conditions, orientation of the pit with respect to the main flows and extent of the pit in the main flow direction. Since artificially deepened areas such as navigation channels and MBAs will experience lower bed stresses from tidal flows and wave action, spoil deposits in these areas are unlikely to be re-eroded except by extreme events.

3.8 *ASSESSMENT METHODOLOGY*

3.8.1 *Suspended Sediment*

The water quality modelling used for this EIA predicts the increase in SS concentrations above the ambient level. Therefore, to interpret this data, this predicted increase must be added to the existing ambient SS concentration to obtain the 'actual' SS concentration which is likely to occur. Compliance is assessed by comparison of this 'actual' SS concentration with the existing baseline, thus it is important to determine an accurate baseline concentration for potentially affected areas.

This study has modelled scenarios which examine backfilling operations at both South Tsing Yi and North of Lantau MBAs. The plume movement diagrams have demonstrated substantial waterbody exchange throughout the Western Harbour and that it is appropriate to use one value to represent background concentrations in this area. Baseline concentrations were determined by amalgamating and evaluating the most recent data (1992-1994) from all EPD routine water quality monitoring stations in the study area (ie. stations VM8, VM12, WM2, WM3, WM4, NM1, NM2, NM3), to determine the overall baseline SS and DO concentrations. This approach was agreed by EPD at the 2nd Study Management Group meeting held 26 May 1995 for all SS sensitive receivers except for the Water Supplies Department Kennedy Town Water Intake. Due to its low threshold criterion for SS, ambient values of SS in the vicinity of the Kennedy Town Intake are calculated using data from Station VM8 alone. EPD routine water quality monitoring stations used in this assessment are shown in *Figure 3.8a*.

At the 26 May 1995 meeting it was also agreed that the 90th percentile value (ie the value that 90% of the data points fall below) from the above data was the most appropriate value to use to represent ambient conditions for purposes of calculating the WQOs. The 90th percentile concentration was calculated as 25 mg l^{-1} for the entire study area and thus the applicable water quality objective is 32.5 mg l^{-1}. The ambient SS concentration calculated from Station VM8 for the WSD Kennedy Town Intake is 16.9 mg l^{-1}.

Summary of Modelling Exercises

Suspended sediment plumes resulting from backfilling and dredging activities at the North of Lantau and the South Tsing Yi MBA were assessed using the WAHMO water quality model. The sediment plume model used to conduct the simulation forms part of the WAHMO suite of hydraulic and water quality models set up by HR Wallingford and WRC and transferred to the Hong Kong Government.

The hydrodynamic data was provided by the extended WAHMO 2-dimensional 2-layer model of tidal flows using a grid size of 250m. The SEDPLUME model then refined the flow model grid to 125m by interpolation. The flow model was re-run for this project with the following reclamations: Black Point Power Station, Chek Lap Kok airport platform, Tung Chung, North Lantau, Container Terminal 8, West Kowloon and Central-Wanchai.

During the IAR, initial scenarios were modelled to assess potential impacts resulting from simultaneous backfilling operations at the South Tsing Yi and North of Lantau MBAs, independent of other works in the vicinity (Scenarios 1-3). These scenarios investigated varying volumes of dumping trailer-dredged material at South Tsing Yi MBA while maintaining constant backfilling rates and volumes at North of Lantau MBA (10,000 m^{-3} day^{-1} of mechanically dredged material). The scenarios were modelled on the wet season spring tide, as it was assumed that this would be likely to lead to the worst degree of water quality impacts, based upon maximum tidal excursion data available. The assessment determined that the worst case IAR scenario (Scenario 1: 150,000 m^3 day^{-1} of trailer-dredged material at South Tsing Yi MBA, and 10,000 m^3 day^{-1} at North of Lantau MBA) would not result in unacceptable water quality impacts in terms of exeedances of SS and DO criteria (as described in *Section 3.2.3)* at the identified sensitive receivers.

For the EIA, a fourth scenario was undertaken which increased the volume of backfilled material at South Tsing Yi MBA from 150,000 to 200,000 m^3 day^{-1}, which was postulated as the maximum acceptable volume when extrapolated from the findings of the IAR. This scenario was modelled on each of the wet and dry season, spring and neap tides to determine the worst case tidal state in terms of resulting overall sediment losses (Scenarios 4a-4d). The dry season spring tide was identified as being of most concern with respect to SS elevations, as the high water velocities inhibited sedimentation and resulted in larger coherent sediment plumes. Subsequent scenarios were, therefore, simulated using this season-tide combination to determine the effects of reduced backfilling rates (Scenario 4e) and cumulative effects arising from backfilling in combination with other dredging/disposal projects (Scenarios 5-8). Finally, a validation scenario (Scenario 9) was performed to test the accuracy of the WAHMO model's predictions using SS concentrations that have actually occurred and for which data has been collected. Details of the methodology used to model each of these scenarios is presented later in this Section; a discussion of the modelling results is provided in *Section 3.9* and an evaluation of compliance with WQOs is contained in *Section 3.10.*

Results from the sediment plume simulations are presented in the form of colour contour plots of suspended sediment concentration at peak ebb and flood phases of the tide for both the upper and lower layers, together with a colour contour plot of sediment deposition over one tide. Also presented are time history plots of SS concentration at selected sensitive receivers, and colour contour plots of 'absolute DO concentration' resulting from DO calculations derived from the suspended sediment predictions. The assessment methodologies for DO and nutrient calculations are presented in *Sections 3.8.2* and *3.8.3;* an evaluation of potential impacts is provided in Section 3.10.

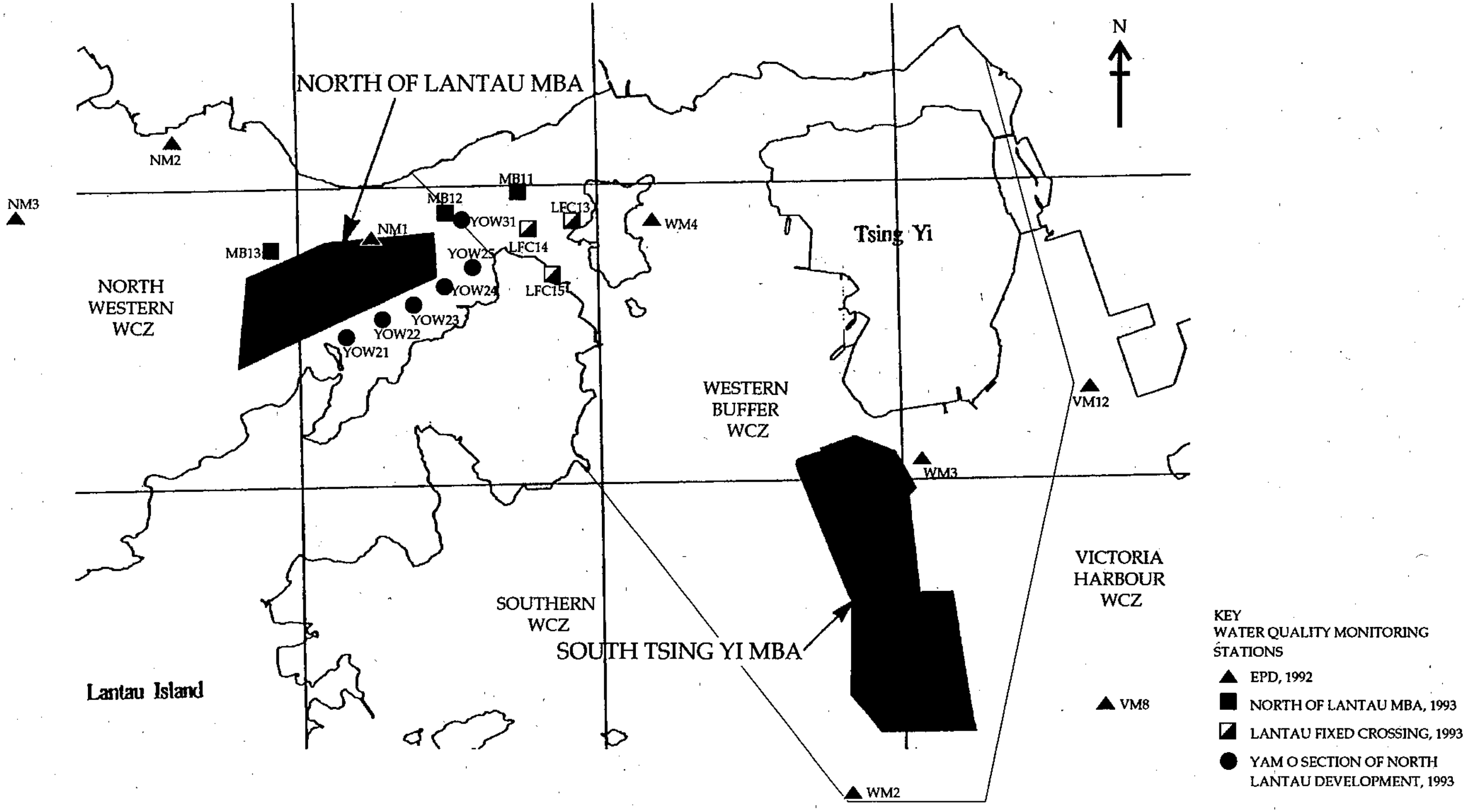

FIGURE 3.8a - LOCATION OF RELEVANT WATER QUALITY CONTROL ZONES AND WATER QUALITY MONITORING STATIONS

ERM Hong Kong
6th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

ERM

Field Data Collection

As discussed previously, an accurate estimate of the velocity profile in each MBA is essential for the prediction of spoil loss both during and subsequent to backfilling operations.

In a previous study of the stability of dumped spoil at South Tsing Yi MBA, observations of the vertical velocity profile at the South Tsing Yi MBA were made using an Acoustic Doppler Current Profiler (ADCP). Nevertheless, these data indicated that, for dry season conditions, there was a tendency for tidal flows (especially peak ebb flows) to pass over the MBA with little change, while the water velocity in the MBA below natural bed levels remained low. Therefore the development of a continuous velocity profile below natural seabed levels was not indicated. However, the depth of the water column at the time of this study(over 50m), combined with high sediment concentrations near the bed of the pit, resulted in a data set which was not sufficiently comprehensive to allow detailed calculations of bed stresses close to the bed, or to determine whether the development of a velocity profile over the entire water column was likely.

During this EIA study further velocity measurements were carried out using the most recent broad-band ADCP. The data was presented in the form of vertical profiles of water velocity at a number of Stations and as longitudinal sections along the ADCP vessel tracks (*Annex O*). The data collected indicated that, on the tides monitored (large amplitude dry season spring tides on consecutive days at North Lantau and South Tsing Yi), the velocity profile did develop over the entire water depth at both MBAs, even below the natural seabed level. There was little evidence of any sheltering of the lower water column below natural bed levels.

In this Study it will therefore be assumed that the velocity profile develops over the entire water column, in order to consider worst case sediment losses through re-erosion of dumped spoil. Thus a constant rate of sediment loss will be assumed throughout the water column in the MBA, as it has been determined that the spoil will not settle through quiescent water below the natural level of the seabed.

Assumed Sediment Losses

As detailed in *Section 3.7.3*, the 5% assumed rate of sediment loss to suspension has been based on conservative estimates of sediment loss rates. Thus in all modelled scenarios, a loss rate of 5% is assumed to present the worst case, and it is likely that the actual sediment loss rates will be lower than the rate assumed in this Study.

Sediment Plume Models

The WAHMO sediment transport model was designed to simulate the processes of sediment transport, deposition and re-erosion, and has been calibrated using a large field data set [25] to investigate the natural transport of mud through Hong Kong coastal waters. The data set includes the results of laboratory testing of large mud samples (1 ton) collected in the Western

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(25) Hydraulic and Water Quality Studies in Victoria Harbour. Two Layer Mathematical Model Simulation of Mud and Particulate Effluent Transport Calibration and Validation. HR Wallingford Report EX 1688, May 1988.

Harbour and over Chek Lap Kok Bank [26] [27], in order to assess the consolidation and erosion properties of typical Hong Kong mud.

Two models in the WAHMO suite are appropriate for simulating sediment plumes generated by dredging activities:

- *WAHMO Sediment Plume Model* (SEDPLUME) does not rely on a fixed grid and so can focus on localised impacts and near-bed sediment movements. The plume model is able to track large numbers of discrete particles in a three dimensional plane. The transport of fine sediment in suspension, dispersion by turbulent mixing, deposition to the seabed and re-erosion are all simulated by this model, based on the same physical parameters used in the sediment transport model. The plume model, however, can become time consuming and unwieldy when used to simulate large area plumes as it was designed to simulate relatively small, narrow plumes.

- *WAHMO Sediment Transport Model* (MUDFLOW) is an advection/diffusion model which yields concentrations of particles within a fixed grid. The results of the model, in terms of sediment concentrations and bed deposits, must be averaged over the grid cell dimensions (250m horizontally and two layers over the depth in this study). The need to use a grid of fixed dimension can lead to numerical dispersion which tends to spread the plume over a larger area, and at a lower concentration, than might be found in practice. This effect would be most noticeable for narrow plumes when the model grid is large and unable to resolve the plume width.

The initial scenarios modelled in the IAR (Scenarios 1-3) used the SEDPLUME model (designed to simulate small loss rates at high resolution) and were intended to provide an initial comparative assessment of the likely impacts of different dumping rates at the South Tsing Yi and North of Lantau MBAs in isolation from other concurrent dredging projects. These scenarios were based on initial estimates of the likely range of dumping rates which were later refined in the further development of the EIA. The locations and method of injection were also refined in subsequent scenarios.

In the modelling undertaken for the detailed EIA(Scenarios 4-9), higher dumping rates at the South Tsing Yi and North of Lantau MBAs were considered alone (Scenario 4) and in conjunction with dredging at the South Tsing Yi and West of Sulphur Channel MBAs (Scenarios 5-8). The increase in sediment loss rates for these scenarios meant that it was no longer appropriate to use the SEDPLUME model for these simulations. Plumes from each operation were expected to combine and it was essential to simulate periods of several days in order to allow background concentrations to build up. During the simulations, the sediment plumes would be dispersed over large areas and, following some initial sensitivity tests, it was decided that the MUDFLOW model was the most appropriate tool with which to assess the sediment plumes. Since different models have been used

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(26) Hydraulic and Water Quality Studies in Victoria Harbour. Properties of Hong Kong Mud. HR Wallingford Report EX 1617, September 1987.

(27) Port and Airport Development Strategy. Enhancement to the WAHMO Mathematical Models. Physical Properties of a bed samples from the North West New Territories. HR Wallingford Report EX 2208, October 1990.

for Scenarios 1–3 and 4–9 and the source terms are different, it is not appropriate to make detailed comparisons between the two sets of results.

Details of Scenarios Simulated

Scenarios 1 to 3 were performed for IAR assessment and examined effects due to backfilling at both MBAs simultaneously under a range of rates and volumes. Scenarios 4 to 8 were conducted to assess effects arising from backfilling at the two MBAs simultaneously, and the concurrent operations of other dredging projects in the Western Harbour. A summary table listing the dumping, dredging and total loss rates for each scenario is presented in *Table 3.8a*.

Table 3.8a *Summary of Sediment Plume Simulations*

Scenario	Simulation	Dumping Losses (t/d)		Dredging Losses (t/d)		Total Losses	
		South Tsing Yi	North Lantau	South Tsing Yi	West Sulphur Channel	(t/d)	% Maximum
1	Combined Dumping, Wet Season Spring Tide	5,933	400	0	0	6,333	7
2	Combined Dumping, Wet Season Spring Tide	1,978	400	0	0	2,378	2
3	Combined Dumping (daytime only at STY), Wet Season Spring Tide	400	400	0	0	800	1
4a	Combined Dumping, Dry Season Spring Tide	7,943	400	0	0	8,343	9
4b	Combined Dumping, Dry Season Neap Tide	7,943	400	0	0	8,343	9
4c	Combined Dumping, Wet Season Spring Tide	7,943	400	0	0	8,343	9
4d	Combined Dumping, Wet Season Neap Tide	7,943	400	0	0	8,343	9
4e	Combined Dumping, Dry Season Spring Tide	3,972	400	0	0	4,372	5
5	Scenario 4a + Dredging STY Top Marine Sand	7,943	400	65,814	0	74,157	79
6	Scenario 4a + Dredging STY Bottom Alluvial Sand	7,943	400	2,938	0	11,281	12
7	Scenario 5 + West Sulphur Channel Dredging	7,943	400	65,814	19995	94,152	100
8	Scenario 6 + West Sulphur Channel Dredging.	7,943	400	2,938	19,995	31,276	33

Scenario 1

This scenario assumes 150,000 m^3 day^{-1} of disposal at the South Tsing Yi MBA and 10,000 m^3 day^{-1} at the North of Lantau MBA.

At the South Tsing Yi MBA, it was assumed that trailer–dredgers would operate on a 24 hour basis, and that the total mass of sediment released per dump was 4,450 tonnes. Assuming a 5% loss to suspension results in a loss of 222.5 tonnes per dumping event (see *Section* 2.5.2). The frequency of dumping was estimated to take place every 0.9 hours (ie 26.7 dumps per day). Therefore, the total sediment losses per day are 5,933 tonnes. The SEDPLUME model simulated intermittent dumping with the release of sediment assumed to occur over a period of approximately 5 minutes. A single circular release point with a radius of 100m, in the centre of the MBA (coordinates 827400mE, 819800mN) was simulated, and the sediment was released into the model at the water surface to give a worst case approximation.

At North of Lantau MBA it was assumed that dumping would be by split barge with operations occurring throughout the day. The frequency of dumping was taken to be every 1.57 hours (ie 15.4 dumps per day) with the total dry mass of solids being 520 tonnes, and assuming a 5% loss to suspension gave a loss of 26 tonnes per dump and a total of approximately 400 tonnes per day. In the SEDPLUME model the release of sediment was simulated at a single release point at coordinates 820500mE 822750mN, which is the centre of the MBA. The release point was defined as being a circle of radius 100m centred at the coordinates given above. This was to represent the dredgers being in motion during dumping which is a requirement of the Marine Department, and was based upon the time taken to dump and distance the vessel would move in that time. The release of sediment was assumed to occur over a period of approximately 5 minutes every 1.57 hours, thus representing an intermittent release of sediment. The sediment was released into the model at the water surface in order to present a worst case approximation.

Scenario 2

In this scenario the total volume of material being dumped at South Tsing Yi was reduced to 50,000 m^3 day^{-1}, thus resulting in a reduction of the number of dumps per day to 8.9 and the frequency of dumping to every 2.7 hours. Each dumping event was simulated in the same way as for Scenario 1.

At North of Lantau MBA the volume, frequency and rate of dumping were the same as for Scenario 1 (ie 10,000 m^3 per day), and the loss of sediment was thus simulated in the same way.

Scenario 3

This scenario involved restricting disposal at the South Tsing Yi MBA to split barges dumping during daylight hours, which for the purposes of this simulation were assumed to be from 0600 to 1800. The frequency of dumping was assumed to be every 1.57 hours (ie 15.4 dumps per day). The simulation of barge dumping at the South Tsing Yi MBA was the same as for the North of Lantau MBA in Scenarios 1 and 2 except that the release point was in the centre of the South Tsing Yi MBA.

As previously, at North of Lantau MBA the frequency and rate of dumping were the same as for Scenario 1 and loss of sediment was simulated in the same way.

Scenario 4

In this scenario, the WAHMO sediment transport model (MUDFLOW) was used to simulate the maximum anticipated simultaneous spoil dumping of 200,000 m^3 day^{-1} and 10,000 m^3 day^{-1} at South Tsing Yi and North Lantau respectively. It was assumed that sediment losses to suspension during the dumping process would amount to 5% of the dry mass of the dumped spoil (ie 222.5 tonnes per dump for trailer dredgers and 26 tonnes per dump for grab dredgers). It was assumed that the North Lantau site would receive grab-dredged spoil only, while South Tsing Yi would be backfilled with mainly trailer-dredged spoil. (Although some disposal of grab-dredged spoil is also proposed for the STY MBA, trailer-dredged spoil was modelled as a worst case). The number of dumps per day was assumed to be 35.7 at the South Tsing Yi MBA and 15.4 at the North of Lantau MBA. Since the dumping process would be intermittent, a programme of several independent dumping events per day was simulated at each borrow area. Based on estimates of spoil densities, the sediment losses were calculated to be 7,943 tonnes day^{-1} and 400 tonnes day^{-1} at South Tsing Yi and North Lantau, respectively.

Based on comments on the draft EIA, it was proposed to reduce the maximum allowable rate of backfilling at the South Tsing Yi MBA from 200,000 m^3 day^{-1} to 100,000 m^3 day^{-1} to further protect sensitive receivers from the effects of elevated suspended sediment concentrations. Since none of the draft EIA modelling scenarios directly represented this backfilling rate an additional scenario, Scenario 4e, was performed. Scenario 4e was run under conditions identical to Scenario 4a except that the rate of backfilling at the South Tsing Yi MBA was halved.

Scenario 5

The simulation of maximum simultaneous backfilling at the South Tsing Yi and North Lantau MBAs was repeated at the rates used in Scenario 4a, with the addition of the estimated dredging losses resulting from dredging of surface layer marine sand from the southern part of the South Tsing Yi MBA. Sediment release rates due to dredging of surface marine sand at South Tsing Yi were estimated by DRL [28] as 1,500 kg s^{-1}. It was assumed that 75% of this material, or 1,125 kg s^{-1} would remain in suspension. Considering the duration and frequency of the dredging, the loss rates were estimated at approximately 66,000 t day^{-1}. The losses to suspension due to dredging, therefore, are considerably greater than the losses due to dumping.

Scenario 6

For this scenario, the simulation of maximum simultaneous dumping at the South Tsing Yi and North Lantau MBAs (Scenario 4a) was repeated with the addition of estimated dredging losses resulting from dredging lower layer alluvial sand from the southern part of the South Tsing Yi MBA. Sediment release rates for dredging of bottom alluvial sands from South Tsing Yi were

[28] Dredging Research Limited, Submission to ERM Hong Kong, 11 February 1995

estimated by DRL [29] at 85 kg sec^{-1} and it was assumed that 40% of this amount, ie 34 kg sec^{-1}, would remain in suspension. The loss rates for bottom alluvial sand are estimated to be much lower than those for surface marine sands due to the much lower fines content in the bottom alluvial sand. These loss rates translate to a total volume of approximately 3,000 t day^{-1} of fine material released to suspension from dredging. Total daily dredging losses for bottom alluvial sands are thus approximately 5% of those expected during the dredging of the top of the marine sand and less than losses estimated for disposal of trailer dredged material at South Tsing Yi under Scenario 4a.

Scenario 7

This scenario employed the largest combined dumping and dredging load of all the modelling scenarios. This load consisted of the combined maximum dumping rates at South Tsing Yi and North Lantau MBA (Scenario 4a), dredging of surface marine sand at South Tsing Yi with estimated losses to suspension of 66,000 t day^{-1} (described in Scenario 5 above), and dredging in the West Sulphur Channel MBA (including dredging and reclamation at Green Island) with estimated losses to suspension of approximately 20,000 t day^{-1}. The total daily loss rate is estimated as 94,152 t day^{-1}.

Scenario 8

This scenario repeated the maximum combined dumping of spoil at the South Tsing Yi and North Lantau MBAs (Scenario 4a), with dredging of alluvial sand at South Tsing Yi MBA (as described above for Scenario 6), plus dredging in the West Sulphur Channel MBA (including dredging and reclamation at Green Island) with estimated losses to suspension of approximately 20,000 t day^{-1}. The total daily loss rate is estimated at 31,276 tonnes day^{-1}.

Scenario 9

Scenario 9 was simulated to verify the validity of the WAHMO model and address concerns regarding discrepancies between WAHMO and measured SS concentrations in a previous project.

In January 1994, during the initial backfilling of the South Tsing Yi MBA, high SS concentrations (>100 mg l^{-1}) were recorded at the Ma Wan FCZ. These concentrations exceeded both the specific maximum criteria for the Ma Wan FCZ and the range of natural fluctuation, and were therefore considered unacceptable. The WAHMO modelling conducted to simulate the backfilling activities at South Tsing Yi MBA had not predicted these increases. Instead WAHMO predicted that the maximum dumping rate (as specified by PAA) would not generate sufficiently large increases in SS, above the background concentrations, to account for the increases which occurred at the Ma Wan FCZ.

As part of the EIA for backfilling the South Tsing Yi and North of Lantau MBAs, validation of WAHMO was therefore required to verify whether the WAHMO model could accurately predict SS increases resulting from backfilling activities. In order to do this, Scenario 9 simulated the maximum backfilling rate that actually occurred at South Tsing Yi MBA (as opposed to

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(29) Dredging Research Limited, Submission to ERM Hong Kong, 11 February 1995

those values assumed during the original simulation) and the background conditions at the time of the backfilling, which were influenced by airport construction and related works in the North Western Waters.

The background SS concentrations were determined by examining water quality data from the Provisional Airport Authority (PAA) monitoring programme, and a survey commissioned by CED GEO to map SS concentrations within Hong Kong Territorial Waters, both of which were on-going at the time of backfilling.

The PAA water quality monitoring programme in North Western Waters indicates the background conditions at the time of backfilling. The data available were collected from *Stations 40* and *53* of this monitoring programme (*Station 53* was re-named *Station 64* on 4 December 1994); the stations are indicated on *Figure 3.8b*. From this data it can be seen that the peak SS concentrations at each station were recorded in January 1994 (see *Figures 3.8c and 3.8d*). At *Station 54/63* the surface concentration on 4 January 1994 was 80 mg l^{-1}, and the bed concentration was 114 mg l^{-1}. No corresponding data was available for *Station 40* on the same date, however on 3 January 1994 concentrations were 45 mg l^{-1} in the surface layer and 209 mg l^{-1} in the bed layer, while on 5 January surface and bed concentrations were 75 mg l^{-1} and 231 mg l^{-1} respectively.

In addition to PAA's data, an extensive survey was commissioned by the GEO to map SS concentrations in Hong Kong Territorial waters, which was conducted during August 1993. These data also provide an indication of likely background concentrations in the North Western Waters, although they were collected during the wet season as opposed to the dry season when the elevated concentrations of SS were observed at Ma Wan FCZ. The GEO survey data indicate that the highest SS concentrations in the North Western Waters are on the ebb tide as sediment is carried down from the Pearl River Estuary. SS concentrations of 25-50 mg l^{-1} were recorded at the Ma Wan FCZ, with levels greater than 100 mg l^{-1} immediately to the west of the Brothers. A plume with concentrations ranging between 25 mg l^{-1} and 50 mg l^{-1} was recorded extending from Ma Wan, along the West Lamma Channel to the area west of the mid-point of Lamma Island.

In modelling Scenario 9, the background SS concentrations were simulated by injecting sediment along a line extending northwards from the eastern side of Chek Lap Kok (*Figure 3.8e*). A line was used since a point source would not have accurately created the background levels monitored throughout the North Western Waters. The rate of input of sediment along the selected line was adjusted until the simulated SS concentrations in the WAHMO model corresponded to the SS values observed at the time of backfilling (ie 100 - 150 mg l^{-1} in the surface layer and 150-200 mg l^{-1} in the bed layer at the PAA monitoring stations). The maximum backfilling rate at South Tsing Yi MBA used during the project was then run and superimposed upon this background.

3.8.2 *Methodology for Calculating Dissolved Oxygen Impacts*

This section describes the methodology by which potential oxygen demand and reduction in oxygen concentration generated by the modelling scenarios were investigated.

The oxygen demand associated with disposal of dredged materials will depend on the source of the materials and its sediment quality. For example, in the vicinity of the proposed Container Terminals 10 and 11 on the eastern shore of Lantau Island, the total sediment oxygen demand has been determined to be of the order of 20,000 mg kg^{-1} of dry bed mud [30]. In the vicinity of Green Island [31] where the bed sample showed some contamination, the total sediment oxygen demand was found to be 51,750 mg kg^{-1} dry bed material. Since material disposed during backfilling will be uncontaminated and similar in nature to that in the vicinity of the proposed Container Terminals 10 and 11, the following analysis used a total sediment oxygen demand of 20,000 mg kg^{-1} dry bed material.

EPD 1992 monitoring data (*Table 3.8b*) indicate that typical mean dissolved oxygen saturation values vary from a low mean value of 70% near the seabed to 100% saturation (ignoring supersaturation) in the Study Area. Most areas have DO values exceeding 85% saturation. For typical salinities and temperatures in Hong Kong waters, 85% saturation is equivalent to approximately 6.5 mg l^{-1} dissolved oxygen.

EPD data on dissolved oxygen concentration in mg l^{-1} from 1992–1994 analyzed for this Study further support that waters in the study area, in the vicinity of both MBAs, are well oxygenated in both surface and bottom layers. The depth- averaged dissolved oxygen (DO) measurements ranged between 2.5 - 13.1 mg l^{-1} and the mean concentration was 5.9 mg l^{-1}. Additional water quality data obtained from monitoring stations MB11 and MB12 (see *Figure 3.8a*) showed DO concentrations ranging between 4 and 9 mg l^{-1}, verifying well-oxygenated conditions in the North of Lantau MBA.

Table 3.8b *EPD Monitoring Data, Dissolved Oxygen Concentration (% saturation)*

Station	Dissolved Oxygen Concentration (% saturation)	
	MEAN Surface/bed	RANGE Surface/bed
WM 2	88/90	(68–119)/(62–157)
WM 3	83/88	(64–130)/(64–130)
WM 4	86/87	(67–127)/(62–136)
SM 9	83/70	(65–103)/(51–86)
SM 7	93/75	(72–112)/(35–104)
SM 3	106/90	(87–165)/(43–160)
NM 1	102/100	(75–137)/(75–137)

In order to assess the impact of dumping different material at the MBAs, the suspended sediment results were reanalysed in order to determine the dissolved oxygen deficits which could be generated by dumping sediment

(30) Total oxygen demand of sediment = BOD + COD = 1.5 x COD. The COD is a measured value obtained from sediment testing undertaken in the Lantau Port Development - Stage 1 Study Container Terminals No. 10 & 11 Ancillary Works (Design). Environmental Impact Assessment Final Report, December 1994. Halcrow Asia Partnership Ltd for the Civil Engineering Department, Hong Kong Government.

(31) Green Island Reclamation (Part) - Public Dump. Environmental and Traffic Impact Assessment. Scott Wilson Kirkpatrick for the Civil Engineering Department of the Hong Kong Government.

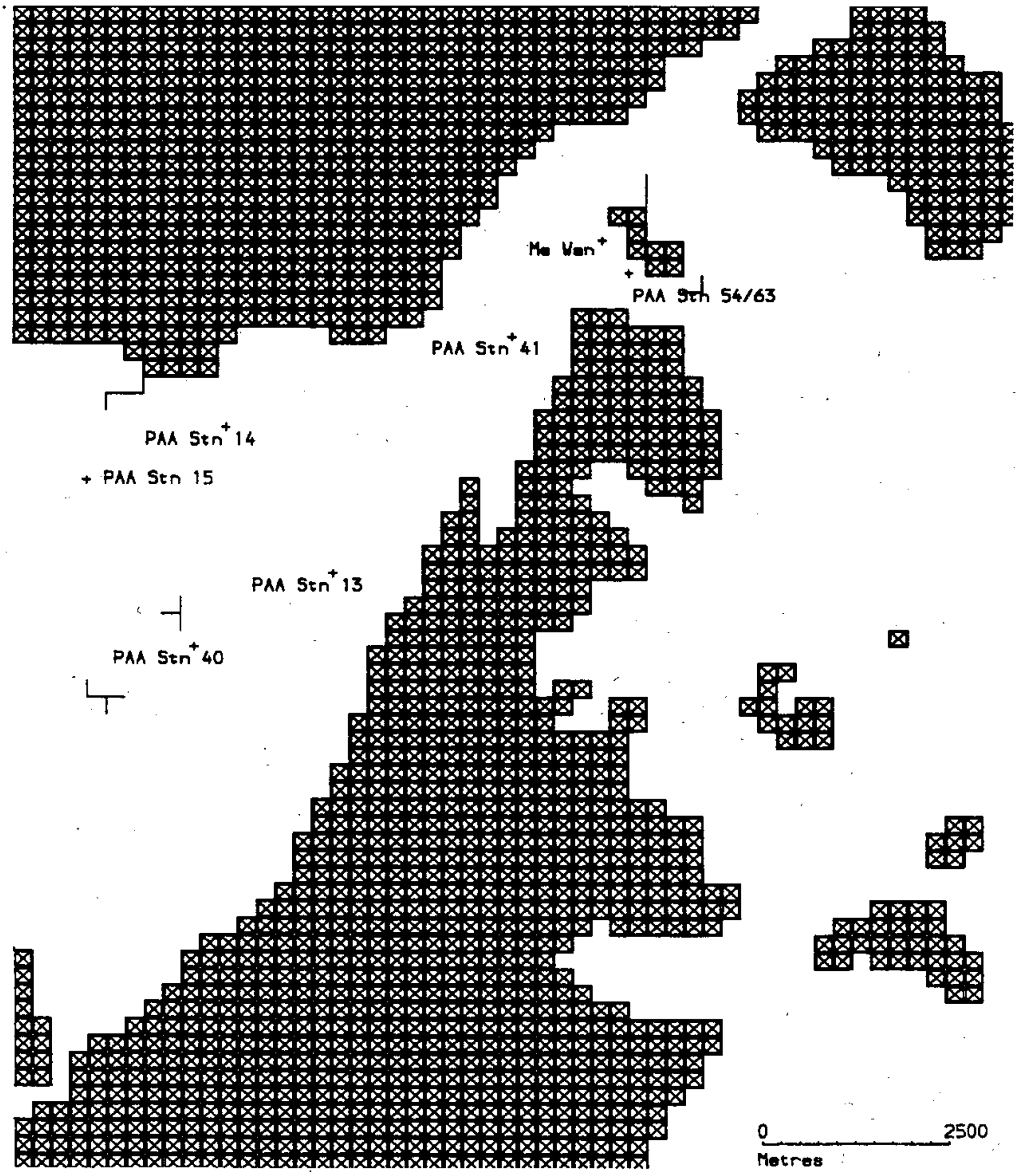

FIGURE 3.8b - LOCATION OF PAA WATER QUALITY MONITORING STATIONS

ERM Hong Kong, Ltd
6th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong
ERM

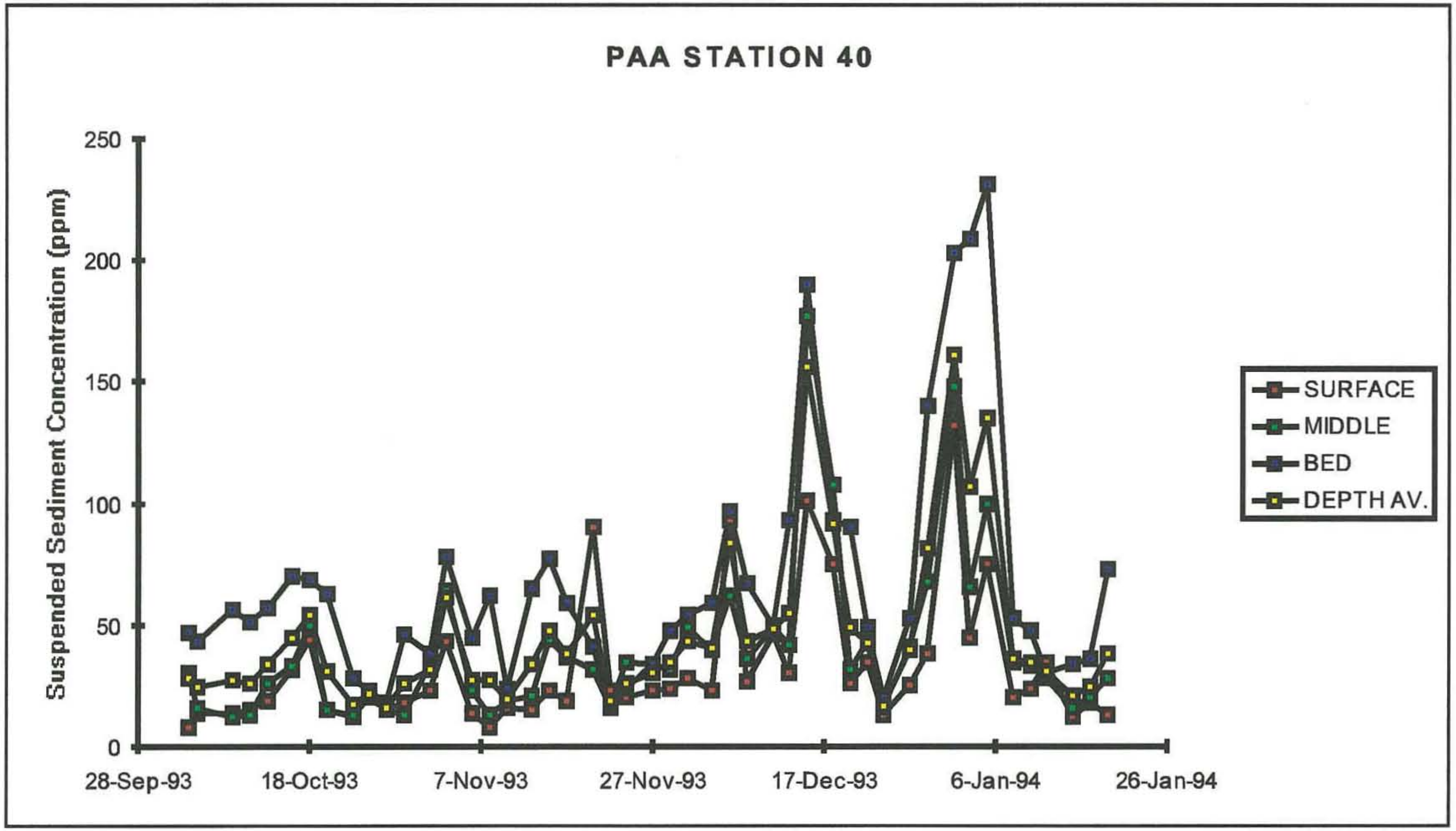

FIGURE 3.8c - STATION 40

ERM Hong Kong, Ltd
6th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

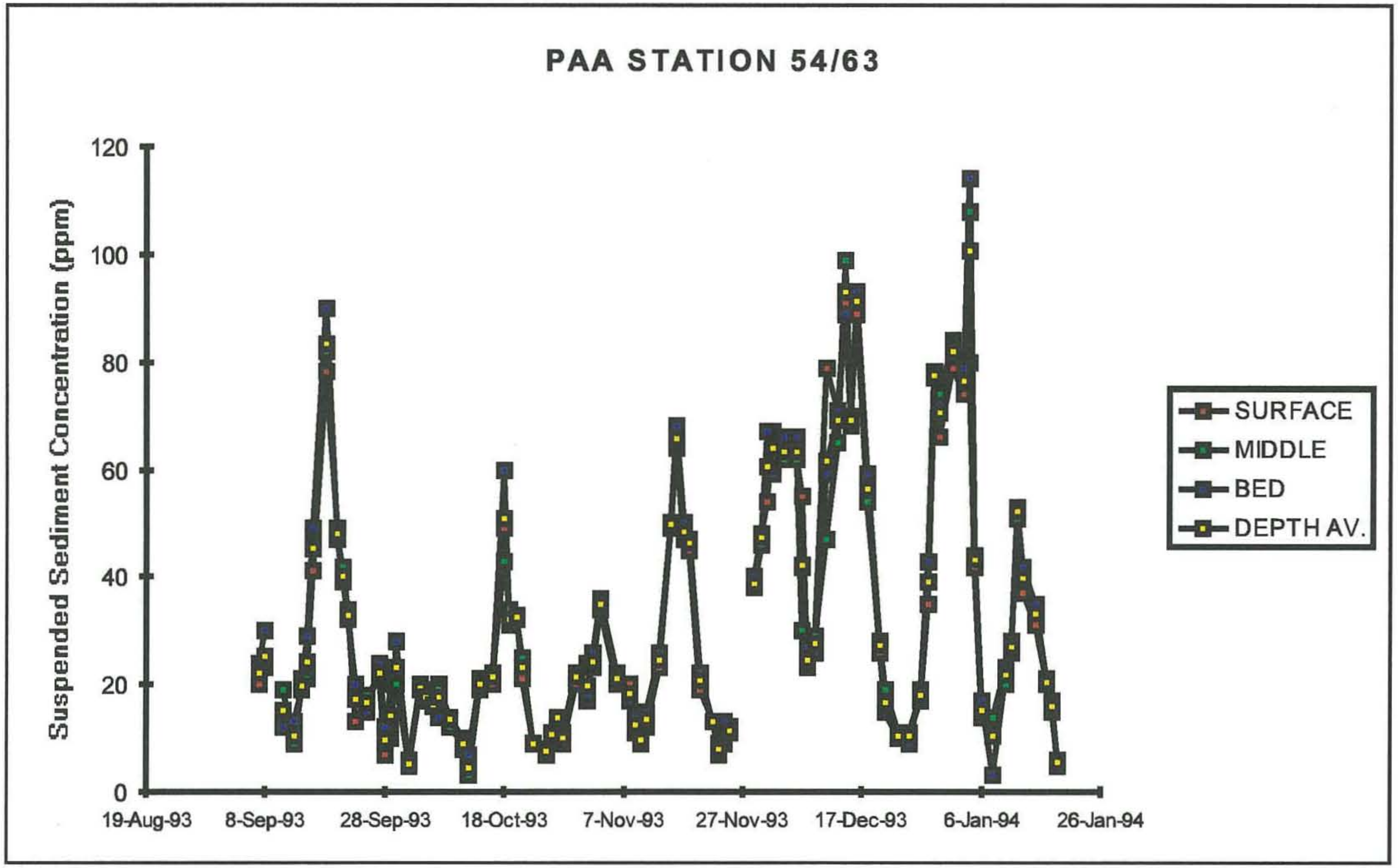

FIGURE 3.8d - STATION 54/63

ERM Hong Kong, Ltd
6th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

ERM

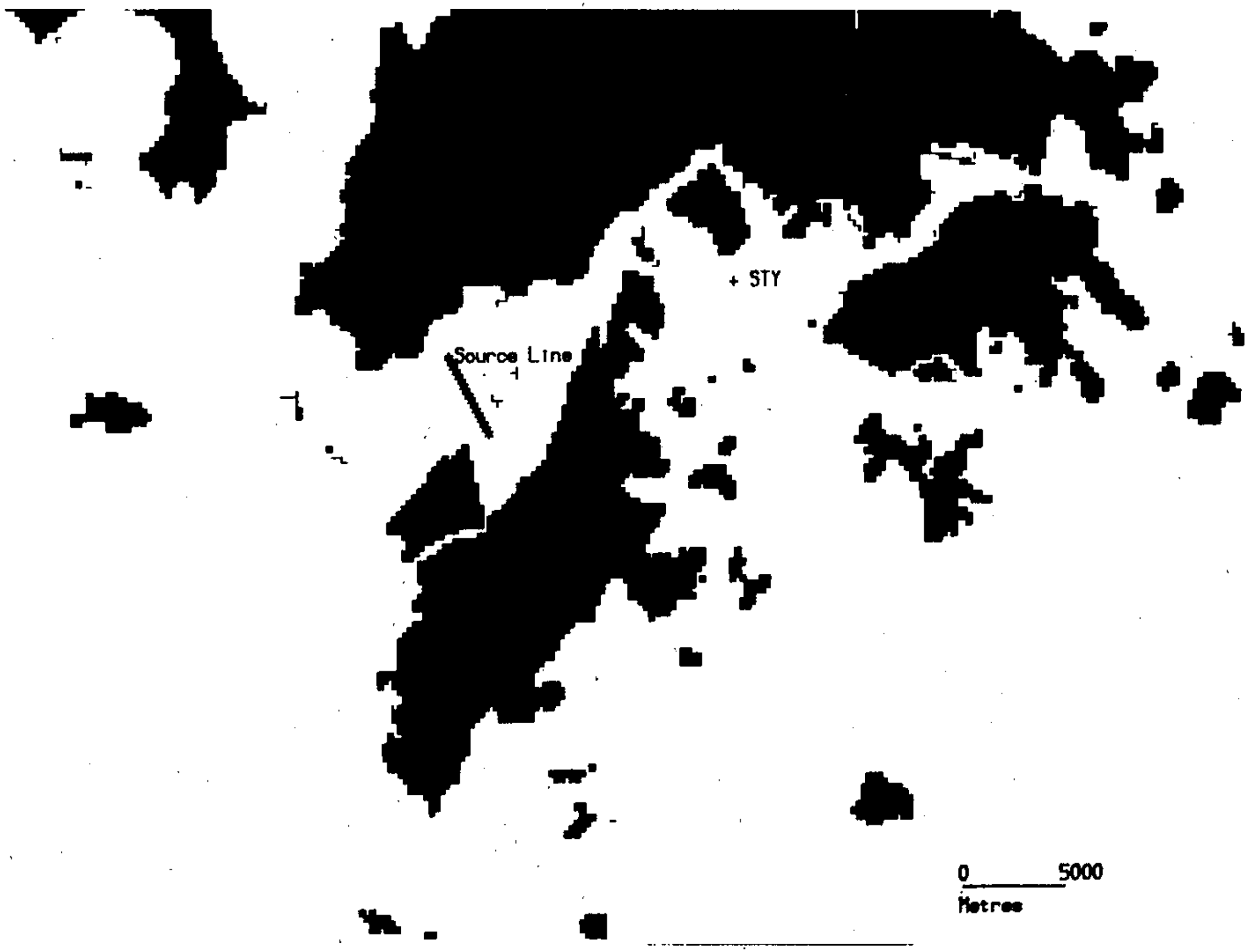

FIGURE 3.8e - SEDIMENT SOURCE LINE AND SOUTH TSING YI RELEASE POINT

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9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

ERM

with a total oxygen demand of 20,000 mg kg^{-1} of material. For this study, a mean background concentration of 85% saturation was assumed. As discussed in *Annex N*, the drop in background DO concentrations is a linear function of the oxygen demand. When sediment is released into the water column, it will take time for the oxygen demand and the rate of supply of oxygen in solution to reach equilibrium. In order to allow an estimate of the longer term DO deficits which could result from the sediment losses, the sediment plume model results were averaged over the tidal cycle and the resulting tide–averaged DO concentrations calculated. The results are presented for each modelling scenario in *Section 3.9* and discussed in terms of compliance with WQOs in *Section 3.10*.

