FINAL REPORT

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CONSULTING SERVICES BY ENVIRONMENTAL RESOURCES MANAGEMENT

Provisional Airport Authority

Proposed Aviation Fuel Receiving Facility at Sha Chau: *Environmental Impact Assessment*

Volume 1: Report

January 1995

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For and on behalf of ERM Hong Kong	
Approved by:	[signature]
Position:	Technical Director
Date:	19 January 1995

CONTENTS

CONTENTS

1 INTRODUCTION

1.1 BACKGROUND TO THE STUDY

The Provisional Airport Authority (PAA) proposes, in the interim term, to supply aviation fuel to Chek Lap Kok Airport from an Aviation Fuel Receiving Facility, hereafter called the AFRF, located in the vicinity of the Chek Lap Kok Airport. The AFRF will receive aviation fuel from vessels and transfer the fuel directly to an on-airport tank farm via subsea pipeline.

The AFRF is intended as an interim arrangement for supply of aviation fuel until the completion of the preferred solution, which is a pipeline supply direct from an off-airport source to the on-airport tank farm. It is anticipated that the AFRF will be operational for 5 to 7 years and thereafter it will be used only as an emergency back-up facility.

In searching for a potential location for the AFRF, the PAA in conjunction with Government considered ten possible areas in the vicinity of the airport *(Figure 1.1a)*. A variety of technical problems (described in *Section 2*) identified by PAA in consultation with Government narrowed down the AFRF location to two potentially viable sites, namely, at Sha Chau (Area 10) and north of the new airport (Area 1).

Concerns centred on environmental issues and hence PAA commissioned in May 1994 an initial environmental assessment for the two potential sites with a view to:

- establishing the preferable site on environmental grounds;
- identifying any insurmountable environmental problems;
- outlining practical and cost-effective mitigation to minimise predicted impacts; and
- identifying any Key Issues associated with the preferred site that would require consideration during an Environmental Impact Assessment (EIA).

The results of the initial environmental assessment were presented in an Initial Assessment Report (IAR) completed by ERM Hong Kong in May 1994. The IAR concluded that the site north of the new airport (Area 1) could not be recommended in view of its proximity to the Contaminated Mud Pits (CMPs) and associated potential adverse impacts. The Sha Chau Area (Area 10) was therefore recommended to be the environmentally preferable site subject to a detailed EIA study. AFD, however, had great reservation with regard to Area 10 as they considered that the proposed AFRF could have significant impact on the Chinese White Dolphin population around Lung Kwu Chau and Sha Chau areas. AFD, therefore, requested that the detailed EIA should carefully address the ecological impacts on the population.

After the endorsement of the IAR, ERM was commissioned by PAA to carry out an EIA to study of all the key issues identified in the IAR, associated with the AFRF based on its conceptual design.

It should be emphasised that the overall construction programme for the airport has compressed considerably the time available for these studies.

1.2 *Purpose of This Environmental Impact Assessment*

The purpose of this EIA is to assist in minimising pollution, environmental disturbance and nuisance arising from the construction, operation and maintenance of the AFRF by providing information on the nature and extent of the potential environmental impacts and recommending appropriate mitigation measures. AFD have stated that in their view the purpose of the EIA should not exclude the possibility of a "no-go" alternative in case insurmountable environmental impacts are identified in the study. The objectives and broad scope of the EIA Study are as outlined in the Environmental Protection Department (EPD) Study Brief entitled *"Aviation Fuel Supply System to CLK Airport - Environmental Impact Assessment Study Brief"* with emphasis on the Key Issues as summarised below and defined in the Scope of Work attached as *Annex A*.

1.2.1 *Key Issues*

The Key Issues covered by this EIA have arisen either from the IAR and/or from its appraisal by the Sub-committee of the Advisory Committee on the Environment (ACE) as part of the consultation process on 12 September 1994.

Dolphin Studies

Consideration of the findings of the IAR led to the identification of the potential impacts to Chinese White Dolphins (*Sousa Chinensis* - hereafter referred to as *Sousa*) which had been sighted in the marine waters north of Lantau, around Sha Chau and Lung Kwu Chau Islands, as a key issue. In June 1994 PAA commissioned ERM to undertake a two staged detailed dolphin study with the following objectives:

- Optimising the AFRF location (Site Selection Study) in the vicinity of Sha Chau with regard to environmental impacts by minimising potential impacts on *Sousa*; and

- Identifying practical and cost-effective mitigation measures and EM&A requirements to minimise the scale, extent and severity of construction and operation impacts on *Sousa*.

The Site Selection Study (June - July 1994) comprised of a one month intensive field survey and an international literature survey from which a site was selected for further study. From the outset the Consultants liaised in consultation with AFD *Sousa* research studies such that an appreciation of the latest data could be incorporated into the PAA studies. Secondly, the field results were synthesised with a detailed impact assessment (July – August 1994) of the construction, operation and maintenance of the AFRF on *Sousa*. The results of the dolphin studies are included within this report.

Construction Phase

- *Water Quality:* Including impacts of construction activities such as dredging, pipelaying and piling and assessment of alternative methods with respect to Water Quality Objectives. Assessment of potential interference with CMPs from pipelaying.

- *Waste Management:* Assessment of quantities, quality, and means and location of disposal for dredged, construction and other material.

- *Marine Ecological Impacts:* Assessment of impacts of construction activities.

- *Noise:* Assessment of AFRF construction and cumulative noise impacts.

- *Cultural:* Assessment associated with temple and graves on Sha Chau.

- *Other Considerations:* Cumulative impact assessment of the non-PAA developments on Sha Chau; and consideration of nearby developments due to comments from government including Route 'Y' and the River Trade Terminal at Tuen Mun Area 38.

Operational Phase

- *Water & Sediment Quality*: Assessment of impact of maintenance activities including dredging and regular discharges.

- *Waste Management*: Solid and liquid waste disposal and associated impacts.

- *Risk to life*: Consideration of the risks from the total operations of the AFRF including shipping through the Ma Wan Channel.

- *Environmental Risk:* An appraisal of the frequency, scale, extent and severity of an aviation fuel spill and assessment of direct and indirect marine ecological impacts from spills.

- *Noise:* Assessment of AFRF operational noise impacts.

In all cases recommendation of appropriate mitigation measures is covered.

Environmental Monitoring and Audit

Definition of requirements and any necessary programme for impact compliance monitoring.

Key Issues Identified by the Advisory Committee on the Environment for Detailed Assessment

Information requested by the ACE EIA Sub-Committee based on their assessment of the IAR on 12 September centred on:

- the impact of the project on the Chinese White dolphin and Chinese King Crab and prawn fisheries;
- greater integration of the risk assessments between Ma Wan Channel and this interim facility;
- more details on ecological risk;
- benthic studies related to the site and coastal ecological issues;
- hydrodynamic modelling with regard to Sha Chau;
- justification for screening out the other alternatives; and
- an assessment of what other government departments or agencies are or are proposing to build on Sha Chau.

These key issues are included within the EIA scope. The assessment of other government works on Sha Chau is based on information supplied by government via request to NAPCO.

Items Excluded

Construction and operation phases have been reviewed with regard to potential impacts on air quality. However, neither construction nor operational air quality is considered an issue as the construction will be mainly marine based with minimal dust generation. No major operational air emissions are anticipated and thus air quality has not be included in this assessment.

1.3 STRUCTURE OF THE REPORT

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

- *Section 2* details PAA's screening process in selecting preferred sites 1 & 10, summarises the IARs recommendations with respect to Sha Chau and the selection of the specific location for the AFRF at Sha Chau.

- *Section 3* describes the proposed AFRF, works/programme associated with the AFRF construction and its operation (including maintenance).

- *Section 4* covers the construction phase with respect to the key issues discussed above.

- *Section 5* discusses the scale, extent and severity of environmental impacts during the 5–7 year operational phase.

- *Section 6* discusses the risks associated with the operation of the AFRF, comprising assessment of the risk to the environment (potential impacts of aviation fuel spill) and risk to life hazard assessment.

- *Section 7* outlines the recommended environmental monitoring and audit (EM&A) including biological monitoring requirements necessary to ensure the effectiveness of the construction and operation phase environmental protection (mitigation) measures recommended; and

- *Section 8* summarises the findings of the EIA Study, draws the conclusions, recommends the way forward and further study required.

2 AREA AND SITE SELECTION

2.1 INTRODUCTION

Various factors have led to the selection of Sha Chau as the preferred area for the AFRF. Broadly the process can be summarised as follows:

- *Permanent Fuel Supply Options:* PAA's overall objective is to establish a permanent supply route as soon as practical. This is to comprise a pipeline supply direct from an off-airport fuel depot to the on-airport tank farm. A site selection process was undertaken by the PAA and Government from 1992 to early 1994 on 12 off-airport sites. However to a number of reasons it was determined that it was not possible to have such a facility operational for Chek Lap Kok (CLK) airport opening, and hence it became necessary to look for a site for the AFRF which would operate in the interim period of up to 5 - 7 years before the permanent fuel supply system comes on line.

- *AFRF Alternative Area Selection and Initial Screening:* Once it became apparent that the AFRF was required PAA began to look for a suitable area within which a site for the AFRF could be located. Ten alternative areas selected by PAA were subjected to an initial screening process which reduced the number of alternatives to two areas where the remaining concerns were essentially environmental.

- *Initial Assessment Report and Preferred Area Selection:* In May 1994 ERM Hong Kong were commissioned to conduct initial environmental studies of both remaining areas. In August 1994 the IAR report, which established Sha Chau as the environmentally preferable alternative of the two areas, was endorsed by Government.

- *Site Selection:* Remaining concerns still being mainly environmental ERM was again commissioned to conduct a study of six indicative sites around Sha Chau to assist PAA in the selection of their preferred site for the AFRF.

The remainder of this section summarises the latter three of the above site selection processes. It should be stressed that the last three aspects have been completed within a compressed timescale in order that the AFRF can be operational for the CLK Airport opening.

Section 2.2 comprises a summary, prepared by PAA, detailing the alternative area selection and initial screening.

Sections 2.3 *and* 2.4 summarise the studies completed by the Consultants on behalf of the PAA, based on conceptual design data provided by the PAA.

2.2 *ALTERNATIVE AREA SELECTION AND INITIAL SCREENING*

2.2.1 *Introduction*

The initial intention of the PAA was to utilise a jetty attached to the airport platform as the AFRF. This was in-line with the original master plan concept which called for fuel to be supplied directly to the airport platform by dedicated fuel vessel. After considering various alternatives around the CLK Airport, it was decided that the most feasible location for the proposed jetty was a site attached to the north of the CLK Airport. However the PAA was informed by the Royal Observatory that this site was potentially not acceptable due to interference with radar and associated reductions in air safety. Accordingly, to evaluate this potential problem, a consultant with expertise on Terminal Doppler Weather Radar was hired to study the viability of the location of jetty at north Chek Lap Kok (Area 1 on *Figure 2.2a*).

Given the uncertainties with the north Chek Lap Kok site, it was also decided at this time to investigate other off-airport locations.

2.2.2 *Area Selection Criteria*

In locating potential areas for the AFRF a number of considerations were taken into account namely:

- *Availability:* Areas need to be free, or freeable, of any existing incompatible uses, or planned or committed developments. Further, since after the interim operation period the AFRF will act as an emergency back up facility, any area must remain available for the expect life of the airport.

- *Distance from CLK*: The study area was limited to not more than 5 km from the CLK Airport platform for various reasons including:

  - Guidelines on security of supply from Government dictated that this facility should be as close to the airport as possible.

  - Cost and construction programme – the further away the AFRF from the CLK Airport, the more the pipeline would cost and the longer it would take to construct. In particular, pipeline crossings of shipping channels would effect both cost and construction programme significantly and pose increased risk of pipeline rupture.

  - Access – the AFRF needs to be accessible to vessels up to 10,000 dwt originating from points east of Ma Wan and from international and Chinese waters to the west of CLK.

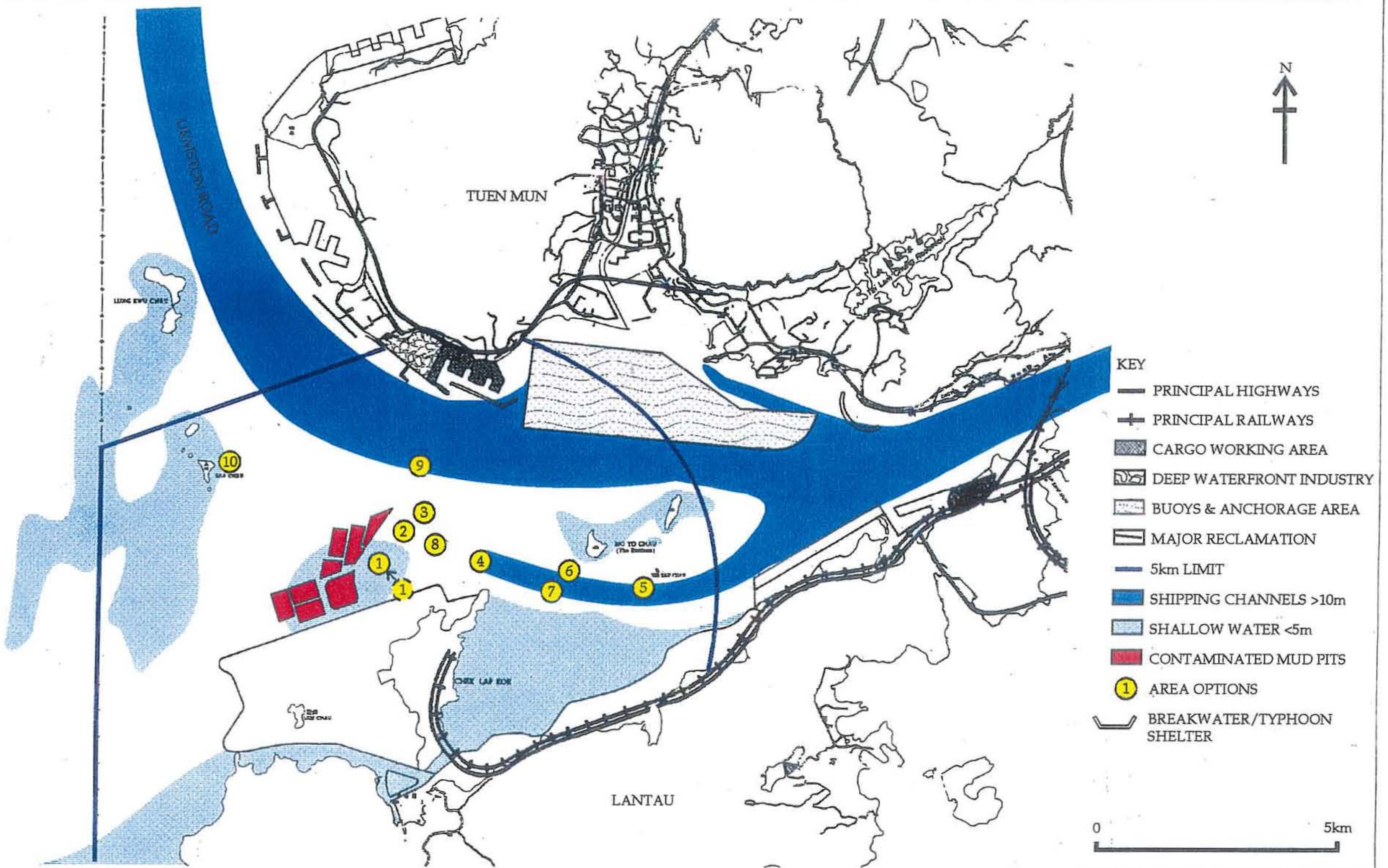

FIGURE 2.2a - CURRENT & PROPOSED DEVELOPMENTS AND INITIAL AREA SELECTION

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- *Water depth:* Two factors favoured areas with a water depth of between 5 and 10m:

  - *Shipping Channels (water depth greater than 10m):* Busy shipping channels – Urmston Road and the South Brothers Channel and associated waters greater than 10m in depth were to be avoided due to marine traffic conflicts, but it was thought desirable to have the AFRF near a shipping channel to minimise both costs and works associated with initial and maintenance dredging of the AFRF access channel. Areas in already dredged borrow pits or near access channels already dredged for other marine uses were favoured on similar grounds.

  - *Shallows (water depth less than 5m):* Any area in water depth below 5m was excluded due to factors including cost concerns and the different impact upon dredging of shallow versus deep water and the need for an access channel. A facility in shallow water requires higher dredging costs and more frequent maintenance dredging resulting in higher annual maintenance cost.

- *Technical Feasibility:* Two considerations were taken into account:

  - From a geotechnical perspective, short piles near land were preferred because of rising rockhead. At most other areas, the rockhead is deeper, thus requiring deeper and more costly piles.

  - The facility should be able to be oriented to face into currents for docking and mooring purposes, and ideally to be radial to radar.

Ten alternative areas were considered for locating the AFRF. These are general areas that were considered rather than specific locations. For example, Area 6 could have been anywhere around West Brother. Similarly Area 10 could be anywhere around Sha Chau, and so on. These areas therefore covered all practical variations for the AFRF. The ten areas are shown in *Figure 2.2a* with the backdrop of the constraints covered by the area selection criteria given above. The planning map is taken from the HK Government's *Broad Long Term Pattern of Port Development*. The areas are:

- Area 1 — North Chek Lap Kok Offshore;
- Area 2 — Borrow Pit (West);
- Area 3 — Borrow Pit (West);
- Area 4 — Borrow Pit (East);
- Area 5 — Tsz Kan Chau;
- Area 6 — West Brother;
- Area 7 — Brothers Channel (South);
- Area 8 — Borrow Pit (Mid);
- Area 9 — Urmston Road; and
- Area 10 — Sha Chau.

2.2.3 *Initial Screening*

In order to highlight any problems with the selected areas and to screen preferable areas extensive discussions were undertaken by the PAA with a number of Government Departments and agencies particularly:

- Civil Aviation Department;
- Marine Department;
- Environmental Protection Department;
- Fill Management Committee;
- Royal Observatory; and
- Agriculture and Fisheries Department.

In addition, views of the following other Departments and agencies were sought by the PAA: Economic Services Branch, Planning, Environment and Lands Branch, Planning Department, Lands Department, Fire Services Department, Civil Engineering Department, Territory Development Department, New Airport Project Coordination Office (NAPCO), Royal Hong Kong Police Force, Customs and Excise Department and City and New Territories Administration (CNTA).

The main concerns of government are detailed below:

- *Civil Aviation Department*: CAD must have efficient operation of their radars for aviation safety. Siting of the aviation fuel receiving facility near or in a location which would obstruct the aircraft approach path of some of their radars could cause interference and could reduce the efficiency of the radars and consequently aviation safety. Therefore from CAD's perspective there is a need to:

  - Avoid obstructions to radars and therefore interference with efficiency of radars;

  - Avoid areas on or near the axis of the northern runway (due to become operational within 2 - 3 years of airport opening) because of its Category III Instrument Landing System i.e. not within 600m of the centreline of the runway.

  The consequence of these constraints were that Area 1, north Chek Lap Kok off-shore had to be moved further north from the airport platform, that is, instead of a jetty, it would be an offshore fixed receiving facility in the sea north of CLK Airport as show on *Figure 2.2a*.

- *Marine Department* have the general requirements that:

  - It is imperative to avoid siting the facility in open waters near shipping channels due to impact on and from marine traffic (large vessels impacting the AFRF);

- Siting the AFRF in "other open waters" was not favoured due to risk of impact of marine traffic and increased risk of oil spills. Hence the MD's preference for an area near land;

- The effect of wind direction needs to be allowed for by orientation into the wind if possible to increase berthing safety;

- Allowance needs to be made for a vessel dragging anchor in typhoons; and

- The need for protection from waves needs to be considered and hence again the department's preference for a site near land.

- *Fill Management Committee:* The Committee is required to identify the location of new contaminated mud pits because the capacity of existing pits is severely limited. FMC has plans to use the West Borrow Pit possibly followed by Mid Borrow Pit for contaminated mud. FMC is concerned that the use of sites in or around existing borrow pits will prevent them from being used for contaminated mud in the future. FMC thus believes that siting an AFRF near borrow pits is incompatible since if needed as contaminated mud pits in the future this would present a risk that they would be disturbed. Thus according to FMC requirements:

  - West Borrow Pit is not available for the AFRF;

  - Use of other pits is undesirable due to restricted capacity elsewhere for mud disposal in Hong Kong; and

  - Care needs to be taken in the selection of pipeline route for the above reasons.

- *Royal Observatory* is extremely concerned about the potential adverse effects on the operation of the Terminal Doppler Weather Radar (TDWR) system which will monitor windshear above and around the CLK Airport. The specialist consultant reported that to ensure that efficiency is not impaired, the TDWR requires that no large slow moving vessel, such as a fuel vessel, berth or anchor within 3 nautical miles (5.5 km) from the east and west ends of both runways and half a nautical mile (900m) north and south of the centre line of the runways. There was also a potential for detection of false alarm in approach/departure airspace on TDWR. As a consequence of that Area 1, North Chek Lap Kok Offshore had to be moved further north, as shown on *Figure 2.2a*.

- *Environmental Protection Department* have the general requirement that an initial EIA of the shortlisted areas be conducted followed by a detailed EIA of the selected option.

- *Agriculture and Fisheries Department (AFD)*, based on advice given them by their Hong Kong University Dolphin Research Team from their research work from December 1993 to April 1994, were concerned that due consideration/assessment is given to potential impacts of the AFRF on Chinese White Dolphins on any site selected within waters known to be frequented by the dolphins. This includes all of the study area to varying degrees.

- *City and New Territories Administration* has advised that "Fung Shui" is a sensitive issue and the AFRF should be aligned so as to alleviate potential fung shui issues.

2.2.4 *Results of Initial Screening*

Considering the above factors, the following 8 alternative areas did not meet the minimum requirements due to (see *Figure 2.2b*) the following reasons, tabulated below.

Table 2.2a *Results of Initial Screening*

Area No.	*Name*	*Main Reasons*
2	Borrow Pit (West)	A, B, C, F
3	Borrow Pit (West)	A, B, C, F
4	Borrow Pit (East)	B, C, D, F
5	Tsz Kan Chau	D
6	West Brother	D
7	Brothers Channel (South)	D, E
8	Borrow Pit (Mid)	B, C, F
9	Urmston Road	E

Reasons: - those given in *bold type* were considered by PAA as insurmountable whilst those in normal type were regarded as significant disadvantages:

- *A. Required for contaminated mud disposal.*
- B. Potential disturbance to contaminated mud pits.
- C. Difficult to orientate to currents.
- *D. Compromises the efficiency of radars and thus air safety.*
- *E. In open water close to marine shipping channel.*
- F Marine traffic impact in open waters compromises marine safety and increases the potential for spills.

Area 8, whilst not ruled out by any single insurmountable reason, was near to and constrained by similar factors to the more preferable relocated Area 1. Areas 1 and 10 were thus the only remaining potentially viable sites but it was recognised that there were residual significant concerns with each, which were mainly environmental:

- *Area 1* - Reasons B, C and F but favoured due to its proximity to the CLK Airport.

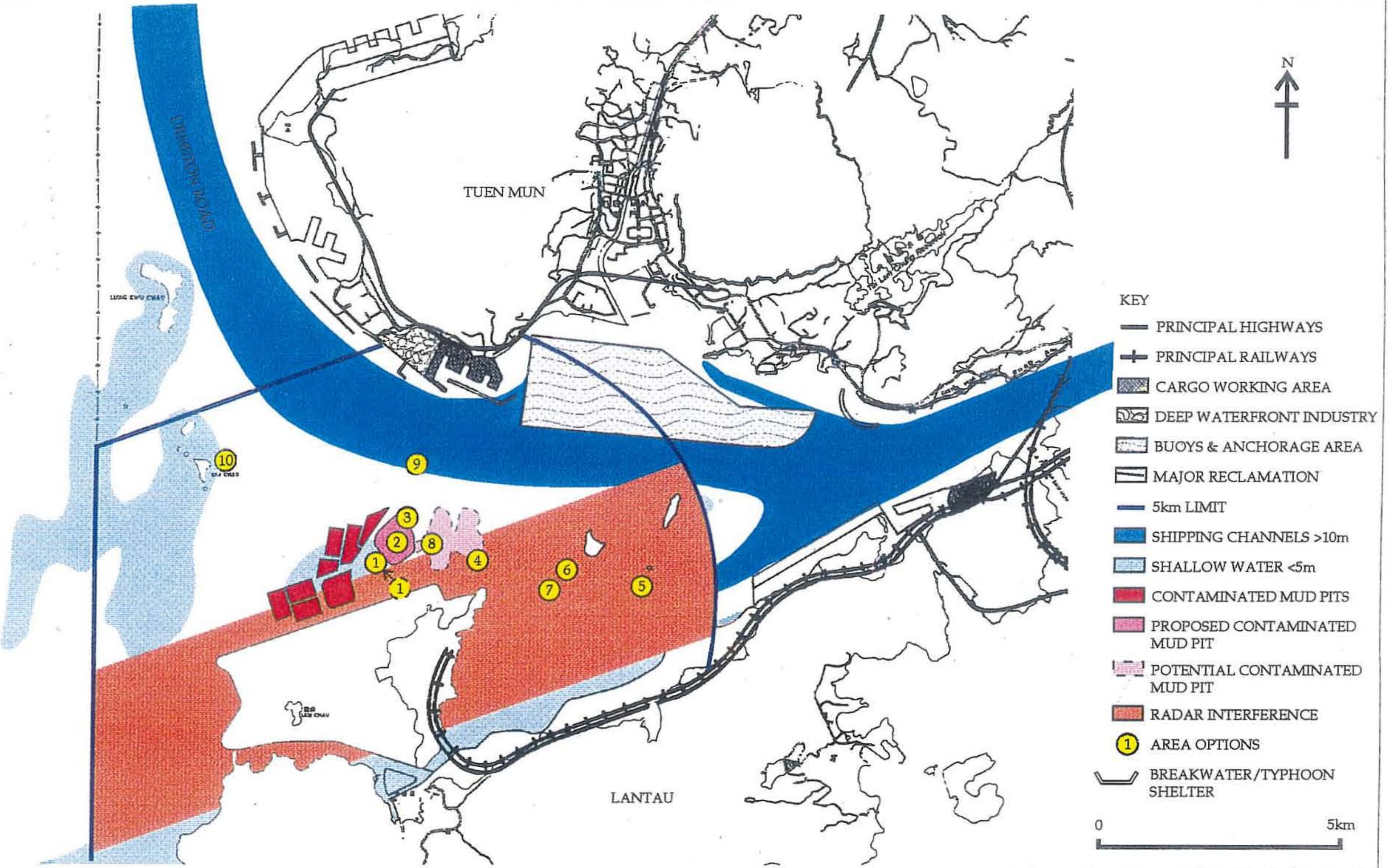

FIGURE 2.2b - FURTHER CONSTRAINTS

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- *Area 10* – The area was known to be a preferred location of the Chinese White Dolphin and a Site of Special Scientific Interest (SSSI). This site is relatively distant from CLK.

All the considerations are shown in *Figure 2.2b.* Although Areas 1 and 10 had certain constraints no better alternatives had been identified. Hence PAA wanted to establish the viability of each area from an environmental perspective.

2.2.5 *Conclusion*

As a result of this screening of a range of possible areas for the AFRF, PAA in consultation with the Government concluded that Area 1, North Chek Lap Kok Offshore and Area 10, Sha Chau be taken forward and be subjected to an initial environmental impact assessment.

2.3 *The Initial Environmental Assessment*

The results of the Initial Environmental Assessment were given in the Initial Assessment Report (IAR) endorsed by Government in August 1994 and subsequently presented to the ACE EIA Sub-Committee.

The IAR concluded that of the two areas considered, sites around 8Sha Chau were preferable on environmental grounds for the location of an offshore fixed receiving facility for the AFRF. The main problem associated with Area 1 - North of CLK Offshore was its proximity to and potential to cause disturbance of contaminated mud pits.

2.4 *Site selection at Sha Chau*

2.4.1 *Introduction*

The IAR had identified potential impacts on Chinese White Dolphins *(Sousa)* as a major concern with Area 10 at Sha Chau and hence in advance of the detailed EIA for the AFRF, PAA commissioned ERM to conduct a two staged Dolphin Study with following objectives:

- optimising the AFRF location (site selection study) with regard to environmental impacts by minimising potential impacts on *Sousa* (Stage 1); and
- identifying practical and cost-effective mitigation measures to minimise the scale, extent and severity of construction and operation impacts on *Sousa* (Stage 2).

The purpose of the *Site Selection Study* (included as *Annex B)* was to identify from six indicative locations a preferred site around Sha Chau Islands with the least potential to impact on *Sousa*. The main findings from the study are summarised below.

2.4.2 *Approach to the Stage 1 Study*

In consultation with AFD, *Sousa* research studies to date have indicated that *Sousa* number around 40–100 individuals in the North Lantau Waters. Therefore, a one month field survey (daily boat and land-based surveys) was undertaken to describe the presence and habitat utilization of *Sousa* in the marine waters around Sha Chau and Lung Kwu Chau. Incidental sightings observed in the vicinity of the Brothers Islands, Castle Peak Power Station and Northwestern Waters, when travelling to and from Sha Chau, were also recorded as part of the survey to provide an indication of the presence of *Sousa* in the surrounding areas.

In conjunction with this effort an international literature survey of 86 scientific papers on the locational, feeding and breeding preferences of *Sousa*/ Indopacific Humpback Dolphins, was conducted. A fundamental premise in the selection of the AFRF location was that the facility should be located as remote as possible from areas where *Sousa* were sighted in highest numbers or frequency ie. in an area where there were lowest *Sousa* sightings during the field survey, in order to minimise direct or indirect negative impacts on *Sousa*.

These survey findings were used to assist in selection of preferred sites for the AFRF from among six indicative locations (Sites A–F) around Sha Chau (*Figure 2.4a*).

2.4.3 *Results of the Study*

The main findings, obtained in the one-month *Site Selection Study* field survey, are summarised as follows:

- *Sousa* were sighted on 20 of the 29 surveyed days
- A total of 61 sightings were recorded involving from 1 – 10 individuals
- 201 *Sousa* sightings, suggesting a number were seen on several occasions (see *Figure 2.4b*):
  - Sha Chau: 18 sightings and 64 dolphins
  - Lung Kwu Chau: 25 sightings and 79 dolphins
  - Incidental (Castle Peak Power Station, the Brothers Islands, Pak Chau Island and other locations in Northwestern Waters): 18 sightings and 58 dolphins
- Although the survey was not designed to identify large-scale *Sousa* movements, the results indicated that *Sousa* moved inshore and offshore of Sha Chau. Adherence to survey protocols prevented tracking of *Sousa* from Sha Chau, although the findings suggest that *Sousa* may move between different areas, possibly in search of food. Similar movements were indicated in consultation with AFD *Sousa* research studies first nine months of land based surveys.

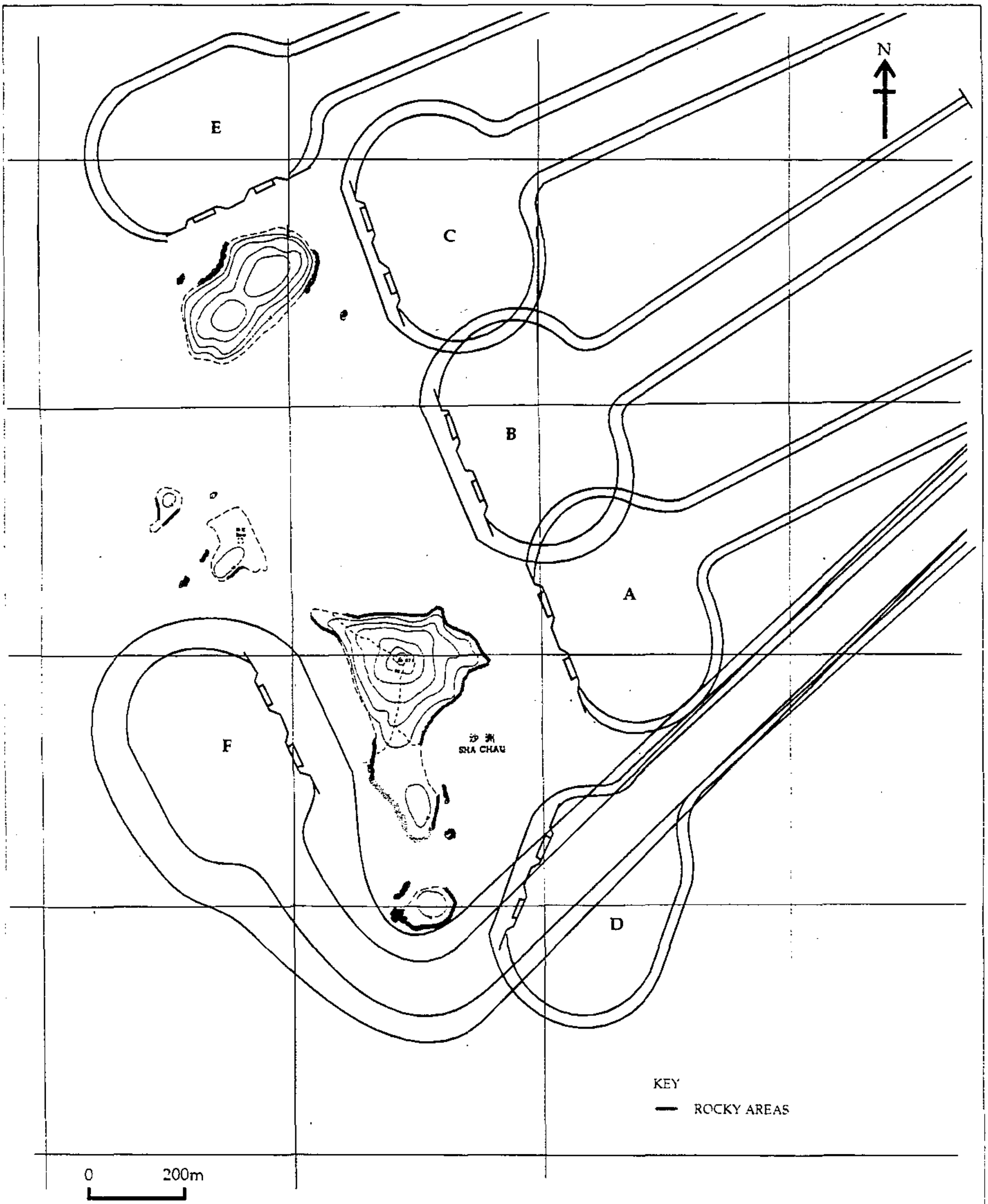

FIGURE 2.4a - MAP OF SHA CHAU SHOWING THE SIX INDICATIVE AFRF SITES

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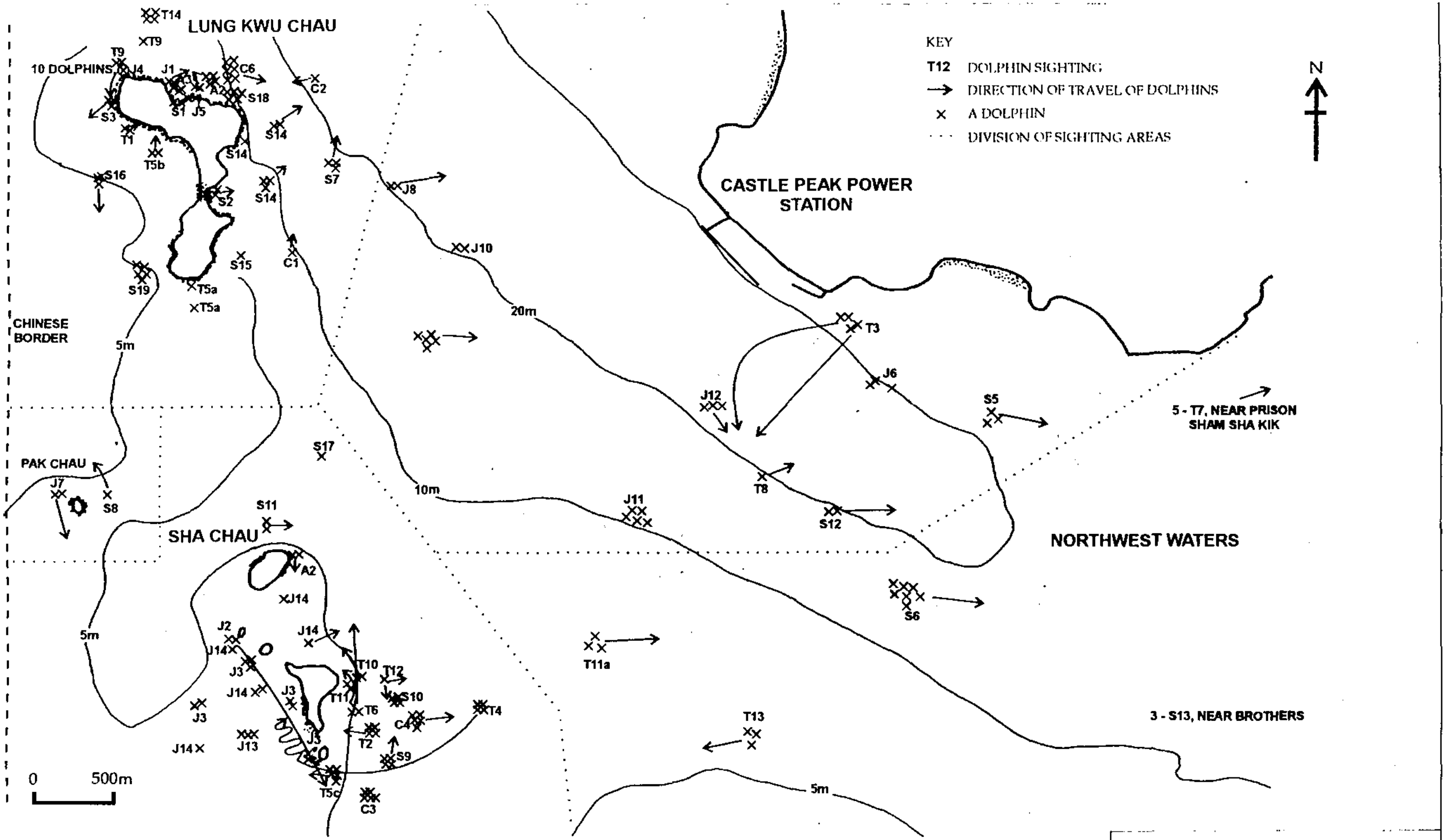

FIGURE 2.4b - MAP OF SURVEY REGION

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- The *Site Selection Study* (included as *Annex B*) also concluded that surveys conducted over longer periods may indicate that *Sousa* exhibits other patterns of habitat usage under different seasonal or other conditions.

2.4.4 *Conclusions and Recommendations*

Based upon the sighting records obtained in the one-month *Site Selection Study* survey, the majority of *Sousa* in the vicinity of Sha Chau were observed within Sites D and A (southern and eastern Sha Chau). The data indicate that these sites may contain valuable habitat for *Sousa* and are thus not recommended as sites for the AFRF. Site F is also not recommended as its vessel access channel passes through a region where a substantial number of *Sousa* were observed. Although relatively few *Sousa* were seen near Site B, the numbers of *Sousa* observed in Sites A and D indicate that the Site B location could provide a buffer area between areas more intensively used by *Sousa* and areas less intensively used, and thus Site B is not recommended.

Based upon the sighting records obtained in the one-month *Site Selection Study* survey, areas contained within Sites C and E (*Figure 2.4c*) had the lowest observed *Sousa* habitat usage of the six indicative AFRF sites, and were therefore recommended as the preferred sites for the location of the AFRF. Of the two, Site C provides a slightly reduced buffer between areas of relatively higher and lower usage, compared to that provided by Site E, and for this reason Site E was marginally recommended over Site C for the AFRF location on purely *Sousa* related grounds. The *Site Selection Study* (included as *Annex B*) also concluded that surveys conducted over longer periods may indicate that *Sousa* exhibits other patterns of habitat usage under different seasonal or other conditions. Recent results received from limited land based survey work, over a two hour period observed from over 4 km from Sha Chau undertaken by AFDs Dolphin Research Team (DRT) on 12 October 1994 indicated the presence of *Sousa* within Sites C and E. These most recent DRT sightings were taken at a time after the construction of the CAD jetty at Sha Chau was underway and thus may not reflect an unimpacted site condition; although this speculation can not be substantiated with any scientific data at this time (Annex K).

Following the *Site Selection Study*, Site C was selected by the PAA as their preferred site for the AFRF location, due to ease of orientation to currents, the greater water depth (and hence lower dredging requirement) and potential difficulties and interference with the Civil Aviation Department's radar on Lung Kwu Chau and other requirements imposed by Site E.

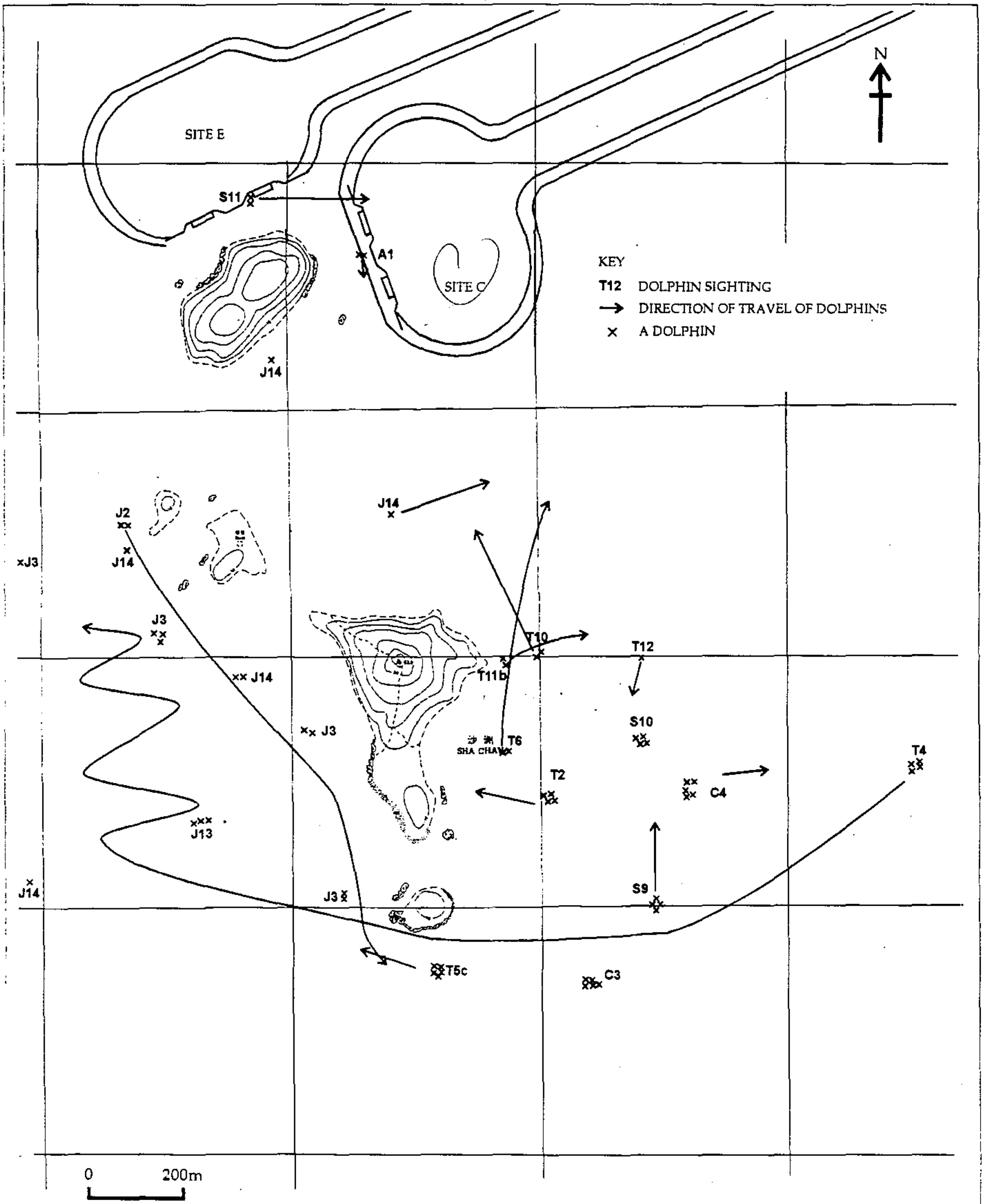

FIGURE 2.4c - PREFERRED SITES C AND E

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3 PROJECT DESCRIPTION

3.1 INTRODUCTION

Aviation fuel will be transported to the AFRF via the existing marine channels in Hong Kong Waters (Urmston Road, Ma Wan & East Lamma Channels). The proposed development will comprise a vessel turning basin of approximately 300m x 450m with an access fairway (approximately 1100m long) leading to the main marine channel (the Urmston Road), an offshore fixed receiving facility and a twin pipeline system for delivery of fuel to on-airport storage tanks.

3.2 AVIATION FUEL RECEIVING FACILITY

The AFRF will be designed to accommodate fuel vessels from around 3,000 dwt to 10,000 dwt and to discharge aviation fuel received through proprietary unloading arms and via the pipeline to on-airport storage tanks, using the on-board fuel vessel cargo pumps.

The facility will comprise 6400m^2 of fuel vessel berthing space (two berths) and a Supply and Emergency Response Base. The general layout of a typical AFRF is given in *Figure 3.2a*. Depending on vessel size, between 1 to 4 vessels will normally use the AFRF per day.

3.2.1 *The Supply and Emergency Response (SER) Base*

The AFRF and vessels using the facility will require operational, maintenance and emergency support. This support is provided from an attached facility known as the SER Base which will include the following features:

- standby and transport vessel and associated berth;
- office/accommodation/laboratory/workshop/crane;
- fire pump house;
- spill clean up equipment;
- helipad; and
- fire boat berth.

3.2.2 *Berths*

The AFRF will comprise two fuel vessel berths (plus the SERs berth) which will be approximately 320 m long, 5 m high and 15 m wide. Each of the two fuel vessel berths will include the following facilities:

- central platform equipped with proprietary unloading arms, fire fighting system, metering and sampling facilities;
- berthing dolphin and fenders;
- mooring dolphins;

- interconnecting walkways between dolphins;
- navigational aids; and
- subsea pipeline terminal and pig trap.

3.3 *FUEL VESSEL*

The facility will be designed to receive fuel vessels from around 3,000 dwt to 10,000 dwt. Vessels using the AFRF will be either:

- dedicated aviation fuel vessels (3,000 dwt – 5,000 dwt) for transporting the bulk of the aviation fuel from an off-airport source to the AFRF designed with special safety features to Marine Department conditions (*Annex E*); and

- larger vessels (>5,000 dwt) in occasional use for transport of fuel from other sources.

Figure 3.3a comprises a figure showing a fuel vessel type commonly used in Hong Kong. The typical dimensions and requirements for the fuel vessels are given in *Table 3.3a*.

Table 3.3a ***Characteristics of Aviation Fuel Vessels***

Vessel size (dwt)	3,000	5,000	10,000
Length (m)	87	103	150
Draught (m)	5.7	6.5	8
Beam (m)	12.8	15.1	19
Required depth (m)	9.0	9.5	11
Channel width (m)	65	75	100
Turning circle (m)	260	300	450

3.4 *CONSTRUCTION ACTIVITIES*

The construction of the proposed AFRF will involve the dredging of the turning basin and an access fairway leading to the main marine channel; the construction of the offshore fixed receiving facility and the installation of the twin pipeline. Details of the construction are discussed in the subsequent sections. It should be noted that no underwater blasting will be required for the construction of the AFRF or of the pipeline. The estimated dredging volumes associated with the different AFRF elements are shown in *Table 3.4a* below.

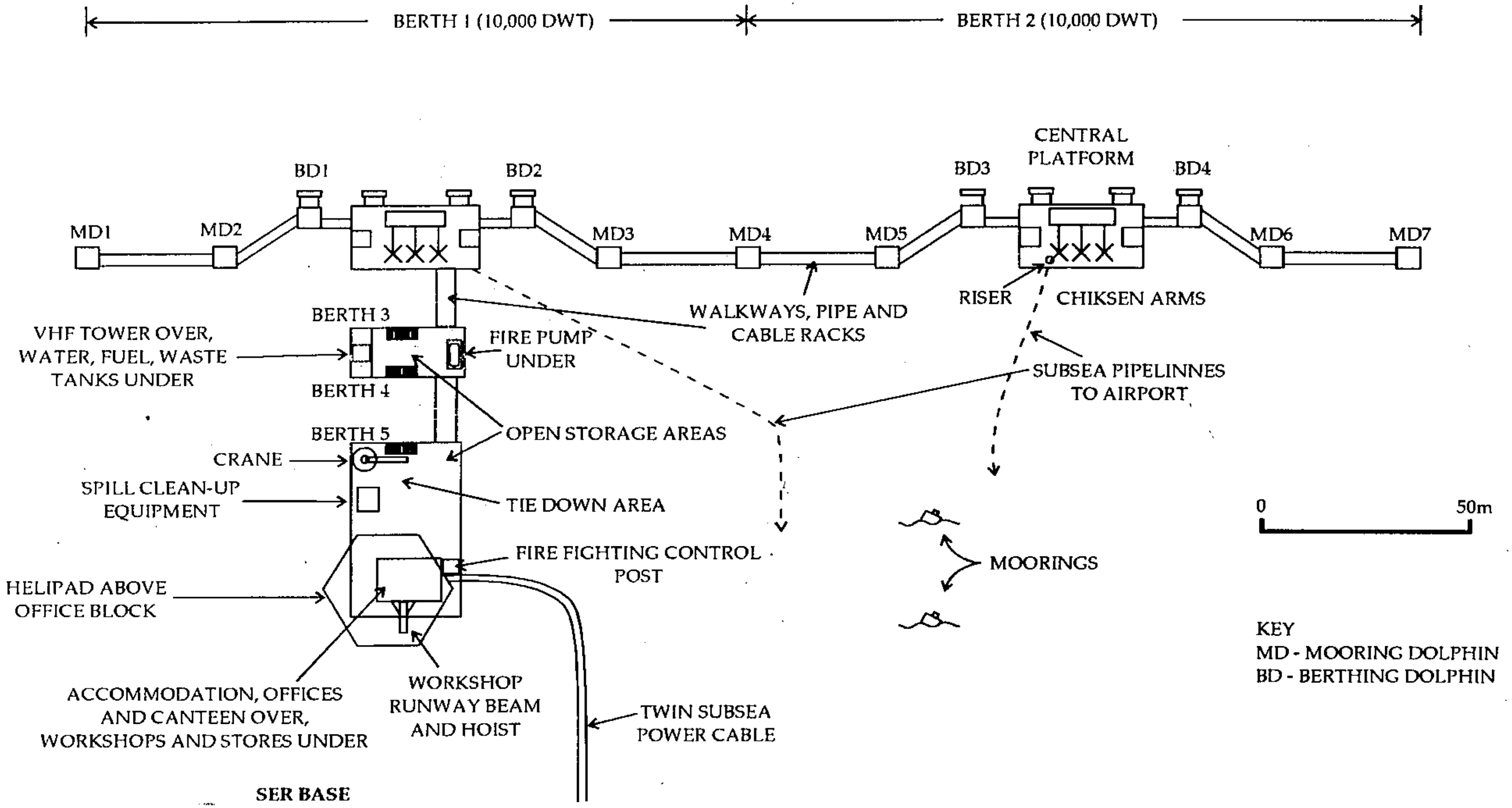

FIGURE 3.2a - SER BASE ADJACENT TO DOLPHIN

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FIGURE 3.3a - TYPICAL FUEL VESSEL COMMONLY USED IN HONG KONG

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Table 3.4a *Estimated Volume of Dredged Sediment*

Location	Turning Basin & Access Fairway (m^3)	Twin Pipeline (m^3)*1	Total Volume (m^3)
Site C	500,000	500,000	1,000,000

*Note : *1 Assuming 3m trench depth for twin pipeline and 30m² cross-sectional area.

3.4.1 *Turning Basin*

A turning basin and access fairway will have to be dredged to a depth of around 11m to allow access and facilitate manoeuvring of vessels up to 10,000 dwt. The depths shown above in *Table 3.3a* indicate the minimum depths required for the respective vessel size. The dredging requirements for construction of the turning basin and access fairway are estimated to be approximately 500,000m^3, as a natural scour hole at this location minimises the quantity of dredging required. Thus it is anticipated that the dredging programme will be for a period of approximately 2–3 months.

3.4.2 *Offshore Fixed Receiving Facility*

The facility will comprise an offshore fixed receiving facility supported by steel piles driven into the substrata. The initial proposal for a blockwork AFRF 'reclamation' design, with a construction similar in form to many of Hong Kong's seawalls, is no longer being considered due to the greater potential for environmental impacts. The nature of the seabed, with relatively little marine mud in the vicinity of Sha Chau, would necessitate a non-percussive piling method. The in-situ bored piling method could therefore be used. In addition, bored piling is preferred as noise levels generated will not be of an impulsive high sound power level nature and will therefore be less than with percussive piling. It should be noted that no underwater blasting will be required for the construction of the AFRF.

The key construction activities for the facility structure on piles will comprise the following:

- Piling – a marine based boring rig would in *situ* grind-out and crush a pile seat into the bedrock. Marine steel piles would then be driven into the bedrock. It is estimated that approximately 120 and 60 piles (1 m in diameter) may be needed for the offshore fixed receiving facility and SER Base respectively.

- Construction of offshore fixed receiving facility and SER base superstructure would include tubular steel walkways, building, mechanical and electrical equipment installation and berth hardware installation.

3.4.3 *Submarine Pipeline*

Two submarine pipelines will be laid within the proposed services corridor to deliver the aviation fuel from the unloading facility at the AFRF to the on-airport storage tanks. The precise length of the pipeline will depend on the finalised site details and the precise pipeline route to be chosen. Based on the pipeline gazettal plans it is anticipated that the pipeline will be approximately 5.5 km in length for the section between Sha Chau and Chek Lap Kok. The two pipelines may be laid in a single trench or two separate trenches, depending on the security assessment of the fuel delivery system to be undertaken in the detailed design. *Figure 3.4a* shows a typical cross-section for the submarine pipeline. It is understood that the depth of the pipeline installation should be at least 3m below the seabed so as to allow Civil Engineer, Port Works (CEPW) to dredge if necessary and provide a tolerance in addition to the dropping or dragging of ships anchors in the vicinity. In this regard CEPW will be consulted as to the required depth during the detailed design.

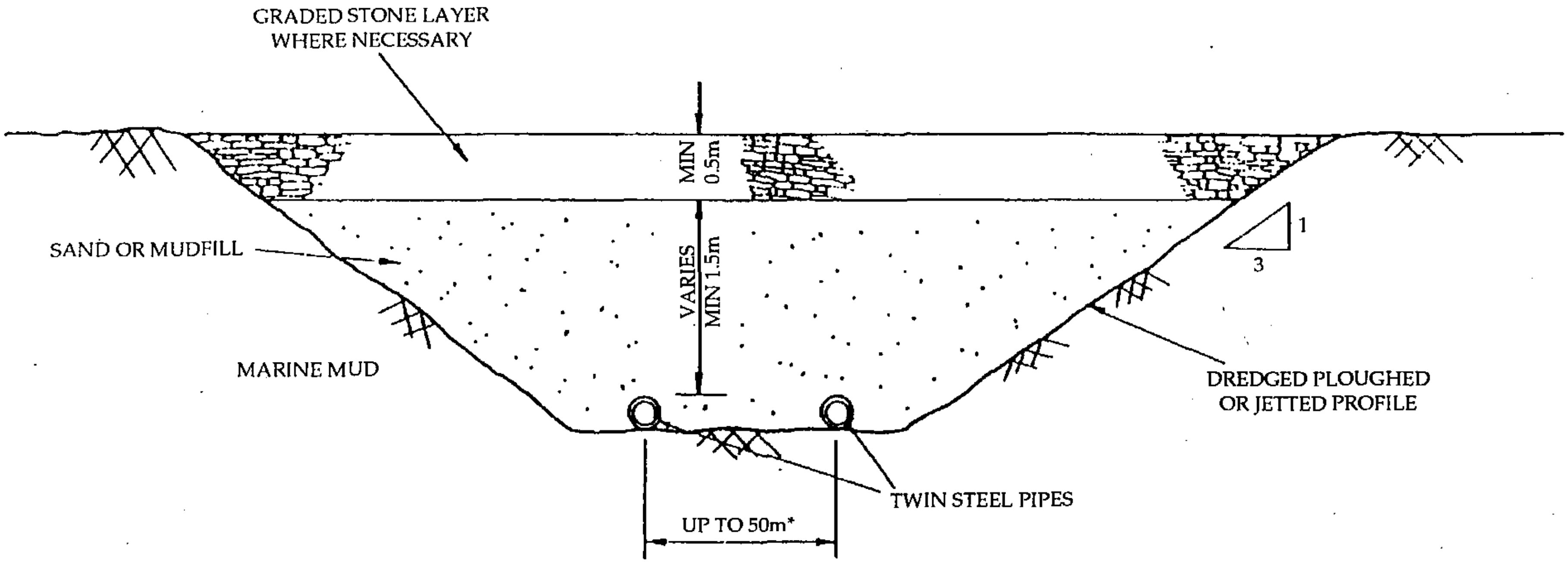
Whilst details of the submarine pipeline method of construction have not yet been finalised, typical operations will involve the following:

- pre-trenching;
- pipelaying;
- post trenching; and
- backfilling.

Depending on the final decision on the installation method, submarine pipeline installation can involve either pre-trenching by conventional dredging; post trenching by mechanical pipeline trenching devices such as ploughing, or by jetting or fluidisation; or a combination of both. Direction drilling is not a feasible option due to unsuitable bed conditions. The pipeline installation method employed will also depend on the trench depth with the ploughing/jetting method employed for a depth of 1.5 m - 2 m and the grab dredger for greater depths.

Pre-trenching

Pre-trenching will be necessary to ensure a smooth pipeline pull in/launch profile and traditional dredging methods can be employed for this method. The dredged sediments generated will require disposal. Access dredging may also be required for the lay barge depending on water depth. A pipelaying method not requiring additional access dredging should be selected to minimise environmental impacts. The selection of the dredging equipment will be determined by a number of factors such as plant availability, water depth, volume of material to be dredged, sediment quality, location of dredged material disposal, time available for vessel to remain in the channel, construction schedule, costs and environmental considerations. The environmental considerations pertaining to the use of dredging for the pipeline installation and the recommended mitigation measures are discussed in *Section 4.1*.



* SEPARATE TRENCHES MAY BE REQUIRED

FIGURE 3.4a - TYPICAL CROSS SECTION FOR SUBMARINE PIPELINE

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Pipelaying

With the pre-trenching installation methods a single lay barge will be used for pipelaying and the conventional pipelay method will be employed. Conventional pipelaying will require a minimum water depth of approximately 5 m. Offshore pipeline installation by a lay barge is considered to be suitable for both the deep and shallow waters in Hong Kong. The lay barge will include a floating pipeline welding and testing facility, where the pipeline is made up, and from which the pipeline is laid directly on the seabed.

Post Trenching

Post trenching is carried out subsequent to pipelaying installation to sink the pipeline to the desired depth in the seabed. Most recent developments on post trenching include mechanical pipeline trenching (ploughing), jetting or fluidization, each of which are detailed in *Section 4.1*.

During post-trenching, marine mud removed from the path of the jet sled or `plough' is deposited along the side of the pipe route. Disposal of trenched material is therefore not necessary.

Backfilling

Irrespective of the pipeline installation method, the trench will have to be reinstated after pipeline installation and the pipeline protected with a cover layer sufficient to resist damage by anchors or fishing activities. The seabed will be restored to its original level.

3.4.4 *Submarine Power Cable for Airport Projects*

A submarine power cable (SPC) will be laid within the proposed services corridor for the AFRF to supply the required power to the CAD Radar facilities on Sha Chau and also for the AFRF at Shau Chau. It should be noted that the proposed route of the SPC is tentative and will not be finalised until the detailed design and therefore may alter. The tentative route of the SPC and its location relative to the AFRF twin submarine pipeline is indicated on *Figure 3.4b*. The SPC will be laid at a distance of 150 m from the twin submarine pipeline. It is considered preferable to lay the submarine pipeline or SPC first, but not concurrently, as both require a works area within the gazetted services corridor and thus will have to share the available area. There will be no land-based construction involved for the power supply to the AFRF. Preliminary details on the nature of the power cable and the method of installation are given below.

Nature of the Cable

The submarine power cables used are likely to be steel wire armour protected, cross linked polyethylene protected, 3 cores cable with an outer diameter of approximately 5 inches and designed for 11 KV operation.

Method of Power Cable Laying and Burying

The cable placed on the sea bottom will be buried to a depth of 3 metres by means of a specialized cable burying machine comprising a plough with the assistance of water jets. The installation action is automated with no manual digging or laying operations. The burying depth can be monitored/ controlled continuously by the use of a pendulum sensor which is equipped on the movement frame of the burying machine. As the water jet pushes aside the sediment in the seabed, the cable lay drops from the plough and automatically lays itself into the trench. The backfilling action is also automatic with the soil returning to its original position as the plough moves forward. The cable will be protected from outer damage, including that from waves and currents, by the use of an articulated pipe and a concrete mat laid over the pipeline.

Future Repair Method

In the event that the cable is found faulty, the faulty location can be pinpointed by instrumentation. The faulty section (approximately 50 m) will be exposed by water jetting and suction, then lifted onto the work barge for repair. After repair, these actions will be reversed to reinstate the cable.

