Agreement No CE89/95
Supplementary Environmental Impact Assessment for Dredging of the Anchorage Area for Stonecutters Island Naval Base

Final Report

May 1996

Mott Connell Limited

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

Agreement No CE89/95
Supplementary Environmental Impact Assessment for Dredging of the Anchorage Area for Stonecutters Island Naval Base

1. INTRODUCTION

1.1 General

The objectives of this Supplementary Environmental Impact Assessment (EIA) are summarised as follows:

(i) to define the nature and extent of the environmental impacts arising from the proposed dredging activities associated with the provision of an anchorage area for the Stonecutters' Naval Base;

(ii) to identify any unacceptable environmental impact associated with the implementation of the works; and

(iii) to recommend measures to minimise any adverse impacts to acceptable levels.

The present Study supplements the findings of the Environmental Impact Assessment of the Stonecutters Island South Shore Naval Facilities (Agreement No. CAO B18) and focuses on the assessment of the impacts associated with the provision of two Class A and two Class B mooring buoys.

Approximately 710,000m^2 of seabed within the Study Area will be dredged to a depth of -10.5m or -12.5m CD to accommodate the proposed facilities. An estimated 2.3Mm^3 of marine deposits will require to be dredged and disposed of off-site. A sediment quality study was undertaken to determine the quality of the marine deposits in the anchorage area.

The findings of the sediment quality study and the interpretation of the sediment plume modelling studies were used to determine the acceptable impacts associated with dredging and disposal of the marine mud.

2. ENVIRONMENTAL SETTING

2.1 Environmental Legislation

Marine water quality in Hong Kong is governed by the 1980 Water Pollution Control Ordinance (Cap 358) (WPCO). Territorial waters are divided into Water Control Zones which have each been ascribed a series of Water Quality Objectives. The Study Area is located within the Victoria Harbour Water Control Zone and the relevant water quality objectives promulgated for this area are given in Table 2.1 below:

Table 2.1 Water Quality Objectives for Victoria Harbour

Water Quality Parameter	Objective	
	Victoria Harbour*	Sub-Zone
Offensive odour, tints and colours	- Not to extend natural by >10%	- Whole zone
Visible foam, oil, grease scum, litter	- Not to be present	- Whole zone
E.coli	- Not to exceed 1000/100ml, calculated as the geometric mean of the most recent 5 consecutive samples taken at intervals of between 7 and 21 days	- Secondary contact recreation subzone - Inland waters
D.O. within 2m of bottom	- not less than 2mg/l within 2m of the seabed for 90% of the sampling occasions during the whole year	- Marine waters
Depth average D.O.	- Not less than 4 mg/l for 90% of the sampling occasions during the whole year; values should be calculated as the annual water column average (see note 1).	- Whole zone except fish culture zone - Fish culture zone; (BU-2)
pH	- To be within the range of 6.5-8.5 units. In addition, human activity should not cause the natural pH range to be extended by more than 0.2 unit - Human activity should not cause the pH of the water to exceed the range 6.0 - 9.0 units.	- Marine waters - Inland waters
Salinity	- Change due to discharge not to exceed 10% of natural level	- Whole zone
Temperature change	- Change due to discharge not to exceed 2°C	- Whole zone
Suspended solids	- Discharge not to raise the natural ambient level by 30% nor accumulation of SS.	- Whole zone
Toxicants producing significant toxic effects	- Not to be present	- Whole zone

Table 2.1 Water Quality Objectives for Victoria Harbour (Cont'd)

Water Quality Parameter	Objective	
	Victoria Harbour*	Sub-Zone
Ammonia	- Annual mean not to exceed 0.021 mg/l calculated as unionised form	- Whole zone
Nutrients	- nutrients not to be present in quantities sufficient to cause excessive or nuisance growth of algae or other aquatic plants. - level of inorganic nitrogen should not exceed 0.4 mg per litre, expressed as annual water column average (see note 1)	- Marine Waters - Marine Waters

Note 1: Expressed normally as the arithmetic mean of at least 3 measurements at 1m below surface, mid depth and 1m above the seabed. However in water of a depth of 5m or less the mean shall be that of 2 measurements (1m below surface and 1m above seabed), and in water of less than 3m the 1m below surface sample only shall apply.

* Objectives shown for Victoria Harbour are for Beneficial Use Criteria No. 3, (BU-3), except for *E.coli* which BU-6 criteria have been used. Below is a summary of the beneficial Use Criteria.

- BU-1; As a source of food for human consumption. WQOs apply to the food itself, not the waters.
- BU-2; As a resource for commercial fisheries and shell fisheries (mariculture).
- BU-3; As a habitat for marine life and a resource for human exploitation.
- BU-4; For bathing (March to October).
- BU-5; For secondary contact recreation including diving, sail-boarding and dinghy sailing.
- BU-6; For domestic and industrial purposes, including cooling, toilet flushing and desalination.
- BU-7; For navigation and shipping including the use of officially approved and endorsed sheltered harbours and typhoon shelters as temporary havens.
- BU-8; For aesthetic enjoyment.

In addition to the foregoing, in 1990 an amendment to the Ordinance contained a series of standards to be used as control measures for discharges to sewers, inland and coastal waters.

For this Supplementary EIA, both the Water Quality Objectives for Victoria Harbour and the Technical Memorandum on Standards for Effluents Discharged into Drainage and Sewerage Systems, Inland and Coastal Waters (TM) (WPCO Cap 358 S.21) were adopted as the legislative criteria to be adhered to.

2.2 Environmental Baseline

2.2.1 The Study Area

Stonecutters' Island is 77 hectares in area and located 2.1km west of the Kowloon Peninsula. To the north west and west is Container Terminal 8 (CT8) Development and to the north and north east is the West Kowloon Reclamation (WKR). In 1992 Stonecutters' Island was joined to the Kowloon peninsula by land reclamation associated with the CT8 and WKR projects.

In 1993, reclamation work started on the construction of a new Hong Kong Government Dockyard within the north basin already occupied by the HMS Tamar Naval Base. Construction of the buildings for the Dockyard started in January 1994 and was completed in 1995. Work has also commenced on the provision of Stonecutters' Naval Base and access channel which is located on the Southern Shore of Stonecutters Island as illustrated on Figure 2.1.

2.2.2 Adjacent Shipping Activities

The Northern Fairway

The western breakwater of the Naval Base will be approximately 170m from the eastern edge of the North Fairway.

The boundaries of the Northern Fairway stated in Cap. 313 Shipping and Port Control Regulations are as follows:

On the north, straight lines joining the following positions:-

(i)	latitude	22°17'52' north,
	longitude	114°08'37' east;
(ii)	latitude	22°19'04' north,
	longitude	114°07'38' east;
(iii)	latitude	22°19'39' north,
	longitude	114°06'30' east;
(iv)	latitude	22°19'21' north,
	longitude	114°05'35' east;
(v)	latitude	22°19'34' north,
	longitude	114°05'11' east;

On the south, straight lines joining the following positions:-

(i)	latitude	22°17'47' north,
	longitude	114°08'28' east;
(ii)	latitude	22°18'56' north,
	longitude	114'07'31' east;
(iii)	latitude	22°19'18' north,
	longitude	114°06'48' east;
(iv)	latitude	22°19'19' north,
	longitude	114°06'33' east;
(v)	latitude	22°19'15' north,
	longitude	114°06'18' east;
(vi)	latitude	22°19'09' north,
	longitude	114°05'59' east;

(vii)	latitude	22°18'57' north,
	longitude	114°05'49' east;
(viii)	latitude	22°18'25' north,
	longitude	114°05'46' east;

On the east and west, straight lines adjoining the extremities of the north and south boundaries.

On the east and west, straight lines adjoining the extremities of the north and south boundaries. The vast majority of ships now calling at Hong Kong enter and leave the port via the Western Approaches (the East Lamma Channel) and those proceeding to and from the berths within harbour limits use the Northern Fairway. The Director of Marine has advised that while he has tentative plans to re-align parts of the Northern Fairway, these proposals would have little effect on the Stonecutters' Naval Base and its associated Anchorage Area.

2.2.3 Shipping in the Northern Fairway

On average, about 1,500 ocean-going vessels and China ferries arrive and depart from berths within harbour limits each month. On the basis that 5% of these vessels use the Sulphur Channel or the North Green Island Fairway (as advised by the Marine Department during the EIA for Stonecutters Island South Shore Naval Facilities) the average number of vessels using the Northern Fairway each month is 1,350 inward bound and 1,350 outward bound. This equates to 90 vessels per day (45 inward and 45 outward).

It was also concluded in the foregoing EIA Study that for 18 hours a day the average number of vessel movements in the Northern Fairway is just over 4 per hour. During the period between midnight and 6.00 a.m. the average number of vessel movements in the Fairway is 2 per hour.

It has been conservatively estimated that 90 ocean-going vessels and China ferry movements take place per day in the Northern Fairway, of which about 78 take place between the hours of 6.00 a.m. and midnight. This equates to one vessel movement every 15 minutes. If there is more shipping in the Northern Fairway, the contribution from the four new anchorage buoys will be even less.

The total water area covered by the various existing anchorages and harbour mooring buoy area is about 1,600 hectares. The cargo handling capacity of these buoy and anchorage areas varies widely, depending on the types of vessels and cargoes handled. Both buoy and anchorage areas are being significantly reduced by reclamations in the harbour. The West Kowloon, Central, Wanchai and Green Island reclamations will between them cause a loss of 745 hectares of anchorage, including about 25 buoys, by 1996, if they proceed. New buoy and anchorage areas to replace the lost facilities will be required, but these will be located to the west of the existing central harbour and will be served by the East and West Lamma Channels.

On the basis of the foregoing it may surmised that the provision of the four new mooring buoys is therefore not expected to significantly contribute to the overall vessel traffic in this area either during or following their construction.

2.3 Water Quality

2.3.1 Existing Circulation Patterns

Seasonal variations in the circulation patterns in Hong Kongs' coastal waters are best illustrated by the residual flows, which vary extensively between summer and winter, as illustrated in Figure 2.2. Freshwater inflow from the Pearl River plays a significant role in the overall variations in temporal and spatial conditions in the wet season in terms of salinity gradients and transport of pollutants. In the dry season conditions are generally well mixed. Even within the relatively small Study Area there are significant differences in local circulation patterns.

2.3.2 Existing Water Quality

In the vicinity of the Study Area, some dramatic physical changes have occurred over the past two or three years with a consequential impact on local water quality. Not only has the channel between Northern Stonecutters Island and West Kowloon been closed but extensive marine works have also been, and are still being, carried out within the area. For the purposes of this Supplementary EIA, recourse has been made to the results of water quality monitoring provided in the EIA for the Stonecutters Island Southshore Naval Facilities included as Table 2.2.

Table 2.2 Summary of Selected Water Quality Monitoring Data

Period	Parameter								
	DO (mg/l)			SS (mg/l)			Turbidity (NTU)		
	mean	min	max	mean	min	max	mean	min	max
* Station C2 Sept 1992 - Aug 1993	4.3	2.5	7.4	17.6	1.9	73.5	14	2	61
Sept 1993 - Feb 1994	4.2	2.4	7.0	14.2	2.9	33.3	12	3	33
* Station W4 Sept 1992 - Aug 1993	4.3	2.0	6.8	20.6	2.3	136.4	18	2	116
Sept 1993 - Feb 1994	4.1	2.4	6.7	22.3	4.8	59.3	19	5	56

* Refer to Figure 2.3.

2.3.3 Sediment Transport and Quality

The seasonal and diurnal variations in sediment transport and deposition in Hong Kong' western waters are well documented. Data collected under a Geotechnical Engineering Office programme confirmed the dominant effect of oceanic waters in preventing the ingress of suspended sediments from the Pearl River to Hong Kong's coastal waters on the flood tide. The same study confirmed that on the ebb tide, sediment deposition takes place in the Western Harbour. Deposition in this area is temporary as material is known to be reworked by wave and tidal action.

2.4 Future Environment

External factors which will affect future conditions within the Study Area, include alterations to circulation rates or changes in sediment transport and deposition patterns as a consequence of major reclamation and dredging projects planned at various time horizons. Reclamations which could affect the local hydrodynamic regime in the longer term, include Container Terminal No. 9 and the Tsuen Wan Bay Further Reclamation which is scheduled to be developed around the year 2005.

Dredging works for the midstream operations site and the access channel to the Stonecutters Naval Basin will not overlap with the dredging of the anchorage area as the construction programmes indicate all works will be completed by May and September 1996 respectively. Dredging of the Rambler Channel and Approaches was not included in the modelling study as the dredging works will be in an area influenced by a different tidal regime. Dredging works for the Rambler Channel and Approaches will involve removal of $6Mm^3$ compared to $2.3Mm^3$ for this project and could have a greater impact on receiving water quality.

As indicated on Figure 2.1 the existing boundary of the Yau Ma Tei Typhoon Shelter will need to be modified to accommodate the new anchorage area for Stonecutters Naval Base. Marine Department have advised that an amendment to the Schedule of the Shipping and Port Control Regulations, Cap. 313 is in progress.

It has already been identified that the marine traffic generated during construction or operation of the buoys will not contribute significantly to vessel movements in the area.

2.5 Sensitive Receivers

2.5.1 Water Quality Sensitive Receivers

Sensitive receivers within the area of influence are mainly confined to seawater/cooling water intakes during the construction period as illustrated on Figure 2.3. "Beneficial Use 3 as a habitat for marine life and a resource for human exploitation" is also ascribed to the Victoria Harbour Water Control Zone and, as such, the protection of the marine waters is a basic tenet for the construction of the anchorage buoys.