3.8.3 Assessment of Potential Nutrient Releases

The potential impact for nutrients to be released into the water column during backfilling has also been assessed, due to concerns regarding eutrophication. High nutrient levels are often observed in the study area, mainly as a result of organic–laden wet season discharges which are flushed from storm water drains and associated illegal sewerage connections, contributing to nitrogen enrichment.

As the characteristics of the material to be used in backfilling are not available, this Study relies upon estimates of nutrient composition based on samples of uncontaminated mud collected by EPD routine sampling programmes. Recent EPD data on nutrient concentrations in sediment samples from the study area are presented in *Table 3.8c*.

Table 3.8c Total Dissolved Nitrogen Concentration at EPD Sediment Sampling Stations, EPD Data (1992)

EPD Routine Sediment Sampling Station	Total Nitrogen Concentration (mg l^{-1})	
	Mean	Range
WM2	0.62	0.31–1.07
WM3	0.73	0.34–1.85
WM4	0.74	0.36–1.81
SM9	0.67	0.28–0.90
SM7	0.6	0.21–0.89
SM3	0.46	0.11–0.68
NM1	0.73	0.10–1.15

These data indicate typical total nitrogen content of marine mud in harbour waters (using total nitrogen content as a measure of the nutrient concentrations present) to be 300–500 mg kg^{-1} of dry solids. In typhoon shelters, Rambler Channel and parts of Kowloon Bay, the total nitrogen content increases to 700 mg kg^{-1} dry solids. However, as it is likely that areas with high nitrogen content are also contaminated with heavy metals, the bed deposits from these areas would not be used for backfilling at the South Tsing Yi or North Lantau MBAs.

In addition, these data are derived from samples of surface mud deposits which can be assumed to have been reworked fairly continuously by storm action and bioturbation. Therefore, these sediments may be significantly influenced by any pollutants in the water body, and recently settled organic particulates. Since marine muds used for backfilling at the MBAs will likely have been removed from levels below the bed surface, surface-derived nutrient concentrations are expected to represent a worst case estimate of potential nutrient releases.

Therefore, in order to examine potential nutrient impacts which may result from backfilling of marine mud, it will be assumed that the total nitrogen content of the material dumped has a nutrient concentration of 500 mg kg^{-1}, as this represents the upper end of nutrient concentrations for uncontaminated material. If it is further assumed that nutrients associated with the sediment lost to suspension are transported and diluted at the same rate as the sediment in suspension, then a SS concentration of 0.1 kg m^3 would have an associated total nitrogen concentration of 50 Mg m^3, ie. 0.05 mg l^{-1}. In the waters which may be impacted by the sediment losses, the average natural background concentrations of total nitrogen are likely to be of the order of 0.7 mg l^{-1}, with a range of observed concentrations from 0.10 to 1.85 mg l^{-1} (*Table 3.8c*). The results of the nutrient assessments are discussed in *Section 3.9* for each scenario and are discussed in terms of compliance with WQOs in *Section 3.10*.

3.9 *PRESENTATION OF MODELLING RESULTS*

The scenarios modelled during this EIA comprised plume simulations to investigate the movement of sediment plumes resulting from backfilling operations, and erosion simulations to investigate sediment losses to suspension once the dumped material had settled on the seabed. This section evaluates the potential changes to concentrations of SS, DO, nutrients and bed deposition arising from sediment loss to the water column during disposal; modelling of sediment loss due to erosion and resuspension is discussed in *Section 3.11*.

Colour plots illustrating the results of the plume modelling scenarios are shown in *Annexes B* through *M*. In this discussion, SS, DO and nutrient concentrations are given in units of mg l^{-1}, which is equivalent to the units of ppm used in the colour plots. All colour plots of suspended sediments show concentrations above background whereas plots of dissolved oxygen represent absolute concentrations.

3.9.1 *Scenario 1*

As detailed above, this scenario involves disposal of 150 000 m^3 day^{-1} of trailer-dredged material at South Tsing Yi MBA and concurrent disposal of 10 000 m^3 day^{-1} of barge-dredged materials at North of Lantau MBA. This scenario was performed for the Initial Assessment Report (IAR), using the SEDPLUME model and was run for the wet season spring tide only. *Annex B* contains the modelling output plots.

Peak Flood Suspended Solids

The dumping rates assumed are greater than either of the other two scenarios modelled with the SEDPLUME model for the IAR (Scenarios 2 and 3) and therefore generate the largest predicted impacts of the IAR scenarios. The contour plots for the wet season spring tide on peak flood show little suspended sediment in the surface layer, as the majority of the sediment has settled into the bed layer. Around the South Tsing Yi MBA a small plume is shown in the surface layer with concentrations at the source greater than 40 mg l^{-1} reducing to 1–10 mg l^{-1} within 500m of the source. In the region of North of Lantau MBA, a wider coverage of SS is shown in the surface layer, with a plume extending approximately north–south across the main flow channel and a smaller plume along the northern side of the channel. Concentrations are low with the majority of the plume being in the range 1–10 mg l^{-1} with peaks in the range of 10–20 mg l^{-1}. There is an isolated area of high concentration, 20–40 mg l^{-1}, on the flood side of the source for North of Lantau MBA which is a recent release which has not had time to settle into the bed layer.

In the bed layer there is a continuous plume extending from the South Tsing Yi MBA source to the waters off Pillar Point. The plume extends from the South Tsing Yi MBA to the north of Ma Wan and along the New Territories coastline where it meets the plume from North of Lantau MBA. The plume from North of Lantau MBA spreads across the waters between the north Lantau coast and the New Territories coast to beyond Yam O Wan where the plume extends along the Urmston Road to Pillar Point. At the South Tsing Yi MBA concentrations are greater than 40 mg l^{-1}, declining to a range of 10–20 mg l^{-1} within the north western tip of Tsing Yi. From Ma Wan to the region beyond Yam O Wan the concentrations within the plume are low ranging from 1 to 10 mg l^{-1}. There is an area of higher concentration to the east of Tuen Mun, in the range 10–20 mg l^{-1} with isolated areas of up to 40 mg l^{-1}, however these areas are in deep water and do not approach the coastline or sensitive receivers.

Peak Ebb Suspended Solids

The contour plots for peak ebb also show little suspended sediment in the surface layer, with the majority of the sediment having settled into the bed layer. In the surface layer there is a distinct plume from the South Tsing Yi MBA extending southward a distance of approximately 2 km. Concentrations at the centre of the plume are in the range 20 – 40 mg l^{-1} reducing rapidly to less than 1 mg l^{-1} at the edge of the narrow plume. Suspended sediment is spread in a diffuse manner over the area between Tsing Yi and the eastern tip of Lantau Island, with concentrations in the range of 1–10 mg l^{-1}. Isolated areas of greater than 40 mg l^{-1} are shown at North of Lantau and South Tsing Yi MBAs but these correspond to the sediment release points.

In the bed layer three distinct plumes are evident: one extending south from South Tsing Yi, one which extends through the Ma Wan channel and then south to Kau Yi Chau, and the other which extends from Kap Shui Mun and along the eastern tip of the Lantau coast. The majority of the plume from South Tsing Yi MBA has concentrations in the range 20 – 40 mg l^{-1} with higher concentrations towards the sediment source. This plume extends to the west of Green Island but does not impact the coast. The plume through the Ma Wan Channel extends along the coast of the New Territories to Anglers Beach and then travels southwards to Kau Yi Chau. The majority of the plume has concentrations in the range 1 – 10 mg l^{-1} but there is a small area in the centre of the plume of higher concentrations (10–20 mg l^{-1}). This plume comprises sediment from North of Lantau MBA and portions of the flood plume from South Tsing Yi MBA which has been carried back on the ebb tide. The plume through Kap Shui Mun does not extend as far as Pennys Bay and has low concentrations (1–10 mg l^{-1}). There are isolated areas of high concentration (greater than 40 mg l^{-1}), along the deep water channel towards Tuen Mun which are due to erosion of the recently deposited sediment. This material would be expected to remain within the bed layer, resettling onto the bed at slack water without extension dispersion.

SS Concentrations at Sensitive Receivers

The time history graphs of SS concentration at the sensitive receivers show zero or low concentrations. Maximum concentrations of 14 mg l^{-1} are recorded at Kennedy Town WSD intake. This peak occurs in the bed layer; no elevations were recorded in the surface layer.

The only other sensitive receivers for which elevations in SS levels are predicted are Anglers Beach (surface and bed layers), Gemini Beaches (bed layer only), Casam Beach (bed layer only), Ma Wan Fishery (bed layer only), Ma Wan FCZ (bed layer only) and Kau Yi Chau fishery (surface layer only). None of these elevations exceed 3 mg l^{-1} and most average approximately 1 mg l^{-1}.

Bed Deposition

The contours of bed deposits, presented in *Annex B*, show two distinct areas of deposition which are each associated with backfilling at one of the MBAs. There is a narrow band from the South Tsing Yi MBA extending from the region between Ma Wan and Tsing Yi to Green Island which has high deposition, greater than 1 kg m^{-2} for the majority of its length. This deposition will be almost exclusively from the dumping into the South Tsing Yi MBA. The other area is to the west of Yam O Wan between the coast of north Lantau and the New Territories. Deposition rates are low, in the range 0.01–0.25 kg m^{-2}, and this sediment will comprise material from the dumping at the North of Lantau MBA. There is very little deposition between Yam O Wan and Ma Wan and in Kap Shui Mun due to high current velocities in these areas.

Dissolved Oxygen

The calculations have determined that the DO concentrations would range from 5.99 - 6.00 mg l^{-1} throughout the area at the time of backfilling. Small areas southwest (in the surface layer) and west (in the bed layer) of Tsing Yi near the MBA, would experience greater reductions in DO concentrations.

Nutrient Release

This assessment determined that the peak increase in total nitrogen would be between 0.005 to 0.008 mg l^{-1} in the surface layer, and between 0.005 to 0.01 mg l^{-1} in the bed layer.

3.9.2 *Scenario 2*

Scenario 2 simulated backfilling of 50 000 m^3 day^{-1} of trailer–dredged material at South Tsing Yi MBA and concurrent disposal of 10 000 m^3 day^{-1} of barge–dredged material at North of Lantau MBA on the wet season spring tide. This simulation was performed using the SEDPLUME model. *Annex C* contains the modelling output plots.

Peak Flood Suspended Solids

In general, the behaviour of the plume from Scenario 2 is similar to that from Scenario 1. The contour plots show little suspended sediment in the surface layer, as the majority of the sediment settled into the bed layer. A wide SS plume emanates from the North of Lantau MBA, extending approximately north–south across the main flow channel with a smaller plume along the northern side of the channel. Concentrations are low, with the majority of the plume being in the range 1–10 mg l^{-1} with peaks in the range of 10–20 mg l^{-1}. There is an isolated area of high concentration (20–40 mg l^{-1}), on the flood side of the source for North of Lantau MBA which is a recent release which has not had time to settle into the bed layer. Around the South Tsing Yi MBA a small plume is shown in the surface layer with concentrations at the source less than 40 mg l^{-1}.

The plots of suspended sediment concentration show that the concentrations to the west of Ma Wan are similar to those for Scenario 1 as the disposal rates for the two scenarios are the same for the North of Lantau MBA. The plume from North of Lantau MBA spreads across the waters between the north Lantau coast and the New Territories coast to beyond Yam O Wan where the plume extends along the Urmston Road to Pillar Point. At the South Tsing Yi MBA, concentrations are greater than 40 mg l^{-1} and decline to a range of 10–20 mg l^{-1} near the north western tip of Tsing Yi. From Ma Wan to the region beyond Yam O Wan the concentrations within the plume are low (1–10 mg l^{-1}). There is an area of higher concentration to the east of Tuen Mun, in the range 10–20 mg l^{-1}, with isolated areas with concentrations of up to 40 mg l^{-1}. The area is in deep water, however, and does not approach the coastline or sensitive receivers. To the east of Ma Wan, the plume is not continuous and maximum concentrations fall below the range of concentrations identified in Scenario 1.

Peak Ebb Suspended Solids

No surface layer plumes are evident from the South Tsing Yi MBA, which may be due to the absence of a dumping event at this state of the tide. The same three plumes identified in Scenario 1 are present here, although the concentrations are generally lower. One plume extends through the Ma Wan channel and then south to Kau Yi Chau and another extends from Kap Shui Mun and along the eastern tip of the Lantau coast. Most material in these plumes is derived from the North of Lantau MBA, with a small contribution entering through the Ma Wan Channel on the flood tide. Most of the area covered by these plumes has a sediment load of 1–10 mg l^{-1} although a small area peaks at 10–20 mg l^{-1}. The third plume extends south from Tsing Yi and also carries a sediment load of 1–10 mg l^{-1}. A thin band extends 2 km north of Green Island at higher concentrations of up to 40 mg l^{-1}.

SS Concentrations at Sensitive Receivers

The time history graphs of SS concentrations at the sensitive receivers show the maximum SS increases to be at Anglers Beach with a value of 4 mg l^{-1} in the surface layer. The concentration at Kennedy Town WSD Intake is 2.5 mg l^{-1} in the bed layer but is not detectable in the surface layer. Other stations predicted to experience elevated concentrations are Ma Wan Fishery (bed layer only), Ma Wan FCZ (bed and surface layer), Tsing Yi Power Station (bed layer only) and Kau Yi Chau Fishery (surface layer only). None of these sensitive receivers are predicted to experience elevated concentrations of greater than 2 mg l^{-1}.

Bed Deposition

The contours of bed deposits show the mass of deposits to the west of Ma Wan to be the same as for Scenario 1, ie, deposition in the range of 0.01–0.25 kg m^{-2} to the west of Yam O Wan between the northern coast of Lantau and the New Territories. This result is explained by the fact that sediment deposition in this area results from backfilling at North of Lantau and the rate of backfilling has not varied between Scenarios 1 and 2. Sediment deposition to the east of Ma Wan is related to backfilling rates at South Tsing Yi. As the rate under Scenario 2 has been reduced from 150,000 m^3 day^{-1} (Scenario 1) to 50,000 m^3 day^{-1}, deposition, while showing a similar pattern, occurs in fewer areas at depositional masses greater than 0.25 kg m^{-2}. These areas of higher deposits occur immediately to the east of Ma Wan, around the release point and to the north of Green Island. As in Scenario 1, there is little deposition between Yam O Wan and Ma Wan and in Kap Shui Mun due to high current velocities in these areas.

Dissolved Oxygen

Modelling for Scenario 2 determined that most areas affected would experience DO concentrations in the range of 5.99–6.00 mg l^{-1}. Small areas southwest (in the surface layer) and west (in the bed layer) of Tsing Yi near the MBA, would experience greater reductions in DO concentrations.

Nutrient Release

Based upon the results of the sediment modelling, it was calculated that the peak increases in nitrogen resulting from Scenario 2 would be less than 0.005 mg l^{-1} in both the surface and bed layer.

3.9.3 *Scenario 3*

This scenario simulated disposal of 10 000 m^3 day^{-1} of barge–dredged material at both South Tsing Yi and North of Lantau, on the wet season spring tide. The simulation was run using the SEDPLUME model. *Annex D* contains the modelling output plots.

Suspended Solids

The behaviour of the plume from this scenario is, in general, similar to that for Scenarios 1 and 2 but with greatly reduced suspended sediment concentrations in the area to the east of Ma Wan due to the reduced dumping rate at South Tsing Yi MBA.

The contours of SS concentration show that those to the west of Ma Wan are similar in pattern to, but reduced in concentration from, Scenario 2 due to there no longer being a significant contribution from the South Tsing Yi MBA. There is also no longer an obvious source of high concentration at South Tsing Yi MBA in the surface layer. This is due to the absence of a release coinciding with the peak ebb and flood tides. A distinct plume no longer forms from the South Tsing Yi source on the ebb tide and the sediment is spread in a diffuse manner over a larger area. Apart from isolated areas of high concentration (up to 40 mg l^{-1}), the suspended sediment concentrations for surface and bed layers in peak flood and peak ebb tides are in the range of 1–10 mg l^{-1}.

SS Concentrations at Sensitive Receivers

The time history graphs of SS concentration at the sensitive receivers show maximum increases of 3 to 4 mg l^{-1} at Anglers Beach and Kau Yi Chau Fishery in the surface layer only. There is no increase at Kennedy Town WSD Intake. The only other sensitive receivers affected are Gemini Beaches (bed layer only) and Ma Wan FCZ where the peak values are less than 2 mg l^{-1} for both the surface and bed layers.

Bed Deposition

The contours of bed deposits show the area of bed deposits to be similar in extent and depositional mass to the west of Ma Wan when compared with Scenarios 1 and 2. However, in contrast to Scenarios 1 and 2 the deposits are patchy and do not cover a continuous area. This is due to the reduced contribution from South Tsing Yi, particularly in the region closer to Ma Wan. There is an area of higher deposition immediately to the east of Ma Wan, greater than 1 kg m^{-2}, which is due to low velocity flows in this area. The area of coverage of the bed deposits in the region to the south and east of Ma Wan is greatly reduced from the other two scenarios and there being no sediment deposited in the region of Green Island. As in the area west of Ma Wan, the sediment deposition is patchy and the mass of deposition is low ranging from 0.01–0.25 kg m^{-2}.

Dissolved Oxygen

Calculations have determined that as a result of Scenario 3, the changes in DO at the sensitive receivers are minimal with the majority of areas predicted to experience dissolved oxygen concentrations not lower than 5.98 mg l^{-1}.

Nutrient Release

The nutrient release calculations, based upon the sediment plume results, determined that Scenario 3 would result in only minor increases in the total nitrogen concentration in the water column. Peak concentrations of less than 0.005 mg l^{-1} were predicted in both the surface and bed layers.

3.9.4 *Scenarios 4a– 4d*

This scenario models the maximum rate of dumping (200 000 m^3 day^{-1} at South Tsing Yi MBA) plus 10 000 m^3 day^{-1} at North of Lantau MBA, on the four major seasonal/tidal states of dry season spring tide (*Annex E*), dry season neap tide (*Annex F*), wet season spring tide (*Annex G*) and wet season neap tide (*Annex H*). These scenarios were run using the MUDFLOW model.

Scenario 4a – Dry Season Spring Tide

Observations made on large amplitude dry season spring tides, during velocity profiling studies conducted for this study in December 1994, indicated that peak near-surface speeds at South Tsing Yi were approximately 1.5 m s^{-1} and, at the North Lantau pit, 1.4 m s^{-1}. *Annex O, Figures 1–9* show the observed velocity profiles and variation in depth averaged water speed over the two tidal cycles monitored. The higher water speeds on the dry season spring tide (especially in the bed layer), compared to the wet season spring tide, resulted in much lower deposition of spoil losses close to the MBA, and a much larger coherent sediment plume covering both MBAs (*Annex E*).

Peak Flood Suspended Solids

The colour contour plots for the peak flood show less suspended sediment in the surface layer than other tidal conditions since the majority of the sediment has settled into the bed layer. Within the surface layer there is a highly localised area of high SS concentration (above 40 mg l^{-1}) at the South Tsing Yi MBA source where SS has not yet dispersed, and an area with SS concentrations between 10 and 20 mg l^{-1} extending between the southern tip of South Tsing Yi and Ma Wan Island. The majority of the surface layer plume has concentrations in the range of 1–10 mg l^{-1}, and extends in a coherent plume from the South Tsing Yi MBA, north-west through Kap Shui Mun and north of Ma Wan, ending between the points of Sham Shui Kok and Tuen Mun.

Both the extent and concentrations within the bed layer SS plume are greater than at the surface. There is an area of high SS concentration situated in the channel between the south of Ma Wan and Tsing Yi Island, which is surrounded by an area of lesser concentration (10–20 mg l^{-1}) extending the length of both Ma Wan and Tsing Yi Islands. The majority of the plume has concentrations of between 1–10 mg l^{-1} although the plume has been carried further southeast until almost parallel with Pok Fu Lam on Hong Kong Island, and further northwest almost parallel with Pillar Point.

Peak Ebb Suspended Solids

At peak ebb the extent of the sediment plume is greater in both the surface and bed layers than during peak flood. In the surface layer, although the plume extends a shorter distance along the coast of Lantau to a line parallel with Tai Lam Kok, it extends in a coherent form further south-east between the southern tip of Lamma Island and Cheung Chau (approximately 15 km from South Tsing Yi MBA). The majority of the plume has concentrations ranging between 1 and 10 mg l^{-1}. There is an isolated area at the South Tsing Yi MBA with concentrations between 20 and 40 mg l^{-1} where SS has not yet dispersed, and an area with concentrations ranging from 10–20 mg l^{-1}, between the western edge of Hong Kong Island and the southern edge of Tsing Yi.

In the bed layer the plume is less coherent although the areas of high concentration are greater than in the surface layer. The plume extends northwest to the Brothers Islands and stops almost parallel with Siu Lam along the southwest New Territories coastline. The majority of the plume has concentrations of 1 to 10 mg l^{-1}. The area of the plume between the northern edge of Lamma Island, and the southern edge of Tsing Yi has higher SS concentrations ranging from 10 to 20 mg l^{-1}. There are also two distinct areas of high concentration on the edge of the plume: a thin band extending between Tsing Yi and Hong Kong Island, and another band extending south from Kau Yi Chau Island to the northern edge of Lamma Island, with concentrations ranging between 20 and 40 mg l^{-1}.

SS Concentrations at Sensitive Receivers

Examination of the SS concentrations time history plots indicated that more of the sensitive receivers would experience an impact on the dry season spring tide, and the impact would be of a higher concentration, than on any of the other tidal conditions examined. Concentrations (surface and bed layers) at Anglers Beach peaked at 10 mg l^{-1} above background for a short period, and at 8 mg l^{-1} at Gemini Beach also for a short period. At the Ma Wan Fishery (surface and bed layers) and Tung Wan Tsai (surface layer only) concentrations slightly exceeded 14 mg l^{-1} and 12 mg l^{-1} above background respectively for a period of less than an hour. Most other sensitive receivers are predicted to experience transitory peak concentrations of less than 10 mg l^{-1} above background.

At the water intakes on the north-west of Hong Kong Island, peak surface layer concentrations of around 7 mg l^{-1} were predicted for periods of less than 3 hours at the Kennedy Town WSD Intake, and around 5 mg l^{-1} and 3 mg l^{-1} at the Queen Mary Hospital Intake and Wah Fu Estate Intake respectively. Peak bed layer concentrations at all three water intakes are predicted to be 7 mg l^{-1} for periods of less than 3 hours.

Bed Deposition

The predicted net bed deposits over one tidal cycle tide reflect the stronger tidal flows on the dry season spring tide. Whereas on the wet season spring tide (see Scenario 4c below), sediment was predicted to settle over much of the Western Harbour, on the dry season spring tide, no deposition was predicted in the main flow channels in the Western Harbour or the Urmston Road. The highest deposition rates (1 kg m^{-2}) were predicted in, and very locally to, the MBA with some light deposition in the East Lamma Channel and over the deeper waters immediately to the south of the Western Harbour.

This pattern of sediment distribution on the seabed reflects the expected pattern of bed stability. For the natural transport of sediment from the Pearl Estuary, some light deposition is expected in the shallower nearshore margins (such as east of Lantau Island), which will be subsequently removed during tidal or storm conditions. The predicted light deposition in the East Lamma Channel is unusual, but it is anticipated that this sediment would be re-eroded under stronger tidal currents than simulated by the model or by storm action.

Dissolved Oxygen

The model results indicated that for backfilling operations alone, over the whole area affected, except in the South Tsing Yi MBA, DO concentrations would remain above 6.3 mg l^{-1} (83% saturation) in both the surface and bed layers. Immediately at the South Tsing Yi dump site, the DO deficit would be between 6.1 and 6.3 mg l^{-1}.

Nutrient Release

The nutrient release assessment determined that peak nitrogen level increases would be 0.005 mg l^{-1} in the surface layer, and 0.013 mg l^{-1} in the bed layer.

Scenario 4b – Dry Season Neap Tide

On the dry season neap tide, water speeds are low for much of the tidal cycle and sediment losses settle to the seabed relatively quickly, leaving comparatively little material in suspension. The overall area impacted by the sediment plumes on the dry season neap tide is the smallest area for Scenarios 4a through 4d.

Peak Flood Suspended Solids

The concentrations and coherence of the sediment plume in the surface and bed layers on the peak flood were very similar to that of the dry season spring tide simulation, although marginally reduced in areal extent.

Peak Ebb Suspended Solids

The plume generated on the peak ebb tide was reduced in terms of extent and concentrations relatively to the peak ebb simulation for Scenario 4a. In the surface layer the plume extended along the Tsing Yi coastline, northwest past Ma Wan and approximately 2 km west in a narrow plume to a point parallel with Siu Lam. The coherent southern extent of the plume reached Pa Tau Kwu on Lantau coastline, and stopped between Tsing Yi and Hong Kong Island. The majority of the plume comprised SS concentrations between 1 and 10 mg l^{-1}. However there was a localised area at the South Tsing Yi MBA with concentration of 20-40 mg l^{-1} in the centre, surrounded by concentrations of 10 -20 mg l^{-1}.

SS Concentrations at Sensitive Receivers

Examination of SS concentrations at the sensitive receivers indicated no increases above background in excess of 10 mg l^{-1}, except at the Ma Wan Fishery where concentrations peaked at around 14 mg l^{-1} above background in the surface and bed layers for a period of approximately 2 hours just before high water.

At Anglers and Gemini Beaches (surface and bed layer), and Tung Wan Tsai (surface layer only) peak increases in concentrations of 7 mg l^{-1} to 9 mg l^{-1} were predicted. At Anglers Beach the increase occurred for 3 hours, while at both Gemini and Tung Wan Tsai, the increase lasted for less than two hours. The sediment plumes did not reach the water intakes at Kennedy Town, Queen Mary Hospital and Wah Fu. All other sensitive receivers were either not impacted or impacted at concentrations of less than 3 mg l^{-1}.

Bed Deposition

Deposition rates of 0.5 kg m^2 day^{-1} to 1 kg m^2 day^{-1} were predicted over a relatively large area around the South Tsing Yi MBA and along the western shore of Tsing Yi Island but were less than 0.25 kg m^2 day^{-1} in all other areas.

Nutrient Release

The results of the nutrient release assessment for Scenario 4b were the same as 4a, with predicted peak total nitrogen increases in the water column of 0.005 mg l^{-1} in the surface layer, and 0.013 mg l^{-1} in the bed layer.

Scenario 4c - Wet Season Spring Tide

This scenario presents the effects of maximum combined dumping rate occurring on a wet season spring tide.

Peak Flood Suspended Solids

On the flood tide when the simulated water velocities are relatively low (0.3 m s^{-1}), apart from a general increase of 1–10 mg l^{-1} in SS concentrations in the area affected under other tidal conditions, coherent surface plumes with concentrations in excess of 10 mg l^{-1} were localised at the South Tsing Yi MBA. Plumes generated in the surface layer at the North of Lantau MBA had low concentrations (1–10 mg l^{-1}). In the bed layer, in addition to settlement of the disposed sediment through the water column, a single larger plume with concentrations over 10 mg l^{-1} was generated by the disposal at South Tsing Yi.

Peak Ebb Suspended Solids

On the ebb tide, when water velocities in the surface layer (0.7 m s^{-1} at South Tsing Yi and 0.9 m s^{-1} at North Lantau) are greater than on the peak flood, the surface sediment plumes were larger and extended further south of Tsing Yi in both the surface and bed layers. The concentrations and plume shape in the surface layer were similar to those generated on the dry season spring tide peak ebb (the majority of the plume consisted of SS concentrations between 1 and 10 mg l^{-1}) although the plume did not extend west along the southern coast of Hong Kong Island. In addition, the area of high concentration between the southern edge of Tsing Yi and Green Island was reduced and ranged between 10 and 20 mg l^{-1}, with localised concentrations at the South Tsing Yi MBA between 20 and 40 mg l^{-1}. In the bed layer the plume was less coherent, and small isolated peaks occurred along the edge of the plume with SS concentrations between 10–40 mg l^{-1}. There was a thin broken area of higher SS concentration (between 10–20 mg l^{-1}) extending from between Ma Wan and Tsing Yi southward to Green Island.

SS Concentrations at Sensitive Receivers

The sediment plume did not lead to increases in SS concentration in excess of 10 mg l^{-1} at any of the sensitive receivers. At the Ma Wan Fishery and at Anglers and Gemini Beaches, peak concentrations reached approximately 9 mg l^{-1} above background in both the surface and bed layers. At Tung Wan Tsai (surface layer only) and the Ma Wan FCZ (surface and bed layers), concentrations peaked at around 5 mg l^{-1}. At the Tsing Yi Power Station and Kennedy Town WSD intakes peak bed layer concentrations approached 7 mg l^{-1}. The increase in SS concentration above background in the surface layer was predicted to peak at around 3 mg l^{-1} for the Kennedy Town intake. All other sensitive receivers were either not impacted by elevated concentrations or were impacted at levels less than 3 mg l^{-1}.

Bed Deposition

The South Tsing Yi MBA is in an area where, in the wet season, bed layer water speeds are low on the main ebb tide, as a result of the landward salinity gradient which inhibits ebb flows in the lower water column. As a result, on the ebb tide, the sediment plume in the lower water column is not carried far from the disposal site. The area impacted by the sediment plume can be identified by the predicted bed deposits which show that the bulk of the spoil settles over a relatively narrow band extending from Green Island through the Western Harbour almost reaching Ma Wan. Maximum deposition rates of 0.5–1.0 kg m^2 day^{-1} are predicted along the western coastline of Tsing Yi Island, and to the east and south of the South Tsing Yi

MBA. Outside the MBAs, deposition rates were predicted to be less than 0.25 kg m^2 day^{-1}.

Nutrient Release

The peak increase in total nitrogen concentration predicted to result from Scenario 4c was greater than Scenario 4a and 4b in the surface layer (0.008 mg l^{-1} as opposed to 0.005 mg l^{-1}), but reduced in the bed layer from 0.13 mg l^{-1} to 0.01 mg l^{-1}.

Scenario 4d – Wet Season Neap Tide

Peak Flood Suspended Solids

On the wet season neap tide, water speeds are low for much of the tidal cycle and sediment settles to the seabed relatively quickly, leaving comparatively little in suspension. Examination of SS concentration contour plots indicates that the wet season spring (Scenario 4c) and neap tide plumes are similar on the flood tide.

Peak Ebb Suspended Solids

The behaviour of the sediment losses on the neap tide are similar to those on the wet season spring tide (Scenario 4c) described above. However on the ebb tide, the wet season neap tide plumes do not extend as far south from South Tsing Yi as the wet season spring tide plumes.

SS Concentrations at Sensitive Receivers

At the sensitive receivers, peak increases in concentration for the wet season neap tide were similar to those predicted for the wet season spring tide. The sediment plume did not lead to increases in SS concentration in excess of 10 mg l^{-1} at any of the sensitive receivers except for the Ma Wan Fishery where peak concentrations reached 10 mg l^{-1} in the surface layer, and 13 mg l^{-1} in the bed layer just before high tide. It is probable that the lower water velocities, and possible increased landward residual flow in the lower water column on the neap tide, result in reduced dispersion of the sediment and marginally higher impact on local sensitive receivers to the north of the South Tsing Yi MBA. At Anglers and Gemini Beaches, peak concentrations ranged from 8 to 9 mg l^{-1} above background in both the surface and bed layers. At Tung Wan Tsai concentrations peaked at 9 mg l^{-1} in the surface layer only and at the Ma Wan FCZ (surface and bed layers), concentrations peaked at around 5 mg l^{-1}. At the Tsing Yi Power Station peak bed layer concentrations approached 8 mg l^{-1}. All other sensitive receivers were either not impacted by elevated concentrations or were impacted at levels less than 3 mg l^{-1}.

Bed Deposition

The smaller tidal flows and possibly stronger landward residual flow of the wet season neap tide are manifested in the bed deposition predictions. The bed deposits occur to a lesser extent in the area south of Tsing Yi, but to a slightly greater extent toward Castle Peak and beyond, than on the wet season spring tide. Most of the sediment settles locally in the vicinity of the South Tsing Yi MBA with peak deposition rates of just over 1 kg m^2 day^{-1} off the west coast of Tsing Yi Island.

Nutrient Release

The predicted peak total nitrogen increases resulting from Scenario 4d were the same as for Scenario 4c, with 0.008 mg l^{-1} in the surface layer and 0.01 mg l^{-1} in the bed layer.

Scenario 4e

Scenario 4e models the dry season spring tide conditions of Scenario 4a with an identical rate of backfilling at the North of Lantau MBA (10,000 m^3 day^{-1}) and a 50% reduction in the rate of backfilling at the South Tsing Yi MBA (100,000 m^3 day^{-1}). Modelling results are plotted in *Annex W*.

Peak Flood Suspended Solids

The peak flood modelling results for Scenario 4e are very similar to those for Scenario 4a with an area of elevated SS concentrations between the southern tip of South Tsing Yi and Ma Wan Island. However, within the surface layer there is no evidence of a highly localised area of high SS concentration at the South Tsing Yi MBA source and the concentration in the area between South Tsing Yi and Ma Wan is of a lower concentration (1–10 mg l^{-1}) than that for Scenario 4a (10–20 mg l^{-1}). As in Scenario 4a, the coherent surface plume (1–10 mg l^{-1}) extends from the South Tsing Yi MBA, north-west through Kap Shui Mun and north of Ma Wan, ending between the points of Sham Shui Kok and Tuen Mun.

Both the extent and concentrations within the bed layer SS plume are greater than at the surface. There is an area of high SS concentration (10–20 mg l^{-1}) situated in the channel between the south of Ma Wan and Tsing Yi Island, which is surrounded by an area of lesser concentration (1–10 mg l^{-1}) extending from Pillar Point in the west to beyond the western edge of Hong Kong Island in the south.

Peak Ebb Suspended Solids

As with peak flood conditions, peak ebb conditions are similar in pattern to those noted for Scenario 4a but show reduced plume concentrations. At peak ebb the extent of the sediment plume is greater in both the surface and bed layers than during peak flood. In the surface layer, although the plume extends a shorter distance along the coast of Lantau to a line parallel with Tai Lam Kok, it extends in a coherent form further south–east between the southern tip of Lamma Island and Cheung Chau (approximately 15 km from South Tsing Yi MBA). The majority of the plume has concentrations ranging between 1 and 10 mg l^{-1}. There is an isolated area at the South Tsing Yi MBA with concentrations between 10 and 20 mg l^{-1} where SS has not yet dispersed.

In the bed layer the plume is less coherent and extends northwest to the Brothers Islands and stops almost parallel with Siu Lam along the southwest New Territories coastline. The majority of the plume has concentrations of 1 to 10 mg l^{-1} with limited areas between the South Tsing Yi MBA and Green Island and between Kau Yi Chau and the northern edge of Lamma Island at concentrations of 10–20 mg l^{-1}.

SS Concentrations at Sensitive Receivers

Peak surface and bed layer SS concentrations of 5 mg l^{-1} above background were predicted at Angler's and Gemini Beaches, and 4 mg l^{-1} and 3 mg l^{-1} at Casam Beach and Hoi Mei Wan respectively. At the other affected beaches (Lido and Butterfly Beaches), peak SS elevations above background did not exceed 2 mg l^{-1}. Peak surface layer concentrations of 4 mg l^{-1} were predicted for the Kennedy Town WSD Intake, the Queen Mary Hospital Intake and the Wah Fu Estate Intake. At all affected fisheries or fish culture zones, transitory peak concentrations of less than 7 mg l^{-1} above background were predicted by Scenario 4e. Predicted concentrations were highest at the Ma Wan Fishery (7 mg l^{-1}), Tung Wan Tsai (6 mg l^{-1}), Kau Yi Chau Fishery (4 mg l^{-1}) and the Ma Wan Mariculture area (3 mg l^{-1}). All other fisheries and fish culture zones were predicted to experience above ambient concentrations of less than 1 mg l^{-1}.

Bed Deposition

Scenario 4e, like Scenario 4a, predicted no deposition in the main flow channels in the Western Harbour or the Urmston Road. The highest deposition rates (0.5–1 kg m^{-2}) were predicted in, and very locally to, the MBA with some light deposition (0.01–0.25 kg m^{-2}) in the East Lamma Channel and over the deeper waters immediately to the south of the Western Harbour.

Dissolved Oxygen

The model results indicated that over the entire affected area, except in the South Tsing Yi MBA, DO concentrations would remain above 6.44 mg l^{-1} in both the surface and bed layers. Immediately at the South Tsing Yi dump site, the DO deficit of between 6.1 and 6.4 mg l^{-1} would result.

Nutrient Release

The nutrient release assessment determined that peak nitrogen level increases would be 0.02 mg l^{-1} for both surface and bed layers in the immediate vicinity of the South Tsing Yi MBA and 0.005 mg l^{-1} in the surface and bed layers outside the South Tsing Yi MBA.

Scenario 5

Scenario 5 was the first of four scenarios investigating cumulative impacts of the backfilling activities and simultaneous dredging in the Western Harbour. Scenario 5 used Scenario 4a as the base scenario for backfilling alone (maximum backfilling at both MBAs, on the dry season spring tide), plus dredging of surface marine sands from South Tsing Yi at a rate of 2.4 Mm^3 $month^{-1}$. Modelling results are plotted in *Annex I*.

Peak Flood Suspended Solids

The results of this simulation predict a coherent plume in the surface layer extending from the Brothers Islands in North Western Waters south to Sunshine Island. The sections of the plume branching north of Ma Wan and through Kap Shui Mun comprise SS concentrations of 10–50 mg l^{-1}. There was also a narrow area approximately 3 km in length with concentrations of 50–100 mg l^{-1}, south of Tsing Yi on an axis between Ma Wan and Green Island. In this area of the plume there were also two small areas, one at

South Tsing Yi MBA and one further south in the centre of the Western Buffer Zone where concentrations peaked above 100 mg l^{-1}.

Peak Ebb Suspended Solids

The size of the plume was far greater on the peak ebb tide, extending into southern waters past Lamma Island. SS concentrations in the surface and bed layer were predicted to exceed 250 mg l^{-1} over limited areas. Throughout most of the plume in the open waters of the Western Harbour, it was predicted that SS levels would exceed the background conditions by concentrations ranging from 20 to 100 mg l^{-1}.

SS Concentrations at Sensitive Receivers

Concentrations at Ma Wan Fishery were predicted to increase by approximately 60–70 mg l^{-1} for a short period around high water in both the surface and bed layers with concentrations at Anglers and Gemini Beaches increasing by approximately 30 mg l^{-1} in both surface and bed layers. It was also predicted that Kau Yi Chau Fishery and Tung Wan Tsai would experience increases in concentrations of up to 50 mg l^{-1} in the surface layer only. The Ma Wan FCZ, Hoi Mei Wan Beach (surface layer only), Casam Beach and Tsing Yi Power Station were predicted to receive elevated concentrations of 15–30 mg l^{-1} in both the surface and bed layers and Lido Beach (surface layer only) and the Lo Tik Wan FCZ (surface and bed layers) were predicted to experience elevated concentrations up to 10 mg l^{-1}.

At the sea water intakes for Kennedy Town WSD intake, Queen Mary Hospital and the Wah Fu Housing estate, concentrations in the bed layer were predicted to rise to between 40 and 60 mg l^{-1} above background for periods of a few hours. In the surface layer, elevated concentrations of up to 30 mg l^{-1} are predicted.

Bed Deposition

On the dry season spring tide, deposition of sediment in the main flow channels was limited to an area west of Green Island and the northern area of the East Lamma Channel. In the areas of slacker water to the south of the South Tsing Yi MBA deposition rates of just over 2 kg m^2 day^{-1} were predicted while in the slack water areas along the eastern shore of Ma Wan and the Western shore of Tsing Yi Islands, deposition rates of the order of 1 kg m^2 day^{-1} were estimated. In the South Tsing Yi MBA immediately under the dredger, deposition rates actually peaked at almost 150 kg m^2 day^{-1} over an area 250 m^2 dropping off rapidly to 10 kg m^2.

Dissolved Oxygen

In most of the area between the South Tsing Yi and West Sulphur Channel MBAs, DO concentrations were predicted to be reduced by up to 0.4 mg l^{-1} (5%) with a larger area oxygen deficit in the bed layer extending further south to north Lamma Island. Immediately between the two borrow pits, the maximum DO deficit of up to 0.8 mg l^{-1} ($\approx$10% saturation) covered an area of approximately 1,700 m long by 700 m wide in the bed layer. The greatest reduction (0.8 mg l^{-1}) would result in an actual concentration of 5.1 mg l^{-1} (calculated from the mean concentration of 5.9 mg l^{-1}).

Nutrient Release

Scenario 5 was predicted to results in peak increases in total nitrogen concentration of 0.05 mg l^{-1} in the surface layer and 0.125 mg l^{-1} in the bed layer. These figures equate to nitrogen increases in the water column of 10% in the surface layer, and 25% in the bed layer, of the mean observed total nitrogen concentration over the central area of the Western Harbour. At locations more remote from the dredging operations, including the sensitive receivers, maximum increase in total nitrogen would be less than 5% of the mean.

3.9.5 *Scenario 6*

Scenario 6 simulated the base Scenario 4a (maximum backfilling at both MBAs, on the dry season spring tide), plus dredging of bottom alluvial sands from South Tsing Yi at a rate of 2.4 Mm^3 $month^{-1}$. The sediment plumes generated by this combination of dumping and dredging (*Annex J*) had typical concentrations of less than 40 mg l^{-1} over the entire area affected. Plumes were larger in both the surface and bed layers during the peak ebb tide.

SS Concentrations at Sensitive Receivers

At Anglers and Gemini beaches, it was predicted that increases in background concentrations of approximately 10 mg l^{-1} would occur for approximately 1–2 hours in both the surface and bed layers, with increases in concentration of less than 5 mg l^{-1} being predicted for most of the tidal cycle. At Hoi Mei Wan and Casam Beach, elevations in surface layer concentrations of 5–10
mg l^{-1} were predicted.

At the Ma Wan Fishery, increases in concentrations of 15–20 mg l^{-1} were predicted to occur for a short period (around 1 hour) in both surface and bed layers with elevations in concentration remaining below 10 mg l^{-1} for the majority of the tide. At Tung Wan Tsai, plume concentrations in the surface layer only were predicted to be 10–15 mg l^{-1} for a short duration during the tide. At the Ma Wan FCZ and Tsing Yi Power Station, elevations in background concentrations of approximately 5 mg l^{-1} or lower were predicted for both the surface and bed layers. At the Kau Yi Chau Fishery, increases in background concentrations of up to 10 mg l^{-1} at times were predicted for the surface layer only, while at the Kennedy Town, Queen Mary Hospital and Wah Fu Housing Estate water intakes, increases in surface and bed layer concentrations of typically 5–10 mg l^{-1} were predicted for period of up to 4 hours during the tidal cycle. All other sensitive receivers were either not predicted to be impacted or were predicted to be impacted at concentrations below 3 mg l^{-1}.

Bed Deposition

Settlement of the suspended sediment to the seabed was confined mainly to the MBA, and those areas outside the main flow channels. Peak deposition rates of around 1 kg m^{-2} day^{-1} were predicted over the borrow area but most deposition occurred over a larger area at rates of 0.01 kg m^{-2} day^{-1} to 0.5 kg m^{-2} day^{-1}.

Dissolved Oxygen

The sediment losses resulting from dredging of deeper alluvial sand were predicted to have little additional effect on DO concentrations when compared to Scenario 4a. The dissolved oxygen patterns for this scenario were very similar to those for Scenario 4a, apart from very localised sag at the borrow area of up to 0.4 mg l^{-1} (5% saturation).