3.5 *PRE-COMMISSIONING AND COMMISSIONING ACTIVITIES*

Pipeline pre-commissioning and commissioning operations consist of the following stages:

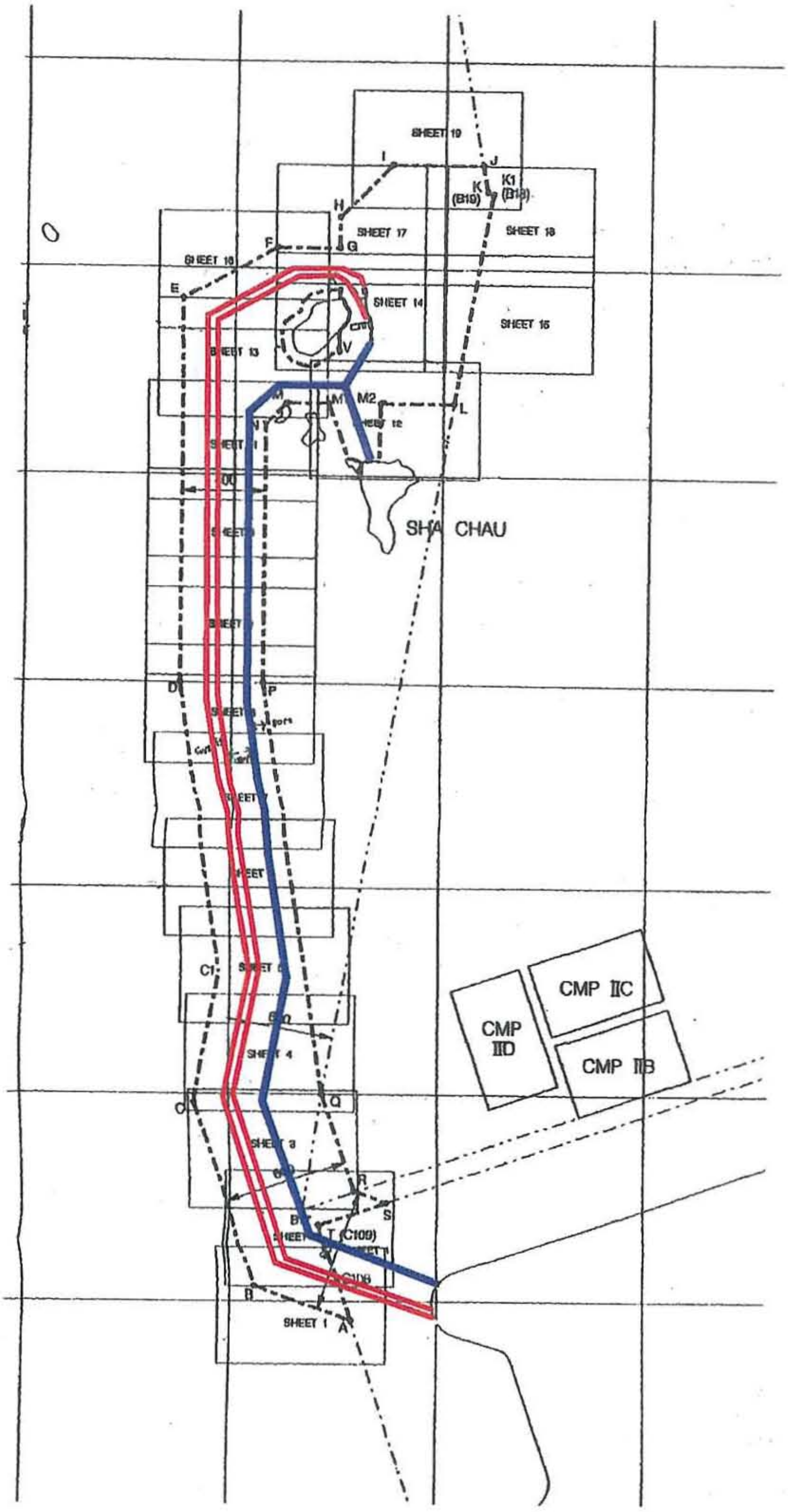
- Post Pipelay Operation

  Pipeline flooding is normally carried out as soon as possible after the completion of the pipelaying. The pipeline can either be flooded from shore to subsea or subsea to shore. The flooding "pig" [1] train normally consists of bi-directional "pigs" including cleaning "pigs" and a "pig" fitted with a gauge. The cleaning "pigs" are used for removal of minor surface rust and millscale on the pipewall, whilst the gauging "pig" is to determine if the pipeline is free of gross deformations in cross section. The volume of water required will be approximately equivalent to the volume of the pipe to be cleaned, which will be around 70-320m^3.

- Post Tie-in Operation

  Post tie-in operations will involve system hydrostatic testing, dewatering and drying.

(1) Robotic device used in pipeline pre-commissioning and commissioning operations.



KEY

POWER CABLE

SUBMARINE PIPELINE

FIGURE 3.4b - TENTATIVE ROUTE OF POWER CABLE AND SUBMARINE PIPELINE WITHIN SERVICES CORRIDOR

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- System Pressure Test

  In general, the pipeline will be tested at 1.25 times the maximum allowable operating pressure and the test pressure must be held for a minimum of 24 hours.

- Pipeline Dewatering

  Dewatering is the most critical operation as the efficiency of the dewatering operation will determine the time required for drying. Large air compressors will be employed due to the length of the completed pipeline.

- Drying

  All free water must be removed from the pipeline prior to any fuel transfer operations to prevent formation of corrosive products. There are a number of drying methods such as methanol/glycol swabbing; dry air drying; vacuum drying; or a combination of these techniques. The vacuum drying method is considered most suitable for this application provided vacuum drying plants can be sited at both ends of the pipeline. Vacuum drying removes free water from a pipeline by reducing the pressure such that the water evaporates at ambient temperature. Hydrocarbon gas can be introduced directly upon completion of drying operations due to the very low air content of the pipeline. The drying process will expel residual water as water vapour from both ends of the pipeline.

· Commissioning

  Nitrogen purging may be carried out as a contingency operation to prevent the ingress of air and/or air borne water in the pipeline. However, if fuel is available immediately after completion of the vacuum drying operations, nitrogen purge/fill will not be required.

The pipeline would be ready for trials with introduction of fuel after the above preparation procedures.

Water and Chemical Requirements

Fresh water or seawater will need to be treated for all pre-commissioning operations. The water should be filtered to remove suspended solids and treated with typical water treatment chemicals, namely, polymeric amines (corrosion inhibitor), ammonium bisulphite (oxygen scavenger), sodium hypochlorite (biocide). Typical chemical dosage is given in *Table 3.5a*.

Table 3.5a *Estimated Chemical Dosage Requirements*

Chemical Treatment	Typical Chemicals	Dosage
Corrosion Inhibition	Polymeric amines	200 ppm
Oxygen Scavenger	Ammonium bisulphite	150 ppm
Biocide	Sodium hypochlorite	200 ppm

3.6 CONSTRUCTION PROGRAMME

The construction and commissioning of the AFRF is likely to take around 22 months to complete, with the commissioning lasting 4 months. The proposed project programme is as outlined in *Section 3.8*. The estimated durations for the construction of various sections are presented in *Table 3.6a*. Parallel construction activities are envisaged for the offshore fixed receiving facility, SER Base and submarine pipelines. Most construction activities are likely to be limited to daytime (0700:1900). However it is anticipated that some construction activities associated with the AFRF will proceed 24 hours per day and 7 days per week.

Table 3.6a *Construction Durations*

Facilities	Activities	Approximate Duration (months)
Offshore Fixed Receiving Facility		
	Piling	2-3
	Deck	6
	Building and Services	6
SER Base		
	Piling	2
	Deck	6
	Building and Services	6
Submarine Pipeline	Pipe laying	1-3
Submarine Power Cable	Installation	1-2
Turning Basin	Dredging	2-3
AFRF Construction Period		18*
AFRF Commissioning Period		4
AFRF Construction and Commissioning Period		22*

*Note : Certain construction activities are concurrent

Interface with Other Construction Contracts

There are a number of ongoing or planned construction activities in the vicinity of the AFRF and their schedules are listed in *Table 3.6b*. The construction work for the AFRF is scheduled to commence in July 1995, after the completion of substantial portions of the Tung Chung Reclamation and Airport Reclamation.

Table 3.6b *Schedule of Construction Activities in the Vicinity of the Study Area*

	Start Date	Finish Date
New Airport Platform Formation	1992	April 1996
Tung Chung Reclamation Phase 2a	late 1993	late 1994
Tung Chung Reclamation Phase 2b	early 1994	early 1995
NLE Tung Chung Section	late 1993	mid 1996
Airport Rail Tung Chung Station*	late 1993	late 1996
Airport Rail Lantau Formation*	late 1995	mid 1996
CAD Jetty on Sha Chau	mid 1994**	mid 1995
Submarine power cable from Airport Platform to CAD Radar on Sha Chau	late 1995	early 1996
FMC Fill Winning East of Sha Chau	no timing at present	no timing at present
Black Point Power Station	early 1993	end 1995

Source : NAPCO
Note : * Tentative Schedule due to funding
** works underway

3.7 OPERATION OF THE FACILITY

3.7.1 *General Activities*

The AFRF, subject to approval, will operate 24 hours a day and will involve the following activities:

- vessel loading off-airport;
- vessel transit via designated route to the fuel receiving facility;
- vessel berthing at receiving facility;
- hook-up of unloading arms;
- discharge of aviation fuel using unloading arms and via a pipeline to on-airport storage using vessel pumps or possibly booster pumps;
- disconnection of unloading arms;
- vessel ballasting (probably simultaneous operation to fuel discharge);
- vessel unberthing and departure via designated route to off-airport location; and
- off-airport and facility site deballasting.

From *Table 3.7a* below, between 1 to 4 vessels will use the AFRF per day depending on vessel size and at most, two vessels can berth at the facility at any one time due to the AFRF size.

Table 3.7a ***Daily Trips Based on Vessel Size***

Year	Tonnes/day	No of Daily Return Trips		
		3,000 dwt	5,000 dwt	10,000 dwt
1997	8,000	2.7	1.6	0.8
2004	10,300	3.4	2.1	1.0

During a typhoon no fuel will be delivered to the facility. Extra delivery of fuel will thus be required to replenish stock after this enforced downtime, estimated to be approximately an extra 40 to 50% within a one week period.

Aside from the normal fuel unloading operations, routine inspection and repair and maintenance of the vessels, dolphin, pipelines and associated equipment will be carried out at the facility.

The emergency operations likely to be encountered at the facility will include:

- fire fighting, towing or assistance to vessels;
- spill clean-up en route to or at receiving facility;
- fire fighting at receiving facility;
- airlift operations;
- security operations; and
- typhoon protection procedures.

3.7.2 *Vessels*

Outwith the vessel access fairway and turning basin the fuel vessels will travel at around 10 knots in the designated lanes shown in *Figure 3.7a* from an off-airport location to the AFRF. Anticipated transit time from Tsing Yi, one possible off-airport location, would be 1.5 hours.

It is anticipated that the dedicated fuel shuttle vessel size would be between 3,000 - 5,000 dwt. Other vessels of up to 10,000 dwt would allow air carriers the opportunity to bring in larger competitively priced fuel parcels on an infrequent basis, where necessary.

It is important for AFRF operational reasons that vessels should be highly manoeuvrable and able to approach the facility at very low speed to eliminate damage to the AFRF. For this reason it is expected that all fuel vessels would be required to approach the facility through a system of gated buoys at low speeds of 0.2–0.3 m/s (maximum 0.6 knots). In order to cost-effectively maximise manoeuvrability of the dedicated shuttle vessels it is proposed that they should comprise a single propeller vessel with a 'Schilling' rudder and bow thrusters, which will afford the vessel around the same manoeuvrability of a twin propeller vessel with bow thrusters. As the vessels may have to pass through the Ma Wan Channel, the crew would be required to be trained to respond to the Vessel Traffic Management (VTM) system to be installed to control vessels in this channel (*Annex E*). Further discussion of fuel vessels is included in *Section 5.1*.

3.7.3 *Vessel and Facility Solid and Liquid Waste Disposal*

The following sources of waste arisings will be generated during the operation of the AFRF:

- Sewage effluents
- Domestic Waste
- Chemical Waste
- Commercial/Industrial Wastes
- Office Wastes
- Marpol Wastes
- Foam and Fuel Spill Remediation Chemicals

The disposal requirements of the above identified solid and liquid wastes necessary to prevent environmental impacts are discussed in *Section 5.3*.

3.7.4 *Minor Fuel Spills associated with Coupling and Uncoupling Activities*

Minor aviation fuel spills associated with coupling and uncoupling activities may occur from time to time. Areas where un/coupling activities would be undertaken or such spills could occur would be fitted with drip tray/spill collection and temporary storage systems.

3.7.5 *Turning Basin and Access Channel Routine Dredging*

The AFRF would only be required to be fully operational for a period of 5–7 years after which it would act as an emergency back–up facility. During the fully operational period there would be no routine maintenance dredging programme. During subsequent back up and emergency use, maintenance dredging would be required intermittently to remove sediments settled within the turning circle and access channel. The frequency of maintenance dredging is not presently known, although it is likely to be relatively infrequent given the existing natural water depths in the vicinity of the proposed location. The sedimentation study presently underway by PAA will provide this information.

3.8 PROJECT PROGRAMME

The AFRF will be required to be operational from day one of the Chek Lap Kok Airport opening, scheduled for June 1997. The key dates for the AFRF project programme are as tentatively proposed in *Table 3.8a* below.

Table 3.8a *Key Dates for the AFRF Project Programme*

Activities	**Key Dates**
Gazettal	late October 1994
Design	late October 1994 to April/May 1995
Construction and Commissioning	July 1995 to June 1997
Operation	June 1997

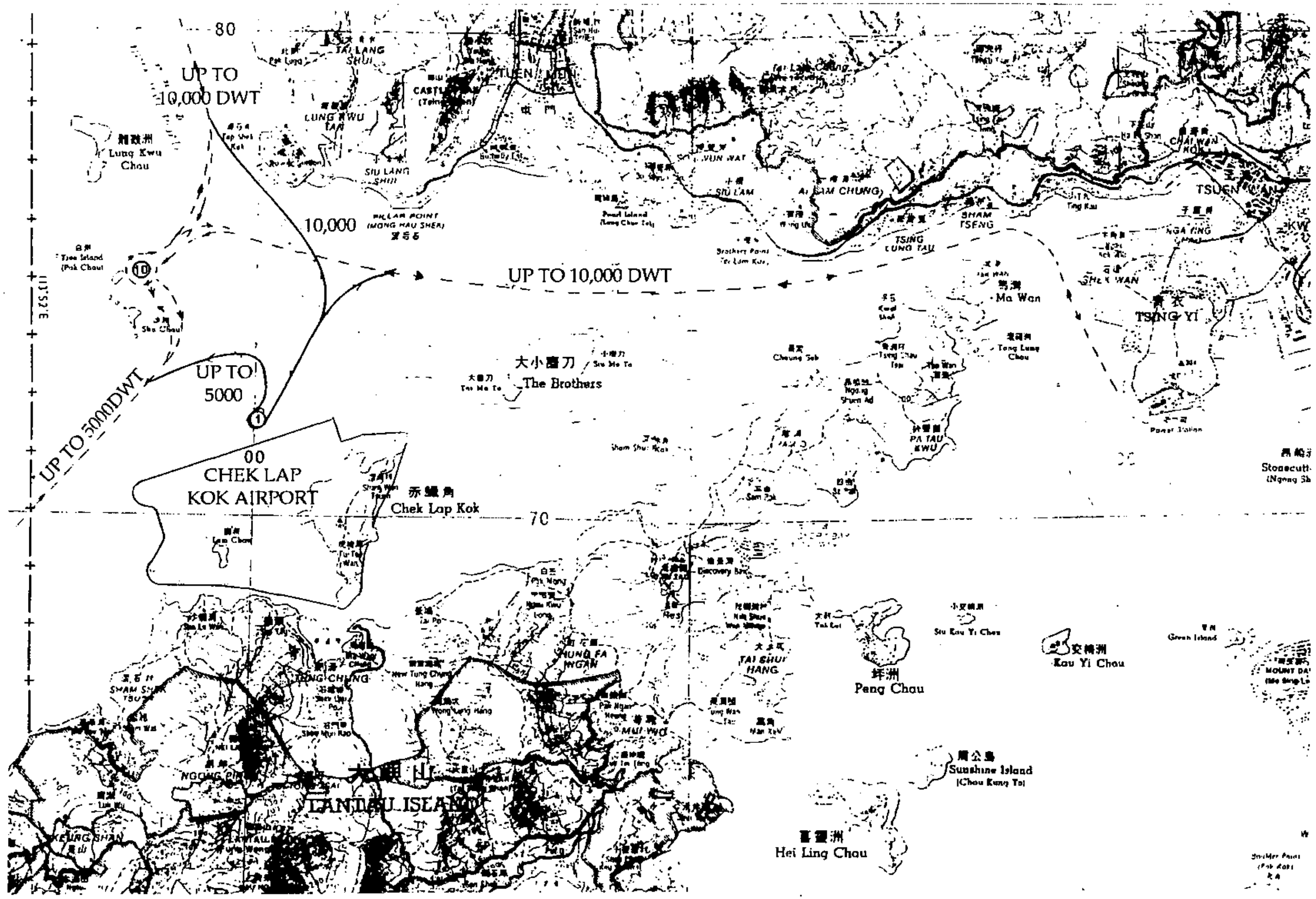

FIGURE 3.7a - POSSIBLE AVIATION FUEL ACCESS ROUTES

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4 CONSTRUCTION PHASE ASSESSMENT

4.1 CONSTRUCTION PHASE WATER AND SEDIMENT QUALITY

4.1.1 *Introduction*

Potential water quality impacts may arise from the construction of the proposed AFRF, as a result of the construction of the vessel turning basin and access fairway, and associated twin pipeline construction activities. This section comprises a more detailed and specific examination of the key water and sediment quality impacts likely to arise as a result of the AFRF construction at the preferred location at Sha Chau.

A key issue will be the methodology employed during the construction of the facility, as there are several options available regarding the type of dredging and pipeline installation methods as discussed within this section, which will result in varying degrees of water quality impacts. These associated impacts have been assessed, detailing the most environmentally acceptable methods and appropriate mitigation measures to minimise potential impacts on water quality to acceptable levels.

4.1.2 *Statutory Requirements*

Marine Waters

Under the Water Pollution Control Ordinance, Hong Kong waters are subdivided into 10 Water Control Zones (WCZ). Each gazetted WCZ has a designated set of statutory Water Quality Objectives (WQO). The proposed AFRF site falls within the North Western Waters WCZ, which was gazetted in April 1992. Of particular relevance to this EIA Study is the suspended solid water quality objective for this WCZ which is as follows:

- Waste discharges shall neither cause the natural ambient level to be raised by more than 30% nor give rise to accumulation of suspended solids which may adversely affect aquatic communities; and

- Waste discharges shall not cause the annual median of suspended solids to exceed 20 mg per litre.

Marine Sediments

The sediments are classified according to their level of contamination by toxic metals as stipulated in the *Environmental Protection Department Technical Circular No. 1-1-92, Classification of Dredged Sediments for Marine Disposal.* The contamination levels presented in the Technical Circular serve as criteria for determining the disposal requirements of the dredged sediments. 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 receptors 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.

Class C – Seriously contaminated material, which must be dredged and transported with great care, which cannot be dumped in the gazetted marine disposal grounds and which must be effectively isolated from the environment upon final disposal.

For sediments to be identified within a particular class, it should be noted that only the concentration of one metallic species need be exceeded. EPD contamination criteria of marine sediments delineating these classes are shown below in *Table 4.1a*.

Table 4.1a *Classification of Sediments by Metal Content (mg/kg dry weight)*

Class	Cd	Cr	Cu	Hg	Ni	Pb	Zn
A	0.0–0.9	0–49	0–54	0.0–0.7	0–34	0–64	0–140*
B	1.0–1.4	50–79	55–64	0.8–0.9	35–39	65–74	150–190
C	1.5 or more	80 or more	65 or more	1.0 or more	40 or more	75 or more	200 or more

*Note: It should be noted that an error in the Class A contaminated criteria is contained within EPD TC No 1-1-92, and it has been assumed that the upper limit for Class A zinc contaminationis in fact 149 mg/kg rather than 140 mg/kg stated.

General Requirements

All contractors involved in the construction of the AFRF will be required to operate in accordance with the *Marine Department General Conditions for Dredging and Backfilling at Marine Borrow Areas (Annex E).*

4.1.3 *Baseline Conditions*

Existing Water Quality

The waters in the study area fall within the transition zone between oceanic and estuarine conditions, being located within the mouth of the Pearl River estuary. This exerts a strong influence upon the characteristics of the receiving water body as 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. Changes in silt and pollutant loads being released by Pearl River create seasonal variations in water quality, while the large influx of freshwater from the Pearl River catchment during the wet season also results in sharp salinity gradients, and subsequent changes in temperature and dissolved oxygen. During the dry winter months the water column is well mixed as oceanic waters move northwards into the Pearl River estuary due to the greatly reduced influx of freshwater from Pearl River.

The water quality in the study area of the North Western Waters is well documented by the routine monthly EPD marine water quality monitoring programme. The most useful source is provided by Station NM6 located between Sha Chau and Chek Lap Kok. NM3 and NM5 also provide an indication of the water quality in the Study Area. In addition, several field studies have investigated the baseline water quality conditions within the vicinity of the Study Area, including the East Sha Chau Monitoring Programme conducted to monitor the disposal of contaminated muds within the East Sha Chau Contaminated Mud Pits (CMPs).

A summary of EPD monitoring data (for 1993) is given in *Table 4.1b*, and the sampling locations are shown on *Figure 4.1a*. The summary data indicates that these North Western Waters are well oxygenated in both surface and bottom layers throughout the year, and biological oxygen demand (BOD) and E.coli levels are generally low, except south of Tuen Mun due to a localised effect of sewage discharge in the area, with the highest levels typically measured during the wet season. Seasonal variations are also evident in the oxidised nitrogen values and chlorophyll–a concentrations.

Overall the mean water quality conditions are considered to be good in these North Western Waters, as discussed below, although the water quality of beaches along the shoreline of Castle Peak Road is generally poor as a result of sewage discharge, and discharge from the Tuen Mun nullahs.

Currents

Tidal divergence and convergence in the Study Area creates areas of slow current movement as indicated by monitoring within the area. The currents are mainly within the range of 0.2–0.4 m/s (0.4–0.8 knots), of which more than 68% of the current speeds are below 0.4 m/s. The tidal flow is of the order of 0.1–0.2 m/s (0.2–0.4 knots). Suspended solid concentrations tend to settle rapidly as a result of these weak currents. The ebb tides flow down through Urmston Road, bifurcate north west of Chek Lap Kok to flow south down the west coast of Lantau, southeast round the north and south of Chek Lap Kok island, and east along the southern Tuen Mun shoreline. During the flood tides water flows west from Victoria Harbour back round Chek Lap Kok and north up the west coast of Lantau to converge once more in the Study Area.

Suspended Solids

The levels of suspended solids (SS) in the water varies with the season and tide as well as the flow and depth. There have been a number of previous studies in the area for the Chek Lap Kok Airport developments where extensive water quality surveys have been conducted which have verified this including those associated with the Chek Lap Kok Airport. However, with the ongoing Airport Core Programme (ACP) dredging and reclamation work on North Lantau, the baseline SS levels in the water within the Study Area is likely to be presently elevated. The EPD monitoring data collected in 1992 and 1993-4 have indicated an overall increase in SS levels in the area. A summary of these results is presented below (*Table 4.1c*), and at each location the minimum recorded values for 1993-4 were greater than the previous year in each area, as were the overall means.

Table 4.1c ***Comparison of EPD Suspended Solid Monitoring Data (1992 and 1993-4)***

Year	**East Sha Chau NM6**	**South of Tuen Mun NM3**	**Urmston Road NM5**
1992	9.4 (2.5-16.8)	13.8 (2.8-29.0)	12.9 (2.5-16.8)
1993-4	19.8 (6.5-75.3)*	14.3 (6.6-24.4)	17.2 (7.1-34.3)

Note * EPD note that this is an odd occurrence which should be discounted.

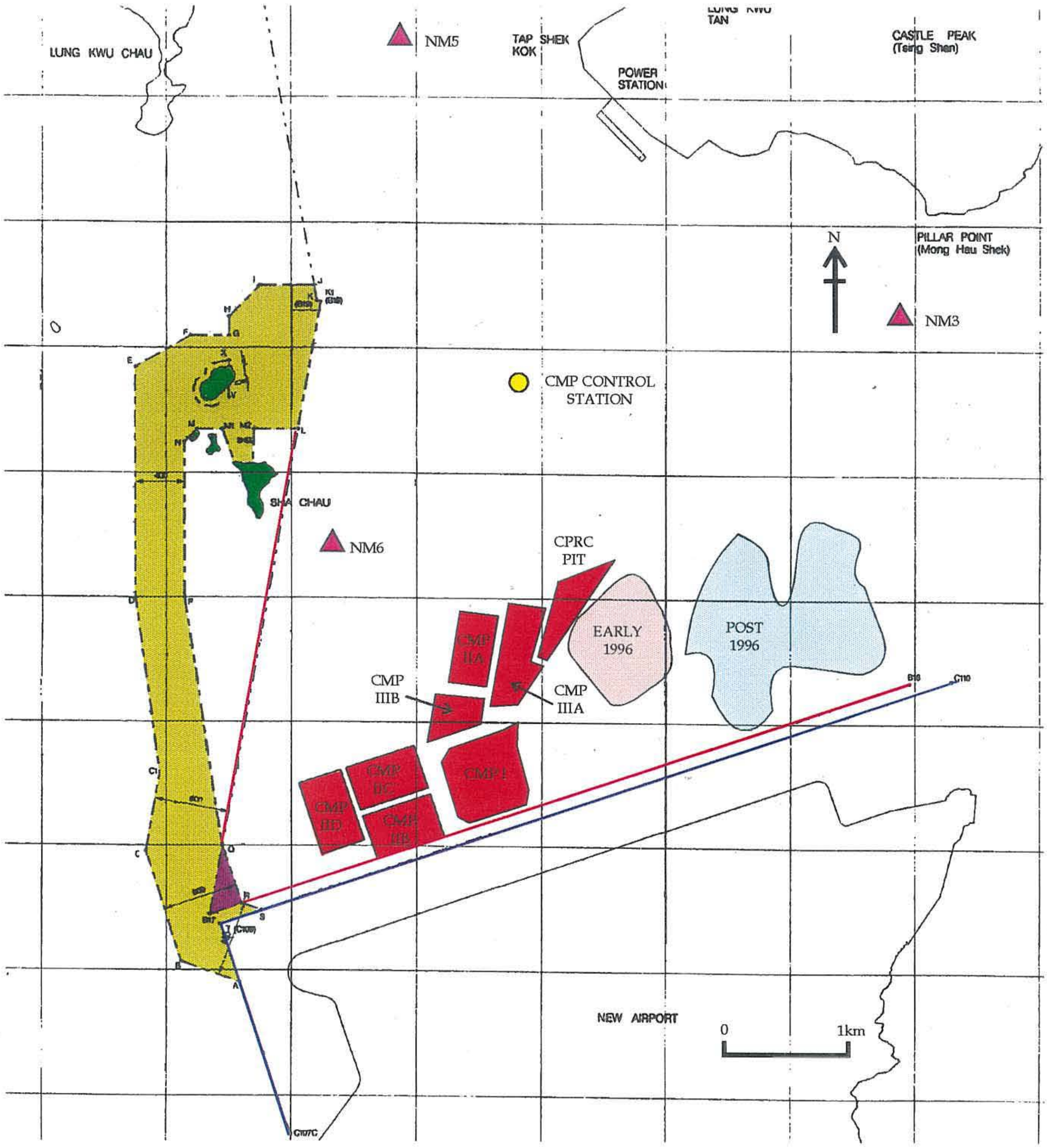
No consistent long-term averages prior to the dredging and construction activities within the Chek Lap Kok area exist, however EPD data from 1991-1994 indicate the water quality conditions in the area. Measurements carried out at the EPD stations (NM6, NM3 and NM5) during the period from 1993-1994 all present similar average values of 20 mg/l, as detailed by the EPD. The minimum value range was as low as 7 mg/l, and although NM6 recorded a maximum of 75 mg/l which EPD revealed to be an odd event which should be discharded, all other mean measurements at this station were below 25 mg/l. In addition, a recent control station was set up during the monitoring programme of the CMPs, located at a distance of over 1.5 km from the CPMs, in order to establish baseline water quality unaffected by the CMPs (see *Figure 4.1a*). Data from this station is indicative of the water quality in the vicinity of the AFRF Study Area, and indicates background values in the range of 2 mg/l to around 100mg/l, showing that occasional peak occurences of SS occur. The results therefore indicate rapid settling of SS levels due to slow currents, which generally decreases during periods of high current speeds, resulting in high SS levels which may be compounded by resuspension of settled fine sediment on the sea-bed due to the relatively shallow water depth in the area (5 to 9 m).

Table 4.1b *Summary Statistics of Water Quality of North Western Waters*

Determinant		East Sha Chau NM6	South of Tuen Mun NM3	Urmston Road NM5
Number of Samples		8	8	8
Secchi Disc (m)		1.0 (0.4-1.6)	1.1 (0.8-1.4)	0.9 (0.5-1.3)
Turbidity (NTU)		19.9 (7.2-50.6)	13.3 (6.6-24.4)	70.4 (9.8-449.3)
SS (mg/l)		19.8 (6.5-75.3)	14.3 (6.6-24.4)	17.2 (7.1-34.3)
Salinity (ppt)	Surface	24.5 (6.2-33.5)	27.5 (18.5-33.4)	24.6 (8.2-34.4)
	Middle	25.7 (7.8-33.5)	30.8 (27.6-33.5)	29.3 (23.3-33.4)
	Bottom	30.7 (27.6-33.6)	31.1 (27.3-33.5)	30.2 (24.0-33.4)
DO (mg/l)	Surface	7.2 (5.6-8.7)	6.9 (6.1-7.6)	6.8 (5.8-7.6)
	Middle	7.0 (5.2-8.0)	6.3 (4.5-7.7)	6.4 (5.4-7.7)
	Bottom	6.6 (4.5-7.9)	6.0 (3.9-7.4)	6.2 (5.1-7.4)
	Depth Average	7.0 (5.1-8.0)	6.4 (5.2-7.6)	6.5 (5.4-7.6)
DO (% satn.)	Surface	99.8 (83.1-121.4)	95.3 (90.7-103.5)	94.2 (87.0-101.3)
	Middle	94.2 (77.7-102.7)	85.5 (61.8-99.7)	88.4 (72.3-98.4)
	Bottom	90.0 (63.5-103.1)	81.1 (52.0-94.5)	84.5 (70.4-94.6)
pH		8.2 (8.1-8.5)	8.2 (8.0-8.4)	8.2 (8.1-8.4)
BOD_5 (mg/l)		0.7 (0.4-1.0)	0.7 (0.5-1.0)	0.7 (0.4-1.0)
PO_4 -P (mg/l)		0.022 (0.002-0.047)	0.026 (0.004-0.045)	0.03 (0.007-0.047)
TP (mg/l)		0.10 (0.05-0.17)	0.12 (0.05-0.23)	0.12 (0.06-0.25)
Chlorophyll a (µg/l)		1.29 (0.40-4.35)	0.92 (0.27-2.95)	1.20 (0.30-4.47)
Temperature(°C)	Surface	22.8 (15.0-29.9)	22.6 (15.2-28.9)	22.8 (15.2-29.7)
	Middle	21.1 (14.9-29.6)	21.8 (15.0-28.5)	22.3 (15.0-28.8)
	Bottom	21.8 (14.9-28.5)	21.3 (15.0-28.0)	22.1 (15.0-28.6)
E. coli (no./100ml)		22.8 (3.0-156.7)	261.221 (70.0-986.7)	292.13 (110.0-1766.7)

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

Source: Environmental Protection Department monitoring results, January 1993 to April 1994



KEY

- SHA CHAU
- AFRF GAZETTED AREA
- IMPINGEMENT ON CMP
- CONTAMINATED MUD PITS (CMPs)
- LIMIT OF NEW AIRPORT GAZETTED AREA
- LIMIT OF EAST SHA CHAU GAZETTED DUMP AND BORROW AREA
- EPD WATER QUALITY MONITORING STATION
- CMP CONTROL STATION
- PROPOSED CMPs

FIGURE 4.1a - LOCATION OF WATER QUALITY MONITORING STATIONS AND CONTAMINATED MUD PITS

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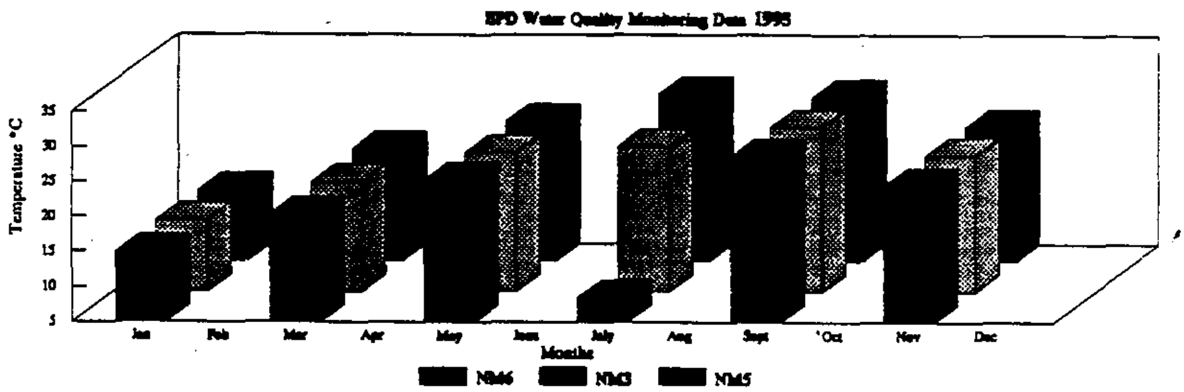
Temperature

Within the area the measured water temperature fluctuates seasonally both as a result of the climatic variation, and due to fluctuations in salinity resulting from increased freshwater loadings from Pearl River during the wet-season. In addition, the increased levels of SS during the summer months generally leads to retention of heat within the water column. Based on existing data collected during the monitoring at East Sha Chau and EPD data (from stations NM6, NM3, NM5) the water temperature reflects the seasonal climatic variations, decreasing from October to reach its lowest point in January and then rising again to a seasonal maximum in September, as indicated in *Figure 4.1b*.

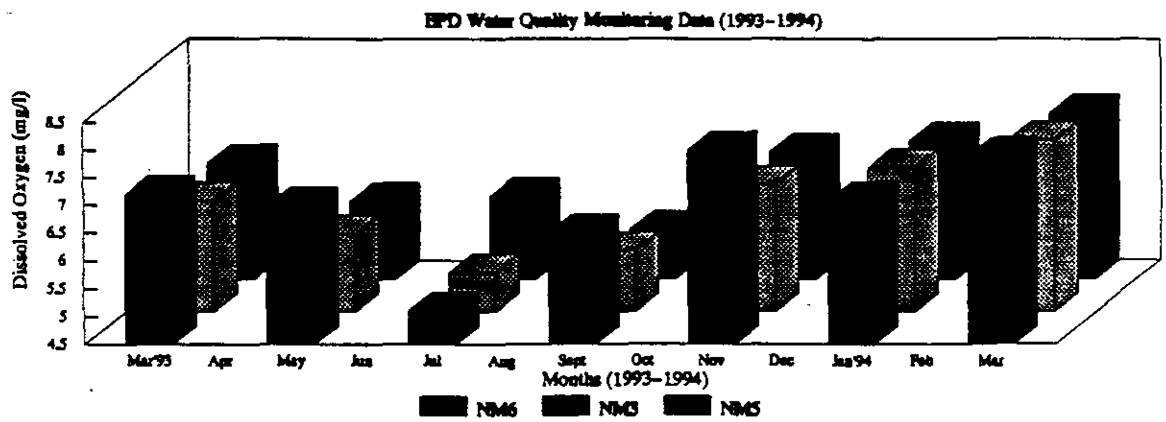
Figure 4.1b ***Annual Temperature Fluctuation***



Dissolved Oxygen

Overall the North Western Waters are considered to be well oxygenated. EPD monitoring data within the vicinity of Sha Chau (NM6, January 1993-April 1994) indicated the DO ranges from a minimum values of 4.5 mg/l in the bottom layer (minimum depth average of 5.1 mg/l), to a super saturated maximum of 8.7 mg/l in the top layer of the water column (maximum depth average of 8.0 mg/l). The seasonal changes in temperature result in marginal changes in dissolved oxygen (DO) levels recorded as indicated on *Figure 4.1c*, as oxygen dissolves more readily in colder water. Levels measured during monitoring of the East Sha Chau CMPs indicated this slight increase in DO from the end of August 1993 to December 1993.

Figure 4.1c ***Annual Fluctuation of Dissolved Oxygen Concentrations***



Existing Marine Sediment Quality

A large percentage of the bottom sediment along the proposed possible pipeline route from Sha Chau consists of marine mud (60–80%) ie. silt and clay. Hydrographic and geophysical surveys were recently conducted on behalf of PAA [(1)], in the area of the proposed AFRF to determine the sea bed and underlying geological horizon levels. This information provides a clear indication of the bottom sediment characteristics in the Study Area. The marine deposits on the sea bed consist mainly of soft silty clay and sometimes sand at the base of this layer. These deposits are underlaid by alluvium, a stiff silty sandy clay and dense silty fine/course sand.

As part of this EIA study sediment sampling was conducted at 15 locations within the Study Area using a surface grab sampler, to gain an indication of the likely levels of contamination within the marine sediments which will be disturbed during construction of the AFRF. The locations were specifically located along the gazetted pipeline corridor, the access fairway, turning basin, and at the proposed site of the fuel receiving facility at Sha Chau as detailed on *Figure 4.1d*. The sediments were analysed (USEPA Method 3050) for the seven criterion heavy metals: cadmium, chromium, copper, mercury, nickel, lead and zinc, and the results are detailed in *Table 4.1d*.

In addition, data obtained from EPD bottom sediment sampling (Marine Water Quality 1993–1994) at NS3, NS4 and NS6, illustrated on *Figure 4.1d*, indicate the sediment characteristics in the Study Area, and reflected the findings of the additional sampling.

Table 4.1d ***Marine Sediment Sampling within the Study Area, September 1994.***

	Heavy Metal Parameter (mg/kg dry weight)							Class***
Sample Number**	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Mercury (Hg)	Nickel (Ni)	Lead (Pb)	Zinc (Zn)	
1	0.2	27	27	<0.1	27	53	110	A
2	0.2	29	29	<0.1	29	48	86	A
3	0.4	28	43	0.1	28	71*	150*	B
4	0.2	24	36	<0.1	24	49	110	A
5	0.1	26	38	0.1	25	50	110	A
6	0.4	26	39	<0.1	26	65*	120	B
7	0.2	17	17	<0.1	17	34	63	A
8	0.2	28	37	<0.1	28	56	97	A
9	0.2	32	43	<0.1	32	53	110	A
10	0.2	30	40	<0.1	30	40	110	A
11	0.2	29	38	<0.1	29	58	96	A
12	0.2	29	39	<0.1	29	49	100	A

(1) Site Investigation around Sha Chau, Hydrographic and Geophysical Surveys, Preliminary Report, Job Number HK79994, May 1994

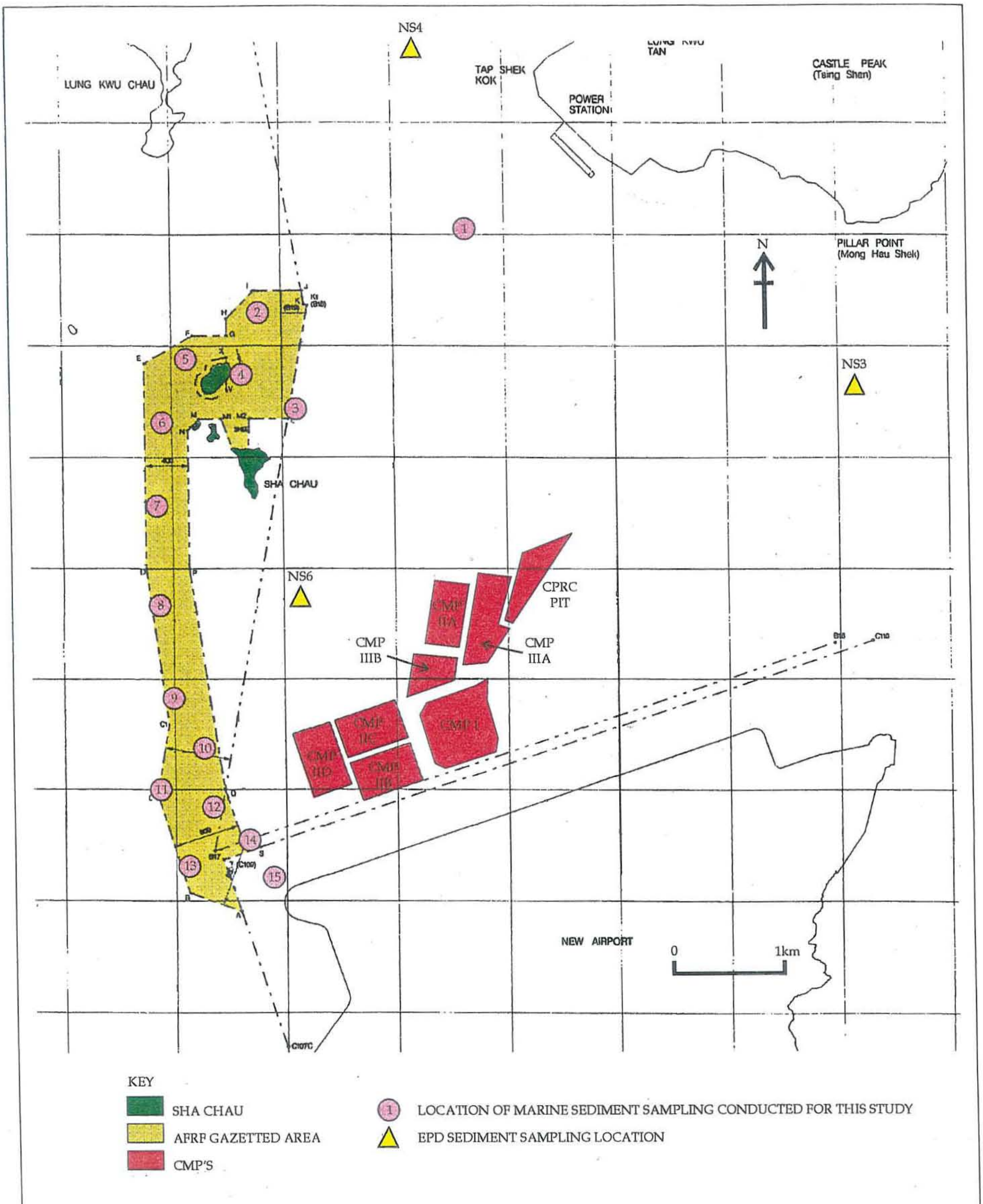


FIGURE 4.1d - SEDIMENT SAMPLING LOCATIONS

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Sample Number**	Heavy Metal Parameter (mg/kg dry weight) Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Mercury (Hg)	Nickel (Ni)	Lead (Pb)	Zinc (Zn)	Class***
13	0.2	30	40	0.1	30	69*	110	B
14	0.2	30	39	<0.1	30	59	110	A
15	0.2	31	41	0.1	31	62	100	A

* Criterion level which places sediment in Class B
** Sample number refers to location indicated on *Figure 4.1d*
*** Classification according to *'EPD Technical Circular No. 1-1-92, Classification of Dredged Sediments for Marine Disposal'*, to indicate contamination level

The EPD sediment data indicates that the level of heavy metal pollutants in Urmston Road, south of Tuen Mun and north of Chek Lap Kok are low, and heavy metal concentrations in sediments of the North Western Waters, although relatively high, are below that found in Victoria Harbour. These reflect the water quality of the Pearl River estuary which dominates the oceanography of this area.

In addition, as can be seen from *Table 4.1d* the dedicated sediment sampling conducted within the Study Area, for this EIA on behalf of PAA, indicate that the majority of the sediments are Class A and are uncontaminated, with the exception of three locations which were found to be Class B due to slightly elevated levels of zinc (sample number 3), and lead (number 3, 6 and 13). The numbers indicated refer to the locations of sampling as shown on *Figure 4.1d*.

Future Conditions

The enforcement of the Livestock Waste Control Scheme, the Sewerage Master Plan for Tuen Mun, Tseun Wan, Kwai Chung and Tsing Yi, and the declaration of the North Western WCZ suggest that the water quality will improve generally in the mid-term in the Study Area, with the reduced pollution loading from the surrounding environment. However, it should be noted that the pollutant loads transported by the Pearl River will still exert a strong influence on the quality of the Hong Kong Waters, and in particular in the AFRF Study Area.

Sensitive Receivers

As identified within the IAR, there are a number of sensitive receivers in the North Western WCZ which may be affected by the construction and operation of the AFRF and any resulting changes in water quality. *Figure 4.1e* shows the locations of the identified Water Sensitive Receivers. These have been listed below in accordance with the HKPSG:

- Chinese White Dolphins (*Sousa chinesis*) – sighted in the marine waters around Sha Chau and Lung Kwu Chau;

- Fishing Grounds – located between North Lantau and Castle Peak;
- Spawning Grounds – favoured spawning grounds for major commercial fishes and prawns are located within the Study Area because of abundant food supply;
- Bathing Beaches – gazetted and non–gazetted bathing beaches are located along the Tuen Mun coastline, namely Upper and Lower Lung Kwu which may be slightly affected by water quality impacts; and
- Castle Peak Power Station - increased particulate matter from SS in seawater supply could block filters and damage cooling water intake pumps. The AFRF site is located within the 5km radius for the Castle Peak Power Station within which the water quality must be maintained below 150 mg/l SS although the tolerable level of a seawater intake for cooling water is considered by EPD to be much lower than this. In addition the Black Point Power Station is scheduled to be commissioned in 1996, and depending on the scheduled progress, may or may not be affected by the AFRS construction.

Further sensitive receivers have been identified in the vicinity of Sha Chau, during the ecological survey, including the penaeid shrimp and other important commercial fish species; the habitat as a nursery and spawning ground of marine animals in general and penaeid shrimps and other food fish in particular; and sea pens and corals. However due to the specific nature of the survey in the vicinity of Sha Chau, it is not possible to identify the full extent of each of these sensitive receivers in the surrounding area.

4.1.4 *Evaluation Criteria*

The Water Quality Objectives and the Technical Memorandum will be the general evaluation criteria. Water quality impacts from the construction of the vessel receiving facility, the twin pipeline construction works within the proposed pipeline corridor, the access fairway and turning basin, and associated dredging activities will be assessed with respect to the North Western Waters WQO, and in relation to the baseline data collated from EPD monitoring data and other recent monitoring programmes undertaken within the Study Area. The WQO of most relevance during the AFRF construction will be the suspended solids (SS) and the dissolved oxygen (DO) level parameters.

SS levels: Marine activities during the construction works for the AFRF must not cause the natural ambient SS level to be raised by more than 30% nor give rise to accumulation of SS.

DO levels: DO levels should not be less than 2mg/l at the sea bottom and above 4mg/l at depth average.

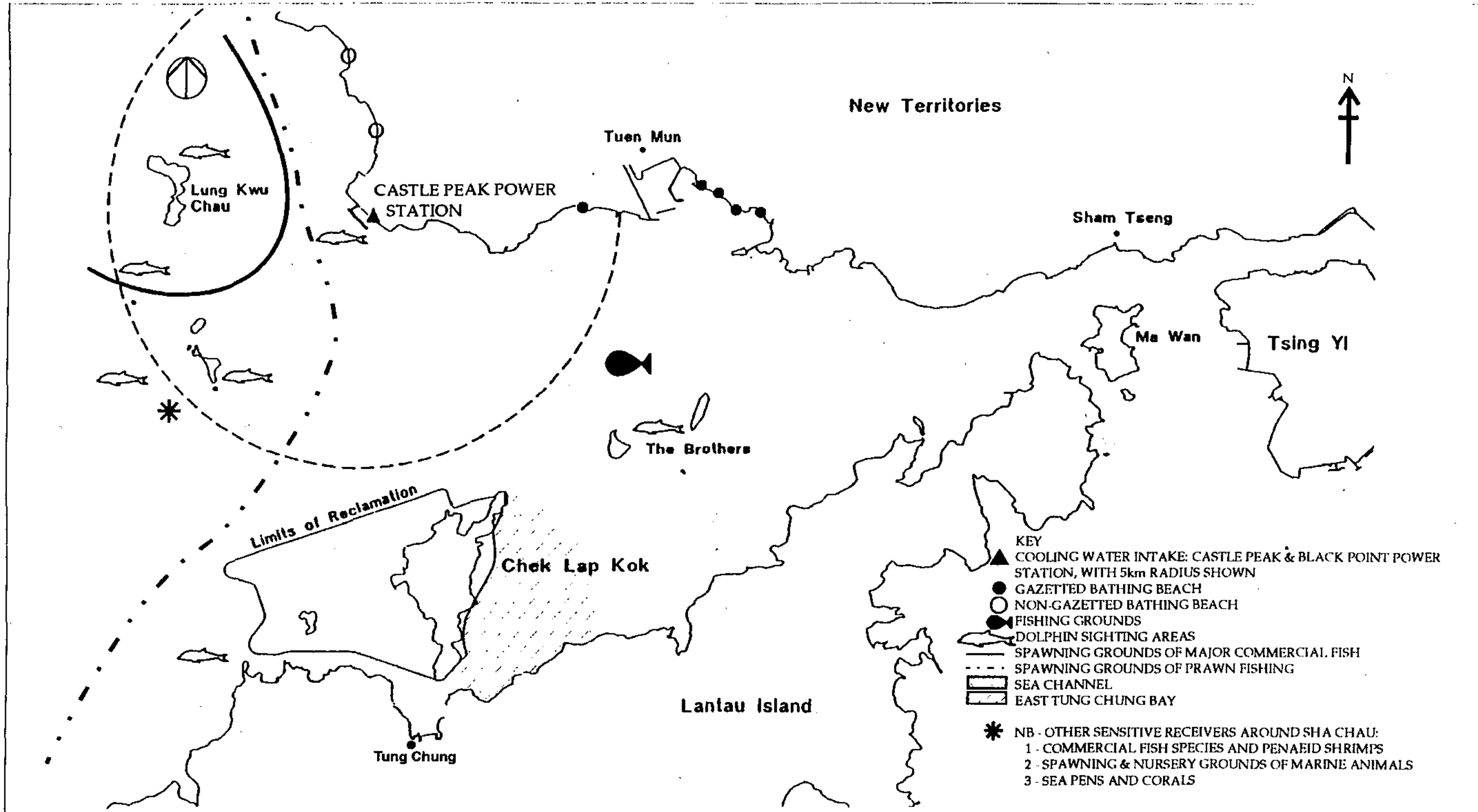

FIGURE 4.1e - LOCATION OF WATER QUALITY SENSITIVE RECEIVERS

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4.1.5 *Dredging and Pipeline Installation*

There are several feasible options regarding the types of dredging and pipeline installation methods which may be used during the construction of the AFRF. Each of these and the associated plant are discussed below to ascertain their environmental acceptability for use during construction of the proposed AFRF. Based on this assessment, recommendations have been made for the preferred, and most practical environmental option.

Dredging Methodology

Dredging operations can be categorised broadly into capital dredging and maintenance dredging. Capital dredging involves bulk excavation of excess volumes of material for large scale deepening or land reclamation, whereas the latter primarily involves the removal of silt in thin layers to maintain navigation facilities in waterways. The construction of the AFRF will require moderate capital dredging, and the aim of this assessment is to determine the most acceptable construction methods, taking into account impacts upon water quality, and sensitive receivers in the Study Area. Maintenance dredging will not be conducted during the fully operational interim 5–7 year period for the AFRF, and thus will only be required during emergency backup AFRF use.

The main phases of dredging are:

- loosening (by means of mechanical and/or suction methods);
- transportation of dredged material, by hydraulic transport in slurry form through pipelines, barges, or trailer suction hopper dredgers; and
- deposition in reclamation or disposal sites.

Differences in the nature of the site of dredging, the material being dredged, and the quantities requiring removal influences the choice of dredging equipment used. Modern dredgers can be classified broadly into hydraulic or suction dredgers, and mechanical dredgers. Some combine the features of both types.

Mechanical Dredgers

Bucket Dredgers

Bucket dredgers, illustrated in *Figure 4.1f*, are stationary in nature and achieve a high level of precision during operation. This type of dredger can dredge a wide range of material types including rock, and is particularly suited for dredging clays and bouldery soils. A bucket dredger performs most efficiently in depths up to 15 m, although some of the larger plant can dredge deeper. It has a continuous chain of buckets attached to a ladder which is lowered onto the sea bed, prior to dredging. During dredging side wires are used to move the dredger laterally. The excavated material, which is cut by the outer rims of the buckets, is retained in the buckets and discharged via a chute to barges moored alongside the dredger. For normal operation, the bucket chain is left slack, but it can be tightened if high precision is required. Larger buckets are generally used for dredging soft materials and smaller buckets used for hard materials including rock.

Backhoe Dredgers

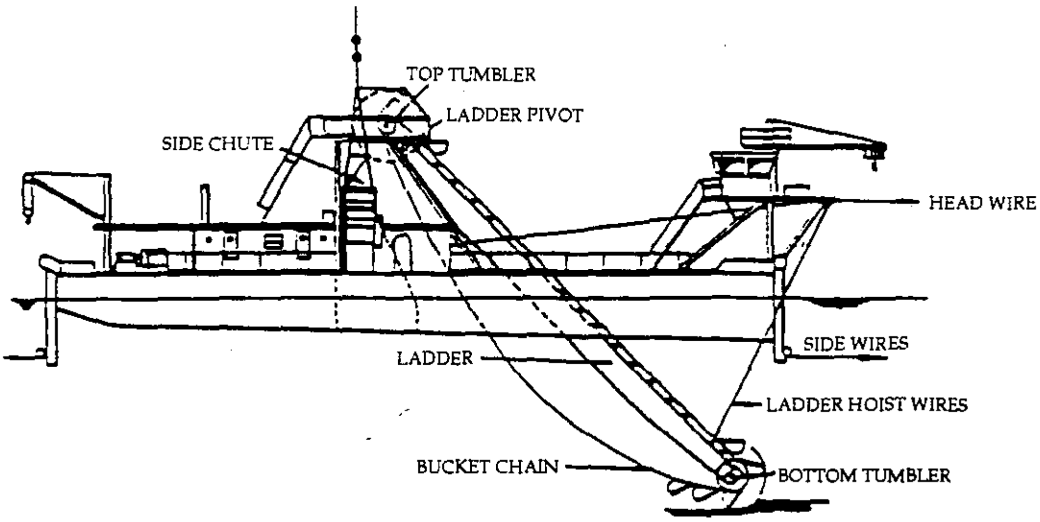
The backhoe consists of a backacter excavator positioned on a barge, as illustrated in *Figure 4.1f.* Backhoe dredgers are suited more to dredging of gravel, bouldery soils and rock. Bucket sizes are chosen according to the type of material to be dredged, but as with the bucket dredger smaller buckets are used for harder materials. The dredging control and accuracy of backhoes are higher than that of a grab dredger making this an option for use during maintenance dredging. A backhoe dredger can achieve tighter tolerance (within 10 to 20 cm, in the presence of tides) than a grab or clamshell dredger. Most backhoe dredgers are only capable of dredging to relatively shallow depths, generally less than 20 m.

Grab Dredgers

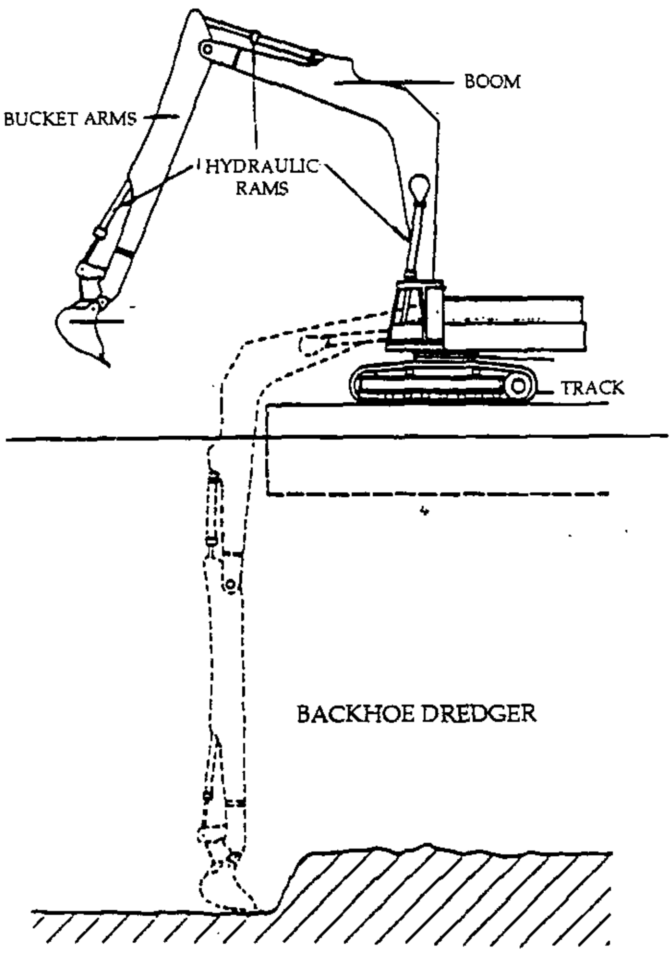
The grab dredger (see *Figure 4.1g*) is one of the most common types of mechanical dredger in use. A grab or clamshell dredger is basically a slewing crane, installed on the end of a barge or pontoon, which is used to raise or lower a suspended grab. Material is removed from the seabed by the weight and cutting action of the jaws of the grab which are closed hydraulically or by winch, and normally deposited into barges moored alongside for transport to the disposal or reclamation site. This allows almost continuous operation, which will minimise the time span of construction operation. Some types of grab dredgers have been constructed with a built-in hopper.

The two main types of grabs commonly used are open form and closed form. The shape and size of grabs (as with bucket dredgers) varies according to the type of the material to be dredged although the digging principle is generally common to all types. Grab dredgers perform most efficiently in loose or soft materials. More recently water-tight closed grabs have been developed for dredging contaminated materials and use in environmentally sensitive areas, to limit turbidity and the dispersion of contaminants/materials during dredging.

Three forms of closed grabs can be used to remove contaminated material, or to minimise sediment dispersion to the receiving water body. These are the orange-peel grab, the closed-box grab and bucket grab with visor. Large orange-peel grabs are a type of grab dredger particularly suitable for removing debris such as old anchor chains from the seabed, because they have a large closing force, but they are generally less suited to dredging where greater accuracy on dredging depths are necessary. Closed-box grabs are generally suited to carrying out the bulk removal of contaminated materials following the removal of overlying debris by orange-peel grabs. Again, however, they are generally less suited to dredging where tight tolerances on depth are necessary. The bucket-type closed grab



BUCKET DREDGER



BACKHOE DREDGER

FIGURE 4.1f - MECHANICAL DREDGERS

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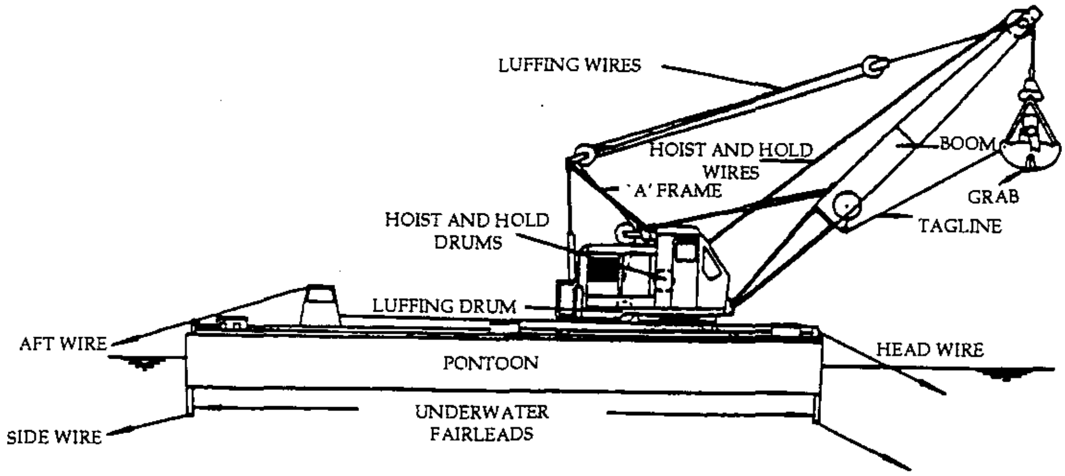
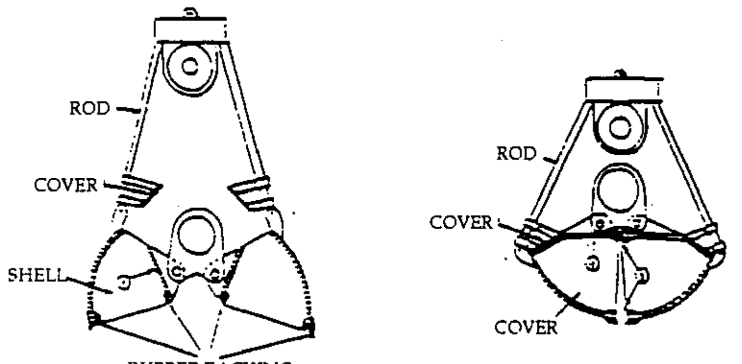
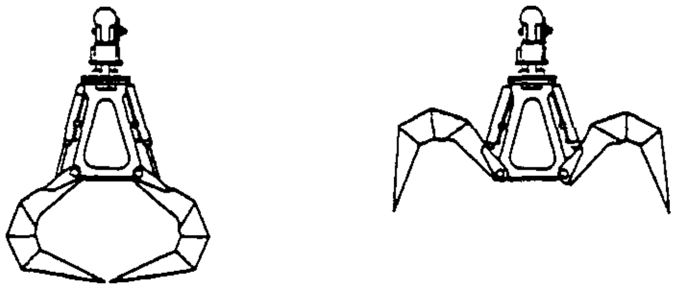


GRAB DREDGER



CLOSED-FORM GRAB



OPEN-FORM GRAB

FIGURE 4.1g - GRAB DREDGERS

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incorporating a visor, which can be hydraulically closed to retain contaminated material during removal, is best suited to dredging contaminated materials where tight depth tolerances are required. They are often used together with orange-peel and closed-box types to complete dredging to the design formation level.