Figure 2.1
The Study Area

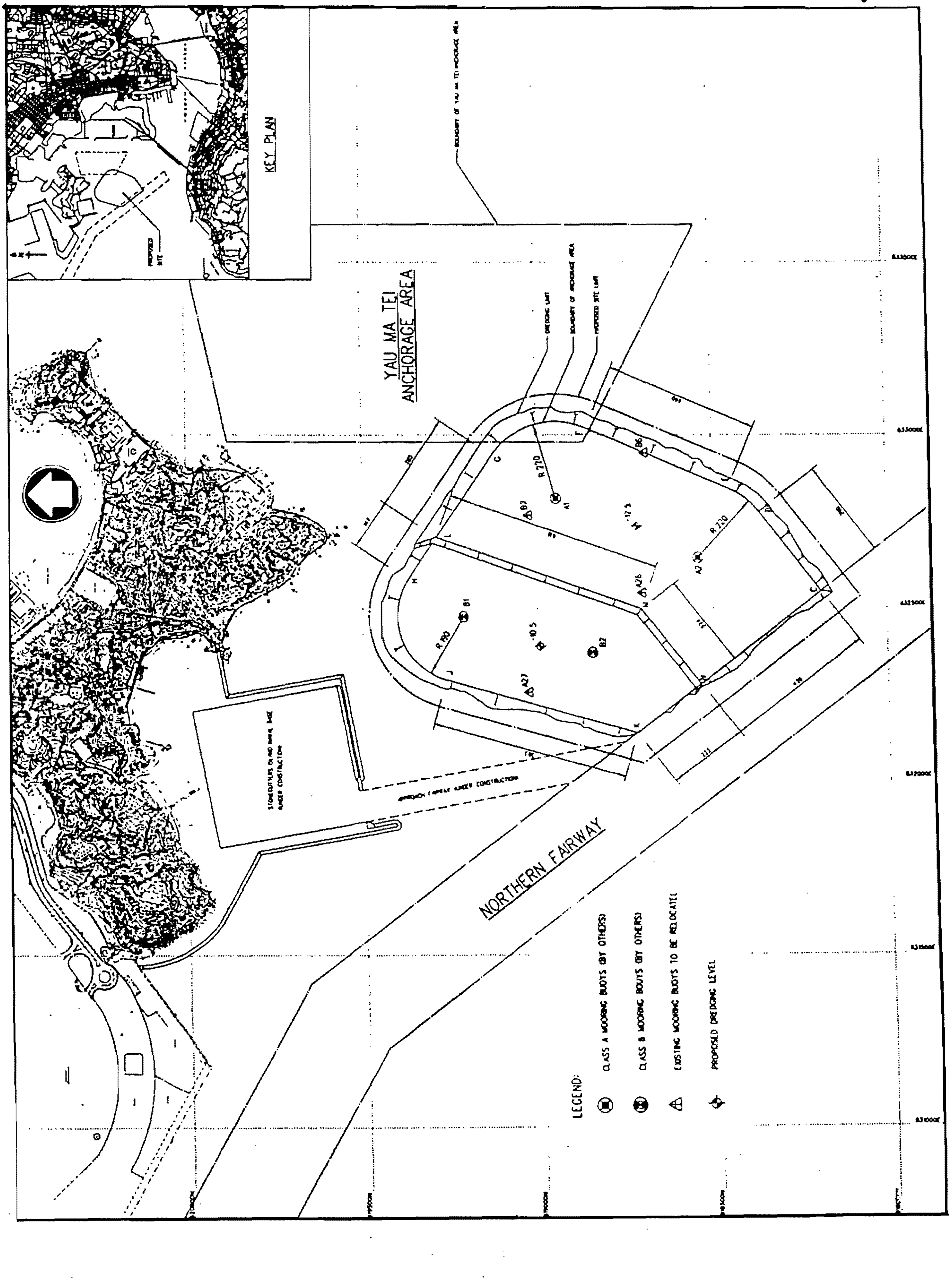


Figure 2.2a
Residual Flows in Winter

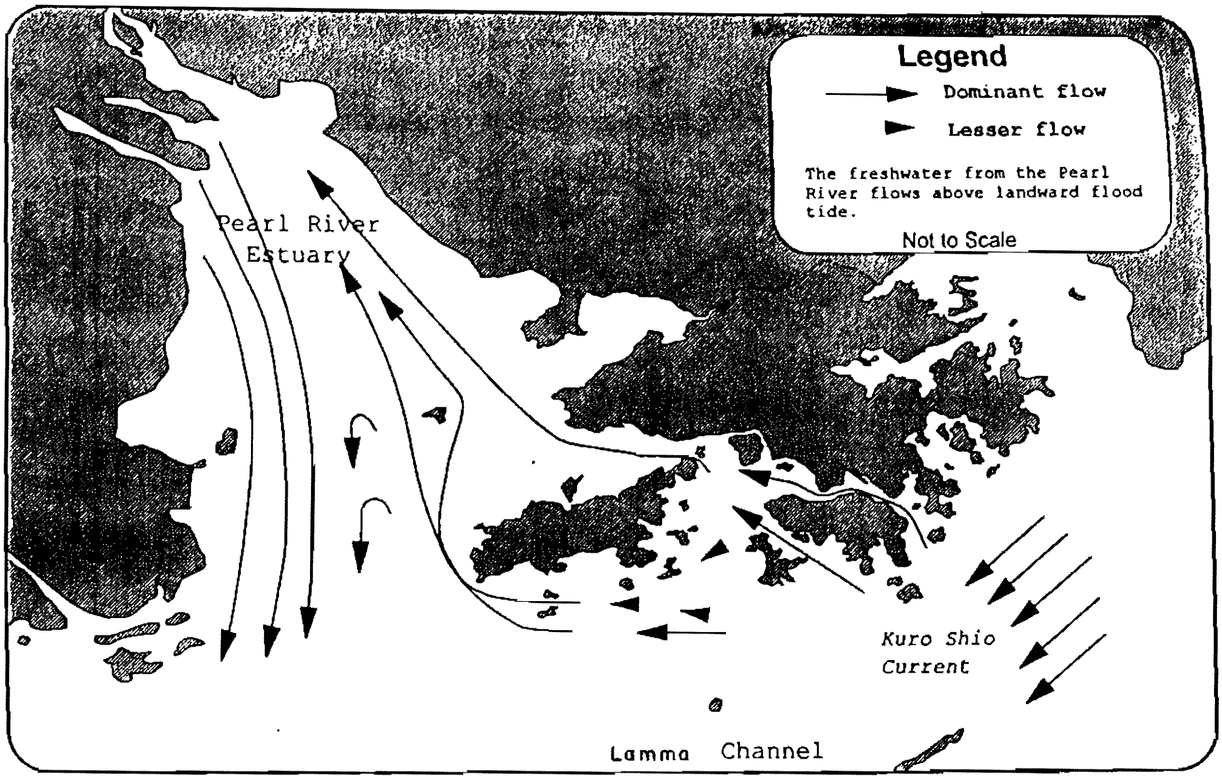


Figure 2.2b
Residual Flows in Summer

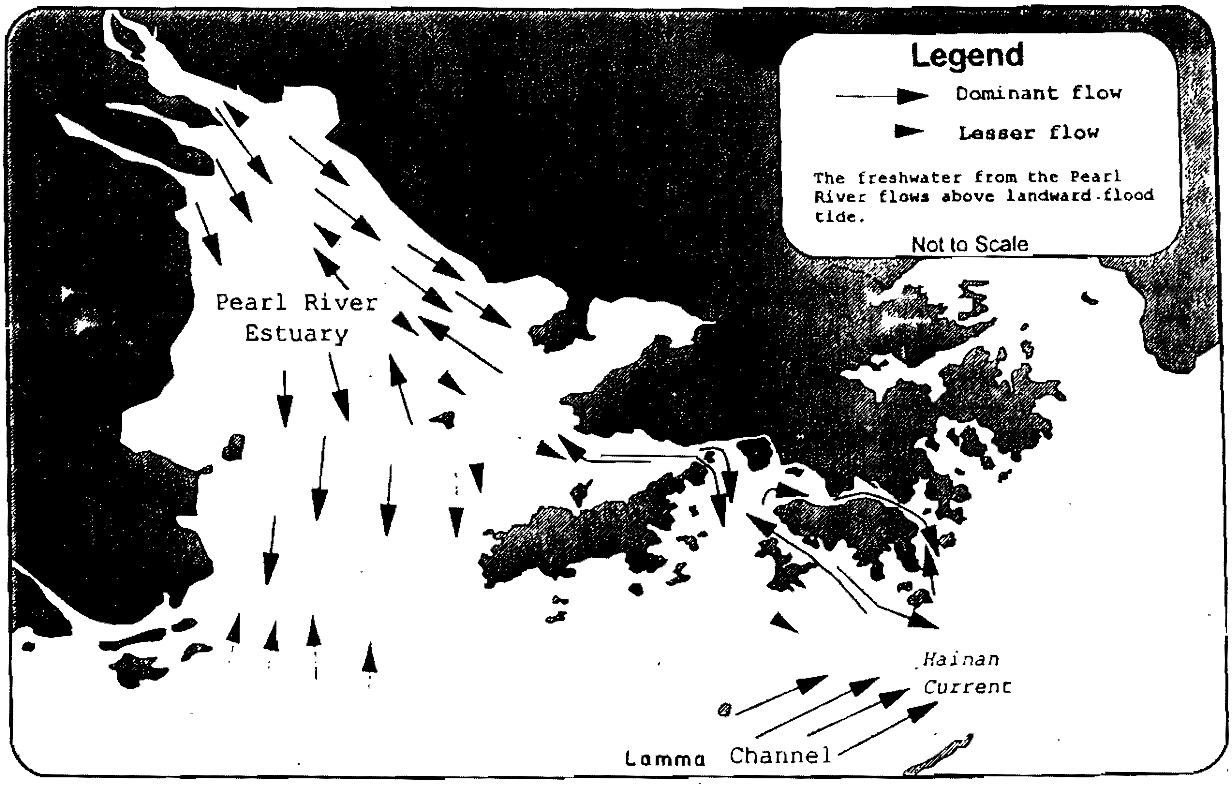
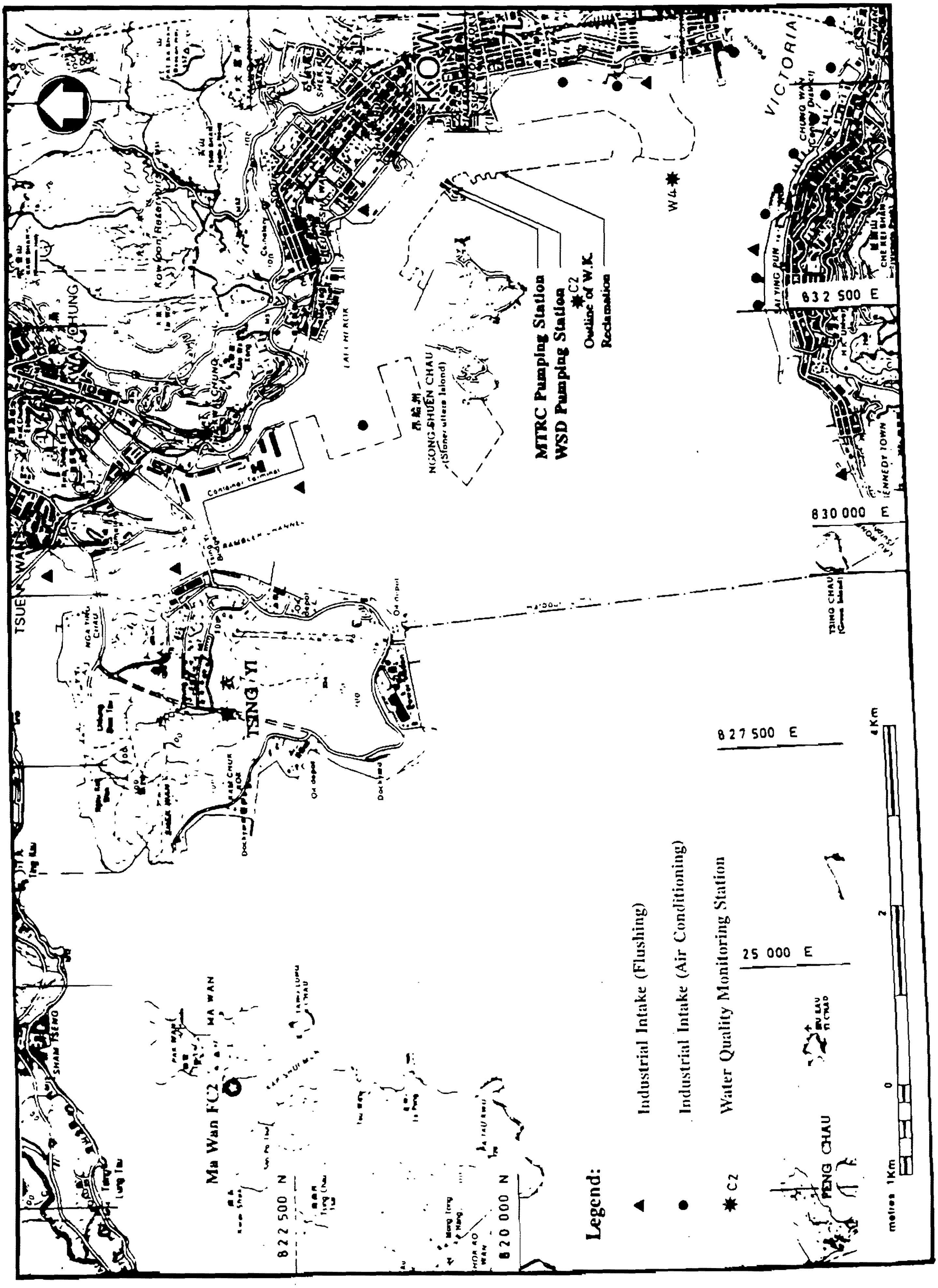


Figure 2.3
Water Quality Monitoring Stations and Sensitive Receivers



3. IMPACT ASSESSMENT

3.1 Key Issues to be Addressed

Construction works required to provide the new anchorage area for the four permanent mooring buoys include dredging to a depth of between -10.5 and -12.5mCD by removing an estimated 2.3Mm^3 of marine deposits. The quality of the material to be dredged will determine any constraints on the dredging methods adopted as well as the disposal of the spoil. Sediment quality and the potential release of pollutants to the receiving waters during dredging and disposal of the marine deposits are therefore key issues to be addressed through this Study.

Once the anchorage area has been established the local tidal regime could be affected by changes in bathymetry which could in turn alter the existing sediment transport and deposition patterns both locally and further afield. The key issue to be addressed in connection with the post construction phase relates to the extent of any changes in the tidal and sedimentation regimes.

3.2 Assessment Methodology for the Construction Phase

3.2.1 Effects of Dredging

Dredging of the anchorage area for the provision of four new permanent mooring buoys will be undertaken in the area illustrated on Figure 2.1. The tentative works programme indicates that construction will be carried between August 1996 and March 1997.

Construction schedules have been prepared for two dredging scenarios as shown on Figures 3.1 and 3.2. One Scenario assumes the use of grab dredgers (which equates to the scenario where mud is found to be contaminated) while the other scenario has been developed assuming the use of the trailing suction dredgers for all uncontaminated mud. A sediment quality study was undertaken to define any restrictions on dredging or disposal of spoil by surveys, bulk sediment quality analyses and a suite of elutriate tests.

3.2.2 Sediment Quality Study

Marine dumping of dredged marine mud is controlled by licence under the Dumping at Sea Act 1974 (Overseas Territories) Order 1975. Procedures to be adopted are set down in Works Branch Technical Circular No. 22/92 for all works, both public and private, which involve the marine disposal of dredged mud. Marine sediments are classified in the EPD Technical Circular (TC) No. 1-1-92 according to their level of contamination by toxic metals. The classes are defined 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 Requirements, 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 minimises 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.

The contamination limits of dredged sediments delineating these classes are shown in Table 3.1.

Table 3.1 Classification of Dredged Sediments for Marine Disposal

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	≥ 80	≥ 65	≥ 1.0	≥ 40	≥ 75	≥ 200

Note : Test results should be rounded off to two significant figures before comparing with the table, e.g. Cd to the nearest 0.1 mg/kg, Cr to the nearest 1 mg/kg, and Zn to the nearest 10 mg/kg

Source : EPD Technical Circular No. 1-1-92

Details of the sediment sampling and testing programmes are given in Appendix A.

The two tier testing programme was derived as follows:

Tier One

- to provide an estimate of the quantity of sediment which is contaminated and requires special disposal arrangements; and
- to quantify the metal loads associated with disposal of the dredged material.

Tier One Tests : bulk sediment analyses which are the standard method adopted for all dredging projects in Hong Kong. Sediment samples were analysed for heavy metals and organic pollutants as defined in the relevant technical circulars.

Tier Two

- to define the concentration of metals and other persistent pollutants which could be released during dredging.

Tier Two Tests : elutriate tests which provide an indication of the potential extent of contaminant release into the water column as a result of dredging and disposal of marine deposits. These tests also allow the effects of resuspended dredged material to be more realistically defined than if bulk sediment analyses were used in isolation.

Elutriate tests were developed by the US Army Corps of Engineers and the US EPA following publication of research work which indicated that direct analysis of sediments did not provide an accurate guide to the potential effects of resuspended sediments on the water column or life supported therein. Elutriate tests essentially consist of mixing one part of sediment sample with four parts seawater, agitating the mixture to resemble the action of hydraulic dredging, and leaving it to settle. The mixture is then filtered and the supernatant analysed for the components of concern. The laboratory schedule for the tests on sediment, elutriates, and seawater, testing procedures and the location of the three samples is given in Appendix A.

3.2.3 Mathematical Modelling Study

Mathematical modelling techniques were employed to:

* determine the potential for migration of sediments from the dredging site;
* to define the extent of the near-field impacts; and
* to identify the need for maintenance dredging.

The sediment plume model of the WAHMO suite was used to simulate the action of dredging and the release of sediment to the water column. The plume model was set to simulate the release of all of the sediment to the surface layer thereby predicting the worst case scenario in terms of off-site transportation. Two discrete scenarios were modelled. The first assumed that dredging would be conducted using a trailing suction dredger, with the second set of simulations assumed the use of two grab dredgers.

It was ascertained that:

(i) dredging for Stonecutters Island Permanent Site for Mid-Stream Operations is scheduled to be completed by the end of May 1996;

(ii) there is no further dredging required for SSDS Stage I;

(iii) the dredging of the Naval Basin per se will be undertaken behind well established seawalls; and

(iv) dredging for the access channel to the Naval Base has now been advanced and will be completed before this Project commences. There will therefore no overlap with the construction works programmed for the Anchorage Area.