Nutrient Release

The nutrient release assessment determined that the peak concentration of total nitrogen would increase by 0.01 mg l^{-1} in the surface layer and 0.02 mg l^{-1} in the bed layer.

Scenario 7

This scenario modelled Scenario 4a (maximum backfilling at both MBAs, on the dry season spring tide) and dredging of surface marine sands from South Tsing Yi MBA plus dredging in West Sulphur Channel (including dredging and reclamation at Green Island). This scenario therefore represents Scenario 5 with the addition of an estimated loss to suspension of approximately 20,000 t day^{-1}. Modelling results are presented in *Annex K*.

SS Concentrations at Sensitive Receivers

At most of the sensitive receivers, the results from this scenario are very similar to those obtained in the simulation without the West Sulphur Channel dredging (Scenario 5). At most sensitive receivers, the additional dredging losses from the West Sulphur Channel dredging only increased SS concentrations by 1-2 mg l^{-1}. The notable exceptions to this were the water intakes at Kennedy Town, Queen Mary Hospital and Wah Fu Housing Estate, which are located close to the West Sulphur Channel MBA, where peak concentrations above background reached approximately 38 mg l^{-1}, 40 mg l^{-1} and 27 mg l^{-1} respectively in the surface layer and 60 mg l^{-1}, 75 mg l^{-1} and 75 mg l^{-1} in the bed layer during the tidal cycle.

Bed Deposition

This scenario resulted in the greatest extent of sediment deposition. Although similar in overall pattern to the deposition pattern for Scenario 5, the deposition rates were higher and covered a slightly larger area as a result of the additional dredging losses from West Sulphur Channel. The highest deposition rates in coastal areas were predicted along the eastern coast of Ma Wan and western coast of Tsing Yi where deposition was expected to reach levels of approximately 1.5 kg/m^3 and in the vicinity of Green Island where the deposition rates were predicted to exceed 2 kg/m^3.

Dissolved Oxygen

The results from this scenario were similar to those for Scenario 5. The area with an oxygen deficit of less than 0.2 mg l^{-1} covered approximately the same area but the extent of the oxygen deficit of 0.4-0.2 mg l^{-1} and 0.8-0.4 mg l^{-1} covered slightly larger areas spanning both MBAs. As a result of the dredging at West Sulphur Channel, a local oxygen deficit of 0.8-0.4 mg l^{-1} which was not present for Scenario 5, was generated over the West Sulphur Channel borrow pit.

As a result of the slightly higher overall sediment concentrations caused by the additional dredging compared to Scenario 5, a very localised dissolved oxygen deficit of 0.4–0.2 mg l^{-1} was predicted close to the North Lantau borrow area. The impact of the West Sulphur Channel dredging at North Lantau is very marginal and it is thought that the predicted oxygen deficit of 0.8–0.4 mg l^{-1} compared to 0.4–0.2 mg l^{-1} for Scenario 5 actually represents a very small change in concentration close to the contouring boundary.

Nutrient Release

It was predicted that Scenario 7 would result in the largest peak increases in total nitrogen concentration, of 0.055 mg l^{-1} in the surface layer and 0.15 mg l^{-1} in the bed layer. These equate to increases of approximately 10% (surface layer) and 25% (bed layer). However, at locations more remote from the dredging operations, including the sensitive receivers, maximum increases in total nitrogen would be expected to be less than 5% of the mean.

Scenario 8

This scenario modelled Scenario 4a (maximum backfilling at both MBAs, on the dry season spring tide) and dredging of bottom alluvial sands from South Tsing Yi MBA plus dredging in West Sulphur Channel (including dredging and reclamation at Green Island). This scenario therefore represents Scenario 5 with the addition of an estimated loss to suspension of approximately 20,000 t day^{-1}. Modelling results are presented in *Annex L*.

The extent and concentrations of the peak ebb simulation were far greater than those during the peak flood. In the peak ebb tide modelling, a large coherent plume formed in the surface layer extending west along the south coast of Hong Kong island, and south past Lamma Island. Peak concentrations in the bed layer of open waters of the Western Harbour reached concentrations of nearly 150 mg l^{-1} for a short period during the tidal cycle. Over most of the tidal cycle, however, elevations in suspended sediment concentrations were predicted to remain below 50 mg l^{-1} within the bed layer and maintain even lower concentrations in the surface layer.

SS concentration at Sensitive Receivers

At Anglers and Gemini Beaches, elevations in concentrations in both surface and bed layers were predicted to peak at approximately 14 mg l^{-1} for a period of approximately 1 hour during the tidal cycle, falling to near ambient levels within 4 hours. At the Ma Wan Fishery, elevations of up to 25 mg l^{-1} are predicted for approximately 2 hours in both surface and bed layers, but with the increase in concentration remaining below 10 mg l^{-1} for the majority of the tide. At the Kau Yi Chau Fishery, short duration (1–2 hours) peak concentrations of up to 18 mg l^{-1} were indicated in the surface layer, while at the Kennedy Town, Queen Mary Hospital and Wah Fu Housing Estate water intakes, elevations in concentrations varied from approximately 23 mg l^{-1} in the surface layer to between 33 and 61 mg l^{-1} in the bed layer persisting for approximately 4 hours.

Other sensitive receivers were effected to a lesser extent. At Hoi Mei Wan, Casam and Lido beaches concentrations in both surface and bed layers were predicted to remain below 10 mg l^{-1} throughout the tidal cycle. Predicted suspended sediment concentrations at fish culture zones ranged from up to 20 mg l^{-1} in the surface layer at Tung Wan Tsai to below 10 mg l^{-1} in both surface and bed layers at the Ma Wan and Lo Tik Wan FCZs. Predicted SS levels at the Tsing Yi Power Station were below 10 mg l^{-1} in the bed layer and below 5 mg l^{-1} in the surface layer.

Bed Deposition

The pattern of bed deposition for Scenario 8 is generally similar to that for Scenario 6 except for higher deposition predictions for the areas around the West Sulphur Channel borrow pit. The effects of the sand dredging at the West Sulphur Channel MBA act to increase bed deposition in the area of the South Tsing Yi MBA to between 1 and 2 mg l^{-1} and elevate concentrations in the vicinity of Green Island to above 2 mg l^{-1}.

Dissolved Oxygen

The results dissolved oxygen calculations for Scenario 8 were also similar to the Scenario 6 results. The main impact of the dredging at West Sulphur channel can be seen in the larger dissolved oxygen deficit (up to 0.8–0.4 mg l^{-1} in the surface layer and 0.4–0.2 mg l^{-1} in the bed layer) to the west of Green Island.

Nutrient Release

The nutrient release assessment has determined that Scenario 8 would lead to peak increases in total nitrogen concentration of 0.025 mg l^{-1} in the surface layer and 0.075 mg l^{-1} in the bed layer. These concentrations would be substantially reduced through dispersion before reaching sensitive receivers.

Scenario 9

As detailed in *Section 3.8*, Scenario 9 was conducted to validate whether the WAHMO model could accurately predict increases in SS concentration resulting from the backfilling operations. This was tested by modelling the maximum backfilling rates that were used during the initial backfilling at South Tsing Yi MBA under another project and sediment inputs from dredging and filling activities at the Chek Lap Kok Airport, to determine whether the model could predict those SS concentrations that actually occurred. Modelling results are presented in *Annex M*.

Surface Layer SS Concentrations

In the surface layer this scenario predicted a high concentration plume, ranging from 100 mg l^{-1} to 150 mg l^{-1}, extending approximately 10 km from the 'sediment source line' (representing the airport's contribution) to a point parallel with the north-eastern tip of Lantau Island. Within this plume there were several areas of concentrations in excess of 150 mg l^{-1} in the immediate vicinity of the Brothers. There was also a localised increase ranging from 100 to 150 mg l^{-1} predicted adjacent to Tsing Lung Tau.

The plume extended approximately 15 km, with predicted concentrations between 50 mg l^{-1} and 100 mg l^{-1}, along the coastlines of North Lantau and the North West New Territories, through Kap Shui Mun and the Ma Wan Channel, and along the coast of Tsing Yi Island. A lower concentration plume of sediment extended further, approximately 25 km from the source line, with SS concentrations ranging from 1 to 50 mg l^{-1}. This lower concentration plume extended along the West Lamma Channel to the southern tip of Lamma Island, and along the East Lamma Channel to Round Island.

At the South Tsing Yi MBA release point elevated SS concentrations ranging between 50 to 100 mg l^{-1} were predicted. However, this was highly localised and rapidly fell to concentrations ranging between 1 and 50 mg l^{-1}.

Bed Layer SS Concentrations

In the bed layer, a high concentration plume in excess of 150 mg l^{-1} was predicted to extend from the 'sediment source line' to the coast of Yam O. The plume SS concentrations then reduce to within the range of 100 to 150 mg l^{-1} and extend until parallel with Tsing Lung Tau and the northern tip of Ma Wan Island. The plume extends west through Kap Shui Mun and the Ma Wan Channel in the same concentrations as the surface layer (1–50 mg l^{-1}), and then extends south–west to a point past Stanley Bay in concentrations ranging from 1 mg l^{-1} to 50 mg l^{-1}. Within this low concentration plume, there is one additional area at Kau Yi Chau where SS concentrations range between 50 and 100 mg l^{-1}.

SS Concentrations at PAA Monitoring Locations and Ma Wan Mariculture Zone

The time history graphs of SS concentrations at *Station 40* indicate values varying between approximately 10 mg l^{-1} and 150 mg l^{-1}. These predicted increases correspond to the actual PAA monitoring results, although this data represented a single instant during the tidal cycle so direct comparison is not possible. At *Station 54/63* predicted concentrations ranged between 100 mg l^{-1} at the end of the ebb phase of the tide, to below 20 mg l^{-1} during the flood phase. Similar concentrations are shown at the Ma Wan Mariculture Zone, in both the surface and bed layers. Again this is similar to the data recorded at the PAA monitoring station with the model reproducing the peak values.

3.10 DISCUSSION OF RESULTS

3.10.1 Suspended Sediment Concentrations

Eight different dredging and dumping scenarios were examined in this series of simulations, in addition to a simulation conducted for the purpose of validating the WAHMO model (Scenario 9). In order to summarise the potential impact of each scenario's predicted suspended sediment concentrations on sensitive receivers, the results have been summarised in *Table 3.10a*.

Examination of the plots of SS concentration over the tidal cycle at each sensitive receiver, shows that in all the dumping–only scenarios and most of the combined dredging and dumping scenarios, significant elevations in SS concentration were predicted for only relatively short periods (1–4 hours typically) during the tidal cycle, as the main sediment plume is carried backwards and forwards on the tide. In order to present this feature, *Table 3.10a* lists the following two concentrations occurring at each sensitive receiver:

- Peak predicted elevation in surface layer SS concentration; and

LOCATION	COMBINED DUMPING ONLY					COMBINED DUMPING PLUS DREDGING			
	Scenario 1	Scenario 2	Scenario 3	Scenario 4a	Scenario 4e	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Anglers Beach	3/0	4/0	3/0	10/5	5/3	32/10	12/5	32/10	14/5
Gemini Beach	0.25/0	0/0	0/0	8/5	5/2	28/7	10/5	29/7	12/5
Hoi Mei Wan	0/0	0/0	0/0	5/1	3/1	20/5	7/2	20/5	9/2
Casam Beach	0/0	0/0	0/0	5/1	4/1	16/5	5/2	18/5	7/2
Lido Beach	0/0	0/0	0/0	3/1	2/1	8/1	3/1	8/1	4/1
Tung Wan Tsai Fish Culture Zone *(50 ppm)*	0/0	0/0	0/0	12/2	6/4	47/10	15/7	49/10	19/7
Ma Wan Fishery *(50 ppm)**	0/0	0/0	0/0	14/6	7/4	63/20	17/10	65/20	25/10
Ma Wan Fish Culture Zone *(50 ppm)**	0.25/0	1/0	2/0	5/4	3/2	20/5	5/3	20/5	7/3
Lo Tik Wan Fish Culture Zone *(50 ppm)*	0/0	0/0	0/0	1/0	1/0	5/2	2/0	8/2	4/1
Kau Yi Chau Fishery *(50 ppm)**	1/0	1/0	4/0	7/1	4/2	50/5	10/3	51/5	18/3
Tsing Yi Power Station *(140 ppm)**	0/0	0/0	0/0	3/1	3/1	15/5	4/3	16/5	5/3
Kennedy Town WSD Intake *(20 ppm)**	0/0	0/0	0/0	7/0	4/1	30/5	9/5	38/10	23/5
Queen Mary Hospital Intake *(140 ppm)**	0/0	0/0	0/0	5/2	4/1	30/2	7/2	40/5	25/2
Wah Fu Housing Intake *(140 ppm)**	0/0	0/0	0/0	3/2	4/1	15/2	4/2	27/2	20/2

Notes

Predicted concentrations show peak surface layer value / concentration not exceeded for over 50% of the tidal cycle.

* Concentrations in italics indicate the specific criterion for each water intake or fish culture zone.

Table 3.10a Indicative Concentrations (ppm) at Sensitive Receivers

- Typical mean elevation in concentration which could persist for at least 50% of the tidal cycle.

Table 3.10a also lists any applicable specific criteria for the sensitive receivers. Where no specific criterion is listed, the maximum allowable suspended sediment concentration is the water quality objective (WQO) (ie 32.5 mg l^{-1}; see *Section 3.8.1* for details). Compliance with applicable WQO and specific criteria is discussed for bathing beaches and sensitive water bodies, power stations, water intakes, and fisheries and mariculture zones below.

Bathing Beaches and Sensitive Waterbodies

The sensitive receivers within this category include a number of bathing beaches along the Tsuen Wan and Tuen Mun coastline and several waterbodies of special concern. Bathing beaches and sensitive waterbodies considered in this assessment include: Anglers Beach, Butterfly Beach, Gemini Beach, Hoi Mei Wan, Casam Beach, Lido Beach, Cafeteria Beach, Sha Chau Beach, Discovery Bay Beach, Silvermine Bay Beach, the Chek Lap Kok Sea Channel, East Tung Chung Bay and Rambler Channel. The beaches for which detectable SS concentrations were predicted under any of the modelled scenarios were Angler's Beach, Gemini Beach, Hoi Mei Wan, Casam Beach and Lido Beach.

Evaluation of suspended sediment concentration at these sensitive receivers is determined through comparisons to the EPD Water Quality Objective for SS (32.5 mg l^{-1}, see *Section 3.8.1*). Assuming an ambient SS concentration of 25.0 mg l^{-1} (see *Section 3.8.1*), any elevation of greater than 7.5 mg l^{-1} will result in a predicted non-compliance at bathing beaches and sensitive waterbodies SRs. Of the scenarios simulating concurrent backfilling at the North of Lantau and South Tsing Yi MBAs, Scenarios 1, 2, 3 and 4e do not result in any predicted non-compliances. Scenario 4a, the maximum rate modelled for backfilling in the absence of other dredging/disposal projects, results in slight exceedances of WQOs at Anglers and Gemini Beaches (*Table 3.10a*).

More substantial exceedances of WQOs were predicted for scenarios modelling backfilling in conjunction with indicative dredging/disposal projects. Scenarios involving dredging of top marine sand at the South Tsing Yi MBA (Scenarios 5 and 7) resulted in elevated SS concentrations at bathing beaches ranging from 16 to 32 mg l^{-1}. These concentrations would exceed the WQO by 8.5–24.5 mg l^{-1}. Although scenarios involving dredging of bottom alluvial sand (Scenarios 6 and 8) predict lower elevations in SS concentration (5–14 mg l^{-1}), under these scenarios, WQOs could still be exceeded by up to 6.5 mg l^{-1}.

Power Stations

Power stations evaluated in this Study include the Castle Peak, Black Point, Lamma and Tsing Yi Power Stations. No elevated concentrations of suspended sediments were predicted for the Castle Peak, Black Point or Lamma Power Stations. The Tsing Yi Power Station, listed in *Table 3.10a*, was predicted to experience elevated SS concentrations under some scenarios. For this sensitive receiver, both the WQO of 32.5 mg l^{-1} and the specific criterion of 140 ppm (mg l^{-1}) are applicable.

SS concentrations predicted at the Tsing Yi Power Station can be categorized into three groups: undetectable, elevated but compliant with the WQO, and elevated and not compliant with the WQO. All scenarios' predicted SS concentrations are compliant with the specific criterion.

Scenarios 1, 2 and 3 predict no detectable elevation in SS concentrations at the Tsing Yi Power Station. Scenarios 4a, 4e, 6 and 8 predict elevations of 3–5 mg l^{-1} and, assuming an ambient value of 25 mg l^{-1}, will not exceed the WQO of 32.5 mg l^{-1}. Scenarios 5 and 7, both involving dredging of top marine sand at the South Tsing Yi MBA, are predicted to result in SS elevations of 15–16 mg l^{-1} and thus will exceed the WQO.

Water Intakes

Water intakes included in the sensitive receiver evaluations for each scenario comprise the Tsing Yi, Tsuen Wan, Tuen Mun, Kennedy Town Water Supplies Department (WSD), Queen Mary Hospital and Wah Fu Estate water intakes. The Tsing Yi, Tsuen Wan and Tuen Mun water intakes are not predicted to experience detectable elevations in SS concentration under any of the modelled scenarios and thus are not included in *Table 3.10a*.

Similar to the power stations described above, evaluation of SS concentration compliance at water intakes involves comparison to WQOs and specific criteria required by the individual facilities. The specific criteria for the three water intakes of concern are:

- Kennedy Town WSD Intake: 20 ppm (mg l^{-1})
- Queen Mary Hospital Intake: 140 ppm (mg l^{-1})
- Wah Fu Housing Estate Intake: 140 ppm (mg l^{-1})

For the Queen Mary Hospital and Wah Fu Estate Intakes, none of the modelled scenarios result in predicted elevations of SS in exceedance of the specific criteria. In addition, all of the backfilling only scenarios (Scenarios 1, 2, 3, 4a and 4e) predict elevations of 0–7 mg l^{-1} which, assuming an ambient value of 25 mg l^{-1}, would not exceed the WQO of 32.5 mg l^{-1}. Scenarios involving backfilling in conjunction with other dredging/disposal projects (Scenarios 5, 6, 7 and 8) predict elevations in SS concentration of up to 40 mg l^{-1} and are in all cases but one (Scenario 6 at the Queen Mary Hospital Intake) in exceedance of the WQO for SS.

In contrast to these intakes, the Kennedy Town WSD Intake has a conservative specific criterion of 20 mg l^{-1} which is considerably lower than the WQO used for all other sensitive receivers (32.5 mg l^{-1}). However, as described in *Section 3.8.1*, based on an agreement with the Study Management Group, a site–specific ambient value of 16.9 mg l^{-1} is used to calculate the WQO for the Kennedy Town intake of 21.9 mg l^{-1}. Therefore, for this sensitive receiver, the WQO and the specific criterion are quite similar and substantially lower than for other sensitive receivers.

For scenarios involving backfilling only, both Scenarios 4a (7 mg l^{-1}) and 4e (4 mg l^{-1}) exceed the specific criterion of 20 mg l^{-1} when added to the ambient value of 16.9 mg l^{-1}. However, Scenario 4e does not exceed the WQO of 21.9 mg l^{-1}. Scenarios 1, 2 and 3 do not predict exceedances of either the WQO or the specific criterion. The reason for a predicted exceedance in Scenario 4e, which models a backfilling rate at the South Tsing Yi MBA of 100,000 m^3 day^{-1}, and no prediction of exceedance in Scenario 1, which models a backfilling rate at the South Tsing Yi MBA of 150,000 m^3 day^{-1}, is due to differences in the models used.

Scenarios involving backfilling in conjunction with other dredging/disposal projects (Scenarios 5, 6, 7 and 8) result in substantial predicted exceedances of both the WQO and the specific criterion (*Table 3.10a*). Predicted elevations ranging from 9 to 38 mg l^{-1} result in exceedances of the specific criteria by approximately 6 to 35 mg l^{-1}.

While it is clear that backfilling in conjunction with the other dredging/disposal projects modelling is unacceptable in term of SS concentrations at water intakes, backfilling activities alone are either in compliance with WQOs and specific criteria, or are predicted to marginally exceed these criteria (less than 4 mg l^{-1}). Further, at the reduced rate of backfilling at South Tsing Yi MBA (100,000 m^3 day^{-1}), the predicted SS concentration is within the WQO limit and exceeds the specific criterion by only 0.9 mg l^{-1}. It is also important to note that this reduced backfilling rate has been modelled for the worst case seasonal–tidal condition and that the SS concentration resulting in the exceedance will only occur for less than 4 hours during the tidal cycle.

For these reasons, the backfilling rate represented by Scenario 4e is considered acceptable. Higher rates of backfilling at the South Tsing Yi MBA, and backfilling at the reduced rate in conjunction with other dredging/disposal projects may require additional mitigation measures to ensure compliance with water intake WQOs and specific criteria. These evaluations are described in and facilitated by the Cumulative Effects Assessment Manual (CEAM) and will be verified through monitoring conducted in accordance with the Environmental Monitoring and Audit (EM&A) Manual.

Mariculture and Fisheries

Fisheries areas evaluated by this Study for potential impacts associated with backfilling include the Silvermine Bay Fishery, the Ma Wan Fishery, the Kau Yi Chau Fishery, the Penny's Bay Fishery, the Tai Pak Wan Fishery, the Ma Wan Fish Culture Zone (FCZ), the Tung Wan Tsai FCZ, the Lo Tik Wan FCZ and the So Kwu Wan FCZ. Of these fisheries areas, only the Tung Wan Tsai FCZ mg l^{-1}, the Ma Wan Fishery, the Ma Wan FCZ, the Kau Yi Chau Fishery and the Lo Tik Wan FCZ are predicted to experience elevated concentrations under any of the modelled scenarios.

Compliance evaluations for fisheries areas are determined by the WQO for SS (32.5 mg l^{-1}) and specific criteria for each fisheries area or FCZ. Consultation with AFD has confirmed that a value of 50 mg l^{-1} should be adopted as the appropriate criterion to be used for potentially impacted fisheries and fish culture zones in the area. [32]

None of the backfilling only scenarios modelled at the lower rates of backfilling (Scenarios 1, 2, 3, and 4e) resulted in exceedance of either the WQO of the specific criterion. These scenarios predicted elevated SS concentrations of 0–7 mg l^{-1}, which in combination with the ambient value of 25 mg l^{-1}, does not exceed 32.5 mg l^{-1} (WQO) or 50 mg l^{-1} (specific criterion). Scenario 4, which models a higher rate of backfilling, predicts

(32) Wilson K AFD 12 June 1995 Fax AF POL 01/18/7.

compliance with the specific criterion for all five fisheries areas and compliance with the WQO for all but the Tung Wan Tsai FCZ and the Ma Wan Fishery. At these two areas, the WQO is predicted to be exceeded by 4.5–6.5 mg l^{-1}.

For the indicative cumulative scenarios, most fisheries areas were predicted to experience SS concentrations exceeding the WQO. Notable exceptions include Scenarios 5, 6 and 8 at the Lo Tik Wan FCZ and Scenarios 6 and 8 at the Ma Wan FCZ. The highest elevations (47–65 mg l^{-1}), and those which exceeded the specific criterion when combined with the ambient value, occurred in Scenarios 5 and 7 for the Tung Wan Tsai FCZ, the Ma Wan Fishery and the Kau Yi Chau Fishery.

Validation Results

The aim of Scenario 9 was to investigate the cause of the high suspended SS concentrations which occurred at the Ma Wan Mariculture Zone during January 1994, and to verify whether the WAHMO model could accurately predict increases in SS concentrations. The results of this scenario have shown that SS concentrations greater than 150 mg l^{-1} in the North Western Waters would result in elevated SS concentrations of approximately 100 mg l^{-1} at the Ma Wan Mariculture Zone. This result corresponds with the field data recorded at the beginning of January 1994, collected when the highest concentrations of SS were recorded at the Ma Wan Mariculture Zone. The modelling exercise has therefore shown that the elevated concentrations at Ma Wan were almost certainly the result of high concentrations in the North Western Waters, rather than the result of backfilling at South Tsing Yi MBA.

3.10.2 Mixing zone calculations

This section presents calculations for the area within which SS concentrations predicted for each modelled scenario exceed the WQO of 32.5 mg l^{-1}. In order to derive the areas given below, the SS concentration results from the sediment plume modelling were reanalysed to calculate the maximum concentration throughout the tidal cycle in each model grid square. Contour plots of maximum of SS concentration for the upper and lower layers were produced showing the area with concentrations greater than 32.5 mg l^{-1}. The outline of the 32.5 mg l^{-1} contour was then digitized and the plan area calculated using AUTOCAD software. This procedure was carried out for non-cumulative impact scenarios 1 and 4, and cumulative impact Scenarios 5, 6, 7 and 8. The results of the calculation of the mixing zones are given in *Table 3.10b* below.

Dissolved Oxygen (DO)

The Water Quality Objectives for the WCZs affected by the oxygen deficit require:

- Dissolved oxygen of not less than 2 mg l^{-1} within 2m of the bottom
- Dissolved oxygen of not less than 4 mg l^{-1} depth averaged
- Dissolved oxygen of not less than 5 mg l^{-1} in fish culture zones

EPD routine water quality monitoring data was used to calculate a background concentration for DO of 85% saturation (6.5 mg l^{-1}). Given this ambient level, any drop in DO of less than 1.5 mg l^{-1} (19% drop in saturation) can be tolerated without causing an exceedance of WQOs for DO.

Table 3.10b *Mixing Zone for Suspended Sediments*

Scenario	Layer	Mixing Zone Area (km^2)
1	Surface	0.27
1	Bed	0.18
4a	Surface	0.68
4a	Bed	3.56
4b	Surface	0.79
4b	Bed	1.14
4c	Surface	0.57
4c	Bed	0.67
4d	Surface	0.57
4d	Bed	0.68
4e	Surface	0.27
4e	Bed	0.22
5	Surface	101.50
5	Bed	70.13
6	Surface	1.10
6	Bed	7.30
7	Surface	110.60
7	Bed	63.10
8	Surface	31.30
8	Bed	40.80

The modelling assessment has shown that for the worst case non-cumulative scenario (Scenario 4a) the DO deficit would be less than 4% saturation, and for the cumulative scenarios (Scenario 5, 6, 7 and 8) DO deficits of up to 10% were predicted. As these concentrations are not sufficiently depressed to cause exceedance of the WQOs, all scenarios are found to be acceptable in terms of DO.

Nutrient Release

A summary of the results of predicted nutrients concentrations showing the expected peak (worst case) increase in total nitrogen, calculated from suspended sediment concentrations in the Western Harbour, is provided in *Table 3.10c*.

As the WQO for nutrients (*Section 3.2*) is given in terms of annual mean, depth averaged, inorganic nitrogen, it is difficult to evaluate compliance using the above data representing total (organic and inorganic) nitrogen at its maximum concentration. Further, it must be noted that the concentration of nitrogen released from disposed sediments will depend to a large extent on the characteristics of the source material. This assessment has used conservative estimates of nitrogen content and actual nitrogen content of backfilling material may vary considerably.

Table 3.10c *Expected Peak Increases in Total Nitrogen Concentrations (mg l^{-1})*

Scenario Number	Peak Surface Layer Increase	Peak Bed Layer Increase
3	<0.005	<0.005
4a	0.005	0.013
4b	0.005	0.013
4c	0.008	0.01
4d	0.008	0.01
4e	0.02	0.02
5	0.05	0.125
6	0.01	0.02
7	0.055	0.15
8	0.025	0.075

Despite these difficulties in evaluating compliance with the WQOs for nutrients, several conclusions may be drawn from this analysis. For all scenarios except those involving dredging of the upper marine sand at South Tsing Yi (Scenarios 5 and 7), the expected increase in total nitrogen is very small and well within the natural range of observed concentrations. For Scenarios 5 and 7, increases in the total nitrogen concentration are predicted to be of the order of 25% (bed layer) and 10% (surface layer) of the mean observed total nitrogen concentration over the central area of the Western Harbour. Therefore, this assessment indicates that there are unlikely to be exceedances of nutrient WQO for backfilling operations alone based on the small values of nitrogen increases under worst case assumptions.

3.11 *EROSION OF SPOIL FROM THE MBAS*

The existing seabed in areas of fine sediments is determined by the rate of supply of sediment in suspension, the tidal currents and intermittent wave action. Water depth in such areas will adjust (ie sediment will erode or deposit) until an equilibrium is reached between the peak tidal currents, the rate of supply of sediment in suspension, and the local wave climate. Any changes to these factors will result in a corresponding change in erosion or accretion of sediment.

The ease with which marine mud can be eroded from the seabed is a function of its density. As a result, if the MBAs were backfilled to natural bed levels using mud with the same density as the natural seabed, it is expected that the surface material in the backfilled pit would be as stable as the surrounding seabed and erosion and deposition rates would remain constant. If, however, the surface material in the backfilled pit is less dense than the surrounding seabed, some erosion will occur until a new but deeper stable bed level is achieved. Ultimately, assuming the natural sediment supply continues, natural bed levels will again be achieved through gradual deposition and consolidation.

The composition of backfill material has been estimated by mud types defined below. The bulk density, dry density and stress required to erode material is presented for each mud type (*Table 3.11a*).

Table 3.11a *Bulk Density, Dry Density and Stress Required to Erode Material*

MUD TYPE	BULK DENSITY (kg m³)	DRY DENSITY (kg m³)	EROSION STRESS (N/m²)
Fluid	1,080	90	0.3
Grab (surface mud)	1,160	210	0.9
Trailer	1,230	330	1.5
Grab (subsurface mud)	1,320	480	2.3

Estimates of erosion can be derived from these figures if the type of material being disposed is clearly defined. However, straightforward calculations for grab– or trailer–dredged material are often complicated by the presence and production of fluid mud during the dredging and disposal process.

During backfilling, fluid mud will be generated in the MBA either as a result of disturbance of previously disposed material or overflow of fines, the impact of disposed material on the natural sea bed, or as a result of unconsolidated material in the barges and dredgers settling through the water column.

In monitoring studies at the East Sha Chau Contaminated Mud Pits (CMPs), it was determined that the rate of production of fluid mud from grab dredged material, either as a result of settlement through the water column or following impact of dumped material on the bed, was less than 3% of the dumped mass. For trailer dredged material, as described under "Properties of Dumped Mud", up to 20% of the dumped mass could be semi–fluid or fluid. Therefore, using these estimates and the results of the recent field trials, volumes of fluid mud generated by backfilling can be estimated.

In order to examine the stability of dumped material for a range of backfill levels, ADCP observations of water velocities (*Annex O*) and the results of wave prediction and tidal flows at each MBA were analysed. Potential erosion losses from the South Tsing Yi and North of Lantau MBAs are summarized in the following sections and discussed in detail in *Annexes P* and *Q*, with the background theory presented in *Annex R*.

3.11.1 *Erosion Losses At South Tsing Yi MBA*

In this section, the possible erosion losses of dumped material from the South Tsing Yi MBA are examined. These erosion losses will depend on the availability of soft material which could be eroded and the bed stresses induced by tidal flows and wave action. The bed stresses used in this assessment which could be expected for a range of conditions and backfill levels were calculated from model results and field data and are summarised in *Annex P*.

Analysis of the water velocity observations made along the transects at the South Tsing Yi borrow pit over a large amplitude dry season spring tide indicated typical peak bed stresses in the order of 0.3N/m² to 2.1N/m² depending on location and water depth (*Annex O, Figure 1*). These bed stresses were used in combination with estimates of wet and dry season spring tides and wave induced bed stresses for 0.1, 1, 10, 50 and 100 year return periods to predict the stability of disposed backfill material. These analyses showed that grab- and trailer-dredged materials would be stable under wave and current induced bed stresses at all backfill levels up to -24mPD (*Figure 3.11a*).

In contrast, fluid mud would be eroded at all levels in amounts varying in response to bed stresses (*Figure 3.11a*). Under typical dry season currents, fluid mud at bed levels up to -28mPD would be generally stable, but would erode at all levels, even the existing bed level, under large amplitude spring tides. Under wet season conditions and when exposed to 1/10 year storm waves, fluid mud is stable at bed levels up to about -26mPD. When subject to 1/50 year storm waves, fluid mud would be stable for bed levels up to -33mPD; fluid mud would erode under the action of the 1/100 year storms plus typhoon currents even at the existing bed level (-37mPD).

Since these analyses indicated the main concern for dispersion of sediments through erosion is associated with fluid mud, estimates of the amount of fluid mud available for erosion at the South Tsing Yi MBA were developed. It has been assumed that mainly trailer dredged material would be dumped at South Tsing Yi. For the maximum dumping rate (Scenario 4), assuming the same rate of generation of fluid mud during dumping trailer dredged material at South Tsing Yi as that for grab dredged material at East Sha Chau, approximately 4,300 t day^{-1} of fluid mud would be generated with up to 28,700 t day^{-1} of very soft material (20% of dumped mass) also forming on the seabed.

Assuming the MBA has a plan area of 1km², all of which is exposed fluid mud, in order to erode the entire mass of the 4,300t of fluid mud generated each day, water speeds of over 0.9 m s^{-1} in typical water depths at South Tsing Yi over the whole pit for a period of 3½ hours would be required. From *Annex O, Figure 1* it can be seen that, on the observed large amplitude dry season spring tide, such conditions are not found at the South Tsing Yi MBA. Using the following calculation:

mass eroded = 0.0007 x time x (shear stress - 0.3) x plan area

and integrating the eroded mass at each point over the tidal cycle, it was found that up to 3,000 t day^{-1} of fluid mud could be eroded. However, it is more realistic to assume that only 50% of the MBA surface area is exposed to the higher currents which could erode fluid mud and, assuming even dumping over the MBA, the potential erosion losses on the larger dry season spring tides would then be equivalent to only 1,500 t day^{-1}. This erosion loss is equivalent to 20% of the total simulated losses to suspension during dumping of 7,168 t day^{-1} (*Table 3.8a*). Unlike the simulated losses to suspension, however, any fluid mud eroded would be transported initially in the lower part of the water column.

The amount of fluid mud eroded is expected to vary by location within the MBA. The eastern side of the South Tsing Yi pit is outside the main East Lamma to North Lantau flow channel and experiences lower current speeds and stresses (*Annex O, Figure 1, Stations TY_2, TY_3 and TY_4*). Only areas towards the western side of the pit will experience sufficiently high flows to erode some, if not all of the softest fluid mud component in that area (*Annex O, Figure 1, Stations TY_1, TY_5, TY_6, TY_7 and TY_8*). It should also be noted that the presence of mounds of mechanically dredged material could reduce water speeds near the bed and protect the fluid mud component from erosion to some extent.

Therefore, most if not all of the softest fluid mud contained within the western side of the MBA could be eroded. A dumping strategy which generates a bed slope towards the east is therefore recommended. This would result in fluid mud migrating to areas where bed stresses are lower, and would allow fluid mud to consolidate without being eroded, so reducing the overall erosion losses. Restricting disposal at the South Tsing Yi MBA to grab-dredged material would further reduce the potential erosion losses.

3.11.2 *Erosion Losses at North of Lantau MBA*

This section summarizes the findings of the erosion analyses for the North of Lantau MBA. Details of these analyses are provided in *Annex Q* and background theory is provided in *Annex R*.

Maximum flow-induced bed shear stresses on wet and dry season tides and wave-induced bed shear stresses for 0.1, 1, 10, 50 and 100 year return periods were examined independently and in combination. Since grab-dredged material is proposed for disposal at the North of Lantau MBA, two material types of densities 1,160 kg m^{-3} and 1,320 kg m^{-3} representing surface -derived and subsurface-derived material, respectively, were considered.

Neither surface-derived nor subsurface-derived material were predicted to be eroded under typical wave-induced stresses at backfill levels up to -16mPD (*Figure 3.11b*). However, soft surface materials may be subject to erosion at backfill levels above -20mPD due to current-induced stresses. Subsurface material is the more cohesive of the two and is expected to be stable at backfill levels up to -16mPD for typical currents and the 0.1, 1 and 10 year storm events. Surface material is expected to be stable at or below -20mPD for the same storm events. Bed stresses associated with 1 in 50 and 1 in 100 year storm events were predicted to erode both surface-derived and subsurface-derived materials at backfill levels above -19mPD.

Erosion of fluid mud was also considered as a third material type. Fluid mud was predicted to erode due to tidal current bed stresses alone, (ie in the absence of wave action) on both wet and dry season spring tides at all backfill levels. It thus follows that fluid mud would be eroded under all modelled wave scenarios as well.

Measurements made of dumping at the East Sha Chau CMPs indicate that up to 15% of the deposited material from a grab dredging operation may be in the form of fluid mud. Given that 10 000 m^3 of grab dredged materials will be disposed per day at the North of Lantau MBA, up to 150 t day^{-1} of fluid mud could be generated and all of this material could be eroded from

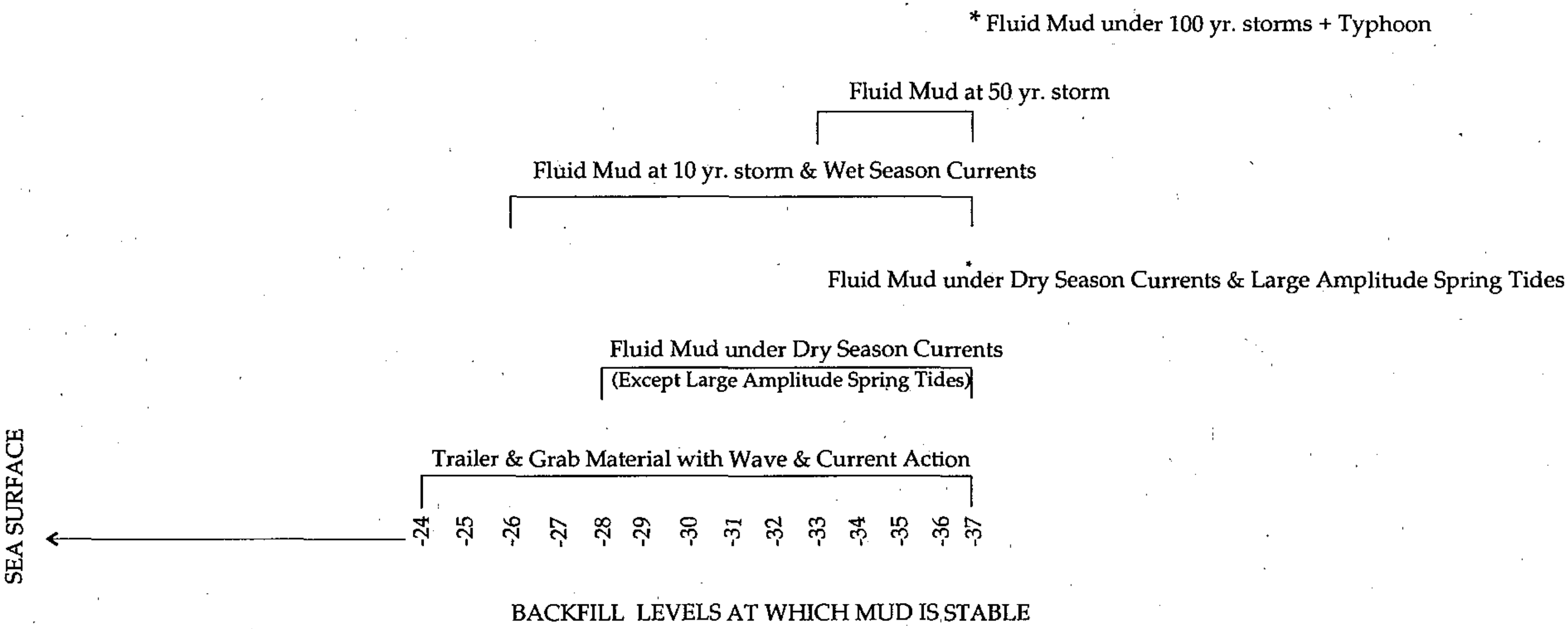

FIGURE 3.11a - EROSION ANALYSES FOR THE SOUTH TSING YI MARINE BORROW AREA

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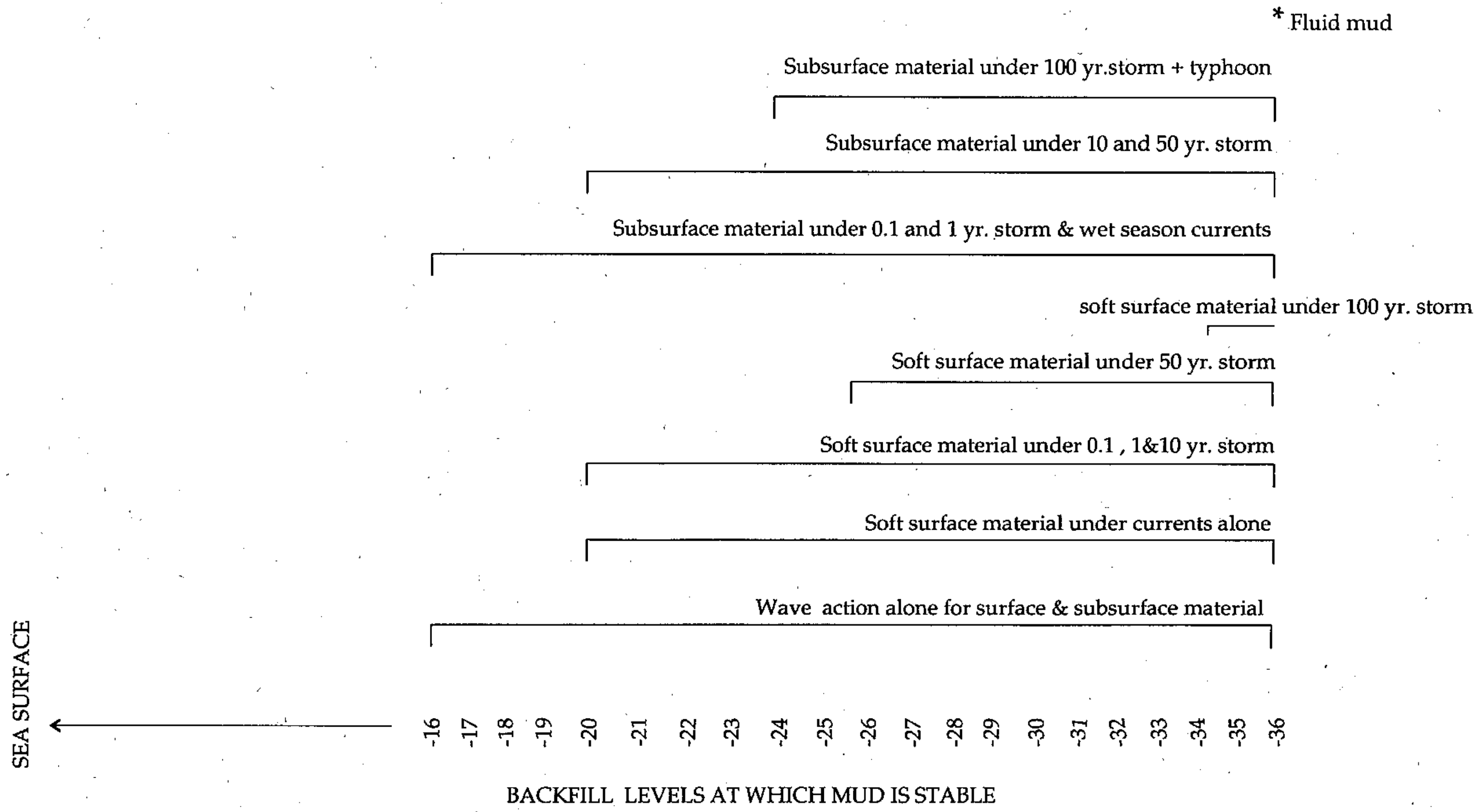

FIGURE 3.11b - EROSION ANALYSES FOR THE NORTH LANTAU MARINE BORROW AREA.

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9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

ERM

the MBA. This loss of fluid mud should be compared with the 382 t day^{-1} (*Table 3.8a*) assumed to be the sediment lost to suspension during dumping. If all of the fluid mud is eroded, the local sediment loss rate at North Lantau would be approximately 40% larger than simulated. From the simulated sediment plumes, however, it was found that the contribution of the sediment losses from North Lantau was not likely to cause concern at the sensitive receivers and a 40% increase in the sediment contribution from North Lantau would not change the conclusions.

Currently, the North of Lantau MBA is open to the deeper waters along its northern edge and is not constrained by a pit wall. Unless material dumped in the pit is retained through placement of mechanically dredged material along this northern edge, fluid mud or other soft material will tend to migrate northwards down any slopes and may not be retained within the MBA.

3.11.3 *Impact of Erosion Losses on Sediment Plume Simulations*

When simulating the sediment plumes, it was assumed that 5% of the dry mass of dumped material would go into suspension at the water surface. For reasons given above (see *Section 3.7.3*) this was considered to be a conservative estimate of sediment losses. Losses due to erosion would represent an additional source of suspended sediments but unlike losses due to disposal, would enter the lower water column on the larger tides only and mainly at times of peak ebb flows.