Suction Dredgers

Suction dredgers mainly excavate the soil utilising the suction power of a dredge pump, or in the case of cutter suction dredgers, by the additional material loosening of a "cutterhead". Common types include: trailing suction hopper dredger, deep suction dredger, cutter suction dredger, dustpan dredger, reclamation dredger, and water injection dredger. Some of the main features of feasible dredgers are detailed below:

Trailer Suction Hopper Dredgers

There are two types of construction for trailing suction hopper dredgers (or "trailers" illustrated in *Figure 4.1h*) i.e. bottom-dumping and split-hull. The split-hull trailer is especially effective in discharging cohesive soils, as a result of the larger and wider opening through which dumping can occur. For bottom-dumping trailers, the bottom opening is in the form of a series of conical, sliding or flapping doors. The trailer slowly sails over the dredging area removing material using one or two dragheads, connected to the suction pipe, positioned over the sea-bed. Soil is taken up and loaded into the vessel's hopper using a combination of mechanical excavation by the draghead (often by using water jets to first loosen the soil), and suction force created by the dredging pump. When loading of the associated hopper is completed, suction pipes and draghead(s) are lifted and the vessel sails to the unloading location. The hopper load is then either bottom-dumped, pumped from the bow of the dredger directly, or pumped via a pipeline to the disposal or reclamation area.

The trailer suction hopper dredgers are now commonly used internationally for both capital and maintenance dredging, and were employed in the construction of Hong Kong's Container Terminals 6 and 7. Many trailer dredgers have electronic sensors installed in the dragheads to provide continuous monitoring of the dredging depth.

Cutter Suction Dredgers

The cutter suction dredger (or "cutter" illustrated in *Figure 4.1h*) is a type of stationary dredger which operates most effectively in water depths of 30 m or less. This type of dredger comprises two main components; the rotating cutterhead and the dredging pump. The cutter suction dredger operates by loosening or breaking down the soil (or rock) mass with a rotating cutterhead, installed at the end of a rigid suction ladder. The dredged spoil is lifted by the suction action of a pump located in the hull of the dredger. Most soils and even rock can be dredged using this method.

The usual cutterheads are the crown cutterhead which is most commonly used; the bucket wheel (or dredge wheel); and the disc bottom cutterhead which is particularly suitable for dredging of thin layers and for precision dredging. A cutter is very efficient in bulk dredging, and moves using a pivoting action or a system of anchors at greater depths. For relatively shallow dredging, usually two pivot points or 'spuds' are used, one of which remains anchored at the seabed. The other spud, which can be lifted, tilted or slid along a carriage, allows forward and lateral movement of the dredger. During cutting, the dredger is pivoted on one spud which penetrates into the ground. The cutter then swings from side to side, using side wires which are anchored on either side of the dredging area, cutting the soil in an arc-like motion. After cutting, the second spud is lowered, and the pivoting spud is raised and moved (either transversely or in an inclined manner), so that the cutter effectively steps forward by a nominal amount. Transverse-moving pivots are good for shallow water depths, as in this case the movement magnitude will be the same (usually up to 6 m) regardless of the water depth. During the dredging operation, the vessel should be suitably oriented taking the tide into account. Cutter suction dredgers normally discharge their materials through a pipeline.

4.1.6 *Methods of Pipeline Installation*

The method of submarine pipeline installation has not been finalised and will involve either pre-trenching by conventional dredging such as grab dredging, post-trenching by mechanical submarine pipeline trenching devices such as ploughing or jetting, or a combination of both. Directional drilling is not a feasible option for the AFRF project due to unsuitable heterogeneous bed conditions. Thus the pipeline which will be installed to a depth of 1.5-3.0m below the existing seabed will also result in sediment disturbance. Feasible methods of AFRF pipeline installation are discussed below.

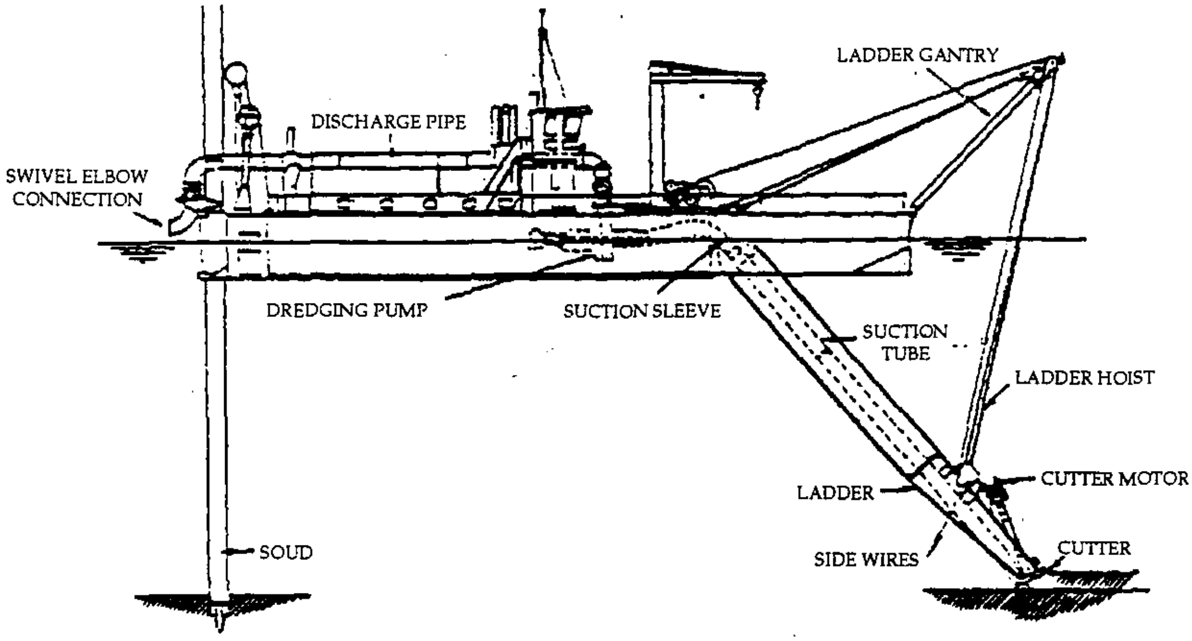
Grab Dredging

As detailed above this method of dredging is the most common type of mechanical dredger in use. Open or closed grabs can be used, depending upon the characteristics of the receiving water body or the material being dredged.

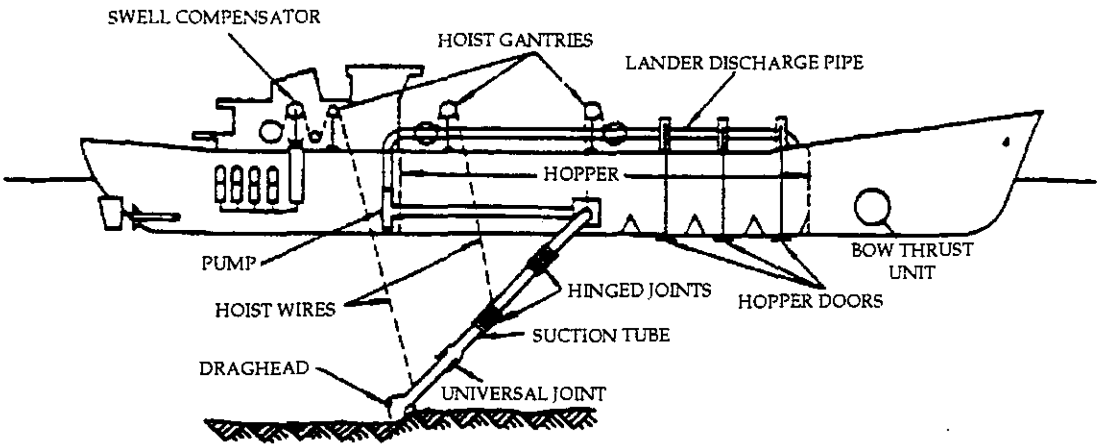
Post Trenching

Post trenching is carried out subsequent to pipelaying on the seabed to sink the pipeline to the desired depth in the seabed. Most recent developments on post trenching include mechanical pipeline trenching (ploughing), jetting or fluidization.

- Of the several different types of mechanical ploughing methods available, towed ploughs are likely to be the most suitable and productive method due to the very soft seabed conditions which would hinder self-propelled ploughs. Ploughing involves pulling a plough device under



CUTTER SUCTION DREDGER



TRAILER HOPPER DREDGER

FIGURE 4.1h - SUCTION DREDGERS

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and around the pipeline forming a furrow which the pipeline automatically lowers into. The plough cuts a trench with a side slope matching the angle of repose of the sediment. This slope controls the volume of soil to be removed, and the characteristics of the soil (ie. the density, compaction, and the resultant strength) greatly influences the magnitude of the force required to pull the plough. During operation of the plough, marine muds or sediments are automatically deposited along the side of the pipeline route. Disposal of material is therefore not required.

- Post-trenching by jetting or fluidisation is accomplished by means of high pressure, high velocity sea water jetted through nozzles to cut and emulsify the sea bottom material. Air is simultaneously injected hydro-pneumatically, causing the emulsified materials to lift from the trench, allowing the pipeline to sink to the desired depth. The disturbed sediments/particles then settle along the sea bottom and the air rises to the surface.

4.1.7 *Evaluation of Dredging Techniques*

An evaluation of the advantages and disadvantages of each of the possible dredger types which may be used during the construction and/or maintenance of the AFRF is presented below.

Mechanical Dredging Methods

Grab Dredgers

As with other types of mechanical dredgers, grab dredgers do not normally result in significant bulking of dredged material during extraction and generally retain the *in situ* density of the excavated material. The shallow draughted, generally pontoon-mounted, dredgers such as the grabs are highly suitable for operating in relatively shallow water depths and would therefore be suited for use in the vicinity of Sha Chau. The ability to handle sediment containing clay deposits is another advantage of this dredging method.

Closed grab systems reduce material losses to the water column, and are therefore particularly suitable for dredging in environmentally sensitive areas or handling contaminated sediments. Investigations into sediment resuspension conducted in the Hori River and the Oyabe River in Japan (Yagi et al, 1976), suggested that leakage losses from a conventional open grab were about 1.56 times those from a closed grab. These tests also indicated that the grab hoisting speed influences turbidity, suggesting that suspended solid (SS) concentrations in the upper water column are around 20–30% lower with a hoisting speed of 0.85m/s than those grabs with a hoisting speed of 1.25m/s. Therefore reduction of grab hoisting speed, and the use of closed grab systems would effectively minimise the impacts arising from use of grab dredgers. Employment of these measures would render grab dredgers the environmentally preferred option.

Bucket Dredging

An advantage of the bucket dredging method is that, as with other types of mechanical dredgers, bucket dredgers generally remove materials at close to their *in situ* density as little mixing with the surrounding water takes place during the dredging process. However, the buckets are open to the environment which allows for heavy losses during handling. Observations by Pennekamp and Quaak (1990) reported that the bucket dredger using open buckets result in 20 kg of material released into suspension for each cubic metre dredged. This high figure results from the open nature of the buckets transferring material to the surface for transportation from the site.

Another disadvantage of using bucket dredgers is the anchorage system required. Head wires in the anchor system, which are used to slowly advance the dredger and also provide the main reaction during dredging, can be several hundred metres long impinging upon vessel movements within the area. In addition, the mechanical operation can be noisy which may locally impact upon sensitive receivers within the immediate vicinity of the dredger, including in particular the Chinese White Dolphin *(Sousa chinesis)*. Therefore the bucket dredger is not considered to be an appropriate method for use during construction of the AFRF.

Suction Dredgers

The main advantage of the trailer suction dredger is its mobility and ability to operate in exposed conditions without the need of an anchor, where significant swells may be present. This makes it highly suitable for dredging in busy harbours such as Hong Kong, especially in or close to main marine channels.

However, only the very smallest trailers are able to operate in water depths of a few metres due to the draught requirements of many medium to large trailer dredgers (40 to 5m minimum). Use of the trailer suction dredger is also restricted by the sediment characteristics within the study area. The trailer operates most efficiently with free-flowing materials and the presence of clay in between dredged layers can significantly reduce the production rates. Clay is known to be present to some degree in most of the marine sands in Hong Kong, and the deposits on the sea bed around Sha Chau have been found to consist mainly of soft silty clay [(1)]. In addition, the use of the suction dredger is environmentally disadvantageous as the dredged material is normally in the form of a low density slurry as a result of mixing with water during the dredging process.

Therefore the use of the suction dredger is not a preferred option for the shallow waters near Sha Chau, which are mainly within the depth range of 4-8m. However, the trailer suction dredger may be a practicable option in the deeper waters at the start of the AFRF access fairway in the vicinity of

(1) Site Investigation Around Sha Chau, Hydrographic and Geophysical Surveys, Preliminary Report, Job Number HK79994, May 1994.

Urmston Road, a major throughway for ships entering Victoria Harbour from the Pearl River Delta, due to suction dredgers high mobility and ability to operate in exposed conditions.

Cutter Suction Dredgers

The cutter dredger is particularly effective for bulk removal of material. However the cutting action used by this type of dredger induces significant disturbance to the soil at a depth of 0.5 to 1 m beneath the cutting level. A cutter also generates more turbidity in the dredging operation than a grab dredger, as a result of the rotating action of the cutterhead. This resuspension of sediment is indicated to be greatly reduced by reducing the rate of advance/swing speed of the cutterhead (Kaneko and Watari 1983). As with other types of stationary dredgers, the cutter operates best in sheltered locations with little or no swell.

4.1.8 *Quantification of Dredging Techniques*

Dredging operations have been examined in detail in several studies in Hong Kong [(1)], investigating suspended solid loads released to the environment as a result of various dredging methods. Estimates of the suspended sediment level increases caused by dredgers have been made in terms of the total quantity of sediment released by the dredger per cubic metre dredged. This is termed the 'S' factor, expressed in kg/m^3, and provides a means of comparison of different dredging techniques. ie.

$$S = \frac{\text{Amount resuspended}}{\text{Amount of material dredged}} \quad (kg/m^3)$$

The 'S' factor can be used as a reasonable estimate of the quantity of sediment being released to the marine environment outside the area immediately adjacent to the dredging operations. The boundary of this area is typically defined as around 50 m from the dredger.

The higher the 'S' factor of a dredger, the higher the potential to increase SS levels in the water bodies. However, it should be noted that the 'S' factor only gives an indication of the relative suspended solids generation potential of dredgers and should not be used as an absolute value of sediment loss in any particular situation, because of the numerous potential differences between the conditions in which the measurements were undertaken and the conditions at the site in question. The losses at a particular site can only be established by careful measurement at the dredging site.

Based upon the previous evaluation of dredging techniques, when taking into consideration the depths in the Study Area, there are only a few practical options remaining for the construction phase dredging. It is anticipated that the most practical and environmentally acceptable dredging

(1) Contaminated Spoil Management Study Final Report, for the Hong Kong Government EPD, 1991.

method for use during the construction of the AFRF, in order to minimise the potential water quality impacts upon sensitive receivers, would be the closed grab dredger, provided the measures recommended in this Section are incorporated into the operation of the dredger.

Table 4.1e below details the approximate 'S' factors resulting from various grab dredgers, to provide an indication of the water quality impacts resulting from the use of different grab dredging techniques.

Table 4.1e *'S' Factors for Various Grab Dredgers*

Dredger	"S" Factor kg/m³
Grab (Open, silt screen)	12–25
Grab (Closed, no silt screen)	11–20
Grab (Closed, silt screen)	2–5

In general, open grab dredgers have a high potential for the release of sediment into the nearby marine environment. However, the use of closed grab dredgers with silt screens greatly reduces sediment loss and thereby minimises the potential for causing adverse water quality impacts.

4.1.9 *Evaluation of Pipelaying Techniques*

Either pre-trenching by conventional closed grab dredging, post-trenching by mechanical submarine pipeline trenching devices such as ploughing or jetting, or a combination of both could be used for the pipelaying activities. If either jetting or ploughing techniques are used for pipeline installation disposal of trenched material will not be necessary. However, jetting results in the highest loss of sediment to the water column, due to the techniques causing suspension of all material from the sea bed along the path of the jet. EPD consider that, while the SS will eventually settle onto the seabed, because of its unconsolidated state it can be easily eroded and re-suspended into the water column. EPD consider the result to be a persistent density flux at the lower layer of the water column, the effect of which may be detrimental to the benthic communities, in particularly corals which are found within the Study Area (see *Section 4.3*). Ploughing results in the least sediment loss, and grab dredging creates intermediate sediment loss levels but requires a longer period to complete trenching. Jet/ploughing comprises a conventional plough with jets to fluidise the sediments and generates sediment resuspension only in the water horizons close to the seabed.

The construction period for the submarine pipeline installation is estimated to be approximately two weeks using the jet/plough method, whereas the duration of conventional grab dredger and backfilled methods would necessitate a construction period of around 2 – 3 months in total. The use of grab dredgers would require a trench width of approximately 20–25 m for each of the two parallel trenches, whilst jet/plough techniques would require a significantly narrower trench width of approximately 5–10 m. The area of seabed affected by the jet/ploughed pipelaying method would thus be about half that affected by the conventional dredged methods.

4.1.10 *Preferred Methods of Construction*

It should be noted that the actual pipeline construction method will depend on local equipment availability, engineering constraints and seabed conditions. The following recommendations should be employed wherever practical.

Turning Basin and Access Channel Dredging

Based upon the method of operation and the site conditions, the closed grab clamshell dredger is considered to be particularly suited to the turning basin and access channel dredging requirements of the AFRF. Provided the mitigation measures recommended in this section are fully implemented, it is considered that closed grab dredging would represent the environmentally preferred and most practical option for the dredging associated with the construction of the AFRF turning basin and access channel.

Pipeline Installation

EPD consider that the use of closed grab clamshell dredging is the preferred method for construction of the AFRF pipeline, due to the potential detrimental effects upon water quality in the study area if the jet/plough technique is employed. It is considered that the clamshell dredger will minimise the water quality impacts within the marine environment, and therefore associated impacts upon the marine biota in the area. Therefore as detailed above, provided the mitigation measures recommended in this section are fully implemented it is considered that the closed grab dredger would represent the environmentally preferred construction method.

However if, during further assessment in the detailed design stage, the successful Tenderer demonstrates the acceptability of another pipeline installation method (ie. jet/plough or directional drilling) in terms of the impact upon water quality, and marine ecology in the area, then this method could be proposed for EPD consideration. This will therefore minimise impacts on the marine biota, particularly the coral communities within the area which are sensitive to suspended solid levels.

4.1.11 *Potential Sources of Impacts*

Disturbance to Marine Sediments

The major impact on water quality during the works associated with the AFRF construction at Sha Chau will inevitably arise as a result of sediment suspension and dispersion from disturbance of the sea bed. Dredging for construction of the turning circle, access fairway and twin pipeline installation will all result in sediment disturbance. The general associated impacts are addressed below. The extent of marine impacts will be highly dependent upon a number of factors which include:

- physical and chemical nature of the marine sediment;
- dispersion characteristics of the water receiving body at the site;
- method of dredging used during construction of the AFRF;
- submarine pipeline installation method used; and
- the number, nature and proximity of the sensitive receivers.

Physical Impacts: Water quality impacts due to sediment disturbance are often directly caused by dispersion of sediment material and an increase in the concentration of suspended solids in the surrounding water column. A number of effects produced by elevated suspended solid levels combine to reduce DO concentrations. An increase in solids in the water column leads to reduced light penetration, decreasing photosynthesis and thus the rate at which oxygen is produced in the water column. Similarly, the increased levels of solids results in more energy from sunlight being retained and results in rises in temperature. This also acts against oxygen levels as oxygen is less soluble in warmer water. Furthermore, reduced primary productivity reduces the uptake of nutrients from the water column. It may also result in the smothering of some benthic biota due to resettlement of suspended matter. Physical effects will depend on the amount of material put into suspension during the dredging and trenching activities. However, this deposition occurs annually within the Study Area to a far greater degree than that which would occur as a result of the AFRF construction. Therefore the organisms in the Study Area will be highly adapted to this large annual deposition of suspended solids.

Chemical Effects: Chemical effects result from the release of sediment constituents such as any toxic metals or complex organic compounds, or material that has an oxygen demand. Chemical effects are also a function of the degree of sediment contamination. Chemical effects include:

- Remobilised contaminants, if present, from the spoil may be taken up by both animals and plants;
- Adsorption of contaminants, if present, in the water onto clay particles will remove some contaminants from the water column, but the clay particles may be ingested by filter or deposit feeding animals;
- Complexation reactions between dissolved metals and sediment may alter the toxicity of certain contaminants; and

- Possible increased biochemical oxygen demand may occur, depending on the proportion of organic matter in the spoil.

The specific sediment analysis conducted for this EIA study indicates that the majority of the marine muds in the Sha Chau area are uncontaminated. Mobilisation and release of toxic metals into the surrounding water column is therefore likely to be environmentally acceptable, due to the low levels of heavy metals present within the marine sediments. Therefore the chemical effects described above are not anticipated to occur.

In the case of both physical and chemical effects, the extent of the impact is related to the amount of material released into suspension. This is a function of the quantity and nature of the disturbed sediment. In addition sediment consolidation rates and sediment entrainment from the natural seabed after disturbance, which effect the amount of sediment in suspension, depend heavily on the dredging and trenching methods used. The amount of sediment dispersion during the construction period will also alter under different tidal and storm current conditions.

Marine Mud Disposal

Activities during the construction of the turning circle, access fairway, and twin pipelines will result in the generation of dredged marine muds. The potential environmental effects of marine sediment disposal will vary according to the quantities and their level of contamination. In general water quality impacts resulting from marine disposal may include:

- suspension of solids in the water column during dredging and marine sediment dumping with the likely consequence of reducing the dissolved oxygen level as detailed above;

- disturbance and suspension of previously dissolved organic, and inorganic materials such as heavy metals; and

- release of suspended solids due to leakages and overflowing of the barges during transportation.

All of the above can result in a deterioration in water quality and may have associated direct or indirect adverse effects on marine biota, as discussed *Section 4.4*.

General Construction Activities

The facility, vessel turning basin, access fairway and pipelaying activities will all be marine based and could, if uncontrolled, have the potential to cause water pollution from solid and liquid waste such as packaging and construction materials, sewage effluents from the construction workforce, discharge of bilge water, and spillages of oil, diesel and solvents. Any release of such potential pollutants into marine waters would be likely to have detrimental effects on sensitive receivers in the area such as fishing grounds, and hence indirect effects on other sensitive receivers such as Chinese White Dolphins (*Sousa chinesis*). Increased nutrient levels resulting from contaminated discharges and sewage effluents could also lead to a number of secondary effects which may result in adverse effects on marine biota due to elevated pH values, reduced decay rates of faecal micro-organisms due to decreased light penetration, and localised increases in the proportion of un-ionised ammonia (NH_3). To prevent the occurrence of these impacts, there will be no discharge into the marine waters during construction of the AFRF.

Impacts Associated with Specific Locations

Turning Circle and Fairway Construction

Dredging for construction of the turning basin will be to a depth of around 11 m to allow access and facilitate manoeuvring of vessels up to 10,000 dwt, and will therefore result in water quality impacts through sediment disturbance and dispersion. The dredging requirements for construction of the turning basin and access fairway are estimated to be approximately 500,000 m^3 for the preferred site, as a natural scour hole at this location minimises the quantity of dredging required for the turning basin. There are several methodology options for construction of these parts of the proposed AFRF as detailed in *Section 3*. Of concern are the physical and chemical water quality, and noise impacts associated with each of these methods and the effects of these upon water sensitive receivers.

Assessment of the Stability of Sha Chau Beaches

In addition the ACE EIA Sub-committee questioned whether dredging of the fairway, to allow vessel access to the facility berths, could result in local changes in the hydrodynamics of the Study Area, and could impact on the sand bars (tombolos) present at Sha Chau (see *Figure 4.1i*). A coastal geomorphological assessment was therefore conducted as part of this EIA to ascertain the impact of the proposed AFRF project on the stability of the Sha Chau sand bar and beaches. The conclusions of this assessment are presented below.

The island of Sha Chau is connected to two islets (or rock outcrops) to the north-west by narrow tombolos which are of a recent origin on a geological timescale. The tombolos are located on the periphery of a large area of shoaling ground to the south-west of the area and have resulted from the balance between the wave forces driving material over the sea bed to the south-west and the sudden shelter provided once the island and islets are reached. The balance which maintains the tombolos in their present form is a delicate one and any increase in wave activity could imitate changes in the beach layout possibly leading to their erosion.

Wave studies carried out for the New Airport Master Plan study showed the wave climate in the area is relatively mild. Waves from the north-east (which could be affected by the dredging for the berthing area and

FIGURE 4.1i - LOCATION OF SHA CHAU SAND BAR AND ASSOCIATED WATER DEPTHS

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Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

approach channel) are unlikely to exceed 1½ m in conditions as severe as the 1 in 100 year event with wave periods likely to be of the order of 4½ s (T_p) (peak period of the wave in seconds). Such waves will not affect the sea bed in the vicinity of the dredged areas and any changes to the wave action due to refraction or diffraction after dredging are likely to be insignificant. As a result, any danger to the tombolos posed by changes in wave action induced by the dredging will also be minimal and, based on the assessment carried out, it is considered extremely unlikely that any deterioration of the beaches will occur as a result of the planned dredging.

The area off the beaches is virtually unaffected by tidal flow induced forces. Indeed, the tombolos would not have formed if tidal currents had been strong. Dredging the approach channel and berthing area will not alter the tidal currents. Dredging the approach channel and berthing area will not alter the tidal regime further afield, to have an impact on the areas of higher ground on which the tombolos are located, and tidal current induced changes to the tombolos are not expected.

In summary, based on a coastal geomorphological review of hydraulic data and photographs of the tombolos, it is considered that the proposed dredging will have negligible impact on the stability of the beaches connecting Sha Chau to the nearby Islets. Any small changes in tidal current speeds following dredging will occur adjacent to the dredged areas and will not affect the areas of higher ground where the beaches are formed. Considering the possible small impact the dredging could have on the wave climate and experience of previous similar studies, it is considered extremely unlikely that the dredging will pose problems for the stability of the tombolos.

Berth Construction Method

As detailed in *Section 3.4.2*, the AFRF berth will be formed on a piled structure, and constructed using a non-percussive piling method, such as bored piling, which is necessitated by the nature of the seabed. Assessment of associated impacts and appropriate mitigation will be undertaken in the successful Tenderer's detailed design.

Pipeline Installation

The associated twin pipelines will also result in sediment disturbance. Two submarine pipelines, of approximately 5.5 km for the section between Sha Chau and Chek Lap Kok, will be laid. This option has been chosen over the single pipeline trench option containing twin pipes, due to the fact that the latter would result in a larger overall volume of material being removed and therefore potentially greater water quality impacts. The precise depth of the pipeline installation has not yet been finalised and will depend on the results of a sedimentation study presently being undertaken.

For the purpose of this assessment it is assumed that the pipeline will be laid in either a 1.5–2.0 m deep trench, or a 3 m deep trench; and similarly the pipeline installation method used may be dependent upon the trench depth. The preferred method, as detailed previously, will be closed grab dredging for a 3.0 m deep trench. However, other methods of installation may be considered if the successful Tenderer demonstrates their compliance with WQO. Of concern are the water quality impacts of these pipelaying activities, which will result from those physical and chemical changes to water quality, in varying degrees, as detailed previously in this section.

Pipeline Proximity to Contaminated Mud Pits

The proposed pipeline route to the west of the East Sha Chau contaminated mud pits, (CMPs as shown in *Figure 4.1a*), is routed within the AFRF gazetted area. Locating the AFRF at Sha Chau would not result in insurmountable impacts to the CMPs since the site is 2.25 km from the AFRF. However the proximity of the AFRF service route to the CMPs necessitates evaluation to address the concerns that the proposed AFRF may impinge upon the existing and future planned CMPs, causing potential impediment of the filling and capping programme, and interference with the CMPs integrity and long term stability. Adequate mitigation measures as detailed in this section should be adhered to thus ensuring the short, medium and long term stability of the CMPs from the close proximity of the AFRF submarine pipeline.

Submarine Power Cable Installation

A submarine power cable (SPC) will be laid within the gazetted corridor for the AFRF pipeline and its installation will therefore also result in local sediment disturbance and related water quality impacts. The location is presently tentative and details of the power cable trench are not available.

4.1.12 *Evaluation of Impacts*

Sediment Resuspension due to Dredging

In evaluating the increases in turbidity due to dredging activities, the following criteria will need to be considered:

- background SS levels in the water column;
- increase in SS levels while dredging; and
- whether the increase in SS level is within the statutory (WPCO) requirements, i.e. 30% above the background concentrations.

Although elevated levels of suspended solids and associated turbidity will inevitably result in the immediate vicinity of any dredger, for most dredging operations the main consideration with respect to sediment resuspension and the environment is the amount which is lost to the site. The amount of resuspended material generated during dredging is highly variable and is specifically dependant upon the methodology used during construction, the specific hydrodynamics of the site, and the nature of the disturbed sediment. If the water currents within the area are weak, as they are at Sha Chau (0.2-0.4 m/s) sediment which is put into suspension can be expected to settle on the seabed in close proximity to the dredger. In areas of stronger currents, the amount of sediment loss will be a function of the turbidity around the dredger, the current speed, and the duration of the dredging works.

Details of the preferred option for dredging activities have been presented. This concluded that the most practical form of dredging for the AFRF turning basin and access fairway is closed clamshell grab dredging.

Sediment Plume Modelling

Sediment plume modelling simulations (WAHMO) were conducted as part of this assessment, to simulate the fate of sediment lost to suspension during dredging associated with the AFRF. The plume modelling predicted the suspended solid level increases above ambient level at 11 identified sensitive receivers, and the results, assuming a 5% loss to the environment, are indicated on *Figure 4.1j* (Wet Season Spring Tide) and *Figure 4.1k* (Dry Season Spring Tide).

Previous studies of sediment plumes in Europe have indicated potential dredged mud losses to suspension from dredging equipment lie in the range of 3% to 5% and the figure of 5% has thus been adopted during this simulation as the worst- case, based upon current available information, for example using an open grab dredger.. Assuming all spoil losses enter the water column at the surface also ensures minimum re-settlement locally and it is thought that the simulated plumes should not, therefore, be an underestimate of the possible dredging plumes which might be generated. However, it should be noted that a total working rate of 8,000 m^3/day was used as an estimate of suspended solid generated during the construction period, based upon information currently available. The exact levels of suspended solid generation will be determined and assessed in the detailed design stage, upon finalisation of construction period and equipment specifications.

During the wet season spring tide, this modelling predicted suspended solid level increases in the range of 0-13 mg/l. However, at four of the eleven sensitive receivers (Deep Bay, NE Brothers, Castle Peak, East Sha Chau, and Chek Lap Kok Sea Channel) it predicted that there would be no increase above the ambient suspended solid levels; and at five of the sites (Lung Kwu Chau, East Sha Chau, West Sha Chau, South Sha Chau, and Sha Chau Beach) all increases were predicted to remain below 5 mg/l above the ambient suspended solid level. In terms of the WQO (see *Section 4.2.1*) this is considered to be acceptable, equating to less than a 30% increase in the natural ambient levels, assuming an average ambient suspended solid concentration of approximately 20 mg/l.

However, at one sensitive receiver (North Sha Chau) the modelling predicted an increase of upto 13 mg/l suspended solids above the ambient levels which is the equivalent of a 65% increase in suspended solids. This WQO exceedance will necessitate mitigation measures, recommended in this section, to be fully implemented to ensure that these exceedances do not occur. These measures include the use of closed grab dredgers for construction. The practicality of using site curtains will also be assessed in the detailed design of the AFRF.

During the dry season spring tide, the modelling predicted that suspended solid increases in the range of 0–7 mg/l above the ambient levels would occur. Again, this was at one sensitive receiver, whereas all the others were predicted to be compliant in terms of the WQO leading to a maximum increase of 5 mg/l. However, mitigation measures recommended in this section should be fully implemented to maintain the water quality in accordance with the WQO and ensure that exceedances do not occur at any of the sensitive receivers. Full details of the results of the sediment plume simulations are provided in *Annex D*.

Berth Construction Method

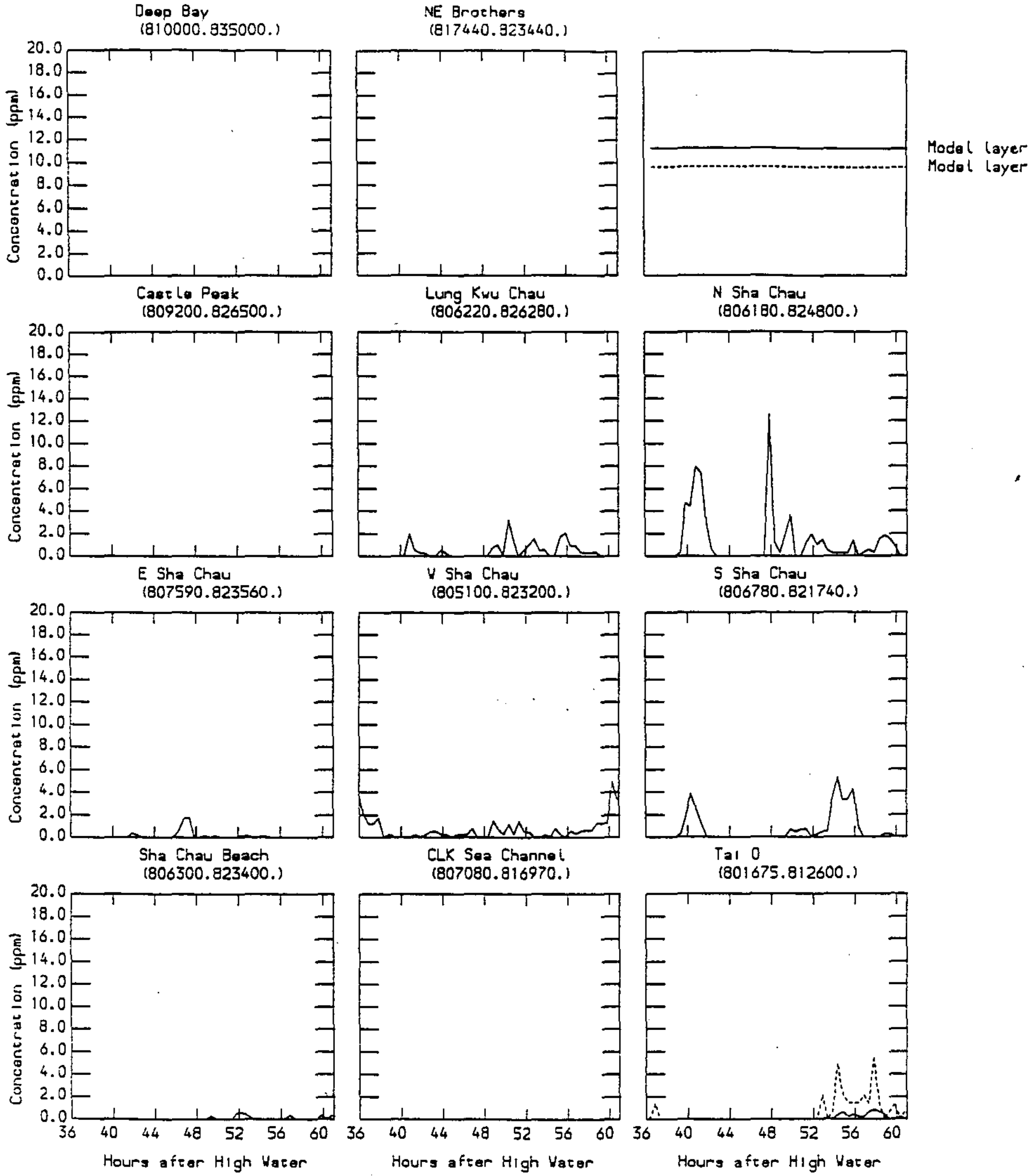
The piled structure is the preferred option as no dredging will occur and thus impacts associated with dredging will be avoided. Also bored piling is preferred as noise levels generated will not be of an impulsive high sound power level nature and will therefore be less than percussive piling. Thus this method will reduce the noise impacts resulting from the construction of the AFRF. The detailed design stage will assess all resulting impacts including those from bored piling upon the marine environment, including the impacts upon water quality in terms of the WQO.

Pipeline Installation

As discussed in this section, closed–grab dredging is the preferred installation method, as this will minimise potential impacts on water sensitive receivers. The specification of closed–grab clamshell dredging as the pipelaying method in the contract specification is therefore recommended. Sediment plume simulations, which modelled the impacts associated with installation using conventional grab dredging, predicted dredging would result in an exceedance of WQO at one sensitive receiver (North Sha Chau). Therefore closed grab dredging is required to minimise increases in suspended solid levels to acceptable levels in accordance with the WQO (see *Annex D*).

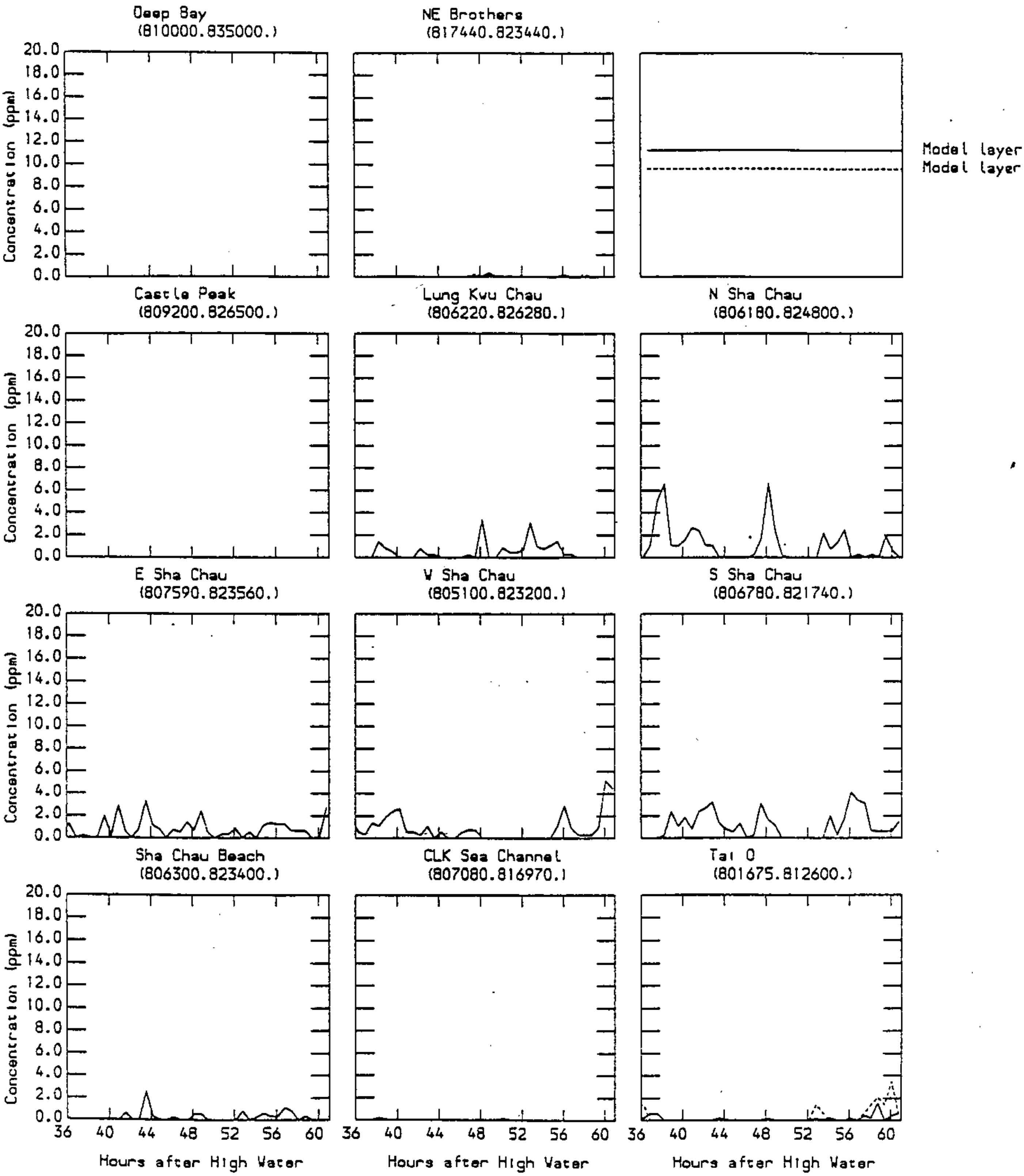
Proximity of Pipeline to Contaminated Mud Pits

The locations of the existing and potential future CMPs are shown in *Figure 4.1a*. The CMP closest to the area gazetted for the AFRF is CMP No. IID, and it is anticipated that it will have been capped by June 1995, as shown by the scheduled timetable for all the CMPs in *Table 4.1f*.



AFRF at Sha Chau
Sediment Losses from Dredging Activities
Suspended Sediment Concentrations
Wet Season Spring Tide

Figure 4.1j



AFRF at Sha Chau
Sediment Losses from Dredging Activities
Suspended Sediment Concentrations
Dry Season Spring Tide

Figure 4.1k

Table 4.1f *Estimated Timetable of Activities at the CMPs*

Contaminated Mud Pit No.	Dates of Scheduled Activity
I	Filled and Capped: Completed
IIA	Filled and Capped: Completed
IIB	Filled and Capped: Completed
IIC	Filled: November 1994 Capped: February 1995
IID	Filled: March 1995 Capped: June 1995
IIIA	Dredged: November 1994 - March 1995 Filled: March 1995 - August 1995 Capped: August 1995 - November 1995
IIIB	Dredged by June 1995 Filled: August 1995 - December 1995 Capped: December 1995 - February 1996
CPRC Pit	Filled and Capped: Completed

The AFRF gazettal area lies no closer than approximately 650 m from the edge of CMP IID. However, the stability of the cut slope at East Sha Chau CMPs and requirements for 'Safety Zones' have been investigated in order to determine an acceptable distance to be maintained between the AFRF pipeline corridor and the CMPs. It has been recommended [1] that a safety zone of 15x10=150m from the crest of contaminated mud pit slopes is maintained, based on an assumption of a cut slope gradient of 1 in 10 for planning purposes, and CMP depth of up to 15 m deep below seabed.

It is anticipated that the depth of the dredged trench, for each AFRF pipeline within the gazettal area, will not be greater than 3 m in depth and have a side slope of approximately 1 in 3. Hence, even if the dredged depth was taken as 5 m below the seabed and the stable slope of the marine muds was taken conservatively as 1:20 (for example, after dynamic disturbance by a typhoon), there would remain a zone of undisturbed seabed of width 250 m, between the two operations. This is calculated as follows:

$$X = 650 \text{ m} - 20\,(5+15) \text{ m} = 250 \text{ m}$$

where X is the zone of undisturbed seabed, 650 m is the distance between the centre line of the CMP and the pipeline trench, and 20 (5+15) is the stable slope assumption for the maximum trench depth of 5 m pipeline and 15 m CMP. Therefore, the construction of the pipelines would be outside the 150m safety zone, and would not affect the CMPs' integrity. PAA have agreed to implement the minimum safety zone recommendation in the form

(1) Fill Management Committee Secretariat, Stability of Cut Slopes at East Sha Chau, and Recommendations for Safety Zones, 1994.

of a 'buffer zone' which would be used only for the purpose of a temporary works area. The extent of this 'buffer zone' is indicated in *Figure 4.1l.*

In addition to the proximity to CMP No.IID, the area gazetted for the AFRF services corridor impinges upon the south western corner of the gazetted contaminated mud disposal area which was originally reserved as a CT9 disposal area, as indicated on *Figure 4.1a*. However the Fill Management Committee have confirmed that this area will not be used for contaminated mud disposal, and have no objection to the area forming part of the proposed pipeline reserve. Any future allocations of areas for CMPs will also take this into account. Therefore, provided the 'buffer zone' recommendations are followed, it is considered that there will be no AFRF impingement upon the CMPs and therefore no unacceptable environmental impacts will result from the location of the pipeline corridor in the proximity of the CMPs.

Submarine Power Cable (SPC) Installation

CLP propose to install the submarine power cable using the jet/plough installation techniques. The installation method will be finalised and assessed during the detailed design.

Cumulative Water Quality Impacts from Other Dredging Activities

The construction activities associated with the AFRF will coincide with a number of ongoing or forthcoming developments for the New Airport and related developments, for which extensive dredging and reclamation work is taking place. These developments include reclamation work for the New Airport, North Lantau Development, North Lantau Expressway and Airport Railway. Programmes for the various works in the vicinity of the Study Area are presented in *Section 3.*

It is estimated that the dredging works for the AFRF construction would require a period of 2–3 months. The proposed works are thus considered to be relatively small scale work when compared with the major dredging activities for the ACP projects. Although these construction activities may coincide with other developments in the North Lantau area, it is envisaged that the AFRF marine works would not significantly increase the suspended solids levels in the area, provided mitigation measure recommended in this section are fully implemented.

Impacts on Water Sensitive Receivers

As detailed above, there are a number of water sensitive receivers in the North Western WCZ which may be affected by the construction of the works. It is anticipated that impacts upon these sensitive receivers can be minimised by the strict application of the preferred construction methods and recommended mitigation measures.

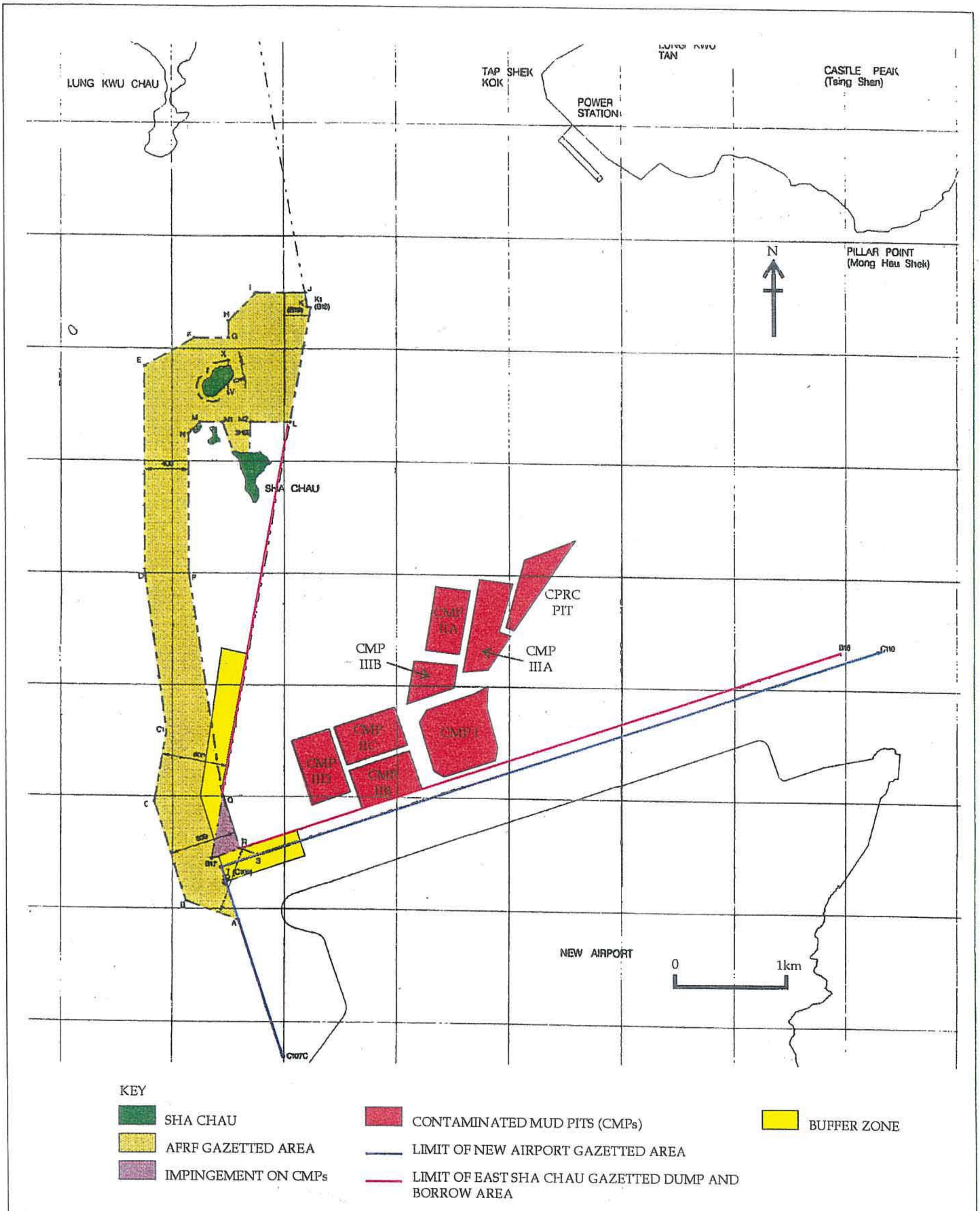


FIGURE 4.11 - LOCATION OF BUFFER ZONE BETWEEN AFRF GAZETTED AREA AND CMPs GAZETTED AREA

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Suspended Solid Levels

Based upon the evaluation of SS modelling simulations conducted as part of this assessment and using information currently available, to simulate the fate of sediment lost to suspension during dredging associated with the AFRF, it is considered that SS levels in the cooling water intake for Castle Peak will not exceed the specified criteria of 150 mg/l as a result of the AFRF provided the recommended mitigation measures comprising those detailed in this section are fully implemented by the contractor. In addition, it is considered that impact upon water quality due to sediment resuspension will not exceed the SS WQO concentration at gazetted and non-gazetted bathing beaches in the area, provided mitigation measures recommended in this section, including use of a closed grab dredger, are fully implemented. Likely impacts upon marine fauna and flora and specific mitigation measures are discussed in detail in *Section 4.4.*

Contaminant Levels

If the pipelaying activities in the vicinity of the CMPs released contaminants into the water column, fisheries and other marine biota within the area may be impacted. In turn this may indirectly impact upon other water sensitive receivers such as the Chinese White Dolphins (see *Section 4.4* for details). However, provided mitigation measures recommended within this section are adhered to, it is not anticipated that this will happen.

The majority of the sediment within the Study area is considered to be uncontaminated, except at 3 locations where the sediments were identified as Class B. These were at site 3 (Zn-Class B), 6 (Pb-Class B), and 13 (Pb-Class B), as indicated on *Figure 4.1d.* As stipulated in the '*Environmental Protection Department Technical Circular No. 1-1-92, Classification of Dredged Sediments for Marine Disposal*', this moderately contaminated material requires special care during dredging and transport, and must be disposed of in a manner which minimizes the loss of pollutants either into solution or by resuspension. Therefore appropriate dredging method and disposal criteria have been incorporated into the recommended mitigation measures. It is considered that there will be no unacceptable contaminant impacts resulting from the construction of the AFRF, provided the recommended mitigation measures, including closed-grab clamshell dredging methods, are fully employed and the relevant technical circulars are strictly adhered to. Adherance to the 'buffer zone' will allieviate potential impacts of the pipeline on CMPs.

General Construction Activities

The effects on water quality and water sensitive receivers from other construction activities are likely to be minimal. Appropriate waste storage, handling, collection and disposal procedures should be defined and monitored by specified personnel to ensure that litter, fuels and solvents do not enter surrounding marine waters. In particular floating refuse would have a significant impact on the aesthetic quality of the marine waters, and would visually impact upon the water quality of the gazetted and non-gazetted beaches in the area. Specific measures to prevent release of liquid and solid waste into the water column are defined in *Section 7*.

4.1.13 *Mitigation Measures*

It is important that appropriate measures be undertaken to ensure that potential impacts on water quality during construction can be kept to within acceptable levels defined by the WQO. The following mitigation measures have been identified and are discussed below. The proper selection of appropriate dredging methods will reduce the amount of sediment resuspension, and this in turn will minimise adverse impacts on water sensitive receivers. Based on the discussion in this section, low impact dredging techniques such as closed grab clamshell dredgers are recommended for the dredging of the turning circle and access fairway, and for installation of the submarine pipeline. In addition, the use of silt curtains should be investigated, during the detailed design basis EIA, to further minimise impacts upon water quality and to confine the sediment plume to within the close vicinity of the site.

Construction of the Turning Basin and Access Fairway

Dredging and disposal of marine sediments may result in diminished water quality through turbidity and increased concentration of contaminants, as detailed throughout this section. Attention to the dredging methods will therefore be necessary. The contractor will be required to minimise adverse impacts on water quality resulting from dredging, and dumping operations to within acceptable levels as defined by the WQO. To achieve these requirements the contractor should design and implement methods of working, to the maximum practicable extent, that:

(a) minimise disturbance to the seabed while dredging;

(b) minimise leakage of dredged material during lifting;

(c) prevent loss of material during transport of dredged material;

(d) prevent discharge of dredged material except at approved locations;

(e) dredging operations should involve leaving sediment in place whenever practicable;

(f) prevent the avoidable reduction, due to the AFRF construction works, of the dissolved oxygen content of the water adjacent to the works;

(g) prevent avoidable deterioration in the water quality which may cause adverse effects to bathing beaches and marine ecology;

(h) prevent excess suspended solids from being present in intake water; and

(i) ensure that the AFRF construction works will cause no visible foam, oil, grease, scum, litter or other objectionable matter to be present in the water within and adjacent to the AFRF site or dumping grounds.

The licensee should formulate his design and construction methods with these factors in mind, and provide specification in the tender submission. Pollution avoidance measures should include but not be limited to the following:

(a) mechanical grabs should be designed and maintained to avoid spillage and should seal tightly while being lifted (closed-grab clamshell dredgers);

(b) 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;

(c) all pipe leakages should be repaired promptly and plant should not be operated with leaking pipes;

(d) excess material will be cleaned from the decks and exposed fittings of barges and hopper dredgers before the vessel is moved;

(e) adequate freeboard will be maintained on barges to ensure that desks are not washed by wave action;

(f) the Contractor will have to monitor any or all vessels transporting material to ensure that no dumping outside the approved location takes place;

(g) all barges and hopper dredgers should be fitted with tight fitting seals to their bottom openings to prevent leakage of material; and

(h) loading of barges and hoppers should be controlled to prevent splashing of dredged material to the surrounding water, and barges or hoppers should not be filled to a level which will cause the overflow of materials or polluted water during loading or transportation.

Additional provisions will be required where marine sediments are contaminated. Recent sediment analyses, conducted on behalf of PAA, indicates that the marine sediments at locations 3, 6, and 13 (*Figure 4.1d*) are moderately contaminated (Class B). Further to the sediment sampling undertaken during this EIA Study, which is indicative of the sediment contamination levels within the Study Area, the successful Tenderer (detailed design stage) would be required to undertake a detailed sediment quality assessment to identify precisely the location and extent of any contamination, presented within a Sediment Quality Report.

Once determined, the locations and depths of any areas of contaminated marine sediments should be indicated in the construction contract. The contractor would ensure that contaminated marine sediments, if present, are dredged, transported and placed in approved special dumping grounds in accordance with the EPD Technical Circular No. 1-1-92, WBTC No. 22/92 and WBTC No. 6/92. Special EPD procedures for the avoidance of pollution during the dredging, transportation and disposal of designated contaminated marine and are listed below:

(a) Uncontaminated mud shall not be dumped other than in dumping grounds as may be approved for the purpose by the Director of Environmental Protection and in accordance with the Dumping at Sea Act (Overseas Territories) Order 1975. If the contaminated mud cannot be left in situ, it should be dumped at East Sha Chau Contaminated Mud Disposal Pits or other disposal pits as may be approved for the purpose by the Director of Environmental Protection. The contaminated mud should be disposed of using the specific methods as directed by the Director of Environmental Protection. The Contractor shall be responsible for obtaining all necessary licences for these operations.

    Notes: *The Engineer shall ensure that the Contractor has access to Works Branch Technical Circular No. 22/92 "Marine Disposal of Dredged Mud"; EPD Technical Circular No. 1.1.92 "Classification of Dredged Sediments for Marine Disposal"; and Fill Management Committee Paper FMC/58 (6.10.92) "General Allocation Conditions for Marine Borrow Areas and Mud Disposal Sites".*

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

(c) The Contractor shall carry out the dumping operation in strict accordance with the method statement agreed by the Director of Environmental Protection, any non-compliance with the agreed method shall be a breach of conditions of the relevant licence issued by the Director of Environmental Protection and is an offence under the Dumping at Sea Act 1974 (Overseas Territories) Order 1975;

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

The Contractor shall

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

(ii) transport designated contaminated marine mud by split barge of not less than $50m^3$ capacity well maintained and capable of rapid opening and discharge at the disposal site;

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

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

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

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

(vii) employ only barges equipped with automatic self-monitoring device for the dumping operation, and shall cooperate with and facilitate the Director of Environmental Protection to inspect the device and retrieve the record stored in the device on a regular basis;

(viii) provide experienced full time personnel on board all dumping vessels and provide suitable training to ensure that appropriate methods to minimise pollution are implemented. Records should be maintained to satisfy the

Director of Environmental Protection that there is no short dumping or dumping outside the Designated Dumping Area. The Contractor shall also make available to the Director of Environmental Protection and the secretary of Fill Management Committee (S/FMC), Civil Engineering Department, at any time upon the written request of the Director of Environmental Protection, all information and records relevant to the dredging and mud disposal operation. This information shall include, but not be limited to, all data on the plant used by the Contractor, up-to-date periodic data on production rates and record copies of Notification of Dumping which have been sent to the Management Team, etc;

(xi) fully co-operate with Government officers to allow access to dredgers and other craft for the purpose of sampling dredged material and for the inspection of samples and other appropriate monitoring and control information.

In addition, it is recommended that the track record of the contractor and vessels is investigated, to ensure poor operators are not contracted for construction of the AFRF. It may also be necessary to investigate the possibility of limiting operations during certain seastates, winds and combinations of both. However, the details of this would be finalised during the detailed design phase of the AFRF.

In addition, all contractors involved in the construction of the AFRF will be required to operate in accordance with the *Marine Department General Conditions for Dredging and Backfilling at Marine Borrow Areas (Annex E).*

4.1.14 Pre-commissioning and Commissioning of Submarine Pipeline

Testing of the Submarine Pipeline

After completion of the pipelaying activities, testing and cleansing of the pipeline will be conducted. Treated freshwater or seawater dosed with typical water treatment chemicals, as detailed in *Section 3*, will be used to flush the pipeline. These waters will be collected, tankered and transported off-site for appropriate and EPD approved disposal. The test water removed from the pipeline will contain iron oxide particles from contact with the pipe interior, however, no harmful pollutants are anticipated in the used test water. Therefore, no impacts on water quality are anticipated as a result of the pre-commissioning of the pipeline.

De-watering of the Pipeline

The pipeline can be de-watered (removal of the bulk of the test water) by either of the following methods:

- displace water with 'pigs' driven by compressed air; or

- displace water with 'pigs' driven by aviation fuel.

The exact de-watering and disposal method will depend on the facilities available or on special requirements at the time. For example, if the test water can be placed in a fuel storage tank at the on-airport tank farm, pipeline de-watering can be accomplished with 'pigs' driven by fuel from the AFRF. If the test water must be placed in a barge at the facility, the test water will be displaced with air-driven 'pigs' from the on-airport tank farm to the AFRF. The water will be discharged using the same procedures used for disposal of water filtered out of the fuel during normal operations. All dewatered liquids will be transported to the Chemical Waste Treatment Centre (CWTC) on Tsing Yi for appropriate treatment.

Nitrogen purging may be carried out as a contingency operation to prevent the ingress of air and/or air borne water in the pipeline. However, if fuel is available immediately after completion of the vacuum drying operations, nitrogen purge/fill will not be required. Such operations are not expected to result in any impacts on water quality.

4.1.15 Mitigation Measures

Pre-commissioning and Commissioning of Pipeline

It is essential to ensure that the bulk collection, transportation and final disposal of the testing and cleansing waters removed from the pipeline is carried out in an appropriate and approved manner. Such operations should also satisfy the requirements of EPD regulations and guidelines.

It is recommended that the test waters be discharged into fuel storage tanks at the on-airport tank farm and that this should not be accomplished at the AFRF. All dewatered liquids should then be transported to the Chemical Waste Treatment Centre (CWTC) on Tsing Yi for appropriate treatment. Thus as no removal of test waters directly from the AFRF will be required there will be no impacts on water quality at the facility.

4.1.16 Environmental Monitoring and Audit

Water Quality Monitoring and Audit

It is recommended that during the facility construction and pipeline installation, a water quality monitoring and auditing programme be conducted in order to pro-actively detect any significant deterioration of water quality. EM&A, in the form of the existing PAA procedures will be required to monitor and audit the efficacy of measures to mitigate any impacts on water quality resulting from AFRF construction.

4.1.17 Further Studies

The successful Licensee will be required to undertake further detailed sediment assessments including production of a Sediment Quality Report, as per WBTC No 22/92, detailing sediment sampling and analysis to confirm the quality of the sediment to be dredged, and thereby recommend appropriate dredging and disposal options. In this context the Licensee's attention is drawn to WBTC No 22/92, WBTC No 6/92 and EPD TC 1-1-92.