Direct, short term or intermittent exposure of benthos or epibenthos to metal or organic compounds associated with the disposal of contaminated material may give rise to acute toxic impacts occurring in the near field, or in close proximity to the point of release. The degree of toxicity and the extent of the impacts depends on the level of contamination, the amount of entrainment which occurs within the water column, the degree and rate of initial dilution and dispersion of the dredged sediments and the sensitivity of any aquatic species which may inhabit the area.

Reference was made to the guidelines and standards proposed by the State of California for the protection of marine life and the guidelines given by the USEPA in connection with the protection of marine life during the dredging operation.

In order to determine the total suspended sediment concentrations from the dredging activities the calibrated simulations of natural suspended sediment concentrations were run with the additional loading from the dredging activities. These results were then assessed in terms of overall suspended sediment concentrations associated with dredging operations.

3.3 Assessment Methodology for the Post Construction Phase

3.3.1 Flow Modelling Study

Several existing two-dimensional two-layer tidal flow and water quality models cover a large area around Stonecutters' Island. It was agreed at the outset that the 100m Western Harbour model would be the most suitable of the existing models for this application, as the area covered is sufficiently large to include the impacts of the construction of the anchorage area.

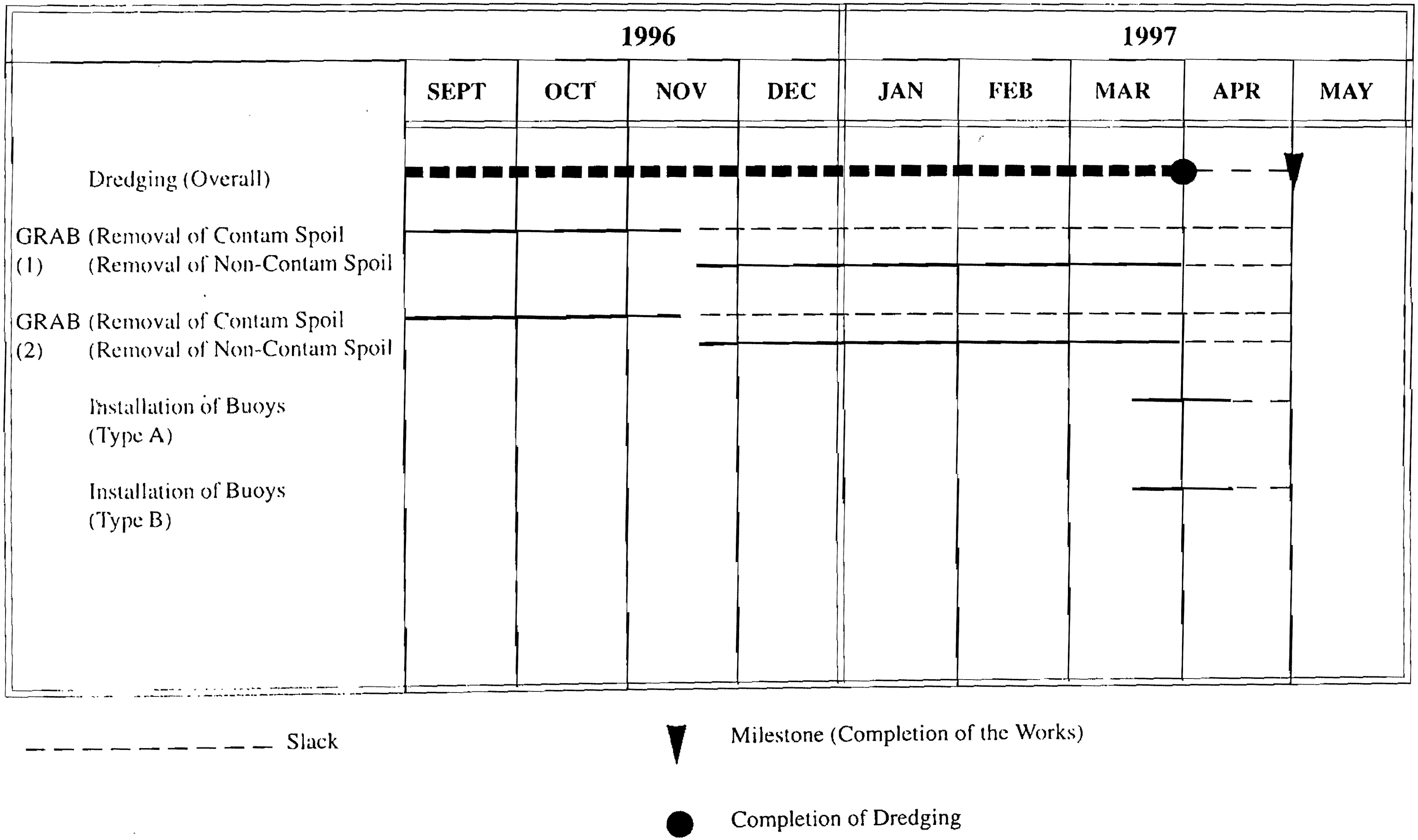
This model has been previously calibrated against a large data set which was collected during 1987/88. The model was set up for present day conditions and run for the four representative tides, which are wet and dry season spring and neap tides, to form the baseline data set. The model was re-run to include the completed anchorage and the results compared with the baseline simulations to quantify the effects of modifying the existing bathymetric conditions the anchorage area on the tidal flow regime.

3.3.2 Sediment Transport and Deposition Study

The WAHMO sediment transport model (MUDFLOW) was used to simulate the natural (background) suspended sediment concentrations over the whole of the Western Harbour and the effects of the completed anchorage sediment regime.

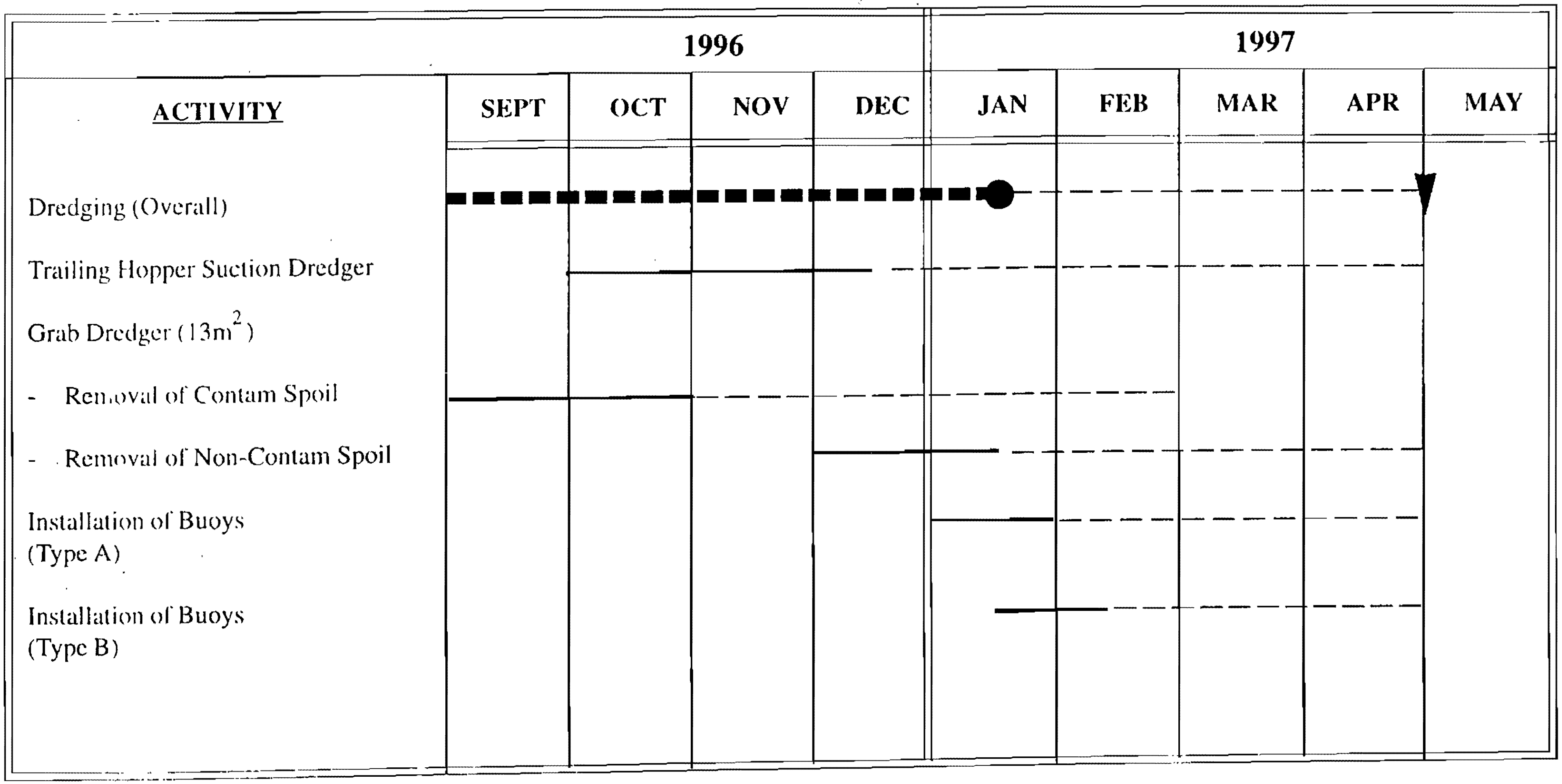
The model was first calibrated against existing data which were measured during 1987/88. Using the results from the tidal flow simulations the existing (1995) conditions were run for the four representative tides to provide baseline data. The completed anchorage was included in the model geometry to simulate the effects of the anchorage on the natural sediment regime in the area and on the likely sedimentation rates within the anchorage area. Using the results from the sediment transport simulations an assessment was thus made of the stability of the deposited material within the anchorage area and the likely re-suspension rates of this material.

Figure 3.1
Construction Programme Option A



OPTION A

Figure 3.2
Construction Programme Option B



— — — — — — — — — Slack

▼ Milestone (Completion of the Works)

● Completion of Dredging

OPTION B

4. IMPACTS ON THE MARINE ENVIRONMENTAL DURING CONSTRUCTION

4.1 Effects of Dredging

Environmental impacts associated with dredging can be subdivided as follows:

- physical effects : resuspension and redeposition of particles during the dredging operations and changes in physical habitat due to smothering of benthos.

- chemical effects : oxidation of released sediments, potential proliferation of bacteria which feed on resuspended organic matter.

- biological effects : short term alteration in phytoplankton productivity as a result of decreased light penetration or proliferation of some species at the expense of others due to overabundance of nutrients, and adverse impacts of silt and clay particles on the branchiae of fish, and abrasive effects on crustaceans.

- social implications : visual impacts of dredging in terms of the recreational use of waters, damage to commercial fishing grounds or high levels of suspended solids at seawater intake points.

Key issues which were addressed through this assessment include:

(i) the definition of the extent of the potential sediment contamination;

(ii) determination of the response of the marine environment to the potential release into the water column of trace metals and organic micropollutants from the material being dredged; and

(iii) definition of the mitigation measures which will minimise the impacts of dredging to the lowest acceptable level.

The geochemical form of trace metals within sediment samples plays a significant role in determining the potential impacts on the marine environment. Although bulk chemical analyses provides an indication of the total contaminant levels within a sediment sample, the mere presence of a contaminant does not necessarily infer that it will either have an adverse impact on water quality or be available for uptake by aquatic organisms.

Metals may be :

(i) bound tightly within the crystalline lattice structure of the minerals within sediments and are not thus released except through the weathering process. Such metals, including aluminium and magnesium, are usually inert and are thus biologically unavailable;

(ii) bound through a variety of ionic interactions, involving negatively charged surfaces of minerals or large organic molecules and positively charged cations including trace metals. Substances in this form, often termed exchangeable cations, are relatively easily mobilised particularly under acidic conditions; or

(iii) dissolved in interstitial waters (pores) and although this fraction is generally relatively small these contaminants are comparatively easily mobilised and are often available to biota. Contaminants in interstitial waters exist as free ions, in various organic and inorganic complexes, and their concentration is independent of the total contaminant level.

Metals, nutrients and organic materials which are bound into the sediment interstitial waters or adsorbed to the cation exchange complex, are the most mobile and potentially available contaminants in dredged material. Anoxic sediments will frequently contain trace elements which are readily mobilised.

Contaminants, such as polychlorinated biphenols (PCB's) and chlorinated hydrocarbons are more complicated than organo-metals as they are not bound within mineral lattices, they do not occupy positions in clays or form sulphides or other insoluble compounds, nor are they part of the exchangeable fraction. Instead, synthetic organics are almost exclusively found in the adsorbed form, usually associated with dissolved and particulate organic pollutants and carbon in sediments, connected to various organic molecules by Van der Waals forces.

Only a fraction of the PCB's and chlorinated hydrocarbons which are bound to the sediments are available in the interstitial water of sediments, and therefore it may be concluded that only a very small percentage of the overall contaminant load will be bioavailable.

Redox potential (Eh) is one of the most important factors influencing the remobilization of metals from sediments. Anoxic sediments which are characterised by an Eh of -100 mV or less, while well oxygenated waters will, in contrast, have an Eh of >400 mV. If anoxic sediments are dredged from or disposed of in well oxygenated waters (i.e. dissolved oxygen levels greater than 4mg/l), the physio-chemical state of metals within the sediments may be affected and some metals will become more mobile.

In addition to redox potential, the pH of both the sediments and the receiving waters can also affect the availability of some metals with a consequential increase in the amount of metal released initially to the water column.

Reference criteria are the Water Quality Objectives, given in Table 2.1 and the guidelines prepared through research by and on behalf of the USEPA for the protection of marine life given in Table 4.1.

Table 4.1 Reference Criteria and Guidelines for the Protection of Marine Life

Parameter	Guidelines for Protection of Marine Life	Effects Associated with Concentration of Pollutants in Sediments
pH	> 6.5 < 8.5	existing conditions acceptable in terms of the overall WQO's and the protection of marine life
Cd	marine life : 0.005 mg/l (USEPA)	well documented evidence to suggest tolerance of marine organisms to Cd is higher than freshwater organisms. Cd chemistry particularly affected by brackish conditions (dredging in the dry season so well mixed water column will prevail). Acute and chronic thresholds for marine organisms documented as being 96 and 31 ppm respectively. Wide range of apparent effects thresholds. ER-L in sediments is 5ppm.
Pb	marine life : 0.050 mg/l (USEPA)	Lethal concentration of Pb 0.1ppm with effects increasing in presence of Ni and Zn. Organolead compounds more toxic than inorganic forms. ER-L 35ppm in sediments.

Table 4.1 Reference Criteria and Guidelines for the Protection of Marine Life (Cont'd)

Parameter	Guidelines for Protection of Marine Life	Effects Associated with Concentration of Pollutants in Sediments
Hg	marine life : 0.10 ug/l (USEPA)	Acute toxicity to marine organisms >3.5ppm, organomercury considerably more toxic than inorganic forms. ER-L of 0.15ppm
Cr	marine life : 0.100mg/l (USEPA)	Toxicity of Cr affected greatly by speciation. Acute toxicity to marine life of Cr (VI) occurs in the range of 2,000 to 105,000ppm. Acute toxicity to Cr (III) observed at concentrations of 10.300 to 31,500 ppm (USEPA). No overall apparent effects threshold able to be defined as the data are wide ranging. ER-L of 80 ppm.
Cu	marine life : 0.050mg/l (USEPA)	Effects on marine life observed between 5 and 600 ppm. Effect on Crassostrea gigas found to be of the order of 400 ppm. ER-L of 70 ppm
Ni	marine life : 0.100mg/l (USEPA)	Toxicity influenced by hardness and salinity. Toxic to marine organisms at concentrations as low as 38 ppm (LC50 for 96 hours for estuarine fish species). No apparent effect threshold on the basis of the data available. ER-L of 30 ppm.
Zn	marine life : 0.100 mg/l (USEPA)	Data suggest sublethal effects 50 - 125 ppm and almost always acute effects observed at >260 ppm. LC_{50} for estuarine fish reported to range from 192 to 320,000 ppm. ER-L of 120ppm.
Amm-N	marine life : 0.400 mg/l (unionised as NH_3) (USEPA)	
DDT	marine life : 0.001ppm as 24 hour average with no exceedance of 0.13ppm (USEPA)	Acute toxicity of DDE in saltwater at 14ppm. ER-L of DDT 1ppb in sediment ER-L of DDE 2ppb ER-L total DDT 3 ppb
Tributyl Tin	marine life : adverse impacts on gastropods and molluscs but levels for protection of marine life not included in the specification obtained.	no conclusions drawn on tin or TBT from the data collected in the research programmes.
PCB's	marine life : <0.001ug/l (USEPA)	Acute toxicity of PCB's in saltwater >10ppm although oyster larvae affected at 400ppb. ER-L of 50ppb

4.2 Sediment Plume Simulations

4.2.1 Introduction

Once in suspension, fine sediment will be carried by the tidal currents and dispersed, possibly over a large area depending on tidal conditions. During transport by the tidal currents, the fine sediment will tend to flocculate forming larger particles which will settle under gravity on the seabed. The rate of settling for cohesive sediments will depend on the concentration and on the local tidal currents. Once the tidal currents become sufficiently weak, the sediment will settle to the seabed and begin to consolidate. If the tidal currents become large enough, the settled material will be eroded and put back into suspension for further transport by the tidal currents where the rate of erosion will depend on the tidal currents and the degree of consolidation which may have taken place.