If fluid mud is generated at both MBAs at the same rate as at East Sha Chau MBA, on a large amplitude dry season tide, the total daily loss rate from both pits could increase from 7,550 t day^{-1} (loss rate for Scenario 4a) to around 10 000 t day^{-1}, an increase of 30% in the total load. The bulk of the erosion losses would be at South Tsing Yi MBA and would be on the order of approximately 1,500 t day^{-1} to 3,000 t day^{-1}. This additional sediment loading due to erosion potentially represents 40–80% of the sediment losses due to dispersion in Scenario 4e. Therefore, the effects of the total sediment loss (dispersion plus erosion) under Scenario 4e are expected to be approximated by Scenario 1 which models backfilling at a rate of 150,000 m^3 day^{-1} (6315 t day^{-1}).

3.11.4 *Erosion Losses From Fill Dredging Operations–Combined Impacts*

It is known that, during dredging of fill material, the dredging overflow forms a dense plume which descends rapidly to the seabed. In the model simulations, it was assumed that 100% of fine material (<63 microns) would be released into suspension in the surface layer of the model which, in the absence of more detailed field data, was assumed in order to maximise the potential transport of fines from the dredging area. In reality, a large percentage of these fines will settle in the pit and may be inhibited from consolidating naturally by the disturbance due to further dredging and overflow of fines.

For Scenario 5, detailed examination of the model results indicated peak deposition rates of the order of 150 kg m^2 per day immediately under the dredger. Over an area 1 km^2 around the South Tsing Yi dredging site on the dry season spring tide, a total mass of approximately 15,000 t day^{-1} of soft mud deposits was predicted to be retained in the pit. This figure is the net deposition following settlement and re–erosion as simulated in the model.

Assuming the soft deposits have a density of the order of 90 kg m³, 15,000 t day^{-1} would be equivalent to the generation of a layer of fluid mud 0.16m thick each day ignoring consolidation effects. This is equivalent to 25% of the total sediment put into suspension each day and it is to be expected that, on a neap tides, a much larger proportion of the dredging losses could be trapped locally.

The fines trapped in the pit could be subject to erosion if tidal and wave induced bed stresses are sufficiently large. However, fines have been known to accumulate in MBAs to the extent that the underlying sand resources become unworkable. Therefore, it would be unrealistic to assume that all the fines predicted to settle locally would be eroded by typical tidal currents. Without prior knowledge of how the pit will be formed and the probable trapping efficiency of the pit, assuming all fines are released to suspension in the surface layer and allowing the pit to retain only the fine material which settles out at slack water periods is considered highly conservative. Therefore, evaluation of effects due to erosion presented in this section are conservative and likely account for any additional impacts associated with concurrent dredging and backfilling operations.

3.12 *SILTATION*

By calculating the total sediment deposits in the model area, it was found that the total deposition rate was very close to the daily total sediment loss rate. That is, all sediment losses eventually settle to the seabed within the area modelled. In the model, it is assumed that over a natural, slowly varying sea bed, the sediment deposits would consist of a thin soft mud layer up to 1cm thick. Once this depth is exceeded, self-weight consolidation was then simulated by assuming that all subsequent deposition resulted in a corresponding amount of consolidation to generate a denser bed below. For the deposition rates expected over much of the area affected (approximately 1 kg m² day^{-1} or less), assuming a dry density of 150 kg m³ for the surface mud deposits and 400 kg m³ for the consolidated deposits, a predicted deposition rate of 1 kg m² day^{-1} would be equivalent to 6½mm day^{-1} loss of depth. Allowing for consolidation as the deposited depth increases gives equivalent deposition rates of 0.08m per month and up to 0.9m per year assuming the deposition rate remains constant on all tides.

The maximum dumping rate alone (Scenario 4) was predicted to generate bed deposits at the rate of up to 0.5-1 kg m² day^{-1} in the vicinity of the pit and along the western shores of Tsing Yi Island, ie, equivalent to 0.5-0.9 m year^{-1}. It is likely that this sediment will accumulate in the more sheltered areas, including dredged channels, without re-erosion except in severe storm events.

The higher deposition rates associated with dredging surface marine sand at South Tsing Yi and West Sulphur Channel MBA could result in deposition rates of 0.9m-2m year^{-1} over a relatively large area. Higher deposition rates of over 2m year^{-1} would be found between the two MBAs. It is also probable that the sediment losses will settle and be retained preferentially in sheltered areas and dredged areas beyond the resolution of the model.

In practice, the dredging operations and backfilling operations would not be continuous for 1 year. If the South Tsing Yi MBA were backfilled at the maximum dumping rate, it would result in an expected deposition of up to approximately 0.2m in sheltered areas adjacent to the MBA. If the dredging operations continued for a long period of time, and larger deposits resulted, it is probable that water speeds would increase over this deposited sediment and inhibit further deposition. However, this process may not occur in dredged channels and sheltered coastal embayments. In the long term, periodic storm action and the larger tidal flows could eventually disperse the sediment deposits over a large area with an eventual return to existing natural bed levels

3.13 *CONSOLIDATION OF FINE MATERIAL IN THE MBAs*

If up to 4,300 t day^{-1} of fluid mud is formed evenly in a very thin layer over 50% of the plan area at South Tsing Yi MBA, consolidation at slack water (without additional disturbance by disposal) could take on the order of 1 hour to achieve a density which would not then be eroded by the peak tidal flows ([33] and [34] – based mainly on laboratory experiments). Analysis of field observations of the dewatering of fluid mud made by Japanese researchers during studies associated with the development of a facility at Kumamoto [35] indicated that, on two occasions, a trial pit 2m deep filled rapidly with fluid mud which then consolidated to form a deposit with an average dry density of 400 kg m^3 within 24 hours.

The Japanese observations suggest that a fluid mud layer 1½–2m thick observed at East Sha Chau could have dewatered within a 24 hour period. It is not known whether the observed fluid mud at East Sha Chau could only dewater very slowly and was accumulating, or whether it was dewatering quite rapidly but being maintained at an equilibrium depth by a steady rate of disposal. Analysis of simulated tidal flows at East Sha Chau indicated that fluid mud would not be eroded on the smaller amplitude tides and fluid mud could accumulate.

The data from the Japanese observations and laboratory experiments indicate that fluid mud generated on small amplitude tides could consolidate within time periods of the order of a tidal cycle and thus would not then be available for subsequent re–erosion on large amplitude spring tides in the dry season. The amount of fluid mud available for erosion on subsequent large amplitude tides, therefore, would only be equivalent to that generated through disposal during these large amplitude tides. Fluid mud accumulated during smaller (non–erosional) tides would likely have consolidated to a non–erodible density prior to the occurrence of the next large amplitude tide.

Consolidation of fluid and very soft mud exposed to continuing disturbance by backfilling operations is difficult to assess and depends on the properties of each particular mud type. In neither the laboratory experiments nor in the field studies was fluid mud present overlying a substantial layer of potentially very soft material generated by dumping trailer dredged material. The soft trailer dredged material, as it dewaters, could hinder consolidation

(33) Estuarine Mud Manual. HR Wallingford Ltd Report SR 309, May 1992

(34) Fluid Mud in Estuaries, Final Report, HR Wallingford Report EX 2392, November 1991

(35) Mathematical Modelling of Mud Transport in Ports with a Multi–layer Model – Application to Kumamoto Port. Report of the Port., Report of the Port and Harbour Institute, Yokosuka, Japan. Vol 29. No.1. March 1990.

of the fluid layer. Thus the ultimate density achieved by the consolidating fluid mud could be lower than that observed in the field studies.

Despite the uncertainty in fluid mud behavior, in this study it was not considered that erosion of fluid mud would generate a significant increase in background suspended sediment concentrations.

3.14 *MITIGATION AND ENVIRONMENTAL MONITORING AND AUDITING*

It is essential that appropriate measures are applied to the dumping procedures to ensure that water quality impacts from backfilling, and subsequent erosion of dumped material, will be minimized and potential environmental impacts on identified sensitive receivers will be reduced. As described above, spoil losses to suspension and subsequent impacts upon sensitive receivers will depend on dumping rates, material characteristics, and site specific hydrodynamic and bathymetric characteristics.

The water quality impacts associated with the proposed backfilling operations at the South Tsing Yi and North of Lantau MBAs will be mitigated by several methods. The primary means of mitigation is through the Operations Plan which is presented in *Section 7*. The Operations Plan specifies rates, volumes, disposal points, and vessel, material and temporal restrictions for backfilling activities. These restrictions therefore become part of the project design and serve to structure the backfilling operations to reduce potential impacts. Other general mitigatory measures concerning plant maintenance and working methods are also proposed to further reduce potential environmental impacts. These plant maintenance and working method general mitigation measures are provided below.

In order to prevent potential water quality impacts, the contractor must implement plant maintenance and working methods during backfilling operations that:

- prevent discharge of fill material except at approved locations, including loss of material during transport of fill or dredged material;
- minimise disturbance to the seabed while backfilling;
- prevent the avoidable reduction, due to backfilling, of the dissolved oxygen content of the water in the immediate vicinity of the MBA;
- prevent avoidable deterioration in the water quality which may cause adverse effects on marine ecology and bathing beaches; and
- ensure that backfilling will cause no visible foam, oil, grease, litter or other objectionable matter to be present in the water within and adjacent to the MBAs.

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

- All barges and hopper dredgers should be fitted with tight seals to their bottom openings to prevent leakage of fill material during transportation;

- The Contractor will have to monitor any or all vessels transporting fill material to ensure that no dumping outside the approved location takes place;

- Mechanical grabs should be designed and maintained to avoid spillage of fill material and should seal tightly while being lowered and lifted;

- All vessels should be sized such that adequate clearance is maintained between vessels and the sea bed at all states of the tide to ensure that undue turbidity is not generated by turbulence from vessel movement or propeller wash;

- After dumping, excess material should be cleaned from the decks and exposed fittings of barges and hopper dredgers before the vessel is moved; and

- Adequate freeboard should be maintained on barges to ensure that decks are not washed by wave action;

The operations plan (*Section* 7) and detailed specifications for the plant maintenance and working method general mitigation measures described above will be provided in the Environmental Monitoring and Audit (EM & A) Manual which will be issued as a separate document from the EIA. The EM & A Manual will also describe a recommended water quality monitoring and auditing programme. This programme will consist of a sampling design comprising control stations, stations at the perimeter of the MBA, and stations at sensitive receivers for which potential impacts have been predicted. Specifications on sampling methodology, reporting and interpretation of results will also be provided. The EM & A Manual will specify review procedures for evaluating the significance of any residual impacts after mitigation, the need for broader supplementary mitigation measures and the consequences of mitigation implementation. It will also provide guidance for revising the Operations Plan and/or plant maintenance and working methods general mitigation measures based on any observed impacts resulting from backfilling operations alone.

The presence of other active dredging/disposal projects within the vicinity of the MBAs may require the application of additional mitigatory measures for the backfilling operations to ensure that impacts associated with backfilling do not exceed acceptable levels. Guidance for assessing potential cumulative effects and modifying the Operations Plan and/or the EM & A manual will be provided in the Cumulative Effects Assessment Manual (CEAM). The CEAM will be issued, concurrently with the EM & A Manual, as a separate document to this EIA.

3.15 *COMPARISON OF CEAM AND WAHMO MODELLING APPROACHES*

Although several indicative cumulative dredging/disposal scenarios were modelled for this Study, it is not possible to address every possible combination of projects which may occur simultaneously and at variable rates. As a result, a need was identified for an assessment tool which could be employed simply and rapidly to predict impacts from various combinations of projects. The CEAM has been developed as a tool to assess these impacts and has been issued as a separate document to this report.

In response to comments made at the 3rd Study Management Group Meeting held 22 September 1995, a comparison between SS concentrations predicted through WAHMO modelling and SS concentrations predicted through the CEAM worksheet has been prepared. The purpose of this exercise is to demonstrate that cumulative impact assessment using the CEAM is comparable to performing a separate WAHMO modelling run. In this Study the cumulative modelling runs included Scenarios 5, 6, 7, and 8. Each of these scenarios was applied to the CEAM worksheet and the resulting SS concentrations tallied for each sensitive receiver. The results of the comparative exercise are given in *Annex V*.

This exercise has shown that predictions for SS concentrations at sensitive receivers resulting from cumulative impact scenarios derived from the CEAM are very similar to those derived from WAHMO modelling runs. For Scenarios 5-8, the ratio of WAHMO to CEAM predictions at 13 sensitive receivers varied from 1.00 to 1.13 with an average ratio of 1.03. This finding illustrates the similarity of the two approaches as well as that the CEAM approach consistently estimates slightly higher SS concentrations than WAHMO and thus is conservative. While both approaches are valid, since the CEAM employs a simple, additive method, it allows impacts to be estimated quickly and easily without resorting to WAHMO modelling each time conditions change.

3.16 *CONCLUSIONS*

Evaluation of impacts to water quality and water sensitive receivers was undertaken through modelling of suspended sediment plumes, sediment deposition, sediment erosion, dissolved oxygen and nutrients. Modelling exercises focused on thirteen scenarios developed to assess non-cumulative effects (backfilling at both MBAs simultaneously), cumulative effects (backfilling at both MBAs in conjunction with other dredging/disposal projects) and validation of the model.

Non-cumulative effects simulating concurrent backfilling at both MBAs were modelled using rates of disposal of 50,000 to 200,000 m^3 of trailer-dredged material at the South Tsing Yi MBA and a rate of 10 000 m^3 of grab-dredged material at the North of Lantau MBA. Predicted elevations in suspended sediment concentrations were found to be acceptable in comparison to both the WQO and the sensitive receivers' specific criteria for Scenarios 1, 2 and 3 at all sensitive receivers. Scenario 4a, which modelled the highest rate of backfilling during the worst case seasonal/tidal conditions, exceeded compliance criteria at Anglers and Gemini Beaches (by less than 3 mg l^{-1}), at the Tung Wan Tsai and Ma Wan fisheries areas (by less than 7 mg l^{-1}) and the Kennedy Town Water Intake (by less than 4 mg l^{-1}).

Due to non-compliance at this highest rate of backfilling, an additional scenario (Scenario 4e) was performed to determine the effects at a lower rate of backfilling (100,000 m^3 day^{-1}). All predicted elevations in SS concentrations for Scenario 4e were found to be in compliance with the exception of concentrations at the Kennedy Town Water Intake where the specific criterion was exceeded by less than 1 mg l^{-1}. However, due to the marginal nature of this exceedance, the fact that it will occur only during the worst case seasonal/tidal conditions and for less than four hours during the tidal cycle, and its compliance with the site-specific WQO, this concentration is considered acceptable. Should environmental monitoring observe any SS concentrations at or above this level at the Kennedy Town Water Intake, additional mitigation measures shall be considered.

Cumulative effects expected from concurrent backfilling at both MBAs and dredging at South Tsing Yi and West Sulphur Channel were modelled using the maximum backfilling rates at North of Lantau and South Tsing Yi MBAs (Scenario 4) and rates representing dredging of surficial marine sand and alluvial sand, and actual dredging rates at West Sulphur Channel. Cumulative scenarios resulted in elevations of suspended sediment concentrations ranging from 2–65 mg l^{-1}. Each of the cumulative scenarios resulted in non-compliances with WQOs at several sensitive receivers and exceedance of the specific criterion for the Kennedy Town Water Intake. Scenarios involving dredging of surficial marine sands at the South Tsing Yi MBA (Scenarios 5 and 7) resulted in a greater number and higher concentration exceedances than scenarios involving dredging of bottom alluvial sands (Scenarios 6 and 8). Due to the worst case nature of the scenarios selected for modelling cumulative impacts, and the high sediment loss rates associated with these projects, none of the scenarios meets the WQOs at all sensitive receivers. However, specific criteria are exceeded only for scenarios involving dredging of surficial sand and at the Kennedy Town Water Intake.

Results of the validation scenario (Scenario 9) have shown that if SS corresponding to expected inputs from dredging and filling activities at Chek Lap Kok are modelled in conjunction with the maximum rate of backfilling at South Tsing Yi, elevated SS concentrations of approximately 100 mg l^{-1} at the Ma Wan Fish Culture Zone (FCZ) result. The plots of SS plumes resulting from these two sources of input (ie Chek Lap Kok area and South Tsing Yi) clearly indicated that the source of the elevated concentrations at Ma Wan is Chek Lap Kok. Field data collected during the period of highest SS concentration at the Ma Wan FCZ correlate well with the model results and corroborate evidence of Chek Lap Kok as the source of elevated SS. These results demonstrate both that the WAHMO modelling approach is valid and appropriate for this Study and that previously observed elevated concentrations at the Ma Wan FCZ were not caused by backfilling at the South Tsing Yi MBA.

Losses of sediment due to long-term erosion from both MBAs was also assessed. At the South Tsing Yi MBA, grab- and trailer-dredged materials are predicted to be stable under wave and current induced bed stresses at all backfill levels up to -24mPD. Fluid mud would be eroded at all backfill levels but is expected to comprise only 20% of the total losses due to suspension during disposal at the maximum backfilling rate. At the North of Lantau MBA, typical wave action alone is not sufficient to erode either soft surface or more cohesive subsurface material at backfill levels up to -16mPD. However, subject to the action of typical currents, soft surface material is eroded at backfill levels above -20mPD. Fluid mud is expected to erode due to tidal current bed stresses alone at all backfill levels but is estimated to comprise only 40% of losses due to suspension during disposal. Estimated additional suspended sediment input to the water column due to erosion from the backfilling rate modelled in Scenario 4e, is expected to result in effects similar to those predicted for Scenario 1 which is considered environmentally acceptable. Furthermore, trapping and consolidation of fines within the MBAs is expected to reduce the volumes of disposal sediment subject to erosion.

4 MARINE ECOLOGY

4.1 INTRODUCTION

This section presents a detailed assessment of the potential impacts to marine fauna and flora which may arise from the proposed backfilling at the South Tsing Yi and North of Lantau MBAs. In addition, potential impacts to fishing activities and resources which may result from the backfilling operations are addressed.

To provide baseline ecological data specific to the area of the MBAs, a literature review has been undertaken to collate information on benthic communities, fish and fisheries resources, intertidal communities and marine mammals. Site specific marine ecological surveys were subsequently undertaken to provide the identified baseline data required, comprising demersal trawl surveys in the vicinity of the South Tsing Yi MBA and benthic grab surveys in the vicinity of the North Lantau MBA.

The objectives of this detailed assessment are as follows:

- to identify ecological sensitive receivers;
- to assess the scale of possible ecological impacts from backfilling;
- to identify if any insurmountable impacts to marine ecological sensitive receivers will arise from backfilling of either the South Tsing Yi or North of Lantau MBAs; and
- to identify, where appropriate, any marine ecological mitigation and monitoring and auditing requirements.

4.2 LEGISLATION AND *EX GRATIA* ARRANGEMENTS

Legislation which applies to marine species in general includes the Wild Animals Protection Ordinance (Cap.170) 1980 which protects all cetaceans, and the Animals and Plants (Protection of Endangered Species) Ordinance (Cap.187) 1988, which for the marine environment of Hong Kong would include the protection of all whales, dolphins and sea turtles. In addition, legislation specific to marine ecology includes the Fisheries Protection Ordinance (Cap.171) 1987 which provides for the conservation of fish and other aquatic life and regulates fishing practices.

In addition to these ordinances, *ex gratia* policies apply to both mariculture and fisheries activities within Hong Kong waters. New *ex gratia* arrangements for mariculturists affected by dredging or dumping projects were approved in July 1993. If at any one time the suspended solids concentration exceeds 50 mg l^{-1} or exceeds by 100% the highest level recorded at the fish culture zone during the five years before commencement of works in the vicinity, mariculturists are eligible for *ex gratia* allowance payments. The eligible mariculturists may then opt to:

- continue mariculture in the same place at their own risk, in which case they would be eligible for an *ex gratia* allowance equivalent to 50% of the normal two-year fish culture cycle; or

- suspend mariculture operations for two years, in which case they would be eligible for an *ex gratia* allowance equivalent to the notional loss of income for a normal two-year fish culture cycle; or

- cease mariculture operations permanently, in which case they would receive the existing *ex gratia* allowance payable for extinguishment, which contains elements for the notional loss of income for two years and the loss of capital investment in rafts and cages.

Ex gratia allowance payments have been administered at the Ma Wan Fish Culture Zone (FCZ) to mariculturists affected by previous works in the vicinity (AFD pers. comm. 1995).

Revised *ex gratia* allowances for capture fisherman were approved in May 1993 and entailed a three-fold increase in the *ex gratia* arrangement and a relaxation on the 15m vessel length restriction (with effect from the 1st April 1993). Thus from this date, *ex gratia* allowances would be eligible to any vessel fishing local waters. (Vessels larger than 15m were originally excluded from *ex gratia* allowances as they were considered to be mobile and less dependent on local waters).

Ex-gratia payments have also been made to capture fishermen who claimed to fish the South Tsing Yi and North Lantau MBAs prior to sand dredging (AFD 1995 pers. comm.). The *ex gratia* arrangement applied only to vessels less than 15 meters in length, however, this would include all fishing vessels that operate in the area of the South Tsing Yi and North Lantau MBAs. It should be noted that the capture fisheries *ex-gratia* arrangement differs from that for mariculture in that *ex-gratia* is paid to fisherman as sand dredging was undertaken, regardless of the demonstrated environmental consequences, whereas for mariculture, *ex-gratia* is paid only if the stipulated WQO at the FCZ are exceeded.

As stated, *ex gratia* arrangements are not statutory requirements. However, as SS concentration limits have been set which serve to activate *ex gratia* payments it is appropriate to consider these limits when evaluating impacts predicted for backfilling operations. These limits, in conjunction with WQOs and specific criteria described in *Section 3.0*, are used as components in the evaluation of environmentally acceptable impacts.

4.3 EXISTING ECOLOGICAL ENVIRONMENT

4.3.1 Introduction

The marine ecology of the study area in the waters to the north of Lantau is characterised by semi-tropical marine and estuarine biota. The hydrology of these waters is that of an estuarine environment affected by the seasonably variable discharge of the Pearl River. The study area in the waters south of Tsing Yi is located in the transition zone between estuarine western waters and more oceanic eastern waters.

A literature search was undertaken on the following data sources for ecological information relevant to the study area:

- Morton B (1990) **A Bibliography of Hong Kong Marine Science: 1842-1990** University of Hong Kong Press; and

- Aquatic Science and Fisheries Abstract 1978–1993 (CD ROM search).

In addition, the following organisations were consulted: the Agriculture and Fisheries Department (AFD), Hong Kong University, City Polytechnic of Hong Kong and Baptist College.

The following EIA studies for major development projects in the North Lantau and South Tsing Yi areas have included baseline ecological studies and assessments, and provide ecological information of relevance to this study:

- Lantau Port & Western Harbour (LAPH) Development Studies;
- Lantau Port Development – Stage 1 Container Terminals No.10 & 11 Ancillary Works (Design);
- New Airport Master Plan (NAMP);
- North Lantau Development (NLD);
- North Lantau Expressway (NLE);
- Reclamation for Shipyard at To Kau Wan, North Lantau;
- Tuen Mun Port Development; and
- Large Thermal Power Station (LTPS) at Black Point.

The IAR for the *Backfilling of Marine Borrow Pits, North Lantau and South Tsing Yi: Feasibility Study/EIA* determined that substantial information on benthic communities exists for characterization of the South Tsing Yi MBA. [1] [2] However, data on benthic communities was lacking for the area of the North of Lantau MBA. Therefore, a limited benthic grab survey was undertaken for the North of Lantau MBA on 31 December 1994, in order to identify benthic species assemblages and sediment types.

The IAR determined that there was sufficient information on fish resources and macro-invertebrates in the area of the North Lantau MBA from previous trawl surveys in the North Lantau area. Due to the lack of site-specific information on fish resources (demersal and pelagic) and macro-invertebrates in the area of the South Tsing Yi MBA, a minimal trawl programme was conducted on 1 January 1995.

The findings from these ecological studies and surveys are summarised below, with particular reference to the identification of any species or habitats of key ecological, conservation or economic importance which might be affected by the proposed backfilling works.

4.3.2 *Summary of Dredging and Backfilling Disturbance*

South Tsing Yi

The northern pit of the South Tsing Yi MBA can be subdivided into three areas which have been subject to sand dredging *(Figure 2.2a)*. In the southwestern and southeastern areas, sand dredging has been completed and the areas have been partly backfilled with uncontaminated dredged material. Sand resources remain in the northwestern area although no

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(1) Furano (1992) Lantau Port and Western Harbour (LAPH) Development: Marine Baseline Studies (Final Report) submitted to ACER Environmental.

(2) Shin P K S and Thompson G B (1982) Spatial Distribution of Infaunal Benthos of Hong Kong. Marine Ecology – Progress Series 10:37–47.

dredging is underway at present. The southern pit of the South Tsing Yi MBA has yet to be exploited for sand.

North of Lantau

Sand has been removed from the North of Lantau MBA resulting in an area ranging in depth from -30 mPD to -40 mPD. At present, the surrounding area is characterized by soft marine muds with some sand, and heterogeneous sediment types to the north of the MBA comprising clay, silt, sand and gravel.

4.3.3 *Benthic Communities*

South Tsing Yi

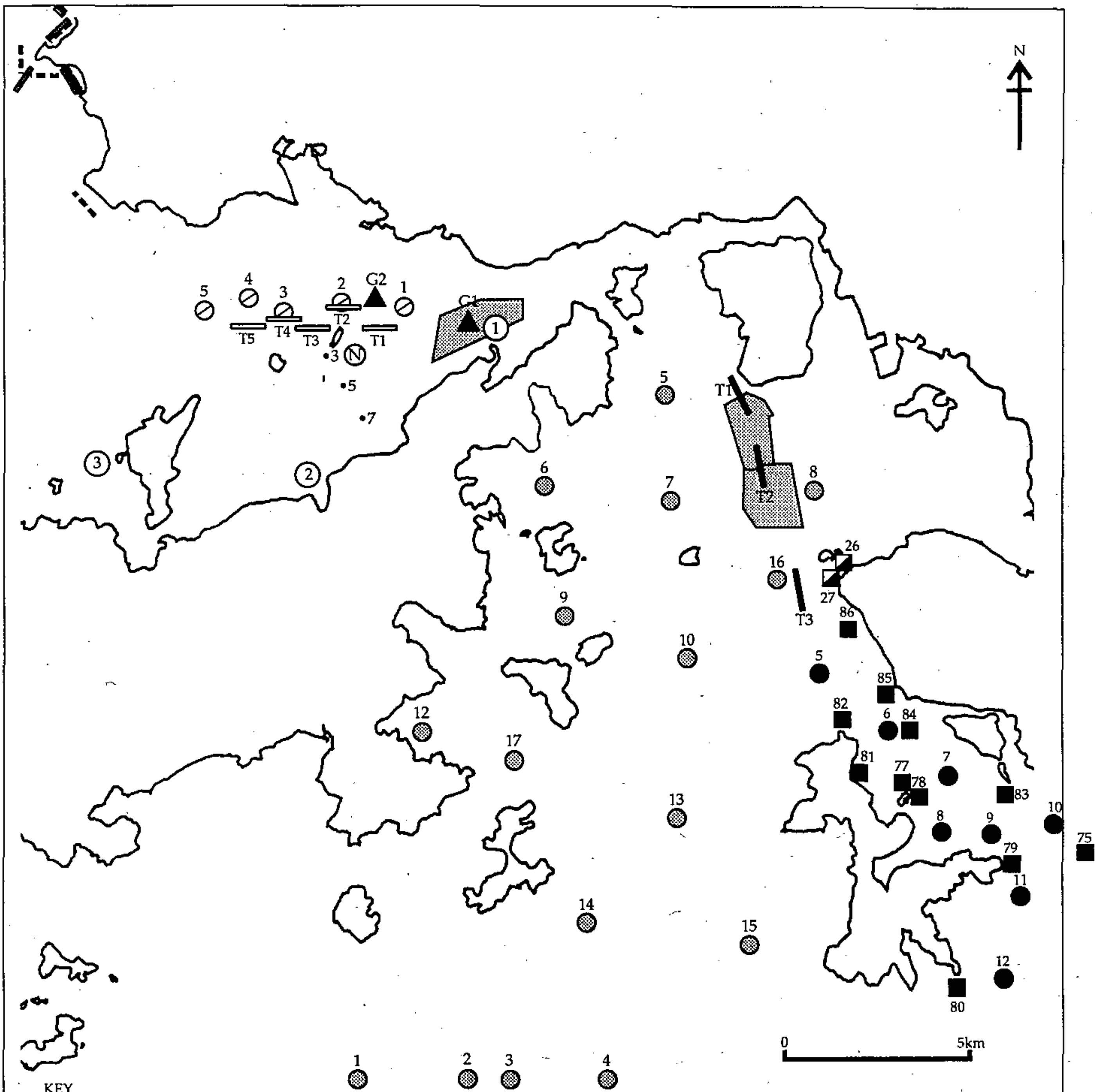
Shin and Thompson (1982) [3] examined the benthic communities at 200 different grab sampling stations in Hong Kong waters during 1976 and 1977. Several stations were located within the South Tsing Yi MBA and in the immediate vicinity. Stations located from south of Ma Wan to between Cheung Chau and Lamma Island were found to represent a single faunal assemblage dominated by polychaetes. This finding suggests that species found in the South Tsing Yi MBA are widely distributed within west-central Hong Kong waters. Sediment in the survey area was composed of 77% silt, 18% sand and 5% clay; this sediment composition was found to be typical of sediments in Hong Kong waters. Shin and Thompson (1982) also showed that in Hong Kong waters, species diversity is generally high and abundance and biomass are generally low. Although these community characteristics are often observed in stable environments, Hong Kong benthic environments are relatively unstable and experience major fluctuations in salinity and temperature.

The comprehensive benthic community survey undertaken for the LAPH Development (December 1991 and June 1992) [4] established grab sampling stations in the west-central waters and included four stations near the South Tsing Yi MBA (Stations 5, 7, 8 and 16 as shown on *Figure 4.3a*). The results of the survey confirmed the findings of Shin and Thompson, identifying polychaetes as the dominant species group and noting that the infaunal benthic community in the area was generally represented by a single, large species assemblage. All species recorded in the survey area had been previously reported in Hong Kong and no environmentally sensitive nor rare species were found.

Sediment types identified in the LAPH Development Study were typical of Hong Kong waters and ranged from sandy-clay silt at Station 7 (located approximately 2 km to the west of the southern pit at the South Tsing Yi MBA) to clay-dominated silt at Station 5 (located approximately 1.75 km to the northwest of the northern pit at the South Tsing Yi MBA). Most of the stations showed homogeneous sediment types similar to those at Station 5. An increase in silt content was evident at the majority of the stations during

(3) Ibid.

(4) Furano (1992) op.cit.



KEY

- ○ BENTHIC GRAB STATIONS, WU & RICHARDS, DECEMBER 1978 - DECEMBER 1979
- ○ FISH COMMUNITY TRAWL STATIONS, RICHARDS & WU, DECEMBER 1978 - DECEMBER 1979
- ◍ BENTHIC GRAB STATIONS, LAPH EIA, DECEMBER 1991 & JUNE 1992
- ⊘ BENTHIC GRAB STATIONS, NAMP EIA, NOVEMBER 1990
- ◩ BENTHIC GRAB STATIONS, FMVI, DECEMBER 1993
- ● BENTHIC GRAB STATIONS, LAMMA DREDGING AUDIT, DECEMBER 1993 & JANUARY 1994
- ■ LOCATION OF UNDERWATER DIVE SURVEY SITES, ECOPED, OCTOBER 1991 - NOVEMBER 1994
- ═ LOCATION OF TRAWLS , NAMP EIA, NOVEMBER 1990
- ▬ LOCATION OF GILL NET STATIONS, LTPS EIA, FEBRUARY, MARCH, MAY & SEPTEMBER 1991
- - - - LOCATION OF TRAWLS, LTPS EIA, FEBRUARY, MARCH, MAY & SEPTEMBER 1991
- Ⓝ BENTHIC GRAB STATIONS, SHIN 1977
- ▲ BENTHIC GRAB STATIONS, G1 & G2, 31 DECEMBER 1994
- ▬ TRAWL SURVEY TRANSECTS, T1 - T3, 1 JANUARY 1995

FIGURE 4.3a - EXISTING ECOLOGICAL INFORMATION IN THE STUDY AREA & LOCATION OF TRAWL AND GRAB SURVEYS

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Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

ERM

the summer wet season and was attributed to deposition from the Pearl River at this time of year (Morton and Wu 1975). [5]

Grab sampling was undertaken at two stations in the Sulphur Channel (December 1993) [6] as part of the Fill Management Phase VI project to determine the baseline conditions of benthic communities (Stations 26 and 27 as shown on *Figure 4.3a*). The survey results presented similar findings to earlier surveys (Shin and Thompson (1982), LAPH Development (1992)) with polychaetes the most abundant group numerically. A benthic grab survey was also completed in the East Lamma Channel for the Lamma Dredging Audit Baseline Survey (December 1993 and January 1994) [7] and included one station near the South Tsing Yi MBA (Station 5 as shown on *Figure 4.3a*). The benthos was characterised by low biomass and polychaetes were again identified as the dominant group.

In studies conducted for this EIA, three trawl survey transects were established in the South Tsing Yi area as shown on *Figure 4.3a*. Trawl sampling was undertaken with three replicate trawls at each transect. Hard rocky bottom was noted near the Tsing Yi coastline (transect T1) as trawl nets were torn by the rocky substrate encountered.

The epibenthic species as collected by trawl are listed in *Tables 1, 2 and 3* in *Annex S* together with their abundance. Of the species identified, only sea pens and gorgonian corals are considered to be of high ecological interest. Sea pens were fairly abundant at trawl transects T2 and T3. Five gorgonian corals were sampled at trawl transect T1 and one individual at both transects T2 and T3. These fauna are sensitive to pollution, particularly oil pollution and siltation resulting from dredging. [8] A photograph of one of the gorgonian corals collected is shown in *Figure S1* in *Annex S*.

Marine ecological surveys conducted for the coastal ecology component of the Territory-Wide Study of the Physical and Ecological Effects of Dredging Programme (ECOPED) (April 1992 - November 1994) [9] included several stations on both sides of East Lamma Channel as shown on *Figure 4.3a*. The abundance and diversity of fish, hard coral, gorgonians, soft corals and other invertebrates were assessed at each site. The survey results indicated that coral cover is high only at Pak Kok and Luk Chau on Lamma Island. The north tip of Pak Kok (Site 82) was found to have a very high percent cover of soft corals and sea fans (gorgonians) in some areas. The site was noted to have a very rich soft coral community compared to other sites within East Lamma Channel. A high abundance and diversity of gorgonians and soft corals was also found on the north-east side of Luk Chau (Site 78). Areas along the south-western coast of Hong Kong (Sites 86, 85, 84, and 83) were reported to have a sparse population of coral and other benthos. A high

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(5) Morton B & Wu R S S (1975) The hydrology of the coastal waters of Hong Kong. Environmental Research 10: 319-347.

(6) Binnie Consultants Limited (1994a) South Cheung Chau and Sulphur Channel Seabed Ecology Pilot Survey By Grab Sample (Draft Report). For Civil Engineering Department, Geotechnical Engineering Office.

(7) Binnie Consultants Limited (1994b) Lamma Dredging Audit Baseline Survey Draft Final Baseline Report. For Civil Engineering Department, Geotechnical Engineering Office.

(8) Furano (1994) A Preliminary Marine Baseline Study and Impact Assessment For The Aviation Fuel Receiving Facility at Sha Chau, Hong Kong, submitted to ERM Hong Kong.

(9) Binnie Consultants Limited (1995a) Marine Ecology of Hong Kong. Report on Underwater Dive Surveys (October 1991 - November 1994) Volumes I and II. For Civil Engineering Department, Geotechnical Engineering Office.

diversity and cover of gorgonians was found at Ngan Chau (Site 75) below the 10m depth and increasing to 20m, and a moderate abundance and diversity of hard and soft corals and gorgonians was found at the northeast tip of Wong Chuk Kok (Site 79).

North of Lantau

The sublittoral survey undertaken for the NAMP EIA [10] (November 1990) included grab and trawl sampling in a borrow area north of The Brothers, approximately 1.5 to 6.5 km west of the North of Lantau MBA (*Figure 4.3a*). Sublittoral sediments ranged from those dominated by coarse material (> 2 mm shell debris, gravel etc) under the influence of strong tidal currents to the north-east of The Brothers, to those dominated by mud, silt and clay (< 63 μm) in the vicinity of Tung Chung Bay and Chek Lap Kok. A high diversity of burrowing infauna, dominated by polychaetes, was found in the sublittoral sediments and was reported to be promoted by the heterogeneity in sediment types and depths in the area. The benthic community as collected by trawl was reported to be typical for Hong Kong coastal waters and a high faunal diversity was noted. The dominant epibenthic fauna included gastropods, bivalves and swimming crabs. There was no evidence of a unique sublittoral ecology.

The Shin and Thompson (1982) study also had several stations in the area of the North of Lantau MBA. In this study, grab stations located from Yam O Bay in the east to Sha Chau in the west had similar characteristics. These stations had a mean silt content of 74% and a sand content of 19%.. The infaunal benthos was dominated by polychaetes with no other group of organisms present in large numbers. Similar to the communities identified south of Tsing Yi, the North of Lantau communities were characterized by low numbers of individuals and low biomass. Shin and Thompson (1982) speculate that such communities may be determined by sediment composition, since the high percentage of silt restricts the number of species able to colonize the substrate. In addition, previous studies have determined that the distribution and abundance of benthic organisms are commonly related to salinity, the organic content and the silt-clay fraction of the sediment (Sanders (1958), [11] Nichols (1970), [12] Bloom et al (1972) [13] and Knight (1974)). [14]

An earlier infaunal benthic study conducted by Shin (1977) [15] involved sampling in the North Lantau area and included three grab stations located approximately 3 km southeast of the proposed North Lantau MBA (*Figure 4.3a*). Stations N3 and N5, just south of The Brothers, were located in areas of sand and gravel substrate and the infaunal benthos was dominated by

(10) Greiner Maunsell (1991) New Airport Master Plan (NAMP) Environmental Impact Assessment Final Report.

(11) Sanders H L (1958) Benthic Studies in Buzzards Bay Animal-sediment relationships. Limnol. Oceanogr. 3: 245-282.

(12) Nichols F H (1970) Benthic polychaete assemblages and their relationship to the sediment in Port Madison, Washington. Mar. Biol. 6, 48-57.

(13) Bloom S A, Simon J L and Hunter V D (1972) Animal - sediment relations and community analysis of Florida estuary. Mar. Biol. 6, 48-57.

(14) Knight G S (1974) Benthic community structure in Lyttelton Harbour. N.Z.J. Mar. Freshwat.Res.8, 291-306.

(15) Shin P K S (1977) A Quantitative and Qualitative Survey of the Benthic Fauna of the Territorial Waters of Hong Kong. A Thesis for the Degree of Master of Philosophy in the University of Hong Kong.

common free-swimming polychaetes. At Station N7, located near the North Lantau coast, a high silt-clay sediment fraction and a different group of polychaetes was found. Since depth varied only slightly, this study concluded that differences in faunal composition probably resulted from differences in sediment type at the three stations.

In another study conducted in the North Lantau area, Wu and Richards (1981) [16] investigated variations in benthic community structure along an environmental gradient of salinity and bottom substratum over a one-year period (December 1978 to December 1979). Three grab sampling sites, one of which is located within the North of Lantau MBA, were established in depths less than 10m (*Figure 4.3a*). The epifaunal benthic communities at the three stations were all dominated by the gastropod *Turritella terebra*, and to a lesser extent by the gastropod *Murex trapa* and the crab *Portunus hastatoides*. Abundance and biomass were relatively constant throughout the study period at Station 1 where the effect of salinity was comparatively small.

The majority of benthos occurring off the north coast of Lantau Island are deposit feeders which may be maintained by the rich organic sediment load carried by the Pearl River. In the North Lantau area the benthic communities are known to be heterogenous. This difference in benthic community structure may be attributed to the influence of the Pearl River. The Wu and Richards (1981) study found that abundance and biomass decreased and diversity increased from west to east (ie. from Station 3 to Station 1 as shown on *Figure 4.3a*). Therefore, it may be inferred that the area of the North Lantau MBA may be less influenced by the Pearl River, and hence have higher salinities, coarser sediments, lower faunal abundance and biomass, and higher species diversity than areas further west in the North Lantau area.

In studies conducted for this EIA, two grab stations were established in the North Lantau area as shown on *Figure 4.3a*. Station G1 is located within the North Lantau MBA and station G2 a distance of approximately 2 km to the west. These two stations were sampled with 5 replicate grabs due to the known high heterogeneity of infaunal communities in Hong Kong waters. A 0.05 m^2 Van Veen grab was used and the samples sieved through a 500 μm mesh. These samples provide a semi-quantitative description of the benthic infaunal community in the affected area. The bottom sediment at station G1 was found to be muddy-sand in nature while the bottom sediment at station G2 consisted of a higher percentage of silt and clay particles.

The species recorded in the grab survey are listed in *Annex S, Table 4*. Both abundance and number of benthic species at stations G1 and G2 were very low. No fauna were found in both replicate no.2 at station G1 and replicate no.1 at station G2. At station G1 the infaunal benthos was dominated by polychaetes and confirmed the findings of earlier benthic grab surveys undertaken for the NAMP EIA (1990) and by Shin and Thompson (1982). Only 3 species of gastropod and 1 species of polychaete was found at station G2. All infaunal benthic species recorded at stations G1 and G2 are commonly found in the coastal waters of Hong Kong. The only ecologically significant species identified is the gorgonian coral (2 individuals) in replicate no. 1 at station G1. The difference in faunal composition at the two stations may have resulted from the difference in sediment types. As

(16) Wu R S S and Richards J (1981) Variations in Benthic Community Structure in a Sub-Tropical Estuary. Mar. Biol. 64: 191-918.

speculated by Shin & Thompson (1982), the higher % of silt at station G2 may have restricted the number of species able to colonise the bottom sediment.

4.3.4 *Demersal Communities*

South Tsing Yi

The IAR for the *Backfilling of Marine Borrow Pits, North Lantau and South Tsing Yi: Feasibility Study/EIA* identified that no previous studies on the demersal fish and macro-invertebrate communities in the South Tsing Yi area are available. However, in comparison with earlier trawl surveys undertaken in the North Lantau area (NAMP EIA (1990) and Richards & Wu (1985) [17]), the diversity of fish and macro-invertebrate communities found in the trawl surveys carried out in the South Tsing Yi area for this EIA was low. The number and abundance of commercial species were also low. Important market species found in low numbers include the fish species Tongue Sole *(Cynoglossus melampetalus)* and Flounder *(Paranychthyis olivaceus)*, the shrimps *Penaeus latisulcata, Metapenaeus enis* and the crab *Charybdis cruciata*. Shrimps and crab were identified as species commonly caught in the LAPH Development Study Area (described in *Section 4.3.6* and *Table 4.3b*). All species recorded are those commonly found in the coastal waters of Hong Kong, and no rare or unique species were identified. The fish and macro-invertebrate species abundance recorded at the three trawl transects (with three replicate trawls at each transect) are listed in *Annex S, Tables 1, 2 and 3*.

North of Lantau

The sublittoral survey undertaken for the NAMP EIA included trawl sampling in the borrow area north of The Brothers, approximately 1.5 to 6.5 km west of the North of Lantau MBA (*Figure 4.3a*). The fish community was found to be highly diverse. *Table 4.3a* provides a summary of fish species recorded in the North Lantau area from both the NAMP EIA survey and other previous trawl surveys. [18]

Table 4.3a *Fish Species Common to the North Lantau Study Area*

Common Name/Type	Specific Name
NA	*Ambassis gymnocephalus*
Chinese anchovy	*Anchoviella chinensis*
Cardinal	*Apogon quadrifasciatus*
Cardinal	*Apogon doederlini*
Goby	*Acentrogobius caninus*
Japanese Eel	*Anguilla japonica*
NA	*Argyrosomus pawak*
NA	*Argyrosomus macrocephalus*
NA	*Arnoglossus tenuis*

(17) Richards J and Wu R S S (1985). Inshore Fish Community Structure In a Subtropical Estuary. Asian Mar Biol 2: 57-68.

(18) ERL (Asia) Ltd (1982) Impact of the Proposed Replacement Airport at Chek Lap Kok on the Marine Environment, Appendix 2; Wet season and extension survey data Vol 2 Civil Aviation Department, Hong Kong Government.