4.1.18 *Summary*

Impacts on SS and DO concentrations will result from the construction phase of the AFRF. The use of closed grab clamshell dredgers is the preferred method of turning basin/access channel dredging, and it is therefore recommended that the specification of tightly sealed grab dredgers are included as a contract specification, unless it can be demonstrated such methods are unsuitable. In addition, closed grab clamshell dredging is the preferred method of pipeline installation, and the specification of this method in the contract specification is therefore also recommended.

Mitigation measures have been recommended and these would reduce the scale of impacts resulting from the AFRF project or submarine power cable installation to within acceptable levels as defined by the WQO. The reduction of direct water quality impacts will, in turn, result in reduced indirect impacts upon water sensitive receivers from changes in water quality, including marine biota within the Study Area.

The recommended 'buffer zone' between the CMPs and AFRF service corridor should be strictly adhered to, therefore preventing any interference with the CMPs and any associated contaminant release. The recommended mitigation measures should be strictly followed to minimise any potential adverse impacts of the dredging and pipelaying activities and to protect short term, local water quality and sensitive receivers.

The impacts on water quality, as a result of the submarine power cable installation, will be assessed during the detailed design stage upon finalisation of installation methods.

Based on tidal flow modelling and on coastal geomorphological appraisal, the construction of the turning basin and fairway for access to the sites from the Urmston Road main channel will not change the hydrodynamics in the Study Area, and will have negligible impact on the stability of the beaches connecting Sha Chau to the nearby Islets.

EM&A will be required to monitor and audit the efficacy of measures to mitigate any impacts on water quality resulting from the construction phase of the AFRF, as detailed in *Section 7*.

4.2 CONSTRUCTION NOISE

4.2.1 *Introduction*

A methodology for assessing noise from the construction of the AFRF near Chek Lap Kok has been developed based on the *Technical Memorandum on Noise From Construction Work Other Than Percussive Piling (TM1)*. In general, the methodology is as follows:

- Locate noise sensitive receivers (NSRs) for each worksite;
- Assume plant teams for construction activities based on available information;
- Assign sound power levels to plant teams based on relevant *Technical Memorandum;*
- Calculate appropriate distance attenuation and any barrier corrections; and
- Predict Sound Pressure Levels (L_{Aeq}) at NSRs.

An assessment of impacts is then made by referring to the appropriate noise level criteria.

4.2.2 *Statutory Requirements*

It is anticipated that the majority of the works will be undertaken during the daytime (0700–1900). However a number of the AFRF construction activities may unavoidably need to proceed 24 hours per day and 7 days per week. Under the Noise Control Ordinance (NCO), noise restrictions are imposed during restricted hours: evenings (1900–2300), night-time (2300–0700) and all day (0700–2300) on Sundays and Public Holidays.

For general construction works, noise emission during restricted working hours is controlled legally by the application of a Construction Noise Permit (CNP), under the provisions of the NCO and enacted in accordance with the procedures stipulated in *TM1*. As 24 hour works are proposed, the Contractor will need to apply for a CNP from EPD in order to proceed with construction works during restricted hours.

4.2.3 *Baseline Conditions*

Existing Conditions

The southwestern Tuen Mun District is characterised as an industrial area which is dominated by the Castle Peak Power Station, the Pillar Point Landfill, sewage treatment facilities, and the building of the Black Point Power Station. The noise environment in this region is dominated by traffic noise and noise common to industrial areas. The northwestern Tuen Mun

District is characterised as an undeveloped rural area in which human habitation is confined mostly to village-type developments. The noise environment in this location is 'peaceful' with little disturbance caused by road traffic or industrial operations. The eastern Tuen Mun area is a residential and commercial area in which the noise environment is dominated by traffic road noise.

The north of Lantau Island is currently composed of mostly undeveloped rural areas. The ambient noise environment is quiet with sound levels rarely exceeding 60 dB(A). In November of 1990, a 24-hour baseline noise survey was made in two villages of North Lantau Island as part of the NLE study. Measurements at one of the villages, Pak Mong Village, are applicable to this study and found that during the daytime (0700-1900) the $L_{eq,1hr}$ ranged between 48 and 57 dB(A), the $L_{90,1hr}$ ranged between 35 and 43 dB(A), and the $L_{10,1hr}$ ranged between 50 and 57 dB(A).

Future Conditions

The Tuen Mun District is to see the building of the Tuen Mun Area 38 Special Industries Area (SIA) and the River Trade Terminal (RTT). As a result, the industrial activities, road and marine traffic are expected to increase in the future. It is believed that ambient noise levels will increase with the increase in industrial facility development.

As a result of the building of the Chek Lap Kok Airport, Lantau Island will be the site of many large airport related projects which will have the potential to alter the ambient noise environment. These projects include the Lantau Airport Railway (LAR), North Lantau Expressway (NLE), Tung Chung New Town and other infrastructural projects such as the construction of small roads, container terminals and berthing areas, a refuse transfer station, and water and sewage treatment plants. As most of these projects will be under construction concurrently, much of region to the east of the Chek Lap Kok Airport will potentially be affected by construction noise throughout the AFRF construction period *(Table 3.6a)*. After the completion of these projects, much of the region will be affected by the operational aspects of these projects, primarily road, rail, aircraft and marine traffic noise.

Noise Sensitive Receivers (NSRs)

NSRs, as defined by Hong Kong Planning Standards and Guidelines (HKPSG) and the Noise Control Ordinance (NCO), have been identified with reference to previous environmental studies undertaken in the region of the pipeline, and have been updated by site surveys and by referring to survey sheets and development plans.

The NSRs and their approximate distances from the nearest work area associated with the AFRF are given in *Table 4.2a*, below. It has been identified that Sha Po Kong, Nan Long, Pak Long and Lung Tsai are all close together with Lung Tsai being the nearest to the AFRF, and hence, as

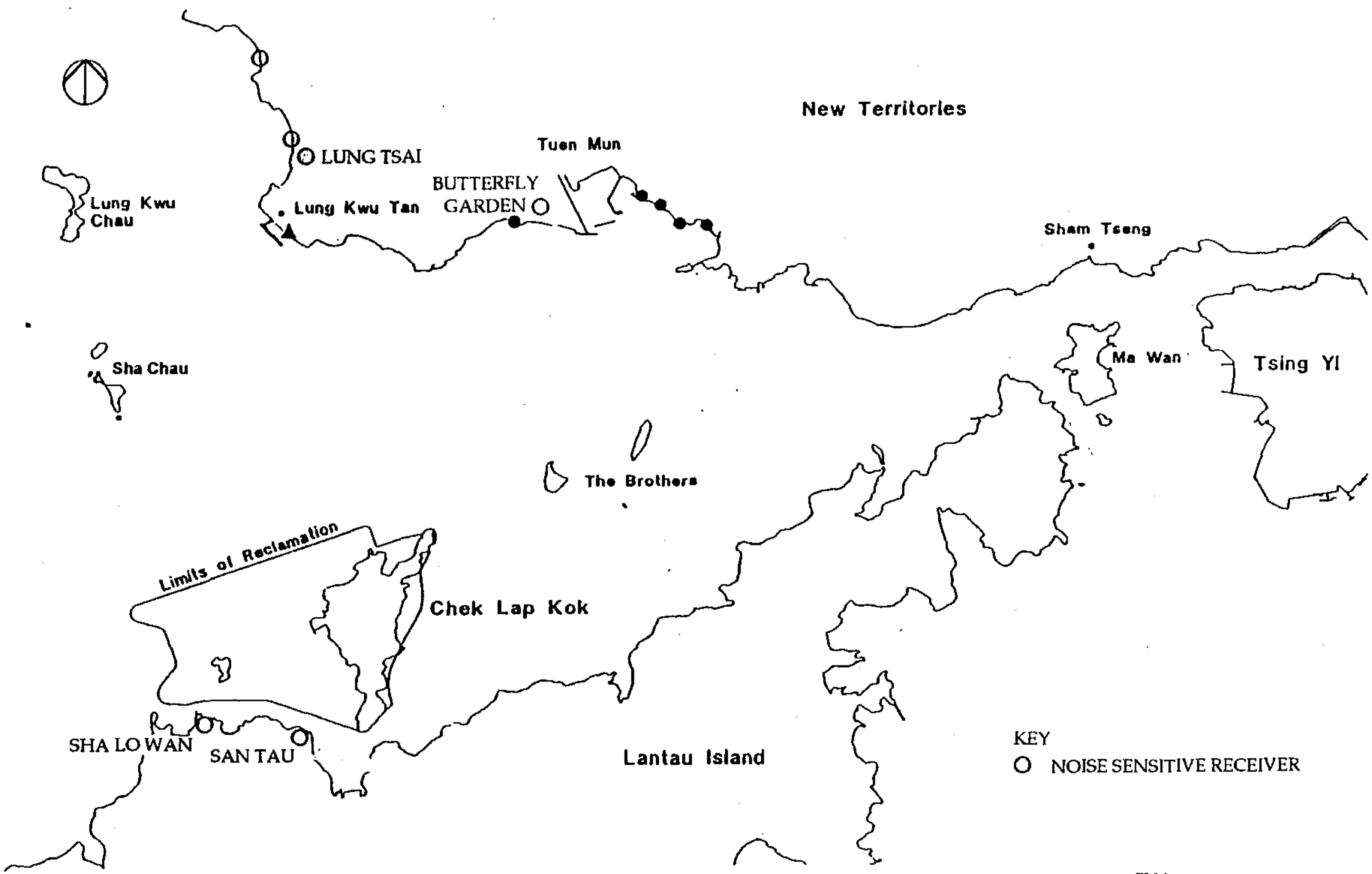

FIGURE 4.2a - NOISE SENSITIVE RECEIVERS

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Hong Kong

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a worst case, Lung Tsai will be assessed. It should be noted that Sha Chau Island, though uninhabited, is the site of an abandoned temple. As there are no permanent residents at this temple, it is assumed to be unused and therefore the temple will not be considered a NSR for this assessment.

Table 4.2a *Noise Sensitive Receivers and Distances to Temporary Receiving Facility*

NSR	Sensitive Use	Approx. Distance to NSR (km)
Sha Lo Wan (Lantau Island)	Residential	6.5
San Tau (Lantau Island)	Residential	7.0
Lung Tsai (Tuen Mun)	Residential	5.25
Butterfly Garden (west of Tuen Mun)	Residential	7.5

Distances have been calculated according to Clause 2.7 in the *TM1*. Locations of the NSRs are indicated on *Figure 4.2a*.

Other NSRs considered in this study will be *Sousa* sighted in the marine waters around Sha Chau and Lung Kwu Chau. Potential impacts on *Sousa* arising from noise generated during construction activities are discussed in *Section 4.4*.

4.2.4 *Evaluation Criteria*

In accordance with the NCO, the surrounding noise environment near the NSRs in the North Lantau area and in the Tuen Mun District should be given an Area Sensitivity Rating (ASR) of "A" (village type development/rural areas). The corresponding noise criteria ($L_{Aeq\ 5min}$), or Acceptable Noise Level (ANL) for all construction work in the region during restricted hours, in accordance with the "A" ASR, are dictated to be as follows:

- 60 dB(A) for all days during the evening (1900–2300) and for general holidays (including Sundays) all day (0700–2300); and
- 45 dB(A) for all days during the night-time (2300–0700).

At this time there is no statutory criterion for control of construction noise during daytime hours (0700–1900 Monday through Saturday, inclusive), however, on the basis of the *Environmental Protection Department Practice Note for Professional Persons* (issued May 1993), the current assessment will use 75 dB(A) $L_{eq,30min}$ as the daytime criterion. This assessment criterion has been widely accepted for major development projects in recent months.

Therefore, the noise criteria used for this assessment will be as in *Table 4.2b* below.

Table 4.2b *Recommended Noise Criteria for NSRs*

Restricted/Unrestricted Hours	Time Period	Noise Criterion
Unrestricted hours	Day time (0700-1900, Monday through Saturday)	$L_{Aeq\ 30min}$ 75 dB(A)
Restricted hours	Evenings (1900-2300) and Public Holidays (including Sundays) (0700-2300)	$L_{Aeq\ 5min}$ 60 dB(A)
Restricted hours	Night-time (2300-0700)	$L_{Aeq\ 5min}$ 45 dB(A)

4.2.5 *Potential Sources of Impact*

There are two main construction operations which have the potential to cause impacts at nearby NSRs. These operations fall into two categories, those that pertain to the construction of the AFRF and those that pertain to the pipeline construction. For the facility the relevant construction activities are turning basin and access channel dredging and *in-situ* bored piling; while for the pipeline the relevant activities are dredging, installation, backfilling and pipeline commissioning. Other activities such as the facility superstructure construction and 'fitting out' operations are not considered to be particularly noisy and so are not assessed in this study.

Facility Construction and Turning Basin/Access Channel Dredging

Turning basin/access channel dredging operations will be carried out to deepen the region near the dolphin and to enable fuel vessel to effectively dock and manoeuvre at the berthing facilities. As a worst-case scenario, the dredging has been assumed to be carried out by two grab dredgers. According to *TM1* two grab dredgers (CNP 063) have a total sound power level of **115 dB(A)**.

In order to anchor the facility, piling activities will be carried out, and non-percussive, *in-situ* bored piling has been assumed. As a worst-case scenario, two large diameter grab and chisel bored piling rig have been assumed to operate simultaneously. According to *TM1*, this type of piling rig has a sound power level of **115 dB(A)**. As a result, two rigs operating simultaneously would have a total sound power level of **118 dB(A)**.

It may be necessary for both turning basin and piling activities to be carried out continuously, 24 hours per day. As a result, the Contractor will need to apply for a CNP for all work carried out during restricted hours *(Table 4.2b)*.

Pipeline Installation

For the pipeline construction there are assumed to be four phases of activity which have the potential to affect nearby NSRs. The worst-case types and quantity of Powered Mechanical Equipment (PME) that are assumed to operate during the construction of the pipeline are outlined in *Table 4.2c* below, although as stated in *Section 4.1*, the environmentally preferred form of pipeline installation comprises a jet/plough method which would be quieter than this worst-case scenario.

Table 4.2c *Pipeline Operations and Plant Inventory*

Operation	Plant	Number	TM Reference Number	Sound Power Level (dB(A))
Pre-trenching	Grab Dredger	2	CNP 063	112+3 **Total: 115**
Pipelaying	Derrick Barge Tug Boat	1 1	CNP 061 CNP 221	104 110 **Total: 111**
Backfilling	Dump Vessel Tug Boat	1 1	 CNP 221	110 110 **Total: 113**
Pipeline Commissioning	Air Compressor	5	CNP 001	109+7 **Total: 116**

Dredging activities may be carried out continuously, 24 hours per day.

4.2.6 *Evaluation of Impacts*

Facility Construction and Turning Basin/Access Channel Dredging

For the proposed site, the predicted impacts at the nearby NSRs from dredging and bored piling activities are given in *Table 4.2b* below. As construction equipment is assumed to radiate at frequencies below 250 hz, reference to the **OCMA** [1] curves indicates that even though distances to NSRs are greater than 300m, no corrections should be made for atmospheric absorption. To consider a worst case, ground absorption effects are also ignored as the intervening terrain is mainly open water. The following standard equation is therefore used to predict the sound pressure level (L_{Aeq}) at the receiver.

Sound Pressure Level = SWL – [20 log(distance) + 8] + 3(facade correction)

[1] Oil Companies Materials Association (now termed the Engineering Equipment and Materials Users Association), Appendix F Publication NW1 Rev 2 Noise Procedures Specifications.

It should be noted that this simplistic conservative formula will tend to predict a slightly higher noise level than may actually result due to climatic effects (wind etc) and to a lesser extent air and ground absorption, all of which can be significant over the large distance relevant to this study.

The predicted worst-case impacts at the nearby NSRs from dredging and bored piling activities are given in *Table 4.2d* below.

Table 4.2d *Construction Noise Impacts at NSRs*

NSR	$L_{Aeq,30min}$ at the receiver facade, dB(A), from: Dredging	Bored Piling
Sha Lo Wan	34	37
San Tau	33	36
Lung Tsai	36	39
Butterfly Garden	33	36

Comparison of these predictions and the *Table 4.2b* criteria indicate that dredging operations for the proposed site can be carried out continuously over a 24 hour period without any NCO exceedance at nearby NSRs. Likewise, bored piling impacts will not cause any NCO exceedance at nearby NSRs over a 24 hour working period. As a result, no mitigation is recommended for either turning basin dredging/access channel or facility bored piling activities at the proposed site.

Pipeline Construction

For a worst-case assessment the two receivers in the Tuen Mun District (Lung Tsai and Butterfly Garden) will be assessed for construction impacts at the proposed site, while impacts at the North Lantau NSRs (Sha Lo Wan and San Tau Villages) will be assessed near the entry point at the airport facility, where the fuel pipeline makes land fall on the Chek Lap Kok Airport. As a result, the distances used for the North Lantau NSRs will be 3.0 km for Sha Lo Wan and 3.5 km for San Tau village. The predicted impacts at the four NSRs from the four phases of pipeline construction from the Sha Chau facility are given in *Table 4.2e* below.

Table 4.2e *Construction Noise Impacts at NSRs near the Pipeline*

Noise Sensitive Receiver	$L_{Aeq,30min}$ at the receiver facade, dB: Pre-trenching	Pipelaying	Backfilling	Pipeline Commissioning
Sha Lo Wan	41	37	39	42
San Tau	39	35	37	40
Lung Tsai	36	32	34	37
Butterfly Garden	33	29	31	34

Comparison of these predictions and *Table 3.3b* indicate that all pipeline installation operations can be carried out continuously over a 24 hour period without causing any exceedance of the NCO at nearby NSRs.

AFRF Cumulative Impacts

If all the facility construction/turning basin/access channel dredging and pipeline construction activities are carried out simultaneously there is the possibility for cumulative impacts. As a worst-case analysis, impacts will be assessed for the noisiest construction activities from each site, bored piling and pre-trenching, acting in parallel. Commissioning will not be assessed in parallel with other activities as it will take place after all other construction activities have ceased.

The predicted cumulative impacts, during night-time hours (2300-0700), at the four NSRs, from bored piling at the AFRF and pre-trenching of the pipeline, for the proposed site, are given in *Table 4.2f* below.

Table 4.2f ***Predicted AFRF Cumulative Construction Impacts at nearby NSRs***

NSR	$L_{Aeq,30min}$ at the receiver facade, dB(A)
Sha Lo Wan	42
Lung Tsai	40
San Tau	41
Butterfly Garden	37

This table indicates that there will be no exceedances of the NCO night-time noise criterion from cumulative AFRF construction impacts associated with the site.

Overall, this analysis indicates that due to the great distances (5.25km) between construction activities and receivers, the cumulative noise impacts are expected in full compliance with the NCO from the facility construction and pipeline installation/construction activities operating in parallel.

It should be noted that other construction activities associated with the Chek Lap Kok Airport will be taking place in parallel with the construction of the AFRF, as a result, there is the potential for cumulative impacts at nearby NSRs from AFRF construction activities acting in parallel with other Chek Lap Kok Airport construction activities. Considering the noise levels which will be generated at nearby NSRs from AFRF construction activities, it is clear that no cumulative impacts could arise due to daytime (0700-1900) or evening (1900-2300) activities. However night-time (2300-0700) construction activities, theoretically have the potential to create cumulative impacts at nearby NSRs above the 45 dB limit of up to 2dB (42 dB + 45 dB). It is noted, however, the prediction methodology used in this report tends to over predict noise levels, and that as the distances encountered in this study are very large, the probability for cumulative impacts would necessitate special circumstances. In particular, cumulative impacts could only arise (assuming all plant teams in question are generating 45 dB(A) noise levels at a particular NSR) if all plant teams affecting a particular NSR emitted noise in similar frequency ranges and were operating simultaneously, and had unobstructed views, over long distances, to that same NSR. It is considered extremely unlikely this could occur.

As a result, the possibility for cumulative impacts exists in theory, but it is believed that the circumstances are extremely unlikely to occur and no mitigation is required.

4.2.7 *Mitigation Measures*

Facility Construction and Turning Basin/Access Channel Dredging

This assessment has indicated that of the two operations assessed for AFRF construction, neither operation will to cause any exceedance of the NCO at the nearby NSRs. As a result, no mitigation measures are recommended for these activities. No noise mitigation measures are recommended for other activities associated with the facility construction and turning basin/access channel dredging.

Pipeline Construction

This assessment has indicated that pipeline construction activities, should not cause exceedances of the NCO at any of the nearby NSRs. Assessment of cumulative impacts has indicated that no NCO exceedance will occur from cumulative impacts. As a result no mitigation measures are necessary for AFRF pipeline construction activities. Working in restricted hours, under the constraint of a CNP, should however, adhere strictly to any specific requirement of the CNP.

4.2.8 *EM&A*

It is considered that no noise monitoring will be required during the construction phase as there will be no construction noise problem.

4.2.9 *Summary*

This worst-case construction noise assessment has indicated that due to the great distances between construction activities associated with the proposed AFRF and the nearest NSRs, AFRF construction activities even when occurring simultaneously and in association with other Chek Lap Kok construction, will not cause any NCO exceedance at the nearest NSRs. As a result, no mitigation is recommended for the constructional phase of the AFRF or the pipeline.

4.3 CONSTRUCTION WASTE MANAGEMENT

4.3.1 *Introduction*

The construction of the proposed AFRF will involve dredging of the turning basin, access fairway, and the submarine pipeline trench if the preferred options are chosen (see *Section 4.1* for discussion of options). The nature of the dredged marine sediments and requirements for their disposal are examined in this section. In view of the small scale of the marine-based construction works, other construction waste arisings are expected to be minimal. At this stage (conceptual design stage) full details of the construction methods and plant to be employed have not been finalised and thus the construction waste arisings will be addressed generically. The successful Tenderer will be required to address in detail the issue of construction waste management in their proposed design of the AFRF.

4.3.2 *Statutory Requirements*

Marine Sediments

The evaluation criteria for classifying the level of contamination of marine sediments by their heavy metal content, and the relevant Technical Circular were discussed earlier in *Section 4.1*.

4.3.3 *Baseline Conditions - Marine Sediments*

Existing Conditions

Baseline sediment quality has been discussed in *Section 4.1*. The results of the sediment sampling and analysis undertaken in the area of the proposed access channel, turning basin, AFRF and services corridor (see *Figure 4.1d*) indicates that the majority of the marine sediments within these areas are uncontaminated, Class A sediments. Sediment analyses at three of the fifteen sampling locations (locations 3, 6 and 13) indicates that the sediment is moderately contaminated Class B material, due to exceedance of the concentration of only one metal element, that is Zinc (Zn), Lead (Pb) and Lead (Pb) respectively for these three locations (see *Table 4.1d* for heavy metal levels).

Future Conditions

With the implementation of the North West Water Pollution Control Zone (NWWPCZ), Water Pollution Control Ordinance (WPCO), Sewage Master Plan and Livestock Waste Control Scheme, it is anticipated that the indiscriminate discharge of effluent will be controlled thus reducing the pollutant load to Hong Kong waters.

4.3.4 *Potential Sources of Impact and their Significance*

The marine-based construction activities will result in the generation of a variety of wastes which can be divided into distinct categories based on their nature and ultimate method of disposal. The types of waste include:

- marine sediments;
- construction waste;
- chemical waste;
- sewage effluents; and
- general refuse.

The definitions for each of these categories, and the nature of their arisings and potential impacts are discussed below.

Marine Sediments

Dredged marine sediments will arise from the construction of the turning basin, access fairway and twin submarine pipeline. The estimated volumes of dredged sediment from these areas are shown in *Table 4.3a* below. A small scour hole at Site C (Sha Chau), indicated on *Figure 4.1m*, minimises the quantity of dredging required for the turning basin at this location.

Table 4.3a ***Estimated Volume of Dredged Sediment***

Location	Turning Basin & Access Fairway (m^3)	Twin Pipeline (m^3)*1	Total Volume (m^3)
Site C	500,000	500,000	1,000,000

*Note : *1 Assuming 3m trench depth for twin pipeline and $30m^2$ cross-sectional area.

This total volume is based on the assumption that all dredged material will require disposal. However, if the nearby FMC marine borrow area is dredged before the dredging for the turning basin, access fairway, and submarine pipeline installation, the total volume of dredging required for the AFRF will be reduced.

The potential environmental effects of marine sediment disposal will vary according to the level of contamination of the sediment, and may lead to water quality impacts, and indirect adverse effects on marine biota, as discussed in detail in *Section 4.1*. Sediment should be disposed of in a manner which minimises the loss of pollutants into solution or by resuspension, as detailed in the mitigation measures stated in *Section 4.1*. It is anticipated that, provided all these recommended mitigation measures are enforced, no unacceptable impacts will result from the dredging, transport and disposal of the marine sediments.

Construction Waste

Waste will arise from a number of activities carried out by the contractor during construction and may include materials packaging and equipment wrappings, and slurry/grouting mixes. The volume of construction waste generated will be dependent on the Contractor's operating procedure and practices, and hence cannot be quantified but in view of the scale of the construction activities it is likely to be small.

The construction activities for the facility site, turning basin, access fairway and pipeline installation will be marine-based, and thus have the potential to cause water pollution from packaging and construction materials, and spillages of slurry/grouting mixes. Potential impacts on water quality arising from general construction activities are discussed in *Section 4.1*. This assessment concluded that release of these potential pollutants into marine waters should not be permitted as introduction of these wastes is likely to have detrimental effects on marine biota in the area. Potential direct and indirect impacts on marine biota arising from general construction activities are discussed in *Section 3.5*.

Chemical Waste

Chemical waste as defined under the *Waste Disposal (Chemical Waste) (General) Regulation* includes any substance being scrap material, or unwanted substances specified under *Schedule 1* of the *Waste Disposal Ordinance (Cap. 354)*. A complete list of such substances is provided under the Ordinance, however substances likely to be generated by construction activities will for the most part arise from the maintenance of equipment. These may include, but need not be limited to, routine replacement of oil during equipment maintenance, and equipment cleaning activities producing spent solvents/solutions which may be halogenated.

Chemical wastes arising during the construction phase may pose serious environmental, and health and safety hazards if not stored and disposed of in an appropriate manner as outlined in the *Chemical Waste Regulations*. These hazards include:

- toxic effects to workers;
- adverse impacts on water quality from spills and associated adverse impacts on marine biota; and
- fire hazards.

General Refuse

General refuse may include food wastes and packaging, waste paper, etc and has the potential to cause impacts on water quality as discussed in *Section 4.1*. Release of general refuse into marine waters should not be permitted as introduction of these wastes is likely to have detrimental effects on marine biota in the area.

Sewage Effluents

Sewage effluents will arise from the construction workforce. As discussed in *Section 4.1*, the discharge of sewage effluents into the marine waters has the potential to result in unacceptable water quality impacts and associated adverse impacts on marine biota.

4.3.5 *Handling, Transportation and Disposal of Waste Arisings*

Marine Sediments

In order to minimise any potential adverse effects from marine sediment disposal, the Hong Kong Government has allocated gazetted marine disposal areas which are allocated by the Fill Management Committee (FMC) and EPD, depending on the quantities and levels of contamination of the spoil to be disposed (Works Branch Technical Circular (WBTC) Nos. 22/92 and 6/92).

It is the responsibility of the successful Tenderer (detailed design stage) to satisfy the appropriate authorities that the contamination levels of the marine sediments to be dredged have been analysed and recorded. According to WBTC No. 22/92, this will involve the submission of a formal Sediment Quality Report to DEP, at least 3 months prior to contract tendering or dredging, whichever is earlier. The sampling and testing programme should include the number and locations of sampling stations, the types of samples to be taken (eg, surface grab, vibrocore, etc), the depths of sampling required, and the types and numbers of tests to be undertaken according to the WBTC No. 22/92. Knowledge of the levels of contaminants present is required to ensure that the correct dredging, handling and disposal procedures are followed.

In accordance with the EPD Technical Circular No. (TC) 1-1-92, moderately contaminated material (Class B) requires special care during dredging and transport, and must be disposed of in a manner which minimizes the loss of pollutants either into solution or by resuspension. Seriously contaminated Class C material must be dredged and transported with great care, cannot be dumped in the gazetted marine disposal grounds and must be effectively isolated from the environment upon final disposal. Specific dredging procedures which are required to minimise any potential water quality impacts are discussed and recommended in *Section 4.1*.

In all cases the EPD will advise whether open dumping is environmentally acceptable, or whether disposal at a designated exhausted marine borrow pit is required. Any environmental conditions to be imposed with the dumping licence, and special disposal arrangements will also be specified at this time. According to WBTC No.22/92, with a volume of uncontaminated marine sediment anticipated to be greater than 500 000m^3, the FMC will finalise the disposal allocation.

The dredged marine sediments will be loaded onto barges and transported to designated disposal sites depending on their level of contaminants. The only disposal site at present designated for the disposal of seriously contaminated muds is the East Sha Chau Contaminated Mud Pits. The dredged material, identified as Class A & B, will all be suitable for disposal at a gazetted marine disposal ground. This will be subject, however, to further sediment analysis in the EIA undertaken by the successful Tenderer (detailed design stage) to confirm the sediment quality and recommend disposal options. It will be the Tenderer's (detailed design stage) responsibility to ensure that all dredging and disposal methods are in compliance with the guidelines specified in WBTC No. 22/92.

The number and sizes of barges employed will depend largely on the volume of marine sediments, dredging schedule and operation plan. It will also be dependent on the turnaround time for the barges between loading, transporting and deposition of marine sediments and returning to the dredging area. Hence, the designation of the disposal sites may have an effect on the dredging plan, the capacities and the number of barges utilised.

General Construction Waste

In view of the potential impacts identified in the previous section it is considered important that comprehensive waste management procedures and appropriate staff environmental training is employed, to ensure that waste arisings during the construction works do not enter surrounding waters, in order to minimise adverse impacts on marine biota in particular *Sousa* and fishing grounds in the area. Care should also be taken during the transportation of construction wastes by barge to the disposal site to ensure no impacts on water quality arise from spillages, as detailed in *Section 7*.

Chemical Waste

Chemical waste will arise principally as a result of maintenance activities. It is not possible to quantify the amount of chemical waste which will arise from the construction activities since it will be highly dependent on the contractor's on-site maintenance requirements and the amount of plant utilised.

The Chemical Waste Treatment Centre (CWTC) located at Tsing Yi was commissioned in June 1993 and is the point of disposal for chemical wastes in the Territory. Disposal of chemical wastes at the CWTC will ensure that environmental and health and safety risks are reduced to a minimum, provided that correct storage procedures are instigated on the marine vessels. At the present time there is no charge for this collection and disposal service although there is currently a registration fee of HK$240. It is understood from the EPD that it is likely that the chemical waste charging scheme will be implemented in early 1995.

The contractor should contact the EPD and the contractor operating the CWTC, who offer a chemical waste collection service. The CWTC operator will only supply standard containers no larger than 200 litres. Other storage will have to be provided by the contractor. In addition, the contractor should check to ensure that the handling and disposal methods for the wastes in question are appropriate.

General Refuse

The amount of general refuse which is likely to arise cannot be quantified at this time as it will be largely dependent on the size of the workforce employed by the contractor and the implementation of practices on board the works vessels.

General refuse generated on the vessels should be stored and collected separately from other construction and chemical wastes, by approved contractors. The contractor will be responsible for the removal of waste generated on the works vessels. A private waste contractor may be commissioned by the contractor to remove any general refuse generated. It is important that defined waste management practices, including appropriate staff training be employed to ensure that refuse arising during the construction works do not enter surrounding waters in order to minimise adverse impacts on marine biota, in particular *Sousa* and fishing grounds in the area. These waste management/monitoring procedures have been outlined in *Section 7*.

Sewage Effluents

Sewage storage or initial treatment facilities will be necessary on the works vessels to hold the sewage arising from the construction workforce (such as chemical toilets or storage tanks), prior to collection and removal.

4.3.6 Environmental Monitoring and Audit

It is recommended that during the facility construction and pipeline installation, a waste monitoring programme is implemented to ensure that all wastes are collected, handled, stored and disposed off-site in accordance with EPD regulations and requirements, and at EPD approved disposal facilities, as detailed further in *Section 7*. This will be incorporated into the ongoing PAA monitoring programme.

4.3.7 *Further Studies*

The successful Tenderer for construction or the AFRF will be required to undertake further detailed sediment assessment during to detailed design phase, as detailed in *Section 4.1*. This will facilitate appropriate marine sediment disposal requirements, and possible refining of mitigation measures.

4.3.8 *Mitigation Measures*

The potential environmental impacts associated with waste arisings from the construction of the proposed AFRF and the recommended handling, transportation and disposal options have been detailed. This section outlines appropriate mitigation measures to minimise any impact from these construction waste arisings.

Dredging Activities

The water quality assessment concluded that the proposed dredging works may involve the dredging of some moderately contaminated marine sediments. It is therefore important that appropriate measures are undertaken to ensure that impacts can be kept to a minimum. The recommended mitigation measures detailed in *Section 4.1* should be strictly followed to minimise any potential adverse impacts of the dredging works and to protect short term, local water quality.

Works Practices

Minimisation of the potential for impacts on water quality during construction activities may be achieved by the observation of high standards of waste management on the works vessels and barges, which should be defined by the Tenderer, strictly enforced, and monitored by the specified personnel to ensure that no waste arisings enter surrounding marine waters. Release of these potential pollutants into marine waters during storage, handling or barge transportation should not be permitted as introduction of polluted waters is likely to have detrimental effects on water quality and marine biota.

Monitoring of construction practice controls and waste disposal

There must be strict control over the AFRF construction team/s to ensure that no solid or liquid wastes generated during construction are disposed to the sea and to ensure that all wastes are collected and are disposed off-site, in accordance with EPD regulations and requirements, and at EPD approved disposal facilities. This should be monitored to ensure effective controls and correct disposal procedures are being systematically implemented.

4.3.9 *Summary*

It is considered that, provided the recommended mitigation measures recommended in *Section 4.1* including the *Works Branch Technical Circular No. 22/92 'Marine Disposal of Dredged Mud'* are strictly adhered to, potential impacts of the dredging works and associated sediment disposal will be minimised, ensuring protection of short term, local water quality. It is therefore anticipated that no unacceptable impacts will result from the dredging, transport and disposal of the marine sediments.

The dredged material will be suitable for disposal at a gazetted marine disposal ground. This will, however, be subject to further sediment analysis to be undertaken by the successful Tenderer (detailed design stage) to confirm the sediment quality and finalise the required disposal allocation. Should further studies conclude that the dredged material is seriously contaminated, additional mitigation measures to minimise the potential release of contaminants into the water column will be necessary.

Provided that construction waste arisings are handled, transported and disposed of using approved methods as described previously in *Section 4.3.5* and that no solid or liquid wastes enter surrounding marine waters, no significant adverse environmental impacts are envisioned. Thus, it is anticipated that no insurmountable waste management impacts will arise during the construction period.

4.4 *CONSTRUCTION IMPACTS ON MARINE ECOLOGY*

4.4.1 *Introduction*

The construction of the proposed AFRF will involve dredging works for the turning basin, access fairway, and pipeline installation if the preferred methods are employed, as described in *Section 3.4*. A key issue identified in the IAR is the potential impact of the AFRF construction on *Sousa*, which have been sighted in the marine waters around Sha Chau and Lung Kwu Chau. In order to ascertain the potential impacts to *Sousa*, it was decided to advance the impact assessment elements associated with *Sousa* and to identify practical and cost-effective mitigation measures to minimise the scale, extent and severity of impacts. As discussed in *Section 1.2.1*, this assessment has been undertaken in two parts, firstly the Stage 1 Study which comprised a field based survey and the Stage 2 Study synthesising the field results with an impact assessment of the construction and operation of the AFRF to *Sousa*.

Further key issues identified by the ACE EIA Sub-Committee for detailed assessment include the potential impact of the AFRF project on the Chinese King Crab and prawn fisheries; and benthic studies related to the site and coastal ecological issues. Thus a preliminary (non-seasonal) marine ecological survey has been undertaken to provide baseline ecological data specific to the Sha Chau area.

4.4.2 *Statutory Requirements*

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 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.

4.4.3 *Existing Ecological Environment*

Introduction

The marine ecology of the Study Area in the waters off North Lantau and Urmston Road consists of semi-tropical marine and estuarine biota. In order to provide baseline ecological data specific to the Sha Chau area, a marine ecological survey was undertaken in late September and early October 1994 to provide ecological information on:

- the intertidal communities;
- the fish and invertebrate communities; and
- the benthic communities.

The objective of this survey is to provide baseline data for the identification of sensitive receptors, a preliminary assessment on potential environmental impacts on the marine ecology in the area arising from the proposed AFRF and to identify any future monitoring requirements. It should be noted that the survey does not include data on seasonal variations.

The survey covered areas likely to be directly affected by dredging activities for the proposed turning basin, the marine works for the AFRF construction and submarine pipeline installation, and areas which may be indirectly affected by these construction works.

The following four surveys have been completed:

- Diving Survey: around Sha Chau to record underwater fauna and flora so as to provide supplementary information to the trawl survey results. (Particular attention was given to search for Chinese King Crabs in the area);

- Intertidal Survey: general survey on the three types of intertidal habitats at Sha Cha; namely, rocky shores, boulder shores and sandy shores, during low tides to provide a semi-quantitative description of the littoral communities;

- Benthic Grab Survey: to provide a general description on the soft bottom benthic communities around Sha Chau; and

- Trawl Survey: to provide a semi-quantitative description on the large invertebrates (ie. shrimps (prawns) [1] , crabs, urchins and snails etc.) and fish around Sha Chau.

Details on the survey methodology and the survey results with species lists and data on abundance are presented in *Annex* C. The findings from these baseline ecological surveys are summarised below, in particular the identification of any species or habitats of key ecological, conservation or economic importance which might be affected by construction of the AFRF. Survey efforts were concentrated in defining the dominant marine faunal and floral communities in the area. Seasonal variations, which are known to be significant, could not be assessed.

Soft Bottom Benthic Communities

Sha Chau Area

Twelve stations were established around Sha Chau as shown on *Figure C2* in *Annex* C. A total of 24 benthic species were recorded in the grab survey and are listed in *Table C8* together with their abundance. In contrast to invertebrates and fish, the soft bottom benthic community in the area was barren. Sand worms and snails comprised the dominant benthic groups in the Study Area, and they constituted 67% of the total species recorded over the sampling area. However, both abundance and number of benthic species in the Study Area were low (only two to seven species and individuals were found at each station). It is considered that the high relative abundance of the gastropod *Turitella terebra* on the surface of the bottom sediment may prevent the development of a diverse and rich benthic community in the area.

Fish and Invertebrate Communities

Sha Chau Area

Six survey transects were established around Sha Chau as shown on *Figure C1* in *Annex* C. A total of 65 species were recorded in the trawl survey as listed in *Table C1*. Occurrence and abundance of each species and total biomass of each trawl sample are given in *Tables C2 to C7*.

Biological diversity of fish and invertebrates was high. Thirty four species of invertebrates and thirty one species of fish were found in the survey. Stations south, west and north of Sha Chau (Trawl Stations 2, 3, 4) were dominated by the gastropod *Turritella terebra* and *Murex trapa*. The invertebrate and fish communities here are basically similar to their counterparts to the north of Lantau Island described by Wu and Richards (1981) and Richards and Wu (1985). Sea bottom sediments at Trawl Stations 1, 5 and 6 east of Sha Chau mainly consisted of gravel-sand. Although *T. terebra* and *M. trapa* were found in lower abundance at these three stations,

(1) It should be noted that the generic term shrimps and prawns are taken to refer to the same invertebrate.

the invertebrates and fish fauna were generally similar to the other stations. Thus, it is considered that the area covered by the present study can be regarded as a single community. Sea pens and corals were commonly found in the subtidal zone.

Sha Chau supports a diversity of fish and shrimp species, many of which are commercially important species (e.g. sole, flounder, croakers, flat heads and penaeid shrimps). Penaeid shrimps and sole were particularly abundant in the area. Juvenile fish, shrimps, crabs and molluscan egg cases were commonly found.

North Lantau/Chek Lap Kok Area

The fish community sampled by trawl was found to be of high diversity (NAMP EIA). *Annex* C provides details of the fish species recorded in the trawl surveys supplemented by additional details of species occurring in the area derived from previous surveys. [1] [2] The fishery in the waters to the north of Lantau exploits both bottom and off-bottom free-swimming fin and shell fish that thrive in the estuarine influenced waters. Although various shellfish beds exist they are small and have only supported incidental gathering mainly by coastal villagers. There is no oyster culture.

Fish resource records from the AFD for 1990/91 indicate that the main commercial species include a variety of penaeid prawns, Sea Bream, Yellow Croaker, Japanese Sea Perch, Threadfin, Tongue Sole, White Pomfret and Mantis Shrimps. Most of these species are not common in eastern territorial waters. However, the local fish communities are not special or unique in Hong Kong waters. [3]

Consultation with the AFD has provided information on fishing activities in the North Lantau/Chek Lap Kok area. The latest survey conducted on fishing craft up to 15m in length indicated that in 1990, 401 boats fished in this area at some time during the year. Of these, 259 boats are less than 5m in length, 106 are 5 to 10m and 36 are 10 to 15m. The smallest boats used mostly gill nets and handlines, the 5 to 10m class used mostly gill nets with purse seining, long lining, cage trapping and clam collecting also significantly represented. In the 10 to 15m class, 72% of the effort was expended either by gill netting or purse seining while some long lining, shrimp trawling and hand lining was also conducted. The AFD noted a significant level of fishing effort may be expended in the area by vessels over 15m but sufficient information was not available to AFD to quantify such fishing activities. AFD have indicated that they have no more recent data on fishing activities in this area.

(1) Richards, J and R.S.S. Wu (1985) Inshore fish community structure in a subtropical estuary. Asian Mar. Biol. 2, 57-68.

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

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

Similarly, 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 AFD have noted that mariculturists have in the past collected wild fish fry in the area. It is known that prawn spawning grounds occur in the North Western Waters, as shown in *Figure 4.1e*, and are believed to include the Sha Chau area. However, AFD have indicated that they have no data or existing information on prawn spawning grounds in these waters.

Intertidal Community

Rocky Shores

A total of twelve species were found during the rocky shore survey. Species identified and their general abundance are given in *Annex C, Table C9*. These species were typically distributed in two distinct zones on the shore: a Periwinkle Zone and a Barnacle and Oyster Zone. Limpets and macroalgae were not found in the survey.

Boulder Shores

Boulder shores at Sha Chau typically composed of boulders resting on a clean coarse sand bed. A total of twelve species were found during the survey. Species identified and their general abundance are given in *Annex C, Table C10*. Species on the rocky shores and boulder shores were essentially similar; and the biological diversity of these two intertidal communities was also generally low.

Sandy Shores

Sandy shores at Sha Chau typically comprised clean and coarse sand. Only five species were recorded and both species diversity and numbers were extremely low. In over 50% of the samples, no species were found. The Chinese King Crab and their eggs were not found in the intertidal habitats. However the Chinese King Crab is known to be absent during the month of September and therefore surveying at another time of the year would be more representative. Past studies elsewhere indicate February as the most likely time crabs would be present.

Diving survey

Stone corals (Family *Faviidae*), *Gorgonacea* and sea pens were commonly noted at the subtidal zone. The *sabellid* polychaetes were also common. Again, the Chinese King Crab was not encountered during the diving survey as sampling was conducted during the month of September when the Chinese King Crab is known to be absent.

Marine Mammals

At least one dozen marine mammals occur in Hong Kong waters, with a predominance of Chinese White Dolphins (*Sousa chinensis*), in western Hong

Kong, and finless porpoises, *Neophocaena phocaenoides*, in the eastern waters. It is reported that of marine mammals, only *Sousa chinensis*, occur frequently in the waters of western Hong Kong and have been sighted recently in the marine waters around Sha Chau and Lung Kwu Chau Islands during the field surveys undertaken for the Site Selection Study.

A comprehensive international and local literature review was undertaken in the Site Selection Study with regard to the locational, feeding and breeding site preferences of *Sousa chinensis*, including the Indo-Pacific Humpback Dolphin, the objective being to obtain a background knowledge of *Sousa chinensis* to supplement the field surveys around Sha Chau. The local findings of this literature review are discussed below.

Species Characteristics

Scientists believe that *Sousa chinensis* is a previously unrecorded species of estuary dweller that 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). Research is currently being undertaken by AFD's Dolphin Research Team to identify the taxonomic status of *Sousa chinensis*.

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. They are unique because of their 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 of the estuary waters of the Pearl River Delta. Consultation with AFDs *Sousa* research studies, first nine months of results, suggest that Hong Kong comprises a very small part of the potential range of the dolphins within the Pearl River Delta.

Habitats

Sousa chinensis, hereafter referred to as *Sousa*, have been observed on many occasions in the waters off North Lantau and the Urmston Road area (between Lung Kwu Chau/Sha Chau and Castle Peak), north of the New Airport platform and in the vicinity of the Brothers. During a survey conducted north of Lantau Island on the 15 May 1994, organised by the World Wide Fund for Nature Hong Kong (WWF), more than a dozen *Sousa* were sighted near Chek Lap Kok. A pod of seven *Sousa*, including a number of calves, were also seen regularly near Lung Kwu Chau (Ruxton 1994 *pers. comm.*).

An assessment of the presence of *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 to 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 [(1) (2) (3)], and can be found anywhere in this relatively shallow water area as indicated in *Figure 4.4a*. In addition, *Sousa*, through consultation with AFDs *Sousa* research studies, are often sighted travelling in deeper waters between Castle Peak, Lung Kwu Chau/Sha Chau, The Brothers and Sha Lo Wan. It is noticeable, through consultation with AFDs *Sousa* research studies, 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. *Sousa* have also been commonly seen in the vicinity of fishing activities in Hong Kong's North Western Approaches associated with pair and shrimp trawling vessels, in particular during net–cleaning activities.

Consultation with AFD's *Sousa* research studies for the period January – May 1994 indicate that the Lung Kwu Chau area had the greatest number of sightings, largest group size and was where most feedings occurred during this period. More recent results obtained from consultation with AFDs Sousa research studies, for the period up to September 1994, have shown that Lung Kwu Chau and Sha Chau have remained areas where animals can be seen reliably either resting, feeding or socialising. Other areas that are consistently frequented sporadically are the areas between Tai O and Sha Lo Wan, and the area between Fan Lau and Soko Islands. Furthermore, consultation with AFDs *Sousa* research studies, first nine months of results, suggest that Hong Kong comprises a very small part of the potential range of the dolphins within the Pearl River Delta.

The collated data in Hong Kong waters show that *Sousa* travel through, feed, socialize, rear young and rest in waters immediately adjacent to north and west Lantau Island, including the immediate vicinity of the Sha Chau and Lung Kwu Chau Islands. The *Sousa* population in the North Lantau Waters is reported, through consultation with AFDs *Sousa* research studies, to number around 40–100 individuals. Recent (wet season) findings, reported through consultation with AFDs *Sousa* research studies, have indicated that *Sousa* have been sighted more remote from the Pearl River estuarine areas (as far as the Ma Wan Channel and south of Lantau near Peng Chau). It is suspected that the change in salinity of water may be a contributing factor to the observed extension of their range of appearance. The dolphins may have a limited tolerance of certain salinities and therefore a combination of heavy rain and the added input possibly caused this change, or perhaps the prey of the population was effected and the dolphins distribution changed too . However, it is believed, through consultation with AFDs *Sousa* research studies, that the deluge of freshwater is more likely to effect distribution of prey species rather than the dolphins directly.

(1) Saayman, G.S and C.K. Tayler. 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.

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

(3) 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.

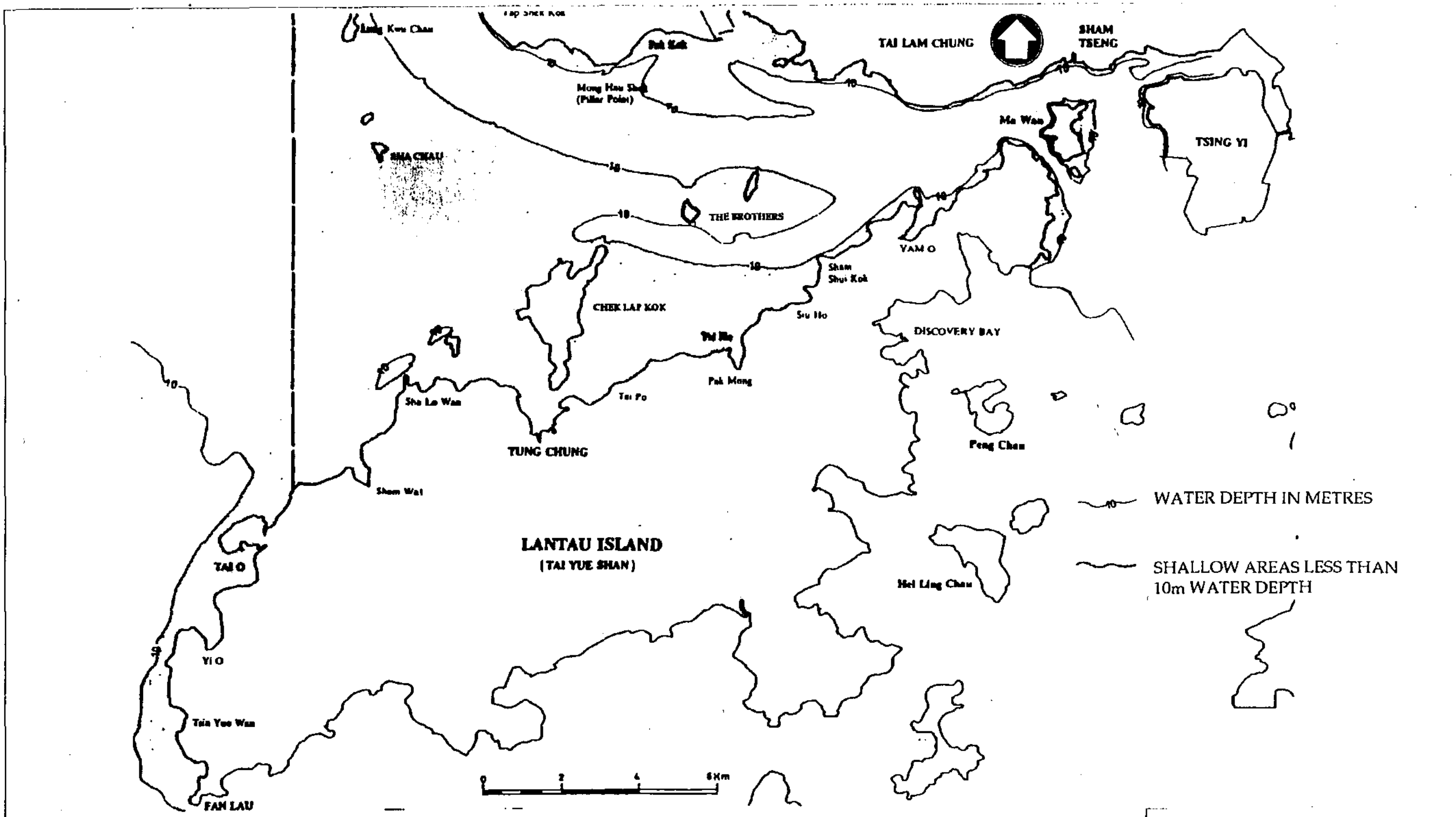

FIGURE 4.4a - DISTRIBUTION OF SHALLOW WATER (<10M) WITHIN THE STUDY AREA

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However, the exact food preferences of *Sousa* and the importance of this area for the survival of the dolphin is not known and comprises one objective of the AFD research study. Thus there is limited information on the *Sousa's* habitat requirements. It may be possible that the concentration of sightings in these areas may indicate either a food chain preference or the need for periodic freshwater (eg removal of marine/freshwater parasites), or for more turbid waters (avoidance of predators).

Ruxton (1993) reported that as the work on the Chek Lap Kok Airport has progressed, there has been a noticeable change in the *Sousa* feeding grounds. No *Sousa* pods had been reported in the Brothers Islands 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 contradicted by both numerous PAA sightings in the vicinity of the Brothers Islands (up to May 1994) and by a single sighting of 3 *Sousa* in the vicinity of the Brothers Islands during the field survey associated with the Site Selection Study.

Records of general observations by WWF since 1990 indicates that *Sousa* may move down the Pearl estuary in the early morning to feed in HK waters and return in the early evening, while others appear to stay within HK waters permanently (Ruxton 1993).

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.). In consultation with AFD *Sousa* research studies initial (first nine months) results suggest, from an increase in certain behavioural patterns associated with courtship and mating, that *Sousa* mating seemed to occur during the month of September although conclusions can not be drawn until at least a full cycle of seasons has been studied. 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).

AFD have very recently (28 October 1994) indicated that there have been tentative interim proposals from their Dolphin Research Team that the area around Sha Chau be designated SSSI as an interim until the government identification of it as a marine reserve (dolphin sanctuary) can be legislated. Please note that our comments stated that these are DRT's proposal rather than being a tentative interim AFD proposal. At the present stage, AFD requires more details of the proposal from DRT for further consideration.

4.4.4 *Evaluation Criteria*

The ecological impact is assessed using the following criteria:

Statutory Requirements

Sousa is 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.

In Hong Kong, stone corals are protected under the Animals and Plant (Protection of Endangered species) Ordinance (Cap. 187) in that the export and import of corals are regulated. Although it should be noted that this protection does not apply to/prevent the collection or damaging of corals in Hong Kong waters.

Planning Guidelines

The islands of Sha Chau, Lung Kwu Chau and Tree Island (Pak Chau) have an interesting avifauna and were designated a Site of Special Scientific Interest (SSSI) in September 1979. However there are currently proposals for the degazettal of the Lung Kwu Chau SSSI. Sha Chau is an important resting ground for migratory birds on route to Mai Po marshes. Tree Island (Pak Chau), as shown on *Figure 2.2b*, is the most important night-time roost site for wintering Cormorants (*Phalacrocorax carbo*) in Hong Kong (around 400 birds). Sites of Special Scientific Interest (SSSI) should be adequately protected from the effects of pollution under the Environmental Section of the Hong Kong Planning Standards and Guidelines. The Agriculture and Fisheries Department should be advised of and consulted on any development proposals which will affect SSSI.

Commercial Value of Fisheries

The waters to the north of Lantau are a traditional area for inshore fishing with two substantial fishing ports at Castle Peak Bay and Tai O. As stated earlier, however, recent and comprehensive data on fisheries production are not available from the AFD for the region. An assessment of the production in 1989-90 by 487 small craft, less than 15m in length, that claimed to fish the North Lantau region (including the area of Sha Chau and Lung Kwu Chau) showed an annual volume of 1340 tonnes with an additional 25,300,000 tails of fish fry (used in the mariculture industry). This represents an annual value of $40 million at 1994 prices. No assessment is available for the larger vessels in the region, however, which are more productive and their contribution to total production could therefore remain significant in relation to that from smaller craft. On the conservative assumption that a third of territorial shrimp trawler production and four-fifths of hang trawler production is from this region, larger vessels probably account for a further $18 to $24 million. The gross value of all fishing catch in the region thus amounts to approximately $60 million at 1994 prices and represents around one seventh of the territories total fisheries production.

Sha Chau supports a diversity of fish and shrimp, many of which are commercially important species (eg. sole, flounder, croakers, flat heads and penaeid shrimps). Penaeid shrimps and sole were particularly common. Juvenile fish, shrimps, crabs and molluscan egg cases were commonly found, indicating the high fisheries value of the area. There is therefore a strong possibility that the Sha Chau area may serve as an important spawning and nursery ground for these commercially important species.

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 marine mammals, including dolphins. The Chinese White Dolphin is a rare species of cetacean and should be considered as a threatened or endangered species. It should be noted that habitat conservation has been recognised as important as individual preservation.

The study area may support two species of Chinese King Crab. The King Crabs are thought to breed only on the Lung Kwu Sheung Tan and Lung Kwu Tan beaches in Hong Kong waters. Although they are not protected in Hong Kong under any statutory Ordinance, this animal is of great zoological interest since it is a surviving member of Xiphosura and occurs in relatively few locations in the world, being recorded only in parts of South-east Asia, the Caribbean and the Atlantic coast of North America (Morton and Morton, 1983).

4.4.5 *Potential Sources of Impact*

Construction methods involved for the offshore facility and pipeline installation, as described in *Section 3.4*, may affect the local marine ecology; of particular concern are potential impacts arising from dredging activities, pipeline construction and berth construction. These activities and other methods which may be employed are discussed below.

Dredging of marine sediment

Dredging for the turning basin and access fairway will lead to the direct loss of seabed and thus inevitably remove or bury the associated benthic communities in the immediate work areas, and cause disturbance to marine biota in the surrounding area through dispersal of suspended sediments. Depending on the contamination level of the marine sediment, pollutants including heavy metals, may be released. This may affect the food chain of the ecosystem in the vicinity and increase levels of organics which can cause de-oxygenation of local waters.

In addition, the resuspended sediment generated will cause an increase in SS concentrations in the water column and hence turbidity of the sea water. Indirect impacts may result as high SS concentrations can cause the smothering of filter feeders such as bivalves and clogging of gill filaments in fish and other organisms. One associated concern is the level of oxygen saturation within the water column as a number of effects produced by elevated SS levels combine to reduce dissolved oxygen (DO) concentrations. An increase in solids in the water column will reduce sunlight penetration, lowering the rate of photosynthesis of phytoplankton (primary productivity) and thus the rate at which oxygen is produced in the water column. Similarly, the increased levels of solids results in more energy from sunlight being retained with resulting rises in temperature. This also acts against oxygen levels as oxygen is more soluble in colder water.

It should be noted that the extent of impact on water quality in terms of the potential physical and chemical effects described above is related to the amount of material put into suspension. This is a function of the quantity and nature of the marine sediment, dispersion characteristics of the water receiving body at site chosen and dredging method employed.

Pipeline Construction

As described in *Section 3.4.3*, the pipeline will also be installed by dredging to a depth of up to 3 metres below the existing seabed which will also result in the direct loss of benthic communities through disturbance of the sea bed. Potential indirect impacts may also arise on marine biota through sediment resuspension and associated physical and chemical effects as described above for other dredging activities.

In addition, as described in *Section 3.4.3*, an anchor spread will be required around the lay barge for the pipelaying stage. The anchor spread may therefore obstruct fishing activities in the area, such as trawler nets for shrimp fishing, gill nets and long lining.

Berth construction

The AFRF will be formed on a piled structure, as detailed in *Section 3.4.2*. Aside from the direct loss of benthic biota and indirect disturbances to marine biota and habitats both within and adjacent to the work areas, underwater noises, movements of propellers and submerged equipments, and induced currents from vessels will also contribute to impacts on the local marine ecology.

4.4.6 Evaluation of Impacts

Introduction

It should be noted that the sediment plume modelling simulations undertaken to simulate the fate of sediment lost to suspension during dredging associated with the AFRF, reported in *Section 4.1*, predicted minimal elevation of suspended solid (SS) levels in relation to the background concentrations in the area. The highest predicted increase in SS levels over background concentrations was 13 mg/l at North Sha Chau which is in excess of the WQO. However, as discussed in *Section 4.1*, water quality impacts in exceedance of the WQO, resulting from the dredging activities during construction of the AFRF, can be effectively minimised to within WQO levels provided the recommended mitigation measures, including the use of closed grabs for dredging, as discussed in *Section 4.1.15*, are included in construction contracts, where practicable.

As reported in *Section 4.1*, the sediment quality data indicate that the majority of marine sediments are classified as uncontaminated with heavy metal concentrations falling within the Class A criteria. Dredging works for the AFRF construction therefore generally will not result in the release of pollutants into the marine environment. It is considered that dredging will involve the disturbance and distribution of largely inert material already contained within the ecosystem. However, in the locations where sediment is found to be moderately contaminated, special care during dredging will be necessary so as to minimise the loss of pollutants either into solution or by resuspension.

Benthic Biota

Dredging of marine sediment will result in the direct loss of the sublittoral habitats in the immediate works area of the turning basin, access fairway and pipeline corridor. It is estimated that dredging for the turning basin and access fairway will result in the direct loss of an area of approximately 245 000 m^2 of sea bed and the associated benthic communities. If the preferred pre-trenching method is employed for the pipeline installation, then dredging will similarly result in the direct loss of an area of approximately 220 000 m^2 of sea bed and associated benthic communities.

As discussed in *Section 4.4.5*, the preferred method for the construction of the AFRF on a piled structure will minimise the loss of habitat. It should be noted that there are proposals by FMC to dredge sand in the area to the east of Sha Chau. Thus at the time of the proposed AFRF construction, the seafloor ecology in the area of the access fairway may have already been disturbed by dredging activities in the Urmston Road.

The waters around Sha Chau fall within the transition zone between oceanic and estuarine conditions. During the wet summer season, silt and pollutant loads are carried into these Hong Kong waters from the Pearl River creating seasonal variations in water quality and high levels of suspended solids (SS). The nearest EPD water quality monitoring station, NM6, is located between Sha Chau and Chek Lap Kok. Data for January 1993 - April 1994 indicate that these waters experience variable levels of SS ranging from 6.5 - 75.3 mg/l, although the average SS level was found to be approximately 20 mg/l.

The effects of dispersed sediments on biota outside the immediate dredging sites are expected to be less significant than for example in eastern territorial waters, since the faunal communities in these North Lantau Waters are to an extent acclimatised and adapted to periods of high suspended solids in the water column and irregular sediment deposition as a result of the Pearl

River discharge. [1] In the long term, after construction is complete, areas no longer being disturbed are likely to be recolonized by benthic fauna with similar communities developing in areas where substrate type is maintained.

Soft Bottom Benthic Communities

Based on the benthic grab survey results around Sha Chau, *Annex C*, the soft bottom benthic community around Sha Chau was poorly represented. The recorded species composition is similar to other studies of soft bottom faunal communities in Hong Kong waters (Shin and Thompson, 1982; Shin, 1982a; 1989; 1990). However, both the abundance and number of species in the Study Area were low compared with that recorded in the eastern waters of Hong Kong (Shin, 1982a; 1989; 1990). All the benthic species recorded have been reported in Hong Kong from previous studies and no particularly environmentally sensitive species were noted.