The WAHMO sediment plume model was designed to simulate these processes of transport, deposition and re-erosion for narrow sediment plumes formed during dredging or dumping activities and was used for this study.

4.2.2 Sediment Plume Model Description

The sediment plume model, SEDPLUME, forms part of the WAHMO suite of coastal hydraulic and water quality 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 suspension using a random walk technique and includes the processes of deposition and erosion at the seabed. The plume model uses results from the WAHMO two-dimensional two-layer model of tidal flows as basic tidal flow data.

The plume model simulates the loss of sediment to suspension by introducing particles into the model area at specified locations and positions within the water column. The particles are released at a set rate and are given a fixed mass to simulate the rate of sediment loss. The particles are tracked throughout the model and at specified storage intervals the number of particles in each cell is summed and the concentration of sediment calculated. The grid size for the sediment plume model can be set to finer than the flow model which forms the input data but the interface level between the upper and lower layers is the same in both models.

An analysis of the results from the plume model may be made to determine the effect of suspended sediment on dissolved oxygen levels. The analysis is based on the following relationship :

$$DO_{res} = DO_{back} - (C*SOD*K*0.001)$$

where

DO_{res}	=	resulting dissolved oxygen level in mg/l
DO_{back}	=	ambient dissolved oxygen level in mg/l
C	=	tidal average suspended sediment concentration in kg/m^3
SOD	=	sediment oxygen demand in mgO/kg sediment
K	=	daily oxygen uptake factor
	=	0.23

The analysis does not allow for reaeration, which would be a minor factor in the above relationship, and so gives conservative results.

The results may also be analysed to determine the concentrations of nutrients released into the water column from the suspended sediments by assuming that the nutrients associated with the sediment lost to suspension are transported and diluted at the same rate as the sediment in suspension.

4.2.3 Scenarios Simulated by the Sediment Plume Model

The sediment plume model SEDPLUME has been used to simulate the following Scenarios for dredging of the Stonecutters Naval Base Anchorage Area:

(i) Scenario 1 simulated dredging of the anchorage area with a trailing suction dredger;

(ii) Scenario 2 simulated dredging of the anchorage area using two grab dredgers;

The SEDPLUME model was set up to cover an area large enough to encompass the maximum excursion of sediment in suspension (Figure 4.1) with an horizontal resolution of 50m, which is finer than the flow model which used a grid size of 100m.

Even with "clean dredging" techniques, sediment will still be released to the water column around the dredging site. The aim is to minimise both the generation of the plume in the water column and the off-site transportation of this material as it can:

- adversely affect water quality, especially at seawater intakes (indicated on Figure 2.3);
- can affect marine life; and
- be visually intrusive.

In order to determine the potential effect of dredging on receiving water quality, an estimate of the potential sediment releases to the water column was made assuming a worst case scenario. The potential impacts in terms of off-site migration of sediment and the potential depletion of dissolved oxygen and elevations in nutrient levels were predicted using the sediment PLUME model from the WAHMO suite and the results compared to the WQO's, given in Table 2.1.

The colour contour plots illustrated the potential impacts for different dredging scenarios/rates in terms of suspended solids concentrations, dissolved oxygen depletion and elevations in concentrations of nutrients in the water column. A baseline DO value of 6 mg/l was used as input to the model on the basis that this represented conditions in close proximity to the site (on the basis of monitoring data collected under other Projects). The release of ammoniacal, organic and total inorganic nitrogen during dredging was simulated by using the data from the elutriate tests as input to the model.

Scenario 1 simulated a very worst case scenario in which a trailing suction dredger with a production rate of 40,000 m^3/day was used. Assuming a loss rate of 5% and a dry density of the fines of 488 kg/m^3 this gives a loss to suspension of 976,000 kg/day. This type of dredger will work continuously which means that the rate of sediment lost to suspension will be 11.3 kg/s. The loss of sediment to suspension was simulated by releasing sediment at six points covering the whole of the anchorage area (Figure 4.2) in order to simulate the maximum possible spread of sediment released to suspension during the dredging. Sediment was continuously released at each of the six points at a rate of 1.88 kg/s. Scenario 1 was simulated for the wet and dry season spring and neap tides.

Scenario 2 simulated two grab dredgers with a total daily production rate of 12,800 m^3. Assuming a loss rate of 5% and a dry density of the fines of 488 kg/m^3 gives a loss to suspension of 312,320 kg/day. The grab dredgers will work during daylight hours only which equates to a total of 16 hours per day which gives a total loss of sediment to suspension of 5.42 kg/s. The loss of sediment to suspension was simulated by releasing sediment at two points within each half of the anchorage area (Figure 4.3) which corresponded to each of the two grab dredgers. Sediment was released at each of the two points for 16 hours at a rate of 2.71 kg/s. Scenario 2 was also simulated for the wet and dry season spring and neap tides.

In order to minimise settling of the sediment in the immediate vicinity of the release points the sediment was introduced into the model at the water surface which is a worst case approximation.

The analysis of the impacts of suspended sediments on dissolved oxygen levels was based on an ambient, background, dissolved level of 6 mg/l, with a sediment oxygen demand of 52,500 mgO/kg sediment. These values are the same as those used for the assessment of the Permanent Site for Mid-Stream Operations at Stonecutters and equate to very contaminated mud.

Elutriate testing of sediment samples from the existing seabed at the site of the anchorage area has shown the sediment has maximum available levels of ammoniacal nitrogen of 12 mgN/kg sediment and levels of inorganic nitrogen of 16 mgN/kg sediment.

The sediment plume model was thus used to simulate the (unmitigated) impacts of dredging on receiving waters during the wet and dry seasons during both the spring and neap tides before any mitigation measures were considered. As the results are linear it was possible to consider any dredging scenario which may be considered on a pro rata basis, using the above reference scenario.

The results from the sediment plume simulations have been presented as time varying suspended sediment concentrations at 25 selected stations (Figure 4.4) and as colour contour plots of suspended sediment concentrations at times following the peak ebb and flood phases of the tide. The results from the sediment plume simulations have been processed to determine the impact of the sediment plumes on dissolved oxygen levels and nutrient concentrations and these are shown as colour concentration plots of daily averages. The results from all the sediment (unmitigated) plume simulations are contained within Appendix D.

Discussion of the results obtained from the modelling study follows in Section 4.2.4 and 4.2.5 with the implication of these results and mitigation measures discussed fully in Section 6.

4.2.4 Scenario 1 : Trailing Suction Dredger

The graphs of suspended sediment concentrations at the 25 stations show maximum concentrations of over 70 ppm for stations 12 and 13, which are within the anchorage area, for the wet season and over 40 ppm in the dry season. Of the stations which are not in the immediate vicinity of the anchorage area the maximum concentrations are at Station 4 in both the wet and dry seasons, with values in the lower layer of up to 40ppm on the wet season spring tide and up to 30ppm on the dry season spring tide. On the dry season spring tide suspended solids values at Station 2 of up to 30ppm are predicted which is due to the stronger flood tide in the dry season because the large fresh water discharge from the Pearl Estuary does not dominate flow conditions as it does in the wet season. On the ebb side of the anchorage area, at Stations 21, 22 and 23, maximum concentrations are up to 10ppm on the wet season spring tide and 20ppm on the dry season spring tide.

The contours of suspended sediment concentrations show plumes on the flood tide extending from the anchorage area to beyond Container Terminal 8 and beyond Kai Tak along the northern side of Victoria Harbour on the ebb tide. The plots for the flood phase of the tide show suspended sediments being present on the eastern, ebb, side of the anchorage area. These suspended sediments are a result of sediment in suspension from the previous ebb tide being carried back in the flood direction once the tide turns. Maximum sediment concentrations at the anchorage area are over 45ppm but these elevated suspended sediment concentrations rapidly decrease outside the anchorage area to be no more than 15ppm.

On the flood tide suspended sediment concentrations are up to 15ppm in the vicinity of The Permanent Site for Mid-Stream Operations but reduce to be in the range 1-5 ppm further along the plume. On the ebb tide sediment concentrations in the surface layer up to 15ppm at Kai Tak are forecast with a reduction further eastwards. In the lower layer there is a consistent plume of 15ppm up to the western end of Kowloon Bay, with peak concentrations in the range 15 - 25ppm.

Using the water quality monitoring data given in Table 2.2 for Station C2 the baseline concentration of suspended solids in this area is taken to be 15.9mg/l. The WQO for suspended solids allows 30% elevation i.e. 20.7mg/l (which equates to 5mg/l permitted to be added to the water column). On this basis and assuming that no mitigation measures are applied, at stations 6, 7, 12, 13 and 18 and to a lesser extent at 4, 17, 19 and 22 (mainly in the dry season), the WQO will be exceeded (refer to Table 4.2). It should be noted that the dredging rate assumed in the model is twice that which would be anticipated (and twice the rate assumed in the programme given in Figure 3.2).

In addition to which Stations 6, 7, 12, 13 and 18 are all within the dredging area, and none of the stations external to the actual works area will exceed the WQO even assuming this highest (and unmitigated) dredging rate.

Table 4.2 Summary of Maximum Impacts Associated with Dredging (ppm)

Station	Trailing Suction Dredger (TSD)				Grab Dredger (GD)			
	Wet, Spring	Wet, Neap	Dry, Spring	Dry, Neap	Wet, Spring	Wet, Neap	Dry, Spring	Dry, Neap
1	-	-	-	-	-	-	-	-
2	2	1	14	6	-	-	2	3
3	2	1	1	1	1	-	-	-
4	8	6	18	19	1	2	14	13
5	4	-	1	1		-	-	-

Table 4.2 Summary of Maximum Impacts Associated with Dredging (ppm) (Cont'd)

Station	Trailing Suction Dredger (TSD)				Grab Dredger (GD)			
	Wet, Spring	Wet, Neap	Dry, Spring	Dry, Neap	Wet, Spring	Wet, Neap	Dry, Spring	Dry, Neap
6	**10**	**18**	**32**	**32**	**15**	**18**	**25**	**20**
7	**40**	**33**	**24**	**15**	**2**	**31**	**3**	**2**
8	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-
12	**45**	**62**	**45**	**42**	**12**	**5**	**3**	**10**
13	**65**	**69**	**35**	**32**	**62**	**72**	**45**	**40**
14	**4**	**3**	**4**	**5**	**1**	-	**2**	**2**
15	3	2	3	4	-	-	-	1
16	2	-	-	1	-	-	-	-
17	5	7	4	8	-	-	2	2
18	**41**	**37**	**40**	**32**	**32**	**38**	**55**	**30**
19	13	3	10	13	4	-	4	4
20	-	-	-	-	-	-	-	-
21	2	2	-	-	-	-	-	-
22	15	2	10	14	8	-	3	8
23	3	-	2	4	-	-	-	-
24	-	-	-	-	-	-	-	-
25	3	-	-	-	-	-	-	-

The plots of sediment deposition show the majority of the sediment settling in and around the anchorage area, with an area of deposition on the southern side of Container Terminal 8 and towards Kowloon Point. On the spring tides, reflecting the stronger tidal currents and hence the greater transport of sediment, deposition is shown to occur along the northern edges of Victoria Harbour and the entrance to Kowloon Bay, but at low rates of deposition, 0.01-0.1 kg/m^2/tide.

The plots of daily dissolved oxygen levels show areas of depleted oxygen levels extending from Container Terminal 8 to Kai Tak. Within Victoria Harbour the oxygen levels are depleted by less than 0.02 mg/l in the upper layer and 0.04 mg/l in the lower layer, with a narrow band of higher depletion levels, up to 0.06 mg/l, extending along the northern side of Victoria Harbour between the southern end of the West Kowloon Reclamation and Ocean Terminal. In the vicinity of the anchorage area dissolved oxygen levels are less than 5.92 mg/l in both the upper and lower layers but still achieve the WQO's.

The plots of ammoniacal and inorganic nitrogen show extremely low concentrations throughout, with maximum levels of greater than 0.0003 mg/l at the site of the release points in the sediment plume model. The majority of the area affected by elevated levels of nitrogen has concentrations of less than 0.00006 mg/l and thus will achieve the WQO's.

Following the assessment of the results of nitrogen release for Scenario 1 it was decided not to analyse the sediment plume results from Scenario 2 for either ammoniacal or inorganic nitrogen impact because the values given for Scenario 1 are so low as to be beyond detection limits and the suspended sediment results from the other Scenarios do not show significantly higher suspended sediment concentrations.

It may therefore be concluded that the WQO's will not be exceeded for DO, ammonia or nutrients. It should also be noted that none of the sensitive receivers (seawater intakes) will affected as the plumes do not ingress the sheltered Yau Ma Tei embayment.

4.2.5 Scenario 2 : Grab Dredgers

The graphs of suspended sediment concentrations at the 25 stations show maximum concentrations at Station 13, which is within the anchorage area, of 70ppm in the wet season and 40ppm in the dry season. Along the edges of the anchorage area, at Stations 7 and 18, maximum concentrations are up to 40ppm at Station 7 for the dry season spring tide and 30ppm at Station 18 for the dry season neap tide. At the stations remote from the dredging, suspended sediment concentrations are less than 5ppm, reflecting the lower dredging rate and hence lower concentrations. The graphs of suspended sediment concentrations at the 25 stations show that the high suspended sediment concentrations will be contained in the region local to the anchorage area.

The contours of suspended sediment concentrations again show plumes extending from the anchorage area to Container Terminal 8 on the flood tide and along the northern side of Victoria Harbour to Kai Tak on the ebb phase of the spring tides but the plumes do not extend beyond Ocean Terminal on the ebb phase of the neap tides. For the spring tides the ebb plume does not fully form until after dredging has stopped after each 16 hour cycle and so no suspended sediments are shown at the dredging site. On the spring tides concentrations on the ebb plume within Victoria Harbour are low, less than 5ppm in the upper layer and less than 10ppm in the lower layer. Neap tides show similar low concentrations in the vicinity of Ocean Terminal, with diffuse areas of sediment concentrations of less than 5ppm along the northern shore of Victoria Harbour on the wet season neap tide.

The largest flood tide plume is formed on the dry season spring tide with concentrations of up to 15ppm in the surface layer and 25ppm in the lower layer in the vicinity of Container Terminal 8. The other tides show low concentrations, less than 5ppm, at the limits of the flood plumes. The contour plots show that the higher concentrations, greater than 25ppm, generally occur within the anchorage area close to the dredging site.

The plots of sediment deposition show that most of the sediment settles in and around the anchorage area, with deposition, for the most part, being contained within the area between Container Terminal 8 and the tip of the West Kowloon Reclamation. The spring tides show some deposition occurring within Victoria Harbour, along the coastline of the Kowloon Peninsula, but the rates are low, less than 0.1 kg/m^2/tide. The highest deposition rates of greater than 0.7 kg/m^2/tide, particularly on the neap tides where there is less dispersion by the weaker tidal currents, occur at the site.

The plots of daily dissolved oxygen levels shows a similar area of depleted oxygen levels as Scenario 1 but the areas of higher depletion levels, greater than 0.02 mg/l, are greatly reduced reflecting the lower dredging rate in Scenario 2.