Common Name/Type	Specific Name
NA	*Callionymus richardson*
Sole	*Cynoglossus puncticeps*
Sole	*Cynoglossus macrolepidotus*
Tongue Sole	*Cynoglossus melampetalus*
NA	*Chilloscyllium plagiosum*
NA	*Conger cinereus*
NA	*Clupanodon thrissa*
Common blenny	*Dasson variabilis*
Ray	*Dasyatis akajei*
Mud grouper	*Epinephelus brunneus*
Pony fish	*Leiognathus brevirostris*
Pony fish	*Leiognathus ruconius*
NA	*Lepidoptrigla japonicus*
Snapper	*Lutjanus russelli*
Snapper	*Lutjanus sanguineus*
Snapper	*Lutjanus argentimaculatus*
Sea Bream	*Mylio latus*
Sea Bream	*Mylio berda*
Grey mullet	*Mugil cephalus*
Goby	*Oxyurichthys tentacularis*
Flathead	*Ophichthus cephalozona*
NA	*Platycephalus indicus*
NA	*Pleuronichthys cornutus*
NA	*Polycaulus uranoscopus*
NA	*Saurida elongata*
Rabbit fish	*Siganus fuscessens*
Rabbit fish	*Siganus oramin*
Silver whiting	*Sillago sihana*
Sole	*Solea ovata*
Puffer fish	*Takifugu oblongus*
NA	*Trypauchen taenis*

An earlier study conducted by Richards and Wu (1985) [19] investigated the variations in inshore fish community structure and diversity along the north coast of Lantau over a one-year period (December 1978 to December 1979). Three trawl sampling sites, one of which is located within the North of Lantau MBA (Station 1 as shown on *Figure 4.3a*), were established in depths less than 10 m and provide the most complete and quantitative data on fish communities in the area. In contrast to the LTPS study findings, the fish

[19] Richards J and Wu R S S (1985) op.cit.

community was characterised by a high degree of spatial variation within a relatively small area. The numerically dominant species were different at the three stations with *Leiognathus brevirostris* dominating Station 1 (representing approximately 46% of the total number of individuals). Despite marked seasonal variations in salinity and temperature, no clear seasonal variation in the major features of the community was observed. However, the influence of the Pearl River in determining the demersal communities in this area, as for the benthic community structure, was demonstrated.

Baseline marine studies in 1991 for the proposed LTPS at Black Point [20] included fish and invertebrate surveys to assess the seasonal occurrence and abundance of bottom dwelling fish and invertebrates in the area. Trawl sampling was undertaken along 5 transects around Black Point at a distance of approximately 9 to 12 km from the North of Lantau MBA (*Figure 4.3a*). This survey is thus not located in the immediate vicinity of the MBA. Similar to the findings of the NAMP EIA, biological diversity of bottom-dwelling fish and invertebrates was high. The community was mainly dominated by a species of sea urchin (*Temnopleurus reevsi*), a species of croaker (*Johnius belengeri*), a species of crab (*Charybdis variegata*), a Hermit Crab and a species of sea pen (*Cavernalaria obesa*), and was similar at all stations in the survey area.

4.3.5 *Pelagic Communities*

South Tsing Yi

The IAR for the *Backfilling of Marine Borrow Pits, North Lantau and South Tsing Yi: Feasibility Study/EIA* identified that no previous studies on the pelagic fish and macro-invertebrate communities in the South Tsing Yi area are available. This information was not considered essential for the detailed EIA. Therefore trawls conducted for this EIA study targeted the demersal community with only opportunistic sampling of pelagic species.

North of Lantau

A pelagic fish survey was undertaken as part of the baseline marine studies for the proposed LTPS at Black Point. The survey was undertaken in four seasons in 1991 by the use of gill nets. Four stations were established around Black Point at a distance of approximately 12 km from the North Lantau MBA (*Figure 4.3a*). The midwater fish community identified by this study was characterised by low abundance, low biomass and low diversity. The species assemblage was dominated by two species of croakers (*Johnius belengeri* and *Sciaena russelli*) and a species of white herring (*Ilisha indicus*). Even though there was seasonal variation in the species assemblages encountered at the survey stations, little spatial variability in species assemblages was observed. Juveniles of several species of fish, shrimp and brooding crabs were found in low numbers in September, suggesting that the area may serve as a spawning and/or nursery ground for these species.

[20] Furano (1991). Baseline Marine Ecological Studies for the Proposed Large Thermal Power Station at Black Point, Hong Kong (Final Report) submitted to ERL Asia Ltd.

4.3.6 *Fisheries Resources*

South Tsing Yi

Fisheries resources in the vicinity of the South Tsing Yi MBA area comprise capture fisheries, mariculture and fish fry collection. Since information on the tonnage, monetary value and importance of these fisheries derives from various sources, the figures given below should be considered as a range rather than as definitive estimates.

As part of the LAPH Development Study (1991-1992), fisheries resources in the area from south of Ma Wan to Cheung Chau and Lamma Island were evaluated through consultation with the AFD and representatives from the Local Fishermen's Association. A list of commonly caught species within this area is provided in *Table 4.3b*.

Table 4.3b *List of Marine Species Commonly Caught in the LAPH Development Study Area*

Common Name	Common Name
Shrimp	Anchovy
Jacks	Grouper
Scad	Seabream
Conger/pike/eel/family	Rock fish
Golden sardine	Flat head
Croakers	King mackerel
Yellow croaker	Grey mullet
Slipmouth	Lobster
Rabbit fish	Crab
Squid	

Note: Data compiled from information from Agriculture and Fisheries Department and Local Fisherman's Association (1991-1992).

The LAPH Development Study also estimated the fisheries production in the study area by small craft (vessels less than 15 m in length), based on AFD data for the years 1989-1990. AFD noted a significant level of fishing effort may be expended in the LAPH Development study area by vessels over 15 m in length, however sufficient information was not available to quantify such activities. AFD have indicated that handline, gill-net and recreational fishing operators based at Ma Wan and Tsing Lung Tau are of commercial importance. The small craft estimates provide a general indication of the quantity and value of both adult fish and fish fry taken within the west-central waters (*Table 4.3c*). The greatest tonnage of adult fish was caught in the northern sub-area, while the greatest number of fish fry came from the southeastern sub-area (*Figure 4.3b*).

Table 4.3c *Estimated Fisheries Production by Small Craft (1989-90) from LAPH Development Study*

FISHING AREA	ADULT FISH		FISH FRY	
	QUANTITY (Tonnes)	VALUE (HK$)	QUANTITY No.	VALUE (HK$)
Northern Sub-Area (Peng Chau to Pokfulam)	2,181	30,821,000	1,313,000	2,741,000
Southwestern Sub-Area (Hei Ling Chau and Cheung Chau)	782	14,342,000	262,000	758,000
Southeastern Sub-Area (Lamma and Aberdeen)	1,177	15,218,000	2,012,000	2,933,000
Total	4,140	60,381,000	3,587,000	6,432,000

Note: Data excludes fishing vessels larger than 15 m in length, recreational fishing, fish collected from the shore and fish farms.
Source: Agriculture and Fisheries Department

Other estimates of the quantity and value of fisheries for adult fish in approximately the same area are also available from AFD (*Figure 4.3b*). These figures are the result of two separate studies to estimate landings in 1984 and fisheries value for compensation purposes in 1994. The 1984 landings estimates are based on actual weights of landed catches at area ports and indicate that the annual production for the area at that time was 956 tonnes. This was equivalent to approximately 9% of the total fisheries production in Hong Kong coastal waters for 1984, and is less than 25% of the estimate provided for the LAPH Development Study. While this difference may be due to the 5-6 year difference in timeframe, it is probably also due to differences in methodology.

In contrast, the 1994 AFD estimates of the value of annual production in the area is in the same range as the LAPH Development Study's figure. The AFD estimated that the 1994 production value totalled HK$48.8 million, which amounts to just over 6% of the total fisheries production value in Hong Kong. This figure is approximately 80% of the HK$60 million estimate given by the LAPH Development Study for adult fish.

In addition to the west-central waters being an important area for capture fisheries, several other areas within these waters contain key fisheries resources or habitats. These areas include fish culture zones, fry collection areas and rocky habitat supporting a fishery for groupers.

Mariculture Fisheries

Gazetted Fish Culture Zones (FCZs) in the west-central waters are located at Ma Wan, and Sok Kwu Wan and Lo Tik Wan on eastern Lamma Island. Data from AFD on the estimated total area of cage nets in each of these FCZs is given in *Table 4.3d*.

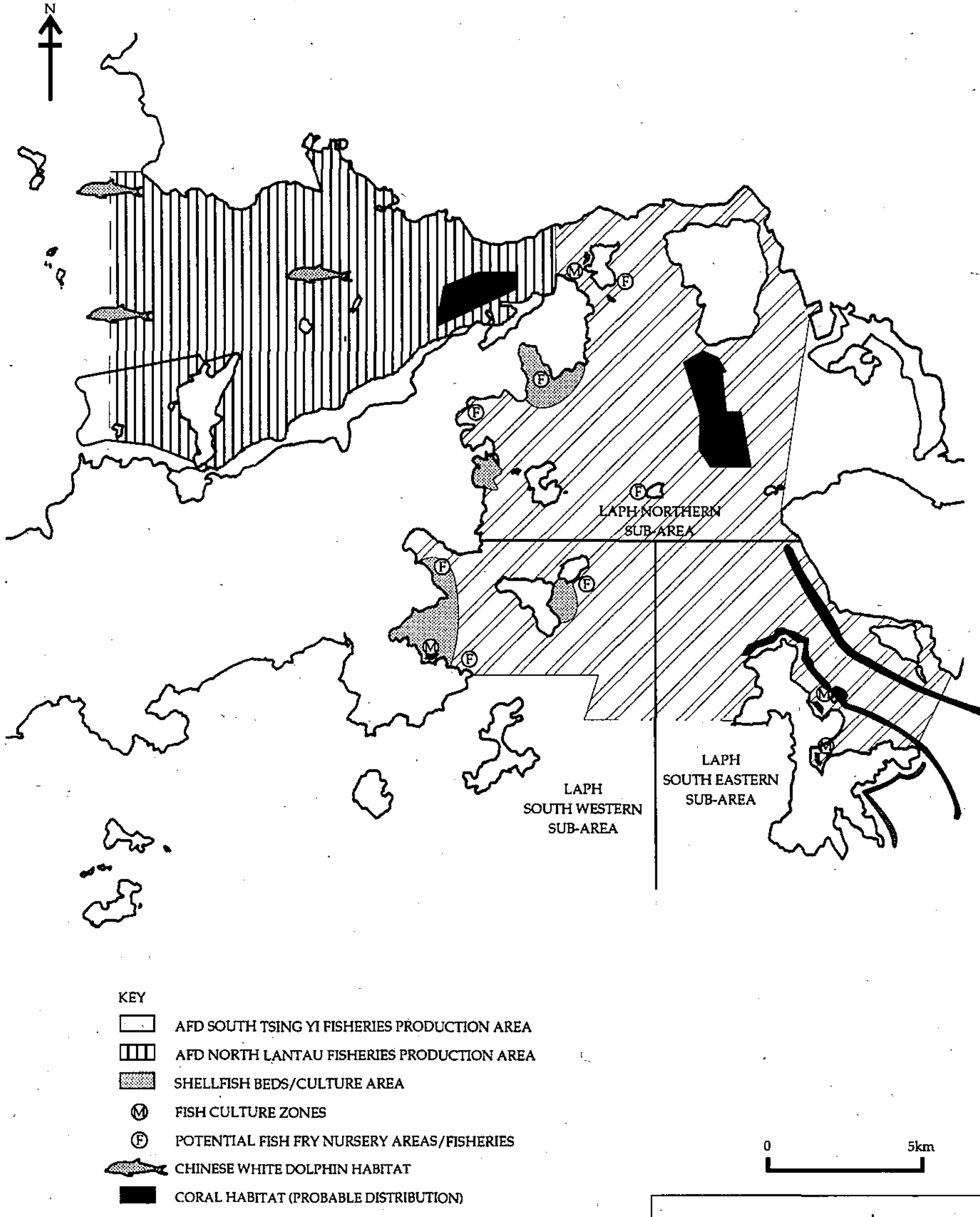

FIGURE 4.3b - ECOLOGICALLY SENSITIVE RECEIVERS IN THE STUDY AREA

ERM Hong Kong
6th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

ERM

Table 4.3d *Estimated total area of cage nets in the Fish Culture Zones located in the Study Area*

Fish Culture Zone	Total Area of Cage Nets (m^2)
Ma Wan	11,000
Sok Kwu Wan	24,000
Lo Tik Wan	25,000

Although the Ma Wan FCZ is the smallest of the three areas, it is located closer to the South Tsing Yi MBA than the other FCZs and therefore may be of greater concern.

Fish Fry Nursery Areas

Fishing for fry occurs in shallow, inshore waters and sheltered bays as shown on *Figure 4.3b*. The fry collection season for mariculture species extends from January to June (AFD 1995 pers. comm.). However, as fry are predominantly concentrated within these areas between March and April, fry collection peaks during this period.

Rocky Substrate Fisheries

Information cited in the LAPH Development Study indicates that the rocky substrate around Ma Wan provides important areas for sheltering fish and supports a fishery for groupers on the eastern coast, as shown on *Figure 4.3b*.

In the trawl surveys conducted for this EIA study, rocky substrate was noted in the area south of Tsing Yi, particularly in survey transect T1 located adjacent to the southwest Tsing Yi coastline *(Figure 4.3a)*.

North Lantau

The waters to the north of Lantau and south of the western New Territories are a traditional area for inshore fishing. Within this region there are two large fishing ports at Castle Peak Bay and Tai O. Fisheries in the region exploit both demersal and pelagic fish species which typically reside in estuarine-influenced waters. Although various shellfish beds exist, they are small and have supported only incidental gathering mainly by coastal villagers.

The most recent, available records from the AFD indicate that in 1990-1991 the main commercial species caught in the above region comprised a variety of penaeid shrimp, Sea Bream, Yellow Croaker, Japanese Sea Perch, Threadfin Sole, Tongue Sole, White Pomfret and Mantis Shrimp. Although these species are not common in eastern territorial waters, they are common estuarine-dwelling species and do not represent special or unique fish communities in Hong Kong waters. [21] More recent consultation with the AFD has identified the main commercial fisheries in the vicinity of the North Lantau MBA to be shrimping and purse seining for migratory croaker (Wilson AFD 1995 pers. comm.).

(21) Greiner Maunsell (1990) New Airport Master Plan Working Paper 7 IEIA Volume 1.

The latest AFD survey on fishing activities by vessels up to 15 m in length was conducted in 1991 and covers the area shown in *Figure 4.3b*. Results indicated that 401 boats fished in this area at some time during the year. The results of this survey are shown on *Table 4.3e*. The AFD noted a significant level of fishing effort may be expended in this area by vessels over 15 m in length, however sufficient information was not available to quantify such activities.

Table 4.3e *Fishing Activities in the North Lantau Area – AFD Survey Results (1991)*

Fishing Craft Length (m)	Number of Boats	Fishing Activities
< 5	259	gill nets & handlines
5–10	106	mostly gill nets with purse seining, long lining, cage trapping & clam collecting
10–15	36	gill netting/purse seining (72%), with long lining, shrimp trawling & hand lining

Similar to the fisheries production figures for the South of Tsing Yi area, a range of estimates are available which provide a general indication of the importance of the North Lantau waters for fisheries activities. The findings of a 1989–1990 AFD assessment of small craft fisheries in the area are shown in *Table 4.3f* below.

Table 4.3f *Estimated Fisheries Production in North Lantau Area (1989–1990)*

FISHING CRAFT	ADULT FISH	
	QUANTITY (Tonnes)	VALUE (HK$M)*
Small craft (<15 m)	1340	40
Larger Vessels (>15 m)	not known	18–24
TOTAL	–	60

Note : *Annual value at 1994 prices.
Source : Agriculture and Fisheries Department.

It should be noted that larger vessels in the region, which were not included in this estimate, could augment the total volume caught by a substantial margin. The above AFD assessment has therefore assumed that a third of territorial shrimp trawler production and four–fifths of hang trawler production occurs in the North Lantau area. The gross value of all fishing catch in the area thus amounts to approximately HK$60 million at 1994 prices and represents around one seventh of the territories total fisheries production (Gaiger AFD 1994 pers. comm.).

AFD estimates for 1984 landings and 1994 compensation values are also available for the North Lantau area. The landings estimate for 1984 is based on actual weights of landed fish and totals 352 tonnes. This is equivalent to approximately 3% of the total fisheries production in Hong Kong coastal waters. However this estimate is only approximately 25% of the landings estimates in the 1989–1990 small craft study described above. The 1994 compensation–based value estimates for fish production in the North Lantau area are HK$28 million. This represents almost 4% of the total fisheries production in Hong Kong coastal waters but is slightly less than 75% of the value estimate produced in the small craft study described above.

Spawning and Nursery Grounds

Although no detailed studies have been carried out on fish breeding in the area nor on the importance of the area as a nursery ground, the North Lantau area appears to provide nursery grounds for several species. According to unpublished data collected in the trawl survey of Wu and Richards (1981) and Richards and Wu (1985), penaeid shrimps, juvenile fish and macro-invertebrates were commonly found at survey stations shown in *Figure 4.3a*. This finding suggests that the waters off the north coast of Lantau are likely to be nursery and spawning grounds for local commercial fish species and support a high abundance of penaeid shrimps. The results of the fish and invertebrate surveys carried out for the proposed LTPS at Black Point also indicate that the coastal areas around Tap Shek Kok (Castle Peak) may serve as a nursery and spawning ground for fish, shrimps and crabs. Further support for the existence of nursery habitat is provided by a 1989-1990 AFD estimate of 25.3 million tails of fish fry collected in the area for the mariculture industry.

4.3.7 *Intertidal Communities*

South Tsing Yi

The LAPH Development Study established that intertidal areas of the west-central waters are relatively sparsely populated and the species present are not unique or rare to the territorial waters of Hong Kong. Exceptions to this finding are the rocky substrate fish habitat around Ma Wan and fish fry nursery areas along the east Lantau coast.

North of Lantau

Results of studies in the Yam O Wan area for the North Lantau Expressway (NLE) EIA [22] provide an indication of the intertidal habitat along the north coast of Lantau. This study identified that the littoral zone in this area is extensively polluted and supports an impoverished fauna in relation to the other areas examined along the North Lantau coastline. The EIA suggested that this is partly the result of very high BOD loadings associated with effluent discharged into the bay from chicken units on the southeastern side of the inner bay. The EIA concluded that construction of the NLE will result in the permanent modification of the coastline with subsequent direct loss of species and depletion of the littoral zone. [22]

Intertidal areas north of the North of Lantau MBA comprise several gazetted beaches of poor water quality. The water quality characteristics of these beaches are routinely monitored (see *Section 3*) and potential water quality impacts are discussed in *Section 3.10*. Detailed ecological studies of these beaches were not performed for this EIA study.

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(22) Mott MacDonald Hong Kong Ltd (1991) North Lantau Expressway Environmental Assessment Report Yam O and Tai Ho Sections Highways Department, Hong Kong Government.

4.3.8 *Chinese White Dolphins*

At least one dozen marine mammals occur in Hong Kong waters, although only the Chinese White Dolphin (*Sousa chinensis*) occurs frequently in the waters of western Hong Kong. A comprehensive international and local literature review has been undertaken with regard to the locational, feeding and breeding site preferences of *Sousa chinensis* and more generally the Indo-Pacific Humpback Dolphin. The full list of the references consulted are given in *Annex S*. The local findings of this literature review are discussed below.

Species Characteristics

Scientists believe that *Sousa chinensis* is a previously unrecorded estuarine species which may be related to the Indo-Pacific Humpback Dolphin (Wursig pers comm.). However, they differ because of their colouring, which can vary from white to pink, grey and speckled, and their lack of a distinctive hump (Godfrey 1993). [23] Research is currently being undertaken by AFD's Dolphin Research Team (DRT) at the Swire Institute of Marine Science to identify the taxonomic status of *Sousa chinensis*, and to assess the population dynamics and foraging strategies of the Chinese White Dolphin in Hong Kong's territorial waters.

The Chinese White Dolphin may be unique because of its geographical isolation from other similar species. Such separation and lack of inter-breeding may mean these dolphins have evolved to be suited to the specific and unique habitat characteristics of the Pearl River Delta. The HK Marine Conservation Society (cited in Godfrey 1993) believes that *Sousa chinensis* can only survive in the estuary waters of the Pearl River Delta.

Habitat

An assessment of the presence of *Sousa chinensis*, hereafter referred to as *Sousa*, was undertaken in the North Lantau Development Study (NLDS): *Detailed Study of Potential Impact of the Sewage Outfall on Sousa* Topic Report TR22, June 1993. The study identified that *Sousa* appear to occur reliably in Hong Kong only to the north and west of Lantau Island, and in the area immediately west of the Western New Territories. *Sousa* have a reported preference for waters close to shore (ie. within 1 km) and less then 10 m deep [24] [25] [26], and can be found anywhere in this relatively shallow water area as indicated in *Figure 4.3c*.

A dolphin survey was undertaken for the Lantau Port Development (LPD) EIA Study, [27] October 1994, in an extended area around the proposed site

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(23) Godfrey P (1993) Ecology: Rare White Dolphins Facing Extinction - Airport Work Takes Its Toll On Marine Species Window.

(24) Saayman G S and Tayler C K (1979). The socioecology of humpback dolphins (*Sousa sp.*) In Behaviour of Marine Animals, Vol. 3: Cetaceans, ed. by H.E. Winn and B.L. Olla, Plenum Press, N.Y., London.

(25) Cockcroft V G (1990). Dolphin catches in Natal Shark nets, 1980 to 1988. South Africa Tydskr. Natuurnav. 20:44-51.

(26) Corkeron P J (1990). Aspects of the behavioral ecology of inshore dolphins *Tursiops truncatus* and *Sousa chinensis* in Moreton Bay, Australia. In The Bottlenose Dolphin, ed. by S. Leatherwood and R. Reeves, Academic Press, N.Y.

(27) Halcrow Asia Partnership Ltd. Lantau Port Development - Stage 1 Container Terminals No. 10 & 11 Ancillary Works (Design) EIA Final Report December 1994 Civil Engineering Department.

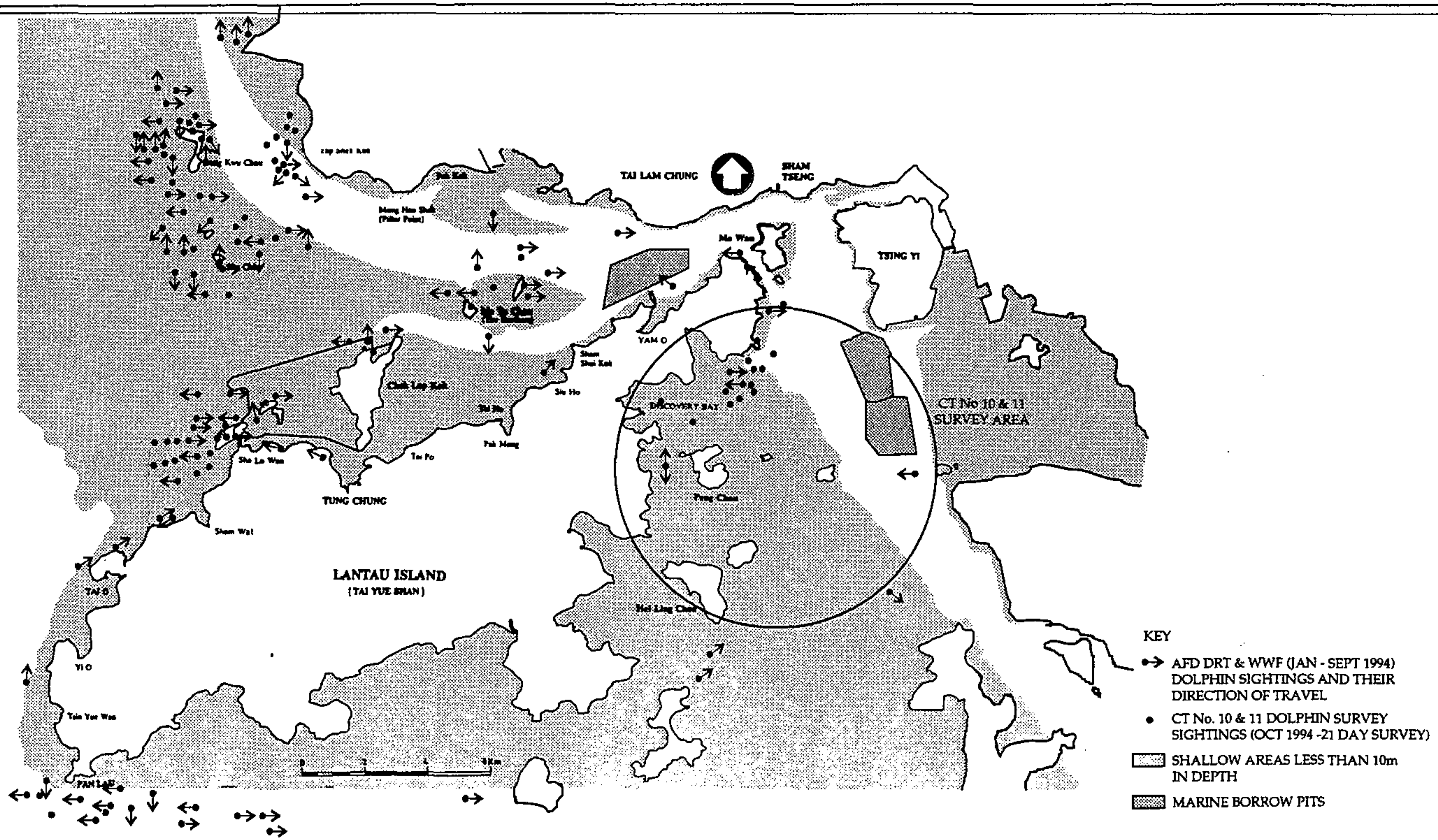

FIGURE 4.3c - LOCATION OF CHINESE WHITE DOLPHIN SIGHTINGS
FIGURE 4.3c - DISTRIBUTION OF SHALLOW WATER (<10m) WITHIN STUDY AREA

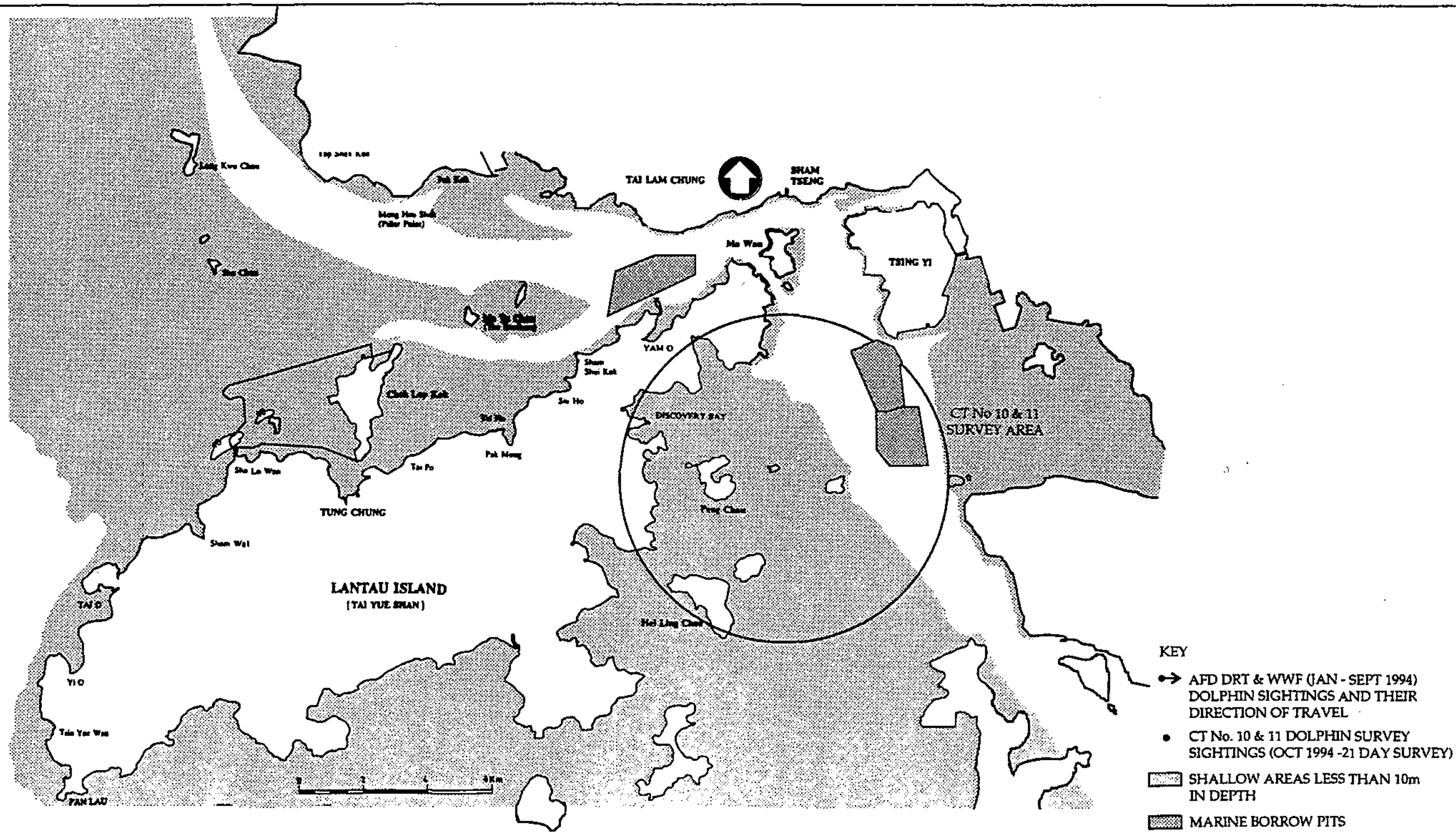

FIGURE 4.3c - DISTRIBUTION OF SHALLOW WATER (<10m) WITHIN STUDY AREA

for Container Terminals 10 & 11 (*Figure 4.3c*), and included the area of the South Tsing Yi MBA. Small numbers of *Sousa* were sighted off the northeast coast of Lantau, in the area between Discovery Bay and Ma Wan. The mean pod size calculated was four. No *Sousa* were sighted in the area of the South Tsing Yi MBA. The LPD EIA Study concluded that the survey area appears to be less utilised by *Sousa* than the waters to the north of Lantau Island, and thus does not appear to be of high habitat value to *Sousa*.

The *Sousa* population in the waters to the north of Lantau is reported by the AFD DRT to number around 40–100 individuals. *Sousa* sightings recorded during the first nine months of AFD's *Sousa* research studies (January to September 1994) together with their direction of travel are shown on *Figure 4.3c*. Research results for this period have shown that Lung Kwu Chau and Sha Chau have continued to be areas where dolphins are often sighted either resting, feeding or socialising. More recent results (October 1994 to January 1995) have shown that the majority of sightings remain in the Lung Kwu Chau and Sha Chau areas and that these areas are the preferred habitat. [28] These key areas are located a considerable distance – approximately 12 km – from the nearest MBA at North of Lantau. Based on other generically similar species of dolphins, *Sousa* is likely to feed on various species of fish, molluscs and crustaceans. [29] The exact food preferences of *Sousa* and the importance of the above key areas for the survival of the dolphin is not currently known and is the subject of study by the AFD DRT.

Sousa are often sighted travelling in deeper waters between Castle Peak, Lung Kwu Chau/Sha Chau, The Brothers and Sha Lo Wan. [30] It is reported that the pods of *Sousa* seem to follow stereotyped routes. For example, pods approaching Castle Peak from Lung Kwu Chau will veer off at ninety degrees and head towards Sha Chau. Other areas where dolphins are often sighted are the areas between Tai O and Sha Lo Wan, and the area between Fan Lau and Soko Islands. Through liaison with institutions in China undertaking marine mammal research, the AFD DRT believe Hong Kong may comprise a very small part of the potential range of the dolphins within the Pearl River Delta and the wider South China Sea area.

Numerous on–going construction projects in the North Lantau area may have altered this area's habitat value for *Sousa*. Ruxton (1993) [31] reported that as work on the Chek Lap Kok airport has progressed, there has been a noticeable change in the *Sousa* feeding grounds. At one point, the World Wide Fund for Nature Hong Kong (WWF) noted that no *Sousa* pods have been reported at The Brothers since January 1993, although *Sousa* pods had been spotted to the west and southeast of Lantau where sightings were previously rare. This report, however, is now contradicted by numerous Provisional Airport Authority (PAA) sightings in the vicinity of The Brothers during 1994 and several recent DRT *Sousa* sightings around The Brothers (October 1994 – January 1995) where the animals have been in transit. [32] Thus, despite this reported shift in habitat usage it appears that *Sousa* have

(28) Porter L J (1995) Draft Progress Report October '94 – January '95 Chinese White Dolphin Project. Swire Institute of Marine Science.

(29) Jean–Pierre Sylvestre (1993) Dolphins & Porpoises Sterling Publishing Co. Inc. New York.

(30) Parsons E C M (1994). *Sousa chinensis* Project Nine Month Research Summary. Swire Institute of Marine Science.

(31) Ruxton J (1993) The Chinese White Dolphin – *Sousa chinensis*.

(32) Porter L J (1995) op.cit.

returned to The Brothers and other areas along the North Lantau coast, such as Sha Lo Wan, upon cessation of works in these areas. For example, during a WWF survey conducted in the North Lantau area on 15 May 1994, more than a dozen *Sousa* were sighted near Chek Lap Kok.

It has been suggested that the North Lantau area may be particularly critical as a 'nursery ground' for the caretaking of young as *Sousa* adults with calves have been sighted in this area, and it is known that many near-shore dolphins seek shallow, relatively weather-protected waters for rearing their young (Ruxton and Pryke 1993 pers. comm.).

Behavioural Characteristics

The 18 months of surveys which have now been conducted by the AFD DRT have not yet discerned any clear patterns of mating and breeding in *Sousa.* Mating behaviour, comprising aerial displays, is reported to be rare. Calves were born in March and April 1994, however in 1995, calves and pregnant females have been observed in October and November. WWF estimates that *Sousa* have a breeding cycle of three years producing one calf per birth. Each calf is anticipated to require two to three years of nursing (Tam 1993). [33]

Recent reports by the AFD DRT have indicated that *Sousa* have been sighted more remotely from the Pearl River estuarine areas (as far as the Ma Wan Channel and south of Lantau near Peng Chau). There have also been reports of dolphin sightings near Green Island. [34] It is suspected that the change in salinity of water may be a contributing factor to the observed extension of their range. The dolphins may have a limited tolerance of certain salinities and therefore a combination of heavy rain and the atypically large flow of freshwater from the Pearl River possibly caused this change. Alternatively, the change in salinity may have affected the prey population and hence the dolphins distribution. It is believed by the AFD DRT that the deluge of freshwater is more likely to effect distribution of prey species rather than the dolphins directly. More recent findings have shown that as the dry season progressed, *Sousa* were less frequently sighted to the east of Lantau. [35]

4.4 SENSITIVE RECEIVERS

Following the above review of baseline ecological conditions in the Study Area, ecological sensitive receivers which may be affected by the proposed backfilling operations have been identified, as shown on *Figure 4.3b,* and are listed below.

- Fish Culture Zones at Ma Wan, Lo Tik Wan and Sok Kwu Wan;
- Fishery nursery areas and fry collection areas;
- Commercial fisheries resources south of Tsing Yi and north of Lantau;
- *Sousa* habitat north of Lantau;
- Coral habitats (soft, hard and gorgonians) especially along coasts of east Lamma and south-west Hong Kong.

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(33) Tam (1993). Chinese White Dolphins; Risk of Extinction, Daily Express.

(34) Porter L J (1995) pers. comm.

(35) Porter L J (1995) op.cit.

4.5 *EVALUATION CRITERIA*

4.5.1 *Statutory Requirements*

Sousa has designated protection in Hong Kong under the Wild Animals Protection (Cap.170) Ordinance and the Bonn Convention on the Conservation of Migratory Species of Wild Animals.

4.5.2 *Rarity of Individual Species and Communities*

This is often used as an indication of ecological significance or importance. Rarity may be officially recognised through regulatory protection, such as for cetaceans like *Sousa*, or may serve as an indicator of threatened species or habitats. In such cases, habitat conservation is often as important as individual species preservation.

4.6 *EVALUATION OF IMPACTS*

4.6.1 *Introduction*

The changes in water quality and sediment erosion and deposition expected to result from backfilling of MBAs at South Tsing Yi and North of Lantau (*Section 3*) may affect marine organisms, ecological habitat and community structure. As discussed in *Section 3.2*, effects due to spoil-associated contaminants are not expected since backfilling materials will be restricted to Class A and B sediments under the EPD's dredged material classification scheme (no seriously contaminated Class C sediment will be disposed), and many of the heavy metals are very tightly bound to both clay and organic mud fractions within the sediment. However effects due to increased suspended sediment concentrations, decreased dissolved oxygen and increased nutrient concentrations are possible and may affect ecologically sensitive receivers through smothering, burial, reduced primary production and changes in community structure.

Sediment disposed at the MBAs will lead to the direct disturbance and modification of the seabed and thus inevitably smother or bury the benthic communities in the immediate area. It should be noted, however, that the benthic habitat in the area of the MBAs has already been disturbed and modified through sand dredging activities.

Suspended sediment generated during the backfilling operations will cause an increase in turbidity in the water column and higher rates of deposition on the sea floor. Such concentrations may cause the smothering of filter feeders such as bivalves and clogging of gill filaments in fish and other organisms. However, many marine organisms have mechanisms to avoid adverse effects arising from elevated SS concentrations and sediment deposition. [36] Large mobile organisms, such as fish, can swim to avoid turbid waters and can clear gills by flushing with water. Slow-moving benthic and sessile organisms rely on body motion and sweeping movements of appendages and cilia to remove unwanted sediment. If the rate of sediment deposition or SS concentration reaches a level that is greater than clearance mechanisms can remove, then organisms will be

(36) Binnie Consultants Limited (1994c) Marine Ecology of the Ninepin Islands Civil Engineering Department, Geotechnical Engineering Office.

injured and may die. In general, susceptibility decreases with age and larvae and juveniles tend to be more sensitive to sedimentation injury than adults.

Another potential impact involves reduction in dissolved oxygen concentration caused by elevated concentrations of suspended sediments. An increase in solids in the water column will result in the following effects on dissolved oxygen:

- reduced sunlight penetration, lowered rate of photosynthesis of phytoplankton (primary productivity) and thus lower rate of oxygen production in the water column; and

- higher energy retention from sunlight, resulting in higher temperatures, and thus possibly lower oxygen levels as oxygen is more soluble in colder water.

It should be noted that the extent of water quality impact in terms of the potential physical and chemical effects described above is dependent on the amount of sediment lost to the water column. This is a function of the quantity and composition of the marine sediment, dispersion characteristics of the receiving water body at the MBAs and the backfilling method employed. Water quality impacts arising from elevated levels of SS, reduced DO concentrations and potential nutrient release are discussed in *Section 3.10.*

Aside from the direct loss of benthic communities and indirect impacts to marine biota and habitats both within and adjacent to the work areas, underwater noises from backfilling operations and disturbance from vessel traffic may also impact *Sousa chinensis*.

In addition to these potentially adverse environmental impacts, there are likely to be environmental benefits to the ecological communities associated with backfilling, such as restoration of the MBAs to benthic conditions existing prior to the initiation of sand dredging activities. Potential adverse and beneficial impacts, as well as an evaluation of their significance on the ecologically sensitive receivers likely to be impacted by backfilling activities at the South Tsing Yi and North of Lantau MBAs are described below for benthic, fisheries, intertidal and marine mammal resources.

4.6.2 *Benthic Communities*

Expected Impacts

The primary effects on benthic communities due to backfilling will include smothering, burial and habitat modification within the MBAs themselves and within areas of substantial deposition outside the MBAs as described in *Section 3.9*. The following sections describe the ability of marine organisms to tolerate and adapt to higher sedimentation rates, and the ecological significance of the communities likely to be impacted.

Sediment Deposition Tolerances

Adverse effects on benthic fauna due to increased rates of sedimentation may be lethal or sublethal depending upon the rate, duration and periodicity of sedimentation and other factors such as the motility or tolerance of the organisms affected. Where sediment deposition rates exceed the marine organisms' tolerances, burial and faunal mortality will occur and the benthos will become temporarily azoic. This condition may continue throughout the duration of backfilling as colonizing organisms are continually buried by disposed sediment. However, upon completion of backfilling activities, colonizing organisms are expected to survive and the community progress through successional stages to achieve the natural benthic assemblage for the area.

The extent of faunal mortality during backfilling will depend upon the rates of sediment deposition and individual organisms' tolerances of these rates. Tolerances may be defined to include the organism's ability to reposition itself in response to sediment deposition in order to maintain its preferred habitat position (eg digging through deposited sediment to the surface). Tolerances may also relate to the organisms' ability to cope with abrasion or gill clogging (eg. increased cilia action or mucous production) or to withstand reduced levels of dissolved oxygen at the seabed surface.

Sediment deposition will affect various species of benthic invertebrates differentially. Some polychaetes (Spionidae) are known to abandon their tubes and swim to new areas when exposed to stress such as high sediment deposition or suspended sediments in the bed layer. [37] In the absence of specific data from Hong Kong, a recent report identified bed layer suspended sediment loads of 100 mg l^{-1} as the chronic tolerance limit for benthic invertebrates and 200 mg l^{-1} as the acute limit. [38]

Modelling simulations for worst–case non–cumulative (Scenario 4) and worst– case cumulative (Scenario 7) impacts indicated that predicted bed layer suspended sediment concentrations never exceeded the acute threshold and rarely exceeded the chronic threshold. The worst–case non–cumulative scenario (Scenario 4) predicted a maximum elevation of bed layer concentrations of 40 ppm (= 40 mg l^{-1}). Therefore, backfilling activities alone are not expected to cause either threshold to be exceeded under any tidal conditions even at the maximum rate modelled.

The worst–case cumulative scenario (Scenario 7) predicted elevated bed layer concentrations exceeding 100 ppm in limited areas south of Tsing Yi and north of Lamma Island. According to this scenario, some areas would be exposed to concentrations above the chronic threshold during combined backfilling and dredging activities. Since no time period was given for the chronic effects threshold, it is difficult to accurately predict whether chronic effects will occur. However, given that few, if any, areas would be exposed to concentrations above the chronic threshold on both peak ebb and peak flow tides, continuous exposure to these concentrations is unlikely and chronic effects are not expected to occur.

Tolerance thresholds have also been developed for hard and soft corals. [39] Previous studies of corals in Pacific and Caribbean waters have shown that hard coral mortality results at sedimentation rates of 8 mg cm^2 day^{-1} and 200 – 500 mg cm^2 day^{-1} respectively. In the absence of empirical data for Hong Kong corals, 20 mg cm^2 day^{-1} was proposed as a damage threshold for hard corals. [39]

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(37) Ibid.

(38) Ibid.

(39) Ibid.

Octocorals (composed of the families Alcyonacea (true soft corals), Pennatulacea (sea pens and sea pansies), and Gorgonacea (gorgonians)) may be more tolerant of sediment deposition than hard corals due to their body shape and their propensity for areas with fast-flowing waters. Sea pens occur predominantly in soft substrates [40] and are, therefore, adapted to areas with higher sediment loads. Sea pansies are reported to be able to uncover themselves when buried by sediment and reanchor when dislodged. [41] Although no information on octocoral tolerances is available from Hong Kong, sedimentation rates of 3.8 mg cm^2 day^{-1} have been shown to have no effect on these organisms in another study. [42]

The results of sediment deposition modelling described in *Section 3.10*, indicate that for both worst-case non-cumulative (Scenario 4) and worst-case cumulative (Scenario 7), sediment deposition rates in most areas are low. In Scenario 4, deposition in most areas is less than 25 mg cm^2 day^{-1} and is less than 100 mg cm^2 day^{-1} in all areas. For Scenario 7, most areas are predicted to experience deposition at less than 100 mg cm^2 day^{-1} and the maximum deposition is predicted as 200 mg cm^2 day^{-1} for limited areas. Using the available information to bracket the expected effects range, deposition rates of 20–200 mg cm^2 day^{-1} may result in sublethal impacts to corals. Therefore, while deposition rates in some areas under cumulative scenarios may result in adverse impacts, deposition rates under non-cumulative (backfilling only) are expected to fall within the low range of expected effects. In addition, areas of coral habitat are far removed from the areas of backfilling (*Figure 4.3b*) and thus bed layer concentrations and deposition rates in these areas are likely to be lower than the maximum values cited above.

Finally, reductions in dissolved oxygen concentrations may potentially affect benthic fauna. In a study of a stratification-caused hypoxia event in Mirs Bay in 1994, [43] DO in the bottom waters was recorded at levels as low as 0.5 mg l^{-1}, although surface waters contained 7 mg l^{-1} of DO. Mass mortality of benthic epifauna was observed, including heart urchins, anemones, gorgonians and black corals. Although not examined directly, it was noted that benthic infauna were probably affected similarly. The results of worst-case non-cumulative modelling (Scenario 4a), *Section 3.10*, indicate that DO concentrations would remain above 6.3 mg l^{-1} (83% saturation) in both the surface and bed layers along the north and east Lantau coastline and around Ma Wan. As discussed in *Section 3.10*, reductions in DO mean concentrations predicted for worst-case cumulative impacts (Scenario 7) would be localised within the MBAs and the immediate surrounding area, and within the concurrent dredging areas. The predicted mean DO concentration in the bed and surface layers would not fall below 5.7 mg l^{-1}. Thus predictions of dissolved oxygen levels under a variety of modelling scenarios (*Section 3.10*) indicate that effects from cumulative and non-cumulative backfilling activities would not cause adverse impacts to benthic fauna.