Thus surveys of the marine ecology around Sha Chau have revealed that the benthic species noted are typical of soft bottom benthic communities in the coastal areas of Hong Kong. Hence, the estimated loss of soft bottom benthos resulting from the AFRF construction is considered unlikely to have an adverse effect on the sublittoral marine ecosystem as a whole to the north of Lantau.

Hard Bottom Benthic Communities

As identified in *Section 4.4.3*, stone corals (Family *Faviidae*), *Gorgonacea* and sea pens were commonly noted at the subtidal zone during the diving survey around Sha Chau. Sea pens and stone corals are unique marine fauna of biological interest. The protection over the export and import of stone corals in Hong Kong, as discussed in *Section 4.4.4*, identifies the ecological importance of this species.

These species are sensitive to pollution, particularly major siltation resulting from dredging, although they are adapted to some degree to the fluctuation in sediment loads resulting from the Pearl River. The abundance of sea pens and corals in Hong Kong waters has decreased in recent years. Results from the trawl survey and diving survey indicated that the sea pens (*Pteroides esperi, P. sparmanni, Sclerobelemnon burgeri, Virgularia gustaviana*) and stone corals (faviidae and gorgonacea) were common in the area.

Therefore it is recommended that further surveys be undertaken to identify the extent of the area of stone corals and sea pens around Sha Chau. It is considered important that the recommended mitigation measures are fully implemented to minimise the loss of suspended solids to the water column during dredging, as detailed in *Section 4.1.15*. In addition, identified areas of stone corals and sea pens should be accorded a high level of protection and thus not used as works areas if possible.

[1] New Airport Master Plan EIA Final Report, Greiner-Maunsell 1991.

Fisheries and Invertebrates

The great majority of fish and invertebrate species recorded in the present study are those commonly found in the coastal waters of Hong Kong (Annon, 1972; Chan & Chilvers, 1972; Morton, 1979; Wu and Richards, 1981; Wu, 1982; Richards & Wu, 1985; Hodgkiss, 1988), and no "rare species" were recorded in the present study.

Results of the trawl survey indicated that the area around Sha Chau supported a high diversity and abundance of invertebrates and fish fauna that are of both fisheries and biological interest. Many fish and invertebrate species recorded in the trawl survey are common, local food species. This included the penaeid shrimps *Penaeus spp., Metapenaeus ensis, Parapenaeopsis spp.*, the mantis shrimp *Oratosquilla oratoria*, the crab *Portuns pelagicus*, the cuttle fish *Sepia* sp., the sole *Cynoglossus spp.* and *Solea orata*, the flounder *Paralichthys olivaceus*, the croaker *Johnius belengeri*, the lion head *Collichthys lucida*, the conger pike eel *Muraensox cinereus* and the flat head *Platycephalus indicus*. Amongst the above mentioned species, the penaeid shrimps (shrimps belonging to the Family Penaeidae, or "Duixiao" in Chinese) and the soles are of particular interest, since they are commercial species with high market value and were abundant in the area.

Juvenile fish and invertebrates (eg. croaker, sole, flounder, flat head, mantis shrimp, shrimps) and molluscan egg cases were commonly found indicating the high fisheries value of the area. The survey results strongly suggest that the area may serve as a valuable spawning and nursery ground for these commercially important species. The juvenile stage is the most vulnerable stage in the life cycle of a species. Any adverse impact on the juvenile stages of fish and shrimps may affect recruitment at population level and thus exert a long term adverse impact. The present preliminary survey data do not permit a detailed assessment on the importance of the area as a nursery and spawning ground as seasonal factors were excluded. It is therefore recommended that a detailed ecological study be carried out to properly establish the importance of the area as a spawning and nursery ground for fish and peneaid shrimps. This is discussed further in *Section 4.4.7*. This will enable suitable mitigation measures to be identified and will establish specific measures that could be taken to minimise the potential impacts of the AFRF construction works on these potentially sensitive fishery grounds.

The mitigation measures recommended to minimise sediment resuspension, as discussed in *Section 4.1.15*, should be fully implemented. In addition, spawning and nursery grounds in particular should be accorded a high level of protection and thus not used as works areas if possible.

In evaluating the overall significance of potential impacts on the fisheries resource it is necessary to consider major developments in the North Lantau area. The Chek Lap Kok Airport reclamation and the North Lantau Development may adversely affect fish communities in the immediate shoreline area. Offshore fish communities may be adversely affected by the reclamation, dredging and construction works underway for the Airport Core Programme projects (ACPs), for example by direct habitat loss, deposition of disturbed sediments and elevation of suspended solids. Spawning and nursery grounds for penaeid shrimps and commercial fish species will be lost and others disturbed during these major construction projects.

AFD have little information on fish breeding grounds in the North Lantau region. The impact on local species which are of commercial value are unknown but will depend on the density of other suitable spawning and nursery grounds in the area unaffected by the Chek Lap Kok Airport and ACP dredging programme.

In the most recent AFD data available from 1990 the total annual fish catch in the North Lantau region accounted for approximately one seventh of the territories total fisheries production. However, in view of the major developments in the North Lantau/Chek Lap Kok area and the distance between Sha Chau and other major ACP works, the relative impact on fish communities from the relatively minor construction works for the AFRF facility construction and pipeline installation in the North Lantau/Chek Lap Kok area is therefore anticipated to be relatively small in scale. Nevertheless, in order to minimise any potential for cumulative/combined impacts it is considered that all practical measures are adopted and implemented to minimise impacts to marine ecology from AFRF construction. These required mitigation measures are described in *Section 4.4.7*.

As identified in *Section 4.4.5*, fishing vessels may be affected by obstruction to their line of fishing from the laybarge anchoring. The extent of this interference will depend on whether the obstruction could be avoided without a considerable change in direction. However, the anchor spread will be a temporary area and therefore potential impacts from pipelaying on fishing activities in the area are not expected to be significant.

Littoral Community

The results of the survey of the sandy shore and sand bar at Sha Chau indicates that it is virtually a biological 'desert'. The extremely low species numbers and biological diversity are typical features of exposed sandy shores with an unstable substrate (Morton and Morton 1983). Species identified on the rocky and boulder shores in the Study Area are common intertidal species that might be expected for these types of habitats elsewhere in Hong Kong (Morton 1979; Morton & Morton 1983). No "rare species" or species of special scientific interest were found in these shore habitats.

The Chinese King Crab (*Tachypleus tridentatus* and *T. gigas*) is a key species of clean, sub-tidal sand flats in Hong Kong. These two species used to be common in Hong Kong (eg. in Tolo Harbour); however their occurrence and abundance in Hong Kong coastal waters has rapidly declined since the

1960's. In a previous study (Furano 1992), *Trachypleus gigas* was recorded at Tap Shek Kok whilst *T. tridentatus* was found at Tap Shek Kok, Yung Long and Lung Kwu Sheung Tan. The Chinese King Crabs were recorded in all seasons but September near the area. According to the villagers at Lung Kwu Sheung Tan and local marine biologists, the Chinese King Crabs come ashore and breed on the beach at Lung Kwu Sheung Tan and Sha Chau.

The Chinese King Crab and their eggs were not, however, found in the present survey. According to local fisherman and marine biologists, the occurrence of Chinese King Crabs in Hong Kong coastal waters is seasonal: the species spawns in February/March and is abundant in April and May. Since Sha Chau is near to Lung Kwu Sheung Tan and the two sites are similar in nature in terms of marine fauna and habitat type, there is very good reason to believe that Sha Chau may also serve as the spawning and nursery ground of the Chinese King Crab. Thus, based on the documented occurrence of the Chinese King Crab in similar habitats in the vicinity (Furano 1992), the absence of this species in the present survey may only reflect the seasonal occurrence of this species. It is therefore recommended that another survey be carried out in February 1995 to verify the occurrence of the Chinese King Crab in the area and to allow identification of mitigation measures where necessary and appropriate.

Marine Mammals

Introduction

The preferred site for the AFRF location has been chosen in an area where, during a one month field survey (June 1994), the lowest relative number of *Sousa* were sighted. The purpose of the selection of this location was to maximise the distance between all AFRF construction activities and *Sousa* presences. It is considered that this physical separation may provide a buffer area and may thereby minimise direct impacts or harm on *Sousa,* and may thus minimise the scale, extent and severity of potential direct and indirect impacts. However, the *Site Selection Study* (included as *Annex B*) also concluded that surveys conducted over longer periods may indicate that *Sousa* exhibits other patterns of habitat usage under different seasonal or other conditions. Recent results received from limited land based survey work, over a two hour period observed from over 4 km from Sha Chau undertaken by AFDs Dolphin Research Team (DRT) on 12 October 1994 indicated the presence of *Sousa* within Sites C and E; although these most recent DRT sightings were taken at a time after the construction of the CAD jetty at Sha Chau was underway and thus may not reflect an unimpacted site condition.

Potential sources of impacts on marine mammals are listed below, although it should be noted that the effect of the project on the dolphin population in the Pearl River Delta (PRD) areas as a whole can not, at present, be addressed in view of the absence of PRD dolphin data.

Dredging Activities

The sighting records show that the Dolphins' range extends to the waters around Macau, which are subject to higher solids loadings from the Pearl River than the Sha Chau area. This suggests that *Sousa* in the waters around Sha Chau may possibly be tolerant of naturally higher background SS levels as a result of the higher SS levels in the Pearl River Delta.

High SS concentrations can cause the smothering of filter feeders such as bivalves and clogging of gill filaments in fish and other organisms. Thus there may be an indirect effect on *Sousa* in terms of food availability, since fish stocks and breeding grounds may be adversely affected by a deterioration in water quality, resulting from the suspension of solids in the water column during dredging with the likely consequence of reducing the dissolved oxygen level. Although, as discussed earlier in *Section 4.4.5*, the sediment plume modelling simulations undertaken for the dredging activities associated with the AFRF construction predicted minimal elevation of SS levels in relation to the background concentrations in the area.

Sousa as air breathing mammals will be less affected by high SS concentrations than fish. The significance of this potential impact is dependent upon the size of the feeding range of the dolphin and the proportion of its range which would be affected by the construction works which is not presently known. However, based on consultation with AFD research study findings, the feeding range of *Sousa* is believed to be large comprising estuarine areas west of Hong Kong, in Chinese waters.

Consequently, the potential dredging impacts on water quality could have less significant adverse direct impacts on *Sousa* based on its possible tolerance of silt laden waters. It is considered, however, that the potential exists for adverse impacts to arise on *Sousa* through the associated indirect effects on food availability arising from sediment resuspension and reduced DO levels in the water column. Therefore, it is important that the recommended appropriate measures be undertaken by the Authority to ensure that the impacts of dredging can be kept to a minimum. Details of recommended mitigation measures were discussed in *Section 4.4.15*.

Pipeline Construction

The pipeline route from the preferred AFRF site in the immediate vicinity of Sha Chau is recommended to be constructed to the west of Sha Chau and thereby avoid, as far as possible, the areas where *Sousa* were sighted in greatest numbers, and most frequency, during the one month site selection field study *(Annex C)*.

As discussed in *Section 4.4.5*, the use of closed grab dredging techniques for the pipeline installation would, if practical, have lower impacts on water quality and associated marine biota, particularly corals in the vicinity or the pipeline. It is therefore considered that with the employment of this preferred installation method the potential for adverse impacts to arise on

Sousa through sediment resuspension and associated direct and indirect physical effects will be minimised.

General Construction Noise

Marine Mammal Hearing

Aspects of marine mammal hearing that are relevant to an understanding of the effects of industrial noise on marine mammals are discussed in the review 'Effects of Noise on Marine Mammals.' (1) This review discusses the topics considered in the papers of Popper (1980 a,b), Fobes and Smock (1981), Schusterman (1981a), Ridgway (1983), Watkins and Wartzok (1985), Johnson (1986), Nachtigall (1986), Moore and Schusterman (1987), Bullock and Gurevich (1979) and Fay (1988) and includes some more recent references (The titles of these papers are given in *Annex H*). The review notes that 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. Thus, there has been a growing concern that as man-made facilities move offshore, noise associated with the operation and construction of these projects will negatively impact the lives and breeding of marine mammals.

Research has indicated that toothed whales are most sensitive to sounds above ~10 kHz(1). 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 (1).

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. Seely et al (2) 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 (3). However, below ~10 kHz sensitivity deteriorates with decreasing frequency and below 1 kHz, the frequencies of most industrial noises, sensitivity appears to be poor(1). Sensitivity also decreases as the duration of a single sound pulse decreases below about 0.1-0.2 s(1). *Figure 4.4b* indicates the threshold noise level necessary for

(1) Richardson W J, Greene C R, Malme C I and Thomson D H with contributions by Moore S E and Wursig B (1991) **Effects of Noise on Marine Mammals** LGL Ecological Research Associates Inc.

(2) 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-A029 178.

(3) 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.

bottlenose dolphins to just detect sounds over the range 100 to 100,000 Hz. (1) (2) (3) (4) Though, sensitivity is poor in the range of construction and operational noises, studies (5) have indicated that because of the efficient transfer of sound in water, dolphins can detect dredgers at distances up to approximately 5 km away. In addition, studies (5) have indicated that toothed whales have good frequency and intensity discrimination abilities, as well as good directional localisation capabilities.

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 communicating, detecting predators, locating prey and in echolocation. Above ~2 kHz, critical ratios (6) increase with increasing frequency, and are generally similar to those of the human at corresponding frequencies (5). Critical bands (7) in the bottlenose dolphin appear to be wider than would be predicted based on the equal-power assumption(5). This indicates that some odontocetes (such as bottlenose dolphin and white whale) can detect certain sounds when the signal is less intense than the total background noise in the masking band.

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).*

It should be noted that whether or not dolphins are actually disturbed by noise from a construction or operational activity, their hearing ability will make them aware of disturbances at distances in excess of tens of kilometres from the site. Research has indicated that industrial operations in the Beaufort Sea were theoretically detectible to toothed mammals up to 100 km away while responses to noise were noted in the range of 5 to 25 km distant(5).

Potential Impacts

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

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

(2) 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

(3) 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.

(4) 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.

(5) Richardson W J, Greene C R, Malme C I and Thomson D H with contributions by Moore S E and Wursig B (1991) **Effects of Noise on Marine Mammals** LGL Ecological Research Associates Inc.

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

(7) The frequency band within which background noise can affect detection of a sound signal at a particular frequency.

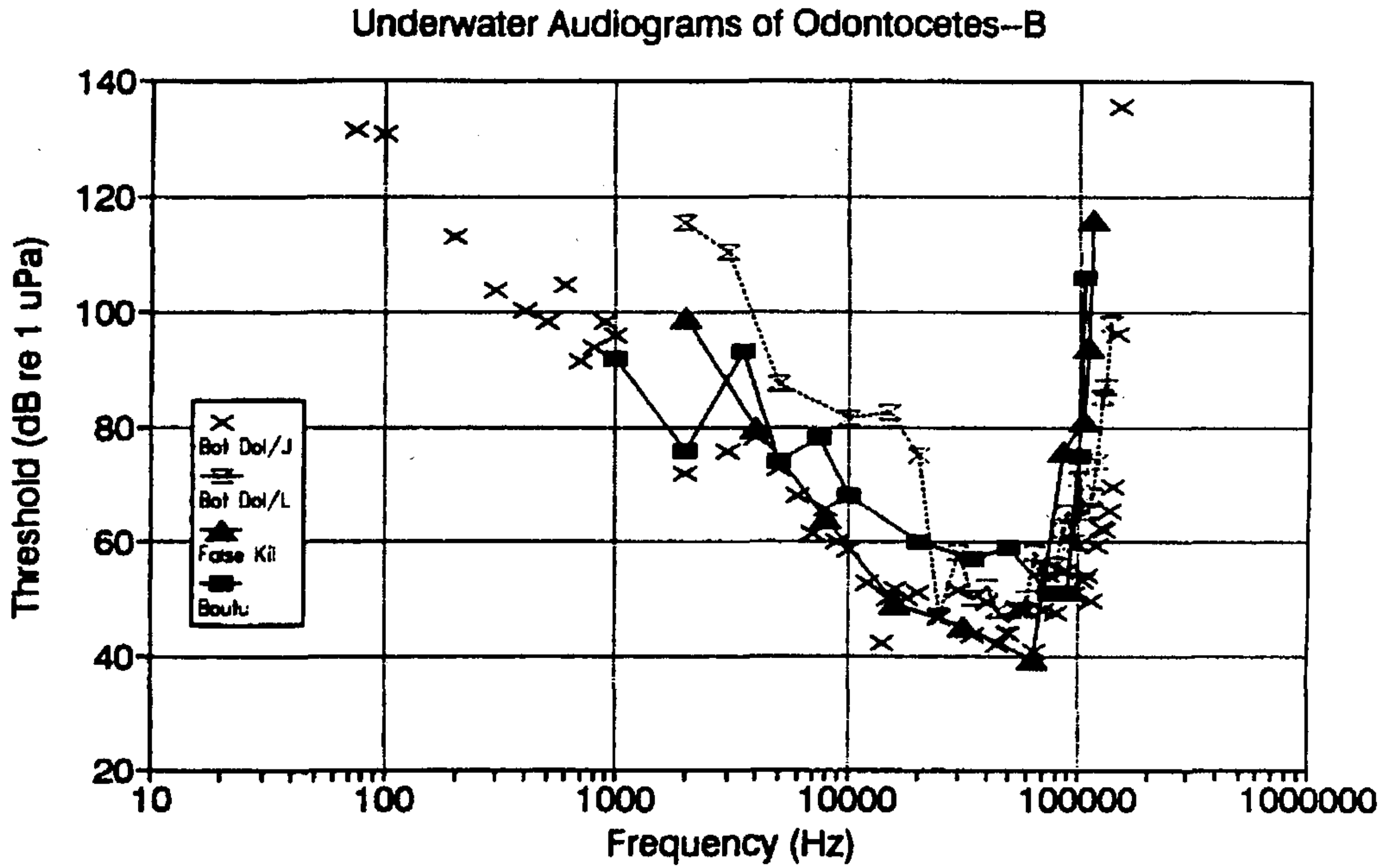

FIGURE 4.4b - UNDERWATER AUDIOGRAMS OF ODONTOCETES: BOTTLENOSE DOLPHIN (JOHNSON 1968a; LJUNGBLAD ET AL. 1982c); FALSE KILLER WHALE (THOMAS ET AL. 1988); AMAZON RIVER DOLPHIN OR BOUTU (JOCOBS AND HALL 1972). n=1 EXCEPT WHERE NOTED

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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.

Stationary offshore activities often seem to have less effect on cetacean behaviour than do moving sound sources such as aircraft and ships [1] However, the effects of noise from dredging, drilling and oil production operations on toothed whales are not well researched.

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 [1]. Besides avoidance responses, other behavioral reactions, eg changes in surfacing–respiration–dive cycles are sometimes seen as well [1]. 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 [1].

It should be noted that since Hong Kong, and in particular the region around the new airport, contains a large variety of intensive operations which include marine vessels and construction activities, the detectability of noise by marine mammals will be much lower than the theoretical maximum. It is believed, however, that dolphins will still be aware of offshore construction operations at distances of not less than a few kilometres and so impacts can be expected. Thus it is important that AFRF construction noise be limited, wherever possible, to minimise noise impacts to *Sousa*. Mitigation measures are recommended in *Section 4.4.7* to minimise the noise impact during the construction works.

These measures should allow dolphins to acclimate to the noise disturbance of the facility construction without incurring any long term hearing damage. It is recommended AFRF construction activities should cease, where practicable, for a period of 4 to 6 hours each day, this period of zero-activity occurring at the same time each day. The quiet period should allow dolphins and their food sources to return to normal behaviour for at least a predictable period of time each day. The use of `quiet` or silenced construction vessels and plant is also recommended wherever practicable to minimise noise disturbance on *Sousa* and the AFRF contractors should ensure all construction vessels, plant and equipment are well-maintained to minimise noise levels.

(1) Richardson W J, Green C R, Malme C I and Thomson D H with contributions by Moore S E and Wursig B (1991) Effects on Noise on Marine Mammals LGL Ecological Research Associates Inc.

Berth construction

A piled structure, with a lower potential to impact on water quality and with minimal loss of habitat, is preferred over the blockwork AFRF design in order to minimise resulting potential indirect impacts and disturbance to *Sousa*.

In addition, with the bored piling method for the construction of the offshore facility on piles, noise levels generated will not be of an impulsive high sound power level nature and will be less than with percussive piling. As discussed, under general construction noise impacts, there are indications that some cetaceans may partially acclimate to continuous noise and thus the potential for direct noise impacts on *Sousa* from noise disturbance will be minimised with the use of bored piling. The impacts of berth construction, including any impacts from bored piling on water quality, will be further assessed in the detailed design stage.

Vessel Movements

Although limited, the data 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)].

Vessel movements during construction activities have the potential to result in impacts on *Sousa* from the following:

- physical harm;
- sediment resuspension caused by movements of propellers; and
- underwater noise.

As described earlier under general construction noise, dolphins generally avoid stationary offshore activities such as dredging. However, it is recommended that the number of construction related vessels and small craft be minimised, where practicable, in order to minimise the physical harm potential to *Sousa*. This reduction in vessel numbers will also minimise potential impacts of underwater noise and sediment resuspension arising from vessel traffic on the normal movement patterns of *Sousa*.

General Construction Activities

As discussed in *Section 4.1*, the marine based construction activities have the potential to cause water pollution from debris and refuse such as packaging and construction materials, sewage effluents from the construction workforce and spillages of oil, diesel and solvents. Release of these potential pollutants into marine waters should thus not be permitted as introduction of polluted waters is likely to have detrimental effects on *Sousa* in this area. There may also be indirect effects on *Sousa* in terms of food

(1) Richardson W J, Greene C R, Malme C I and Thomson D H with contributions by Moore S E an Wursig B (1991) Effects of Noise on Marine Mammals LGL Ecological Research Associates Inc.

availability, since fishing grounds would be adversely affected by poor water quality.

Thus it is important that practices are employed, such as those outlined in *Section 4.3*, to ensure that waste arisings do not enter surrounding marine waters in order to minimise impacts on *Sousa* and fishing grounds in the area.

Background activities

East Sha Chau Contaminated Mud Pits

The AFRF would be located approximately 2.25 km from the nearest Contaminated Mud Pits (CMPs) at East Sha Chau. The proposed services corridor is located nearest to the CMPs at the south–western corner of the East Sha Chau Marine Borrow Area. At this location the pipelines and cables will be installed to the west of a 'Buffer Zone' currently considered to be adequate at 150 m wide. At such a distance it is considered that the construction and operation of the CMPs would have no adverse impacts on *Sousa* in the marine waters around Sha Chau.

CAD Jetty on Sha Chau

There will be no cumulative impacts on *Sousa* arising from the construction of the CAD Jetty on Sha Chau and the proposed AFRF construction. The construction programmes are indicated on *Table 3.6b*. The CAD jetty construction has commenced and is scheduled to be completed before the construction of the proposed AFRF, which would commence in mid 1995. However, the consecutive timing would lead to an almost continuous construction period at Sha Chau from the start of the CAD Jetty construction to the completion of the AFRF construction. The CAD Jetty contractors should therefore be cognizant of the potential for impacts on *Sousa* and should aim to minimise construction impacts, wherever practicable.

FMC Fill Winning East of Shau Chau

There are proposals to dredge sand in the area to the east of Sha Chau. This could lead to cumulative impacts on *Sousa* if the proposed dredging activities are concurrent with the AFRF construction. The FMC should be cognizant of the potential for cumulative impacts on *Sousa* and should aim to minimise impacts, wherever practicable.

Infrastructure Projects in the Chek Lap Kok/North Lantau Area

There are general concerns that the cumulative effects of the major infrastructure projects in the Chek Lap Kok/North Lantau area may have adverse effects on the *Sousa* population. [1] A research study of *Sousa* is

(1) North Lantau Development Study TR10 Environmental Assessment (Revised) 1991.

being undertaken by AFD which will include a review of the cumulative effects on the species from the Chek Lap Kok Airport and ACP infrastructure developments in the North Lantau area. This will assist in clarifying and confirming the ecological requirements and distribution of *Sousa*, and hence their ability to respond to the effects of construction works in the North Lantau waters. To minimise potential adverse impacts on *Sousa* it is PAAs intention to implement practical mitigation measures recommended in consultation with AFD *Sousa* research studies.

Historical

It is believed that a variety of reasons may have caused temporal changes to *Sousa* numbers in the area of the Brothers Islands, such as levelling of the islands for fill, noise associated with the works, blasting, the large number of vessels, and vessel movements associated with collecting spoil and travelling back and forth to the Chek Lap Kok Airport.

The construction of the AFRF will be short term and transient in comparison and thus it is considered the likely impacts to *Sousa* from AFRF construction will be significantly less than from the works at the Brothers. In addition, as stated earlier, in contrast to several other concurrent ACP projects, no blasting will be undertaken at Sha Chau for the AFRF construction.

4.4.7 *Mitigation Measures*

The following section gives recommendations on the identified further ecological studies and appropriate mitigation measures that should be implemented during the construction of the AFRF at the preferred site location to minimise impacts on the marine ecology.

Further ecological studies

The present data from the preliminary ecological survey does not permit a detailed assessment on the importance of the area as a nursery and spawning ground. A detailed ecological study should therefore be carried out, in parallel with the facility design, to provide seasonal data and properly assess the importance of the area as the nursery and spawning ground for penaeid shrimps, fish and the Chinese King Crab. In addition, this will enable suitable and specific mitigation measures to be identified and will establish whether particular measures could be taken to minimise the potential impacts of the AFRF construction works on these sensitive grounds.

The study should also identify the reproductive seasons of the penaeid shrimps and commercially important fish species, so that potential impacts on reproduction of these sensitive species can be avoided/minimised, wherever practicable. For example, by scheduling the dredging activities so as to avoid the peak reproductive periods, where practical, impacts following the peak reproductive season would have less adverse effect than losses before the peak season.

Selection of Dredging Method and Equipment

Strict engineering control must be exercised during dredging activities. Low impact dredging techniques, such as closed grab dredgers, are recommended for the dredging of the turning basin, access fairway and submarine pipeline. Mitigation measures identified to minimise potential impacts arising from dredging are detailed in *Section 4.1.15*. These recommended mitigation measures should be included in construction contracts. In view of the particular sensitive nature of the Sha Chau area, the whether the use of silt curtains is practical during dredging should also be investigated to minimise the potential for any marine ecological impacts.

Dolphin Impact Monitoring Programme

A *Sousa* monitoring programme in the vicinity of the AFRF site and around Sha Chau is recommended during the construction works to monitor the presence of *Sousa*. Further details of this are given in *Section 7*.

Dolphin Research Studies Contribution

To minimise potential adverse impacts on *Sousa* it is PAAs intention to implement practical mitigation measures recommended in consultation with AFD *Sousa* research studies.

Pollution Control Measures

As described in *Section 4.3*, strict pollution control measures should be introduced during the construction phase to reduce environmental damage. Minimisation of the potential for impacts on marine ecology arising from general construction activities may be achieved by the observation of waste management procedures, which should be strictly enforced and monitored by the engineer to ensure that no refuse, fuels and solvents enter surrounding marine waters. Release of these potential pollutants into marine waters should not be permitted as introduction of polluted waters is likely to have detrimental effects on *Sousa* and spawning and nursery grounds in the area. Indirect effects on *Sousa* may also arise in terms of food availability, since fishing grounds could be adversely affected by any associated deterioration in water quality. These pollution control measures are discussed further in *Section 7* in the context of the control and efficacy of monitoring.

Local Restocking of Sensitive Species

Local restocking of penaeid shrimps, sea pens and commercial fish species could be carried out, as is presently being conducted by the PRC, to mitigate any adverse impacts identified in the further ecological studies, described earlier.

Local Selection of Berth Construction Method

The piled structure is preferred over the blockwork AFRF design. The use of piling methods with a lower potential to impact on water quality and with minimal loss of seabed will significantly reduce the loss of benthic communities, and potential impacts and disturbance to the surrounding marine ecology. In addition, the *in-situ* bored piling method is preferred as noise levels generated will be less than with percussive piling and thus noise disturbance on *Sousa* will be minimised.

Selection of Submarine Pipeline Route

The pipeline route from the preferred AFRF Site in the immediate vicinity of Sha Chau is recommended to be constructed to the west of Sha Chau and outwith the areas where dolphins were sighted in greatest numbers and most frequency during the one month site selection field study.

Of particular concern in terms of the potential for adverse environmental impacts, will be that the pipeline route should avoid any interference with the East Sha Chau Contaminated Mud Pits (CMPs). Although, as discussed in *Section 4.1*, the pipeline will be located outside the buffer zone and at such a distance it is considered that the construction of the pipeline would have no adverse impacts on marine biota, including *Sousa*, in the marine waters around Sha Chau and would have no adverse impacts on the CMPs.

Minimisation of noise disturbance

Based on dolphins sensitivity to construction noise, as discussed in *Section 4.4.6*, and in order to minimise disturbance, all AFRF construction activities should be considered wherever practicable such that:

- construction activities are as short in duration and are as quiet as is practicable;
- activities should be continuous without short breaks or unpredictable outbursts at random intervals;
- events should be scheduled on a regular basis with similar activities planned for similar time period each day; and
- all activity should cease for a period of 4 to 6 hours each day, this period of zero-activity occurring at the same time each day.

The strict adherence to these measures may in theory allow dolphins to acclimatise to the noise disturbance of the facility construction without incurring any long term hearing damage. In addition, the quiet period each day should allow *Sousa* and their food sources to return to normal behaviour for at least a predictable period of time each day.

The use of 'quiet' or silenced construction vessels and plant is recommended, wherever practicable, to minimise noise disturbance on

Sousa. In addition the Contractor should ensure all construction vessels, plant and equipment are well-maintained to minimise noise levels.

Scheduling of Construction Works

The impact of construction works on *Sousa* could possibly be reduced by scheduling the works during the wet season period when it is believed *Sousa* are more dispersed. Although not scientifically substantiated recent (wet season) findings have indicated that the dolphins have ranged farther from the Pearl River estuarine areas (as far as the Ma Wan Channel and south of Lantau near Peng Chau). Thus it may be more favourable to construct the key activities with potential to impact *Sousa*, which comprise the dredging and piling activities and pipeline installation works, during the wet season when dolphins could be less concentrated near to estuary areas. Under the present programme the facility is likely to be constructed during the wet season period, and thus it is anticipated the works may have less adverse impact on *Sousa* than if scheduled during the dry season.

Vessel Movements

The number of vessels and small craft should be minimised during the construction phase, in order to minimise potential impacts, identified in *Section 4.4.6*, on *Sousa* arising from the following:

- physical harm potential to *Sousa* from collisions with vessels;
- potential impacts of sediment resuspension caused by movements of propellors and submerged equipment;
- underwater noise ; and
- disturbance from vessel traffic on the normal movements of *Sousa*.

4.4.8 *Conclusion*

The results of the preliminary marine ecological study indicate that the sub-tidal invertebrates and fish community of Sha Chau are of both ecological and fisheries interest. However follow up work is required both to assess their importance and to identify and evaluate practical mitigation measures. The area supports a high diversity of fish and shrimp, many of which are commercially important species (eg. sole, flounder, croakers, flat heads and penaeid shrimps). Penaeid shrimps and sole were particularly abundant. Juvenile fish, shrimps, crabs and molluscan egg cases were commonly found, indicating the high fisheries value of the area. It is likely that the area may serve as an important spawning and nursery ground for these commercially important species.

The sensitive environmental receptors identified are:

- the penaeid shrimp and other important commercial fish species;
- the habitat as a nursery and spawning ground of marine animals in general and penaeid shrimps and food fish in particular; and
- sea pens and stone corals.

Dredging activities during the construction phase of the AFRF are likely to locally increase the turbidity of water, smother/disturb the sensitive species and modify the bottom substratum, and hence potentially affect the sensitive receptors described above. The ecology and survival of sea pens and stone corals, juvenile stages and recruitment of fish and shrimps in the area are of particular concern. The sediment plume modelling simulations undertaken to simulate the fate of sediment lost to suspension during dredging associated with the AFRF, predicted an elevation of suspended solid (SS) levels in exceedance of the WQO at one of eleven sensitive receivers, in relation to the background concentrations in the area. However, provided the mitigation measures recommended in Section 4.1.13 are fully implemented, including the use of closed-grab dredgers for construction of the turning circle, fairway and submarine pipeline, it is considered that water quality impacts will be minimised to within WQO acceptable levels. It should be noted that, at the time of the proposed AFRF construction the seafloor ecology in the area of the access fairway may have already been disturbed by dredging activities in the Urmston Road.

Fish and benthic communities in Hong Kong typically exhibit marked seasonal variations and thus the survey does not take account of seasonal changes. Judging from the documented occurrence of the Chinese King Crab species in similar habitats in the vicinity, the absence of this important species in the present survey may only reflect the seasonal occurrence of this species in the area. The importance of the area as a nursery and spawning ground for penaeid shrimps, food fish and the Chinese King Crab needs to be further established so that appropriate mitigatory measures can be introduced to minimise potential impacts as far as possible.

It is recommended that:

- a detailed ecological study be carried out in parallel with the further AFRF design stages, with a view to assess the importance of the area as a nursery and spawning ground for fish, peneaid shrimps and the Chinese King Crab in the area, such that the most appropriate mitigation measures can be identified;

- appropriate mitigation measures should be developed in the detailed design stage, based on the detailed ecological survey, to protect any ecologically sensitive species which are identified to be impacted by the facility construction;

- strict pollution control measures be introduced during the construction phase of the facility; and

- local restocking of peneaid shrimps, sea pens, corals and commercial fish species should be considered to mitigate the environmental impact, if significant impacts are identified by more detailed survey work.

Practicable efforts should be taken to minimise potential impacts on *Sousa* arising from the construction works. 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, and this should be taken into consideration during construction of the AFRF. There are indications that some cetaceans may partially acclimate to continuous noise (1). To minimise potential adverse impacts on *Sousa* it is PAAs intention to implement practical mitigation measures recommended in in consultation with AFD *Sousa* research studies, and consider incorporating these in the detailed design of the AFRF. As such it is considered that the implementation of this comprehensive package of mitigation measures and the recommended comprehensive monitoring and audit requirements are likely, in combination, to minimise the potential for both direct and indirect impacts on *Sousa* from the AFRF construction.

4.5 OTHER CONSIDERATIONS

4.5.1 *Cumulative Impacts: Sha Chau - CAD RADAR Stations*

The following information was provided by Government sources following a request from the ACE EIA Sub-committee for inclusion in the EIA:

- An Approach Surveillance Radar (ASR) Station and a Secondary Surveillance Radar (SSR) Station for the Civil Aviation Department (CAD) will be located on the high area of Sha Chau Island. A CAD jetty is currently being constructed to provide a service access to the island. The CAD jetty is to be located on the eastern coast of the southern Sha Chau island with a pathway constructed from the CAD jetty leading to the Stations. Construction works for the CAD jetty commenced in July 1994 and are scheduled for completion in June 1995, and thus the jetty will be completed when the construction works for the AFRF commence in July 1995.

  No direct cumulative impacts on water quality are therefore anticipated to arise, from the construction of the jetty.

- The power for the ASR and SSR Stations will be supplied via a submarine power cable (SPC) extending from Chek Lap Kok to Sha Chau. Further, a power supply to Lung Kwu Chau will be required to serve the DVOR/DME Stations on the Island. CLP and the Government are considering SPC routes from Sha Chau. The SPC from Chek Lap Kok to Sha Chau will be laid within the proposed services corridor for the AFRF. The proposed tentative route of the cable and its location relative to the AFRF twin submarine pipeline is indicated on *Figure 3.4b*. It should be noted that the exact routing and construction timing of the cable will be finalised at the detailed design stage and may therefore alter. The present understanding is that SPC section from Chek Lap Kok to Sha Chau will be installed between December 1995 and February 1996.

- Whilst the installation schedule for the AFRF submarine pipeline (estimated construction duration of 2-3 months) cannot be confirmed at this stage, it is presently understood that it will not coincide with the

SPC installation. Preliminary details of the method of the SPC laying and burying are given in *Section 3.5.4*. As described in this section, there will be no dredging or backfilling operations for the SPC installation. The major potential disturbance to the water column is anticipated to be from the cable burying process which may involve ploughing operations with the assistance of water jets. Impacts from the installation works for the SPC are not anticipated to have a adverse potential water quality impacts although this will be verified during the detailed design basis-EIA upon finalisation of construction techniques.

4.5.2 *Route Y*

A potential concern raised in the IAR is the possible implication of the future "Route Y" option, which is under the consideration of the Territorial Development Strategy Review, on the proposed AFRF development near Sha Chau.

According to the Planning Department, the intention of "Route Y" is to relieve the traffic flow between China and Hong Kong by linking up their port and container terminal facilities. It is understood that the "Route Y" option at present is no more than an idea stemmed from the identified planning needs to link the new Chek Lap Kok Airport and China, possibly at Zhuhai and Huangtiao airports. However, there is currently no commitment from the Hong Kong Government as to the actual alignment or programme of "Route Y". Therefore it is considered not possible at this stage and indeed inappropriate to assess the implications of the future "Route Y" option on the proposed AFRF near Sha Chau.

4.5.3 *Cultural Impacts*

Information from the Antiquities and Monuments Office indicates that Sha Chau is designated a "Special Site of Archaeological Interest" (SSAI/NT 18) on account of the considerable quantity of prehistoric and historic artefacts discovered in past investigations. There is also a Tin Hau Temple on the island, built in 1862, which is a Grade II historical building. According to the District Office (Tuen Mun), the temple was built by fisherman from nearby waters including those from Lung Kwu Tan, and has significant cultural importance to the local fishermen with respect to good health, climate and business. In addition, it is understood that the fishermen have two or three ancestral graves on the island not far behind the temple, which may also have clan significance.

The AFRF will be an offshore facility and there will be no land-based construction. Thus, direct physical impacts on these culturally significant features will be avoided.

The proposed offshore fixed receiving facility will be essentially a horizontal structure on piles comprising two vessel berths approximately 320 m long, 5 m high and 15 m wide. It is anticipated that only 1 to 4 vessels will visit the berths per day. This horizontal form is expected to minimise the intrusion to the open aspect (Fung Shui) of the temple and graves. In addition, the proposed offshore berths are located to the northeast of Sha Chau, therefore avoiding direct intrusion to the "Fung Shui" of the temple which has a northwest aspect. Screening of the temple from the berths could be achieved by planting to the immediate northeast of the temple with a "Fung Shui" plant such as bamboo, subject to agreement with the local fishermen. It is recommended that consultation with the local fishermen be undertaken at an early stage to explain the proposed development and thereby avoid unnecessary defensive objections at a later stage. This action will benefit the overall progress of the proposed development.

5 OPERATIONAL PHASE ASSESSMENT

5.1 OPERATIONAL WATER QUALITY AND WATER MOVEMENTS IMPACTS

5.1.1 Introduction

This section addresses the potential impacts on water quality which may arise during the temporary, 5–7 year, operation of the proposed AFRF. Full–time operation beyond this interim 5–7 year period will require further environmental assessment. The possibility of impacts from aviation fuel spillage is assessed in *Section 6.3* on Environmental Risk.

5.1.2 Baseline Conditions

Baseline water quality conditions are as described in *Section 4.1* under future conditions.

5.1.3 Evaluation Criteria

Oil and fuel spills to coastal waters are controlled under the *Shipping and Port Control Ordinance (Cap. 313) (SPCO)* and are the responsibility of the Marine Department. The SPCO prohibits pollution of the sea by oil from land–based and marine sources, and also the dumping of refuse and general littering from vessels or port–based operations.

5.1.4 Potential Sources of Impact and Their Significance

Operations that may have potential impacts on water quality in the marine waters surrounding the AFRF are as follows:

- solid and liquid waste arisings;
- vessel operation and movements;
- alterations in water movements after completion of facility construction;
- maintenance dredging;
- accidental spillage of aviation fuel; and
- use of chemical spill response technologies.

These impacts are addressed further below.

Solid and Liquid Waste Arisings

A number of sources of waste will be generated during the operation of the AFRF including sewage effluents, domestic waste, chemical waste, commercial/industrial waste, office waste and MARPOL wastes. These solid and liquid wastes have the potential to cause unacceptable water quality impacts. Thus, these waste arisings will require appropriate methods of removal from the AFRF to prevent the potential for adverse impacts on water quality. The necessary solid and liquid disposal requirements are discussed in *Section 5.3.4*. It is anticipated that, with the enforcement of appropriate handling, storage and removal of solid and liquid waste arisings, the potential to result in adverse water quality impacts will be minimised.

Vessel Operation and Movements

The fuel delivery vessels and transport workboats will need to discharge their bilge water which is an oily waste classified as MARPOL wastes as discussed in *Section 5.3*. However this should not be undertaken at the AFRF but be accommodated by discharge into appropriate bilge water reception tanks at a suitable off-facility location. Thus as no removal directly from the AFRF will be required there will be no impacts on water quality at the facility.

Potential impacts on water quality may arise from vessel movements during transit and manoeuvring at the facility, and from turbulence in the vessel wake and propeller wash. Such vessel movements may cause the resuspension of marine sediments.

Maintenance Dredging

In order to maintain a sufficient depth to allow for turning and manoeuvring of vessels associated with the facility operation any sediments deposited within the turning circle and access fairway must be dredged. During the fully operational period of 5-7 years, there would be no routine maintenance dredging programme. During subsequent back-up and emergency use, maintenance dredging would only be required intermittently to remove sediments settled within the turning basin and access channel. The frequency of maintenance dredging is not presently known, although it is likely to be relatively infrequent given the existing natural water depths in the proposed AFRF location.

Potential impacts on water quality from disturbance of marine sediments are as described earlier in *Section 4.1* for dredging activities during the construction phase. It is considered that the potential for adverse impacts on water quality through sediment resuspension may be minimised with the use of an appropriate low impact dredging technique and the observation of good operational practice.

5.1.5 *Mitigation Measures*

Solid and Liquid Waste Generation

All wastes should be handled, stored and disposed of in accordance with waste management practices defined by the Tenderer, and EPD regulations and requirements. No solid nor liquid wastes should be allowed to enter the marine waters at the facility and discharges into the marine waters from the operating facility should not be permitted. The disposal requirements of the identified solid and liquid wastes necessary to prevent impacts on water quality are discussed in *Section 4.3.4.*

Vessel Operation and Movements

The discharge of oil from vessels into the sea is forbidden under the *Merchant Shipping Ordinance.* The Licensees dedicated fuel shuttle vessels should contain solid and liquid waste storage tank facilities and should never empty or wash out bilges or discharge any solid waste at the AFRF site.

As described in *Section 3*, the Licensees dedicated fuel shuttle vessels will generally be 3,000 - 5,000 dwt in size. Normally, single propeller vessels without bow thrusters will generate significantly greater propeller wash during berthing manoeuvres than a twin propeller vessel. Therefore, in order to ensure high manoeuvrability of vessels and thereby decrease the amount of vessel movement and propeller wash, particularly when berthing at the receiving facility, PAA propose to require the Licensee to use a single propeller vessel with a "Schilling" rudder and bow thrusters which will afford the shuttle vessel at least the manoeuvrability of a twin propeller vessel with bow thrusters. Details of the `Schilling` Rudder are given in *Annex* G. Thus it is considered that the use of dedicated fuel shuttle vessels designed specifically for the AFRF operation will minimise the potential for adverse impacts through sediment resuspension generated by vessel movements.

Another measure proposed to reduce vessel movement and thereby minimise sediment resuspension is to impose restrictions on vessel speed. The Licensees dedicated shuttle vessels should be required to approach the facility at low speeds 0.2–0.3 m/s (maximum), through a system of gated buoys. All such vessels should be fitted with sophisticated navigation systems and should have berthing capability up to a Typhoon No 3 signal. It is recommended to place slow speed restrictions at the entrance to the access fairway and to inform all vessel captains of these operational controls. The 10,000 dwt, non–Licensee, vessels should also be subject to the same controls in operation and speed restrictions as the dedicated 5,000 dwt Licensee fuel vessels in order to minimise potential vessel related impacts.

Maintenance Dredging

Potential adverse impacts on water quality may be minimised with the use of an appropriate low impact dredging technique, and the observation of appropriate practices detailed in *Section 4.1.* The mitigation measures recommended to minimise potential impacts arising from maintenance dredging are as discussed in *Section 4.1* for dredging activities during the construction phase.

Spillage of Aviation Fuel/Spill Response Technologies

Both spillage of aviation fuel into the marine environment, and spill response technologies used during spill clean-up have the potential to impact upon water quality, as detailed in *Section 6.3.5*. However, provided detailed assessment in the successful Tenderer's detailed design, identifies rapid, non toxic spill response technologies, impacts upon water quality are not considered to be of great concern.

5.1.6 *Summary*

It is considered that with the appropriate handling, storage and removal of the identified solid and liquid waste arisings from the AFRF, the potential to result in adverse operational phase water quality impacts will be minimised. Discharges into the marine waters from the facility should not be permitted and no solid nor liquid wastes should be allowed to enter the marine waters at the facility. It is recommended that solid and liquid waste disposal be monitored and audited to ensure that the correct disposal requirements are being implemented.

Other activities such as fuel vessel operation and movements and maintenance dredging (during subsequent back-up and emergency use) will not cause any unacceptable impacts on water quality, provided the recommended mitigation measures, including the use of dedicated fuel shuttle vessels, operational controls over vessel movements, and low impact dredging techniques, are implemented.

As detailed in *Section 6.3*, it is considered that no water quality impacts of concern will arise due to accidental aviation fuel spill and subsequent clean up, provided detailed assessment, during detailed design, identifies rapid, non-toxic spill clean-up methods.

5.2 OPERATION NOISE

5.2.1 *Introduction*

This assessment is carried out to assess operational noise impacts associated with the interim use of the AFRF and pipeline on surrounding NSRs.

5.2.2 *Statutory Conditions*

It has been proposed that the operational activities associated with the fuel receiving facility and pipeline will proceed 24 hours per day and 7 days per week. Under the Noise Control Ordinance (NCO), noise restrictions are imposed during daytime (0700-1900), evening (1900-2300) and night-time (2300-0700). The Acceptable Noise Level (ANL) for an NSR, which is dependent on the local noise environment near the NSR, determines the applicable noise criteria which must be met by operational noise impacts at the NSR location. The appropriate noise criteria for a particular NSR can be obtained by referring to the *Technical Memorandum for the Assessment of Noise from Places Other Than Domestic Premises, Public Places or Construction Sites.*

5.2.3 *Baseline Conditions*

Existing Conditions

Existing conditions are as described in *Section* 4.2.

Future Conditions

Future conditions are as described in *Section* 4.2.

Noise Sensitive Receivers (NSRs)

NSRs, as defined by HKPSG and the Noise Control Ordinance (NCO), have been identified with reference to previous environmental studies undertaken in the region of the pipeline, and have been updated by site surveys and by referring to survey sheets and development plans.

The NSRs and their approximate distances from the nearest operational areas associated with the temporary receiving facility are given in *Table 5.2a,* below.

Table 5.2a *Noise Sensitive Receivers and Distances to Temporary Receiving Facility*

NSR	Sensitive Use	Approx. Distance to NSRs (kilometres)
Tung Chung New Town	Residential	8.0
Sha Lo Wan (Lantau Island)	Residential	6.5
San Tau (Lantau Island)	Residential	7.0
Lung Tsai (Tuen Mun)	Residential	5.25
Butterfly Garden (Tuen Mun)	Residential	7.5

Please refer to *Figure 4.2a* for locations of the NSRs.

Other NSRs considered in this assessment will be *Sousa* sighted in the marine waters around Sha Chau and Lung Kwu Chau. Potential impacts on *Sousa* arising from noise generated during the operation of the AFRF are discussed in *Section 5.4*.

5.2.4 *Evaluation Criteria*

In Hong Kong, as noted in the section on Statutory Conditions above, the NCO places restrictions on the maximum noise level that operational activities can generate at NSRs. In practice, however, EPD generally require that operational noise impacts at nearby NSRs not exceed the criteria set by the Hong Kong Planning Standards and Guidelines (HKPSG).

The criterion for assessment, according to the HKPSG, is that measurement be taken over a 30 minute period ($L_{eq,30min}$) and noise levels not exceed the Acceptable Noise Level (ANL)-5 dB(A). As a result, noting that the NSRs all have Area Sensitivity Ratings (ASR) of 'A' (and since the noise sources are not expected to have 'tonal', 'intermittent' or 'impulsive' character), the recommended criterion for assessing operational activities associated with the fuel receiving facility and pipeline is as given in *Table 4.2b* below.

Table 4.2b *Recommended Noise Criteria for NSRs*

Time Period	Noise Criterion, $L_{eq,30min}$
Daytime (0700–1900) and Evenings (1900–2300)	55 dB(A)
Night-time (2300–0700)	45 dB(A)

5.2.5 *Potential Sources of Impact*

There are two operational activities which have the potential to cause noise impacts at nearby NSRs. These operations fall into two categories, those that pertaining to the facility and that pertaining to the pipeline. For the facility the relevant operational activities are the berthing of tankers at the facility and the pumping of fuel from the tankers into the facility. For the pipeline, the relevant activity is simply the pumping of fuel through the pipeline. It should also be noted that maintenance dredging will be required intermittently during the subsequent back up and emergency use of the AFRF, however, with reference to *Section 4.2* on construction impacts, it is concluded that these impacts will not lead to NCO exceedance at nearby NSRs.

Another possible potential impact to the nearby NSRs will be the movement of fuel vessels via the possible aviation route from Tsing Yi to the AFRF as shown in *Figure 3.7a*.

5.2.6 *Evaluation of Impacts*

As the closest NSRs to the proposed site are approximately 3 km distant, the HKPSG criterion implies a maximum sound power level of 119 dB(A) for noise from the pipeline or from tankers. As the pipeline will be under water, it is not predicted that it will be audible above the water surface; as a result the pipeline will not lead to any HKPSG noise criteria exceedance at nearby NSRs.

The majority of the operational noise from fuel vessels will be produced by on-board pumps during fuel pumping operations. Ship fuel pumps are estimated to have a maximum sound power level of 110 dB(A). As a result, even should two tankers pump fuel simultaneously into the fuel receiving facility, tanker operational noise will not lead to any HKPSG noise criteria exceedance at nearby NSRs.

The maximum number of vessels used by the AFRF will be 4 per day travelling at around 10 knots in designated lanes, as shown in *Figure 3.7a*. The distance from the designated route to any NSRs will be at least 400 m and since marine traffic around the Tsing Yi and Ma Wan area is generally quite busy, and the speed of the vessels will be quite slow (and thus the noise levels relatively low), the additional vessels are unlikely to cause a significant increase to the overall noise levels. The vessels at the turning basin will represent a new noise source, however, the nearest NSR will be at a distance of at least 5.25 km, and hence will not lead to any HKPSG noise criteria exceedance at the nearby NSRs.

5.2.7 *Mitigation Measures*

As the assessment in the previous section has predicted the AFRF will not lead to any HKPSG noise criteria exceedance from unmitigated operational activities at any of the NSRs near the proposed AFRF and pipeline, and thus no mitigation is recommended.

5.2.8 *EM&A*

It is considered that no noise monitoring will be required during the temporary, 5–7 year, operational phase of the AFRF.

5.2.9 *Summary*

This study has indicated that neither of the two potential sources of operational noise impacts (fuel tankers berthing at the AFRF and pipeline activities) will lead to any HKPSG noise criteria exceedance at NSRs due to the substantial distance separating the sources from the NSRs. Maintenance dredging, which will only take place during subsequent emergency back up relatively infrequently use of the AFRF, will not lead to any HKPSG noise criteria exceedance impacts at NSRs. As a result no mitigation is recommended for the operational phase of the AFRF or the pipeline.

5.3 OPERATIONAL WASTE MANAGEMENT

5.3.1 *Introduction*

A number of sources of waste will be generated during the temporary operation of the AFRF, as identified in *Section 3.7.3*. The appropriate disposal requirements for these solid and liquid wastes, necessary to prevent environmental impacts, are discussed below.

5.3.2 *Statutory Requirements*

Chemical Waste

The *Waste Disposal (Chemical Waste) (General) Regulation* provides the control for the storage, collection, transportation and disposal of chemical wastes in Hong kong. Under the Regulation, a chemical waste includes any substance being scrap material or byproduct arising from industrial/trade activities as specified under *Schedule 1* of the *Waste Disposal Regulation* in such form, quantity and concentration that it will cause pollution or constitute a danger to health or risk to the environment. A complete list of such substances is provided under this Regulation. A chemical waste producer will be required under this Regulation to register with the Director of Environmental Protection and to dispose of chemical waste to a licensed treatment facility such as the Chemical Waste Treatment Centre (CWTC) located at Tsing Yi, which was commissioned in June 1993 and is designed to treat most of the chemical waste arisings in the territory.

Waste Generated on Board Vessels Associated with the AFRF

Hong Kong is a signatory to the *MARPOL 73/78 Convention Annex I and II* in that it is obliged to provide a reception facility to handle MARPOL waste from ocean going vessels. In Hong Kong, the *Merchant Shipping Ordinance* and *Regulation (Cap 281)* prevents pollution from ships by forbidding the discharge of oil from ocean going vessels into the sea. The *Ordinance* requires that all ocean going vessels must have an oil water separator aboard. Oily mixtures must be treated on board before discharge or be sent to an appropriate treatment facility.

The CWTC can handle such oily wastes from vessels to meet Hong Kong's obligations under the *MARPOL 73/78 Convention Annex I and II.* The design of the CWTC has incorporated features specifically for the purpose of receiving waste generated from marine–tank cleaning and deballasting.

Marine Sediment

The statutory requirements for the transportation and disposal of dredged marine sediments and the relevant Technical Circular have been discussed in *Section 4.1*.

5.3.3 *Potential Sources of Impact and their Significance*

During the temporary operation of the AFRF, the following solid and liquid waste arisings may be generated:

- sewage effluents;
- domestic waste;
- chemical waste;
- commercial/industrial waste;
- office waste;
- waste generated on board vessels associated with the AFRF;
- foam and fuel spill remediation chemicals; and
- dredged sediments from maintenance dredging.

The above solid and liquid waste arisings at the AFRF have the potential to cause unacceptable water quality impacts and may therefore result in detrimental effects on marine biota. These sources of waste will thus require appropriate methods of removal from the AFRF in order to prevent the potential for adverse water quality impacts and associated adverse impacts on marine fauna and flora.

Sewage

It is presently considered that approximately 17 persons will be located on the facility at any time with the equivalent of a total of around 35 persons employed on daily shift work (morning, afternoon or night shifts) or in residence on the AFRF. This staffing level will generate around 2,000 litres of sewage and wastewater per day. The SER would be serviced by chemical toilets and all effluent produced would be collected and disposed off-site in accordance with EPD requirements.

Domestic Waste

The estimated daily total of 35 persons will also generate a total of approximately 50 kg/day of domestic waste, based on 1.4 kg/person/key per head. This type of waste would normally be contained in plastic bags, except for items such as broken fluorescent lighting strips or clinical waste which may require special measures. In addition, further wastes of a similar domestic nature would arise from the canteen and cleaning service.

Chemical Waste

Chemical wastes will arise from the drips and small spills collected from coupling and uncoupling of the unloading arms to and from the fuel vessel manifold. The aviation fuel would be directed through an oil interceptor to remove water (for example rainwater) before draining to a slops tank containing all intercepted oil from other sources, such as the workshop area.

Other typical chemical wastes likely to arise include used lubricating oil, spent acid/alkali from batteries, spent mineral oil, paint, solvents and cleaning agents etc used in routine maintenance activities, and other wastes such as spent filter cartridges containing heavy metals and scrap battery casings.

It is difficult to quantify the amount of chemical waste which will arise from AFRF maintenance activities since this will be highly dependent on the facility maintenance requirements.

Commercial/Industrial Wastes

The workshop and stores will generate waste such as packaging, metal swarf, spent filters, irreparable and replaceable components and gaskets.

Office Wastes

Waste generated from office activities will comprise mainly paper, plastic, consumable components and cans.

Waste Generated on Board Vessels Associated with the AFRF

Oily waste generated from aviation fuel vessel stripping and deballasting operations will be classified as MARPOL waste. These oily mixtures may include:

- dirty ballast water;
- tank washings;
- oil bilge wastes; and
- oily residues and liquid and solid sludges.

It is difficult to estimate the volume of these "MARPOL waste "arisings as it will vary with the size and type of the vessels. Stripping or deballasting will not be required for every trip and will be carried out only as necessary. In general, such stripping and deballasting "MARPOL waste" arising will be in the region of 100 to 200 tonnes per vessel per occasion, depending on the vessel size.

The fuel delivery vessels and transport workboats will need to discharge their bilge water. However, this will not be permitted at the AFRF but will be accommodated by discharge into appropriate bilge water reception tanks at a suitable off-facility location. No removal directly from the AFRF will be required.

Foam and Fuel Spill Remediation Chemicals

Should it be found to be appropriate to allow the storage of foam for fire fighting and chemicals for aviation fuel spill remediation against the relatively rare occasions that they would be deployed, then the waste resulting from their use would, of necessity, spread over the water surface. No waste removal would be required.

Dredged sediments from maintenance dredging

As discussed in *Section 4.1*, maintenance dredging would only be required intermittently during subsequent back up and emergency use, to remove sediments settled within the turning basin and access fairway. It is considered that the potential for impacts on water quality through sediment resuspension, and associated adverse direct and indirect impacts on marine fauna and flora, may be minimised with the use of an appropriate low impact dredging technique and the observation of good operational practice. The mitigation measures recommended to minimise potential impacts arising from dredging are detailed in *Section 4.1*.

The disposal requirements of the identified solid and liquid wastes necessary to prevent environmental impacts are discussed below. It is anticipated that, with appropriate handling, storage and removal of solid and liquid waste arisings from the AFRF, potential water quality and marine biota impacts will be minimised.

5.3.4 *Mitigation Measures*

All wastes should be handled, stored and disposed of in accordance with good practice, and EPD regulations and requirements. The recommended disposal requirements for the AFRF should be incorporated into the comprehensive Environmental Management Plan to be developed for the entire new airport operation. It is anticipated that those wastes that need to be removed from the AFRF will be removed at regular intervals (to be determined at a later stage) by the following means (using either a specialised hired service vessel or via the fuel shuttle vessel):

Sewage: pumped from temporary storage tank to transit tank on the vessel.

Domestic and office wastes: by hand or compacted and bound into packs and hoisted aboard the vessel. Putrescible wastes should not be stored on board for longer than 48 hours and may require a chiller room for storage.

Chemical waste (paint, solvents): enclosed in sealed reusable acid resistant containers. The Code of Practice on the Packaging, Labelling and storage of Chemical Wastes issued by EPD shall be followed. These wastes should be sent to the CWTC. Recycling of chemical wastes should be considered where possible. It may be possible for used lubricating oil to be sent for recycling to the oil recovery plant in Yuen Long should this be operational.

Other chemical wastes, such as spent filter cartridges containing heavy metals and scrap battery casings, which are not acceptable for treatment and disposal at the CWTC can be disposed of by licensed chemical waste collector at a designated landfill approved for chemical waste.

Chemical waste (oily water): drip tray/spill collection systems collected via a manifold arrangement and pumped from temporary slops tank to transit tank on the vessel, for off-site disposal at the CWTC.

Commercial/Industrial waste: collect for disposal to landfill using separate containers. Certain commercial/industrial wastes such as scrap metals and other suitable waste materials should be reused wherever possible.

Waste Generated on Board Vessels Associated with the AFRF: the discharge of bilge water will normally be accomplished by discharge into appropriate bilge water receipt tanks at a suitable off-AFRF site location. No removal of bilge waters directly from the AFRF will be permitted. Under the *Merchant Shipping Ordinance,* this "MARPOL waste" will have to be treated on board the vessel or sent to the CWTC for appropriate treatment. The discharge of oil from vessels into the sea is forbidden under this ordinance. The Licensees dedicated fuel shuttle vessels should contain solid and liquid waste storage tank facilities and should not empty or wash out bilges or discharge any solid waste at the AFRF site. The Licensee should arrange collection of this "MARPOL waste" with the CWTC operator where necessary.

It is therefore considered that with the appropriate handling, storage and removal of solid and liquid wastes arisings from the AFRF as defined above, the potential to result in adverse impacts on water quality and marine flora and fauna will be minimised. No solid nor liquid wastes should be allowed to enter the marine waters at the facility and discharges into the marine waters from the operating facility should not be permitted. Stringent control and audit, as outlined in *Section 7*, will be necessary to ensure that the correct disposal requirements for the various waste arisings are being implemented.

In addition to the above waste disposal management measures, it is recommended that waste generation should be minimised and materials reused on the facility as far as practicable to minimise the disposal requirements.

Mitigation measures to minimise potential impacts arising from dredging activities during maintenance dredging will be as recommended in *Section 4.1* under the construction phase.

5.3.5 *EM&A*

It is recommended that solid and liquid waste disposal is monitored and audited by specified resident AFRF personnel during the temporary operation of the AFRF. Requirements for EM&A are outlined in *Section 7*, and will be finalised by the Licensee during the detailed design of the AFRF.

5.3.6 *Summary*

It is considered that, if appropriate handling, storage and removal of the identified solid and liquid waste arisings from the AFRF is enforced, the potential to result in adverse water quality impacts and associated detrimental effects on marine biota will be minimised.

Stringent EM&A will be necessary to ensure that the correct disposal requirements for the various waste arisings are being implemented. No solid nor liquid wastes should be allowed to enter the marine waters at the facility, and discharges into the marine waters from the operating facility, and discharges into the marine waters from the operating facility should not be permitted. The recommended disposal requirements for the AFRF should be incorporated into the comprehensive Environmental Management Plan to be developed for the entire Chek Lap Kok Airport operation.