It may be concluded that the WQO for DO would not be exceeded, nor would any sensitive receiver be adversely affected. Using the some criteria for SS it may be concluded that if no mitigation measures are applied, at a release rate of 5%, the WQO for SS will be exceeded at Stations 12, 13 and 18 on all tides/seasons and at stations 4, 6, 7, 12, 18 and 22 under varying conditions albeit to a lesser extent. Mitigation measures and methods of minimising the release rates are discussed in Section 6.

4.2.6 Dredging Methods

It should be stressed that the choice of dredging plant will ultimately be the Contractor's choice. As the water depth is about 10m, both trailer suction and grab dredgers could be used for this Project. The relative performance of trailer suction dredger versus grab dredgers is summarised in Table 4.3 below.

Table 4.3 Performance of Trailer Suction and Grab Dredgers

Trailer Suction Dredger	Grab Dredger
Main causes of turbidity around the dredger from the use of overflows and discharge from degassing systems.	Main causes of turbidity around the dredger from the use of grabs, and the overflow of material.
Suspended solids concentrations are of the order of 100mg/l except in the immediate vicinity of the dredger.	Suspended solids concentrations in excess of 100mg/l throughout the water column are expected. An increase in the size of grab will result in a corresponding increase in the suspended solids concentration in the water column.
Operational performance variable depending upon the size of dredger with respect to the water depth.	Operational performance variable depending on the duty of care provided.
Note: if overflow not permitted, the suspended solids concentrations can reduce to about 100mg/l near the bottom of the water column.	Use of water tight grabs is reported to reduce the suspended solids loads to the upper part of the water column but increase the concentrations in the bottom waters.
Extensive reworking of material, more likely to release contaminants to receiving waters.	Less reworking or crushing of material cannot be used if sediment has a high water content.
Careful operation can reduce the release rate to <1% of volume being dredged	Careful operation can effectively reduce the sediment losses by >50%, compared to the unmitigated scenario, especially if sealed and water tight grab dredgers are used.

4.3 Release of Pollutants During Dredging

The elutriate tests were carried out to determine the concentrations of metals, organometals and synthetic organic substances which could be released from the sediments in the Study Area during dredging. The results of these analyses are presented in full in Appendix C.

Background concentrations of all of the parameters tested were also defined by analysing samples of seawater collected from the same location and used as the medium for the elutriate tests (refer to Appendix A). Definition of each parameter in seawater was essential for the computation of the actual release of each contaminant from the sediment sample.

It should be noted that the elutriate tests were originally derived to examine the effects of hydraulic dredging and disposal of marine deposits. As hydraulic dredging involves the entrainment of water within the mass of sediment and denatures the material to a greater extent than grab dredgers (by the action of entrainment and agitation) it may be surmised that the release of hitherto bound pollutants will be greater during hydraulic dredging than if grab dredgers are used. Notwithstanding the foregoing the elutriate testing procedure allows a comprehensive assessment of the effects of dredging on the marine environment to be undertaken compared to using the results of the analyses of bulk sediment samples.

Field studies which have been carried out in the US and Canada to relate the accuracy of the elutriate test to the field situation indicate that the results obtained for chromium, cadmium, arsenic, nickel and zinc have been found to be particularly accurate compared to elutriate test results. The results obtained for lead, mercury and copper were not so accurate as these metals are adsorbed by suspended solids during the dredging and especially disposal operations.

Field studies have also indicated that the release of nitrogen from sediments may be over-estimated (more than an order of magnitude) during the elutriate testing although it is pertinent to note that the concentrations predicted in the present study are less than those for the Permanent Site for Mid Stream Operations, due north of the Study Area. There are several factors which could explain the differences. For example the redox potential in the Study Area indicates that the sediments are more anoxic (the samples may have been taken further down the column, rather than on the surface), the degree of contamination is higher at the more sheltered mid-stream operations site (ie less erosion or reworking of the polluted sediments) and the surface materials could have been eroded before the sediment samples were taken (by wind or wave forces) thus exposing the more anoxic deposits.

Reference criteria for this Project are the WQO's defined under the Water Pollution Control Ordinance, given in Table 2.1. As one of the beneficial uses for this Water Control Zone is protection of marine life specific reference was made to guidelines and standards applied by, inter alia, the USEPA and Environment Canada. Reference was made to the National Ocean Services Technical Memorandum (summarised in Table 4.1) which provided details of the biological effects of sediment sorbed sediments, testing procedures and the apparent effects threshold values for metal, organic and inorganic pollutants. The latter are referred to the lower end of the range of concentrations at which biological effects have been observed in a wide range of organisms (ER-L) for both sediments and marine waters.

A summary of the data obtained from the laboratory testing and the criteria adopted for this assessment are provided in Appendix C and Tables 4.4 and 4.5.

Table 4.4 Contribution of Pollutants from Sediments to the Water Column

Parameters	Elutriate I - Seawater	Elutriate II - Seawater	Elutriate III - Seawater	Average Concentration of Additional Load
Range of pH value	7.6 - 7.9	7.7 - 7.8	7.9 - 8.0	7.6 - 8.0
Redox potential, mV at 25°C in elutriate	-72 to -61	-64 to -56	-60 to -63	-
Total organic carbon content, mg C/L	< 1	< 1	< 1	< 1
Copper content, μg/L	1	0.5	0.5	0.7
Nickel content, μg/L	2.5	24	8.5	11.7
Zinc content mg/L	<0.05	<0.05	<0.05	<0.05
Lead content, μg/L	1.5	n.d.	n.d	1.5
Cadmium content, μg/L	0.5	0.1	0.2	0.3
Chromium content, μg/L	3	1.5	7	3.8
Mercury content, μg/L	< 1	< 1	< 1	< 1
Ammoniacal nitrogen content, mgN/L	7.15	1.38	7.82	5.45
Organic nitrogen content, mgN/L	6.69	0.92	7.35	5.0
Total inorganic nitrogen content, mgN/L	3.55	0.20	2.05	1.9

n.d. seawater concentration below detection level therefore not able to determine the actual extent of the release.

Table 4.5 Organic Pollutant Load

Test	Test	Concentration, μg/L								
No.	item	E1-Sea water	E1-Elutriate	E1-Elutriate II	B1-Seawater	E1-Elutriate I	E1-Elutriate II	E1-Sea water	E1-Elutriate I	E1-Elutriate II
1	TBT	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
2	DDT	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
3	PCB-1016	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
	PCB-1221	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
	PCB-1232	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
	PCB-1242	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
	PCB-1248	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
	PCB-1254	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
	PCB-1260	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1

Comparing the results given in Appendix C and Table 4.4 with the reference criteria given in Table 4.1 it may be surmised that the release of contaminants from the sediments (even using trailing suction dredging) would not cause the criteria for protection of marine life to be exceeded, nor would the cumulative load (i.e. seawater plus pollutant released from sediment) exceed the criteria. It should be however noted in the case of mercury, and PCB's the detection limit is higher than the standard given. It is also worthy of note that despite the extensive studies conducted by and on behalf of USEPA, there were no conclusions drawn from TBT.

The percentage release of contaminants from the bound form (in sediment) to the aqueous phase (seawater) has been calculated and the results are summarised in Table 4.6, from which it can be seen that the maximum release rate is ≤0.1%.

Table 4.6 % Release of Pollutant from Bound to Aqueous Phase

Parameter	Sample 1	Sample 2	Sample 3
Copper	0.1%	0.1%	0.1%
Cadmium	0.1%	n.d.	0.1%
Chromium	0.1%	0.1%	0.1%
Lead	0.1%	0.1%	0.1%
Nickel	0.2%	0.1%	0.1%
Zinc	0.1%	n.d	n.d.
Mercury	0.2%	n.d.	n.d.
TBT	n.d.	n.d.	n.d.
DDT	n.d.	n.d.	n.d.
PCB's	n.d.	n.d.	n.d.
Total Organic Carbon	0.1%	<0.1%	<0.1%

n.d. below detection limits

4.4 Disposal of Spoil

In order to assess the likelihood of heavy metal contamination in the area of proposed dredging for the Stonecutters' Island Naval Base (see Figure 4.5) it was proposed that a suite of sampling and testing of the in situ marine sediments be carried out.

Samples from a total of thirty vibrocore locations across the site were recovered for testing during a marine investigation carried out by Bachy-Soletanche in November 1995. The locations of these vibrocores are shown on Figure 4.6. Sub-sampling and testing for heavy metal contaminants was also carried out in accordance with the Works Branch Technical Circular (WBTC) No. 22/92. The results showed that Class C contamination, as defined in Section 3.2.2, existed in the in-situ deposits to a maximum depth of 6m below existing seabed level.

Sub-sampling of deposits was carried out at 1m intervals between the seabed and 3m depth, and at 6m depth. At each sub-sampling horizon a single sample, approximately 200g in weight was recovered from the centre of the vibrocores using a plastic sampling device. Each sample was taken from just above the proposed sample target depth (with the obvious exception of the surface sample). For example at 3.0m depth, the sub-sample was taken from 2.9m - 3.0m.

All samples were subsequently tested by MateriaLab for the standard suite of heavy metals described by the relevant WBTC. The EPD Technical Circular No. (TC) No. 1-1-92 classifies dredged sediments according to their level of contamination by toxic metals, as outlined in Section 3.2.2. The analytical methods used for detecting the trace metals in the sediment samples were in accordance with the procedures outlined in Table A1 "Analytical Methodology" of Works Branch Technical Circular No. 22/92. Laboratory testing was carried out by MateriaLab in accordance with the American Public Health Association (APHA) testing standards 3111 & 3112B and the American Society for Testing of Materials (ASTM) D3974-81 (Practice B). Results of the tests on the vibrocore samples are summarised in Appendix B, Tables B1-1 to B1-3.

Testing of vibrocore sub-samples taken during the investigation identified that Class C contamination existed at 23 of the 30 locations. In general, Class C contamination was limited to the upper 1 to 2m of sediment. However, two vibrocores VA17 and VA18 indicated elevated levels of lead at 6m depth. However since these concentrations are isolated, lie below the proposed base of dredging and no class C contamination was indicated in the sub-samples directly above (2.9m to 3.0m), these results have been ignored for the purposes of the overall contamination assessment.

Figure 4.7 shows the existing seabed contours at 0.5m intervals, while Figure 4.8 shows the proposed dredging layout for the contaminated material. Figure 4.8 should be compared with Figure 4.9 which shows the proposed dredging layout for the project. An approximate in situ volume of 2,300,000 m^3 (unbulked volume) of soft marine clay will be removed by dredging, of which approximately 1,400,000 m^3 (unbulked volume) will be classified and disposed of as contaminated sediment. Details of the calculations carried out to derive the volumes are given in Appendix B.

The results of the testing carried out on the samples recovered by vibrocore sampling indicate widespread heavy metal contamination generally within the upper two metres of material. It is recommended that the contaminated sediment is dredged and disposed of in accordance with the WBTC 22/92 guidelines for Class C material. It should be noted that closed grabs will be required for the removal of all contaminated material and that trailing suction dredgers will not be permitted for the removal of contaminated sediment.

Figure 4.8 shows the contours of the base of Class C contaminated deposits. The final design of the dredging layout and levels should be based on these contours and should ensure that all highly contaminated material is removed, whilst minimising the amount of over dredging to limit disposal quantities of this type of spoil.

Below the levels shown on Figure 4.8, the sediment is classified as Class A "uncontaminated material" which requires no special dredging, transport or disposal methods beyond those which would normally be applied for the purpose of ensuring compliance with EPD's Water Quality Objectives, or for the protection of sensitive receivers near the dredging or disposal areas.

A total in situ volume of approximately 2,300,000 m^3 of soft marine clay will be removed by dredging of which approximately 1,400,00 m^3 will be classified as "contaminated". Thus, using a bulking factor of 1.3 for the dredged material, the volumes of contaminated and uncontaminated mud to be disposed of become 1,820,000 m^3 and 1,170,000 m^3 respectively.

4.5 Impacts on Marine Traffic

Depending on the construction programme adopted up to 4 barges and 3 tugs may be required to dispose of the marine deposits on a daily basis. In their letter of 29 February 1996 (Ref (53) in PA/S 909/2/87) Marine Department have advised that:

(i) the Contractor will need to apply for the promulgation of an "Notice to Mariners" from MD before any marine work is carried out.

(ii) all working craft are required to remain within the work site during the dredging operation;

(iii) all dredgers and barges should proceed along the appropriate fairways while leaving/entering the work site;

(iv) all working craft involved in the project work should not await in the adjacent Yau Ma Tei Anchorage; and

(v) passage of vessels through the Western Harbour should be specified.

In addition to which, although Marine Department have advised they have no objection to the proposed plan for dredging of the Anchorage Area or the methods assessed (trailing suction dredger or 2 grab dredgers), it should be noted that if the Contractor selects to use a trailing suction dredger to undertake these works, this vessel will be precluded from transiting the Central Harbour. All movements to and from the works area must be via designated fairways.