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(40) Morton B and Morton J (1983) The Seashore Ecology of Hong Kong. Hong Kong University Press.

(41) Barnes R D (1987) Invertebrate Zoology. Saunders College Publishing. Philadelphia 893pp.

(42) Marzalek D S (1982) Impact of dredging on a subtropical reef community, South-east Florida, USA p147–153. In: E D Gomez (ed.) Proc. 4th Int. Coral Reef Symp., Manila, 1981.

(43) Binnie Consultants Limited (1995b) 1994 Hypoxia and Mass Mortality Event in Mirs Bay Final Report.. Civil Engineering Department, Geotechnical Engineering Office.

Ecological Significance of Potentially Impacted Communities

As described in *Section 4.3.3* other studies [44] [45] found the soft bottom benthic communities in the vicinity of the South Tsing Yi MBA to be moderately populated and numerically dominated by polychaetes. These communities were found to be of a similar structure to others in Hong Kong. Neither of these surveys identified any unique, rare or environmentally sensitive species in the area.

The results of the benthic grab survey undertaken in the North Lantau area for this EIA (*Annex S*), indicate that the soft bottom benthic community was depauperate. Both the abundance and number of species were low compared with other studies in the area: while more than 120 species were found in a previous EIA study [46], only 13 species were found in benthic grab samples conducted for this EIA. This result may be attributable to the reduced sampling effort in this EIA's survey or to disturbance from dredging in the North of Lantau MBA. Most of the soft bottom benthic species recorded in this EIA's survey are commonly found in the coastal waters of Hong Kong and are typical of the western estuarine waters of Hong Kong. [47] [48]

Although the soft bottom communities within and around the MBAs are not unique, hard bottom habitats in these areas are known to support several species of octocorals. As the abundance of octocorals in Hong Kong waters has decreased in recent years (Wu 1995 pers. comm.), these species are identified as being of ecological interest. As described in *Section 4.3.3*, gorgonian corals (unidentified Gorgonacea species) were found at all three trawl transects undertaken in the South Tsing Yi area and sea pens (species *Pteroides esperi, Sclerobelemnon burgeri* and *Virgularia gustaviana*) were found at trawl transects T2 and T3. Two gorgonian individuals (unidentified Gorgonacea species) were also identified at grab station G1 within the North Lantau MBA (*Figure 4.3a*). The following sections describe existing knowledge of gorgonian and sea pen habitat preferences and distribution in Hong Kong waters.

Gorgonians have a worldwide distribution which includes Antarctic and Arctic waters as well as tropical seas from the shallows to the abyssal depths. Unlike hard corals, gorgonians do not possess zooxanthellae and are not, therefore, light dependent. Gorgonians require a firm substratum and are known to be highly intolerant of low salinities (Bayer 1956).

A survey of Hong Kong's gorgonian corals was undertaken by Zou and Scott (1980). [49] A total of 26 species belonging to 15 genera and 6 families have been described and recorded. The northeastern waters of Hong Kong are reported to be the region of maximum species diversity. Most of the 26

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(44) Shin P K S and Thompson G B (1982) op.cit.

(45) Furano (1992) op.cit.

(46) Greiner Maunsell (1991) op.cit.

(47) Ibid .

(48) Shin P K S and Thompson G B (1982) op.cit.

(49) Zou R L and Scott P J B (1980) The Gorgonacea of Hong Kong. The Marine Flora and Fauna of Hong Kong and Southern China, Hong Kong.

species recorded from Hong Kong may be found in this area at depths of approximately 12 m fringing the scleractinian coral community. However, the gorgonians reach maximum abundance below 20–25 m in the relatively deeper oceanic waters in the south-east region of Hong Kong. A combination of rocky substratum, greater depth and the higher, less variable salinity of oceanic waters is stated to favour the growth and reproduction of gorgonians. In addition to these two main habitats, small isolated colonies are also found attached to occasional stable rocks scattered across the sea bottom, particularly near rocky headlands.

As described in *Section 4.3.3*, a high distribution of soft corals and gorgonians were found in some areas of deeper water around the northern coast of Lamma Island. However, both the abundance and diversity of these species were reported to be lower than in the eastern waters. [50] Previous studies, [51] conducted in the area around Sha Chau in late September and early October 1994, have shown that gorgonian corals and sea pens are common. Therefore, although gorgonians are more abundant and diverse in oceanic eastern waters, some species also occur in western waters with fluctuating salinities. These data assist in explaining the presence of gorgonians in and near the South Tsing Yi and North of Lantau MBAs.

Sea pens, which were also found in and around the South Tsing Yi MBA, have a wide distribution in Hong Kong, ranging from Sha Chau in the western waters to Mirs Bay in the east (Wu 1995 pers. comm.). As they are closely related to other corals (ie gorgonians) they are adapted to a similar environment (Wu 1995 pers. comm.). Although sea pens were collected from Sha Chau in a recent survey, they have not been noted in several previous studies in the vicinity of the two MBAs. [52] [53] A literature search has indicated that there is no further ecological information on the distribution of sea pens in Hong Kong.

Although octocorals (gorgonians and sea pens) were found within and near the South Tsing Yi and North of Lantau MBAs, it is unlikely that these areas support major colonies of these species groups. While various species of octocorals may be tolerant of high sediment deposition and suspended loads, the recent dredging and backfilling activities within the northern pit at the South Tsing Yi MBA have resulted in a disturbed habitat which is not likely to represent preferred octocoral habitat. Further, as hard substrate is required for anchoring, the MBAs, which are sited on sand deposits and surrounded by a substrate of fine sediments, are unlikely to provide adequate hard substrate for large communities of octocorals. Finally, as octocorals are somewhat intolerant of low salinity waters and are predominantly located in the eastern waters of Hong Kong, the areas of the South Tsing Yi and North of Lantau MBAs are unlikely to represent preferred habitat regardless of the presence of hard substrate.

Therefore, it is expected that the MBAs contain a few individuals of various species of octocorals which will be lost due to burial during backfilling activities. However, individuals located outside the MBAs and at distances

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(50) Binnie Consultants Limited (1994b) op.cit.

(51) Furano (1994) op.cit.

(52) Shin P K S and Thompson G B (1982) op.cit.

(53) Furano (1992) op.cit.

more remote from backfilling activities are expected to tolerate the temporary increases in suspended sediments and sediment deposition rates resulting from backfilling operations. For example, as discussed in *Section 4.3.3*, the south-west coast of Hong Kong Island and the northern and northeastern coasts of Lamma Island (Pak Kok and Luk Chau) have populations of hard corals and octocorals. However, sediment plumes are expected to reach these areas only under worst-case cumulative scenarios (Scenarios 5 and 7) and only with maximum bed layer concentrations in the range of 10-50 ppm under peak ebb tides.

Conclusions

Backfilling activities will result in smothering and burial of benthic organisms inside the MBAs. Faunal mortality and community disruption is expected in limited areas, predominantly within the MBAs. Previous studies and surveys for this Study have demonstrated that the MBAs do not contain rare or unique species assemblages and that important assemblages, such as large communities of hard corals and octocorals, are located sufficiently far from the MBAs to avoid adverse effects. The presence of octocoral species found within and near the MBAs indicates that some individual mortality will occur, however, this does not indicate that major communities of these organisms will be disrupted.

The extent of impacts outside the MBAs will depend on the magnitude of sediment deposition and concentrations of suspended sediments, and on the benthic community's ability to tolerate these increased sediment loads. Especially for species located in or near the North of Lantau MBA, which naturally receives high suspended sediment concentrations and irregular sediment deposition as a result of Pearl River discharges, a high tolerance for elevated sediment loads is expected. Further, results of plume modelling indicate that levels of suspended sediment in the bed layer and rates of sediment deposition are within the range of species' tolerances for non-cumulative scenarios and cumulative scenarios in most areas. Areas receiving peak suspended sediment and sediment deposition concentrations will only be impacted for short periods during the tidal cycle. Therefore, unacceptable impacts to benthic communities are not predicted.

4.6.3 Fisheries Resources

Expected Impacts

The primary impacts to fisheries resources resulting from backfilling operations are expected to arise from sediment plumes and associated levels of suspended sediments and dissolved oxygen. Since the larval and juvenile stages are generally the most sensitive stage in an organism's life cycle, plume effects on fish and invertebrate nursery areas are of particular concern. Although these impacts may affect capture fisheries as well as mariculture areas, the mobile nature of capture fisheries resources and activities will allow movement away from areas of temporary perturbation. Thus impacts of sediment plumes on mariculture areas are likely to be of greater concern. There is also the potential for cumulative impacts to fisheries as dredging works in the surrounding area contribute to elevated suspended sediment concentrations, reduced dissolved oxygen levels and habitat modification.

Other impacts may occur due to changes in feeding habitat resulting from alteration of the seafloor in the MBAs. However, these impacts are expected to be minor since, as described above, the existing soft bottom benthic habitat within the MBAs has not been found to be unique or particularly sensitive. Therefore, disruption of feeding habitat within the MBAs is mitigated by the restoration of the original benthic habitat once recolonisation of backfilled areas occurs.

Ecological Significance of Fisheries Resources

As described in *Section 4.3.4,* all fish and macro-invertebrate species recorded in the trawl survey undertaken in the South Tsing Yi area for this EIA are commonly found in the coastal waters of Hong Kong. Key fisheries resources within the west-central waters, as discussed in *Section 4.3.6,* consist of rocky substrate around Ma Wan which provides important fisheries habitat [54] and potential fish fry nursery areas along the east Lantau coast as shown on *Figure 4.3b.*

The fish community in the area north of The Brothers, approximately 1.5 to 6 km west of the North of Lantau MBA, was found to be highly diverse. [55] Previous survey findings [56] [57] suggest that the waters off the north coast of Lantau are likely to be spawning and nursery grounds for local commercial fish species and invertebrates. However, recent construction works for the Airport Core Programme projects, such as the North Lantau Development and Expressway, are likely to have caused substantial disturbance to previously existing fisheries habitat in the area and will likely lead to the loss of all nursery habitat along the North Lantau coastline under reclamation. In addition, marine works for future projects in the west-central waters, such as the Lantau Port and Western Harbour Development, Container Terminal No. 9 and the Green Island Reclamation, are also likely to cause disturbance to fisheries habitat within these areas.

Therefore, although no unique or rare species assemblages are found in the vicinities of the MBAs, certain areas off the North Lantau coast may provide nursery habitat for fish and invertebrates. However, recent construction works are likely to have caused substantial disturbance to previously existing fisheries habitat in the North Lantau area and the reclamation of the North Lantau coastline is likely to result in the loss of all nursery habitat in this coastal area.

Suspended Sediment Tolerances

Due to the absence of relevant data on the sediment tolerance of fish species in Hong Kong, the findings from a scientific literature review of the effects of sedimentation on aquatic organisms have been reviewed. [58] The review found that in the majority of reported cases, mortality in waters with SS concentrations lower than 100 mg l^{-1} have not been substantially higher than mortality in control fish in clean water. A SS concentration of 125 mg l^{-1} was suggested as the acute tolerance level for wild stocks of fish larvae and 250 mg l^{-1} for one hour as the acute lethal level for wild stocks of adult fish.

(54) Furano (1992) op.cit.

(55) Greiner Maunsell (1991) op.cit.

(56) Richards J and Wu R S S (1985) op.cit.

(57) Wu R S S and Richards J (1981) op.cit.

(58) Binnie Consultants Limited (1994c). op.cit.

No threshold concentrations were defined for juveniles or larval forms due to lack of data. Based on available scientific literature, a SS concentration of 100 mg l^{-1} was chosen as the chronic tolerance level for invertebrate eggs and larvae (other than corals) and 200 mg l^{-1} as the acute level. These suspended sediment concentration thresholds are considered conservative as they were based on levels at which the most susceptible species began to show observable effects.

The worst-case modelling simulation based on non-cumulative impacts (Scenario 4a reported in *Section 3.9*) indicates that suspended sediment plumes are not likely to extend into the bays along the eastern coast of Lantau and therefore impacts to fish fry nursery areas along this coast are not expected. Sediment plumes were shown to extend along the North Lantau coastline (*Annex E*). However, with the reclamation of the North Lantau coastline as discussed above, plumes impacting this area are unlikely to affect viable nursery areas.

During the wet season, high suspended sediment concentrations occur naturally in the North Lantau area when sediment loads from the Pearl River are heavy (water quality monitoring undertaken at Yam O showed mean depth-averaged SS concentrations reached a peak concentration of 92 mg l^{-1}). Since the results of the worst-case non-cumulative scenario (Scenario 4a) indicate that the North Lantau coastline will be subject to peak elevated SS concentrations in the range of 1-10 ppm in both the surface and bed layers, these additional sediment loads are not considered of concern. Further, these predicted SS concentrations do not exceed the tolerance thresholds for fish larvae and invertebrate eggs and larvae presented above, and therefore are unlikely to result in unacceptable adverse impacts on any spawning and nursery grounds remaining in areas off the reclaimed North Lantau coastline.

The worst-case modelling simulation based on cumulative impacts (Scenario 7) indicates the maximum area to be affected by sediment plumes generated from combined dumping at the North of Lantau and South Tsing Yi MBAs and concurrent dredging works in the surrounding area. Again, these simulations have shown that suspended sediment plumes are not likely to extend into the bays along the eastern coast of Lantau and therefore impacts to fish fry nursery areas are not expected. However, sediment plumes were shown to extend further along the North Lantau coastline (*Annex K*) and thus any remaining spawning and nursery grounds in this area would be affected. Scenario 7 modelling results indicate that areas along North Lantau coastline will be subject to elevated SS concentrations with a maximum concentration in the bed layer of 50 ppm. As discussed in *Section 3.10*, high elevations in SS concentrations were predicted for only relatively short periods (1-4 hours typically) during the tidal cycle and thus the acute tolerance levels have been used to evaluate sediment plume impacts. The peak predicted SS concentration of 50 ppm when added to the 90 percentile background SS concentration (25 mg l^{-1}) would be less than the acute tolerance levels for both fish larvae and invertebrate eggs and larvae (125 mg l^{-1} and 200 mg l^{-1} respectively). However, when background SS concentrations are high the acute threshold for fish larvae could be exceeded, and post yolk sac fry may be affected by transient high elevations in SS concentrations generated by the combined dumping and concurrent dredging works.

Identified fisheries habitat also exists in the vicinity of the Ma Wan Fishery on the east coast of Ma Wan. According to worst-case non-cumulative

Scenario 4a, the Ma Wan Fishery will be subject to elevated SS levels at peak concentrations in the bed layer just exceeding 14 ppm for a period of less than an hour. This predicted peak SS concentration when combined with mean background concentrations would be substantially less than the acute SS tolerance level of 250 mg l^{-1} for adult fish and 125 mg l^{-1} for fish larvae. It is therefore considered that fish health around Ma Wan will not be adversely affected by sediment plume impacts during backfilling activities alone. Under the worst- case cumulative modelling (Scenario 7), elevated SS concentrations at the Ma Wan Fishery will peak at 70 ppm in the bed layer. This predicted peak concentration will not exceed the acute SS threshold for adult fish, even when background SS concentrations in the area are high, and thus no adverse impacts to fish health are anticipated. However, when background SS concentrations are high, the acute threshold for fish larvae would be exceeded.

Dissolved Oxygen and Nutrient Release Impacts

The results of worst-case non-cumulative impact modelling (Scenario 4a), *Section 3.10*, indicate that DO concentrations would remain above 6.3 mg l^{-1} (83% saturation) in both the surface and bed layers along the north and east Lantau coastline and around Ma Wan. This reduction of less than 2% saturation against background DO concentrations is considered acceptable and thus no DO related impacts on fisheries habitats off the north and east Lantau coastal areas and around Ma Wan are predicted. As discussed in *Section 3.10*, greater DO deficiencies resulting from worst-case cumulative impacts (Scenario 7) would be localised within the MBAs and the immediate surrounding area, and within the concurrent dredging areas. Furthermore, the reductions in DO mean concentrations predicted for worst-case cumulative impacts (Scenario 7) would not result in exceedances of the specified WQOs for DO. Therefore no unacceptable DO related impacts on the above identified fisheries habitats of high value are anticipated due to combined backfilling and dredging operations.

The nutrient release assessment undertaken for worst-case non-cumulative impacts (Scenario 4a) indicates that the peak nitrogen level increase would be well within the natural range of concentrations in the study area (*Section 3.10*). Results from worst-case cumulative Scenario 7 indicate a peak increase in total nitrogen concentration of 25% in the bed layer. At the identified fisheries habitats, however, maximum increases in total nitrogen are expected to be less than 5% of the mean background concentrations. Thus no unacceptable impacts on fisheries habitat resulting from potential nutrient release are anticipated under both worst-case non-cumulative and cumulative scenarios.

Capture Fisheries and Fish Culture Zones

As discussed in *Section 4.3.6*, AFD data suggest that the South Tsing Yi area (*Figure 4.3b*) is an important commercial fishing ground with the annual capture fisheries production for 1994 representing just over 6% of the total fisheries production in Hong Kong waters. Other fisheries resources in west-central waters include fish culture zones, fish fry collection areas and the Ma Wan Fishery. In contrast, the trawl survey undertaken in the South Tsing Yi area for this EIA found the number and abundance of commercial fish and macro-invertebrate species to be low. Furthermore, the AFD data characterize fisheries resources prior to the onset of large scale dredging, dumping and reclamation projects, and may overestimate the existing value of this resources in the Western Harbour area.

The North Lantau area also supports commercial fishing activities to extent which is difficult to quantify. As discussed in *Section 4.3.4*, capture fisheries production in the North Lantau area for the year 1994 represents almost 4% of the total fisheries production in Hong Kong waters. Although AFD estimates of commercial landings and value of fisheries resources in the North Lantau area may not be as high as for other areas, previous surveys [59], [60] suggest that the coastal areas may serve as spawning and nursery grounds for fish species and support a high abundance of penaeid shrimps.

As discussed in *Section 4.3.6*, the main commercial fisheries in the vicinity of the North Lantau MBA are shrimping and purse seining for migratory croaker. The previous discussion has shown that SS concentrations predicted by modelling scenarios are unlikely to affect fisheries resources except in cases of extremely high ambient SS concentrations. In addition, fish species such as the croaker are migratory and can move away from the temporarily affected areas, and the shrimp are very prolific, having remained in the area despite major disturbance from recent marine construction works in the area. Thus it is considered that neither of these fisheries in the North Lantau area is likely to be adversely affected by impacts arising from sediment plumes generated during backfilling activities.

It should be noted that disruption of fishing activities in the west-central waters is anticipated during both the construction and operation of the Lantau Port and Western Harbour Development, Container Terminal No. 9, and the Green Island Reclamation and also from the associated increase in marine traffic.

Mariculture fisheries potentially affected by the backfilling operations include Fish Culture Zones (FCZs) at Ma Wan, and Lo Tik Wan and Sok Kwu Wan on Lamma Island as shown on *Figure 4.3b*. The results of the simulation of the sediment plumes generated from the combined dumping at the North of Lantau and South Tsing Yi MBAs alone (Scenario 4, *Section 3.9*) have shown that the Ma Wan and Lo Tik Wan FCZs will be subject to elevated SS levels at peak concentrations in the surface layer of less than 5 ppm and 1 ppm respectively. The predicted SS concentrations are not considered significant in comparison to background suspended sediment concentrations in the area and are well below the 50 ppm criteria for *ex-gratia* payments at Ma Wan. Further, the predicted SS concentrations would not exceed the acute tolerance levels of 250 mg l^{-1} for adult fish and 125 mg l^{-1} for fish larvae, even when background SS concentrations are occasionally high. For example, AFD noted recently [61] that a pulse of high SS loadings (<77.6 mg l^{-1}) was detected in Ma Wan on 3 January 1995. No reclamation, dredging, or dumping works were being undertaken at the time, and the pulse was attributed to natural variations in water quality associated with the lunar cycle. *Ex-gratia* payments to mariculturists were not, therefore, appropriate. Thus sediment plumes arising during backfilling operations alone are not expected to result in unacceptable impacts on mariculture areas. No elevated SS concentrations are detectable at the Sok Kwu Wan FCZ under worst-case non-cumulative scenarios.

(59) Richards J and Wu R S S (1985) op.cit.

(60) Wu R S S and Richards J (1981) op.cit.

(61) Wilson K AFD 9 March 1995 Memo AF CR 41/650 II.

The worst-case cumulative impact scenario (Scenario 7) has shown that elevated surface layer SS concentrations at the Ma Wan and Lo Tik Wan FCZs will peak at 20 ppm and 8 ppm respectively. Although the predicted SS concentrations do not include background SS levels, these elevated SS concentrations at the Ma Wan and Lo Tik Wan FCZs would not exceed the tolerance thresholds for adult fish and fish larvae presented above. In addition, AFD has indicated that SS concentrations of up to 200 ppm for short periods will not seriously disrupt mariculture activities. Therefore, although elevated concentrations of suspended sediments will arise at the Ma Wan and Lo Tik Wan FCZs, these concentrations represent peak concentrations of short duration (less than an hour) and are unlikely to result in unacceptable adverse impacts on fish health. Furthermore, assuming an ambient SS concentration of 25 mg l^{-1} (*Section 3.8.1*), neither of these predicted increases exceeds the 50 mg l^{-1} criteria for *ex-gratia* payments at fish culture zones. No elevated SS concentrations are detectable at the Sok Kwu Wan FCZ under worst-case cumulative scenarios.

The only other sensitive receivers shown to be subject to elevated levels of suspended sediments are the Ma Wan Fishery, the Kau Yi Chau Fishery and the Tung Wan Tsai Fishery. Sediment plume impacts at the Ma Wan Fishery have been discussed earlier in view of this area providing important habitat for certain fish species. It was considered that the fisheries habitat around Ma Wan will not be adversely affected by non-cumulative and cumulative sediment plume impacts.

The worst-case non-cumulative sediment plume modelling (Scenario 4) predicted that the SS concentrations arising at the Kau Yi Chau and Tung Wan Tsai Fisheries will peak at concentrations in the surface layer of 7 ppm and 12 ppm, respectively. This predicted peak SS concentration when combined with mean background concentrations will be less than the acute SS tolerance level of 250 mg l^{-1} for adult fish and 125 mg l^{-1} for fish larvae. It is therefore considered that these fisheries areas will not be adversely affected by sediment plume impacts during backfilling activities alone.

Under the worst-case cumulative modelling (Scenario 7), elevated SS concentrations (surface layer) at the Kau Yi Chau and Tung Wan Tsai Fishery will peak at 51 ppm and 49 ppm, respectively. This predicted peak concentration will not exceed the above acute SS threshold for adult fish (250 ppm), even when background SS concentrations in the area are high, and thus no adverse impacts are anticipated. However, when background SS concentrations are high, the acute threshold for fish larvae (125 ppm) could be exceeded. These concentrations would also result in exceedance of the 50 ppm *ex gratia* criteria.

Conclusions

The waters off the north coast of Lantau may serve as spawning and nursery grounds for fish and invertebrate species. There are also potential fish fry nursery areas along the east coast of Lantau and fisheries habitat around Ma Wan. The larvae and juvenile stage is generally the most sensitive stage in an organisms life cycle, and thus the potential for sediment plume impacts on these spawning and nursery grounds are of concern. Predicted elevations in suspended sediment concentrations within the areas of the sediment plumes are not expected to result in exceedance of acute tolerance levels for fish and invertebrate larvae during backfilling operations alone. However, cumulative impacts arising from concurrent dredging and backfilling activities, in conjunction with high ambient SS levels, may result in SS concentrations exceeding the acute tolerance level for fish larvae in some nursery areas for brief periods. The predicted reductions in DO concentrations (non–cumulative and cumulative scenarios) would not result in exceedances of the specified WQOs for DO and thus no unacceptable DO impacts on the identified fisheries habitats are anticipated. No unacceptable nutrient impacts on the identified fisheries habitats are expected under either worst–case non–cumulative and cumulative scenarios.

Productive capture fisheries areas exist in the vicinity of both the South Tsing Yi and North Lantau MBAs. Other key fisheries resources in the vicinity include fish culture zones and fish fry collection areas. It is considered that capture fisheries, mariculture areas and fish fry collection areas are unlikely to be adversely affected by predicted suspended sediment concentrations associated with backfilling at the North of Lantau and South Tsing Yi MBAs (non–cumulative scenario). However, backfilling activities in conjunction with other dredging/disposal projects and high levels of ambient SS may require mitigation, particularly at the Ma Wan Fishery. Mitigation measures which reduce the sediment concentrations in the water column are described in *Section 3.14* and would serve to reduce impacts to fisheries resources.

4.6.4 *Intertidal Communities*

Potential impacts of backfilling on intertidal communities include elevated levels of suspended sediments, reduced concentrations of dissolved oxygen and habitat modification. Intertidal habitats within the study area which may be affected by backfilling activities include five gazetted beaches located along the Tsuen Wan coast between the two MBAs. Five other gazetted and ungazetted beaches are located south and west of the MBAs at greater distances (*Figure 3.5a*). A discussion of predicted impacts due to elevations in SS, DO and nutrients at beaches is provided in *Section 3.10*. Impacts to other intertidal zones are discussed below.

The results of worst–case non–cumulative modelling (Scenario 4a) have shown that sediment plumes are likely to extend south of Green Island and through the East Lamma Channel. Maximum elevated SS concentrations of 10 ppm (bed layer) are predicted in the intertidal zone along the south–west coast of Hong Kong and around the northern coast of Lamma Island (as reported in *Section 3.9*). Worst–case cumulative modelling (Scenario 7) indicates maximum elevated SS concentrations of 50 ppm (bed layer) in these intertidal zones. However, unacceptable impacts to intertidal habitats arising from suspended sediment concentrations are not expected as no ecological sensitive receivers have been identified in these coastal areas. Impacts to hard and soft corals in these areas are discussed above in *Section 4.6.2*.

4.6.5 *Marine Mammals*

Introduction

The only marine mammal potentially impacted by the proposed backfilling operations is *Sousa chinensis*, the Chinese White Dolphin. This species is known to inhabit waters north of Lantau Island, including The Brothers, and may transit through waters south of Ma Wan, off the north–east coast of Lantau. As discussed in *Section 4.3.8*, results from the AFD DRT on *Sousa* distribution (*Figure 4.3c*) indicate that the North of Lantau MBA does not represent an area of frequent *Sousa* sightings and thus does not appear to be of high habitat value to *Sousa*. Environmental impacts to *Sousa* from backfilling operations may take the form of elevated concentrations of suspended sediments, changes in feeding habitat through indirect impacts to fish and benthic communities, and disturbance from underwater noise and vessel movements.

Alteration of Water Quality and Feeding Habitat

As air breathing mammals, *Sousa* will be less affected by high SS concentrations than fish. However there may be an indirect effect on *Sousa* in terms of food availability, due to adverse effects on fish and benthic communities during backfilling. Of these potential impacts, changes in feeding habitat or food availability are expected to have minimal effect on marine mammals since the MBAs are not located within areas of frequent *Sousa* sightings. Hence it can be inferred that the MBAs do not represent areas of preferred feeding habitat for *Sousa*.

As discussed in *Section 4.3.8*, recent research results from the AFD DRT have shown areas where *Sousa* are often sighted comprise Lung Kwu Chau and Sha Chau (these key areas are located a considerable distance – approximately 12 km – from the nearest MBA at North Lantau), and the areas between Tai O and Sha Lo Wan and the Fan Lau and Soko Islands (located over 25 km from the North Lantau MBA). Recent research results from the AFD DRT do not indicate The Brothers to be a key habitat for Sousa, although as habitat disruption associated with the Chek Lap Kok airport decreases, The Brothers area may become more important. The worst–case sediment plume simulations (reported in *Section 3.9)* have shown that suspended sediment plumes are not likely to extend to the key areas of Lung Kwu Chau and Sha Chau, and the areas between Tai O and Sha Lo Wan and the Fan Lau and Soko Islands. Thus sediment deposition effects on these key feeding habitats are not expected to arise during backfilling operations.

Since the spatial range of *Sousa* has not yet been established, the proportion of its range affected by the proposed backfilling works is not presently known. Existing information based on AFDs DRT research studies suggests, however, that the feeding range of *Sousa* comprises large estuarine areas west of Hong Kong in Chinese waters, which are subject to higher sediment loadings from the Pearl River than the North Lantau and South Tsing Yi areas. This suggests that *Sousa* may possibly be tolerant of naturally high background suspended sediment loads in the Pearl River Delta. It is therefore considered that *Sousa* is not likely to sustain major impacts due to temporarily elevated suspended sediment loads in areas of sediment plumes.

Underwater Noise

Aspects of marine mammal hearing that are relevant to an understanding of the effects of anthropogenic noise on marine mammals are discussed in the review 'Effects of Man–Made Noise on Marine Mammals.' [62] This review discusses the topics considered in the papers of Popper (1980 a,b), Fobes and Smock (1981), Schusterman (1981), Ridgway (1983), Watkins and Wartzok (1985), Johnson (1986), Nachtigall (1986), Moore and Schusterman (1987), Bullock and Gurevich (1979) and Fay (1988) and includes several more recent references. (The full references are given in *Annex S*). The review notes that

(62) Richardson W J, Greene C R, Malme C I and Thomson D H with contributions by Moore S E and Wursig B (1995) **Effects of Man–Made Noise on Marine Mammals** LGL Ltd. Environmental Research Associates.

sound is transmitted very efficiently underwater (in comparison with sound in air) and marine mammals rely chiefly on sound to communicate, sense food and understand their local environment.

Research has indicated that toothed whales or Odontocetes (the Cetacea group to which dolphins belong) are most sensitive to sounds above 10 kHz. [63] The sensitivity of many toothed whales to high frequency sounds is related to their use of very high frequency sound pulses for echolocation and moderately high frequency sounds for other functions, including communication. [64] Thus as dolphins utilise echolocation to understand their local environment and locate food, and use sound to communicate and maintain stability in their social groups, increased noise levels due to marine based construction activities (generally below 1 kHz) and vessel engines may interfere with such activities. In addition, long term exposure to high level noise may potentially lead to temporary or permanent reduction in hearing sensitivity which could affect *Sousa*. It will therefore be necessary to reduce the level of construction noise wherever practicable in order to minimise the potential scale, extent and severity of such noise impacts.

There are no published data on the specific hearing abilities of Indopacific Humpback Dolphin or *Sousa chinensis*, although it is considered that this species is generically similar to the bottlenose dolphin (*Tursiops truncatus*).

In most marine mammal species tested for hearing abilities, only one or two individuals have been studied. The most extensive data on individual variation in marine mammal hearing are on the bottlenose dolphin (*Tursiops truncatus*) and white whale (*Delphinapterus leucas*). Seely et al [65] used a neurophysiological method to determine the high-frequency audiograms (5-200 kHz) of five dolphins. Results from four individuals were similar to one another and to other data for this species, and one elderly animal had much poorer sensitivity. Testing has indicated that bottlenose dolphins can detect sounds at frequencies as low as 40-125 Hz. [66] However, below 10 kHz sensitivity deteriorates with decreasing frequency and below 1 kHz, the frequencies of most industrial noises, sensitivity appears to be poor. [67] Sensitivity also decreases as the duration of a single sound pulse decreases below about 0.1-0.2 s.[67] *Figure 4.7a* indicates the threshold noise level necessary for bottlenose dolphins to just detect sounds over the range 100 to 100,000 Hz. [68] [69] [70] [71] Though sensitivity is poor in the range of

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(63) Ibid.

(64) Ibid.

(65) Seeley R L, Flanigan W F and Ridgway S H (1976) A technique for rapidly assessing the hearing of the bottlenosed porpoise, *Tursiops truncatus*. NUC-TP-522, Naval Undersea Center, San Diego, CA. 15 p. NTIS AD-AO29 178.

(66) Johnson, C S (1967) Sound detection thresholds in marine mammals. P.247-260 In: WN Tavolga (ed.), Marine bio-acoustics Vol. 2, Pergamon Press, New York.

(67) Richardson W J, Greene C R, Malme C I and Thomson D H with contributions by Moore S E and Wursig B (1995) op.cit.

(68) Johnson, CS (1968a) Relation between absolute threshold and duration-of-tone pulses in the bottlenosed porpoise. J Acoust Soc Am 43(4):757-763

(69) Ljungblad, DK, PO Thompson and SE Moore (1982c) Underwater sounds recorded from migrating bowhead whales, *Balaena mysticetus*, in 1979. J Acoust Soc Am 71:477-482

(70) Thomas, J, N Chun, W Au and K Pugh (1988) Underwater audiogram of a false killer whale (*Pseudorca crassidens*). J Acoust Soc Am 84(3): 396-940.

construction and operational noises, studies [67] have indicated that because of the efficient transfer of sound in water, dolphins can detect dredgers at distances up to approximately 5 km away.

Masking of sound signals by background noise has been studied under laboratory conditions in the bottlenose dolphin. The ability to recognize sound signals amidst noise is important in communication, detecting predators, locating prey and in echolocation. Above 2 kHz, critical ratios [72] increase with increasing frequency, and are generally similar to those of the human at corresponding frequencies.

Stationary offshore activities often seem to have less effect on cetacean behaviour than do moving sound sources such as aircraft and ships. [73] Cetaceans are reported to avoid stationary offshore activities such as dredging, drilling and oil production when the received noise levels are intense ie, well above ambient levels, but not when the noise is barely detectable.[73] Besides avoidance responses, other behavioral reactions, eg changes in surfacing–respiration–dive cycles are sometimes seen as well.[73] Although limited, the data suggest that stationary offshore activities producing continuous noise result in less marked reactions by cetaceans than do moving sound sources, particularly ships. There are indications that some cetaceans may partially acclimate to continuous noise.[73]

It should be noted that Hong Kong, and in particular the region around the new airport, contains a large variety of intensive operations which include marine–based construction activities and vessel movements. The detectability of noise by marine mammals will therefore be much lower than the theoretical maximum due to masking of sound signals by background noise. It is believed, however, that dolphins will still be aware of marine activities at a distance of several kilometres. Apart from the dumping operations carried out by dredgers and/or barges at the MBAs there will be no other marine–based activities involved in the backfilling operations, and thus it is anticipated that noise impacts associated with the placement of material only will be insubstantial in relation to other marine works, such as dredging and sea bed piling and drilling. It is considered important, however, that operations noise be limited, wherever possible, to minimise the potential for underwater noise impacts to *Sousa*. Mitigation measures are recommended in *Section 5* to minimise the noise levels generated during the backfilling operations.

Vessel Movements

Vessel movements during backfilling activities have the potential to result in impacts to *Sousa* from physical harm through potential collisions, increased turbidity generated by propellers and submerged equipment, and underwater noise. As described above, the data on marine mammal hearing suggest that moving sound sources, particularly ships, have greater effect on

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(71) Jacobs, D W and J D Hall. (1972) Auditory thresholds of a fresh water dolphin, *Inia geoffrensis* Blainville. J Acoust Soc Am 51(2): 530–533.

(72) The signal to noise (S/N) ratio required to detect a pure tone sound signal in the presence of background noise.

(73) Richardson W J, Greene C R, Malme C I and Thomson D H with contributions by Moore S E and Wursig B (1995) op.cit.

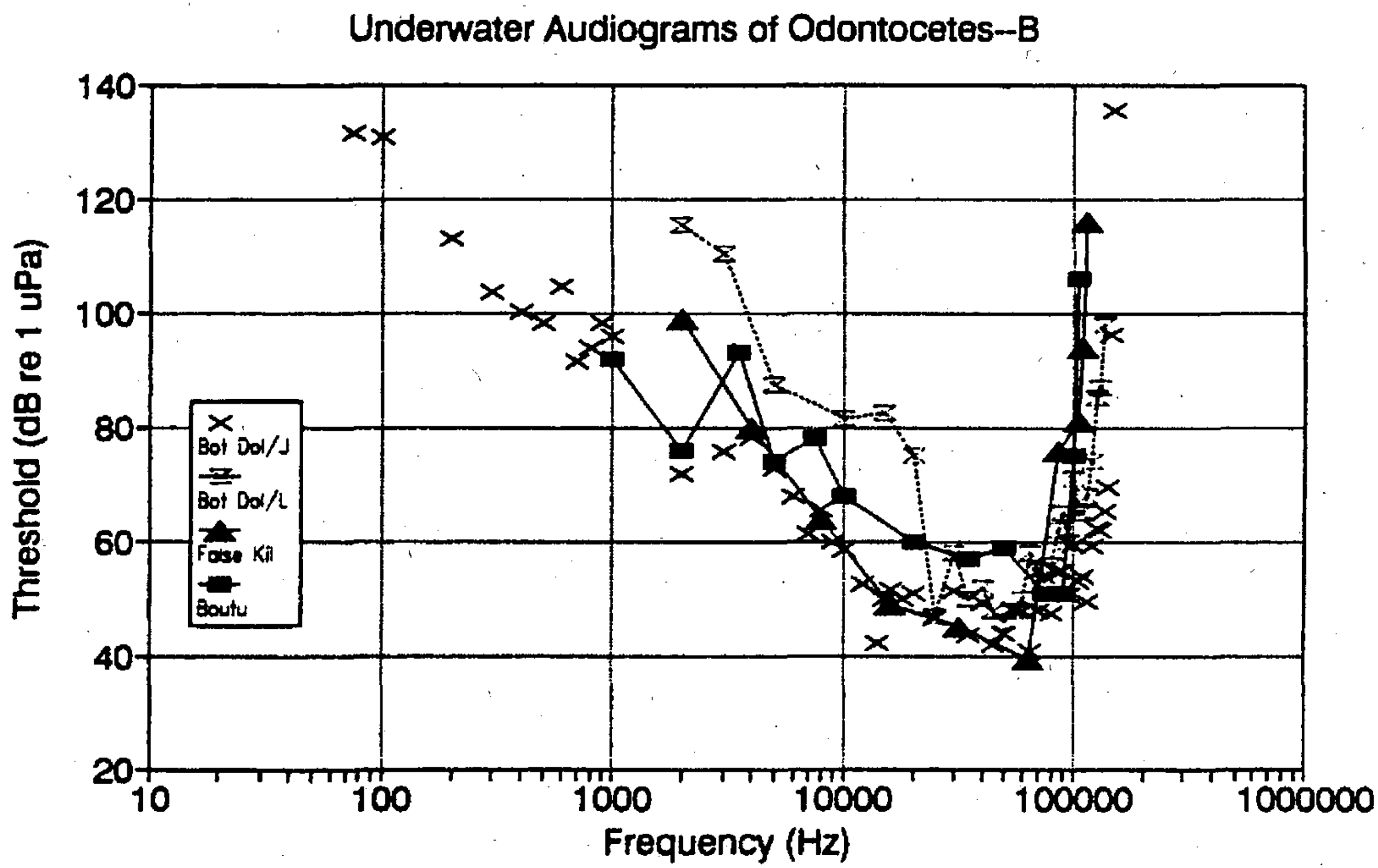

FIGURE 4.7a - UNDERWATER AUDIOGRAMS OF ODONTOCETES: BOTTLENOSE DOLPHIN (JOHNSON 1968a; LJUNGBLAD ET AL. 1982c); FALSE KILLER WHALE (THOMAS ET AL. 1988); AMAZON RIVER DOLPHIN OR BOUTU (JOCOBS AND HALL 1972). n=1 EXCEPT WHERE NOTED

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cetacean behaviour than do stationary offshore activities producing continuous noise. [74]

Odontocetes or toothed whales, however, show considerable tolerance of vessel traffic in many circumstances. [75] The continued presence of *Sousa* in some areas heavily travelled by vessels, such as Urmston Road (between Lung Kwu Chau and Castle Peak), may indicate a considerable degree of tolerance to vessel noise, although most of the movements indicate that *Sousa* are travelling from one area to another.

As discussed earlier, the MBAs are not located within areas of frequent *Sousa* sightings. Therefore, the potential for impacts to *Sousa* arising from collisions with vessels and increased turbidity is not of concern. In comparing vessel noise from backfilling operations to that from present traffic in the surrounding area it should be noted that there are a large number of vessels in the waters off North Lantau and in the South Tsing Yi area. Therefore, it is considered that the increase in vessel noise from backfilling operations is unlikely to contribute significantly to the level of background noise in the surrounding area. However, minimising the number of vessels and small craft involved in backfilling operations, where practicable, would minimise potential impacts of underwater noise on *Sousa*.

Conclusion

Alterations in water quality and feeding habitat are expected to have minimal effect on *Sousa* since the MBAs are not located within areas of preferred *Sousa* feeding habitat. In addition, *Sousa* are not likely to sustain major impacts due to sediment plumes based on their probable tolerance to naturally high suspended sediment loads in the Pearl River Delta and their ability to avoid plumes. The potential for impacts to *Sousa* arising from collisions with vessels is considered minimal since the MBAs are not located within areas of frequent *Sousa* sightings.

Based on dolphin sensitivity to underwater noise, potential noise impacts on *Sousa* during the backfilling operations may be of concern. However, it is anticipated that noise impacts associated with material placement will be insubstantial and impacts associated with increased vessel traffic will be minimal in the context of typical vessel traffic in the waters North of Lantau. Furthermore, the recommended noise mitigation measures (*Section 5*) will minimise the potential for adverse impacts to *Sousa* from underwater noise. In summary, unacceptable impacts to *Sousa* during the backfilling operations are not predicted primarily because the areas near the MBAs do not represent preferred *Sousa* habitat.

4.6.6 *Environmental Benefits*

Sediment Conditions at the MBAs

Prior to sand dredging activities, surficial deposits in the South Tsing Yi area were comprised entirely of soft to very soft marine muds with some sand of the Hang Hau Formation (Holocene). At present, bottom sediments in the South Tsing Yi MBA are comprised of sand banks and sheets of the Hang

(74) Ibid.

(75) Ibid.

Hau Formation. The principal sediment types are sand with some gravel and mud. Sand dredging in the southwestern area of the northern pit (*Figure 2.2a*) was last carried out on the 1 April 1993, with limited (3 to 4 days) dredging in early August 1994. Sand dredging in the southeastern area of the northern pit (*Figure 2.2a*) last occurred on 27 November 1993.

Surficial deposits in the North Lantau area, prior to sand dredging activities, largely comprised soft to very soft marine muds with subordinate sand of the Hang Hau Formation. Areas of heterogeneous sediment types of the older Chek Lap Kok Formation (Pleistocene) occur to the north of the North of Lantau MBA comprising clay, silt, sand and gravel largely of alluvial origin, with some oxidised horizons and organic materials. At present, the bottom sediments in the MBA consist of sand banks of the Hang Hau Formation. The principal sediments are sand with some gravel and mud. Sand dredging was last undertaken at the North of Lantau MBA on 22 February 1994.

The MBAs have been subject to considerable anthropogenic disturbance through dredging. It is considered that backfilling is beneficial, despite short term disturbances, since it restores the sea bed to its original, pre-dredging condition and soft sediment type. In general, fauna colonise only the top 0.5 m of sediment and thus it is the sediment type in this surface layer which will determine the rate of recolonisation. It is probable, therefore, that after anthropogenic disturbance has ceased, soft bottom benthic communities similar to those in undisturbed areas near the MBAs will recolonise the newly created substrate. Special backfilling arrangements at the North of Lantau MBA, described in *Section 7.5*, will promote recolonisation by sequential backfilling of portions this MBA and minimizing the disturbed area.

Recolonisation

The success and rate of recolonisation is dependent upon a suite of factors, including sediment density and grain size, sediment organic content and quality, presence and proximity of stocking populations and the presence and survival of larvae in the water column. For example, recent studies by Science Applications International Corporation (SAIC) at Tung Lung Chau have indicated that compacted clay sediments exposed after sand extraction are not readily recolonised by soft bottom benthic organisms. These studies have shown that high density sediment is difficult to recolonise.

As discussed in *Section 4.3.3*, Shin and Thompson (1982) speculate that benthic communities may be determined by sediment composition, since a high percentage of silt appeared to restrict the number of species able to colonise the substrate. Santos and Simon (1980) [76] note that recolonisation of defaunated sediments, such as those observed in Florida as a result of seasonal anoxia, may be achieved by larval settlement or adult migration. Larval settlement is controlled by selective forces in the water column, the ability of larvae to select a suitable substratum and even to delay maturation until one is located, and predation upon larvae once settled. Adult migration through horizontal (within the substrate) and vertical (through the water column) movement is also possible.

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(76) Santos S L and Simon J L (1980) Marine soft-bottom community establishment following annual defaunation: larval or adult recruitment? Marine Ecology Progress Series 2: 235-241.

Benthic assemblages may be subject to regular, seasonal, fluctuations in abiotic conditions, eg. in dissolved oxygen and salinity, and may exhibit corresponding changes in structure. For example, a pattern of defaunation and recolonization following an annual hypoxic event is described by Santos and Simon (1980). Where the fluctuations are large and predictable, benthic fauna may show a life history pattern of planktonic larvae release and adult migration or death at the time of the impact. These assemblages are, therefore, readily able to recolonize the sediments once conditions become more favourable.