The operational impacts were assessed based on a temporary 5–7 year use and any full operation beyond this interim period will require further environmental assessment.

5.4 *OPERATIONAL IMPACTS ON MARINE ECOLOGY*

5.4.1 *Introduction*

The potential impact of accidental fuel spillage or pipe leakage on the marine environment, during the period that the AFRF will be operational, is discussed in *Section 6.2* on Environmental Risk.

5.4.2 *Potential Sources of Impact and their Significance*

Benthic Communities

Minimal disturbance to the seabed will result from operation of the fuel pipeline as no specific maintenance is envisaged. It is therefore likely that the bottom sediments will be recolonised by benthic fauna. If the sediment is of the same type then a similar fauna would be expected to return by such mechanisms as larval recolonisation and immigration.

As discussed in *Section 5.1,* there will be no routine maintenance dredging programme during the operational period. It is anticipated that maintenance dredging would only be required intermittently during subsequent back-up and emergency use to remove sediments settled within the turning basin and access fairway. This maintenance dredging would result in the destruction of benthic biota in the immediate works area. Surveys around Sha Chau, however, have revealed that the soft bottom benthic species noted are typical of benthic communities in the coastal areas of Hong Kong. Hence, the loss of soft bottom benthos is not considered to be great and is unlikely to have an adverse effect on the sublittoral marine ecosystem as a whole to the north of Lantau.

However, results from the trawl survey and diving survey indicated that the sea pens (*Pteroides esperi, P. sparmanni, Sclerobelemnon burgeri, Virgularia gustaviana*) and stone corals (faviidae and gorgonacea) were common in the suttidal zone around Sha Chau. These species are sensitive to pollution, particularly siltation resulting from dredging. Therefore it is considered important that the recommended mitigation measures are implemented to minimise the loss of suspended solids to the water column during maintenance dredging, as detailed in *Section 4.1.15.*

In addition there may be positive/beneficial long term impacts associated with the proposed facility. These possible benefits include the likely recolonization ('settlement') of the subsea parts of the piled structure as barnacles and other molluscs could grow on the piles. Additionally, the shade provided from the facility may attract certain species of fish. Both of these could be beneficial in the long-term as a possible food source for *Sousa,* after the cessation of the temporary AFRF operation.

Fish and Invertebrate Communities

As discussed in *Section 4.4.3*, the results of the baseline survey strongly suggest that the area may serve as an important spawning and nursery ground, in particular for penaeid shrimps and commercial fish species. The juvenile stage is the most vulnerable stage in the life cycle of a species. It was identified earlier in *Section 4.4.6*, that adverse impacts on the juvenile stages of fish and shrimps arising from the construction works may potentially affect recruitment at the population level and thus exert a long term impact. At present the preliminary baseline data do not permit a full assessment of the importance of the area as a nursery and spawning ground and thus any long term impacts on these grounds cannot be assessed at this stage. Thus the previous requirement for detailed ecological studies, as discussed in *Section 4.4.7*, is recommended. This will provide seasonal data and enable an assessment of the importance of the area as a nursery and spawning ground, in order to detail practical mitigation measures to minimise potential impacts.

Furthermore, as discussed in *Section 4.4.6*, there is reason to believe that the shore at Sha Chau may also serve as the spawning and nursery ground of the Chinese King Crab. Based on the documented occurrence of the Chinese King Crab in similar habitats in the vicinity (Furano 1992), the absence of this species in the present survey may only reflect the seasonal occurrence of this species. It is therefore recommended that another survey be carried out in February 1995 to verify the occurrence of the Chinese King Crab in the area. Although it should be noted that the preferred location for the AFRF (Site C) is to the north-east of the northern Sha Chau island and thus the facility will not be located near the sand bar therefore impacts upon it will be minimised.

However, as described in *Section 3.4.2*, the preferred method for the construction of the AFRF on a piled structure will minimise the loss of seabed and marine habitat, and thus the structure will have a minimal physical presence in the marine environment. The movement of fuel vessels to the facility is unlikely to have direct impacts on free swimming biota, such as fisheries and invertebrates. Thus, it is anticipated that the AFRF facility will have minimal operational impact on the marine ecology around Sha Chau.

After installation of the pipeline in the submarine trench, the pipeline and associated rock armour protection will be located below the level of the seabed, thereby minimising interference with fishing activities. The pipeline will be covered to stand all natural conditions such that no erosion of the top layer due to current or wave action may occur. It will also be protected by a layer with sufficient resistance against damage by dredging, anchors or fishing activities.

Fishing activities which may be interrupted during the pipeline installation will return to normal during operation. In addition, fish communities disturbed by the construction works are likely to return to the area.

Therefore, no operational impacts on the marine ecology are envisaged from the operation of the submarine pipeline system to the on-airport storage tanks.

Marine Mammals

The following activities during the temporary operation of the AFRF have been identified as having the potential to impact on *Sousa*:

- vessel operation and movements;
- solid and liquid waste generation; and
- maintenance dredging.

Based on the proposed pipeline operation, it is assumed that there will be no impacts on *Sousa* associated with the operation of the submarine pipeline. It should be noted that the preferred site for the AFRF location has been chosen in an area where, during a one month field survey (June 1994), the lowest relative number of *Sousa* were sighted, to minimise direct and indirect negative impacts on *Sousa*. It is considered that this physical separation may provide a buffer area and may thereby minimise potential direct and indirect impacts on *Sousa*.

Vessel operation and movements

The operation and movement of vessels at the AFRF has the potential to result in direct and indirect impacts on *Sousa* from the following:

- sediment resuspension;
- noise disturbance; and
- physical harm potential.

Sediment Resuspension

Sediments will be deposited in the turning basin, particularly during the wet season. Potential impacts that may therefore arise from the movement of fuel vessels include the stirring up of sediments during vessel transit and manoeuvring at the facility, and from turbulence in the vessel wake and propellor wash. Of concern with regard to these potential impacts from vessel movements could be the resulting potential impact on water quality which may have indirect effects on *Sousa*, although sediment plume modelling indicated low worst-case SS levels arising from construction dredging and thus significant direct sediment resuspension impact will not occur to marine mammals.

In addition such sediment resuspension potential could have less significant adverse direct impacts on *Sousa* based on its possible tolerance of silt laden waters, having adapted to the estuarine conditions with the North Western waters. Potential adverse impacts may arise on *Sousa* through associated indirect effects on food availability arising from sediment resuspension and reduced DO levels in the water column. Therefore, it is considered that the recommended mitigation measures should be undertaken to minimise the amount of suspended sediment generated by vessel movements, as discussed in *Section 4.1.15*.

It is considered that with the use of dedicated fuel vessels designed specifically for the AFRF operation and the implementation of speed restrictions for all AFRF vessels within the access fairway and turning basin, the potential for adverse impacts to arise on *Sousa* through associated direct and indirect water quality impacts resulting from sediment resuspension will be minimised.

Vessel noise

Vessel noise levels are generally related to vessel size, speed and mode of operation. Large vessels generally tend to emit more sound than smaller vessels and vessels underway with a full load (or towing or pushing a load) produce more noise than unladen vessels. Noise generated by vessels generally increases with a vessel's speed whether loaded or unloaded. In addition, the state of maintenance strongly influences radiated sound level. Vessels with old auxiliary machinery (eg. generators and compressors) tend to radiate more noise than newer, well-maintained vessels. [1]

Research has indicated that small boats, though they may emit less noise than large ones, are more disturbing to dolphins due to the higher frequency of the noise emitted (>1000 Hz). [1] Large vessels tend to emit lower frequency sounds (<250 Hz) and so are not as easily detectible to dolphins due to their poorer sensitivity to these frequencies, as described earlier in *Section 4.4.6*.

It is anticipated that with the recommended speed restrictions all vessels associated with the AFRF will be moving slowly in the vicinity of the AFRF, thus reducing noise disturbance on *Sousa* from engine noise. Furthermore, the high relative manoeuvrability of the dedicated shuttle vessels will minimise the amount of noise disturbance generated from vessel manoeuvring movements and also, as discussed above under *Sediment Resuspension*, will minimise propeller wash.

Fuel will be discharged by the vessel on-board pumps using the unloading arms at the facility. Although much of this noise will be absorbed by the fuel vessel, some noise will be radiated into the water. Therefore, in order to minimise disturbance on *Sousa* it is recommended that the dedicated 'shuttle' vessel specification incorporate a requirement for pump noise insulation.

In comparing vessel noise from the AFRF operation to that from present traffic in the surrounding area it should be noted that movements of high speed ferries to and from Zhuhai frequently occur in the waters between

(1) Richardson W J, Greene C R, Malme C I and Thomson D H with contributions by Moore S E and Wursig B (1991) Effects of Noise on Marine Mammals LGL Ecological Research Associates Inc.

Sha Chau and Lung Kwu Chau, and thus background vessel noise occurs in this area. There are also a large number of vessels in Urmston Road and the waters to the south of Sha Chau, off North Lantau and the Chek Lap Kok area. It is recommended that the dedicated `shuttle' vessel specification incorporate a requirement for the use of large vessels, 5,000 dwt in size, in order to minimise noise disturbance on *Sousa* through the lower frequency of noise emitted by larger vessels, which are not as easily detectible to dolphins due to their poorer sensitivity to these frequencies as detailed in *Section 4.4.6*. Therefore, it is considered that the increase in vessel noise from the operation of the AFRF dedicated large `shuttle' vessels (5,000 dwt) is unlikely to contribute significantly to the level of background noise in this area.

Physical harm potential

The potential exists for *Sousa* to be physically harmed from propellors and collisions with vessels as discussed earlier, in *Section 4.4.6*, in the construction phase under vessel movements.

In common with other Indopacific humpback dolphins, *Sousa* appear to be generally shy of boats and rarely ride the bow or stern pressure waves, however, rare sittings of such activities have been observed in Hong Kong waters (D S Melville, 1993 pers. comm.). Furthermore, with the implementation of proposed speed restrictions all vessels associated with the AFRF will be moving slowly in the vicinity of the AFRF. At lower vessel speeds, resulting from AFRF speed restrictions, it is considered that there will be a lower potential for *Sousa* to be physically harmed from collisions with AFRF vessels.

Solid and liquid waste generation

Solid and liquid waste arisings at the AFRF, as identified in *Section 5.3*, have the potential to cause unacceptable water quality impacts and could without control result in detrimental effects on *Sousa*. It is, however, anticipated that with the appropriate handling, storage and removal of these solid and liquid wastes from the AFRF, as described in *Section 5.3*, the potential to result in detrimental effects on *Sousa* will be minimised.

Maintenance Dredging

Potential impacts on *Sousa* associated with the disturbance of marine sediments are as described earlier in *Section 4.4.6* for dredging activities during the construction phase.

It is considered that the potential for adverse direct and indirect impacts to arise on *Sousa* through sediment resuspension may be minimised with the use of an appropriate low impact maintenance dredging technique and the observation of good operational practice. The mitigation measures recommended to minimise potential impacts are as detailed in *Section 4.1.15* under the construction phase.

5.4.3 *Mitigation Measures*

The following section gives recommendations on appropriate mitigation measures that should be implemented during the operation of the AFRF at the preferred site location to minimise impacts on the marine ecology, and to compensate for identified adverse effects.

Further Ecological Studies

The recommendation for a detailed ecological study, as discussed in *Section 4.4.7*, is reiterated in order to provide seasonal data and to enable an assessment of the importance of the area as a nursery and spawning ground. In addition, a further ecological survey should be undertaken in February 1995 to verify the occurrence of the Chinese King Crab in the area. Restocking of penaeid shrimps, sea pens and commercial fish species should be considered to mitigate potential impacts resulting from the AFRF construction works.

Solid and liquid waste generation control measures

During the operational phase of the AFRF, strict control and audit will be necessary to check that the correct disposal requirements for the various waste arisings are being implemented. These waste monitoring and control measures are detailed in *Section 7*. The appropriate disposal requirements of the identified solid and liquid wastes necessary to prevent impacts on the marine ecology are detailed in *Section 5.3* under Operational Waste Management.

The following section outlines a comprehensive, practical and cost–effective `package` of mitigation measures that should be implemented during the operation of the AFRF at the preferred site location to minimise impacts on *Sousa*.

Vessel operation and movements

The larger dedicated fuel vessel size (5,000 dwt) is preferable to minimise the number of daily trips required to the facility and thus result in a lower potential for direct and indirect impacts on *Sousa*.

Minimisation of Sediment Resuspension

The use of dedicated fuel shuttle vessels designed specifically for the AFRF operation and the implementation of speed restrictions, as detailed in *Section 5.1*, will minimise the potential for associated adverse impacts to arise on *Sousa* through sediment resuspension generated by vessel movements.

Minimisation of Noise

It is recommended that the dedicated `shuttle` vessel specification incorporate a requirement for the use of large vessels, 5,000 dwt in size, in order to minimise noise disturbance on *Sousa* through the lower frequency of noise emitted by larger vessels. The high manoeuvrability of the dedicated shuttle vessels will also minimise the amount of noise disturbance generated from vessel manoeuvring movements. In addition, with the implementation of speed restrictions (0.2 - 0.3 m/s maximum) on the Licensee and non-Licensee fuel vessels and non-fuel vessels associated with the AFRF, all vessels will be moving slowly at lower power, thus reducing noise disturbance on *Sousa* from vessel engine noise.

The dedicated shuttle vessel specification should incorporate, to the extent practicable, a requirement for pump noise insulation in order to minimise disturbance on *Sousa* when discharging fuel into the submarine pipeline at the facility.

Minimisation of Physical Harm Potential

It is recommended that the number of vessels be minimised by the use of 5,000 dwt vessels rather than 3,000 dwt vessels, in order to minimise the direct physical harm potential to *Sousa*, and to minimise the potential impact of vessel traffic on the normal movements of *Sousa*.

Vessel Crew Training

The Licensee should fully brief all crews on the constraints and controls regarding vessel operation and movements at the AFRF in order to minimise impacts on *Sousa*.

5.4.4 ***Summary***

The preferred method for the construction of the AFRF on a piled structure will minimise the loss of seabed and marine habitat, and thus the structure will have a minimal physical presence in the marine environment. In addition there may be positive/beneficial long term impacts associated with the proposed facility. These possible benefits include the likely recolonization ('settlement') of the subsea parts of the piled structure as barnacles and other molluscs could grow on the piles. Additionally, the shade provided from the facility may attract certain species of fish. Both of these could be beneficial in the long-term as a possible food source for *Sousa*, after the cessation of the temporary AFRF operation.

The movement of fuel vessels to the facility is unlikely to have direct impacts on free swimming biota, such as fisheries and invertebrates. In addition, fish communities disturbed by the AFRF construction works are likely to return to the area. Thus, it is anticipated that the AFRF facility will have minimal impact on the marine ecology around Sha Chau.

Fishing activities which may be interrupted during the pipeline installation will return to normal during operation. Therefore, no operational impacts on the marine ecology are envisaged from the operation of the submarine pipeline system to the on-airport storage tanks.

The comprehensive package of mitigation measures and controls recommended for the operation stage should be incorporated in the detailed design of the AFRF. As such it is considered that the implementation of these mitigation measures and the recommended monitoring and audit requirements will minimise the potential for both direct and indirect impacts on *Sousa* and other ecologically sensitive marine species identified, from the AFRF operation.

The incorporation of the *Sousa* impact and operational controls monitoring and audit within the overall AFRF EM&A requirements should be investigated in detail at the detailed design stage, in association with AFD.

6 *RISKS AND THE AFRF*

6.1 *INTRODUCTION*

6.1.1 *Background*

Risks associated with the supply of aviation fuel arise both from its flammability, which can present risks to human life, and from its toxic nature which in the event of a spill can present risks to the environment. The IAR examined the issues on a preliminary basis for the AFRF moorings, pipelines and shipping operations near the moorings. It concluded that:

- Risks to life from the operation of an AFRF at Sha Chau were small due to the absence of populations in its vicinity.
- In respect of environmental risks it was considered appropriate that evaluation of the potential impact of accidental fuel spillages on the environment was necessary in the EIA so that broad spill response requirements could be determined.

Following consideration of the IAR by ACE in mid-September 1994 it was recommended that the EIA also integrate the risks to life associated with the supply of aviation fuel through the Ma Wan Channel with the findings of the IAR. ACE further emphasised that a major concern with the Sha Chau site was the potential impacts of spillages of aviation fuel.

6.1.2 *Organisation of the Section*

This section of the report details the above issues and assesses the relative significance of the risks posed:

- *Section 6.2* presents an analysis of risks to life of the fuel supply operation including those arising from transport in tankers through the Ma Wan Channel. The latter is based on consideration of the IAR and a study [1] that was completed for PAA in 1993 during its search for a potential permanent fuel supply option (referred to in this section as the 1993 Study).
- *Section 6.3* examines the environmental risks and includes assessment of likely spill scenarios and their frequency of occurrence, the potential ecological impacts to marine and coastal ecology, preliminary oil spill modelling and an assessment of the means of minimising the effects of the oil spills in respect of spill clean up technology and response planning.

[1] ERM Hong Kong, Marine Transport of Aviation Fuel Through the Ma Wan Channel - Hazard Assessment for PAA, July 1993

- *Section 6.4* concludes the Risk Section.

6.2 RISKS TO LIFE

6.2.1 Introduction

AFRF Supply Routes

Figure 6.2a shows the possible aviation fuel supply routes to the AFRF. As described in *Section 3* most of the fuel will be supplied from an off airport source in dedicated 3,000 - 5,000 dwt coastal tankers. It is anticipated that up to 10% of the aviation fuel might be supplied in larger vessels (less than 10,000 dwt).

The Risks

Aviation Fuel is a flammable material, but note not highly flammable. Its low volatility and high flash point mean a significant energy source is needed to ignite it - for example lighted matches or cigarettes would not usually ignite a pool of aviation fuel. Its main risks to life in a marine context are:

- leakage from a pipeline or vessel and subsequent ignition (by say fires or hot couplings coming into contact with spilled fuel following leakage) of the liquid on the sea surface resulting in a pool fire; or

- fireballs arising from ignition of vaporised aviation fuel following fires on board vessels.

If such accidents happen in busy shipping channels or close to populated coastlines their effects could cause serious injury and/or loss of life to members of the general public.

Risk or hazard assessment can be used to quantify these risks, both in respect of likelihood of occurrence and expected consequences. The risk can be expressed quantitatively in two ways:

- *Societal Risk*: The likelihood of causing a number of fatalities given the distribution and number of persons in the affected area.

- *Individual Risk*: The likelihood of deaths per year at a particular location.

In transport studies, where the source of the risk is mobile, it is usually the risk to society that is most important. By comparing the risks from a given activity, such as the AFRF, with background risk levels their significance can be assessed. Comparison of hazard assessment results with guidelines or risk criteria can also be used to judge the acceptability of risk and to evaluate the effectiveness of potential risk reduction measures.

In respect of risk to life and the AFRF, the 'worst case' route is if all fuel is shipped through the Ma Wan Channel, due to the high density population adjacent to these shipping channels compared to the alternative routes. The principal concern is the issue of the risk to populations adjacent to the Ma Wan Channel and the risk to populations alongside Urmston Road on the mainland west of Ma Wan. Several previous studies have indicated that the risk to shore based populations around the Ma Wan Channel will increase to significant levels in the next decade if certain proposed industrial developments, using Dangerous Goods (DGs), are approved by Government. These proposed developments are to be sited west of Ma Wan and will be supplied with Dangerous Goods via the Ma Wan Channel.

6.2.2 *Previous Studies*

This section draws mainly from two previous studies to fulfil the objectives given in *Section 6.2.3*:

- *Marine Transport of Aviation fuel Through the Ma Wan Channel – Hazard Assessment (the 1993 Study)* : ERM Hong Kong were commissioned by PAA in early March 1993 to conduct a risk assessment of the two potential *permanent* fuel supply options involving shipment through the Ma Wan Channel. One involved shipment in coastal tankers/barges from Tsing Yi Oil Terminals to a jetty on the north shore of CLK. The other comprised supply in ocean going tankers to a potential site at Sham Shui Kok. The conclusions of this study eliminated as unacceptable, any permanent supply options involving any marine supply through the Ma Wan Channel, but did not preclude temporary barging for a period of a few years whilst a piped supply system was constructed.

- *AFRF Initial Assessment Report:* The IAR identified the hazards and assessed the consequences of incidents that might occur in the vicinity (within about 1 km) of an offshore fixed receiving facility at Sha Chau. It showed that unloading operations at Sha Chau do not involve nearby population and hence pose insignificant risk to the general public.

6.2.3 *Objectives*

The objectives of this study are as follows:

- To summarise and integrate the two studies such that an overall picture of the likely 'worst case' risks from the AFRF can be identified;

- To comment on the overall significance of the risks; and

- To summarise cost effective risk reduction strategies and any requirements for further study where appropriate.

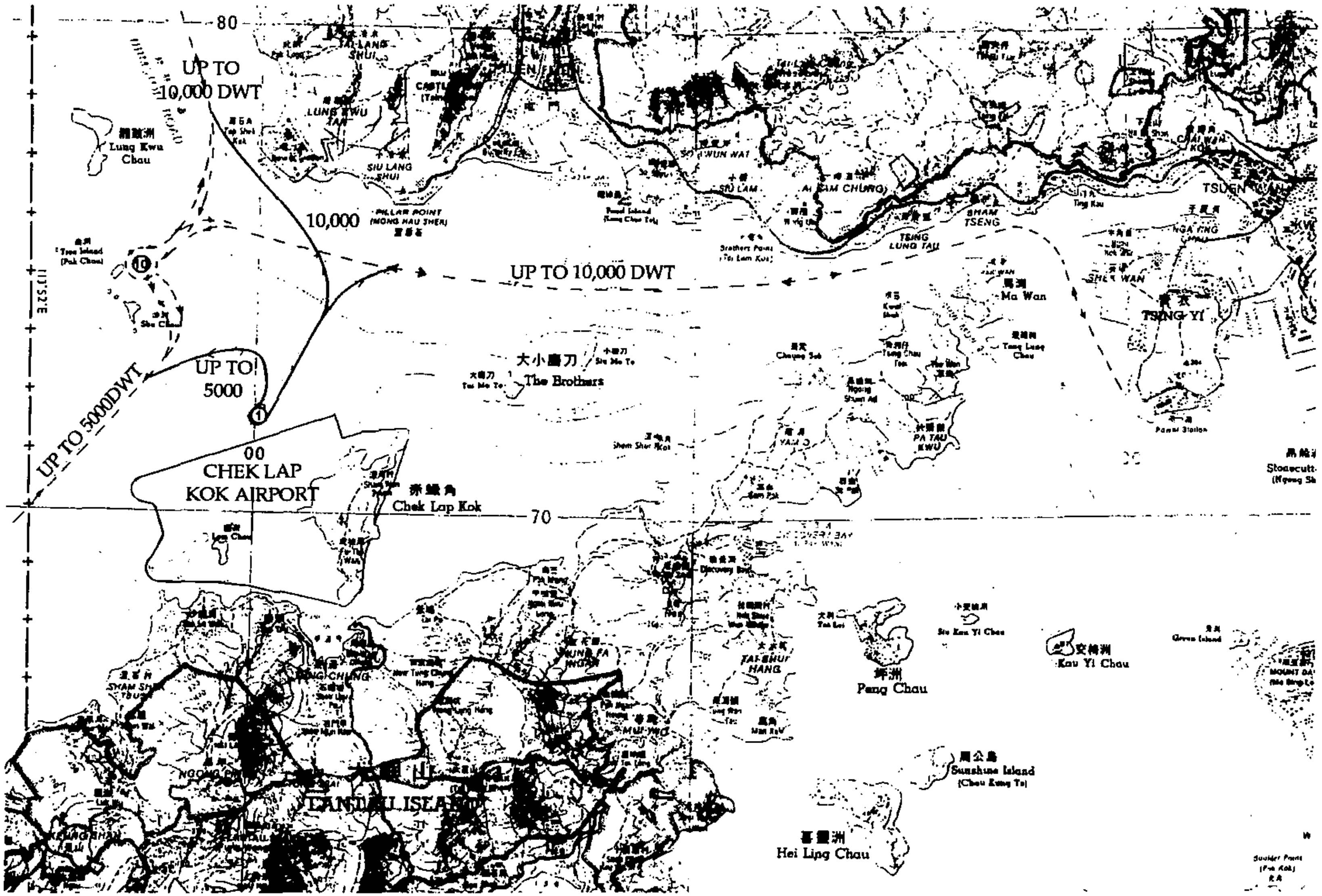

FIGURE 6.2a - POSSIBLE AVIATION FUEL ACCESS ROUTES

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ERM

6.2.4 *Approach*

Ideally in a study such as this, the risks would be quantitatively evaluated on the basis of the risk from the total operation, i.e. from the storage facility to the airport, encompassing both unloading and berthing, and all parts of the transport routes and pipelines. However, this was not possible in the available timescale. Hence the assessment has been approached in the following way:

- the level of Societal Risk in the Ma Wan Channel, quantitatively assessed in the 1993 study for the 5,000 dwt case for 2040 demand, is qualitatively adjusted (by factoring down the risk to account for the lower fuel demand in 2004) to account for the AFRF operational period with could in the worse case extend up to 7 years to 2004.

- the level of risk to remaining populations on the mainland adjacent to Urmston Road west of Ma Wan is estimated based on approximate coastal population estimates and navigational conditions.

- the level of risk from the 10% of fuel that might be supplied in vessels of up to 10,000 dwt is qualitatively assessed via interpolation of the results of the 1993 Study which looked at various vessel sizes between 1,000 and 10,000 dwt.

Prior to detailing the results a description of the study area is given and the process by which the risks are estimated.

6.2.5 *The Study Area*

The area considered in the study where accidents might occur due to AFRF related operations is limited to sea and onshore areas within about 1 km of the Ma Wan Channel, Urmston Road, the offshore fixed receiving facility at Sha Chau and the pipeline to CLK. This being the maximum extent of credible hazardous incidents.

The analysis conducted in this study divides the study area into two main sub-areas:

- The Ma Wan Channel Area

- Urmston Road Area – i.e. areas of population west of the Ma Wan Channel comprising:

  - AFRF at Sha Chau
  - mainland coast along Urmston Road north west of Ma Wan Channel; and
  - Lantau coast, south west of Ma Wan Channel

Residents and workers in these areas, see below, are at risk from the, albeit rare, incidents that may occur. Population levels and background shipping movement frequencies are based on the year 2006 as in the 1993 Study.

Ma Wan

The 1993 study made conservative estimates of the populations at risk adjacent to the shipping channel, particularly existing and planned (to 2006) population centres close to shore at Sham Tseng, Ting Kau, Tsing Yi and Ma Wan Island. Consideration was also given to other populations, including:

- The North Lantau Expressway including sections on the Tsing Ma Bridge;
- The Airport Rail Link including sections on the Tsing Ma Bridge;
- Route 3 and approaches;
- Ferries in the channel area;
- Other vessels crew; and
- People on beaches.

To enable more accurate estimates to be made of population at risk at a given time the 1993 study accounted for:

- Population variations by time period (eg by season, time of day etc);
- Local meteorological conditions (although not for aviation fuel releases which are in the liquid phase and not affected by weather conditions);
- Local topography.

Urmston Road

The most significant areas of population on the mainland coast west of Ma Wan are located around Tuen Mun New Town. The area is serviced by the ferry from Central. The population of Tuen Mun is estimated at 400,000, much of which is located inland, well away from the shoreline. Only population in buildings and other areas close to the shore will be at risk from marine accidents. The area has 2 gazetted beaches: Kardoorie and Cafeteria. Butterfly Park and Beach lie adjacent to Butterfly Estate. To the east of Tuen Mun lie the planned Special Industries Area and River Trade Terminal in Area 38 with significant worker populations planned over the potential operational life of the AFRF. It is estimated that by 2006 the population may be as much as 3 times higher than that in the Ma Wan Channel.

The population on North Lantau will eventually number some 250,000, although much of this will not be developed until the latter stages of AFRF operation. It will comprise 2 new towns: Tung Chung (200,000) and Tai Ho Wan (50,000). The development will also include industry, schools, retail and commercial areas and the North Lantau Expressway and Lantau and Airport Railway. The 1993 study described this development and its population in detail.

The Vessels

It is anticipated that the dedicated fuel shuttle vessel size would at most, be around 5,000 dwt, with the largest tank size being 1,000 tonnes. Vessels of up to 10,000 dwt will be used on an infrequent basis, up to 10% of the time, as necessary to allow Air Carriers the opportunity to bring in larger competitively priced fuel parcels. Depending on vessel size and delivery patterns between 1 and 4 vessels will normally use the AFRF per day.

The loaded movement frequency used for the 5,000 dwt vessels is based on the airport aviation fuel demand for 2004 (seven years after the anticipated airport opening). The fuel demand forecast shows a requirement for about 8,000 tonnes/day (or 2.9 million tonnes/year) in 1997, rising to 10,300 te/day (3.75 Mte/yr) in 2004. The 5,000 dwt dedicated tankers are expected to conform with Marine Department conditions (*Annex E*) and are assumed in this and the 1993 Study to be of double hulled or double 'skinned' design equipped with the most modern safety features.

The fuel vessels will travel at around 10 knots in designated shipping channels shown in *Figure 6.2a* from an off-airport location, of which supply through the Ma Wan Channel presents the worst case option in respect of hazards, to the AFRF. Anticipated transit time from Tsing Yi would be 1.5 hours.

It is important for AFRF operational reasons that vessels should be highly manoeuvrable and that vessels should be able to approach the facility at very low speed to minimise potential damage to the AFRF and the approaching vessel. For this reason it is expected that all fuel vessels would be required to approach the facility through a system of gated buoys at low speeds of 0.2-0.3 m/s (maximum). In order to cost-effectively maximise manoeuvrability of the dedicated shuttle vessels it is proposed that they should comprise a single propeller vessel with a 'Schilling' rudder and bow thruster, which will afford the vessel about the same manoeuvrability of a twin propeller vessel with bow thrusters.

As the vessels would have to pass through the Ma Wan Channel, the crew would be required to be trained to respond to the Vessel Traffic Control (VTC) system to be installed by Marine Department to control vessels in the channel.

6.2.6 *Hazard Assessment*

Approach

The overall approach used in the 1993 Study and that adapted here is that of a Quantitative Risk Analysis or QRA which involves the following 5 steps:

- *Data acquisition*: Data are acquired on the population, meteorology, topography and shipping and fuel movements in the study area.

- *Identification of failure cases*: The conditions under which a release may occur are assessed.

- *Accident Frequency Estimation*: The frequency of accidental release and associated release parameters, such as release rates, are assessed using a combination of historical data and.mathematical modelling.

- *Consequence Analysis*: The likely distances to which a release may pose a threat to life are quantified.

- *Risk summation and evaluation*: This step involves summing the likelihood of releases with the consequence information and overlaying the consequence data over the population plots for the study area. The risk is summed in two ways, namely:

  - *Societal Risk*: The likelihood of causing a number of fatalities given the distribution and number of persons in the affected area.

  - *Individual Risk*: The likelihood of death per year at a particular location (as mentioned previously this measure is not significant for the AFRF)

The measures of risk are compared with published risk guidelines to indicate whether they may be considered acceptable.

Hazards

As discussed above the two principle risks to life associated with aviation fuel transport are pool fires and fireballs. The levels of risk resulting from realisation of these hazards depend not only on the frequency and quantity of fuel released, but also on the location of release and proximity of population to the hazard. Therefore, from a given operation the risk is likely to be most significant for accidents occurring near to the population concentrations described above.

Initiating Events & Accident Frequency Analysis

Based on systematic hazard identification exercises conducted for this and other studies the following events could initiate an incident with the potential to affect population:

- Collisions between vessels
- Groundings of vessels on the banks of the channel
- Impacts with berths and jetties
- Foundering (ie vessel capsizes)
- Fire and explosions onboard vessels

In addition the following events could initiate incidents at the AFRF:

- Loading arm ruptures

In addition the following events could initiate incidents at the AFRF:

- Loading arm ruptures
- Loading arm leaks
- Mooring failures
- Pipeline ruptures
- Aircraft crashes

The frequency of occurrence of each type of event was calculated on the basis of historical accident data and channel/AFRF conditions.

Event Outcome Analysis

Given one of the above initiating events actually occurring there are a number of other factors that determine whether a life threatening outcome will actually result or alternatively if a threat to the environment is posed. The 1993 Study used event outcome analysis to determine items such as the likelihood, rates and volumes of given spills and the probability of ignition. This in itself requires consideration of where and how a vessel might be damaged given its particular design and the physical characteristics of the dangerous cargo it is conveying. Several mathematical models were developed to predict the likely outcomes.

Consequence Analysis

The accident frequency and event outcome analyses determine how often and how much Dangerous Goods cargo is released. Consequence analysis seeks to model the impact of these releases on people.

A given release of Dangerous Goods might result in a number of different consequences depending on the factors discussed above. For example, aviation fuel might be released to form a pool on the sea surface, which if ignited gives rise to a pool fire. Persons exposed to high levels of thermal radiation from a pool fire will be affected. Alternatively aviation fuel may be vaporised due to an onboard fire and released due to rupture of tanks in the vessel. The consequence would be a fireball.

In each case the number of people affected is a function of their location, and degree of protection from blast over pressure or thermal radiation. The models used to predict the consequences of an incident incorporate advanced computer algorithms to accurately map the progression of a release and the distances to which life threatening hazards extend.

Risk Summation

Following hazard identification, accident frequency analysis and consequence analysis, a risk summation exercise was then performed to produce estimates of the Societal Risk for each marine transport option and background Dangerous Goods vessel movements in 2006 (assuming the proposals for these developments are approved by Government). The results are presented in the form of societal risk F–N curves.

A comparison of the levels of risk from the marine transport option was made against two sets of guidelines. The absolute levels of risk are compared to the most applicable criteria, both in the Hong Kong context and for marine shipping in general.

Specifically the guidelines used are:

- Risk Guidelines published by Hong Kong's *Coordinating Committee on Land-use planning and control in the vicinity of Potentially Hazardous Installations (CCPHI) (the HK RGs)* which are directly applicable to fixed land based installations, but are not strictly applicable to the assessment of risk from marine transport operations or the AFRF. See *Figure 6.2b.*
- Risk guidelines for assessment of the transportation of Dangerous Goods by marine vessels recently proposed, after 7 years study, but not yet adopted by the *UK Health and Safety Executive (HSE)* for use in the UK, although note, not Hong Kong. See *Figure 6.2c*

The risk analysis is used to indicate the levels of risk which background activities and the AFRF impose on surrounding populations and whether the level of risk would exceed risk guidelines in absolute terms.

The curves shown express the relationship between the frequency (F) of all identified hazardous events and the number (N) of fatalities to be expected amongst the population effected by the consequences of the hazards. These are known as F–N curves.

Frequency is expressed in terms of the likelihood of events per year. Hence at a frequency of 1.00 E–2/yr an event leading to N fatalities could be expected once in every 100 years, whilst a frequency of 1.00 E–9/yr corresponds to once in every billion years. It is generally accepted that any event occurring with a frequency of less than 1.00 E–9/yr is incredible, i.e. it is so unlikely that it may be ignored for the purposes of assessment. These events with a frequency greater than 1.00 E–9/yr are credible, i.e. whilst they are rare events they could credibly happen (with the shown frequency) at any time.

Both sets of guidelines used incorporate acceptable and unacceptable levels of risk bounded by an *ALARP* region, where risk should be mitigated to a level *As Low As Reasonably Practical (ALARP)*, i.e. all practical measures in respect of design and operation of an activity that can be taken *cost effectively* to reduce risks should be implemented. In respect of the AFRF options considered here, *ALARP* includes:

- design of facilities; and
- safety standards and operational practices

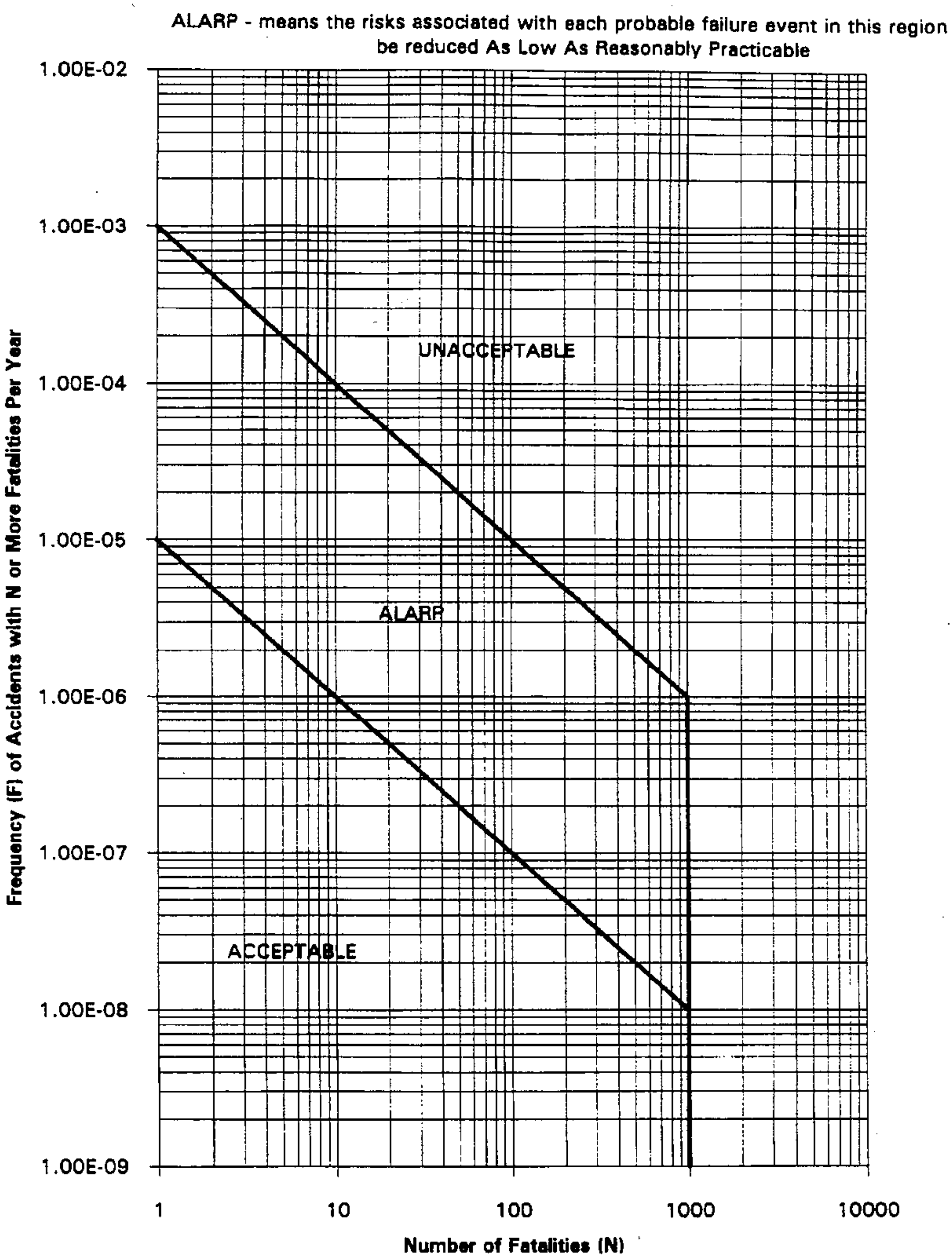

FIGURE 6.2b - HONG KONG GOVERNMENT SOCIATAL RISK GUIDELINES

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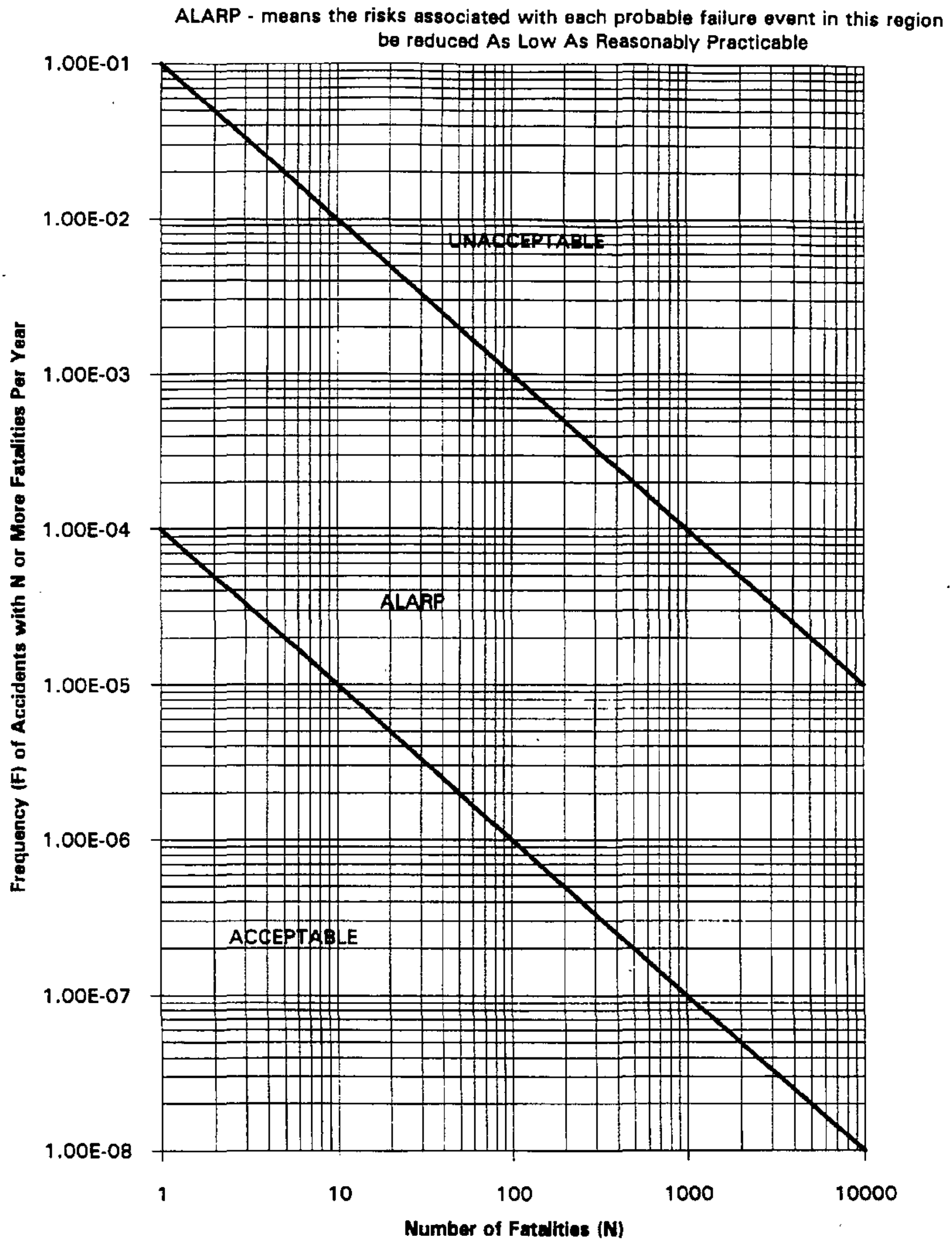

FIGURE 6.2c - UK HSE SOCIATAL RISK GUIDELINES FOR DG TRANSPORTATION

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to be used or considered in unloading operations and transport of fuel to and from storage facilities on and off airport.

The risk guidelines are not used as absolute criterion here as they are not applicable to the specific issue of marine transportation of Dangerous Goods in Hong Kong. The Consultants have supplemented the guidelines with the professional judgement of its staff as necessary.

6.2.7 *Results*

Figures 6.2d & 6.2e present the results compared to each set of guidelines. Three curves are shown:

- *Total background risk (1993 Study)* (from the 1993 Study), in the Ma Wan channel area only, anticipated in 2006 (the nearest planning year for population) if all proposed industrial developments west of Ma Wan proceed

- *Total 5000 te case 2040 (1993 Study)* (from the 1993 Study) - the risk from aviation fuel shipment, in the Ma Wan channel area only, in 5,000 dwt vessels for 2040 (the year used when permanent supply methods were being assessed) demand.

- *Total 5000 te Estimate 2004* - the estimated risk from aviation fuel shipment, in the Ma Wan channel and all points west to the AFRF, in 5,000 dwt vessels for 2004 demand (maximum AFRF demand).

Before discussing qualitatively the likely risk levels from the AFRF based on maximum foreseeable throughputs in 2004, a summary of relevant results from the 1993 Study, which assessed the ultimate airport fuel demand, is presented.

Background Risk (1993 Study)

The background risk curve on the figures shows the levels of risk expected in the Ma Wan area for estimated Hong Kong based DG traffic in 2006. These DGs comprise Liquified Petroleum Gas, Gasoline, Acrylonitrile and various aromatic hydrocarbons. Only a tiny fraction of these shipments are happening at present since the vast majority are for planned or proposed industrial sites in the Tuen Mun area. If these developments do not proceed then this risk will not be created. However the 1993 Study took no account of DG vessels destined for Chinese Pearl River ports since no data could be obtained. Marine Department estimates that up to 60% of the Chinese Ma Wan traffic in the relevant vessels sizes could be Dangerous Goods vessels. Hence it is likely that, regardless of whether the Hong Kong developments proceed or not, background levels of risk in 2006 will be significant.

From the figures it can be seen that the overall level of Societal Risk exceeds the HK RG for events associated with over 1,000 fatalities. The frequency of 1000 to 4000 fatalities exceeds the "incredible" frequency of 1×10^{-9}/yr by factors of between 1 and 354. If these guidelines were applied to this situation then the risks should be mitigated regardless of cost.

In comparison to the UK HSE guidelines the risk level lies within the ALARP region with the implication that risks should be mitigated on a cost effective basis if these criteria were applied.

Ultimate 2040 Demand (1993 Study)

The Societal Risk results for the 5,000 dwt tankers with ultimate (2040) airport fuel demand are shown on *Figures 6.2d & 6.2e* compared to the Government Risk Guidelines and UK HSE proposed criteria respectively.

Risks arising from vessels whilst at sea is mainly to stationary population onshore, particularly around the Ma Wan Channel. Risks to populations on road and rail bridges and routes are considered negligible. Risk to populations on ferries (including those from a prospective Ma Wan Island residential development) are significant in respect of the background risk in the Ma Wan Channel depending on the level of evasive action assumed.

The aviation fuel shipments amount to 25%, or one quarter, of the background risk and hence were considered significant. The most significant events leading to fatalities were estimated to be impacts with bridge piers or jetties, fire and explosion on board, collisions in the channel. Grounding incidents whilst significant, were much reduced due to the use of double hulled vessels (a grounding of a double hulled vessel is roughly three times less likely to result in leakage of fuel).

The total risks lie below the upper intolerable limit of the HK RG but within the ALARP region. In order to bring the risks to levels below the RG lower limit it would be necessary to reduce the volume of traffic by a factor of 38.5 for the year 2040, which leads to a reduction by a factor of 15.5 for the year 1997. Thus, if the HK RG were applicable, the 'acceptable' supply would be 17 days transported through the Ma Wan Channel in 1997. This hypothetical maximum capacity without exceeding the RG lower limit assumes that the balance of the fuel is transported by a means which has negligible risk associated with it, such as a pipeline or marine route through an area which is sparsely populated.

Comparison with the UK HSE guidelines shows that the risks just fall within the ALARP region, but that the exceedence is marginal.

The AFRF

The risks to life due to operations at the AFRF are negligible due to its separation distance from the shoreline population. Therfore *Figures 6.2d & 6.2e* show the Consultants' quantitative estimate of likely risks from the entire AFRF operation in 2004. This estimate is based on the assumptions detailed below.

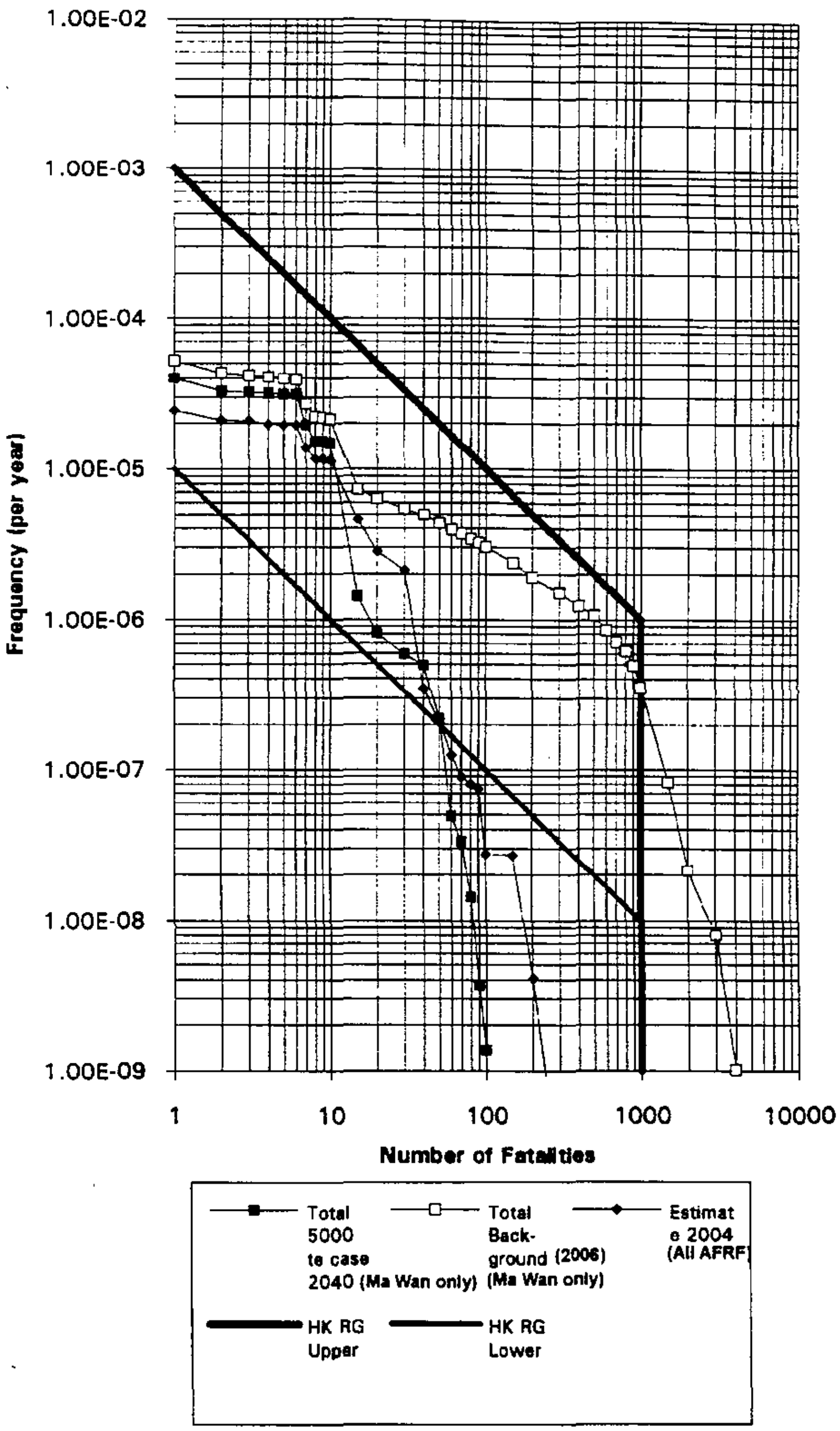

FIGURE 6.2d - COMPARISON SOCIATAL RISK FOR 5,000 TONNE CASE WITH HKRG

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Ma Wan Channel

The AFRF will only operate for 5 - 7 years, and hence the fuel demand is considerably less (2.9Mte in 1997 and 3.75Mte in 2004 as opposed to 7Mte in 2040). The levels of risk will decrease with the tonnage shipped and the lower general levels of shipping. The Consultants estimate levels would reduce by a factor of at least 3 to 3.5 - i.e to approximately 30% of the risks shown for 2040 in the 1993 Study. This equates to roughly 10% of background levels predicted in the channel in 2006 in the 1993 Study. However since the F-N curves shown are log-log plots the risks would still be within the ALARP region (even at current Kai Tak fuel demands) of the HK RG. Compared to the UK HSE Guidelines the risk in the channel area would fall in the 'acceptable' region.

Risk to Mainland North West of Ma Wan

The population in the section of the study area north west of Ma Wan is centred around Tuen Mun and is considered to be roughly 3 times as significant in terms of risk as that in the Ma Wan Channel, this takes account of the proximity of the residential accommodation, beaches, parks and ferries. However shipping hazards are less due to ease of navigation and the likelihood of a marine accident which will affect this population is roughly four times less than for the Ma Wan Channel.

The combined effect will, the Consultants estimate, be the addition of up to approximately 75% (i.e. a factor of 0.75) of the risk for the Ma Wan Channel.

Risk to North Lantau, South West of Ma Wan

Based on the 1993 Study, the risk to the population on North Lantau was limited to those around the jetties originally proposed near shore based populations at CLK and Sham Shui Kok. The waters north of Lantau are relatively shallow so that groundings and other hazardous events occur too far from the shore to affect the population. Thus the risk in this part of the Study Area is negligible.

Risk on Sha Chau

Since all of the population on Sha Chau are involved with the supply of aviation fuel to the CLK Airport, there is no risk to "offsite population" at Sha Chau.

Risk Due to 10,000 tonne vessels

The risks due to the single hulled 10,000 dwt vessels have not been quantified in the Ma Wan Channel and will need to be estimated in more detail in Licensee studies. However, since the maximum throughput will not exceed 10% and the relative number of movements will be fewer to transport the same quantity of fuel, the frequency of accidents will be lower.

Groundings will also occur slightly further away from the shoreline. Spill sizes, particularly for the largest cases, will be greater and thus consequences will be worse. More detailed assessment is necessary to identify whether the level of risk per tonne shipped will be lower. An appropriate conservative estimate is to assume the risks will be broadly similar to that from 5,000 dwt vessels and hence they will contribute an additional 10% to the 'at sea' risks in the worst case that they all use the Ma Wan Channel.

Total AFRF

Comparison of the estimated total AFRF risk with the guidelines show risk levels in the ALARP region of both sets of guidelines. Although in the case of the UK HSE the exceedence is marginal and detailed quantified assessment may show acceptable levels. The HK RG, if applied, would dictate that measures are sought to reduce levels in accordance with the ALARP Principle.

6.2.8 *Mitigation*

Background from the 1993 Study

The 1993 study considered three vessel sizes as potential permanent supply options; 1,000, 5,000 and 50,000 dwt tankers unloading at jetties close to populated areas. Prior to application of risk mitigation measures it is possible to cite the 1,000 dwt option as the least acceptable regardless of risk mitigation and as the option requiring the most mitigation. The "at sea" risks for this option were 3 times higher than for the 5,000 dwt and 50,000 dwt cases. The risks for the "at sea" part were to a large extent fixed, with no specific suitable mitigations identified. The disadvantages of this option were the large numbers of both vessel movements and unloading operations required even to transport the quantities of fuel specified for the year 2006.

Since this is the current means of transport to the existing airport at Kai Tak, it was thought in the 1993 Study it might not be practicable to cease use of this size of vessel immediately. The increasing volumes of aviation fuel required at the CLK Airport and the increasing maintenance costs of the existing aging fleet of barges will necessitate additions to the transportation fleet or some other means of transport.

The above 1993 Study recommendation did not preclude temporary usage of 1,000 dwt barges for a period of a few years whilst, say, a pipeline is constructed. This is because in the early years of airport operation fuel demand is lower and risks from other dangerous cargoes proposed will not have arisen since the facilities they serve will not have been constructed.

Note that the proposed AFRF uses dedicated 5,000 dwt tankers for the most part (and not 1,000 dwt barges) which would be coastal tankers of modern design meeting Marine Departments requirements *(Annex E)*.

The risks calculated for the marine transport options without the background risk, lie above the lower limit of the government Risk Guidelines and the UK HSE risk guidelines. Applied to either the background risk or the risks arising from marine transportation of aviation fuel this would indicate that the risks should be mitigated according to the ALARP principle (mitigate to a level *As Low As Reasonably Practical)*. The following relevant risk mitigation measures were identified:

- Optimisation of vessel size
- Improvements to vessel safety standards
- Containment and dispersion of spills
- Piping of aviation fuel
- Alternative aviation fuel supply from site options west of CLK

- For Government

  - Restrictions on the proposed Potentially Hazardous Installations in Tuen Mun Port
  - Improvements to the shipping channel and navigation aids
  - Population restrictions along the shipping routes

Aviation Fuel Supply

- *Containment and Dispersion*: The main scope for containment and dispersion of spills was close to or at the jetties. Assuming that suitably designed floating barriers could be provided it should be possible to put these in place before each unloading operation thus containing major spills to the sea surface in the immediate proximity of the leak, rather than allowing a large pool to develop with a correspondingly large hazard. The benefit of this type of measure lies not just in the risk reduction but in control of the impact of spills on the environment. Smaller spills are relatively frequent occurrences and will be easier to clean up if contained in the locality of the leak.

- *Vessel Size*: The 5,000 dwt transport method represented one option for improvements to vessel safety standards which has subsequently been adopted for the AFRF. The benefits of smaller vessel inventory and higher safety are, for this particular choice of size of vessel, outweighed by the frequency of vessel movements required to transport the volume of aviation fuel predicted for 2040. The 1993 Study concluded that it is likely that a vessel with modern high standards of safety of capacity of perhaps 10,000 to 20,000 dwt would offer a reduction in risk over the other marine transport methods considered.

- *Permanent Piping Option*: The piping of aviation fuel from an off-airport source to CLK was an alternative to marine transportation. It was considered that the risk associated with marine transportation would be eliminated and that the risks associated with a pipeline would be insignificant by comparison. Thus the construction and use of a pipeline would be driven by the cost benefit arising from elimination of the risk associated with the safest marine transportation method.

Of the above options only piping of aviation fuel would reduce risks to below the ALARP region and be considered acceptable in the context of the risk guidelines, unless it were shown that a pipeline was not *reasonably practical* and that all *reasonably practical* measures had been instituted for a marine transport option. The permanent pipeline option remains PAA's long term preferred option for the new airport.

Risk Mitigation & The AFRF

The following mitigation measures are implied from the 1993 Study and merit further consideration during detailed design:

- *Permanent Pipeline:* PAA are pursuing a permanent pipeline option in the long term and hence the AFRF should be seen in this context. The ALARP principle and mitigation measures considered in 1993 indicated a pipeline as the best option on hazard grounds. The AFRF is an interim measure to be implemented whilst practical and cost effective risk mitigation is pursued.

- *Vessel Size:* All dedicated vessels will be larger than 3,000 dwt and conform to Marine Departments conditions. In view of the findings of the 1993 Study it is possible to surmise that the 10% or so of throughput that might, in the worst case, pass through Ma Wan to the AFRF in 10,000 dwt tankers will not be significantly different from that from a similar quantity shipped by 5,000 dwt double hulled tankers. In can also be inferred that larger vessels (less than 10,000 dwt) with modern safety standards will give lower levels of risk that 5,000 dwt double hulled tankers assessed here. Hence, if it is practical and cost effective, larger dedicated double hulled tankers should be used.

- *Use of Non-Dedicated Vessels* (Craft of up to 10,000 dwt shipping avaition fuel direct to the AFRF from international waters and supplying up to 10% of AFRF demand) It will not be practical to control safety standards and vessel design of these vessels, nor will their crew be as familiar with HK waters and the AFRF approaches. Marine Department pilots should be on board to guide/advise these vessel's Masters.

- *Containment and Dispersion*: Use of floating barriers around unloading vessels as discussed above.

- *Other routes*: Use of other routes, e.g. from west of Sha Chau and Lantau will significantly reduce the risk of death, but may not be cost effective. The environmental risk however may well increase due to the greater environmental significance of South Lantau.

Certain emergency response implications are apparent, particularly for larger ignited spills near the AFRF which are likely to totally engulf the

AFRF, hampering evacuation of staff and use of emergency equipment. This matter should be addressed during detailed design.

6.2.9 *Discussion & Further Study*

Conclusions of the 1993 Study

Principal Findings

The 1993 Study considered quantitatively two fuel service system off airport site options, Tsing Yi and Sham Shui Kok, which could involve marine transport of aviation fuel through the Ma Wan Channel.

The principal findings of the 1993 study indicate that permanent marine transport methods (i.e. 1,000 te barges or 5,000 te coastal tankers from Tsing Yi and 50,000 dwt ocean going tankers going to Sham Shui Kok) exhibit levels of risk that are within an area where they should be mitigated to a level *As Low As Reasonably Practical.*

The need for risk mitigation in the Ma Wan Channel is demonstrated by the assessment of background risk levels expected in 2006. Any additions to the numbers of Dangerous Goods cargoes using the channel will only further increase risk levels that will already be high.

In respect of the 1,000 te barging transport method risk levels reported in the 1993 study were determined to be at a level where permanent use of this means is not recommended.

Risk Mitigation

Application of available practical and cost effective mitigation measures to the marine transport methods do not reduce risk levels to those termed acceptable by Hong Kong Risk Guidelines. After application of mitigation measures 5,000 te coastal tanker supply from Tsing Yi to CLK exhibits lower risk than supply in 50,000 te tankers to Sham Shui Kok, primarily due to the limited scope for reducing risk of aircraft crashes at the Sham Shui Kok jetty as compared to that at CLK.

The 1993 Study determined that technically feasible and cost effective alternatives (ie pipelines) to the permanent marine transportation of fuel through the Ma Wan Channel were preferable and should be pursued by the Authority. In this regard preliminary cost estimates demonstrated the pipeline option from Tsing Yi to be a cost effective alternative to permanent marine transport. Given the existence of this practicable alternative to permanent marine transport, it was concluded that permanent marine transport through the Ma Wan Channel is not ALARP and it is therefore not acceptable in the context of the Hong Kong Risk Guidelines. Only if alternative options were later found not to be feasible, was 1993 study recommended that permanent marine transport methods through the Ma Wan Channel be reconsidered.