Figure 4.1
Extent of SEDPLUME Grid

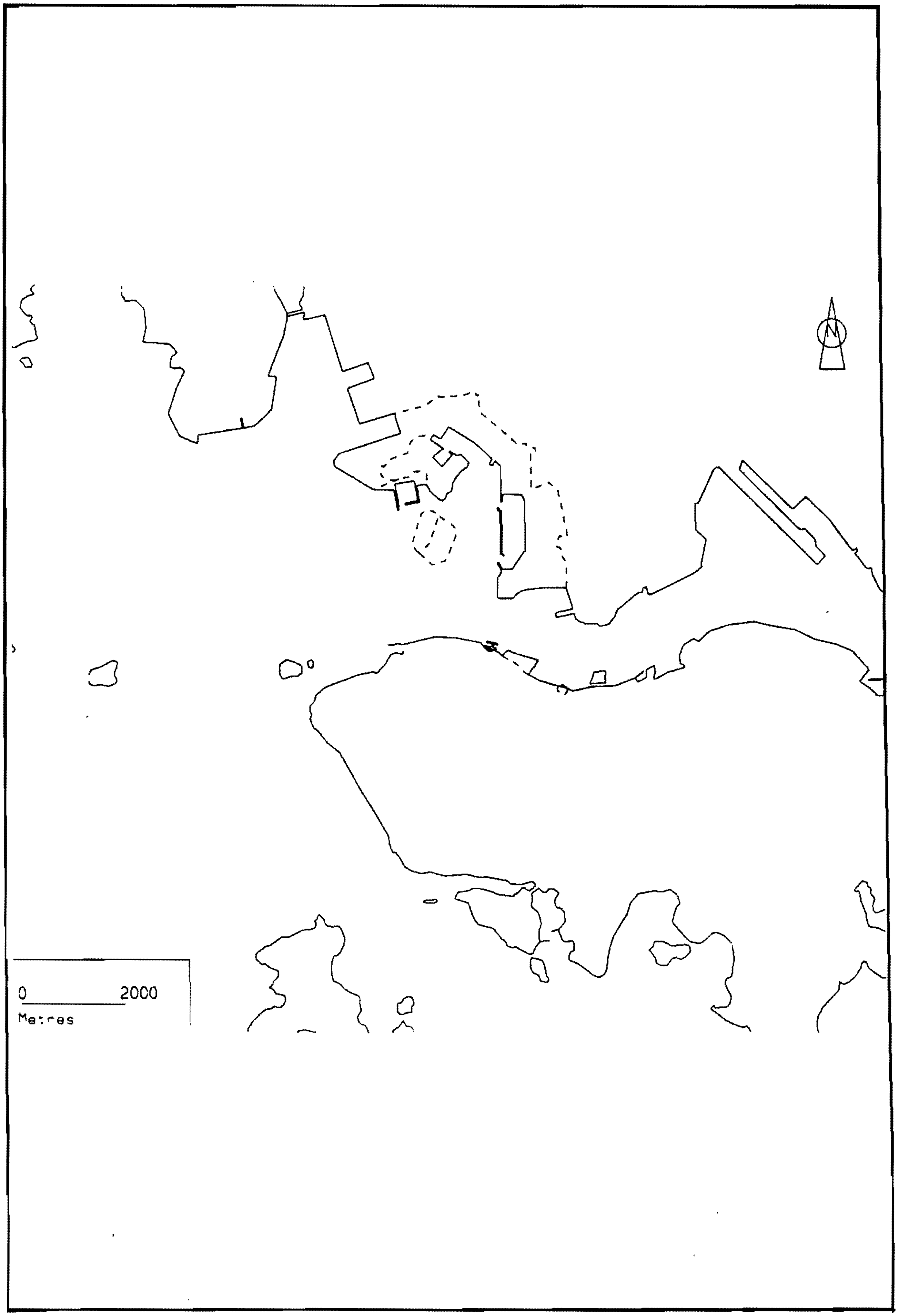


Figure 4.2
Locations of Sediment Release Points in the SEDPLUME Simulations

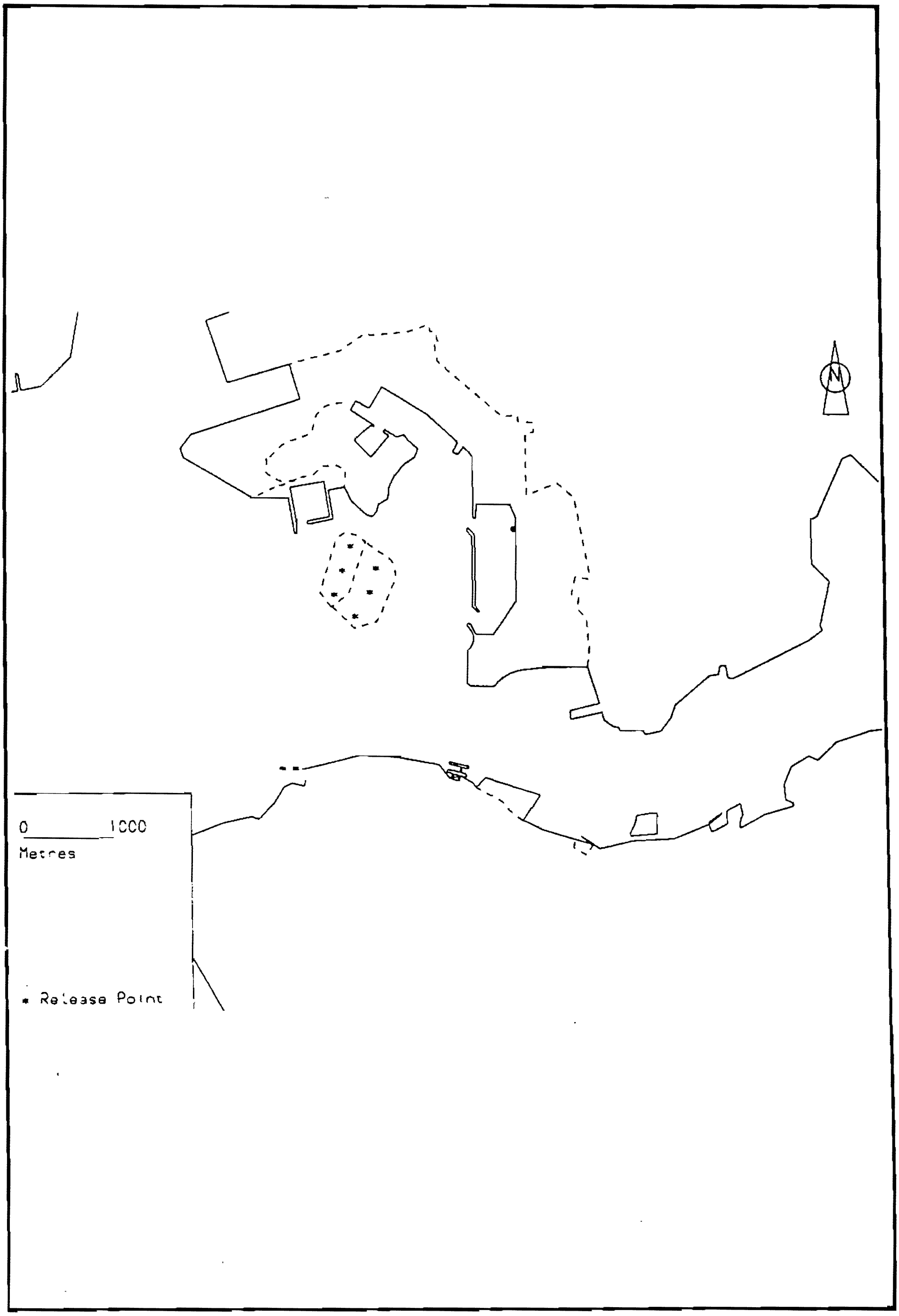


Figure 4.3
Location of Sediment Release Points for Dredging Anchorage Area with Grab Dredger

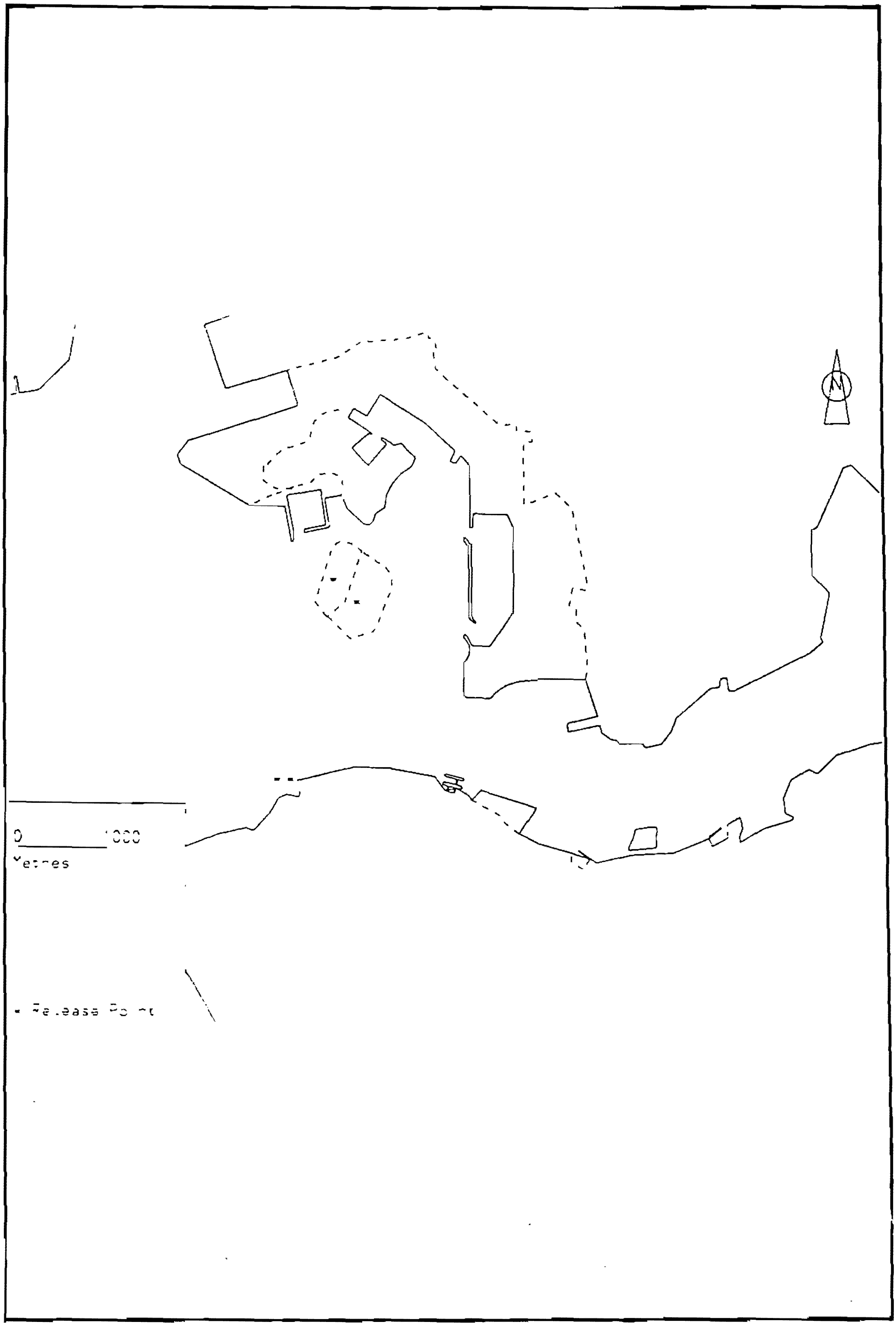


Figure 4.4
Locations of Suspended Sediment Results

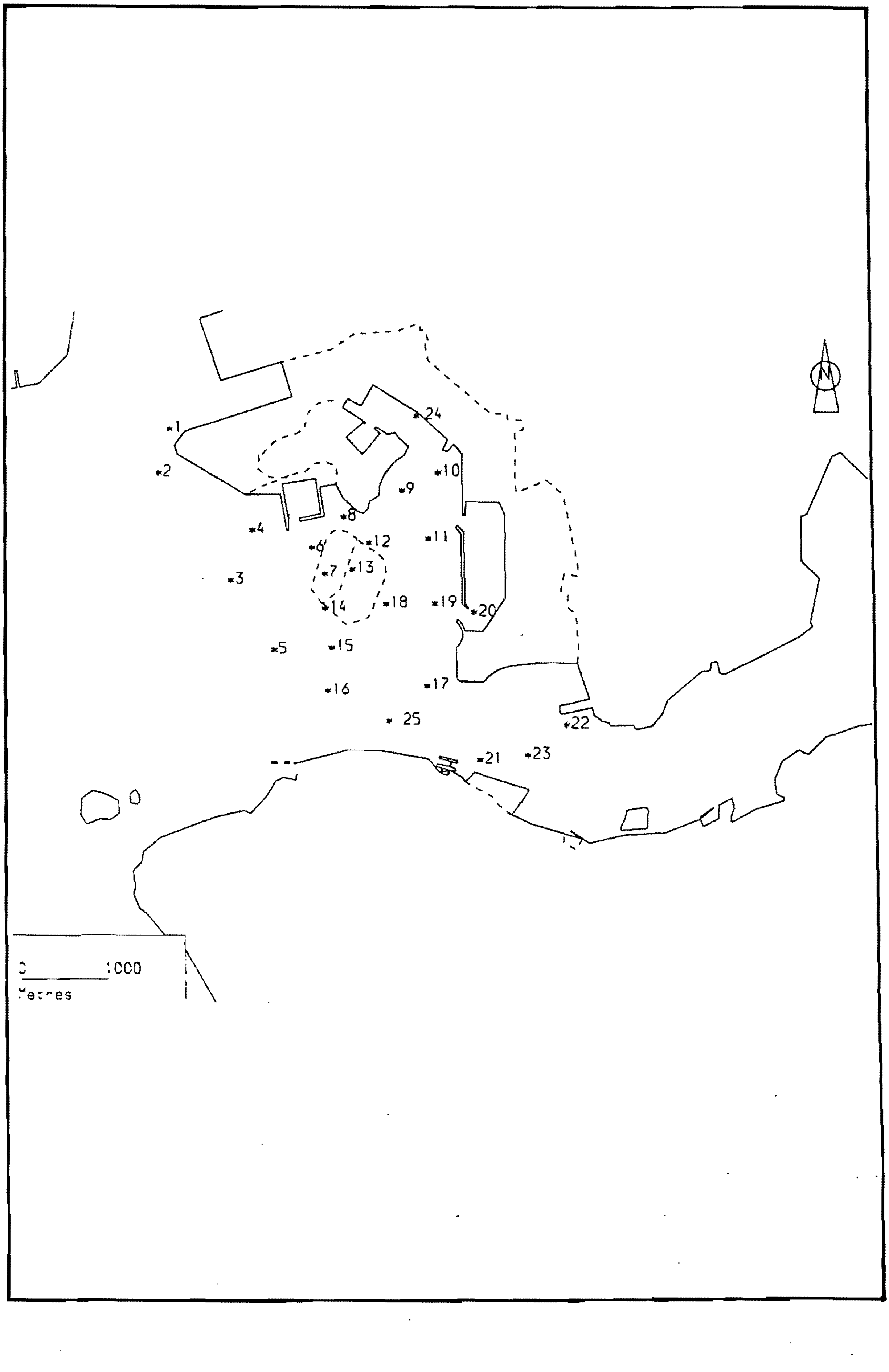
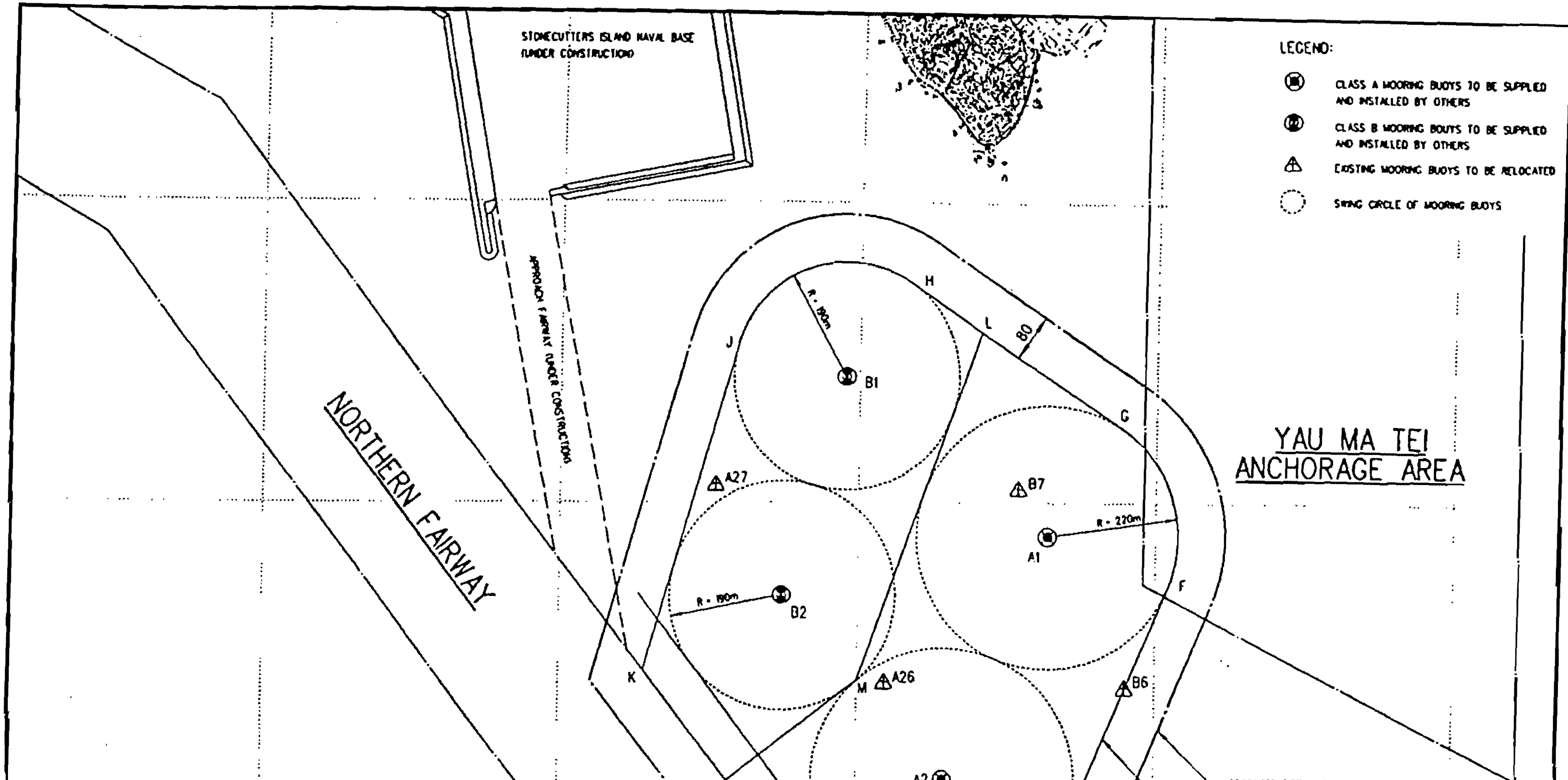