Seasonal variations in the structure of sublittoral benthic communities in Hong Kong are poorly understood. However large fluctuations in salinity and dissolved oxygen have been documented. A recent study [(77)] found that for soft bottom communities in Mirs Bay, recolonisation by some species was rapid. Recolonisation in western waters, such as the vicinity of the MBAs would be expected to occur at an even higher rate since western faunal communities are probably better adapted to fluctuating conditions. This prediction is confirmed by data from ecological monitoring studies [(78)] undertaken at East Sha Chau where the abundances of colonising species such as polychaetes and crustaceans were found to fluctuate substantially in response to seasonal changes.

Recolonization of backfilled sediment by benthic invertebrates has been recorded at East Sha Chau during an environmental monitoring and audit programme [(79)] and in a detailed study. [(80)] The East Sha Chau (east) pit was backfilled from a maximum of -40mPD to -13mPD with uncontaminated trailer-dredged material in the main pit area and a small volume of mechanically dredged material in the southwest corner. Backfilling was completed by January 1995 and grab sampling took place in April 1995 in both sections of the pit and in two reference sites, to determine the extent of recolonization. Juvenile recruitment was occurring throughout the study area at the time of sampling. Low densities of benthic organisms, numerically dominated by polychaetes, were observed in samples from the main borrow pit, suggesting that recolonization had begun. The mechanically dredged material contained a higher density of organisms than the hydraulically dredged material, which was generally softer, indicating the influence of sediment type on recolonization rate.

The grab samples undertaken for this EIA study in the North Lantau area found several species of polychaetes which would probably be initial colonisers of backfilled muds. The NAMP EIA (1990) [(81)] found >120 species of invertebrates in grab samples from areas to the north of Lantau, and grab samples undertaken in the Sulphur Channel and at South Cheung Chau [(82)]

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(77) Binnie Consultants Limited (1995b) op.cit.

(78) Consultants in Environmental Sciences (Asia) Ltd and Binnie Consultants Limited East Sha Chau Monitoring Programme Final Report (November 1992 - December 1993) Agreement No. CE/92 ENPO West Kowloon Project Area. Environmental Protection Department, Hong Kong Government.

(79) Consultants in Environmental Sciences (Asia) Limited and Binnie Consultants Limited Environmental Monitoring and Audit, Contaminated Mud Pits - East of Sha Chau. Progress Reports February 1994 to February 1995.

(80) Binnie Consultants Limited (1995) REMOTS and Grab Survey To Assess Benthic Recolonization Following Backfilling at East Sha Chau (East) Marine Borrow Pit.

(81) Greiner Maunsell (1991) op.cit.

(82) Binnie Consultants Limited (1994a) op.cit.

recorded a total of 170 species of macrobenthos. These results indicate that Hong Kong waters contain a large pool of potential colonising organisms. As discussed in *Section 4.3.3*, the low abundance and number of benthic species found in the grab survey undertaken for this EIA study at the North of Lantau MBA is probably partly attributable to the low sampling effort.

In summary, the literature suggests that recolonisation of benthic habitats following backfilling will not be limited by ecological factors as there is an apparently large pool of potential colonisers in unimpacted areas, and it is likely that the benthic communities in western waters are well adapted to fluctuating conditions.

Existing Recolonisation of Exhausted MBAs

As discussed in *Sections 4.3.3 and 4.3.4*, the faunal assemblages within the MBAs do not contain rare or unique species and are of generally low abundance and diversity. While it is difficult to determine the present extent of MBA recolonisation from limited samples, the presence of gorgonian corals in both MBAs indicates there has been some recolonisation since cessation of dredging activities. Gorgonian corals are known to require a firm substratum, such as rocky outcrops or gravel and grow very slowly (Clarke T 1995 pers. comm.). It is likely that within the South Tsing Yi and North of Lantau MBAs (transect T2 and station G2), the gorgonians colonised natural bedrock exposed after sand dredging to a depth of around -30mPD to -40mPD, or rocks/boulders dropped from passing vessels which settled onto the sandy bottom sediments within the pit. In the absence of empirical data on the growth rate of gorgonian corals in Hong Kong, it is not possible to determine the age of the gorgonians from the size of the specimens found in the surveys undertaken for this EIA study. While the presence of gorgonians indicates the potential for recolonisation of the MBAs, the soft substrate resulting from backfilling the MBAs is unlikely to provide suitable habitat for colonising gorgonians.

4.7 MITIGATION MEASURES AND EM&A REQUIREMENTS

Mitigation required to reduce environmental effects on ecological sensitive receivers to acceptable levels comprises measures to limit sediment plumes and resulting suspended sediment concentrations and deposition rates. These measures also protect water quality and are provided in *Section 3.14*. In addition, limited noise mitigation is also recommended to prevent undue disturbance to *Sousa*. These measures are presented in *Section 5.7*.

4.8 SUMMARY OF MARINE ECOLOGICAL IMPACTS

Assessment of impacts associated with backfilling activities has indicated that the major impacts to benthic communities will include smothering, burial and habitat modification. The extent of these potential impacts will be determined by the magnitude of sediment deposition, the benthic community composition and the organisms' ability to adapt to varying deposition rates. Previous studies in the South Tsing Yi area have shown that benthic assemblages in the MBA are typical of soft bottom communities in Hong Kong waters. Similarly, the grab survey results in the North of Lantau MBA for this EIA have shown that the soft bottom benthic species recorded are commonly found in the waters of Hong Kong. Since species assemblages at these MBAs are typical of soft bottom benthic communities in

Hong Kong waters and do not contain rare or unique species, and the backfilled areas will provide a fresh substrate for recolonisation by the natural benthic assemblages, the identified potential impacts to benthic fauna are considered acceptable.

The waters off the north coast of Lantau may serve as spawning and nursery grounds for fish and invertebrate species. There are also potential fish fry nursery areas along the east coast of Lantau and fisheries habitat around Ma Wan. Predicted elevations in suspended sediment concentrations within the areas of the sediment plumes are not expected to result in exceedance of acute tolerance levels for fish and invertebrate larvae during backfilling operations alone. However, cumulative impacts arising from concurrent dredging and backfilling activities, in conjunction with high ambient SS levels, may result in SS concentrations exceeding the natural range in some nursery areas for brief periods. No unacceptable DO and nutrient impacts on the identified fisheries habitats are anticipated due to backfilling operations (non-cumulative and cumulative scenarios).

Productive capture fisheries areas exist in the vicinity of both the South Tsing Yi and North of Lantau MBAs. Other key fisheries resources in the vicinity include fish culture zones and fish fry collection areas. Suspended sediment concentrations associated with backfilling at the North of Lantau and South Tsing Yi MBAs (non-cumulative scenario), are not predicted to cause unacceptable impacts to capture fisheries, mariculture areas or fish fry collection areas. However, backfilling activities in conjunction with other dredging or disposal projects and high levels of ambient SS may require mitigation, particularly at the Ma Wan Fishery. Mitigation measures which reduce the sediment concentrations in the water column would serve to reduce impacts to fisheries resources.

Intertidal habitats within the study area which may be affected by backfilling activities include ten gazetted and ungazetted beaches located along the Tsuen Wan coast and coastlines south and west of the MBAs. Compliance of predicted SS, DO and nutrient concentrations with WQOs at these beaches is discussed in *Section 3. 10*. Other intertidal habitats of potential ecological concern (eg coral habitat) are located at substantial distances from the MBAs and thus are not likely to experience unacceptable impacts.

Potential changes in water quality and feeding habitat associated with backfilling operations are expected to have minimal effect on *Sousa chinensis* since the MBAs do not represent areas of preferred *Sousa* feeding habitat. *Sousa*'s probable acclimation to high suspended sediment loads in the Pearl River Delta indicates that this species is not likely to sustain major impacts due to sediment plumes generated by backfilling at South Tsing Yi and North of Lantau MBAs. The potential for impacts to *Sousa* arising from collisions with vessels is considered minimal since the MBAs are not located within areas of frequent *Sousa* sightings.

Based on dolphin sensitivity to underwater noise, potential noise impacts on *Sousa* during the backfilling operations may be of concern. However, it is anticipated that noise impacts associated with material placement will be insubstantial and impacts associated with increased vessel traffic will be minimal in the context of typical vessel traffic in the waters North of Lantau. Furthermore, the minimisation of noise levels through the recommended noise mitigation measures (*Section 5.7*) will minimise the potential for adverse impacts to *Sousa* from underwater noise.

Overall, no insurmountable impacts to ecological sensitive receivers have been identified from the sediment plume modelling scenarios. Furthermore, potential environmental benefits associated with the proposed backfilling have been identified and include restoration of the MBAs to soft bottom benthic conditions existing prior to the initiation of sand dredging activities. It is anticipated that recolonisation of the restored original substrate type by benthic communities similar to those in undisturbed areas near the MBAs will be rapid after anthropogenic disturbance has ceased, given the large natural seasonal variation displayed by the benthic community.

5 NOISE

5.1 INTRODUCTION

This study of noise from the proposed backfilling of the South Tsing Yi and North of Lantau Marine Borrow Areas (MBAs) comprises detailed assessment focused on likely scenarios to determine if there is the potential for insurmountable noise impacts associated with either of the backfilling operations. Worst–case assumptions have been used, concerning hours of operation and equipment employed to assess the potential noise climate during backfilling operations.

As the backfilling of the MBAs will be a relatively short–lived activity that is associated with other on–going construction activities, for the purposes of assessment, it has been classified as a *construction* activity rather than an *operational* activity.

A methodology for assessing noise from the backfilling of the South Tsing Yi and North of Lantau MBAs has been developed based on the *Technical Memorandum on Noise From Construction Work Other Than Percussive Piling (TM).* In general, the methodology is as follows:

- locate NSRs that may be affected by the works;
- calculate distance attenuation and any barrier corrections to NSRs from notional noise source point;
- predict construction noise levels at NSRs in the absence of any mitigation measures; and,
- calculate maximum total site sound power (SWL) level for construction activities such that noise levels at NSRs comply with appropriate noise criteria.

The practicability of achieving the aforementioned maximum total sound power level for the works is then considered since this might offer a preferred form of mitigation. Other mitigation measures are then considered and recommended as appropriate.

5.2 STATUTORY REQUIREMENTS AND EVALUATION CRITERIA

In Hong Kong the control of construction noise outside of daytime, weekday working hours (0700–1900, Monday through Saturday) is governed by the Noise Control Ordinance (NCO) and the subsidiary Technical Memorandum (TM). This TM establishes the permitted noise levels for construction work depending upon working hours and the existing noise climate.

The NCO criteria for the control of noise from powered mechanical equipment (PME) are dependent upon the type of area containing the NSR rather than the measured background noise level. As the NSRs surrounding the proposed MBAs fall into mainly rural and urban fringe areas, the Area Sensitivity Rating (ASR) for these NSRs, according to the TM, is specified as 'A' and 'B', respectively. For the urban fringe areas, the 'B' ASR is attributed to influencing factors such as major roads and industrial areas. The *TM* states that a "major road" comprises a road which has a heavy and generally continuous flow of vehicular traffic, and in normal circumstances, means a road with an annual average daily traffic flow in excess of 30,000 vehicles. The NCO requires that noise levels from construction at affected NSRs be less than a specified Acceptable Noise Level (ANL) which depends on the ASR.

It is intended that the construction activities of the proposed works should be planned and controlled in accordance with the NCO. Works requiring the use of PME during restricted hours (i.e. outside of 0700–1900 Monday to Saturday and during public holidays) and particularly at night, will require a Construction Noise Permit (CNP) and will need to achieve the applicable ANL. The ANL is derived from the Basic Noise Levels (BNL) by applying corrections for the duration of the works and the effect of any other nearby sites operating under a CNP. For this assessment these corrections are negligible and so have been set to zero. As a result, the ANLs are equal to the BNLs. These are shown in *Table 5.2a* below.

It should be noted that a *5 minute* interval is used during restricted hours to monitor noise levels relative to the NCO ANL criteria. This 5 minute monitoring interval means that an *average* value rather than an absolute maximum limits the amount of noise that can be produced. As a result, in any instant the noise level can exceed the noise criterion; however, the average value over 5 minutes cannot.

Table 5.2a *Acceptable Noise Levels (ANL, $L_{Aeq,5min}$ dB(A))*

Time Period	ASR A	ASR B
All days during the evening (1900–2300) and general holidays (including Sundays) during the day and evening (0700–2300)	60	65
All days during the night-time (2300–0700)	45	50

Although the NCO does not provide for the control of construction activities during normal working hours, a limit of $L_{Aeq,\ 30\ min}$ 75 dB is proposed in the "Practice Note For Professional Persons, PN2/93" issued by the Professional Persons Environmental Consultative Committee (ProPECC) in June 1993. This limit has been applied on major construction projects in recent months, and is now generally accepted in Hong Kong, and will therefore be adopted in this study in order to protect NSRs to an appropriate extent during normal daytime periods (0700 – 1900 hours).

5.3 BASELINE AND FUTURE CONDITIONS

5.3.1 *Existing Conditions*

In the vicinity of the South Tsing Yi MBA, the nearest noise sensitive area is the North-Eastern Hong Kong coast, i.e. Kennedy Town which is considered an urban fringe area. In this region, the dominant sources of noise are Victoria Road and various construction activities. Secondary sources include industrial operations and marine traffic using the Sulphur

Channel. As a result, the noise environment is dominated by road traffic and construction noise. Industrial activities and marine traffic are secondary components of the overall noise background.

In the vicinity of the North of Lantau MBA, the nearest noise sensitive area is the Tai Lam coast. This area can be characterised as rural in the east and urban fringe to the west. The major sources of noise in this region are the Tuen Mun and Castle Peak Roads which contribute significant levels of traffic noise to the surrounding environment. In addition to these roads there are various construction activities (Tuen Mun and Castle Peak Road Widening) which are or will be taking place in the region from 1995 to 1997. Though secondary to traffic noise, marine traffic noise may become a noticeable source during evening or night-time hours. As a result, the noise environment at these nearest NSRs is dominated by road traffic noise and construction noise. Marine traffic and vessel noise are secondary components of the overall noise background to NSRs directly facing the coast.

The existing ambient noise levels at two locations near Wong Uk (NSR2) and Hong Kong Garden (NSR5) were measured between 02:00 to 03:30 on 4 April 1995. Existing noise sources at these locations include traffic on Castle Peak Road, ships movements in waters near North Lantau and the occasional animal noise typical of rural villages.

Two of the identified noise sensitive receivers (NSRs 1 and 2) are near Brothers Point (i.e. Seamen's Training Centre and Wu Uk village). Access to the Seamen's Training Centre was not possible and noise from dogs' barking prevented the survey being carried out at Wu Uk village. The noise measurement was taken at a sufficient distance from the Wu Uk village to avoid the dogs' barking (at the road junction of Tai Lam Chung Road and Luen Hong Lane behind the Customs and Excise Training School). There was no traffic on Tai Lam Chung Road and Luen Hong Lane during the measurement and no ship movement could be heard, probably due to screening by the Custom and Excise Training School.

The second measurement was carried out at the western corner of Hong Kong Garden which is approximately 20m above Castle Peak Road and has a clear view of the proposed North of Lantau MBA and Castle Peak Road. The main noise sources observed were traffic on Castle Peak Road and ship movements in waters off the North Lantau coastline. A second measurement was taken at this location as ships were sounding their horns during the first measurement. The weather conditions during the survey were dry, cloudy with light wind.

Equipment used for the measurement consisted of a Bruel & Kjaer Type 2236 sound level meter with a Type 4188 microphone. This equipment was calibrated using a Type 4231 calibrator before and after each measurement, and no significant drift was detected. Noise measurements were made in A-weighting and fast response settings, and $L_{10(10\ min)}$, $L_{eq(10\ min)}$ and $L_{90(10\ min)}$ noise levels at 1m above ground were recorded. Standard acoustical principles and practices were followed in the measurement and analysis of the measured noise data. These are summarised in *Table 5.3a*.

Table 5.3a *Measured $L_{10(10\ min)}$, $L_{eq(10\ min)}$ and $L_{90(10\ min)}$ Noise Levels*

Monitoring Location	Measured Noise Level [dB(A)]			Remarks
	$L_{10(10\ min)}$	$L_{eq(10\ min)}$	$L_{90(10\ min)}$	
Road Junction Tai Lam Chung Road and Luen Hong Lane	43	40.9	38	Screened by building
Hong Kong Garden				
Measurement 1	56	52.4	46	Ships Horns
Measurement 2	51.5	49.3	45.5	Traffic and Ships

5.3.2 *Future Conditions*

For the North-Eastern Hong Kong coast region, there are at present a number of planned infrastructure and marine projects which include the Island West Transfer Station and related facilities, the Green Island Reclamation and Route 7, and the Green Island Extension, and dredging of sand from the southern pit of the South Tsing Yi MBA and from the West Sulphur Channel MBA (a comprehensive list of future projects including marine activities can be found in *Annex A*). These operations will increase road, construction and marine traffic in the area and so could increase future ambient noise levels.

For the Tai Lam and Tuen Mun region, there are at present, in addition to the current Tuen Mun and Castle Peak Road Widening operations, plans for the installation of gas and water mains along the coastal areas as well as land-based and marine projects associated with the Tuen Mun Port Development and Tuen Mun Area 38 projects (*Annex A*). As these operations will increase the volume of road and marine traffic in the area as well as increase the levels of local construction activity, it is foreseen that ambient noise levels will increase in time. As a result, future noise levels in the region could be significantly higher than those measured at present.

5.4 NOISE SENSITIVE RECEIVERS

NSRs, as defined by HKPSG and the NCO, have been identified with reference to previous environmental studies undertaken in the region of the North of Lantau and South Tsing Yi MBAs, and have been updated by site surveys and reference to survey sheets and development plans.

The local NSRs and their respective distances to the notional centre of the site are given in *Tables 5.4a and 5.4b* below. NSR locations are shown in *Figures 5.4a* and *5.4b*, respectively.

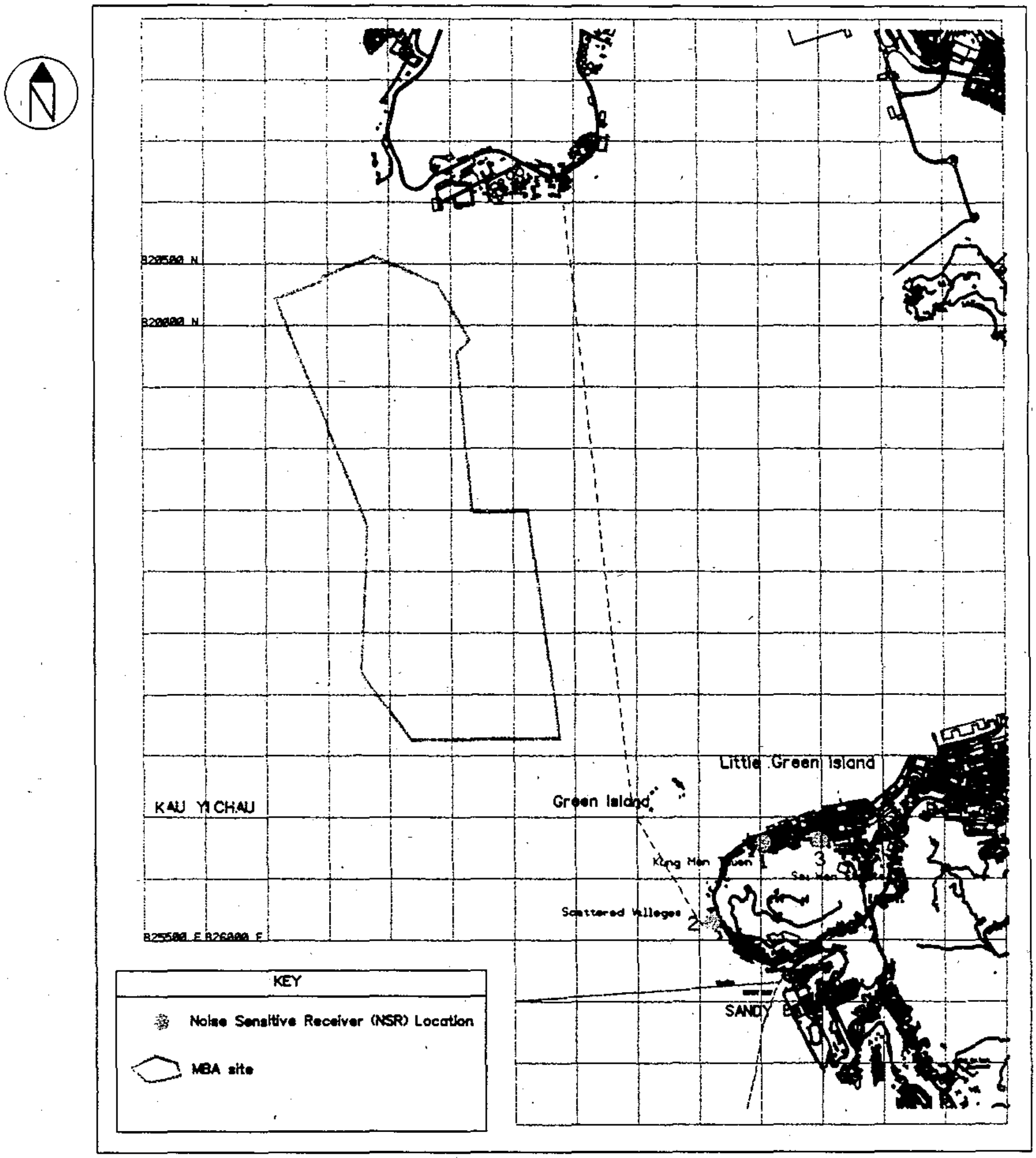

FIGURE 5.4a NSRs near the South Tsing Yi MBA	
Date : 11 April 1995	Project No.: c 1280
Map drawn by GIS and Mapping, ERM	Base map from LANDS DEPT. 1:20k topo

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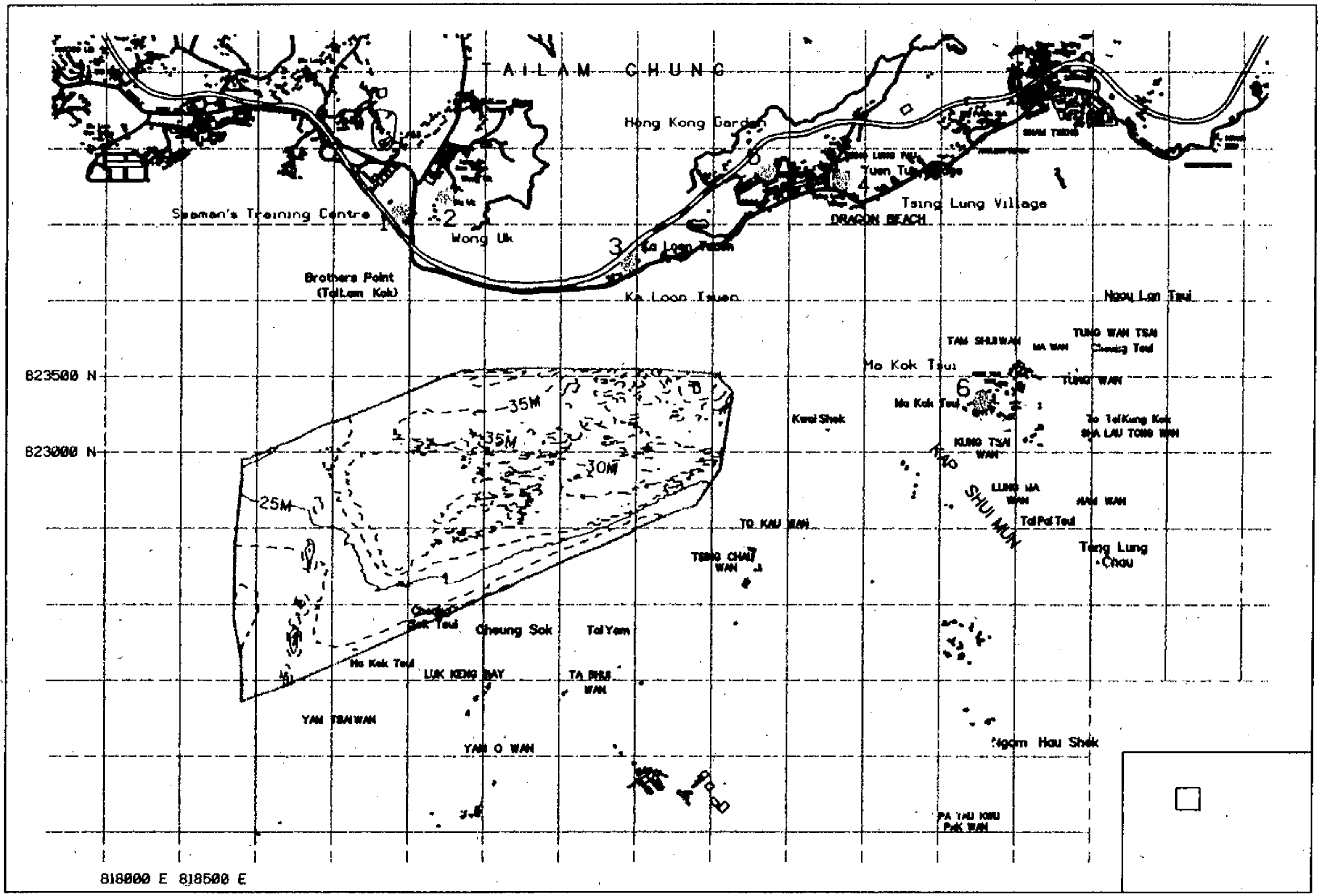

FIGURE 5.4b NSRs and ASRs near the North of Lantau MBA

Date : 11 April 1995	Project No.: C 1280
Map drawn by GIS and Mapping, ERM	Base map from LANDS DEPT. 1:20k topo

KEY

- NSR and ASR Location
- MBA Site

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Table 5.4a *Noise Sensitive Receivers near the South Tsing Yi MBA*

NSR	Location	Area Sensitivity Rating	Distance (m)
Kung Man Tsuen	Kennedy Town	B	1750
Scattered Village Dwellings	Eastern Hong Kong Coast	A	2250
Sai Wan Estate	Kennedy Town	B	1750

As the South Tsing Yi MBA has linear dimensions as follows:

- 2.9 km from East to West; and
- 7.8 km from North to South;

these distance estimates are strictly for a worst-case assessment. The ASR 'B', selected for two of the NSRs above, is attributed to the "influencing factor" noise from Victoria Road on the surroundings.

Table 5.4b *Noise Sensitive Receivers near the North of Lantau MBA*

NSR	Location	Area Sensitivity Rating	Distance (m)
Seamen's Training Centre	Tai Lam	B	1150
Wu Uk Village	Tai Lam	A	1175
Ka Loon Tsuen	Tai Lam	B	750
Tsing Lung Village	Tai Lam	B	1550
Hong Kong Garden	Tai Lam	B	1275
Ma Kok Tsui	Ma Wan	A	1650

As the North of Lantau MBA has linear dimensions as follows:

- 2.5 km from East to West;
- 1.2 km from North to South at the Western extent; and
- 0.6 km from North to South at the Eastern extent;

these distance estimates are strictly for a worst-case assessment. The 'B' ASR, selected for four of the NSRs above, is attributed to the "influencing factor" noise from both Tuen Mun and Castle Peak Roads.

It should be noted that in addition to human noise disturbance in the North of Lantau region, there is the potential for noise disturbance to marine mammals; particularly *Sousa chinensis*, the Chinese White Dolphin. Although the immediate vicinity of the North of Lantau MBA does not represent preferred habitat for *Sousa*, they may transit through the area. As a result, since *Sousa* are social mammals which use sound for echolocation, there is the possibility that noise from backfilling activities may have deleterious effects on their ability to communicate, find food and socialise.

5.5 *Potential Sources of Impact*

There will be two primary potential sources of noise impact from the backfilling operations at the South Tsing Yi MBA, these are:

- dumping operations carried out by trailer suction dredgers; and
- dumping operations carried out by barges.

At the North of Lantau MBA there is only one potential source of noise impact from the backfilling operations:

- dumping operations carried out by barges.

Assumptions based on information supplied by Dredging Research Limited, CED and Marine Department, described in *Section 2*, have been made concerning the number of active plant and the working hours for each of these types of dumping activities.

5.5.1 *Dredger Dumping*

For trailer suction dredger dumping operations, it has been assumed that a worst case would consist of two trailer suction dredgers dumping during the same 5 minute time period at the South Tsing Yi MBA. As a trailer suction dredger has a sound power level of 111 dB(A); two acting together would generate a total site sound power level of 114 dB(A).

There are no legal restrictions limiting the hours of such dredger dumping. As a worst-case, 24-hour dumping has been assumed.

5.5.2 *Barge Dumping*

For barge dumping, it has been assumed that barges will be highly-manoeuvrable self-propelled vessels, as described in *Section 2.5.1*. The worst-case plant inventory for barge dumping is dependent on the particular MBA. The worst case plant inventory for the South Tsing Yi MBA is shown in *Table 5.5a* below, while that for the North of Lantau MBA is shown in *Table 5.5b*.

Table 5.5a *Barge Dumping Plant Inventory (South Tsing Yi MBA)*

Plant	Number	TM Reference Number	Sound Power Level (dB(A))
Derrick Barge	2	CNP 061	104+3[1]
Tug Boat	2	CNP 221	110+3

(1) Two identical items operating simultaneously have a sound power level which is 3 dB(A) noisier than one of the items acting alone.

The total sound power level calculated for all plant operating at one notional point is 114 dB(A). As a result, for the South Tsing Yi MBA, both dredger dumping and barge dumping activities have a worst case total site sound power level of 114 dB(A).

It should be noted that Marine Department has stipulated that no more than two active disposal vessels may be resident in the region of the South Tsing Yi MBA at any one time. The foregoing has indicated that all possible combinations of tug boat(s)/barge(s) and dredgers complying with this limitation; namely:

- 2 dredgers; or
- 2 tug boat/barge combinations; or
- 1 tug boat/barge and 1 dredger;

will have identical sound power levels (114 dB(A)). As a result, considering any of the 3 combinations considers the full range of worst–case activities.

Table 5.5b *Barge Dumping at the North of Lantau MBA*

Plant	Number	TM Reference Number	Sound Power Level (dB(A))
Derrick Barge	5	CNP 061	104+7[1]
Tug Boat	5	CNP 221	110+7[1]

(1) Five identical items operating simultaneously have a sound power level which is 7 dB(A) noisier than one of the items acting alone.

The total sound power level calculated for all plant operating at one notional point is 118 dB(A).

It should be noted that, as described in *Section 2.4*, Marine Department restrictions would limit barge dumping in the vicinity of the South Tsing Yi MBA to daylight hours; there are currently no such restrictions on barge dumping in the vicinity of the North of Lantau MBA.

5.6 EVALUATION OF IMPACTS

5.6.1 MBA Direct Impacts

For both dredger and barge dumping backfilling exercises it has been assumed that dumping activities will take place at a speed of 2–3 knots as detailed in *Section 2.5.1*. Marine Department will not permit backfilling vessels to come to a complete stop during backfilling. As backfilling activities will be quite rapid (less than 10 minutes) it has been assumed that the worst–case notional point would not change dramatically, during backfilling, from that previously noted in *Table 5.4a* and *5.4b*. As a result, the worst–case (closest noise source) values listed in these tables have been used for the assessment of worst–case noise impacts.

Predictions of worst–case noise levels from dredger and barge dumping operations at nearby noise sensitive receivers are shown in *Table 5.6a* below.

Table 5.6a *Predicted Impacts at Noise Sensitive Receivers ($L_{Aeq, 5min}$ dB (A))*

NSR	MBA	Acceptable Noise Level Day	Eve	Night	Dredger Dumping	Barge Dumping
Seamen's Training Centre	North of Lantau	75	65	50	N/A	52
Wu Uk Village		75	60	45	N/A	52
Ka Loon Tsuen		75	65	50	N/A	56
Tsing Lung Village		75	65	50	N/A	49
Hong Kong Garden		75	65	50	N/A	51
Ma Kok Tsui		75	60	45	N/A	49
Kung Man Tsuen	South Tsing Yi	75	65	50	44	44
Scattered Village Dwellings		75	60	45	44	44
Sai Wan Estate		75	65	50	42	42

No exceedances of the daytime, evening or night–time noise criteria have been predicted at any of the nearby NSRs for dumping operations at the South Tsing Yi MBA. As a result, no noise mitigation measures are recommended for dumping activities at this MBA at any time.

No exceedances of the daytime (0700–1900) or evening (1900–2300) noise criteria are anticipated at nearby NSRs for dumping operations at the North of Lantau MBA. However significant exceedances of night–time noise criteria have been predicted at all of the NSRs evaluated near the North of Lantau MBA, with the exception of Tsing Lung Village. The predicted exceedances, if night–time working is carried out, are as follows:

- Wu Uk Village: 7 dB(A);
- Ka Loon Tsuen: 6 dB(A);
- Ma Kok Tsui: 4 dB(A);
- Seamen's Training Centre: 2 dB(A);
- Hong Kong Garden: 1 dB(A).

As a result, noise mitigation measures should be employed for night–time backfilling activities at the North of Lantau MBA to ensure full compliance with the NCO.

In addition, the potential for increases in marine traffic as well as 24–hour backfilling operations, increases the possibility for noise disturbance to *Sousa* passing through the area. As a result, mitigation measures are recommended to minimise the potential noise impact on *Sousa*.

5.6.2 *Cumulative Impacts*

As Hong Kong is a continually developing city in which many different infrastructure projects are either in progress or being planned, there is the possibility for cumulative impacts from MBA dumping activities occurring simultaneously at South Tsing Yi and at North of Lantau in conjunction with other nearby activities (*Annex A*). However, due to the level of impact from MBA operations and the distances to nearby NSRs; cumulative impacts would only be significant if they occurred during night-time hours (2300-0700).

In the vicinity of the South Tsing Yi MBA, the Green Island Reclamation and Route 7 (Green Island Extension) projects (among other projects) could take place simultaneously with the proposed backfilling operations. Considering the noise levels which will be generated at nearby NSRs from South Tsing Yi MBA backfilling operations, it is clear that no cumulative impacts could arise due to daytime (0700-1900) or evening (1900-2300) activities. However, there is the potential for cumulative impacts should MBA backfilling operations take place simultaneously with other large projects during night-time hours.

In the vicinity of the North of Lantau MBA, increased levels of marine traffic and/or construction activities associated with the Tuen Mun and/or Castle Peak Road widening projects, or the Tuen Mun Port Development project, could take place simultaneously with the proposed backfilling operations. As above, considering the noise levels which will be generated at nearby NSRs from North of Lantau MBA backfilling operations, it is clear that no cumulative impacts could arise due to daytime or evening activities. However, there exists the potential for cumulative impacts should MBA backfilling operations take place simultaneously with other large projects during night-time hours.

The foregoing analysis has indicated that there is the potential for cumulative impacts between MBA backfilling operations and other concurrent projects. This potential impact can be quantified by noting that under the NCO, all noise-producing operations will need to limit night-time noise levels to a maximum of $L_{Aeq,30min}$ 45 dB at nearby NSRs. As a result, should MBA night-time activities occur simultaneously with those of another project, there is the potential that cumulative impacts of up to 3 dB above the 45 dB limit (45 dB + 45 dB) would be generated at nearby NSRs. However, since the distances encountered in this study are very large, the occurrence of cumulative impacts would necessitate special circumstances. Assuming all plant teams in question are generating 45 dB(A) noise levels at a particular NSR, cumulative impacts would arise if:

- all plant teams affecting a particular NSR emitted noise in similar frequency ranges;
- wind direction was from the source to the receiver;
- plant teams operated simultaneously;
- all plant teams had virtually unobstructed views, over long distances, to the same NSR.

It is considered extremely unlikely that all these conditions would occur simultaneously for extended periods of time.

As a result, though the possibility for significant cumulative impacts exists in theory, it is believed that the circumstances necessary for generating cumulative impacts are extremely unlikely to occur in practice.

5.7 *MITIGATION MEASURES*

5.7.1 *Human Habitation*

The foregoing analysis has indicated that no exceedances of any noise criterion have been predicted for 24-hour spoil dumping at the South Tsing Yi MBA. In addition, no exceedances of any noise criterion have been predicted for 16-hour (0700-2300) spoil dumping at the North of Lantau MBA.

Significant exceedances (1-7 dB(A)) of the night-time (2300-0700) noise criterion have been predicted for worst-case (5 barges at the northern boundary) spoil dumping operations at the North of Lantau MBA. As a result, noise mitigation measures have been recommended should night-time spoil dumping operations be carried out.

To comply with the night-time noise criterion at the NSRs at which exceedances have been predicted, it is recommended that in addition to the use of good site practice (use of well-maintained equipment, 'quiet' plant used where practicable, on-site noise management, etc.), three types of noise mitigation could be adopted for the North of Lantau MBA.

- One option is to restrict all night-time dumping operations to a maximum of one dredger or one barge/tug boat combination in operation during any 5 minute time period (ie: a maximum of 12 dredgers or barge/tug boat combinations in any given hour).

- A second option is to restrict all dumping operations during night-time hours to locations more than 400m south of the northern MBA boundary ie. south of the 823000 N Hong Kong grid reference line, as shown on *Figure 5.4b*. Such mitigation could permit the simultaneous night-time operation of up to two dredgers or two barge/tug boat combinations in any 5 minute period (ie: a maximum of 24 dredgers or barge/tug boat combinations in any given hour).

- A third option is to prohibit all night-time barge dumping operations at the North of Lantau MBA.

Any of these possible mitigation options would be capable of maintaining all noise impacts at nearby NSRs, from dumping operations, to levels in compliance with those specified under the NCO.

5.7.2 *Marine Mammals*

As discussed in *Section 4.6.5*, the data, although limited, on marine mammal hearing suggest that moving sound sources, particularly ships, have greater effect on cetacean behaviour than do stationary offshore activities producing continuous noise.(1) As a result, in order to minimise noise disturbance to *Sousa*, all North of Lantau MBA backfilling activities should be as short in duration as possible and as quiet as is practicable. The Contractor should ensure plant and equipment are well-maintained to minimise noise levels. In addition, the adoption of the proposed night-time mitigation measures

(1) Richardson W J, Greene C R, Malme C I and Thomson D H with contributions by Moore S E and Wursig B (1995/in press) Effects of Man-Made Noise on Marine Mammals LGL Ltd. Environmental Research Associates.

involving restrictions on the number of vessels would reduce noise disturbance from the backfilling operations.

5.7.3 *Cumulative Impacts*

The previous section has indicated that the potential for cumulative impacts exists. However, additional analysis has indicated that due to the large distances between noise sources and receivers, it is unlikely that cumulative impacts will arise in practice. It is therefore, considered that mitigation measures, specifically designed to reduce the noise levels from cumulative impacts, are not considered necessary.

5.8 *OUTLINE OF EM&A REQUIREMENTS*

As no exceedances of the NCO night-time criteria have been predicted for unmitigated dumping operations at the South Tsing Yi MBA, no noise monitoring is recommended for these dumping operations. However, as significant (up to 7 dB(A)) exceedances of the night-time noise criterion have been predicted for unmitigated night-time activities at the North of Lantau MBA, and the proposed mitigation in order to achieve compliance at this site may be difficult to implement and/or enforce, a night-time noise monitoring and audit programme is recommended to aid the Contractor in quickly identifying and correcting any noise problems which may arise. It should be noted that if no night-time activities are carried out, no night-time noise monitoring would be necessary. No daytime or evening noise monitoring and audit programme is recommended for the North of Lantau MBA, as no potential exceedances of the applicable criteria have been predicted. Details of Environmental Monitoring & Audit (EM&A) requirements are elaborated in the EM&A Manual.

5.9 *CONCLUSIONS*

The foregoing noise assessment has predicted that dumping operations at the South Tsing Yi MBA will not lead to exceedances of the recommended daytime noise limit or the NCO night-time criteria at any nearby sensitive receivers. As a result, no noise monitoring and audit programme was recommended for this site.

Noise modelling of the backfilling activities at the North of Lantau MBA, however, has shown that unmitigated operations during night-time (2300-0700) hours could lead to significant exceedance of the relevant NCO night-time criteria. No significant impacts were predicted for daytime or evening hours.

To reduce noise levels at the nearby NSRs, from North of Lantau MBA backfilling, and to ensure full compliance with the night-time noise criterion, at least one of the following mitigation measures should be employed for night-time backfilling operations:

i) restrict night-time dumping options to at most one dredger or one barge/tug boat combination during any 5-minute period (maximum of 12 dredgers or barge/tug boat combinations in a given hour); and/or

ii) restrict night-time dumping operations to south of the 823000N Hong Kong grid reference line (approximately 400m south of the northern boundary), (*Figure 5.4b*) and permit up to two dredgers or two barge/tug boat combinations during any 5-minute period (maximum of 24 dredgers or barge/tug boat combinations in a given hour); or

iii) prohibit night-time (2300-0700) backfilling operations at the North of Lantau MBA.

In addition, night-time noise monitoring and audit should be conducted at the nearby NSRs should night-time backfilling activities be carried out, with either mitigation i) or ii). No monitoring will be required if mitigation iii) is adopted.

Although significant cumulative impacts are theoretically possible (due to the MBA night-time backfilling occurring simultaneously with other large-scale projects), additional analysis has indicated that due to the large distances between noise sources and receivers, it is unlikely that cumulative impacts will arise in practice. It is therefore noted that additional mitigation measures, specifically designed to reduce the noise levels from cumulative impacts, are not considered necessary for night-time operations. As a result, no insurmountable, residual noise impacts have been predicted for either the proposed South Tsing Yi or proposed North of Lantau MBA backfilling activities.

As discussed in *Section 4.6.5*, the North of Lantau and South Tsing Yi MBAs are not located within areas of frequent *Sousa chinensis* sightings and thus do not represent areas of preferred feeding habitat for *Sousa*. The recommended noise mitigation measures, in combination with these findings, will minimise the potential for adverse impacts to *Sousa* from underwater noise and thus no unacceptable impacts on *Sousa* are expected during backfilling operations at the two MBAs.

In summary, without mitigation, no significant noise impacts are predicted for NSRs near the South Tsing Yi MBA. With mitigation measures, no residual noise impacts are predicted for NSRs near the North of Lantau MBA. In view of the preceding, no South Tsing Yi MBA noise EM&A is recommended; while at the North of Lantau MBA, no EM&A is considered necessary if night-time dumping activities are prohibited. However, if restricted night-time operations are to be carried out, then it is considered appropriate to monitor these operations to ascertain the efficacy of the mitigation employed. Precise noise EM&A requirements are detailed in the EM&A Manual.

6 AIR QUALITY

6.1 INTRODUCTION

This study of air quality impacts from the proposed backfilling of the South Tsing Yi and North of Lantau Marine Borrow Areas (MBAs), comprises a detailed assessment focused on likely scenarios to determine if there is the potential for insurmountable air quality difficulties associated with the MBA backfilling activities. Worst-case assumptions have been used to assess the potential air quality environment during backfilling operations.

6.2 STATUTORY REQUIREMENTS AND EVALUATION CRITERIA

The principal legislation for the management of air quality in Hong Kong is the Air Pollution Control Ordinance (APCO) (Cap 311). The statutory limits of specific air pollutants and the maximum allowable number of exceedances over specific time periods are stipulated by APCO. These limits and conditions on ambient air quality are referred to as the Hong Kong Air Quality Objectives (AQOs). The AQOs are shown below in *Table 6.2a*.

Table 6.2a *Hong Kong Air Quality Objectives*

Pollutant	Concentration in micrograms per cubic metre (i)				
	Averaging Time				
	1 Hour (ii)	8 Hours (iii)	24 Hours (iii)	3 Months (iv)	1 Year (iv)
Sulphur Dioxide (SO_2)	800		350		80
Total Suspended Particulates (TSP)			260		80
Respirable Suspended Particulates (v) (RSP)			180		55
Nitrogen Dioxide (NO_2)	300		150		80
Carbon Monoxide (CO)	30,000	10,000			

Note:

(i) Measured at 298°K (25°C) and 101.325 kPa (one atmosphere).
(ii) Not to be exceeded more than three times per year.
(iii) Not to be exceeded more than once per year.
(iv) Arithmetic means.
(v) Respirable suspended particulates means suspended particles in air with a nominal aerodynamic diameter of 10 micrometres and smaller.

In addition to the above established statutory limits, it is generally accepted that an hourly average TSP concentration of 500 $\mu g/m^3$ should not be exceeded. Such a control limit has no statutory basis but is particularly relevant to construction work and has been imposed on a number of construction projects in Hong Kong in the form of contract clauses.