However, the study also noted that temporary barging was not unacceptable while a permanent alternative transport method (ie pipeline) was developed. This finding was based on the fact that in the early years of airport operation, fuel demand would be low and risks from other potentially hazardous cargoes would not have arisen since the facilities they serve (e.g. those at Tuen Mun Port) will not have been constructed.

This Study

The principal findings of the 1993 Study indicate that permanent marine transport methods considered exhibit levels of risk that are within an area where they should be mitigated to a level *As Low As Reasonably Practical (ALARP)* favouring low risk transport methods such as pipelines or sparsely populated shipping routes.

The levels of risk from the transportation of aviation fuel through the Ma Wan Channel to the proposed AFRF at Sha Chau have been estimated. *Currently there are no risk guidelines or criteria for mobile sources in Hong Kong so the most appropriate local* and international guidelines have been used for benchmarking purposes. It is noted that transport risk guidelines may be proposed in the near future. However, the level of risk lies generally in the low to mid 'ALARP' region of the Hong Kong RGs for fixed land-based installations where it is appropriate to try to reduce risks to a level 'as low as reasonably practical'. The study has shown that, even at airport opening, the risk levels from the marine transport of aviation fuel to the AFRF to populations in the vicinity of the shipping routes are still of a magnitude where the available guidelines indicate practical means should be sought to further reduce risk levels.

Application of available practical and cost effective mitigation measures to the marine transport supply to the AFRF do not reduce risk levels to those termed acceptable by Hong Kong Risk Guidelines. The 5,000 dwt coastal tanker supply from Tsing Yi to CLK exhibits lowest levels of risk of options considered in the 1993 Study. If it is possible for a larger dedicated tanker of up to 10,000 dwt to be used direct to the AFRF then this is expected to exhibit the lowest marine transport risk level, but still well in excess of that from pipelines.

The PAA has proposed that on an interim basis that fuel will be provided to the new airport via dedicated fuel delivery vessels from Tsing Yi through the Ma Wan channel for a period not expected to exceed 5-7 years. During this time the Authority has stated its commitment to work with Government and the private sector to implement a permanent pipeline fuel supply system. The Authority's proposal was based on the findings of the PAA commissioned 1993 study on options for marine transport of aviation fuel through the Ma Wan Channel (The 1993 Study).

The question remains as to whether the AFRF and its five to seven year operation can be termed ALARP in accordance with the above discussion. To comply with the ALARP principle, it is necessary to show:

- It is not practicable to construct a pipeline by airport opening date; and
- The pipeline will be constructed as soon as is reasonable practicable (ASARP).

PAA inform that they, in consultation with government, have concluded that, based on Government policy as well as a combination of technical, programme, and commercial reasons a permanent pipeline cannot *now* be in place for airport opening. The programme for construction of a permanent pipeline has been supplied by PAA and is based on the assumption that the consultative and decision making process has been completed. The programme is as follows:

Activity	*Duration (Months)*
· Gazettal	9
· EIA	(9) – in parallel with Gazettal
· Licence	(9) – in parallel with Gazettal
· Design/Tender	12
· Construction of Pipeline	32
· Testing, Commissioning & Trials	6
Total time required	*59 (4.9 years)*

Even if a go-ahead were given immediately a pipeline could not in place until late 1999 or 2000. Given the above, it was concluded that an interim facility was required.

PAA have noted that the temporary AFRF will be in full time operation for approximately 5–7 years. This is based on projected Fuel demand and operator investment returns. However the PAA have stated their commitment to work closely with Government and commercial interests to ensure that the permanent facility is brought on–line as soon as reasonably practical (ASARP) after airport opening.

Compliance with the ALARP principle centres on the definition of 'reasonably practical'. It is acknowledged that this definition is usually expressed in terms of the technical feasibility and costs of a mitigation measure, in this case the permanent pipeline, versus its benefits on risk grounds. Since the reasons why a permanent pipeline might not be able to be constructed for up to 5 – 7 years after airport opening are a combination of technical and non–technical factors the AFRF is not strictly ALARP. However, if there are 'insurmountable' reasons for the 5 – 7 years timescale of AFRF operation, clearly the pipeline is not a practicable mitigation measure at the present time.

Other relevant points are as follows:

- The risk increases with tonnage transported through the Ma Wan Channel and the risks from use of 5,000 dwt vessels lie within the ALARP region of the HK RGs at 1997 demand levels.
- Any marine aviation fuel transportation should be by a modern design of tanker with high standards of safety as proposed for the around 5,000 dwt AFRF tankers. Use of double hulled tankers is recommended if practical, cost effective and meet Marine Department conditions.
- The risks to populations west of Ma Wan on the mainland along Urmston Road are expected to be of higher consequence on the one hand (due to greater populations at risk) but lower frequency on the other (due to greater ease of navigation than in the Ma Wan Channel). The net effect is, however, an increased contribution to the overall level of risk from AFRF operations.
- Some of the conceptual mitigation measures need further evaluation as recommended, and the possibility of reduction in risk to life may coincide with an increase in risk to the environment. For example if routes via South Lantau were used, instead of the Ma Wan Channel and Urmston Road, risks to life would be dramatically reduced but significantly greater risk would be posed to ecologically sensitive receivers in the event of a spill.

Further Study

Further detailed quantified study is required to both estimate risk levels more accurately and to evaluate the relative practicality and cost effectiveness of the mitigation measures proposed in accordance with the ALARP principle over the 5 - 7 year operational period of the AFRF. In particular these studies should concentrate on:

- Alternative routes;
- Optimum vessel size and design;
- Practicality of containment of spills;
- Emergency response;
- Quantify the risks from non-dedicated vessels; and
- Update of Dangerous Goods shipping destined for PRC ports.

Conclusion

The overall conclusion is that PAA have, in selecting a piped aviation fuel supply for the long term, adopted a low risk option for fuel supply to CLK that will give risk levels in the acceptable region of all guidelines considered. The AFRF is an interim solution to be operated whilst a permanent supply option is pursued. Since the reasons why a permanent pipeline might not be able to be constructed for up to 5 - 7 years after airport opening are a combination of technical and non-technical factors the

AFRF is not strictly ALARP. The risk levels are within an area where risks should be mitigated to a level as low as reasonably practical. These mitigation measures should concentrate on the AFRF operations given that there is no practical alternative in the interim term.

6.3 *ENVIRONMENTAL RISK*

6.3.1 *Background*

The IAR identified that both water quality and marine ecology could be affected by non-routine events associated with the AFRF. The risk of a significant spill due to AFRF operations is remote (about one chance in 750 per year of AFRF operation) and that for a major spill, rarer still, at about one chance in 5,000 per year. These risks should also be seen in the context of other liquid hydrocarbon vessels known to use the shipping channel to transport DGs to Pearl River ports. However the consequences of a major spill at or near the AFRF merit consideration due to number of ecologically sensitive receivers in the vicinity of the proposed AFRF.

Water Quality

Water quality could be directly affected by small as well as large aviation fuel spills at the AFRF as well as by the use of certain spill response technologies as described in *Section 6.3.5*. The IAR also identified that the EIA should also assess the scale, extent and possible severity of a spill, determining spill movement based on prevailing winds and water currents via detailed modelling. The IAR also identified that effects of major spillages from the AFRF or the pipeline will require consideration in the EIA to determine the possible short and long term impacts that would result.

Marine Ecology

The IAR also identified the possibility of aviation fuel contaminating the marine environment by accidental spillages or pipe leakage. The IAR concluded that at some stage prior to commissioning, modelling of the scale and extent of an accidental fuel spillages or pipe leakages would be required to appraise likely impacted sensitive receivers and identify appropriate mitigation measures and spill clean up capability.

Consideration in this conceptual design EIA was limited by the original scope to qualitative assessment, but following the concerns raised by the ACE EIA Sub-Committee in mid-September 1994, the Consultants were asked to provide some quantitative data to support recommendations.

6.3.2 *Objectives & Approach*

As reported in the IAR, when a spill of aviation fuel does not ignite it poses an environmental risk.

The objective of environmental risk assessment is to assess:

- the likely frequency of spills;
- likely extent of spreading and direction and extent of travel;
- risk of impact on sensitive coastlines; and in the light of the results
- advise on appropriate spill response capability.

Ultimately to determine the appropriate level of spill response capability, detailed modelling of all likely spill outcomes using dedicated oil spill modelling techniques is required. This takes several months and hence has not been fully completed in this study. However, by integrating risk to life spill spreading models with tidal models already configured for Hong Kong waters, the Consultants have been able to obtain limited quantitative data on the likely spill development scenarios. The data however should be only taken as indicative and subject to more detailed evaluation during detailed design.

The approach to the assessment of environmental risk from major aviation fuel spills has been to develop a range of spill scenarios, determine their likely frequency of occurrence and then to model the likely travel of each spill under different tidal conditions over its expected duration as a surface based environmental hazard. Resources have been focused on the scenarios which are most significant and on providing estimates of the largest credible significant spills which could occur, thus placing an upper limit on the scale of the clean up facilities required.

The assessment draws on, and includes, similar stages to a conventional risk to life hazard assessment i.e. hazard identification and frequency estimation; consequence analysis; and qualitative consideration of mitigation measures. This links in with the risk to life assessment (described above) and spill movement predictions given by WAHMO computer modelling.

The outputs of this assessment serve to provide an indication of the scale of potential impacts on the Hong Kong shoreline and the scale of the activities likely to be required to clean up spills.

Organisation of the Section

The remainder of this section is organised as follows:

- *Section 6.3.3* draws on the risk to life assessment to identify the means by which spills might happen, evaluates their frequency and identifies some representative spill scenarios for detailed modelling.

- *Section 6.3.4* looks at the consequences of fuel spills and the mechanisms by which they spread and decay.

- *Section 6.3.5* identifies the marine and coastal ecologically sensitive receivers within range of the likely spills and evaluates the potential impacts to them both directly from spills and potential clean up activities.

- *Section 6.3.6* details the approach taken to the oil spill modelling.

- *Section 6.3.7* summarises the results.

- *Section 6.3.8* looks at the range of available spill clean up technologies and evaluates the likely response planning capabilities required in the light of the modelling results from *Section 6.3.7* and the potential impacts evaluated in *Section 6.3.5*.

- *Section 6.3.9* summarises the environmental risk assessment and draws its conclusions.

6.3.3 *Hazards, Initiating Events & Accident Frequency Analysis*

Hazards

As discussed below in *Section 6.3.5* oils (aviation fuel or marine diesel oil) can be toxic to both marine and coastal ecology when released in quantity into the marine environment. Specifically, operation of the AFRF could result in small or large spills of aviation fuel being conveyed to the airport or from the marine diesel oil likely to be used to power the AFRF vessels.

Oil spills in the vicinity of the AFRF raises particular concern due to its location adjacent to an SSSI for avifauna, proximity to commercial fishing and spawning/breeding grounds and proximity of the AFRF and its shipping routes to coastal areas of high ecological value such as Deep Bay and the west coast of Lantau. Associated impacts are loss of recreational amenity value of shorelines and beaches.

Initiating Events

The initiating events for unignited aviation fuel spills from the AFRF are the same as those that can lead to life threatening pool fires described in *Section 6.2.6*.

For the purposes of this study we have concentrated on the more plausible events based both on frequency of occurrence and records of spills in Hong Kong, whilst still covering the likely range of incidents and the worst case. These are classified into scenarios as follows:

- *Scenario 1* Pipeline release at full pumping rate
- *Scenario 2* Loading arm leaks at the AFRF
- *Scenario 3* Loading arm rupture at the AFRF
- *Scenario 4* Collision/grounding at sea and instantaneous spillage of 20% of contents (1,000 dwt)
- *Scenario 5* Grounding on the coastline and rupture of two tanks at the bottom of the vessel
- *Scenario 6* Impact/collision/grounding at the AFRF and one tank ruptured below water level

Accident Frequency Analysis

The frequency of occurrence of each type of event was calculated on the basis of historical accident data and channel/jetty conditions and are derived from the IAR or 1993 Hazard Assessment. In assessing the environmental risks of an aviation fuel spill, of concern is the frequency of and size unignited releases which may pose an environmental hazard. *Table 6.3a* shows the estimated frequency and size of spills across the whole transport operation and *Table 6.3b* shows the frequency and size of unignited releases for each location specific Scenario.

The frequency of any major spill due to AFRF operation is estimated at 1.3E-3/yr or about one chance in 750 per year. This comprises an 'at sea' element of 7.92E-4/yr, equivalent to one chance in about 1,250 per year, and an at AFRF element of 5.17E-3/yr (one chance in 1,930 per year). This can be further broken down by spill size:

- *Small (less than 50 te):* roughly a once in 1,000 years chance
- *Medium (between 50 and 150 te) & Large (greater than 150te):* both roughly a one chance in 5,000 per year event

Historical data (Wu and Tupper 1989) shows that between 1968 and 1988 a total of 13 major shipping/pipeline oil spills occurred in Hong Kong - 9 groundings, one collision, 2 founderings and 1 pipeline releases - ranging in size between 60 dwt and 2,000 dwt. Two of these involved aviation fuel. On this basis it might be assumed that in the operational life of the AFRF a total of five major releases might be expected anywhere in Hong Kong. Thus, whilst it is considered that the frequency of occurrence of aviation fuel spills is low, a spill still might occur. Spill clean-up will need to be handled in accordance with a spill contingency plan to be developed by the operator (*Section 6.3.8).*

Table 6.3a *Spill Incident Frequencies*

Initiating Event	Outcome	Frequency (per year)	Mass Released (tonnes)
'At Sea'			
Collision	One tank holed above waterline	3.83E–5	42
	One tank holed below waterline	3.83E–5	149
Foundering	Ship sinks, 1 tank leaks	1.95E–5	25
	Ship sinks, 2 tanks leak	4.51E–5	51
	Ship sinks, instantaneous loss of 1 tank contents	1.31E–4	1,000
Grounding	1 tank holed at bottom	3.49E–4	25
	2 tanks holed at bottom	8.72E–5	51
	Severe damage, ship breaks up, 1 tank contents lost instantaneously	7.45E–5	1,000
Impact	Bridge pier in Ma Wan, 1 tank holed above water line	2.65E–6	81
	Bridge pier in Ma Wan, 1 tank holed below water line	2.65E–6	149
	AFRF, 1 tank holed above waterline	2.15E–6	81
	AFRF, 1 tank holed below waterline	2.15E–6	149
Total – at sea		7.92E–6	
AFRF			

Table 6.3c *Marine Spreading of Aviation Fuel Spills*

Scenario	Released Mass (tonnes)	Spill Volume (m^3)	Thickness after 1 hour (cm)	Radius after 1 hour (m)	Ultimate Extent at 0.05mm thickness (m)
1. Sha Chau (Pipeline)	230 kg/s for 180 seconds	51	0.024	220	570
2. AFRF (leak)	92 kg/s for 180 seconds	20	0.013	180	360
3. AFRF (rupture)	230 kg/s for 180 seconds	51	0.024	220	570
4. Marine grounding at Brothers 20% released	1000 tonnes instantaneously	1250	0.144	490	2820
5. Marine at Tuen Mun two tanks holed at bottom	50 tonnes	64	0.027	235	640
6. Marine at Sha Chau one tank holed below waterline	150 tonnes	186	0.050	310	1090

Table 6.3b   Frequencies of Unignited Releases

Scenario	Total Failure Frequency (per year)	Ignition Probability (per year)	Frequency of Ignited Releases (per year)	Frequency of Unignited Releases (per year)	Once every (X years)
1. Sha Chau (Pipeline)	4.36×10^{-5}	0.05	2.18×10^{-6}	4.14×10^{-5}	24,000
2. AFRF (leak)	5.00×10^{-4}	0.05	2.50×10^{-5}	4.75×10^{-4}	2,100
3. AFRF (rupture)	7.60×10^{-7}	0.05	3.80×10^{-8}	7.22×10^{-7}	1,385,000
4. Marine grounding at Brothers 20% released	8.84×10^{-6}	0.05	4.42×10^{-7}	8.4×10^{-6}	119,000
5. Marine at Tuen Mun two tanks holed at bottom	2.87×10^{-5}	0.05	1.44×10^{-6}	2.73×10^{-5}	37,000
6. Marine at Sha Chau one tank holed below waterline	8.22×10^{-5}	0.05	4.11×10^{-6}	7.81×10^{-5}	12,800

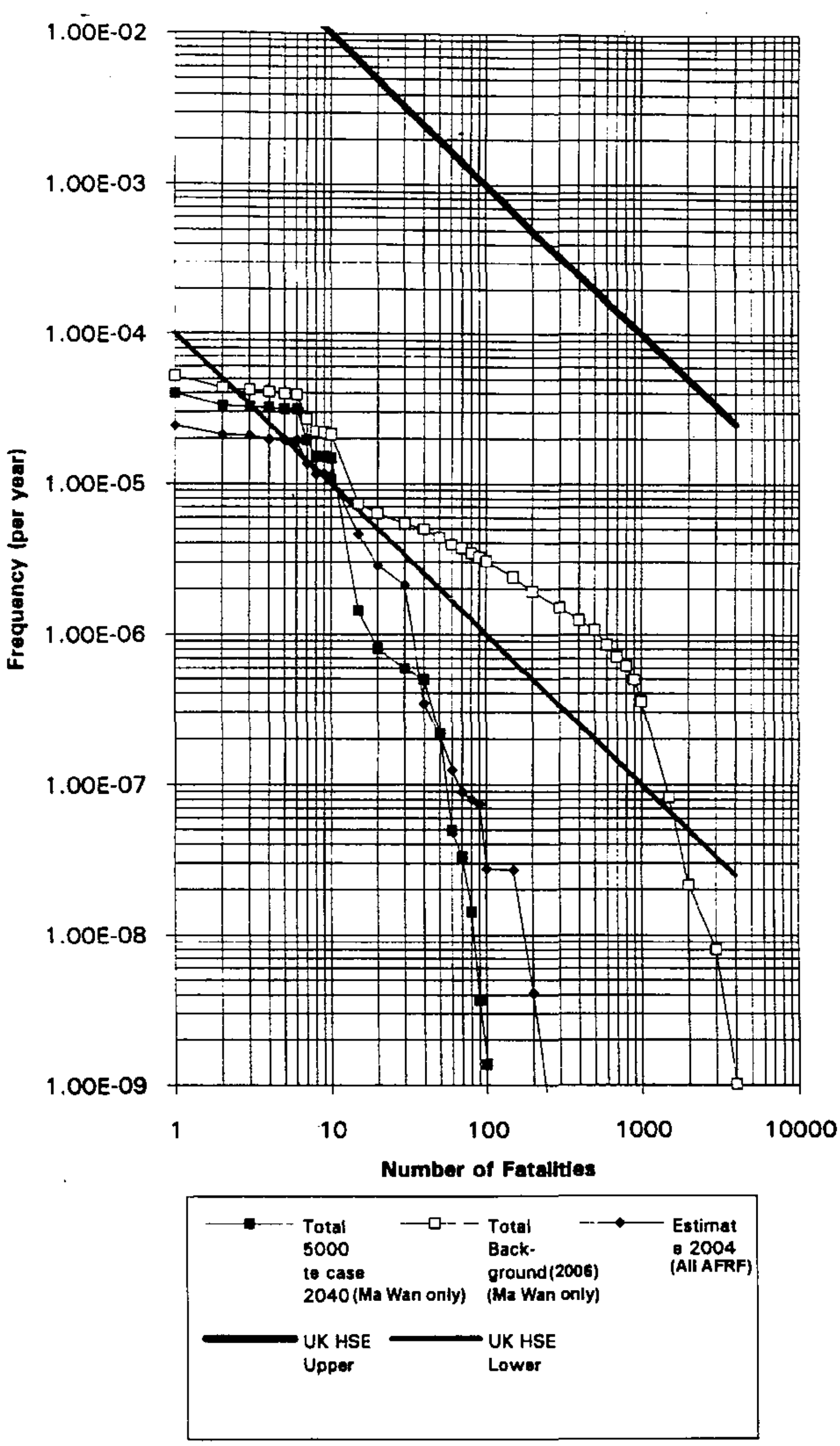

FIGURE 6.2e - COMPARISON SOCIATAL RISK FOR 5,000 TONNE CASE WITH UK HSE RG

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6.3.4 *Consequences of Fuel Spills*

Background

When fuel is released into the marine environment it is immediately subjected to a variety of weathering processes of various significance including:

- spreading and drift
- evaporation
- dissolution and advection
- dispersion of droplets into the water column
- photochemical oxidation
- water in oil emulsification
- microbial degradation
- adsorption onto suspended particulate material
- ingestion by organisms
- sinking and sedimentation

The composition of the aviation fuel (or marine diesel oil) and release location and time from release, greatly influence the significance of each of the above processes. Accurately modelling all of these processes cannot be achieved. In this study an approximate measure has been made of the most important mechanisms in respect of aviation fuel such that the spill modelling is as realistic as possible.

Below a brief account is given of the important parameters and how these have been used to describe the input parameters for the fuel spill model.

Spreading and Drifting

The principle process that determines the behaviour of a fuel spill in the first hours after a release into the marine environment is spreading and drifting. Spreading of the fuel under gravity is greatly influenced by the volume of fuel spilled during the initial spreading period. Thus large spills spread much faster than small ones initially. The principal forces influencing the lateral spread are gravitational, inertial, frictional and those due to surface tension. Eventually the influence of surface tension becomes greater than gravity and the spill spreading becomes slower and largely independent of spill volume. However the inner portion of the spill may be thicker than at the edges. In calm water these processes lead to a continuous decrease in the oil slick thickness in a circular pattern, which finally reaches a minimum value between 0.1 and 0.01 mm. A value of 0.05mm was assumed as the minimum likely spill thickness before wave/wind action breaks up the spill.

As the surface area of the spill increases mass transfer via evaporation and dissolution is greatly enhanced and other mechanisms such as emulsification start to effect spill size and spreading.

In this study the Consultants have used a spill spreading model taken from the 1993 Hazard Assessment to estimate the calm water size of spill at various times after release. This model effectively balances the gravitational and surface tension forces with time but does not account for processes such as emulsification which reduces the rate of spreading and is enhanced by wave and tidal action. These results were then approximately correlated with the spreading and drifting characteristics of the tidal model (*Section 6.3b)* so that an appropriate interface between the two models could be selected. Values used in the model were those after 1 hour.

Table 6.3b shows the predicted spreading distances from pipeline, marine and facility releases, assuming instantaneous spillage.

Decay Rates

Decay of an oil spill will happen relatively rapidly due to a number of natural phenomena, regardless of spill response. These dominant mechanisms include:

- Dissolution
- Evaporation
- Emulsification
- Adsorption.

Evaporation of some oils is rapid – 60% of crude oils can be lost within 24 hours – but that for aviation fuel will be lower since it does not contain the lower chain hydrocarbon species. Jet fuel (JP-8) typically comprises C-13 hydrocarbon chains. Those below C-8 will not persist in a slick for very long whereas those of C-18 will not evaporate appreciably in normal conditions. Nevertheless significant quantities will evaporate. Marine diesel oil contains higher (C-16) chain hydrocarbons and hence will not evaporate as fast.

Dissolution will be relatively insignificant in terms of volume of the spill although up to 1% may dissolve over the lifetime of the spill. However, the environmental consequence may be more important than this figure suggests.

Dispersion/agglomeration of oil droplets is one of the major processes in break up and disappearance of a surface slick. The sea turbulence has a direct impact on droplet dispersion. Depending on the sea state between 5 to 60% of crude oils disappear in this manner. As aviation fuel is less dense than crude, the process will not be as dramatic, yet if high levels of suspended particulate matter are present in the water column agglomeration will be a major source of dispersion. At concentrations greater than 100mg/l massive oil transport may occur with the potential for significant impacts on benthos. Thus the adsorption of dispersed oil onto suspended particulates could provide an efficient mechanism for sedimenting fractions of oil mass (up to 15%). However, as detailed later, agglomeration and subsequent sedimentation are not likely to be major processes in the North Western Waters due to low average suspended solids (20 mg/l).

Emulsification involves the dispersion of water droplets into the fuel medium. As the percentage of water increases (up to 75–80%) the resulting emulsion increases in density to near that of the surrounding water and contributes to significant loss for the spill area. These emulsions however can make spill clean up difficult due to the increase in volume and formation of 'chocolate mousse' by some oils such as marine diesel oil.

Based on the above factors and data derived from the literature it is likely that any credible spill would effectively disappear within 3 days of the spillage. On conservative grounds a linear decay rate of 4 days to disappearance was assumed for the spill modelling.

6.3.5 *Sensitive Receivers and Potential Ecological Impact*

Water Quality

Water quality deterioration may result from accidental aviation fuel spillage, including in particular effects on dissolved oxygen concentrations in the water column. These have been assessed to determine the extent of the water quality impacts that may occur. In addition, the potential impacts of chemical spill response technologies upon water quality have been assessed in this section. These will require further assessment during the detailed design stage when the details of the appropriate spill response technologies are available.

Marine Ecology

Of concern is the possibility of aviation fuel spillage causing detrimental impacts upon marine ecology. Any of the scenarios defined in *Section 6.3.3* would result in the release of aviation fuel into the marine environment with the potential to contaminate or kill marine organisms and indirectly impact upon others, both within the Study Area and further afield in areas which may be impacted by `worst case' fuel spills. This section examines the potential impacts on ecologically sensitive receivers.

Sensitive Receivers

Marine ecological sensitive receivers have been identified within Hong Kong boundaries (*Figure 6.3a*) as follows:

- Benthic organisms as follows, including Chinese King Crab, commercially important penaeid shrimps, and invertebrates such as snails including *Turitella terebra*, stone corals and sea pens;
- Pelagic communities throughout the Territorial waters including major commercial fish species;
- Chinese White Dolphin (*Sousa chinesis*);
- Mariculture Zones such as Ma Wan fish culture zone;

Coastal ecological sensitive receivers have been identified as follows:

- Ecologically sensitive coastline habitats of Mai Po mangrove and wetland communities;

- Lantau coastline which includes the proposed SSSI site where sea grass (*Zostera nana*) is found near San Tau;

- Avifauna, such as Cormorants (*Phalacarocorax carbo*) on the islands of Lung Kwu Chau, Tree Island, and Sha Chau; and

- Breeding Sites of Romer's Tree Frog.

There are also areas of recreational, amenity and tourism value within the range of potential spills such as the salt pits as Tai O and numerous beaches and country park coastlines in the area.

Potential Impacts

Water Quality Impacts

As detailed above, any aviation fuel spills will float on the water surface where they will rapidly disperse, and a small quantity (1% of spill volume) will dissolve into the water column. In addition, aviation fuel will fragment, adhere to suspended solids and sink beneath the water surface as agglomerate particles which may settle on the seabed. Hence, there are several processes involved which have the potential to impact upon water quality as follows:

- dissolution
- dispersion/emulsification
- sinking and sedimentation

Dissolution: In the event of a spill, lower molecular weight aromatics such as benzene, which are present within virtually all petroleum products, partition into the water column. Elevated levels (greater than 100 micrograms/l) of benzene can then be measured directly beneath the water surface [1]. It has been found that lower molecular weight aromatic (including toluene, ethylbenzene, P–xylene, and N–propylbenzene) concentrations peak approximately 8 to 12 hours after the initial release of oil to the water column, in the 10 to 100 parts per billion (ppb) range. The concentration then drops off in an exponential manner due to evaporation and the removal of dissolved compounds by advection (water mass transport).

Dispersion/Emulsification: Oil droplets form as a spill fragments and disappears from the water surface, due to wave action and spontaneous emulsification in calm seas. The thinner the slick the more frequently wave

(1) JW Doerffer '*Oil Spill Response in the Marine Environment*', Ship Research Institute, Technical University of Gdansk, Poland.

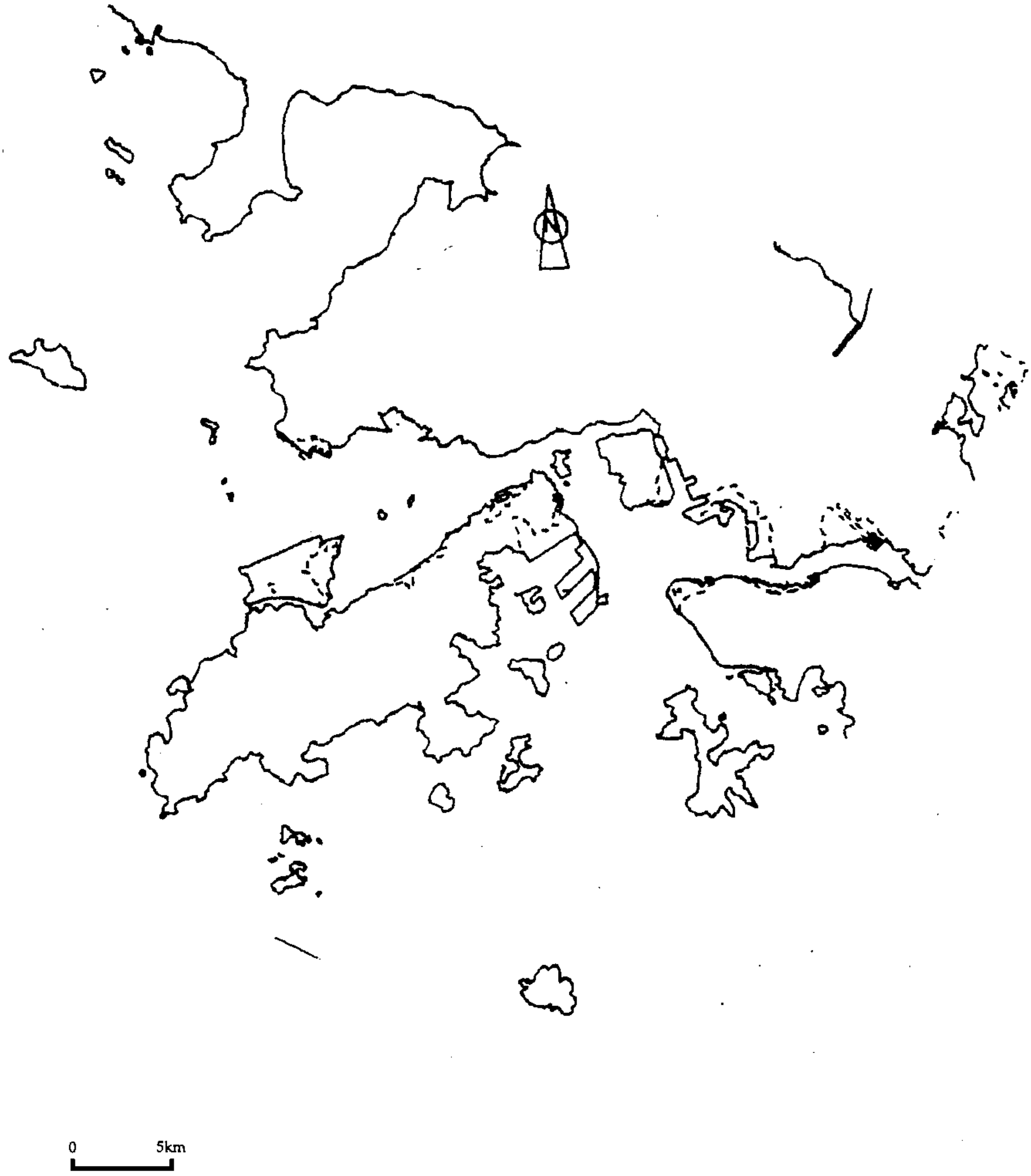

FIGURE 6.3b - EXTENT OF TIDAL FLOW MODEL

ERM Hong Kong

10-11th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

ERM

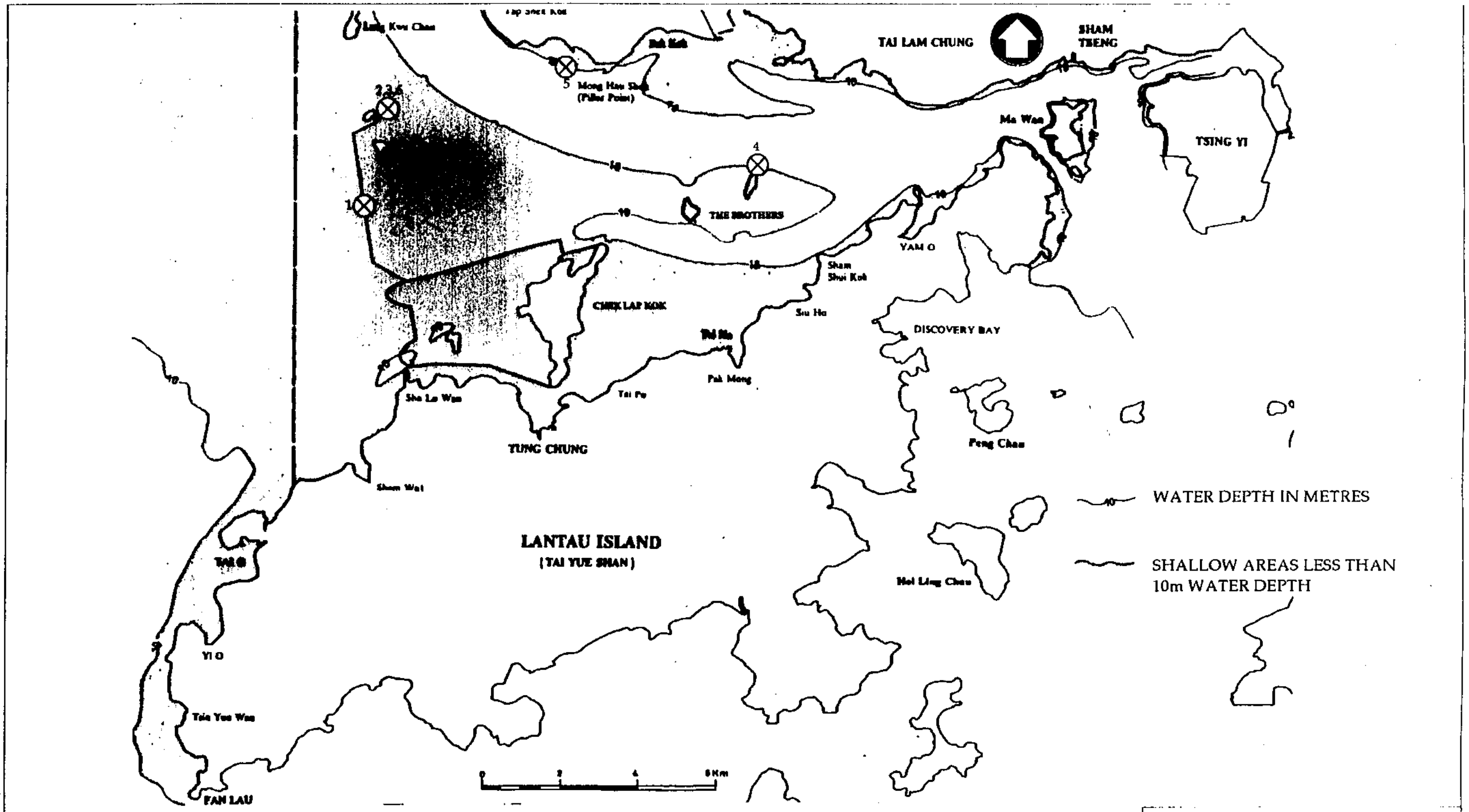

FIGURE 6.3c - LOCATIONS FOR FUEL SPILL SCENARIOS

ERM Hong Kong

10-11th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

ERM

breaking occurs, thus dispersion would be a dominant process during an aviation fuel spill. In addition, as detailed in *Section 6.3.4*, it is thought that emulsification may be a major source of dispersion as the aviation fuel adheres to any suspended solids present within the water column, although this will be dependent upon suspended solid levels present.

Dispersion leads to increased dissolution of the lower molecular weight aromatics, and provides materials which may be ingested by organism and ultimately deposited in sediments in the form of faecal pellets. The dispersion of oil droplets within the water column occurs for 2 to 3 days. These droplets will return to the surface unless adsorbed onto suspended solids, or be used as a substrate for growth by some marine organisms.

Sinking and Sedimentation: Aviation fuel is a low density hydrocarbon and therefore sinking and sedimentation are not considered to be major factors during the decay of an aviation spill, unless high levels of suspended solids are present in the water which the fuel can adhere to. As stated above, it has been found that at concentrations of suspended solids greater than 100 mg/l there is the potential for significant impacts upon the marine benthos, as fuel adheres to suspended solids, sinking and settling upon the seabed. As aviation fuel settles upon the seabed, biodegradation of hydrocarbons will take place as microorganisms within seawater use the fuel as a food substrate. This process could lead to reduced oxygen levels within the water column and associated impacts upon marine ecology, depending upon the type of organism degrading the hydrocarbon. In addition the chemical oxygen demand (COD) of aviation fuel is high (over 1000 mg/l), and therefore any aviation fuel spills may lead to depletion of oxygen levels in the water column.

Aviation Fuel and Marine Diesel Oil Impacts

As discussed above, contamination of the marine environment by accidental spillages or leakage of aviation fuel or marine diesel can result in both direct and indirect effects upon marine organisms and biota which rely on the marine environment. These result from the nature of dispersal of oil. Any aviation fuel spills will float on the water surface where they will be rapidly dispersed by wave action, evaporation and natural biodegradation. A small quantity (1% of spill volume) will dissolve and may cause localised damage to the marine environment in the area of the spill. In addition aviation fuel will fragment and sink beneath the water surface where it becomes agglomerate particles. Aviation fuel is inherently biodegradable and the data presented indicate that spills on water surfaces will biodegrade, emulsify or evaporate within a period of approximately 3 - 4 days. Marine diesel oil is a heavier less volatile hydrocarbon and hence will persist for longer periods. However, the maximum size of such spills are smaller than aviation fuel. Direct impacts resulting from release of fuel into the marine environment include:

- soluble components in the fuel affecting organisms under the water surface. Toxic effects on shellfish and fish result as poly-aromatic hydrocarbons (PAH's) are carcinogenic and acutely toxic to marine organisms at concentrations between 0.2–10 ppm; and at reduced concentrations of 0.005–0.1 ppm fish develop cell abnormalities and tumours. However, risks of the spills occurring presented earlier in *Table 6.3a*, indicate that the risks of a major spill are low;

- agglomeration of hydrocarbon material, which then sinks to the seabed, may cause smothering of benthos gill filaments, and inhibit movement of smaller organisms;
- external impacts due to animals coming into contact and becoming coated with aviation fuel; and
- internal effects on seabirds and marine mammals associated with the pathological effects of ingested oil.

Indirect impacts upon ecological sensitive receivers include:

- oxygen stress and suffocation resulting from interference in oxygen transfer through the water surface; and
- reduction or loss of food sources at all levels of the ecological community. Reduced penetration of sunlight through the water column will result in less primary productivity, which will then result in reduced food supplies throughout the community food webs.

Impacts from Use of Dispersants

The use of dispersants in spill clean up has also been found to cause potential impacts upon water quality, and marine and coastline ecology. Dispersants have been used to break up spills at sea and loosen oil on shore so that it can be removed more easily by cleaning devices or by wave action. However, this practice was discouraged after the *Torrey Canyon* oil spill in 1967 on the southwest coast of Cornwall, England, as it caused more damage to coastal ecosystems than did the oil itself (Nelson-Smith 1968; Southward and Southward 1978). Less toxic dispersants for shoreline cleaning are now being tested, but even with the use of less toxic dispersants the advantages are questionable. Studies on rocky shores and intertidal mud flats reveal little difference in impact between raw crude oil and crude oil that was treated with a dispersant after stranding (Little *et al* 1981; Rowland *et al* 1981; Crothers 1983). Treatment of the oil with a dispersant will generally aggravate the effects caused by high dissolved oil concentration in the water as a direct result of the dispersion, including those impacts upon water, as detailed above.

A variety of aquatic organisms readily accumulate (Kikuchi *et al* 1980) and metabolize (Payne 1982) surfactants from oil dispersants. Enzymatic hydrolysis of the surfactant yields hydrophillic and hydrophobic components. The former are probably excreted via the gills and kidneys, whereas the latter accumulate in the gall bladders of fish and are excreted very slowly. Metabolism of surfactants is rapid enough that there is little likelihood of food chain transfer from marine invertebrates and fish to marine mammals (Neff 1990).

Alternative combat methods, such as mechanical methods are therefore preferable for dispersal of any aviation fuel spills (see *Section 6.3.7*).

Impacts upon Sea based sensitive receivers

Recovery of the water column is generally very rapid and the oil effects in nearshore systems are local and transitory, with full recovery in a few weeks. However, within this period severe impacts can occur on sensitive receivers.

Fisheries Resources

Within the Hong Kong waters, and particularly off the south west coast of Lantau, there are many species of fish and prawn species of economic importance. Oil or fuel spills do not generally result in high kills in fish species. This may be due to the mobility of fish, and their ability to swim from an affected area and subsequently return once pollutants have dispersed. However they may acquire an objectionable, oily odour or flavour, thus loosing their market value and in extreme cases being inedible.

Marine fish do take up petroleum hydrocarbons from water and food. However marine fish metabolize assimilated hydrocarbons, and excrete them fairly quickly within a few days after exposure (Stegeman 1981). For this reason, most fish do not accumulate and retain high concentrations of petroleum hydrocarbons, even in heavily oil-contaminated environments, and so are not likely to transfer them to predators. Fish may nevertheless be tainted with metabolites bound to tissue macromolecules, including DNA. The metabolites are so reactive it is unlikely that they would be released in a toxic form during digestion by the consumer and so would not pose a serious threat. However they may acquire an objectionable, oily odour or flavour, thus loosing their market value and in extreme cases being inedible.

Sea Birds

Sea birds may be effected by a spill due to external effects associated with oiling of plumage, and internal effects associated with the pathological effects of ingesting aviation fuel. The fuel would destroy the waterproofing and insulating properties, which are particularly important for diving birds such as Cormorants. In addition, the birds will suffer from chilling and are often unable to fly or remain afloat in the water. However it is thought that aerial foraging birds, which also experience hypothermia in water when oiled, may still be capable of foraging by restricting the time spent in water. Irritation or ulceration of the eyes and clogging of the body openings and mouth often accompanies oil contamination.

In addition to the decreasing mobility and foraging abilities of birds, the presence of oil will result in the decrease in potential prey numbers.

Chinese White Dolphins

As discussed in *Section 4.4,* the waters in the North Lantau, Sha Chau and Lung Kwu Chau areas are habituated by *Sousa*. One concern arising from the AFRF operation will be the potential for aviation fuel to contaminate the marine environment and thus result in adverse impacts on *Sousa*.

Geraci and Aubin (1990) indicated that oil spills at sea might pose the following risk to dolphins:

- fresh crude oil or volatile distillates release toxic vapours that can damage sensitive tissues; and
- harmful fractions may be swallowed or consumed through contaminated prey.

Little is known about the effects of exposure to oil on marine mammals. Studies by Williams *et al.* (1990) indicated that sea otters *Enhydra lutris* exposed to the *Exxon Valdez* oil spill in 1989 experienced high incidences of emphysema, petroleum hydrocarbon toxicosis, abortion and stillbirths. Less is known about the potential impacts of oil exposure on dolphins and other cetaceans.

Ingestion of Oil Compounds by Dolphins

Marine mammals, except the manatee, are carnivores that rely on invertebrates of fish for sustenance. Their feeding strategies could lead to ingestion of oil-contaminated food as most of the prey organisms can accumulate petroleum hydrocarbons in their tissues (Neff 1979; Capuzzo, 1987). However, marine carnivores are generally inefficient assimilators of petroleum compounds in food. For this reason and because all prey species are able to release hydrocarbons from their tissues (Neff and Anderson 1981), marine food chain biomagnification does not occur. Thus, there is no direct correlation between a marine mammal's trophic level and the concentration of residues that it might consume.

The risk on *Sousa* depends on the prey species. Planktonic crustaceans engulf oil droplets during a spill and retain unmetabolized and metabolized petroleum for a week or ten days thereafter. Thus, these organisms are a potential source of contamination to consumers for only a short time after a spill. As discussed above, bioconcentration through plankton and fish is therefore highly unlikely. Molluscs, however, pose a lingering threat to benthic feeders.

Irrespective of how they take in these compounds, marine mammals appear to have the liver enzymes required to metabolize and excrete them. This ability limits the accumulation of residues in body tissues and minimizes the probability of residual harm following a spill.

Accumulation of Aviation Fuel from Water Column by Dolphins

Accumulation of aviation fuel directly from solution or dispersion in the water column is not likely to be a major concern, as marine mammals probably will not accumulate much oil directly from solution or dispersion throughout the water column. The skin of cetaceans seems relatively impermeable to oil (Geraci and St. Aubin, 1982). Unlike furbearers, cetacean epidermis is nearly impenetrable, even to the highly volatile compounds in oil, and when skin is breached, exposure to these fractions does not impede the progress of healing. Most marine mammals do not drink large volumes of seawater, so significant accumulation of hydrocarbons by this route is unlikely (Neff 1979).

Marine mammals encountering fresh oil are likely to inhale volatile hydrocarbons evaporating from the surface slick. Such fractions contain toxic monoaromatic hydrocarbons (benzenes, toluenes, xylenes) and low molecular weight aliphatics with anesthetic properties. Inhalation of these compounds is potentially dangerous (Carpenter *et al* 1975, 1976).

Inhalation of concentrated petroleum vapours may cause inflammation of mucous membranes, lung congestion, or even pneumonia (Hansen 1985). Volatile hydrocarbons, such as benzene and toluene, that are inhaled are transferred rapidly into the bloodstream from the lungs. They may accumulate from the blood in such tissues as brain and liver, causing neurological disorders and liver damage (Geraci and St. Aubin 1982).

However, aviation fuel is not highly volatile and therefore inhalation of vapours is not likely to be an prominent effect associated with any aviation fuel spill.

Avoidance of Oil by Dolphins

Experimental evidence shows that dolphins can see oil at the surface and that they prefer to avoid the oil. Therefore, Geraci and Aubin (1990) concluded that it was quite improbable that a species or population of cetaceans would be disabled by a spill at sea. In addition, the frequency of occurrence of potential aviation fuel spills from the receiving facility is considered to be very low, as discussed in *Section 6.3.3*.

However in the wild, whales and dolphins have been observed swimming and feeding in the presence of oil spills without apparent ill effect. It has been suggested that in these instances the stimulus was not noxious enough, or perhaps cetaceans disregard oil when they are engaged in more engrossing or important activities.

Recent studies contradict these previous findings, having demonstrated that bottlenose dolphins *(Tursiops truncatus)* in captivity detect and avoid even very light surface layers of oil (Smith *et al* 1983). It was therefore believed that dolphins would rapidly swim away from a spreading oil sheen and thus minimise contact with the highly volatile toxic gases produced at the surface of fresh oil. Thus Geraci and Aubin (1990) concluded that it was quite improbable that a species or population of cetaceans would be disabled by a spill at sea.

However observations of the behaviour of bottlenose dolphins in two oil spills in Texas waters, the *Mega Borg* and *Apex* spills, showed dolphins can detect oil but generally do not avoid it, except for heavy weathered mousse (Smultea, Wursig and Henningsen unpubl; Smultea and Wursig 1991). Dolphins were observed from an aircraft and a small surface vessel, and descriptions given on orientations, inter-individual spacings, respirations, and general movement patterns in oil-free waters, light sheen oil, heavier slick oil and the globular non-toxic weathered mousse.

High rates of reorientations were observed, or changes in direction per time, at interfaces between oil types. This indicated that the dolphins could detect oil and were reacting to its presence. By far the highest reorientations occurred between slick/mousse interfaces and resulted in dolphins moving around or under, not through, patches of thick weathered oil. Very few reorientations occurred at clear/sheen oil interfaces, indicating that thin layers of fresh volatile oil were not as detectable or not cause for concern by the dolphins.

Dolphins inter-individual spacings were greatest in oil-free areas (mean = 2.6 body lengths between nearest neighbours); reduced to 0.8-1.7 body lengths in sheen areas; and reduced further to 0.4-0.6 body lengths in slick and sheen/sick interfaces. These observations suggest that bottlenosed dolphins may respond to certain detectable stimuli by decreasing inter-animal spacing. (This may indicate a "worry factor" which is known to create huddling behaviour by many social animals when confronted with disturbing stimuli).

Respirations, calculated as blows per minute, decreased between clear and sheen oil and showed a rise after dolphins which had been in slick for over 17 minutes returned to sheen oil. These data indicate that dolphins stay below the surface longer and thereby decrease blow rates when in slick rather than sheen oil.

It was reported in the results of these studies were that dolphins did not avoid clear/sheen oil interfaces and were just as likely to travel into as out of oil interfaces. This undetectability or indifference to volatile surface oil was stated to probably increase dolphins vulnerability from potentially harmful exposure to oil chemicals. However it is not known what effect this exposure to considerable amounts of toxic vapours had on their health, longevity, and reproductive potential.

Impacts upon Coastal Communities

As shown on *Figure 6.3a* the two major coastal communities in respect of ecological significance are Deep Bay and the west coast of Lantau. Deep Bay is an area of particular environmental value and sensitivity. The most important environmental resource is the mudflat/mangrove/Gei Wai habitat in Inner Deep Bay and the internationally significant bird population it supports. Deep Bay contains a number of different habitats, the two most extensive being intertidal mudflats and mangrove communities. The west coast of Lantau is the location of ecologically sensitive receivers such as the proposed SSSI site where sea grass (*Zostera nana*) is found near San Tau, several beaches located along the Lantau coastline, and areas of mangrove as indicated on *Figure 6.3a*.

Mangrove Communities

Mangrove communities consist of a variety of species of trees, and sometimes herbs and ferns which can survive and flourish in an environment of seawater mixed with an estuarine fresh water input, hence the location of mangroves in the Hong Kong area, particularly Deep Bay. The associated root systems serve as a firm substrate that support a number of plants and animals, and the prop roots of mangrove communities serve as a breeding ground for many marine species and as shelter for a diverse group of others, including economically important species of fish, molluscs and crustaceans. There are a large number of juvenile fish and fry present in the Bay and the Shenzhen Special Economic Zone (SSEZ) authorities have designated it as an area that should be protected for this reason.

After a spill, mangrove trees in oiled areas become defoliated and the leaves turn yellow. This is particularly so in areas where the trees are rooted in a bern of intertidal sediments. In most places, the berm apparently intercepts and partially absorbs the oil, blocking further movement of oil into the forest. Thus the mangrove trees of the inner fringe, that are rooted in the subtidal sediments, suffer less defoliation, and the trees that are rooted in supralittoral sediments of the oiled region suffer less defoliation than the trees noted at lower leaves.

If mortality follows stress and defoliation of the mangroves, the impact may be much wider than loss of the trees themselves. The thickets of prop roots of many species serve as breeding and nursing areas for many marine species and as a substrate and shelter for a diverse group of others, including economically important species of fish, molluscs and crustaceans. Sediments retained by the roots of mangroves can be released as the roots decompose, which is a potential threat to nearby corals and other organisms that are intolerant of siltation. The mangroves also play an important role in maintaining the stability of the coastline and the intertidal mudflats, which are the principal feeding grounds of many migratory birds visiting Mai Po annually. Thus the decay of affected mangrove root systems undermines the stability of the intertidal mudflat habitats, and associated communities.

Benthic Invertebrates

Oysters within the Deep Bay area are significant both culturally and economically. In the event of an aviation fuel spill reaching Deep Bay, these sensitive receivers would be impacted upon in the same way as general benthic invertebrates. Gill filaments would become clogged by agglomerate particles of aviation fuel, which would result in oxygen stress and gapping, and even death depending upon the amount of fuel present within the water column. This would be further aggravated by the reduction of dissolved oxygen penetration at the water surface, and reduced primary production and oxygen release by algae due to the reduction in sunlight penetrating the water column.

Benthic invertebrates may also accumulate petroleum hydrocarbons from contaminated sediments and food and, to a greater extent, from water (Neff 1979, 1984; Capuzzo 1987). Bivalve molluscs have limited ability to metabolize and excrete oil compounds (Lee, 1981), they tend to accumulate greater concentrations and retain them longer than other taxa (Neff and Anderson 1981; Capuzzo 1987). By contrast, benthic crustaceans have a well-developed mixed-function oxidase (MFO) system to eliminate these compounds (Lee 1981).

In addition, after initial death of intertidal or benthic organisms, repopulation by the original species may be low but some resistant or opportunistic species may undergo dramatic population increases and fluctuations in the affected area. In the case of a severe spill, this could greatly change the ecological characteristics of the area removing less resistant ecologically important species and replacing these with resistant opportunistic species.

Corals

Coral reefs are important in supporting coastal fisheries, protecting tropical coast lines from wave action and erosion. The recent survey conducted as part of this assessment found the presence of stone corals in the waters around Sha Chau, as detailed in *Section 4.4.*

Platforms of fringing reefs, often found in coastal waters, form extensive shallow habitats covered with algae, seagrasses and invertebrates and the effects of oil spill on these reef communities has been investigated previously. Oil spills have been found to cause substantial mortality among fish and invertebrates (including lobsters, crabs, gastropods, bivalves, octopus, sea urchins, sea stars and sea cucumbers) in intertidal areas, on the surfaces and margins of coastal fringing reef platforms, and in adjacent shallow subtidal areas.

During exposure to an oil spill the effects of toxicity on the reefs can be substantial. After a few days of exposure to an oil spill, at low tides a band of substratum 1 to 3 m wide at the reef edge became nearly barren of the normal variety of sessile invertebrates and algae, which contributed to a decrease in the abundance of motile organisms. In three months following a spill, reef edges were colonized by a thin transparent mat of algae such as *Cladophora*, which in a short time become thicker, overgrowing both the vacated substrata and the sessile organisms that survived the oil spill. This algal mat covered more than 54% of hard substratum – more than 4 times the average abundance and more than twice the maximum abundance measured in prespill surveys.

The two common species of zoanthids on a reef flat, *Palythoa caribaeorum* and *Zoanthus sociatus* were found to be less abundant after an oil spill. The reef flat population of *Palythoa caribaeorum* was concentrated in the area where oil accumulated at low tide. Before the spill, its coverage ranged between 10 and 12% in a 2 m wide band at the seaward fringe of the reef flat. Three months after the spill the overall spatial coverage was less than one tenth the average prespill abundance and in 6 months was still less than at any time before the spill.

Most of the *Porites spp* (scleractinian corals) were found in the same habitats as *Polythoa*. After the spill, the area covered by *Porites* was less than 1% of what it had been before, but the corals were always present. The abundance of crustose coralline algae, the main reef builders at the reef crest, also decreased in the aftermath of the oil spill to 10%. The percent coverage of the calcareous green alga *Halimeda opuntia* was reduced slowly after the spill due to delayed mortality. Numerous colonies of shallow water corals were dead or dying at a depth of 1 to 2 m in heavily oiled areas. The proportion of dead or dying colonies averaged between 17 and 30% on oiled reefs.

Many corals generate large quantities of mucous when exposed to oil, a mechanism which may protect them from more serious damage. After the initial toxicity has been dissipated, the recruitment of plankton larvae and adult organisms can begin from nearby unaffected areas. Recovery of impacted reef communities occurs in most cases within a few years.

Beaches

Selfcleaning of beaches is faster on more exposed, sandy beaches than on sheltered, vegetated and muddier shores. The oil concentration on sandy shores with low wave energy levels is reduced by mixing, dilution with new sediment and possibly in *in-situ* water washing, rather than by rapid oiled sediment erosion. Hence after a spill the muddier, vegetated, sheltered shore often requires more assistance during spill clean-up.

Surface oil cover remains almost complete until coverage by the tide occurs, which causes some of the oil to be translocated laterally. The oil is often buried by new sediment deposits (transported by wind, wave or tide) and thus is invisible from the surface. Aerial surveys even a few days after a spill would not reveal the full extent of oil contamination.

Some oil treatments increase the firmness of the sediments so that even on fine or medium grained sands the formation of an "asphalt pavement" may take place. The increased shear strength of oil sediments is thought to be a major factor in increasing the residence time of oil spills on sediment shores. From relatively high-energy, poorly drained muddy sand flat, most of the oil is removed by the first tidal cover due to hydrological protection of the surface sediments and subsequent tidal flushing. Clean-up may be completed by sediment current ripple migration under high-energy conditions.

Moderately exposed tidal flats exhibit low vulnerability to oil pollution, which is contributed to by the high water tables. If the authorities responsible for the clean-up can resist any pressure to clean the visually offensive remainder for 3 to 5 months, tidal flats will self-clean. However amenity and ornithological interests are often a major sources of pressure to clean beaches using chemical dispersants.

Past Experience

EIA of Oil Spills undertaken in Hong Kong

Although there have been several major oil spills in Hong Kong only two environmental impact studies have been carried out relating to the two major oil spills in 1973 and 1985 (Wu and Tupper 1988) [(1)]. The environmental impact of the 1973 Ap Lei Chau spill was investigated by Wormold (1976), Stirling (1977) and Spooner (1977). No appreciable damage was found on the plankton community except for the mortality immediately after the kill. Severe mortalities of bivalves, gastropods, sipunculids and crabs were found. However, there was no great reduction of the natural population for the majority of marine species apart from the gastropods *Monodonta labic* and *Nerita albicilla*. A total kill of the meiofauna on the affected sandy beach was also found. No studies have been carried out on recovery of the benthic communities affected.

Investigations of the 1985 'Frota Durban' spill indicated that the resulting environmental effects were minimal (Shin 1986). There was no reduction in species, number of individuals and species diversity for the rocky shore, soft bottom and the plankton communities in the affected area, except for one species of rocky shore gastropod *Monodonta australis* which suffered severe mortality immediately after the spill.

Evaluation of Impacts

Water Quality Impacts

The maximum impact upon the water resulting from the dissolution of aromatics would result approximately 8 to 12 hours after the spill occurred, in the absence of other processes. However, this would then rapidly dissipate leaving no trace of the aromatics approximately 1 to 2 days after the spill. The effect of these aromatics upon water quality including dissolved oxygen concentrations is not clear, although any impact would be temporary due to the rapid dispersion of the concentrations of aromatics within the water column. Therefore, this is not considered to be of major concern, in terms of impacts upon water quality. In addition, aviation fuel contains few aromatics.

Sinking and sedimentation have the potential to be major processes in the event of an aviation fuel spill. However, as detailed in *Section 4.1.12* the

(1) Wu RSS and Tupper RF (1988) Oil Pollution in Hong Kong: Problems, Control and Recommendations. Pollution in the Urban Environment, Volume 2 (P.653-4) Polmet 88.

suspended solid levels in the North Western Waters average 20 mg/l, and these rarely increase above 25 mg/l. Therefore, the effects of agglomeration and subsequent sedimentation on water quality and the marine environment are not anticipated to be great. However, in the event of a spill it would be important to rapidly deploy spill response technologies in order to ensure that agglomeration did not occur. This would effectively stop any sedimentation of aviation fuel within the marine sediments, and would prevent associated impacts upon dissolved oxygen concentrations.

In order that toxicity within the water column does not result from the use of any recommended spill response technologies, chemical characterisation and toxicity screening will be essential, during the detailed design basis EIA, before the adoption of specific spill response technologies. Further details of necessary mitigation measures are presented in *Section 6.3.8*.

Therefore, the fragmentation and dispersion of the spill will cause temporary water quality impacts as low molecular weight aromatics (such as benzene) dissolve into the water column, yet these concentrations will dissipate rapidly. In addition, agglomeration and sedimentation is not considered likely to occur to a great degree as the suspended solid levels in the North Western Waters only average 20 mg/l, and therefore agglomeration will not be promoted. Further assessment will be required during the successful Tenderer's detailed design basis EIA, once spill response technology specifications are known.

Ecological Impacts

The degree of ecological impact resulting from an aviation fuel spill will depend upon the size of the spill, but also to a large extent upon the area in which the spill occurred.

With respect to the scenarios presented in *Section 6.3.3*, the most severe impacts would occur if aviation fuel were to be carried along Urmston Road and into Deep Bay, or if spills impact the west coast of Lantau. This would impact upon the intertidal and mangrove communities within the area. The potential break down of the outer fringes of the mangrove forests would result in loss of feeding, breeding and nursery habitat for many fish species. In addition it would result in undermining of coastal integrity, and the destabilizing of associated intertidal mudflats. Indirect affects would in turn occur on fish numbers due to reduced habitat, and therefore reduced food availability for avifauna feeding in affected areas, and impacts further on fisheries and marine mammal feeding sources.

As detailed above, the community structure of benthos may be impacted in the long term by changes in dominant species as more resistant, opportunistic benthic species establish themselves. Affects on benthos such as oysters, which are cultivated along the south western and northern shores of Deep Bay may occur as detailed above, would also impact upon wading birds which feed primarily upon the benthos in the area.

Indications are therefore that significant impacts to both shoreline and marine ecosystems could occur from worst case spills in the Deep Bay and west coast of Lantau areas. It is therefore vital that all practical measures are used to ensure spill response capability and planning is minimised. The likelihood of these worst case impacts occurring is discussed in the next sections.

6.3.6 *Oil Spill Modelling*

Simulation of Oil Spills

There are several existing models within the WAHMO suite of models developed for the Hong Kong Government which could have been applied in this study and the most suitable are described below.

Tidal Flow Model

In order to simulate the transport by tidal currents of a fuel spill, it is first necessary to simulate the tidal flows. As a result of recent studies for the PAA and the Government, the WAHMO two-dimensional two-layer model of wet and dry season spring and neap tides has been used to simulate the future reclamation layout with the Chek Lap Kok Airport in place. Tidal flow simulations for two reclamation layouts are available for all planned reclamations to the year 2003. This model has a 250m resolution in the horizontal and uses two layers over the vertical to represent the stratified flow conditions found in the wet season. The existing results from this model are used directly as the basis for further simulations of fuel spills and thus no further tidal flow modelling is required.