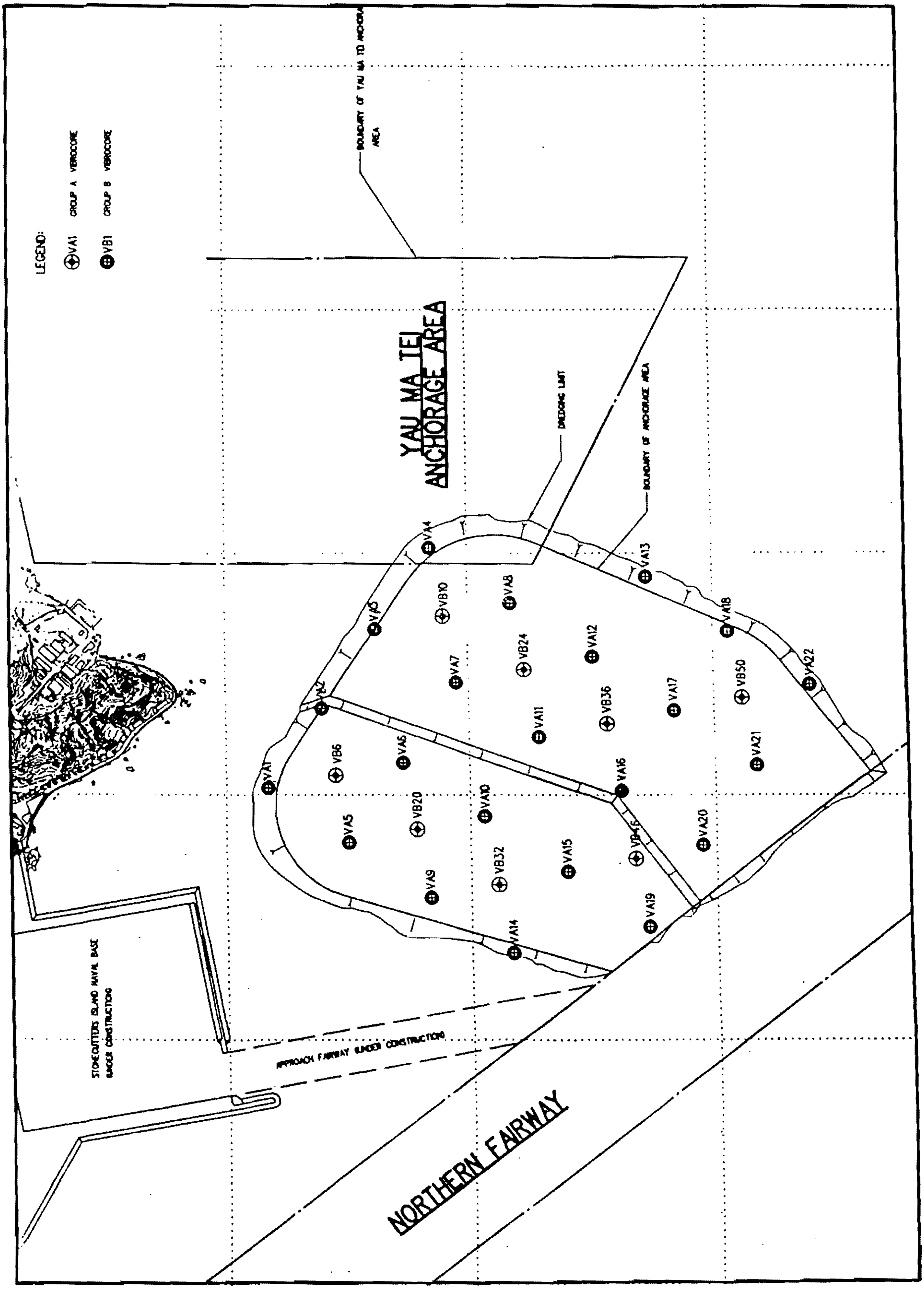
Figure 4.5
Layout of the Anchorage Area



SETTING OUT DATA

POINT	NORTHING (m)	EASTING (m)	LATITUDE	LONGITUDE
A1	818943.667	832818.451	22° 18' 39.56"	114° 08' 27.39"
A2	818538.790	832646.187	22° 18' 26.39"	114° 08' 21.37"
B1	819210.331	832477.934	22° 18' 48.23"	114° 08' 15.49"
B2	818844.963	832373.500	22° 18' 36.35"	114° 08' 11.84"
C	818187.724	832550.000	22° 18' 14.98"	114° 08' 18.07"
D	818364.063	832779.866	22° 18' 20.72"	114° 08' 26.05"
E	818452.658	832848.625	22° 18' 23.60"	114° 08' 28.45"
F	818857.535	833020.889	22° 18' 36.76"	114° 08' 34.48"
G	819125.869	832941.749	22° 18' 45.48"	114° 08' 31.70"
H	819367.685	832584.421	22° 18' 53.34"	114° 08' 19.21"
J	819262.548	832295.250	22° 18' 49.92"	114° 08' 9.11"
K	818721.426	832140.580	22° 18' 32.33"	114° 08' 3.71"
L	819285.364	832706.066	22° 18' 50.67"	114° 08' 23.46"
M	818703.077	832499.866	22° 18' 31.73"	114° 08' 16.26"
N	818536.362	832282.545	22° 18' 26.31"	114° 08' 8.67"

Figure 4.6
Vibrocore Location Plan



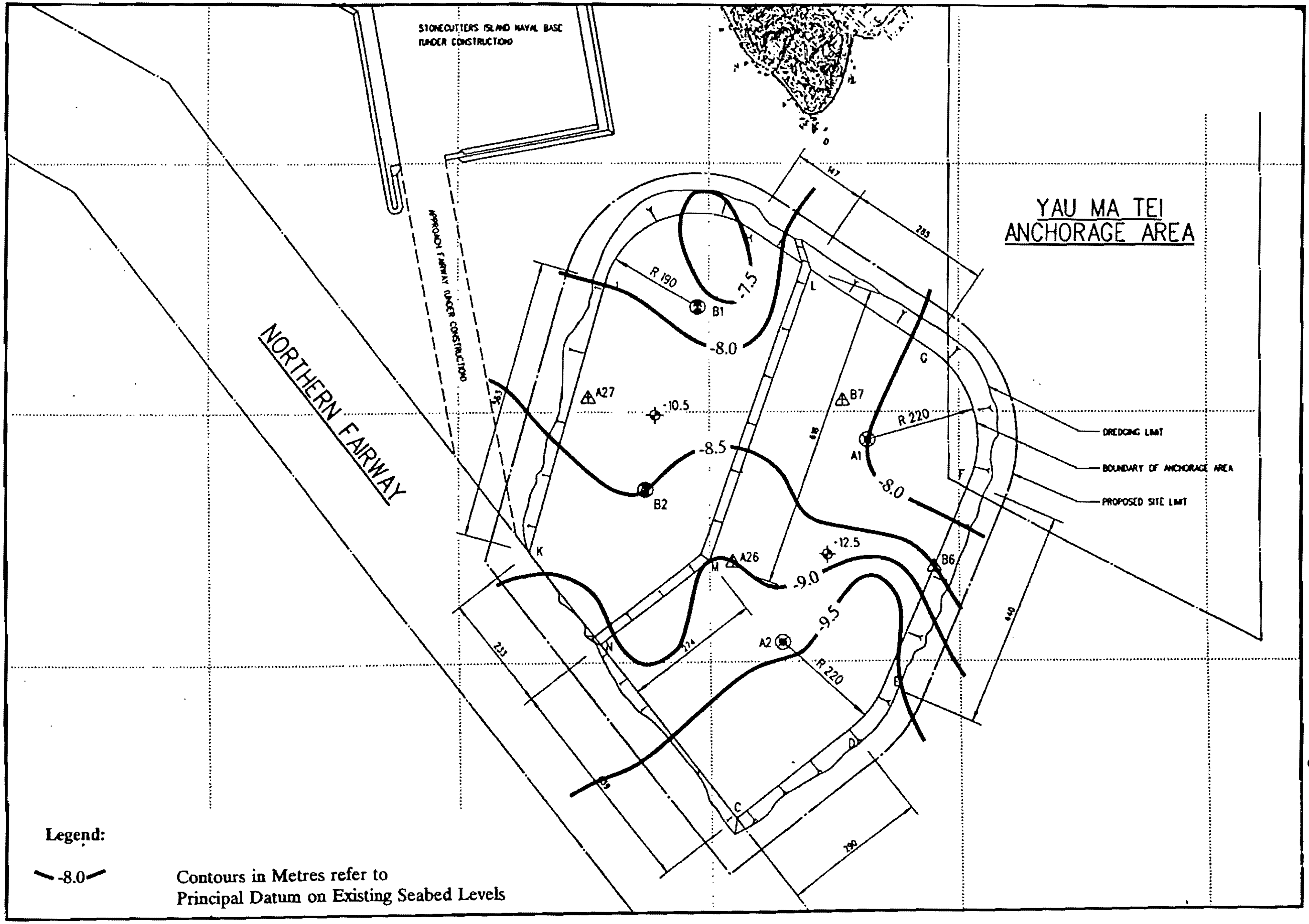
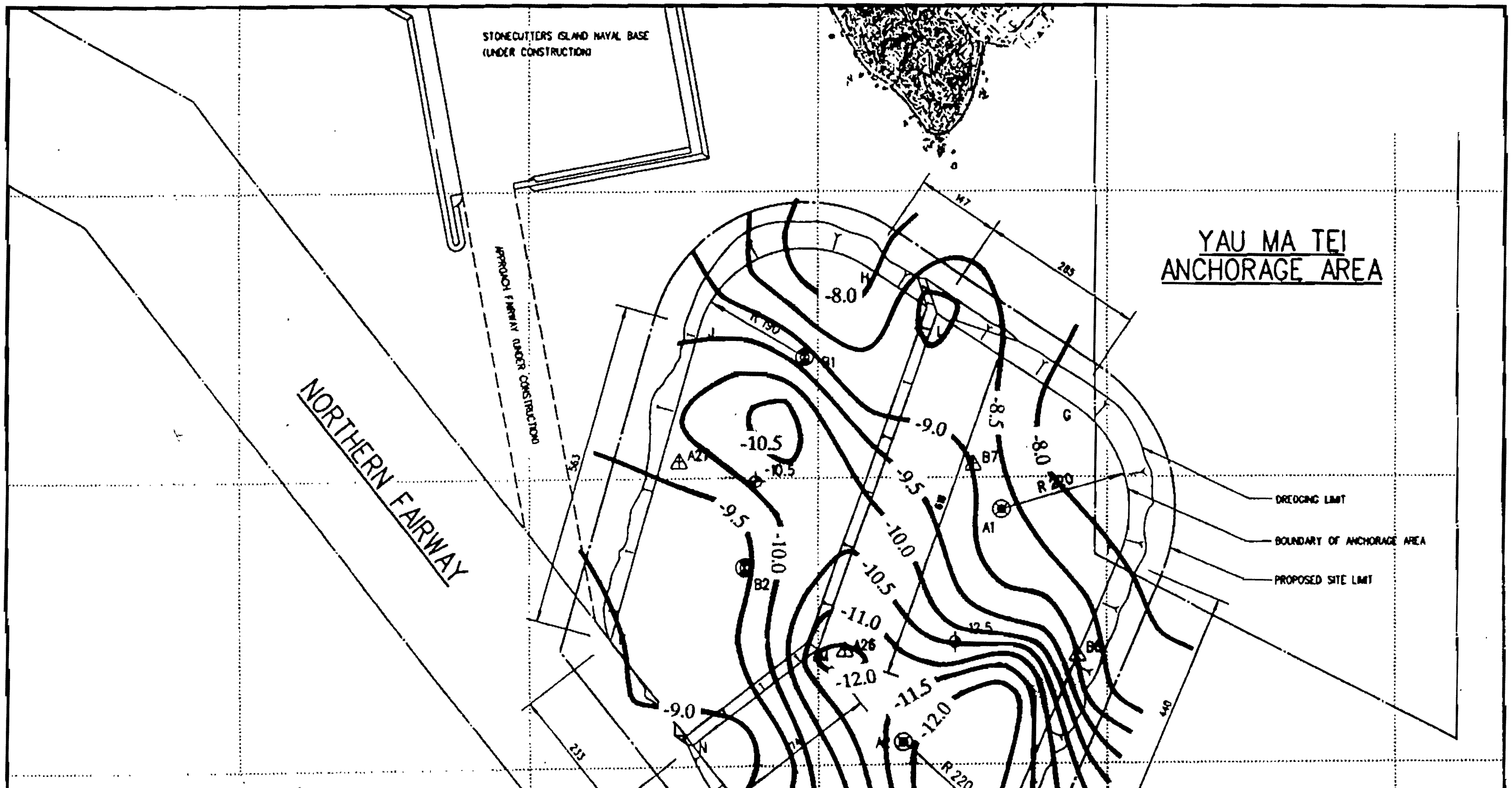


Figure 4.7
Contours on Existing Seabed Levels



Note

1. Contours Based on Vibrocore Surface Levels

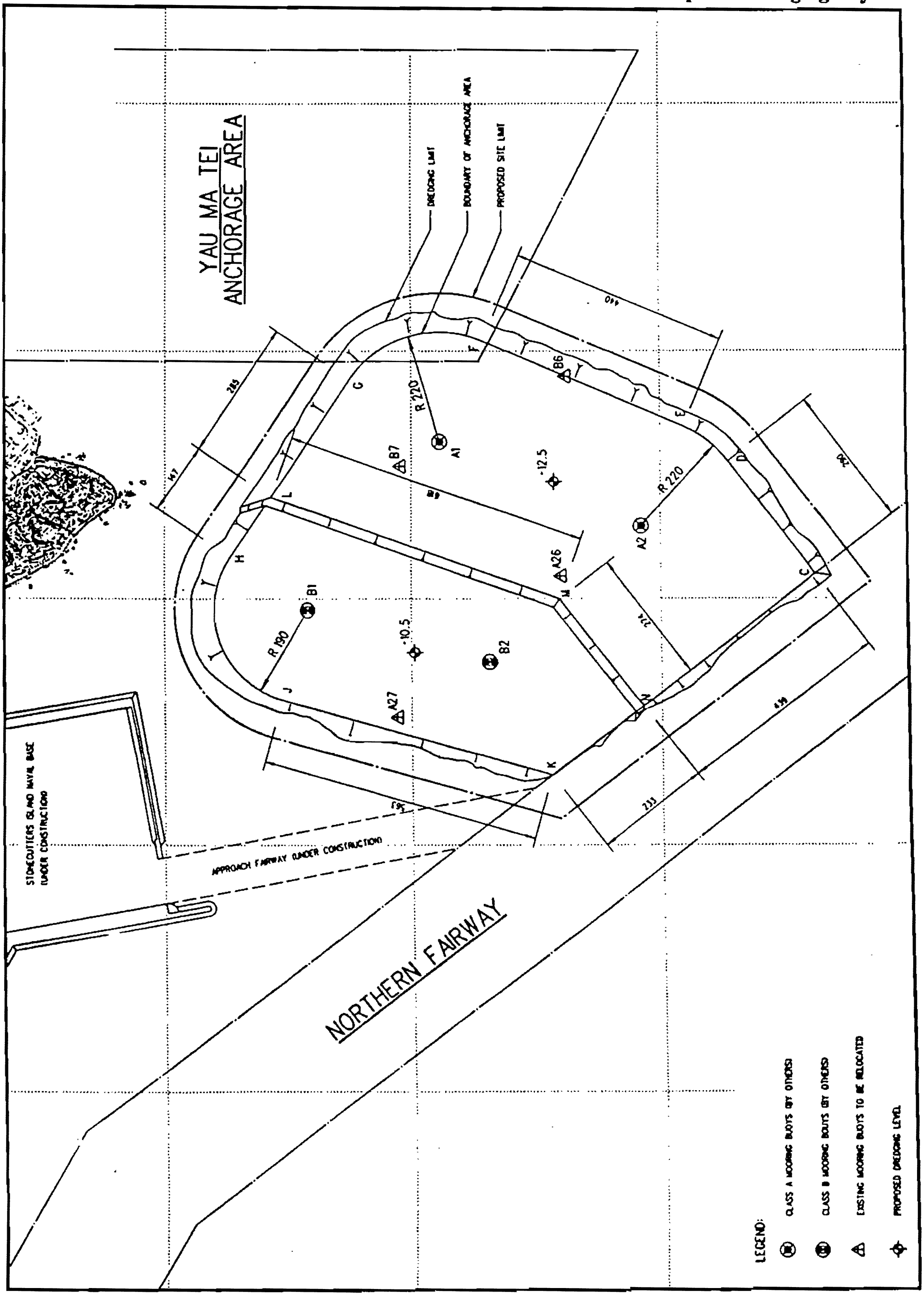
2. Contours produced using SURFER

Legend:

-8.0 Contours in Metres refer to Principal Datum on Existing Seabed Levels

Figure 4.8
Contours on Base Level of Class C Contamination

Figure 4.9
Proposed Dredging Layout



5. POST CONSTRUCTION IMPACT ASSESSMENT

5.1 Introduction

The change in bathymetry in the anchorage area once dredging has been completed may alter the existing sediment deposition and erosion rates. Recourse has been made to mathematical models of the WAHMO suite to determine the need and extent of any maintenance dredging requirements.