6.3 *BASELINE AND FUTURE CONDITIONS*

6.3.1 *Existing Conditions*

In the vicinity of the South Tsing Yi MBA, the nearest air sensitive receivers (ASRs) are located along the North-Eastern Hong Kong coast, i.e. Kennedy Town, which is considered an urban fringe area. In this region, the dominant sources of air quality impact are Victoria Road and various construction activities. Secondary sources include industrial operations and marine traffic using the Sulphur Channel. As a result, the regional air quality is primarily effected by road traffic emission and construction dust. Industrial activities and marine traffic are secondary components of the overall local air climate.

In the vicinity of the North of Lantau MBA, the nearest ASRs are located along the Tai Lam coast. This area can be characterised as rural in the east and urban fringe to the west. The major sources of air quality impact in this region are the Tuen Mun and Castle Peak Roads which contribute significant levels of gaseous emission (NO_x, CO, $S0_2$) and dust to the local environment. In addition to these roads there are various construction activities (Tuen Mun and Castle Peak Road Widening) which are or will soon be taking place in the region. Though secondary to road traffic, marine traffic gaseous emission comprise another source. As a result, the air quality at these nearest ASRs is effected primarily by road traffic emission and construction dust.

6.3.2 *Future Conditions*

For the North-Eastern Hong Kong coast region, there are at present a number of planned infrastructure projects which include dredging/ backfilling in the West Sulphur channel, dredging of South Tsing Yi top and bottom marine sand, the Island West Transfer Station and related facilities, the Green Island Reclamation and Route 7, the Green Island Extension (a comprehensive list of future projects can be found in *Annex A*). These projects will increase road, construction and marine traffic in the area and so will lead to an increase in the ambient air pollution levels in time.

For the Tai Lam and Tuen Mun region, there are at present, in addition to the current Tuen Mun and Castle Peak Road Widening operations, plans for the installation of gas and water mains along the coastal areas as well as land based and marine projects associated with the Tuen Mun Port Development and Tuen Mun Area 38 projects (a comprehensive list of future projects can be found in *Annex A*). As these operations will increase the volume of road traffic on nearby roads as well as the amount of construction in the immediate region, it is foreseen that ambient pollutant gas and dust levels will increase in time. As a result, the quantity of recognised air pollutants and dust should be higher, in this region, than that measured at present.

6.4 *AIR SENSITIVE RECEIVERS*

ASRs, as defined by HKPSG and the APCO, have been identified with reference to previous environmental studies undertaken in the region of the North of Lantau and South Tsing Yi MBAs and have been updated by site surveys and by referring to survey sheets and development plans.

The local ASRs and their respective worst-case distances to the boundary of the MBA sites are given in *Tables 6.4a and 6.4b* below. The locations of these receivers are shown in *Figures 5.4a* and *5.4b* of *Section 5*.

Table 6.4a *Air Sensitive Receivers near the South Tsing Yi MBA*

ASR	Location	Distance (m)
Kung Man Tsuen	Kennedy Town	1700
Scattered Village Dwellings	Eastern Hong Kong Coast	2200
Sai Wan Estate	Kennedy Town	1700

Table 6.4b *Air Sensitive Receivers near the North of Lantau MBA*

ASR	Location	Distance (m)
Seamen's Training Centre	Tai Lam	1100
Wu Uk Village	Tai Lam	1125
Ka Loon Tsuen	Tai Lam	700
Tsing Lung Village	Tai Lam	1500
Hong Kong Garden	Tai Lam	1225
Ma Kok Tsui	Ma Wan	1600

6.5 *POTENTIAL SOURCES OF IMPACT*

There will be two primary potential sources of air quality impact from the backfilling operations, these are:

- dumping operations carried out by trailer suction dredgers; and
- dumping operations carried out by barges.

As all spoil material for the backfilling operation will be dumped directly into the water and will have a high moisture content, negligible dust emission has been assumed to arise from these operations. Instead, the main pollution component has been assumed to be particulate and gaseous emission from the marine vessels used in the backfilling operations.

Assumptions (based on information supplied by Dredging Research Limited, the Civil Engineering Department and the Marine Department) have been made concerning the number of active plant and the working hours for each of these types of dumping activities.

6.5.1 *Trailer Dredge Dumping*

For trailer suction dredger dumping operations, it has been assumed that a worst case would consist of four trailer suction dredgers dumping at the South Tsing Yi MBA during a given 1-hour period. No trailer dredge dumping has been proposed for the North of Lantau MBA.

There are no legal restrictions limiting the hours of such trailer dredge dumping. As a worst-case, 24-hour dumping has been assumed.

In Hong Kong, 8000 m^3 trailer suction dredgers are known to have an engine size of approximately 10,000 kilowatts. However, for this assessment it has been assumed that these dredgers, when dumping, would be moving slowly (2–3 knots) and so would be under minimal load. It is believed that engine output would be only a few hundred kilowatts which is similar to a single large piece of construction equipment.

6.5.2 *Barge dumping*

For barge dumping operations, it has been assumed that a worst case would consist of four tug boat/barge combinations dumping at the South Tsing Yi MBA during a given 1–hour period. (Based on the information presented in *Section 2.5.1*, no more than two such combinations will be allowed at any one time.) For the North of Lantau MBA the worst case scenario has been envisaged as 5 tug boat/barge combination dumping during a given 1–hour period.

For barge dumping, it has been assumed that barges will be moved to location by tug boats, as described in *Section 2.5.1*. It should be noted that restrictions would limit barge dumping in the vicinity of the South Tsing Yi MBA to daylight hours; whereas, there would be no restrictions on barge dumping in the vicinity of the North of Lantau MBA.

In Hong Kong, adequately–sized tug boats used for barge towing (800 m^3) are known to have an engine size of approximately 500–600 kilowatts. However, as in the case of dredgers above, the tug boats would be moving slowly (2–3 knots) and so under minimal load. Again output is assumed to be a few hundred kilowatts or roughly equivalent to a single bulldozer or truck under load.

6.6 EVALUATION OF IMPACTS

The analysis above has indicated that as the dredgers and barges will dump their materials directly into the water, there should be no significant fugitive dust impact. In addition, as each dredger or tug boat will be under minimal load, each marine vessels engine should be operating at a comparable output to a typical large piece of construction equipment (bulldozer, truck, etc.). In view that the distances to the nearest ASRs are in excess of 700m, it is considered that air quality impacts arising from backfilling to these receivers will be negligible and AQOs will not be exceeded even when both MBAs are being filled simultaneously.

6.7 MITIGATION MEASURES

Considering that no significant impact, in terms of any exceedances of AQOs, have been predicted for the local air quality from backfilling operations, no air quality mitigation measures are recommended for these activities.

6.8 OUTLINE OF EM&A REQUIREMENTS

As no exceedances of the applicable AQOs have been predicted for the worst–case analysis, no air quality monitoring is recommended for dumping operations at either the South Tsing Yi or North of Lantau MBA.

6.9 CONCLUSIONS

The foregoing assessment has indicated that no exceedances of the AQOs have been predicted and thus no significant impacts to the local or regional air quality are anticipated from backfilling operations at the South Tsing Yi or North of Lantau MBAs. Even with the addition of cumulative impacts, it is not envisaged that air quality impacts would lead to exceedances of the AQOs at the nearby ASRs. As a result no mitigation measures or air quality monitoring programme has been recommended for these backfilling operations.

7 CONCLUSIONS

7.1 OBJECTIVE OF FEASIBILITY STUDY/EIA

As described in *Section 1*, the objective of this Feasibility Study/EIA is to design an environmentally acceptable Operations Plan for the proposed backfilling of the MBAs at South Tsing Yi and North of Lantau, and to provide information on the nature and extent of environmental impacts and cumulative effects arising from the backfilling projects and other dredging projects which may be operating simultaneously.

7.2 FINDINGS OF THE IAR

The overall purpose of the IAR was to review the environmental acceptability of the proposed backfilling operations at the two MBAs. The IAR was also designed to provide a preliminary recommendation on the environmental feasibility of the backfilling and to determine if the projects should proceed to the detailed EIA stage.

The IAR provided an initial assessment and evaluation of the potential environmental impacts and internal cumulative effects (backfilling at both MBAs simultaneously) that may arise from the proposed backfilling projects. The IAR indicated that there are unlikely to be any insurmountable or unacceptable residual environmental impacts at the two MBAs. Key issues associated with backfilling activities and potential cumulative impacts were identified. The IAR concluded that backfilling operations at the South Tsing Yi and North of Lantau MBAs were considered environmentally feasible and should be assessed further in the detailed EIA.

7.3 EIA APPROACH

In order to undertake a detailed assessment of the key issues identified in the IAR, modelling of sediment plumes, erosion/deposition, noise and air quality was performed and superimposed on baseline conditions. In addition, cumulative impacts were assessed through supplementary backfilling scenarios involving other possible concurrent dredging/disposal projects. Evaluation of the potential environmental impacts that may arise from the proposed backfilling activities are summarised below in *Section 7.4*, with respect to water quality and sediment transport, marine ecology, noise and air quality.

This detailed EIA recommends an Operations Plan for the proposed backfilling projects which will maximise use of the MBAs and minimise environmental impacts by incorporating appropriate mitigation measures into the project design. The proposed Operations Plan is presented in *Section 7.5*. The proposed environmental monitoring and audit (EM&A) requirements for the backfilling projects are also outlined below in *Section 7.6*. The residual impacts resulting after the implementation of these mitigation measures have been assessed and the project's overall environmental feasibility determined (*Section 7.7*). A summary of potential environmental impacts, the proposed Operations Plan and additional mitigation measures, and EM&A requirements is presented in *Table 7.7a*.

7.4 *POTENTIAL ENVIRONMENTAL IMPACTS*

7.4.1 *Water Quality and Sediment Transport Impacts*

Evaluation of impacts to water quality and water sensitive receivers was undertaken through modelling of suspended sediment plumes, sediment deposition, sediment erosion, dissolved oxygen and nutrients. Modelling exercises focused on thirteen scenarios developed to assess non-cumulative effects (backfilling at both MBAs simultaneously), cumulative effects (backfilling at both MBAs in conjunction with other dredging/disposal projects) and validation of the model.

Non-cumulative effects simulating concurrent backfilling at both MBAs were modelled using rates of disposal of 50,000 to 200,000 m^3 of trailer-dredged material at the South Tsing Yi MBA and a rate of 10 000 m^3 of grab-dredged material at the North of Lantau MBA. Predicted elevations in suspended sediment concentrations were found to be acceptable in comparison to both the WQO and the sensitive receivers' specific criteria for Scenarios 1, 2 and 3 at all sensitive receivers. Scenario 4a, which modelled the highest rate of backfilling during the worst case seasonal/tidal conditions, exceeded the WQO at several sensitive receivers and exceeded the specific criterion at the Kennedy Town WSD Water Intake.

Due to non-compliance at this highest rate of backfilling, an additional scenario (Scenario 4e) was performed to determine the effects at a lower rate of backfilling (100,000 m^3 day^{-1}). All predicted elevations in SS concentrations for Scenario 4e were found to be in compliance with the exception of concentrations at the Kennedy Town Water Intake where the specific criterion was exceeded by 0.9 mg l^{-1}. However, due to the marginal nature of this exceedance, the fact that it will occur only during the worst case seasonal/tidal conditions and for less than four hours during the tidal cycle, and its compliance with the site-specific WQO, this concentration is considered acceptable. Should environmental monitoring observe any SS concentrations at or above this level at the Kennedy Town Water Intake, additional mitigation measures shall be considered.

Cumulative effects expected from concurrent backfilling at both MBAs and dredging at South Tsing Yi and West Sulphur Channel were modelled using the maximum backfilling rates at North of Lantau and South Tsing Yi MBAs (Scenario 4) and rates representing dredging of surficial marine sand and alluvial sand, and actual dredging rates at West Sulphur Channel. Cumulative scenarios resulted in elevations of suspended sediment concentrations ranging from 2-65 mg l^{-1}. Each of the cumulative scenarios resulted in non-compliances with WQOs at several sensitive receivers and exceedance of the specific criterion for the Kennedy Town Water Intake. Scenarios involving dredging of surficial marine sands at the South Tsing Yi MBA (Scenarios 5 and 7) resulted in a greater number and higher concentration exceedances than scenarios involving dredging of bottom alluvial sands (Scenarios 6 and 8). Due to the worst case nature of the scenarios selected for modelling cumulative impacts, and the high sediment loss rates associated with these projects, none of the scenarios meets the WQOs at all sensitive receivers. However, specific criteria are exceeded only for scenarios involving dredging of surficial sand and at the Kennedy Town Water Intake.

Results of the validation scenario (Scenario 9) have shown that if SS corresponding to expected inputs from dredging and filling activities at Chek Lap Kok are modelled in conjunction with the maximum rate of backfilling at South Tsing Yi, elevated SS concentrations of approximately 100 mg l^{-1} at the Ma Wan Fish Culture Zone (FCZ) result. The plots of SS plumes resulting from these two sources of input (ie Chek Lap Kok area and South Tsing Yi) clearly indicated that the source of the elevated concentrations at Ma Wan is Chek Lap Kok. Field data collected during the period of highest SS concentration at the Ma Wan FCZ correlate well with the model results and corroborate evidence of Chek Lap Kok as the source of elevated SS. These results demonstrate both that the WAHMO modelling approach is valid and appropriate for this Study and that previously observed elevated concentrations at the Ma Wan FCZ were not caused by backfilling at the South Tsing Yi MBA.

Losses of sediment due to long–term erosion from both MBAs was also assessed. At the South Tsing Yi MBA, grab– and trailer–dredged materials are predicted to be stable under wave and current induced bed stresses at all backfill levels up to –24mPD. Fluid mud would be eroded at all backfill levels but is expected to comprise only 20% of the total losses due to suspension during disposal at the maximum backfilling rate. At the North of Lantau MBA, typical wave action alone is not sufficient to erode either soft surface or more cohesive subsurface material at backfill levels up to -16mPD. However, subject to the action of typical currents, soft surface material is eroded at backfill levels above –20mPD. Fluid mud is expected to erode due to tidal current bed stresses alone at all backfill levels but is estimated to comprise only 40% of losses due to suspension during disposal. Estimated additional suspended sediment input to the water column due to erosion from the backfilling rate modelled in Scenario 4e, is expected to result in effects similar to those predicted for Scenario 1 which is considered environmentally acceptable. Furthermore, trapping and consolidation of fines within the MBAs is expected to reduce the volumes of disposal sediment subject to erosion.

7.4.2 *Marine Ecological Impacts*

Previous studies in the South Tsing Yi area have shown that benthic assemblages in the MBA are typical of soft bottom communities in Hong Kong waters. Similarly, the grab survey results in the North Lantau MBA for this EIA have shown that the soft bottom benthic species recorded are commonly found in the waters of Hong Kong. Since species assemblages at these MBAs are typical of soft bottom benthic communities in Hong Kong waters and do not contain rare or unique species, the potential impacts to benthic fauna are considered acceptable.

Predicted elevations in suspended sediment (SS) concentrations within the areas of the sediment plumes, generated during backfilling operations alone, are not expected to result in exceedance of acute tolerance levels for fish and invertebrate larvae in potential spawning and nursery grounds off the north coast of Lantau. However, cumulative impacts arising from concurrent backfilling activities and other dredging/disposal projects, in conjunction with high ambient SS levels, may result in SS concentrations exceeding the natural range in some nursery areas for brief periods.

Suspended sediment concentrations associated with backfilling at the two MBAs (non–cumulative scenario), are not predicted to cause unacceptable impacts to capture fisheries, mariculture zones or fish fry collection areas. However, concurrent backfilling and dredging activities and/or high levels of ambient SS may require mitigation, particularly at the Ma Wan Fishery. Mitigation measures which reduce the sediment concentrations in the water column (provided in *Section 3.14*) would serve to reduce impacts to fisheries resources.

The results of the sediment plume modelling (non–cumulative and cumulative scenarios) indicate that the predicted reductions in DO concentrations would not result in exceedances of the specified WQOs for DO, and thus no unacceptable DO related impacts on the identified marine ecological resources are anticipated. Similarly, from the results of nutrient modelling, impacts on marine ecological resources arising from nutrient release are not expected.

The MBAs are not located within areas of frequent *Sousa chinensis* sightings and thus do not represent areas of preferred feeding habitat for *Sousa*. Potential changes in water quality and feeding habitat associated with backfilling operations are therefore expected to have minimal effect on *Sousa*. The potential for impacts to *Sousa* arising from collisions with vessels is also considered minimal. Based on dolphin sensitivity to underwater noise, potential noise impacts on *Sousa* during the backfilling operations may be of concern. However, it is anticipated that noise impacts associated with material placement will be insubstantial and impacts associated with increased vessel traffic will be minimal in the context of typical vessel traffic in the waters North of Lantau. In summary, unacceptable impacts to *Sousa* during the backfilling operations are not predicted primarily because the areas near the MBAs do not represent preferred *Sousa* habitat.

Overall no insurmountable impacts to ecological sensitive receivers have been identified from the EIA. Furthermore, potential environmental benefits associated with the proposed backfilling include restoration of the MBAs to soft bottom benthic conditions existing prior to the initiation of sand dredging activities. It is anticipated that recolonisation of the restored substrate by benthic communities similar to those in undisturbed areas near the MBAs will be rapid, given the large natural seasonal variation experienced in this area and the rapid recolonisation of disposed sediments observed at the East Sha Chau disposal sites.

7.4.3 *Noise*

The detailed noise assessment predicted that backfilling operations at the South Tsing Yi MBA will not lead to exceedances of the recommended daytime noise limit or the NCO night–time criteria at any nearby sensitive receivers. Backfilling activities at the North of Lantau MBA during night–time (2300–0700) hours, however, could lead to significant exceedance of the relevant NCO night–time criteria. No significant impacts were predicted for daytime or evening hours at the North of Lantau MBA.

Full compliance with the night–time noise criterion at the North Lantau MBA could be achieved by restricting such night–time dumping operations temporally (eg, prohibition of night–time operations or at most one dredger or one barge/tug boat combination during any 5–minute period) or spatially (eg, restricting night–time dumping operations to a maximum of two dredgers or two barge/tug boat combinations in any 5-minute period south of the 823000N Hong Kong grid reference line.

Further analysis has indicated that cumulative impacts are unlikely to arise in practice due to the large distances between noise sources and receivers. Therefore, additional mitigation measures designed specifically to reduce the noise levels from cumulative impacts are not considered necessary for night-time operations. As a result, no insurmountable, residual noise impacts have been predicted for either the proposed South Tsing Yi or North of Lantau MBA backfilling operations.

7.4.4 *Air*

The detailed assessment predicted no exceedances of the AQOs from backfilling operations at the South Tsing Yi or North of Lantau MBAs. Thus no significant or insurmountable air quality impacts to the local or regional air quality are anticipated. Even with the addition of cumulative impacts, it is not likely that air quality impacts would lead to exceedances of the AQOs at the nearby ASRs. As a result, no mitigation measures or EM&A requirements have been recommended for these backfilling operations.

7.5 *OPERATIONS PLAN*

This Operations Plan provides details of the project design based on considerations of environmental impacts to water quality, ecology, noise and air quality described in the preceding chapters. The project design outlined below defines backfilling operations which, in combination with additional mitigatory measures in the form of plant maintenance and working methods, are not expected to cause unacceptable adverse impacts to sensitive receivers.

The acceptability of the Operations Plan is based on the findings of the EIA and will be verified through the Environmental Monitoring and Audit (EM&A) process. The EM&A Manual will provide guidance on assessing and interpreting impacts and on revising the Operations Plan, if necessary. The acceptability of the backfilling, as defined in this Operations Plan, in conjunction with other dredging and/or disposal projects will be the subject of a separate Cumulative Effects Assessment Manual (CEAM). This Manual will describe methods for estimating cumulative effects and provide a selection of additional potential modifications to the Operations Plan and/or EM&A programme to further mitigate effects on sensitive receivers.

The following section provides the Operations Plan for backfilling at the South Tsing Yi and North of Lantau MBAs in terms of rates and volumes of disposal, backfill level, spatial restrictions, temporal restrictions, marine traffic restrictions and material requirements.

7.5.1 *South Tsing Yi MBA*

Rates and Volumes of Disposal

As described in *Sections 3 and 4* of the EIA, it is considered acceptable to backfill at rates which are equal to or lower than 100,000 m^3/day (Scenario 4e). This rate of disposal is not predicted to cause exceedance of WQOs at any of the identified sensitive receivers. In addition, it is predicted that all sensitive receiver specific criteria will be complied with under this disposal rate except for the Kennedy Town WSD Water Intake where an exceedance of 0.9 mg l–1 is predicted for brief period under worst case seasonal/tidal conditions. As this exceedance is marginal and is predicted to occur very infrequently, it is considered acceptable to allow backfilling at this rate and monitor the Intake to ensure no unacceptable impacts occur.

Indicative calculations provided by CED GEO have estimated volume capacity for the South Tsing MBA in two stages. The first stage entails backfilling from –34mPD to –25mPD in the northern portion of the MBA. This operation is expected to require 15.7 Mm^3 of which at least 50% will probably be grab–dredged material. The second stage occurs once sand resources have been exhausted from the southern portion of the MBA and also involves backfilling from –34mPD to –25mPD. This stage is estimated to require 26.2 Mm^3 of either grab– or trailer–dredged material. Therefore total capacity at the site, under the backfilling operations assessed by this Study, is estimated as 41.9 Mm^3.

Backfill Level

An initial proposal provided in the Study Brief suggested a backfill level of –25mPD. Studies of erosional effects have determined that both trailer– and grab–dredged material will be stable (ie, will not erode) under wave and current action at backfill levels at or below –24mPD. Although fluid mud is not expected to be stable at this backfill level under all conditions, the amount of fluid mud available for erosion is likely to be low with respect to the total amount of sediment released during disposal events. Therefore, a backfilling level of –25mPD is deemed acceptable for the South Tsing Yi MBA.

Spatial Restrictions

If sand in the southern pit of the MBA has not been extracted prior to the commencement of backfilling, it will be necessary to reserve an area at approximately Hong Kong metric grid coordinates 819000N for grab–dredged material. This material will be used to form a slope of approximately 1:20 of cohesive material which will prevent trailer–dredged material from migrating into the southern pit. Once this material has been placed, backfilling can proceed in the northern portion of the MBA using either grab– or trailer–dredged material without impacting remaining sand resources in the southern MBA.

It will also be necessary to construct, from mechanically dredged uncontaminated (Classes A and B) material, a separate small area of mechanically dredged material at the northern end of the northern MBA to prevent movement of disposed material northward toward the Ma Wan channel. In order to accomplish placement of these areas of grab–dredged material, a staged approach is recommended whereby barge–dumping areas are maintained at higher backfill levels than trailer–dumping areas, thus permitting both types of material to be dumped at the same time, after the initial raising of levels in the barge–dumping areas.

A contractor identified by the Civil Engineering Department Geotechnical Engineering Office (CED GEO) will conduct bathymetric surveys every two months during backfilling operations to verify the effectiveness of the slope structure. If the surveys show that the required slopes are not being formed or maintained, then the 'design' slope and, consequently, the management of the dumping operations will be modified to reduce material losses. Such modifications are anticipated to comprise limiting backfilling operations to grab-dredged materials only until sand dredging has been completed in the southern portion of the South Tsing Yi MBA and/or modifying the allowable backfill material types and rates.

Temporal Restrictions

Backfilling operations will be prohibited at the South Tsing Yi MBA during the dredging of surface marine sands from the southern pit of the South Tsing Yi MBA.

Marine Department have indicated that operations may be limited to no more than 2 trailers or barges operating at any one time within the MBA (ie including possible future sand dredging operations in the southern pit of the MBA.) In addition, only one dredging or dumping vessel will be permitted to work in the fairway at any one time. No special daytime or night-time restrictions have been identified beyond the requirements of *General Allocation Conditions for Marine Borrow Areas and Mud Disposal Sites.* Details of temporal restrictions will be the subject of further discussions between CED GEO and Marine Department.

Marine Traffic Restrictions

In addition to the Marine Department concerns described above, other marine traffic considerations must be taken into account. Although prohibition of barge dumping operations is not contemplated at this stage, Marine Department has expressed a preference for the use of trailer dredgers at this MBA. Marine Department has stated that vessels participating in backfilling operations at the South Tsing Yi MBA must be highly-manoeuvrable, self-propelled vessels and that all disposal vessels remain in motion during disposal. Exact specifications resulting from these requirements will be the subject of further discussions between CED GEO and Marine Department.

Material Requirements

There are no special material restrictions for the South Tsing Yi MBA other than those which will arise from the issues described above. Specifically, if it is necessary to retain soft, fluid material within the northern portion of the MBA through creation of a sediment-retaining slope, it will be necessary to dispose of some grab-dredged material in the MBA. Based on indicative capacity estimates provided by CED GEO, approximately 7.8 Mm^3 of grab-dredged material would be required. However, the use of grab-dredged material may be limited by Marine Department's concerns regarding the safety of barges operating in the MBA.

7.5.2 *North of Lantau MBA*

Rates and Volumes of Disposal

The maximum rate of disposal modelled in this Study for the North of Lantau MBA was equivalent to 10,000 m^3/day of grab-dredged material. At this rate of disposal no unacceptable adverse effects were predicted at sensitive receivers. Therefore, it is considered acceptable to backfill at rates which are equal to or lower than 10,000 m^3/day. This rate is not likely to restrict disposal operations as it represents a generous estimate of the maximum amount which could be practically disposed at the North Lantau MBA. Indicative calculations provided by CED GEO have estimated the total capacity at the site, under the backfilling operations assessed by this Study, as 7.0 Mm^3, and approximately 2 years and 8 months will be required to complete the backfilling operations.

The North of Lantau MBA will be backfilled in phases, with backfilling initially confined to an area covering approximately 20% of the western portion of the site (*Figure 7.5a*). It is estimated that 2.2 Mm^3 of grab spoil will be required to achieve the proposed initial backfill profile in the western part of the site. Assuming a dumping rate of 50,000 m^3 per week, this initial phase of operation will require approximately 11 months. After completion of the initial phase, backfilling will proceed sequentially to the east, allowing progressive recolonisation from the west (*Figure 7.5b*). No more than 20% of the gazetted area will be affected by backfilling operations at any one time.

Backfill Level

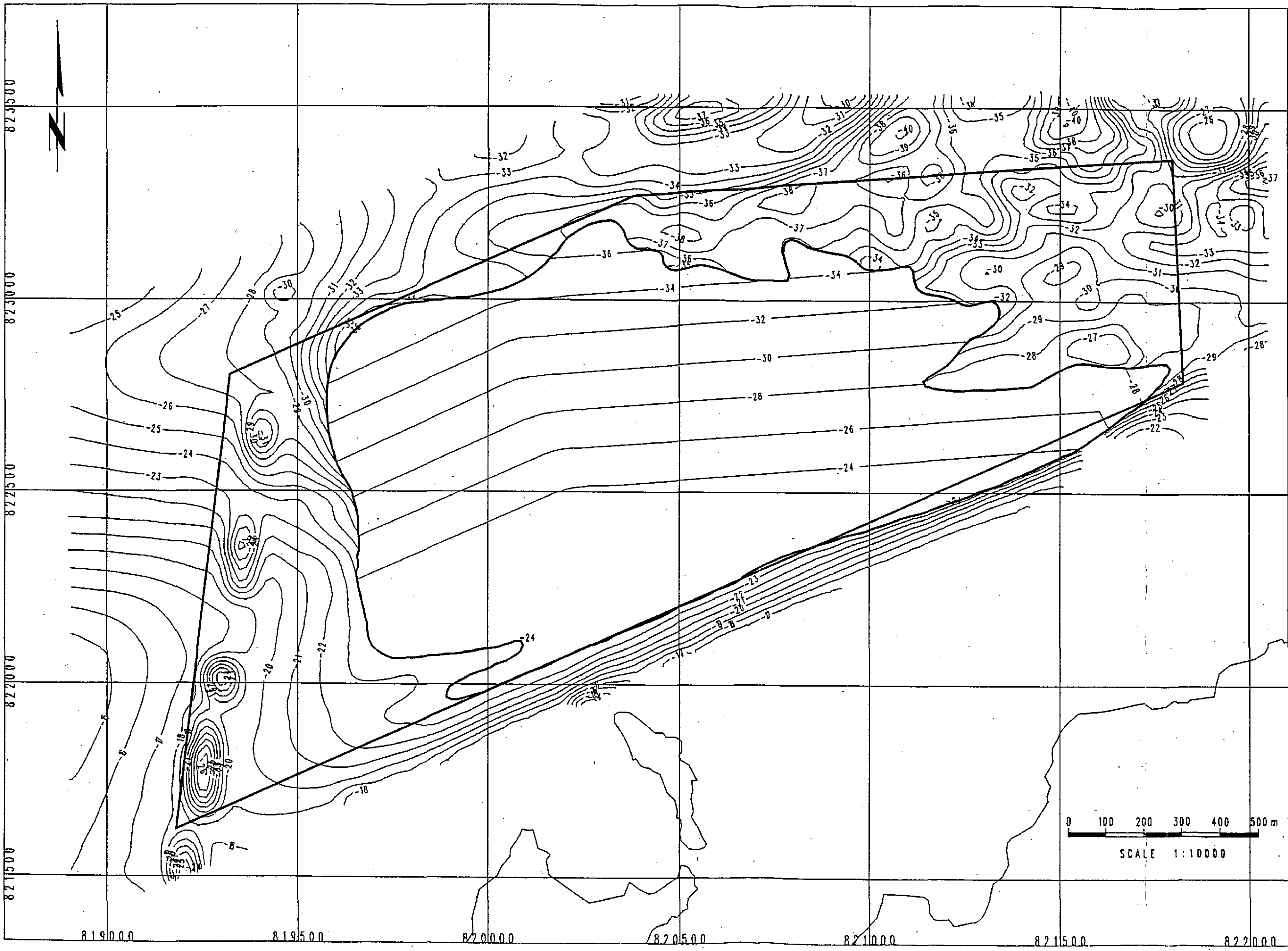
Studies of erosional effects have determined that the stability of material disposed at the North of Lantau MBA will depend on whether it is derived from soft surface deposits or more cohesive subsurface sediments. Although subsurface materials are stable under all but the most extreme storm events at backfill levels up to -16mPD, surface materials are predicted to erode more easily. A backfill level of -25mPD is recommended based on the stability of surface-derived material at and below this backfill level under typical wave and current conditions and the 0.1, 1, 10 and 50 year storm events. Fluid mud is not expected to be stable at any backfill level under even ordinary erosional forces. However, the amount of fluid mud available for erosion is not likely to cause unacceptable impacts at sensitive receivers. Therefore, a backfilling level of -25mPD is recommended for the North of Lantau MBA based on the erosional characteristics of surface-derived backfill material.

Spatial and Temporal Restrictions

The primary issue regarding spatial restrictions for the North of Lantau MBA is the presence of noise sensitive receivers along the Tai Lam coast. As described in *Section 5.7*, mitigation will be required to reduce night-time noise to levels specified in the Noise Control Ordinance (NCO). Several options for achieving reduction in noise were outlined.

This Operations Plan proposes to restrict backfilling operations to daytime hours (0700-2300) in areas north of Hong Kong grid reference line 823000N. No night-time operations (2300-0700) will be authorized in MBA areas north of this line. Backfilling in areas south of 823000N may take place at night, but will be restricted to the operation of no more than two dredgers or two barge/tug boat combinations in any 5 minute period during night-time hours. Land-based noise monitoring will be proposed in the EM&A Manual to audit whether night-time noise levels are sufficiently mitigated by this operational restriction.

In summary, no spatial restrictions are necessary for daytime operations (0700-2300). During night-time periods (2300-0700), backfilling north of 823000N is prohibited; south of this line backfilling will be restricted to no more than two dredgers or two barge/tug boat combinations in any 5 minute period. An EM&A programme will be employed to verify noise levels do not exceed NCO criteria.



ERM

TITLE FIGURE 7.5b

NORTH OF LANTAU - PROPOSED FINAL BACKFILL PROFILE

DATE 8-JUNE-1995

FILE NO.

COMPILED BY N. Evans

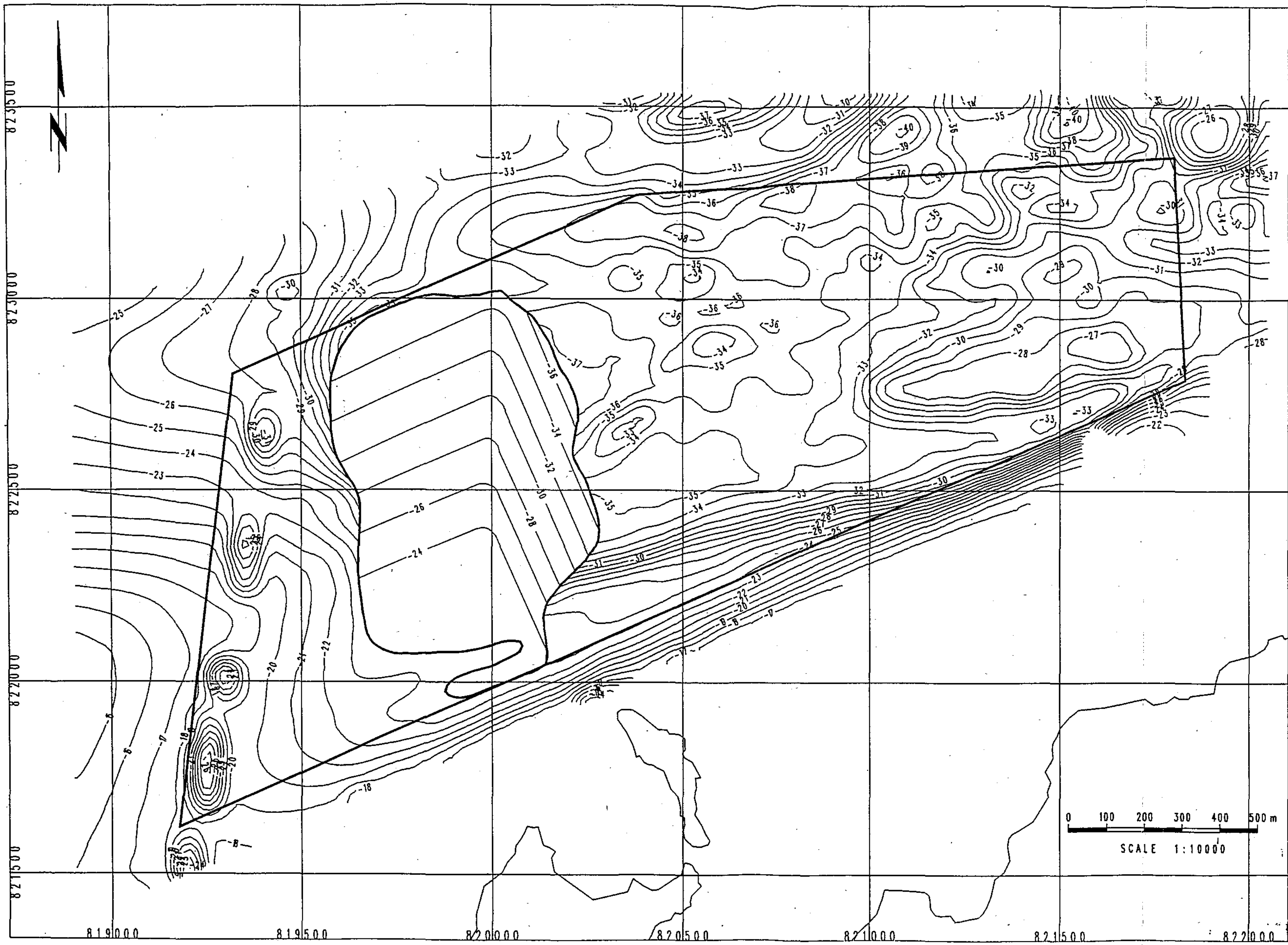
DRAWN BY M.C. Yeung

DRAWING NO. FMC/302/2

SCALE 1:10000

OFFICE
FILL MANAGEMENT DIVISION
Geotechnical Engineering Office

Civil Engineering Department
HONG KONG



ERM

TITLE FIGURE 7.5a

NORTH OF LANTAU - PROPOSED INITIAL BACKFILL PROFILE

DATE	8-JUNE-1995
FILE NO.	
COMPILED BY	N. Evans
DRAWN BY	W.C. Yeung
DRAWING NO. FMC/302/3	SCALE 1:10000
OFFICE	FILL MANAGEMENT DIVISION Geotechnical Engineering Office

Civil Engineering Department HONG KONG

Marine Traffic Restrictions

No special marine traffic considerations have been identified for the North of Lantau MBA. However, backfilling operations must comply with the *General Allocation Conditions for Marine Borrow Areas and Mud Disposal Sites* and any other special conditions required by Marine Department.

Material Requirements

CED GEO has indicated that due to the naturally sloping bathymetric profile in the area, the North of Lantau MBA is expected to be backfilled with grab-dredged material only. Although trailer-dredged material could potentially be accommodated at the site, special provisions for construction of a sediment retaining feature along the northern edge of the MBA would be required. As the need for disposal of trailer-dredged material at the North of Lantau MBA is not anticipated, no such special provisions have been developed.

7.6 ENVIRONMENTAL MONITORING & AUDIT

The EM&A Manual, released as a separate document to the EIA, incorporates mitigation measures contained in the Operations Plan as well as general plant maintenance and working methods into one document. It also describes a monitoring programme to verify the effectiveness of these mitigation measures and an audit programme to interpret and evaluate the monitoring results, and to modify the mitigation measures as necessary. The following section provides a summary of the contents of this document.

Key issues addressed within the EM&A Manual are the water quality and noise EM&A requirements associated with the backfilling operations at the two MBAs. As discussed earlier in *Section 7.4.4*, no air quality mitigation measures or monitoring programme are considered necessary for the proposed backfilling operations. Marine ecology may be impacted by the proposed backfilling operations as a result of changes in water quality. However, environmental mitigation of water quality impacts, including in particular suspended solid and dissolved oxygen concentrations, will effectively mitigate those potential impacts upon marine ecology. Therefore further recommendations specific to monitoring and auditing of marine ecology are not required.

The monitoring of potential environmental impacts during the backfilling operations comprises water quality sampling and noise monitoring at specified noise sensitive receivers. These monitoring programmes are described in detail in the EM&A Manual and are summarized here.

Water quality monitoring stations consist of control stations (to account for ambient characteristics), MBA stations (to determine the effects of backfilling at the perimeter of the MBA) and stations at sensitive receivers (to verify the predictions of the sediment plume modelling and the effectiveness of the mitigation measures). As significant exceedances of the night-time noise criterion have been predicted for unmitigated night-time dumping activities at the North of Lantau MBA, a night-time noise monitoring and audit programme is recommended to enable the Contractor to promptly identify and correct any noise problems which may arise. Noise monitoring should be undertaken at the nearest affected NSRs to the North of Lantau MBA.

The primary objective of the EM&A Manual is to provide a means of determining the efficacy of the 'environmentally acceptable Operations Plan' designed by the EIA Study, for the proposed backfilling activities at the South Tsing Yi and North of Lantau MBAs. This is achieved by the proposed environmental monitoring and audit programmes, and the application of specified procedures and actions through Action/Event Plans (AEPs) to manage the Project's response to any identified unacceptable environmental impacts.

The EM&A Manual specifies review procedures for evaluating the significance of any residual impacts after mitigation, the need for broader supplementary mitigation measures and the consequences of mitigation implementation. It also provides guidance for revising the Operations Plan and/or plant maintenance and working method general mitigation measures based on issues resulting from backfilling operations alone.

The environmental management organisation for the backfilling operations and the interfaces of the project EM&A are also illustrated in the EM&A Manual. Details of the roles and responsibilities of the relevant parties with respect to environmental compliance during the backfilling operations are described. In addition, recommendations for environmental complaint procedures are given and the proposed reporting and audit requirements for the backfilling operations discussed. This reporting structure includes the methodology for recording data, the treatment of exceedances and the format of the monthly and quarterly progress reports.

7.7 *OVERALL CONCLUSIONS*

The detailed assessment of environmental consequences arising from the proposed backfilling activities at the South Tsing Yi and North of Lantau MBAs indicates that, in the absence of other concurrent projects, there are unlikely to be any insurmountable or unacceptable residual environmental impacts with the implementation of the proposed Operations Plan. A summary of the findings of this Study is provided in *Table 7.7a*. The Operations Plan specifies rates and volumes, backfill levels and spatial, temporal, marine traffic and material restrictions for backfilling activities. These restrictions will be incorporated into the project design and will serve to reduce potential impacts likely to arise as a result of the backfilling activities. Thus, concurrent backfilling operations at the South Tsing Yi and North of Lantau MBAs, as defined by the Operations Plan, are considered environmentally acceptable on their own.

The Operations Plan, mitigation measures and monitoring and audit requirements are defined in the EM&A Manual. The EM&A Manual specifies review procedures for evaluating the significance of any residual impacts after mitigation, the need for broader supplementary mitigation measures and the consequences of mitigation implementation. It also provides guidance for revising the Operations Plan and/or mitigation measures based on issues resulting from backfilling operations alone.

The presence of other active dredging/disposal projects within the vicinity of the MBAs may require the application of additional mitigatory measures for the backfilling operations to ensure that impacts associated with backfilling do not exceed acceptable levels. Due to the long lifespan of the current project and hence the large number of possible combinations of other concurrent activities, cumulative assessments of all the possible combinations

Environmental Parameters	Extent of Potential Impacts at Sensitive Receivers (SRs)	Recommended Operations Plan & Mitigation Measures	Residual Impacts After Mitigation	EM&A Requirements	Further Studies
Marine Ecology	Potential impacts to benthic fauna outside the MBAs are considered acceptable. Predicted elevations in SS concentrations resulting from backfilling operations alone are not expected to result in unacceptable impacts on potential spawning and nursery grounds, capture fisheries, fish culture zones or fish fry collection areas. Cumulative impacts in conjunction with high ambient SS levels may result in SS concentrations exceeding the natural range in some areas for brief periods. No unacceptable impacts on *Sousa* and intertidal habitats expected. (see *Section 4.8*)	Recommended mitigation measures (see row above) which reduce SS concentrations in the water column would serve to reduce impacts to ecological SRs.	No insurmountable impacts to ecological SRs identified.	EM&A for ecological impacts not required.	No further studies recommended.
Noise	Significant exceedances (up to 7 dB(A)) of the NCO night-time (2300-0700) criteria predicted at nearby NSRs from unmitigated night-time dumping operations at the North of Lantau MBA north of 823000N (*Section 5.9*).	Backfilling at the North of Lantau MBA restricted during night-time periods to areas south of 823000N (*Section 5.9*)	None (predicted compliance with all NCO criteria) (*Section 5.9*).	Night-time noise monitoring and audit programme will verify whether noise levels are sufficiently mitigated by operational restrictions and in compliance with NCO criteria. (see *EM&A Manual* for details).	No further studies recommended.
Air Quality	No exceedances of AQOs at nearby ASRs predicted. (*Section 6.9*)	No mitigation measures necessary.	NA	NA	No further studies recommended.

Summary of Potential Environmental Impacts and Proposed Operations Plan and Additional Mitigation Measures

Environmental Parameters	Extent of Potential Impacts at Sensitive Receivers (SRs)	Recommended Operations Plan & Mitigation Measures	Residual Impacts After Mitigation	EM&A Requirements	Further Studies
Water Quality & Sediment Transport	*Non-cumulative (Sc. 1, 2, 3 and 4a–d):* Exceedance of SS WQO predicted at some sensitive receivers (3–7 mg l^{-1}) and at the Kennedy Town WSD Water Intake (3.9 mg l^{-1}) for worst case non-cumulative. *Cumulative: Sc. 5, 6, 7 and 8):* Predicted SS elevations of 2–65 mg l^{-1} at sensitive receivers and exceedance of WQO and specific criteria at some sensitive receivers for all scenarios. Dissolved oxygen and nutrient levels acceptable under all scenarios. (see *Sections 3.10 & 7.4.1*)	Mitigation measures consist of the Operations Plan (*Section 7.5*) and general plant maintenance and working methods (*Section 3.14*). Scenario 4e models the backfilling rate adopted by the Operations Plan and shows compliance with WQOs for SS, DO and nutrients at all sensitive receivers for backfilling operations alone (*Section 3.10*).	0.9 mg l^{-1} exceedance of Kennedy Town WSD Water Intake specific criteria under worst case seasonal/tidal conditions (*Section 3.10*).	Details of water quality EM&A requirements given in *EM&A Manual.*	Backfilling operations in conjunction with other dredging/disposal projects are addressed by the *Cumulative Effects Assessment Manual (CEAM).*

cannot meaningfully be carried out at this stage. Further assessment will be required before any dredging or disposal projects can be allowed under these circumstances. A Cumulative Effects Assessment Manual (CEAM) is being developed to provide guidance for assessing potential cumulative effects and modifying the Operations Plan and/or the EM&A manual. A preliminary draft version of the CEAM is issued, concurrently with the EM&A Manual, as a separate document to this EIA. This preliminary version of the CEAM is indicative of the predictive cumulative assessment approach that would be adopted. The precise methodology, which will interact closely with the EM&A programme, will be refined prior to use and will subsequently be validated and updated in parallel with the implementation of the EM&A programme.