The available flow model results are based on the existing bathymetry in the area which would be directly relevant for the simulation. For the simulation of fuel spills, future dredged depths will not be simulated. Considering the relatively small area to be dredged, the model's 250m horizontal resolution would not be suitable for a detailed simulation of the water velocities following dredging and, without setting up a higher resolution model, it is considered that the present flow model results are the most suitable available for use in this study.

Fuel Spill Modelling

In order to simulate a buoyant fuel spill, the plume model was applied using buoyant particles to simulate a surface layer. The model includes a `decay' rate which is set to simulate the process of free/oil evaporation and emulsification as described in *Section 6.3.7*.

In this application, rather than simulating a point source such as a dredger, information on the extent of the initial spread of a spill of a given size has been used to define the starting area over which the particles representing the spill would be distributed. This initial impact area was provided by the ERM spill model as described *Section 6.3.7*.

Having set up the initial spill area, the model was run to simulate the transport, dispersion and degradation of the fuel spill. Coastal areas impacted by the spill were identified by examining plan contour plots attached as *Annex F* different times throughout the simulation.

Tides Modelled

For the fuel spill modelling, wet and dry season spring tides are simulated. The spring tides will transport the spill further than the smaller amplitude tides and so should give a better indication of the overall length of coastline which could be impacted by a spill.

Wind Effects

The most accurate way to simulate the impact of winds on plume movements is to include the wind stress in the simulation of tidal flows. However, simulating many different combinations of winds and tidal types can be time consuming. As a result, the plume model can accept a specified wind speed and use analytical methods to move the plume according to the tidal and estimated wind induced water velocities. For the range of wind speeds of interest (up to Typhoon Signal No. 3 say (17.2m/s)), wind induced water speeds near the surface should be of the order of 1½%-3% of the wind speed (up to 0.05m/s say). Compared to the typical tidal currents (typically 10 to 30 times larger in the areas of interest), in the first instance, it was therefore considered that the impact of winds should not be simulated.

Area to be Modelled

Figure 6.3b shows the area cover by the model. The model in fact covers the whole of the Pearl Estuary and waters to the south of Hong Kong an area large enough to contain the fuel plumes was modelled.

Spill Scenario Locations

A range of likely fuel spill scenarios have been defined in *Section 6.3*. Locations for Scenario's 2 & 3 are fixed at the AFRF. For Scenario 1 a point midway along the pipeline route was selected (*Figure 6.3c*). For the marine spills the locations shown on the figure were selected based on the consultants knowledge of the currents such that likely worst case spill impacts were covered. For example Scenario 5 was modelled as a grounding at Tuen Mun since tidal action was though most likely to carry the spill into Deep Bay. The event modelled as Scenario 4 is very unlikely with an estimated frequency of $1.4*10^{-5}$yr or roughly a once in 70,000 year event. Scenario 4 is included to ensure the spill response plan can be designed such that even very rare events can be prepared for. Obviously, more detailed and extensive studies would be required to model all plausible spill scenarios.

6.3.7 *Results*

The transport and dispersion of the fuel spills have been simulated using the SEDPLUME model in order to determine the likely impact of the spills.

SEDPLUME forms part of the WAHMO suite of coastal hydraulic models set up by HR Wallingford and WRc and transferred to the Hong Kong Government. The plume model simulates the transport and dispersion of sediment in dispersion of sediment in suspension using a random walk technique and includes the process of deposition and erosion of sediment at the seabed. As basic tidal flow data, the plume model uses the results from the WAHMO two-dimensional two-layer flow model.

The sediment plume model simulates sediment in suspension by the use of discreet particles which are released into the model at specified locations at given times and at a particular position in the water column. These particles are given a mass which is dependant upon the rate at which sediment is being lost to suspension. The movement of these particles is determined by the tidal flows and by turbulent diffusion. Turbulent diffusion is simulated by the particles being given a pre-defined displacement in a random direction. At each timestep the number of particles in each grid cell is counted and the total mass of sediment and hence the sediment concentration calculated. The fall velocity of the particles is then determined as a function of the concentration.

In order to simulate an oil spill it is necessary for the model to simulate a buoyant substance and to represent the processes of emulsification and evaporation. The buoyancy of the fuel spill has been simulated by releasing the particles at the sea surface and by specifying a negative settling velocity so that the released substance will remain on the surface. The processes of evaporation and emulsification are represented by the use of a constant decay rate. At the end of each timestep the mass of each particle is reduced by the decay constant, which has been set simulate complete emulsification after 4 days. Particles are introduced into the model at the beginning of the simulation over a circle of a given radius, which represents the maximum buoyant spread of the fuel after 1 hour.

Outputs from the model are shown in *Annex F* and are summarised below. Note when looking at the pictures the concentrations given are related to spill thickness by dividing by the density. Hence:

- 0.1 kg/sq.m is equivalent to a spill thickness of 0.125 mm
- 0.01 kg/sq.m to 0.0125; and
- 0.001 kg/sq.m to 0.00125 mm thickness

These latter areas (shown as blue on the maps) are not likely to be seen in reality as spills are likely to disperse below a thickness of 0.05mm. The plots are included to cover for uncertainties in the modelling technique.

Releases at Sha Chau and from the Pipeline

Scenario 1 (pipeline) and Scenario's 2 & 3 (leaks and ruptures at the AFRF) tend to exhibit similar flow patterns (all release less than 50 m^3 of aviation fuel). Releases on flood tides tend to oscillate between Lung Kwu Chau and Sha Chau, and releases on ebb tides rapidly (within 8 hours) move past the coast of west Lantau and do not return to HK waters. Whilst these would impact shorelines of the close islands, no impacts to coastal areas of Lantau or the mainland are likely. Since these are the more probable spill scenarios the risk of impacts to coastal communities is unlikely.

Scenario 6 – a grounding or impact near Sha Chau resulting in a release of 186 m^3 of aviation fuel whilst showing similar movements to scenarios 1 – 3 on the flood tide, does however show impact of the west Lantau coastline on the ebb release but at spill thickness that is unlikely in reality, indicating that there is a very low likelihood of impacting sensitive Lantau coastlines expect if a much larger, and hence less likely, release were to occur at Sha Chau. However protection of shorelines or prevention of spills reaching this area in addition to the shorelines of Sha Chau, Lung Kwu Chau and Tree Island (Pak Chau) should be considered in the spill response planning process.

At Sea Releases

Scenario 5 – a grounding near Tuen Mun was included in the simulation to assess the likelihood of impacts to Deep Bay from vessels en–route to the AFRF from Tsing Yi. The modelling does indicate that this spill approaches the mouth of Deep Bay after about 12 hours. However, even at concentrations (thicknesses) 100 times less than those likely to be the minimum before break up of the spill, the slick does not appreciably enter into Deep Bay. The implication is that spills 100 times bigger that modeled (64 cu.m) would be unlikely to impact sensitive relievers in Deep Bay. Impacts to fisheries would however be expected.

Scenario 4 – a grounding en–route to Sha Chau represents a very low risk eventuality at a frequency of about one chance in 5,000 per year, but envisages a release of 1,000 tonnes of aviation fuel. Again the model indicates that even worst case tides will tend to take the slick rapidly away from sensitive receivers and through Ma Wan and along the northern edge of the port peninsular. However before dispersing this spill covers an area south to Cheung Chau and along the East Lamma Channel. The spill progression indicates that were it to occur closer to Sha Chau impacts to the Lantau coastline might be expected.

Summary

Overall the results of the spill modelling show a low likelihood of impact to sensitive shorelines. However since the main mechanisms of decay include adsorption on suspended particulate matter and emulsification, impacts to benthos after a spill are more likely. More detailed analysis is warranted to fully investigate the probable outcomes and to facilitate spill response capability and planning requirements.

6.3.8 *Mitigation and Emergency Spill Response Planning*

Objectives, Philosophy and Principles

During the operation of the AFRF, all measures should be taken to prevent spillage of aviation fuel. However, results from the above risk analysis and fuel spill modelling indicate that both the risk of a fuel spill occurring and of impact to sensitive shorelines are remote although they are not incredible. As such, in view of the ecological sensitivity of the area, comprehensive emergency spill response planning will be an important component in the detailed design stage of the facility. The development of a Spill Response Plan (SRP) is considered essential owing to the existence of a number of sensitive receivers (SR) along the vessel transit route, the fuel pipeline route and at the AFRF proper. These SRs will include marine and coastal organisms, Sites of Special Scientific Interests (SSSI), mariculture zones, cooling water intakes for power stations and bathing beaches.

The objectives of the SRP are summarised as follows:

- to provide an appropriate system for detecting and reporting fuel spillage or threats of such spillage;
- to identify areas with high risks of impact from fuel spills;
- to designate priorities for protection of high risk areas;
- to coordinate the efforts of the AFRF–operating organisation, government departments and other organisations to prevent, contain and, where necessary, clean up fuel spills in a way which will minimise the environmental impacts, reduce economic losses and protect public health;
- to provide a command structure and command centres appropriately equipped for controlling the fuel spill procedures;
- to establish a reporting procedure to provide control and decision–making information for the personnel involved, and to keep the public informed, in the event of a fuel spill;
- to provide appropriate and adequate fuel spill response equipment and well–trained personnel; and
- to ensure that proper records are kept for each individual fuel spill incident.

Most importantly, the SRP should aim at providing comprehensive information on the environmental characteristics of the areas concerned so that decisions on appropriate counter–spill strategies and actions can be made quickly on–site in case of a fuel spill. In the case of the AFRF, ecological sensitivity has been found to be high because of the presence of habitats for a number of species, including the Chinese White Dolphin (*Sousa*) and the Cormorants (*Phalacrocorax carbo*). An SRP and spill response resources of the highest quality, taking into account of environmental constraints and sensitivity, is therefore required.

As mentioned above, the SRP should be formulated and should be in place before the commissioning of the facility. During the formulation of the SRP, the following matters should be taken into consideration:

- designation of authority and responsibility for the development and operation of the contingency plan;
- identification of areas of high spill risk;
- fate of fuel spill;
- fuel spill trajectory prediction based on local wind speed and tidal currents;
- coastal sensitivity mapping including seasonal differences;
- priorities for protection;
- fuel spill response policy; and
- organisation for response.

Findings from the above contingency planning should then be included in the SRP for the facility. The SRP will incorporate, but will not be limited, to the following aspects:

- crisis management team responsibilities;
- spill notification requirements;
- fuel spill response requirements;
- environmental sensitivity map;
- suggested containment, recovery, and cleanup procedures;
- fuel spill response equipment;
- incident record-keeping procedures;
- ultimate disposal for fuel-contaminated waste generated during cleanup;
- public relations; and
- fuel spill response training and exercises.

It must be emphasized that not only fuel spills will cause impacts on the environment, but also spill response procedures. For this reason, characteristics of mainstream spill response technologies, and their respective applicability are discussed briefly in the following section.

Spill Response Technological Alternatives

Currently available spill response technologies can be categorised into two main groups, namely chemical and mechanical technologies.

Chemical Technology

A large proportion of chemical spill treatment agents are dispersants. Dispersants exert their effect by transforming the spill into fine droplets that can be more easily dispersed in the water column, carried away and diluted by normal ocean mixing processes. By breaking up the spill, dispersants also help to accelerate the natural biodegradation of the hydrocarbons in the spill. Most dispersants contain surfactants, a solvent, and stabilising agents. Surfactants reduce surface tension of the spill layer, thereby promoting greater dispersion. Solvents are added to lower the freezing point and reduce viscosity, and so make the dispersant easier to apply. Stabilisers may be added to adjust pH, reduce corrosiveness, help fix the dispersion after it is formed, or counteract adverse colour or odour.

There are however much controversies over the application of dispersants to marine spills. Most of these controversies arise from ecological concerns, in particular toxicity of dispersants. Some considerations on the toxicity of dispersants are given in *Section 6.3.5*. Chemical characterisation and toxicity screening will therefore be essential before any dispersants are adopted for use. Under the Dumping at Sea Act 1974 (Overseas Territories) Order 1975, a license is required for all dispersant products to be used in Hong Kong. Toxicity testing is necessary for obtaining the licence.

Although a dispersant may comply with all legal requirements, the application of dispersant in case of a spill during the operation of the AFRF will still require careful considerations because of the large number and variety of highly sensitive receivers involved and incomplete understanding of the effects of dispersants on organisms. These considerations, however, should not rule out completely the use of dispersants. In this case, the SRP should identify the circumstances where application of dispersants will be unacceptable, such as shorebird breeding seasons, and provide clear indications of such circumstances to assistant on-site decisions in the event of a spill.

Other chemical means for treating marine spills are also available, including herding agents, demulsifiers, and gelling, wicking and sinking agents. Herding agents have a higher surface tension than petroleum. Such agents, when applied around a spill, tend to compress it and prevent it from spreading so that the fuel can be recovered or cleaned up more easily. Demulsifiers facilitate the separation of the hydrocarbons and water in emulsions, thus assist in breaking up the spill layer. Gelling agents transform spilled hydrocarbons into a semi-solid mass that can be handled easily with recovery equipment. Wicking agents are only applied if the spilled fuel is intended to be burnt in situ. Sinking agents adsorb hydrocarbons and cause them to sink. Such agents effectively remove the spill from sight, but they may exacerbate the impact of the spill by rapidly depositing the oil on the bottom where it may persist.

Of the chemical agents discussed in the paragraph above, the herding agents, demulsifiers, and gelling agents are considered more useful as alternatives to dispersants. However, in the consideration of including such agents in the SRP, they should be subject to the same scrutiny as for dispersants.

Mechanical Technology

All mechanical spill response technologies comprise some forms of physical barrier floating at the spill/water interface to contain the spill, combined with some forms of physical spill recovery device. The most common form of containment barrier is oil booms.

The four basic components of floating booms are as follows:

- a means of flotation for supporting the boom on the water surface;

- the skirt, which extends below the water surface to provide the basic barrier to the spread of the spill;

- the freeboard, which prevents the waves from washing the spill over the top; and

- the tension member, which extends the whole length of the boom and carries the load imposed upon the barrier by wind, wave and current forces.

The main purpose of the boom is to contain the spill, to reduce spreading and to facilitate recovery. It can also serve the purposes of diverting the spill to areas where recovery is possible, and of protecting specific areas, such as ecologically sensitive areas from impacts of the spill.

Effectiveness of booms in preventing the spread of a fuel spill depends on the sea conditions, as well as current and wind speed. It is ecologically essential, and technically and economically feasible only as long as the spilled fuel is floating on the surface and has not reached a state of total dispersion.

Some other forms of physical barrier can be used apart from the floating boom. One of these is the pneumatic barrier. Pneumatic barriers use a screen of rising air bubbles released below the water surface to deter the movement of floating liquids. However, the use of such barriers is only limited to calm waters and relatively thin layers of floating material.

After the spill has been contained, the spilled material should be removed by some forms of recovery device. The most common recovery device is skimmer, including weir skimmers and suction skimmers. Two major considerations in the deployment of skimmers are the positioning of the device at the fuel/water interface, which is affected by sea conditions, and the viscosity of the spilled material.

Recommendations

Spill Forecasting

In the present study, some preliminary modelling of probable spill movements has been performed. However, in order for a comprehensive and effective SRP to be formulated, further studies to forecast the extent of potential fuel spills during the operation of the AFRF are considered necessary and should be conducted prior to commissioning. Such studies should indicate probable spill movements under a wide range of environmental conditions and pinpoint all the corresponding areas of particular high risk to impacts from potential fuel spills. Such predictions should also be made for different seasons.

In some spills, it may not prove possible to protect all high risk areas. It is therefore necessary to determine in advance which areas are to be given priority for protection. Priorities can be decided both on the basis of known sensitivities of the area concerned to aviation fuel and on socio-economic factors. Factors to be considered in the assignment of priorities include knowledge of the area; practicality of protecting a particular resource; relative importance of competing demands; and variations in priorities due to seasonal factors; such as fish and bird breeding seasons.

Results of the above spill forecasting exercise should be included in the SRP in the form of an Environmental Sensitivity Map (ESM) to be prepared at the detailed design stage by the Licensee. In the preparation of the ESM, the likely effectiveness of available spill control measures will also need to be taken into account. The ESM will be an important decision-making tool for personnel taking command in the event of an aviation fuel spill.

Provisions for spill surveillance should still be made despite comprehensive spill forecasting. This will enable decisions on the most appropriate spill response to be made in an actual spill incident, and sometimes in subsequent clean up exercise.

Spill Response Resources

The effective fuel spill response will depend very much on the prompt deployment of the appropriate spill response resources, including both human resources and equipment. Some of the constraints and applicability of spill control measures have been illustrated in the brief discussions above.

Generally speaking, the most desirable way of treating a fuel spill at sea is to remove it physically so that further harm to the marine and coastal environments posed by the spill will be eliminated. As mentioned above, the effectiveness of such measures will however depend on the wind and current speed. The normal current speeds in the waters around the AFRF and the pipeline route are in the range of 0.5 to 0.6 m/s, while current speeds at the Urmston Road are around 1.5 m/s. The internationally accepted maximum current speed (perpendicular to the span of the boom) is around 0.5 m/s (1 knot). With the boom deployed at an angle to the flow of current, the boom may be effective up to a speed of 1.5 m/s (3 knots). As a preliminary assessment, booms are considered to be effective as a spill control measure for the AFRF.

The potential ecological effects of dispersants should not completely preclude their use as an option for aviation fuel spill during the operation of the AFRF. Dispersants should only be deployed however under certain circumstances, for instance in the absence of certain sensitive migrant birds, and should be strictly controlled and monitored.

In order for prompt actions to be taken in the event of a spill, spill response resources should be positioned at strategic locations within the entire operational range of the AFRF, including the fuel vessel transit route and the pipeline route, rather than only on the SER Base.

Human resource is also an important element in effective fuel spill control. This will involve the establishment of an efficient spill response team. Recommendations on training are presented in the following section.

Training

Requirements for training and exercises should be made an integral component of the SRP. Training programmes should be developed for all levels, including vessel crews, equipment operators, clean-up personnel and the command team. The main objectives of training are to develop competence in personnel in the operation of equipment, to promote safety awareness in spill response operations and to acquaint personnel with environmental sensitivity issues.

Regular exercises are recommended to ensure that the reporting, alerting and communication networks function effectively and the personnel assigned specific responsibilities under the SRP are familiar with such operations. With such exercises, the availability and performance of personnel, equipment and material can be ensured.

6.3.9 Summary

Overall the results of the spill modelling show a low likelihood of impact to sensitive shorelines. However since the main mechanisms of spill decay include adsorption on suspended particulate matter and emulsification, impacts to benthos, commercial fisheries and spawning areas after a spill are more likely. More detailed analysis is warranted to fully investigate the probable outcomes and to facilitate spill response capability and planning requirements, such that in the unlikely situation that a spill does occur, resources will be adequate to minimise its effects in line with the recommendations given above.

Consideration of the likely frequency of these spills, on a theoretical basis about one chance in 750 per year indicates that the probability of more than one major release in the lifetime of the AFRF is very remote. However, historical data for Hong Kong Waters indicate 13 major spillages over a twenty year period of which two concerned avaition fuel. Hence, given that a chance of a significant release is still possible in ecologically sensitive waters, spill response capability at Sha Chau should be well planned and supplied with modern equipment concomitant to the worst case credible spill. The equipment should be well maintained both at the AFRF and at a support base near to the likely transport routes since events may occur at a remote location. Marine Department will retain authority over spill clean up and the Licensee should cooperate fully with them and assist with advice from their spill plans. The potential for conflict between response for a spill that might occur in say, PRC waters but effect HK coastal communities should be addressed by the HK Government ie. the Marine Department.

6.4 *CONCLUSION*

With regard to the risk assessment, the results have indicated that the levels of risk to life associated with the AFRF operation in the vicinity of Sha Chau are negligible in the context of the potential risks in the Ma Wan Channel and to mainland populations along Urmston Road, west of Ma Wan. The Risk Assessment concludes that the level of risk is such that permanent operation of AFRF vessels through the Ma Wan Channel would not be acceptable. The levels of risk predicted are such that the AFRF operational period should be minimised by the expediting the construction of a permanent fuel pipeline system.

In respect of environmental risk the study indicates that it is possible, if remote, that a major spill could occur either at the AFRF or along the shipping routes and that this could impact significant areas of Hong Kong's most sensitive shoreline. Note that there are already significant quantities of dangerous goods being shipped through these waters and the temporary one to four daily vessel movements of aviation fuel should be seen in this context. However, the proximity of the AFRF to sensitive ecological receivers dictates that detailed study is necessary to formulate the best means of spill response, both in respect of where it is most detrimental for spills to occur and what resources would best mitigate the potential impacts.

7 ENVIRONMENTAL MONITORING AND AUDIT (EM&A)

7.1 INTRODUCTION

Environmental impact monitoring, and monitoring and audit of operational controls will be necessary to assess the effectiveness of the mitigatory measures employed during the construction and operational phase of the AFRF, and to allow proactive feedback into the construction and operation processes, where necessary. PAA propose to incorporate environmental monitoring and audit (EM&A) within the existing monitoring programme undertaken which presently monitors air, noise, construction dredging activities, dredged mud disposal, and resultant water quality impacts. PAA propose to finalise details of these monitoring requirements, including both general and specific requirements, with EPD to ensure compliance with environmental standards.

Therefore, this section only details EM&A requirements focusing on the remaining issues as identified in previous sections. The Contractor/Licensee for any AFRF at Sha Chau will be required to complete further studies to confirm the environmental acceptability of his proposed construction and operation of the AFRF, and thus the EM&A requirements will be amended as appropriate, at the detailed design stage, based upon these findings.

7.2 EM&A GENERAL REQUIREMENTS

The PAA will undertake EM&A prior to and during construction and temporary operation (5–7 years) of the AFRF to ensure compliance of the AFRF with environmental standards. This will be accomplished by incorporating the AFRF site into the PAA's on-going monitoring and audit programme (now in its twenty-first month) utilising the same equipment, procedures and personnel currently in place. Prior to start of works at the AFRF, the PAA will update its existing EM&A monitoring manual and submit to EPD for comment. As with the existing monitoring programme, monthly reports will be submitted to the EPD and the site will be available and open for EPD inspection.

7.3 ENVIRONMENTAL MONITORING

The existing PAA monitoring programme focuses upon air, noise and water quality monitoring. As stated in this report, air and noise impacts are not an issue with the AFRF and, as a result, only the PAA's water monitoring programme will be expanded to cover the AFRF site.

In addition, this EIA has concluded that the following issues will also need to be incorporated into the AFRF monitoring programme:

- Construction Waste Disposal;
- Chinese White Dolphin;

- Operational Solid and Liquid Waste Disposal;
- Spill Response Plan; and
- Vessel Crew Training and Speed Restriction.

The PAA currently conducts a compliance audit programme for construction waste (ie solid and liquid wastes) generated at Chek Lap Kok, The Brothers, and Sha Lo Wan headland construction sites. These procedures will be incorporated into the Authority's updated environmental monitoring and audit manual to be submitted prior to initiation of AFRF construction works.

In addition, the PAA has required that each licensed franchisee (fuel, catering, air, cargo, etc) at the new airport submit an environmental management plan for the construction and operation of their facilities. For the AFRF, the successful licensee will be required to develop, in detail, construction waste disposal procedures, operational and solid waste disposal procedures, a spill response plan, a vessel crew training programme and vessel operational procedures. These procedures, plans and training programmes will be evaluated in terms of the recommendations made in this report and outlined below.

7.4 BASELINE MONITORING REQUIREMENTS

Dolphin Monitoring

Requirements for *Sousa* monitoring will be finalised by the contractor with AFD. However tentative monitoring is outlined below.

Dolphin Monitoring Equipment

It is anticipated that the following equipment will be required during the dolphin monitoring:

- Provisions of a monitoring boat, and trained personnel supplied with binoculars should be made, in accordance with the methodology adopted for the Site Selection Study.

- A GPS device should be made available during the course of the monitoring, to allow positioning of animals, identification of potential causes of disturbance, and measurement of distances maintained between animals and human activities.

- For monitoring from shore, theodolite, spotting scope on a tripod to identify location of dolphin relative to the AFRF, and *Big Eye 25X150* binocular scopes mounted on a gambaled tripod will be required.

Chinese White Dolphins Monitoring

A one month *Sousa* monitoring programme in the vicinity of the AFRF at Sha Chau is recommended one month prior to the commencement of construction to establish baseline *Sousa* numbers. This should be undertaken in accordance with a methodology agreed with AFD, for a duration to be discussed and agreed with AFD. In addition, if practicable, aerial surveys should be conducted by helicopter as an integral part of the *Sousa* monitoring programme.

Details of Dolphin Monitoring Data Gathering

a) Boat-Based

It is recommended that the *Sousa* monitoring should be continued using standardized techniques comparable to past work as detailed in the Site Selection Study. Wherever possible, orientations and distances of *Sousa* should be given relative to vessels, sites, or areas of potential disturbance. It is also recommended that, wherever practicable, a dedicated photographic effort is made to identify as many animals as possible from natural marks or pigmentation patterns thereby providing an accurate indication of numbers of *Sousa* individuals in the vicinity of Sha Chau. In practice, this requires one monitoring group member to take photographs with a motor-drive, data back 35 mm camera and low f-stop ("fast") zoom lens of approximately 80 to 200 mm. Staff employed should receive comprehensive training, and preferably have previous experience, to ensure that they are fully aware of the requirements of the monitoring.

b) Shore-Based

Theodolite tracking should be used by trained personnel in order to define exact locations, speeds of movements, and orientations relative to construction activities associated with the AFRF construction. The use of the theodolite should be coordinated with the movement of the survey boat in order to obtain accurate *Sousa* numbers.

Sediment Analysis

Knowledge of the levels of contaminants present in sediments, which will be disturbed during construction, is required to ensure that the correct dredging, handling and disposal procedures are followed. The marine disposal of dredged mud is covered under the following Technical Circulars:

- Works Branch Technical Circular No 6/92 (16/3/92) - Fill Management Committee

- Works Branch Technical Circular No 22/92 (1/9/92) - Marine Disposal of Dredged Mud

- EPD Technical Circular No 1-1-92 (9/11/92) - Classification of Dredged Sediments for Marine Disposal

Depending on the quality and volume of the mud to be disposed, appropriate marine dumping sites will be allocated by the Fill Management

Committee and the EPD. Water quality monitoring requirements at the disposal, and monitoring locations to be incorporated into the existing PAA monitoring programme, can only be confirmed at a later date when the location for marine dumping has been designated.

7.5 CONSTRUCTION STAGE IMPACT MONITORING

Dolphin Impact Monitoring

The impact monitoring programme conducted to establish *Sousa* baseline numbers could be continued throughout the first month of facility construction or via a continuous monitoring programme of land and boat surveys conducted on a fortnightly basis (subject to agreement with AFD) and thereafter throughout the duration of the facility construction works, at a tentative frequency of every three months, if practicable (to be discussed, agreed and finalised with AFD), to monitor the presence of *Sousa* in the vicinity of the AFRF, with all sightings in the vicinity of the AFRF recorded on *Sousa* Sighting Forms (see *Annex B*). In addition, further information on potential disturbance reactions, and on possible changes of activities of dolphins relative to construction should be recorded, whenever possible.

The monitoring results should be passed via the AFD to the two AFD funded PhD students to assist them in their studies and the results should be audited relative to the baseline numbers of *Sousa* sightings in the study area. The auditing will potentially give an indication of measures/controls employed and provide proactive feedback into the construction processes, and thereby identify the need for other practicable mitigatory measures/controls. For the purpose of *Sousa* monitoring and auditing, AFD have tentatively proposed the recommended response level to be defined as a 10% decrease in the number of *Sousa* sightings from the recorded baseline number. The precise percentage response level should be determined when the dolphin monitoring programme is finalised in the detailed design phase of the AFRF. The Authority will need to agree upon the details of the monitoring plan with AFD prior to commencement of the construction works.

Construction Stage Waste Disposal Monitoring

The results of the assessment of construction stage waste disposal have indicated that, unless strict control is exerted during construction, impacts could arise. Therefore, there must be strict control over the AFRF construction team/s to ensure that no solid or liquid wastes generated during construction are disposed to the sea and to ensure that all wastes are stored, handled, and collected for disposal off-site, in accordance with EPD regulations and requirements, and at EPD approved disposal facilities.

PAA already monitor marine dumping of dredged material, and therefore propose to incorporate this into the existing monitoring programme. However, it is anticipated that other wastes will be generated and the monitoring requirements are as follows.

It is anticipated that those wastes that need to be removed from the AFRF will be removed at regular intervals. This will allow for the waste storage, handling, collection and disposal to be monitored at regular intervals to ensure effective controls and correct disposal procedures are being systematically implemented.

Monitoring requirements will be detailed within the EM&A Manual which will be produced prior to initiation of construction works, when details on the specific methods of construction and plant to be employed have been finalised. However, tentative requirements have been outlined below.

- The monitoring of construction waste disposal will be undertaken by specified personnel during the AFRF construction.
- It will be the responsibility of the contractor, as a waste producer, to provide storage facilities on each vessel associated with construction of the AFRF, and specified personnel will inspect this facility at regular intervals to ensure no leakage or build up of waste.
- To monitor that correct procedures are being followed, it is recommended that a 'trip-ticket' system is implemented for the collection of MARPOL and chemical wastes produced by the contractor, as is employed for the collection of chemical waste within the Territory before removal of waste to the Chemical Waste Treatment Centre (CWTC) on Tsing Yi.
- It will be the contractor's responsibility to obtain proof that the wastes generated during the AFRF construction are taken off the marine vessels by approved waste removal contractors, to licensed/approved facility. It should be the responsibility of specified personnel to ensure that records are updated on each occasion of waste collection.
- Control and audit requirements will also be necessary, to ensure that correct disposal procedures for the various waste arisings are being implemented, and that monitoring and recording is being systematically employed. The contractor will be required to provide records or other information to demonstrate that proper arrangements have been made for the disposal of waste created. This information may include details related to waste production, and consignment records.

7.5.1 *Construction Stage EM&A Locations*

Exact locations for construction stage EM&A can only be confirmed during the detailed design phase of the AFRF, when details of the pipeline routing and construction methods have been finalised. PAA propose to define details of monitoring locations with EPD.

7.5.2 *Construction EM&A Equipment*

The water quality monitoring equipment to be used is that which is currently employed in the PAA's on-going monitoring programme and approved by EPD. Equipment requirements during *Sousa* monitoring are summarised in *Table 7.5a* below.

Table 7.5a *Summary of Equipment Requirements*

Equipment Function	Type	Number
Water Quality Monitoring		
As currently employed in the PAA's on-going monitoring programme and approved by EPD.		
Dolphin Monitoring		
Sea-Based Monitoring	Boat, trained personnel, and binoculars in accordance with a methodology agreed with AFD	As appropriate
Navigation and positioning	Global positioning systems now in use on PAA sampling boats	1 per boat
Land-Based Monitoring	Theodolite	2
	Spotting scope on a tripod	2
	Big Eye 25X150 binocular scopes mounted on a gambaled tripod	2

7.6 OPERATIONAL STAGE MONITORING

Operational Stage Dolphin Monitoring

The *Sousa* monitoring programme, proposed during construction, should be continued during the operation of the AFRF at a tentative frequency of every six months (to be discussed, agreed and finalised with AFD), to monitor the presence of *Sousa* in the vicinity of the AFRF, with all sightings in the vicinity of the AFRF recorded on *Sousa* Sighting Forms (*Annex B*). In addition, if resources are available aerial surveys conducted by helicopter may be continued.

The monitoring results should be audited relative to the baseline numbers of *Sousa* sightings in the study area. The auditing should help to assess the effectiveness of the mitigatory measures/controls employed and provide proactive feedback into the operation processes, and thereby identify the need for other mitigatory measures/controls. For the purpose of *Sousa* monitoring and auditing, the response level proposed by AFD is defined as a 10% decrease in the number of dolphin sightings from the recorded baseline number. Details will need to be agreed prior to commencement of the works.

The duration of operational monitoring should be appraised based on the results of the first two operational monitoring periods. It is considered that if there are no reductions in *Sousa* numbers than the operational monitoring frequency may be reduced.

Operational Stage Solid and Liquid Waste Disposal Monitoring

The results of the waste assessment have indicated that, unless strict control is enforced during the operation of the AFRF, unacceptable impacts could arise. It is therefore recommended that solid and liquid waste disposal is monitored and audited by specified resident AFRF personnel, to ensure that all wastes are handled, stored and disposed of in accordance with good waste management practices and EPD regulations and requirements. This will ensure that no adverse environmental impacts result from these potential pollution sources.

It will be the responsibility of specified personnel to ensure that no solid nor liquid wastes are allowed to enter the marine waters at the facility, and that discharges into the marine waters from the operating facility are not permitted. The requirements for monitoring waste storage, handling and disposal will be finalised prior to initiation of construction works. At this stage it is envisaged that the requirements will be the same as those outlined in the construction stage monitoring.

Vessel Crew Training and Speed Restriction

The operational assessment has indicated that water quality impacts and ecological impacts could result, if strict speed controls are not enforced in the vicinity of the AFRF. Therefore it is recommended that monitoring of the vessel speed at the entrance to the access fairway be periodically undertaken to ensure all vessels, including non-fuel vessels associated with the facility, are complying with the designated speed restrictions (A radar based vessel tracking system will be consdiered in later studies). These restrictions include:

- the Licensees dedicated fuel shuttle vessels and all non-fuel vessels associated with the facility, are required to approach the facility at low speeds of 0.2-0.3 m/s (maximum), through a system of gated buoys.

- placing slow speed restrictions at the entrance to the access fairway, and informing all vessel captains of these operational controls.

The dedicated fuel vessel crew should be trained to relevant standards, approved by Marine Department, as the vessels could have to pass through the Ma Wan Channel. Only experienced captains should be employed, capable of proficiently manoeuvring the vessels. All constraints on vessel operation should also apply to the crew of the 10,000 dwt vessels used on an occasional basis. The Licensees should fully brief all crews on the constraints regarding vessel operation and movements at the AFRF in order to minimise impacts on *Sousa*. Documentation should be available for inspection, to prove that experienced staff are employed where appropriate, and that sufficient crew training has taken place.

Operational Stage Water Quality Monitoring

Environmental monitoring will only be required during maintenance dredging for the turning basin. Water quality monitoring parameters and requirements will be same as that for the construction phase.

7.6.1 *Operational EM&A Equipment*

During operation it is envisaged that the contractor will require the following specified equipment (*Table 7.1a*).

7.7 EVENT CONTINGENCY PLAN (ECP)

Dolphin Monitoring

At present there is limited knowledge on the ecological requirements/locational, feeding and breeding preferences of *Sousa*, and thus any Action/Response Plan proposed should be treated as tentative and reviewed in the result of new data gained from other sources such as the AFD *Sousa* research study. A proposed Action/Response Plan in the event of exceedance of the response level is shown below:

- Notify PAA, AFRF construction contractor/operator and AFD immediately;
- Identify source;
- Review working methods operation; and
- Carry out analysis of procedures to identify and implement any required remedial action/mitigation.

Contractors should be advised of the possible presence of *Sousa* in the area and the need for their protection and should instruct employees on procedures for reporting *Sousa* sightings.

Spill Response Plan

In the event of aviation fuel spillage a Spill Response Plan (SRP) should be immediately implemented, as detailed in *Section 6*, to ensure prompt and immediate action in such a situation. Qualified spill clean-up teams and equipment should be deployed rapidly to carry out spill containment or spill clean-up.

7.8 ENVIRONMENTAL MONITORING REPORTS

Environmental monitoring reports should be submitted monthly to indicate:

- that monitoring at the pre-determined frequency was carried out during the period where appropriate;

- the results of any monitoring undertaken;

- actions and mitigation measures adopted or to be adopted to redress unacceptance, consequential or unanticipated environmental impacts, together with an assessment of their likely effectiveness;

- comparison with both statutory and contractual compliance limits; and

- details of response in the event of any omissions or failures.

The reports will include a summarised version of the data sets obtained for each of the environmental parameters measured as well as an interpretation of the trends demonstrated by the monitoring data.

7.9 *ENVIRONMENTAL AUDIT*

The environmental audit will cover the following during the design and construction, operation and maintenance, although specifications will be finalised prior to the construction of the AFRF:

- Water quality
- Construction waste disposal
- Operational solid and liquid waste disposal
- Ecology
- Vessel crew training and speed restriction
- Dolphin Monitoring Programme

Environmental compliance audits will be conducted by the PAA:

- during the commissioning of the AFRF
- 6 months after the opening of the AFRF
- 12 months after commencement of Operation

The period/frequency of monitoring of any environmental parameter may be revised as recommended by the auditor upon the findings of the environmental audits.

8 CONCLUSIONS

8.1 INTRODUCTION

The Provisional Airport Authority (PAA) proposes, in the interim term (5–7 years maximum), to supply aviation fuel to Chek Lap Kok Airport from an Aviation Fuel Receiving Facility (AFRF) located in the vicinity of the Chek Lap Kok Airport. The AFRF will receive aviation fuel from vessels and transfer the fuel directly to an on–airport tank farm via subsea pipeline.

The purpose of this EIA study is to assist in minimising pollution, environmental disturbance and nuisance arising from the construction, operation and maintenance of the AFRF by providing information on the nature and extent of the potential environmental impacts and recommending practical and cost–effective mitigation and environmental monitoring and audit measures, where appropriate.

This Study, and those that proceeded it, have been constrained by the overall construction programme of the airport. The environmental studies have been completed without the benefit of seasonal baseline monitoring of sensitive marine species. As a result in some areas it has been possible to assess the absolute acceptability of impacts, however in other areas it has not been possible to be conclusive. Thus an approach has been taken whereby all practical mitigation measures recommended should be considered and further evaluated during detailed design and operations.

This section summarises the findings of the EIA Study, draws the conclusions, recommends the way forward and any further studies that will need to be initiated.

Main conclusions are summarised as follows:

- *Section 8.2*: Construction Impacts;
- *Section 8.3*: Operation Impacts;
- *Section 8.4*: Overall Conclusions; and
- *Section 8.5*: Final Considerations.

The EIA, as required by the ACE EIA Sub–committee, also contains a justification for the screening out of other alternative areas prepared by the PAA, in *Section* 2 and an assessment of other government and agency plans for construction on or near Sha Chau, in *Section 4.5*.

8.2 CONSTRUCTION IMPACTS

The EIA has determined that there are no impacts associated with AFRF construction noise and as a result no mitigation is suggested or required.

8.2.1 *Construction Water Quality*

Preferred Methods of Construction

The use of closed grab clamshell dredgers (or any other method that can be shown to give equivalent or lower impact) is the preferred method for dredging and for pipeline installation, and the specification of this in the contract specification is therefore also recommended, subject to detailed evaluation of engineering feasibility. This form of mitigation would significantly reduce the scale of impacts resulting from the AFRF project. The reduction of direct water quality impacts will result in reduced indirect impacts upon water sensitive receivers from changes in water quality, including marine biota within the Study Area.

Contaminated Mud Pits (CMPs)

The strict adherence to the recommended 150m 'buffer zone' between the CMPs and AFRF service corridor will prevent any interference with the CMPs and any associated contaminant release and thus any unacceptable environmental impacts.

Hydrodynamics

Based on tidal flow modelling and on coastal geomorphological appraisal, the construction of the turning basin and fairway for access to the sites from the Urmston Road main channel will not change the hydrodynamics in the Study Area, and will have negligible impact on the stability of the beaches (sand bar/tombolo) connecting Sha Chau to the nearby Islets, raised as a potential concern of the ACE EIA Sub-committee.

EM&A

EM&A, in the form of the existing PAA procedures will be required to monitor and audit the efficacy of measures to mitigate any impacts on water quality resulting from AFRF construction.

8.2.2 *Construction Waste Management*

Disposal of Dredged Sediments

The assessment has concluded that provided the recommended mitigation measures are strictly adhered to, potential impacts of the dredging works and associated sediment disposal will be minimised, ensuring protection of short term local water quality. It is therefore anticipated that no unacceptable impacts will result from the dredging, transport and disposal of the marine sediments.

The dredged material will be suitable for disposal at a gazetted marine disposal ground. This will, however, be subject to further sediment analysis in detailed design stage to confirm the sediment quality and finalise the required disposal allocation.

Construction Works Waste

It is anticipated that no significant adverse environmental impacts from construction works wastes will arise during the AFRF construction period, provided that non-sediment construction waste arisings are handled, transported and disposed of using approved methods and that no solid or liquid wastes enter surrounding marine waters.

8.2.3 *Construction Impacts on Marine Ecology*

Preliminary Marine Ecological Survey

Following a request from the ACE EIA Sub-committee to include a dedicated consideration of the marine ecology at and around Sha Chau, the results of a preliminary marine ecological survey, including benthic studies and coastal ecological studies, indicate that the sub-tidal invertebrates and fish community of the area are of both ecological and fisheries interest. The area supports a high diversity of fish and shrimp, many of which are commercially important species (eg. sole, flounder, croakers, flat heads and penaeid shrimps). Penaeid shrimps and sole were particularly abundant. Juvenile fish, shrimps, crabs and molluscan egg cases were commonly found, indicating the high fisheries value of the area. It is likely that the area may serve as an important spawning and nursery ground for these commercially important species.

Sensitive Marine Ecological Receptors

The sensitive ecological receptors identified are:

- penaeid shrimp and other important commercial fish species;
- the habitat as a nursery and spawning ground of marine animals in general and penaeid shrimps and food fish in particular; and
- sea pens and stone corals.

Potential Impacts

Dredging activities during the construction phase of the AFRF are likely to locally increase the turbidity of water and sediment deposition rates and modify the bottom substratum, and hence potentially affect the sensitive receptors described above. The ecology and survival of sea pens and stone corals, juvenile stages and recruitment of fish and shrimps in the area are of particular concern. However, it should be noted that the sediment plume modelling simulations, undertaken to simulate the fate of sediment lost to suspension during dredging associated with the AFRF, predicted minimal elevation of suspended solid (SS) levels. In addition, the loss of suspended solids to the marine environment can be minimised provided that practical mitigation measures recommended in this report are included in construction contracts and fully implemented. It should also be noted that there are proposals by FMC to dredge sand in the area to the east of Sha

Chau. Thus at the time of the proposed AFRF construction, the seafloor ecology in the area of the access fairway may already have been disturbed by dredging activities in the Urmston Road.

Seasonal Considerations Including the Chinese King Crab

Following concern raised by the ACE EIA Sub-committee to include consideration of the potential value of the Sha Chau area for the Chinese King Crab the EIA has included a review of seasonality effects.

Fish and benthic communities in Hong Kong typically exhibit marked seasonal variations and thus the preliminary survey does not take any account of seasonal changes. Judging from the documented occurrence of the Chinese King Crab species in similar habitats in the vicinity, the absence of this species in the survey may only reflect the seasonal occurrence of this species in the area. The importance of the area as a nursery and spawning ground for penaeid shrimps, food fish and the Chinese King Crab needs to be further established so that appropriate mitigatory measures can be introduced.

Further Marine Ecological Studies

It is thus recommended that:

- a detailed ecological study be carried out in parallel with the further AFRF design stages, with a view to assess the importance of the area as a nursery and spawning ground for fish, penaeid shrimps and the Chinese King Crab in the area such that the most appropriate mitigation measures can be identified;

- appropriate mitigation measures should be developed in the detailed design stage, based on the detailed ecological survey, to protect any ecologically sensitive species which are identified to be impacted by facility construction;

- strict pollution control measures be introduced during the construction phase of the facility; and

- local restocking of penaeid shrimps, sea pens, stone corals and commercial fish species should be considered to mitigate the environmental impact, if significant impacts are identified by more detailed survey work.

8.2.4 *Construction Impacts on Sousa*

Potential Impacts

Following a request from the ACE EIA Sub-committee to include EIA consideration of the potential impacts from AFRF construction on *Sousa*. The following activities were identified as having the potential to impact on *Sousa*:

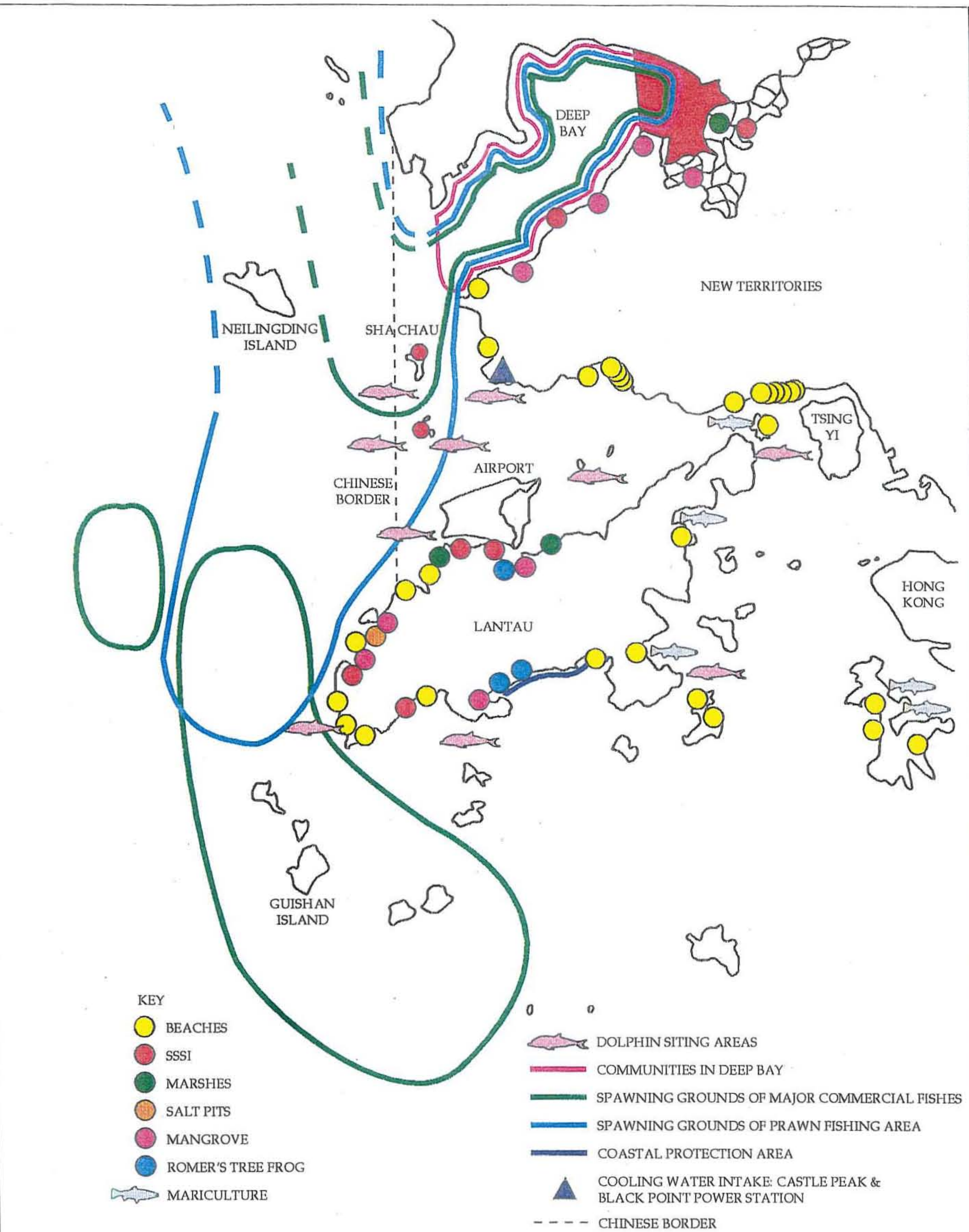

FIGURE 6.3a - ECOLOGICAL SENSITIVE RECEIVERS

ERM Hong Kong

10-11th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

- dredging activities;
- pipeline construction;
- general construction noise;
- berth construction;
- construction vessel movements;
- general construction activities; and
- background activities.

Evaluation, Mitigation and Monitoring

In view of these potential impacts, the EIA concluded that every opportunity must be taken to minimise potential impacts on *Sousa* arising from the construction works. The *Sousa* mitigation measures and controls recommended in this Report for the construction stage should be incorporated in the detailed design of the AFRF. As such it is considered that the implementation of this comprehensive package of mitigation measures and the recommended monitoring and audit requirements will minimise the potential for both direct and indirect impacts on *Sousa* from the AFRF construction.

8.2.5 Cultural Impacts

Information from the Antiquities and Monuments Office indicates that Sha Chau is designated a "Special Site of Archaeological Interest" (SSAI/NT 18) on account of the considerable quantity of prehistoric and historic artifacts discovered in past investigations. There is also a Tin Hau Temple on the island, built in 1862, which is a Grade II historical building. In addition, it is understood that the fishermen have two or three ancestral graves on the island behind the temple, which may also have clan significance.

The AFRF will be an offshore facility and there will be no land-based construction. Thus, direct physical impacts on these culturally significant features will be avoided. The proposed offshore fixed receiving facility will be essentially a horizontal structure on piles comprising two vessel berths approximately 320 m long, 5 m high and 15 m wide. This horizontal form is expected to minimise the intrusion to the open aspect (Fang Shui) of the temple and graves. In addition, the proposed offshore berths are located to the northeast of Sha Chau, therefore avoiding direct intrusion to the "Fang Shui" of the temple which has a northwest aspect.

8.2.6 Other Government Construction Proposed on Sha Chau and Possible Cumulative Impacts

Following a request from the ACE EIA Sub-committee to include a description of other Government construction proposed on Sha Chau the following sub-section briefly describes other construction proposals and assesses the potential for cumulative impacts.

CAD Radar

CAD,propose to build an Approach Surveillance Radar (ASR) Station and a Secondary Surveillance Radar (SSR) Station located on the high area of Sha Chau Island. A CAD jetty is currently being constructed to provide a service access to the island. The CAD jetty is to be located on the eastern coast of the southern Sha Chau island with a pathway constructed from the CAD jetty leading to the Stations. Construction works for the CAD jetty commenced in July 1994 and are scheduled for completion in June 1995, and thus the jetty will be completed when the construction works for the AFRF commence in July 1995. No direct cumulative impacts on water quality are therefore anticipated to arise, from the construction of the CAD jetty.

Submarine Power Cable

A submarine power cable (SPC) extending from Chek Lap Kok to Sha Chau will be required to provide power for CADs ASR and SSR Stations. Further, a power supply to Lung Kwu Chau will be required to serve the DVOR/DME Stations on the Island. China Light & Power and the Government are considering an SPC route from Sha Chau. The SPC from Chek Lap Kok to Sha Chau will be laid within the proposed services corridor for the AFRF. The proposed tentative route of the cable is planned to broadly parallel the AFRF twin pipeline although and its exact routing and construction timing will be finalised at the detailed design stage.

The SPC section from Chek Lap Kok to Sha Chau section will be installed between December 1995 to February 1996. Although the installation schedule for the AFRF submarine pipeline (estimated construction duration of 2-3 months) cannot be confirmed at this stage, it is presently understood that it will not coincide with the SPC installation. Impacts from the installation works for the SPC are not anticipated to have a adverse potential water quality impacts although this will be verified during the detailed design basis-EIA upon finalisation of construction techniques.

8.3 OPERATIONAL IMPACTS

The EIA has determined that there are no significant impacts associated with AFRF operational noise and as a result no mitigation is required.

8.3.1 *Operational Water Quality and Movement Impacts*

Pollution Control

No polluted discharges into the marine waters from the facility should be permitted and no solid nor liquid wastes should be allowed to enter the marine waters at the facility. This is in line with PAA's conceptual design.

that, even at airport opening, the risk levels from the marine transport of aviation fuel to the AFRF to populations in the vicinity of the shipping routes are still of a magnitude where the available guidelines indicate practical means should be sought to further reduce risk levels.

The need for risk mitigation in the Ma Wan Channel is demonstrated by the assessment in previous studies of background risk levels expected in 2006. Whilst the contribution from the AFRF is relatively small, any additions to the numbers of Dangerous Goods cargoes using the channel will only further increase risk levels that will already be high.

The question remains as to whether the AFRF and its five to seven year operation can be termed ALARP in accordance with the above discussion. To comply with the ALARP principle, it is necessary to show:

- It is not practicable to construct a pipeline by airport opening date; and
- The pipeline will be constructed as soon as is reasonably practicable (ASARP).

PAA inform that they, in consultation with government, have concluded that, based on Government policy as well as a combination of technical, programme, and commercial reasons a permanent pipeline cannot *now* be in place for airport opening. The programme for construction of a permanent pipeline which has been supplied by PAA, indicates that almost five years are required. This is based on the assumption that the consultative and decision making process has been completed. Even if a go-ahead were given immediately a pipeline could not in place until late 1999 or 2000. Given the above, it was concluded that an interim facility was required.

PAA have noted that the temporary AFRF will be in full time operation for approximately 5-7 years. This is based on projected fuel demand and operator investment returns. However the PAA have stated their commitment to work closely with Government and commercial interests to ensure that the permanent facility is brought on-line as soon as reasonably practical (ASARP) after airport opening.

Compliance with the ALARP principle centres on the definition of 'reasonably practical'. It is acknowledged that this definition is usually expressed in terms of the technical feasibility and costs of a mitigation measure, in this case the permanent pipeline, versus its benefits on risk grounds. Since the reasons why a permanent pipeline might not be able to be constructed for up to 5 - 7 years after airport opening are a combination of technical and non-technical factors the AFRF is not strictly ALARP. However, if there are 'insurmountable' reasons for the 5 - 7 years timescale of AFRF operation, clearly the pipeline is not a practicable mitigation measure at the present time.

Other relevant points are as follows:

- The risk increases with tonnage transported through the Ma Wan Channel and the risks from the 5,000 dwt vessels used in the study lie within the ALARP region of the HK RGs at 1997 demand levels further emphasising the benefits of a permanent pipeline as soon as is practical.

- Any marine aviation fuel transportation should be by a modern design of tanker with high standards of safety as proposed for the around 5,000 dwt AFRF tankers. Use of double hulled tankers is recommended if practical, cost effective and meet Marine Department conditions.

- The risks to populations west of Ma Wan on the mainland along Urmston Road are expected to be of higher consequence on the one hand (due to greater populations at risk) but lower frequency on the other (due to greater ease of navigation that in the Ma wan channel). The net effect is, however, an increased contribution to the overall level of risk from AFRF operations.

- The risks to populations west of Ma Wan on the mainland along Urmston Road are expected to be of higher consequence on the one hand but lower frequency on the other. The net effect is, however, an increased contribution to the overall level of risk from AFRF operations.

- Some of the conceptual mitigation measures need further evaluation as recommended, and the possibility of reduction in risk to life may coincide with an increase in risk to the environment. For example if routes via South Lantau were used, instead of the Ma Wan Channel and Urmston Road, risks to life would be dramatically reduced but significantly greater risk would be posed to ecologically sensitive receivers in the event of a spill.

Further detailed quantified study at detailed design stage is required to estimate risk levels more accurately and to evaluate the relative practicality and cost effectiveness of the mitigation measures proposed, in accordance with the ALARP principal, over the operational period of the AFRF.

The overall conclusion is that PAA have, in selecting a piped aviation fuel supply for the long term, adopted a low risk option for fuel supply to CLK that will give risk levels in the acceptable region of all guidelines considered. The AFRF is an interim solution to be operated whilst a permanent supply option is pursued. Since the reasons why a permanent pipeline might not be able to be constructed for up to 5 – 7 years after airport opening are a combination of technical and non-technical factors the AFRF is not strictly ALARP. The risk levels are within an area where risks should be mitigated to a level as low as reasonably practical. These mitigation measures should concentrate on the AFRF operations given that there is no practical alternative in the interim term.

8.3.6 *Environmental Risk*

Following a request from the ACE EIA Sub-committee the EIA included consideration of environmental risk. Overall the results of the spill modelling show a low likelihood of impact to sensitive shorelines. However since the main mechanisms of spill decay include adsorption on suspended particulate matter and emulsification, impacts to benthos, commercial fisheries and spawning areas after a spill are more likely. It is considered that agglomeration and subsequent sedimentation will not be of great concern as suspended solid levels rarely reach levels that would promote these processes. More detailed studies are warranted prior to commissioning to fully investigate the probable outcomes and to facilitate spill response capability and planning requirements such that, if a spill does occur, resources will be adequate to minimise its effects in line with the recommendations given in this Report.

Consideration of the likely frequency of these spills, on a theoretical basis about one chance in 750 per year indicates that the probability of more than one major release in the lifetime of the AFRF is very remote. However, historical data for Hong Kong Waters indicate 13 major spillages over a twenty year period of which two concerned aviation fuel. Hence, given that a chance of a significant release is still possible in ecologically sensitive waters, spill response capability at Sha Chau should be well planned and supplied with modern equipment concomitant to the worst case credible spill. The equipment should be well maintained both at the AFRF and at a support base near to the likely transport routes since events may occur at a remote location.

Marine Department will retain authority over spill clean up and the Licensee should cooperate fully with them and assist with advice from their spill plans. The potential for conflict between response for a spill that might occur in say, PRC waters but effect HK coastal communities should be addressed by the HK Government i.e. Marine Department.

Prior to AFRF commissioning, preliminary recommendations made in this report will need to be substantiated by detailed spill modelling and forecasting such that the extent of equipment, resources and training needed are known to ensure sensitive marine and coastal ecosystems are protected with the best practical means available.

8.4 OVERALL CONCLUSIONS

8.4.1 *Marine Ecology*

The EIA has indicated that as a result of the locational proximity of the AFRF to identified and potential marine ecological sensitive resources, including Chinese White Dolphins and possible marine biota spawning and nursery grounds, that comprehensive construction and operational stage mitigation will be needed to minimise AFRF project impacts. Therefore, in order to prevent and minimise impacts all recommended mitigation clauses, unless shown to be impractical, should be included in construction contracts and in the facility design and operational requirements.

Impacts to Sousa

Survey results of this study and AFD's DRT study currently indicate currently high incidence of *Sousa* sightings in the Sha Chau/Lung Kwu Chau compared to other areas in Hong Kong waters. It is considered that, given that Sha Chau was determined by PAA in consultation with government as the only viable area for the AFRF, the potential direct or indirect negative impacts on *Sousa* should be minimised by the adoption of a comprehensive package of mitigation measures.

The preliminary results of AFD's Dolphin Research Team's studies indicate that *Sousa* frequently move over a wide area and thus Sha Chau comprises only one part of *Sousa's* habitat range within the estuarine waters of the Pearl River Delta. Hence any potential impacts on *Sousa* arising from the construction and operation of the AFRF may be less than would be the case had the field survey results indicated sole utilisation of the marine waters around Sha Chau by *Sousa*.

It is considered that the construction methods and mitigation controls recommended will further reduce and should minimise impacts to *Sousa*. The interim operation phase will last up to 5 to 7 years. It is considered that the operational procedures and controls recommended over all vessels, AFRF operation and personnel should minimise the potential for operational phase disturbance and impacts on *Sousa*.

The mitigation measures and controls are, where practical, to be incorporated in the detailed design and operation of the AFRF to minimise the potential for both direct and indirect impacts on *Sousa*. The recommended monitoring and audit requirements during construction and temporary operation will provide a pro-active means of evaluating the efficacy of mitigation measures and identifying any requirements for additional mitigation.

Additional Marine Ecological Survey Work

Additionally the EIA identified the need for further detailed marine ecological survey work to characterise the possible value of the area as a nursery and spawning ground and to identify the presence of species which may only use the site at certain times of the year, including the Chinese King Crab. The results of this survey, to be undertaken in parallel with the AFRF design, will enable the formulation of precise mitigation measures "tailored" specifically to any valuable species identified that may be impacted by either the AFRF construction or operation and effects on spill response planning.

8.4.2 *Environmental Management Plan*

The recommendations made in this Report should be incorporated into the comprehensive Environmental Management Plan to be developed by the Licensee for the AFRF.

8.4.3 *AFRF Risks*

With regard to the risk assessment, the results have indicated that the levels of risk to life associated with the AFRF operation in the vicinity of Sha Chau are negligible in the context of the potential risks in the Ma Wan Channel and to mainland populations along Urmston Road, west of Ma Wan. The Risk Assessment concludes that the level of risk is such that permanent operation of AFRF vessels through the Ma Wan Channel would not be acceptable. The levels of risk predicted are such that the AFRF operational period should be minimised by the expediting the construction of a permanent fuel pipeline system.

The study indicates that the risk of a major spill at either the AFRF or along the shipping routes is remote although such an occurrence cannot be discounted. Note that there are already significant quantities of dangerous goods being shipped through these waters and the temporary one to four daily vessel movements of aviation fuel should be seen in this context. However, in the event of a spill, the proximity of the AFRF to sensitive ecological receivers dictates that detailed study is necessary to formulate the best practical means of spill response, both in respect of where it is most detrimental for spills to occur and what resources would best mitigate the potential impacts.

8.5 *FINAL CONSIDERATIONS*

This assessment has been completed on a compressed programme to enable the AFRF to be in place for airport opening. The EIA has assessed an interim AFRF at Sha Chau, operational for up to 5 to 7 years, and thereafter to be used only as an emergency back-up facility. From previous studies detailed in the Report, Sha Chau is the only viable site.

The PAA is committed to working closely with Government and private sector parties to ensure that the permanent facility is brought on-line as soon as practical after airport opening.

It should be noted that there is insufficient information to fully evaluate potential impacts to marine ecology, fisheries, benthic communities and the coastal ecosystem. As a result, follow on studies have been recommended so that the potential impacts can be fully evaluated and appropriate mitigation measures identified. These studies will be implemented during the detailed design phase of the AFRF.

In respect of *Sousa*, a comprehensive package of mitigation measures and controls recommended for both the construction and operation stages will be incorporated, by PAA or other parties under PAA supervision or licence, in so far as they are practical and cost–effective. As such it is considered that the full implementation of the recommended measures should minimise the potential for both direct and indirect impacts on *Sousa* from the AFRF construction and operation.

In respect of all other issues this report has concluded that there are not likely to be any significant impacts in any areas of the AFRF construction or operation provided that the recommended mitigation measures or equivalent are adopted, wherever practical.