The modelling work comprised the following main elements:

(i) tidal flow modelling determined the effects of the dredged anchorage area on the local tidal flow regime, and

(ii) sediment transport modelling of the natural, or background, sediment regime, simulated any effects of the anchorage area on sediment flows and deposition and determined possible rates of sedimentation within the anchorage area.

5.2 Tidal Flow Modelling

5.2.1 Introduction

The aim of the tidal flow simulations was to determine the effects of lowering the seabed for the anchorage area on the local tidal flow regime.

The flow model was set up by the Civil Engineering Department (CED) as part of the studies into the Port Peninsula and is known as the Lantau Port and Western Harbour (LPWH) model. The model is based on the WAHMO 2-layer 2-dimensional model of tidal flows which was developed by HR Wallingford and transferred to the Hong Kong Government. The model solves the equations describing conservation of momentum and mass for water and salt interactively in two layers which are separated by a fixed interface. The LPWH model covers the whole of the Western Harbour and Victoria Harbour (Figure 5.1) using a grid size of 100m.

The calibration of the flow model against field data measured during 1990 was examined to determine whether any possible improvements could be made to the model's representation of tidal flows. The model was then set up for 1996 conditions, which form the baseline scenario for this investigation, and the model validated against data measured in the western part of Victoria Harbour. Finally the dredged anchorage area was added to the model bathymetry and the model re-run, with the results being compared with the baseline to determine any effects of the anchorage area on tidal flows.

5.2.2 Flow Model Calibration

The flow model was originally set up and calibrated by CED using field data taken during 1990 as part of the Enhanced WAHMO studies. The original field data was recovered and compared against the model predictions at the three field data stations within the model area (Figure 5.2) to verify the original calibration. The results from this comparison are given in Appendix E.

The comparison of the flow model against the field data shows very good comparison for both the dry season tides with peak current speeds and the phasing of the tides being well reproduced. The wet season spring tide shows a similar good comparison except at Station E6 where the model underestimates the peak ebb currents. This is particularly evident in the surface layer and is because the layer averaged speeds do not represent the extremely high near-surface currents well. The wet season neap tide shows a similar behaviour for the twice daily peak ebb currents. In overall terms, it may be surmised that the comparison is with the field data is good.

The comparison of the model with the original calibration field data has shown that the model reproduces the observed tidal conditions well and it may be concluded that the model was well set up and calibrated.

5.2.3 Flow Model Validation

At the end of 1995 during the dry season, tidal current speed and direction data were collected at a number of sites in the western part of Victoria Harbour. The locations of these stations are shown in Figure 5.3. The flow model was run for the baseline configuration which corresponded to the coastline present at the time of the data collection and the model results were compared to the field data in order to validate the performance of the model (Appendix F).

At Stations CR1, CR2 and CR3 data was collected during 20/11/95 on a neap tide and during 27/11/95 on a spring tide. The comparison with the neap tide current data at Station CR1, CR2 and CR3 is good but with peak currents being over-predicted, particularly in the surface layer. This is because the tide in the model is larger than the tide during which the field data was measured which is shown by a comparison of the tidal elevations used in the model and those measured at a tide gauge at Sheung Wan. The comparison with the spring tide current data shows close agreement between the model and the field data except during the semi-diurnal phase of the tide where the model under-predicts the peak current speeds. This can be explained by comparing the actual tidal elevations with those in the model which shows that, although the tidal ranges are similar, the semi-diurnal phase of the tide on which the field data was measured had a larger range than in the model.

At Stations KP1, KP2 and KP3 data was collected for a spring tide on 22/12/95. A comparison of the tidal elevations at Sheung Wan shows that the tide during the field data collection was larger than the tide used in the model. The comparison between the current speeds measured at the three stations and the model data shows close agreement except that the model slightly under-predicts the peak current speeds, particularly at Station KP3 which is close to the southern portion of the West Kowloon Reclamation. This is because of the larger tide during the field data collection and model grid having insufficient horizontal resolution to represent the complex flow patterns in this region.

The comparison of the flow model data with field data collected during late 1995 shows that the model accurately represented the tidal flow conditions and it be surmised that it is well validated.

5.2.4 Scenarios Simulated in the Tidal Flow Modelling

Two layouts for the flow model simulations have been considered, the baseline and completed scenarios. The baseline scenario simulated conditions which will occur immediately prior to the construction of the anchorage area. This scenario included reclamations for Container Terminal 8, West Kowloon, Central Phase I and II, Hong Kong Convention and Exhibition Centre, Stonecutters Site for Mid-Stream Operations and the Stonecutters Naval Base breakwaters and also included dredging for the access to Container Terminal 8, Dredging of Rambler Channel and Approaches, the Naval

Basin and the access channel to the naval basin. The completed scenario then included the dredged anchorage area. Each of the scenarios have been modelled for the wet and dry season spring and neap tides.

5.2.5 Results of the Tidal Flow Simulations

The results from the Baseline and Completed Scenarios are presented here as graphs of time varying current speed and direction at eight selected stations (Figure 5.4). Also given are colour vector plots of the peak ebb and flood phases of each of the four tides for the both the upper and lower layers of the flow model. The vector plots cover the region encompassing the anchorage area and the western portion of Victoria Harbour. The results from the Baseline and Completed Scenario are included in Appendices G and H respectively.

A comparison of the results from the tidal flow simulations for the baseline and completed cases show that the dredging for the anchorage area has no discernable influence on tidal flows in the region around the anchorage area. The only noticeable difference is that the anchorage area, having been dredged, is represented by two layers in the flow model for the Completed Scenario but current speeds in the new lower layer are very low showing that total flows through the anchorage area do not change significantly.

5.3 Sediment Transport Model

The aim of the sediment transport modelling was to determine whether the construction of the anchorage area would affect the natural suspended sediment regime in the waters around it and to predict siltation rates within the anchorage area so that maintenance dredging requirements may be quantified. The results from the sediment transport model were also combined with the results from the sediment plume simulations to give total suspended sediment concentrations during dredging of the anchorage area.

5.3.1 Sediment Transport Model Description

The sediment transport model, MUDFLOW, forms part of the WAHMO suite of coastal hydraulic and water quality models set up by HR Wallingford and WRc and transferred to the Hong Kong Government. The sediment transport model is a two-layer, two-dimensional mud transport model. The model simulates the transport and dispersion of sediment in suspension by solving the equations describing the conservation of mass and includes the processes of deposition and erosion of sediment at the seabed. Tidal flow data is provided by the WAHMO two-dimensional two-layer model of tidal flows. The sediment transport model uses the same grid and layering system as the flow model simulation which provides the flow data.

The sediment transport model was originally calibrated to simulate natural sediment transport and particulate discharges from a large number of outfalls in Victoria Harbour. Since then, it has been calibrated to model the sediment transport in the waters of the North-West New Territories.

5.3.2 Sediment Transport Model Calibration

The sediment transport model has been calibrated for natural suspended sediment transport for the same area coverage as the flow model. The tidal flow data for the calibration was provided by the 100m flow model which simulated 1990 conditions and for which the flow model was calibrated. The calibration of the sediment transport model was based on field data measured in 1990 and 1987. Although the coastline of Victoria Harbour has changed between 1987 and 1990 the field data measured in 1987 will still be valid.

5.3.3 Scenarios Simulated by the Sediment Transport Model

The sediment transport model has been used to simulate the Baseline and Completed Scenarios for the dredging of the anchorage area during with wet and dry seasons on the spring and neap tide, and to provide an indication of potential maintenance dredging requirements. The tidal flow data was provided by the 100m flow model Baseline and Completed Scenarios.

5.3.4 Results from the Sediment Transport Model

Wet Season Spring Tide

The comparison between the Baseline and Completed Scenarios for suspended sediment concentrations shows that the construction of the anchorage area has only small localised effects. Suspended sediment concentrations are shown to increase in the northern fairway to the west of the anchorage area because the deepening of the seabed encourages greater flow from the main flow channel to the west of Tsing Yi which carries with it the increased suspended sediment from this area. On the ebb tide the only real difference between the two scenarios are the slightly increased concentrations in the lower layer between Sheung Wan and the southern tip of the West Kowloon Reclamation because more flow is being encouraged through Victoria Harbour which carries more sediment from the eastern portion of the inner harbour.

The net mud deposits over a complete tidal cycle show that after the construction of the anchorage area, sediment deposition rates will be reduced in the fairway to the south while sediment deposits will be increased around the northern portion of the anchorage area. The reduction in deposition in the fairway is because the slightly increased flows through the fairway increased the bed shear stresses sufficiently to prevent deposition for a greater period of the tidal cycle. On the northern side of the anchorage area the deepening of this area encourages flow around from the fairway around this side of the anchorage area where the suspended sediment is then deposited because of the low tidal current speeds. There is also reduced deposition on the western half of the anchorage area because more of the sediment is being deposited around the edges of the anchorage area rather than evenly over the whole area.

Wet Season Neap Tide

The contour plots of suspended sediments on the flood tide show very small differences between the Baseline and the Completed Scenarios. On the ebb tide in the surface layer there is a narrow area of higher concentration in the Completed Scenario to the east of the anchorage area. This is caused by flows on the ebb tide having higher suspended sediment concentrations than the water around the anchorage area. The same pattern is evident in the lower layer with higher concentrations around the northern side of the anchorage area in the Completed Scenario and lower concentrations on the southern side.

The contour of mud deposits also show the same pattern as in the wet season spring tide with increased sedimentation to the north of the anchorage area in the Completed Scenario and decreased sedimentation to the south. Lower deposition rates are also shown over the eastern half of the anchorage area.

Dry Season Spring Tide

A comparison of the contour plots of suspended sediment concentrations for the flood tide shows no discernable differences between the Completed and Baseline Scenarios, except that there is now sediment present in lower layer over the anchorage area for the Completed Scenario. On the ebb tide there are also no differences evident between the two scenarios in the surface layer and the only difference is that sediment is now present in the lower layer for the Completed Scenario.

The contours of net mud deposits do not show any differences between the two scenarios.

Dry Season Neap Tide

A comparison of the contour plots of suspended sediment concentrations for the flood tide shows no discernable differences between the Completed and Baseline Scenarios, except that there is now sediment present in lower layer over the anchorage area for the Completed Scenario. On the ebb tide there are again no visible differences between the Baseline and Completed Scenarios.

The contours of net mud deposits also do not show any differences between the two scenarios.

Prediction of Annual Siltation Rates

The prediction of annual siltation rates was based on the results of the sediment transport modelling for the deposition of sediment resulting from tidal dispersion. It was assumed that each of the four tide types occurred 89 times per year and the net deposition rates were simply multiplied by 89 and the values summed. This calculation gave the total mass of mud deposited onto the seabed during a year in kg/m^2. In order to determine the depth of deposits it was assumed that over a year the mud would consolidate and would have an average dry density of 350 kg/m^3. The resulting predictions of the annual siltation rates for the Baseline and Completed Scenarios are shown in Appendix I.

The predictions of annual siltation rates show that once the anchorage area has been dredged up to 4 cm/year of mud will be deposited on the western side of the anchorage area, while the eastern side will have up to 2 cm/year. A comparison of the predicted mud deposits for the Baseline and Completed Scenarios shows that after the construction of the anchorage area there will be decreased deposition in the fairway to the south of the anchorage area but that sedimentation will be increased on the northern and eastern sides of the anchorage area.

Combined Suspended Sediment Concentrations during Dredging

The results from the sediment plume simulations for Scenario 1 were added to the results from the sediment transport model simulations for each of the four representative tide types. The results from this analysis are presented in Appendix J. Two sets of results are shown, one set shows the sediment transport model results and the other set shows the combined sediment plume and sediment transport model results thereby allowing comparisons to be made to determine the magnitude of the increases in suspended sediment concentrations from the dredging activities.

Figure 5.1
Extent of Flow Model Grid

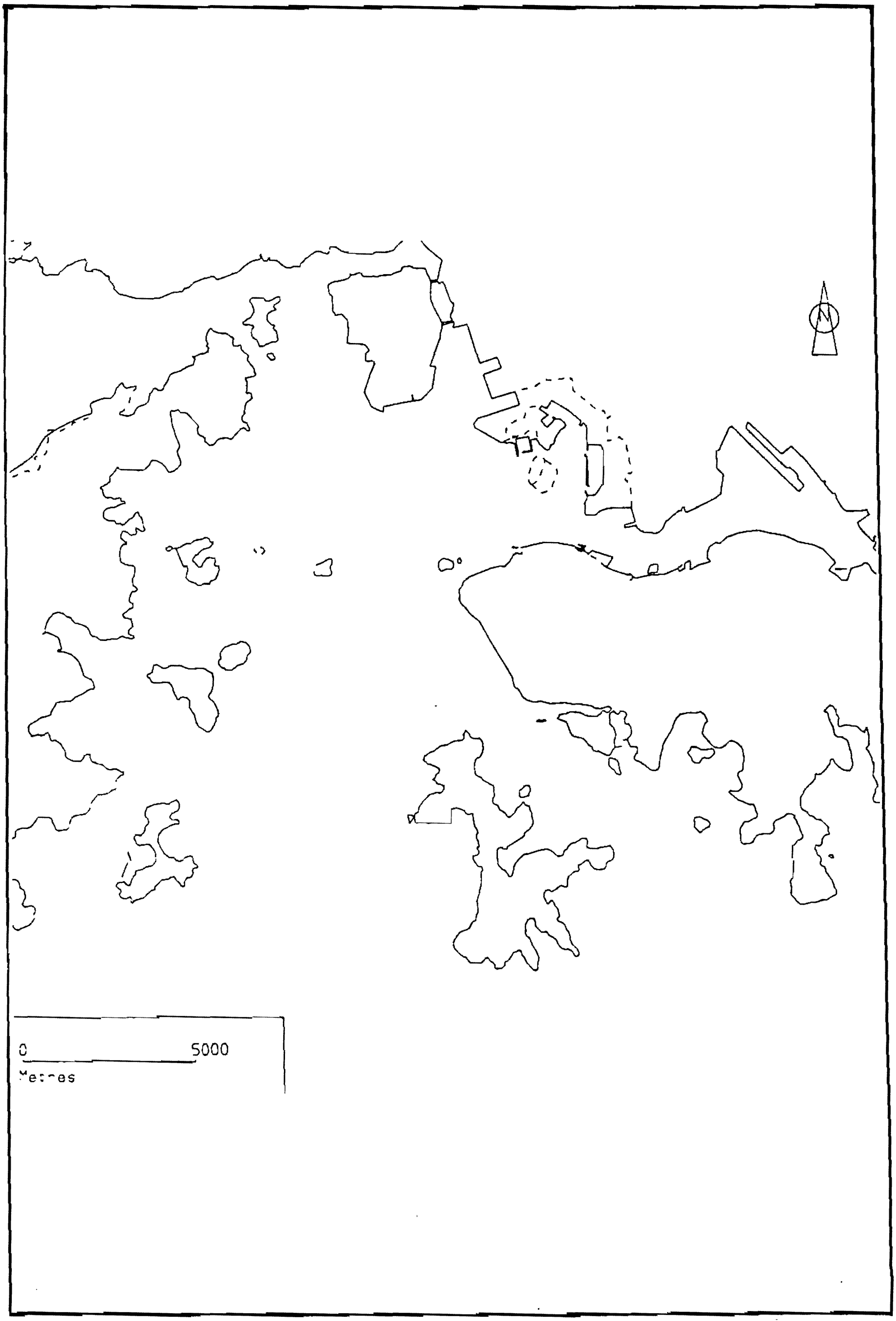


Figure 5.2
Locations of 1990 Calibration Stations

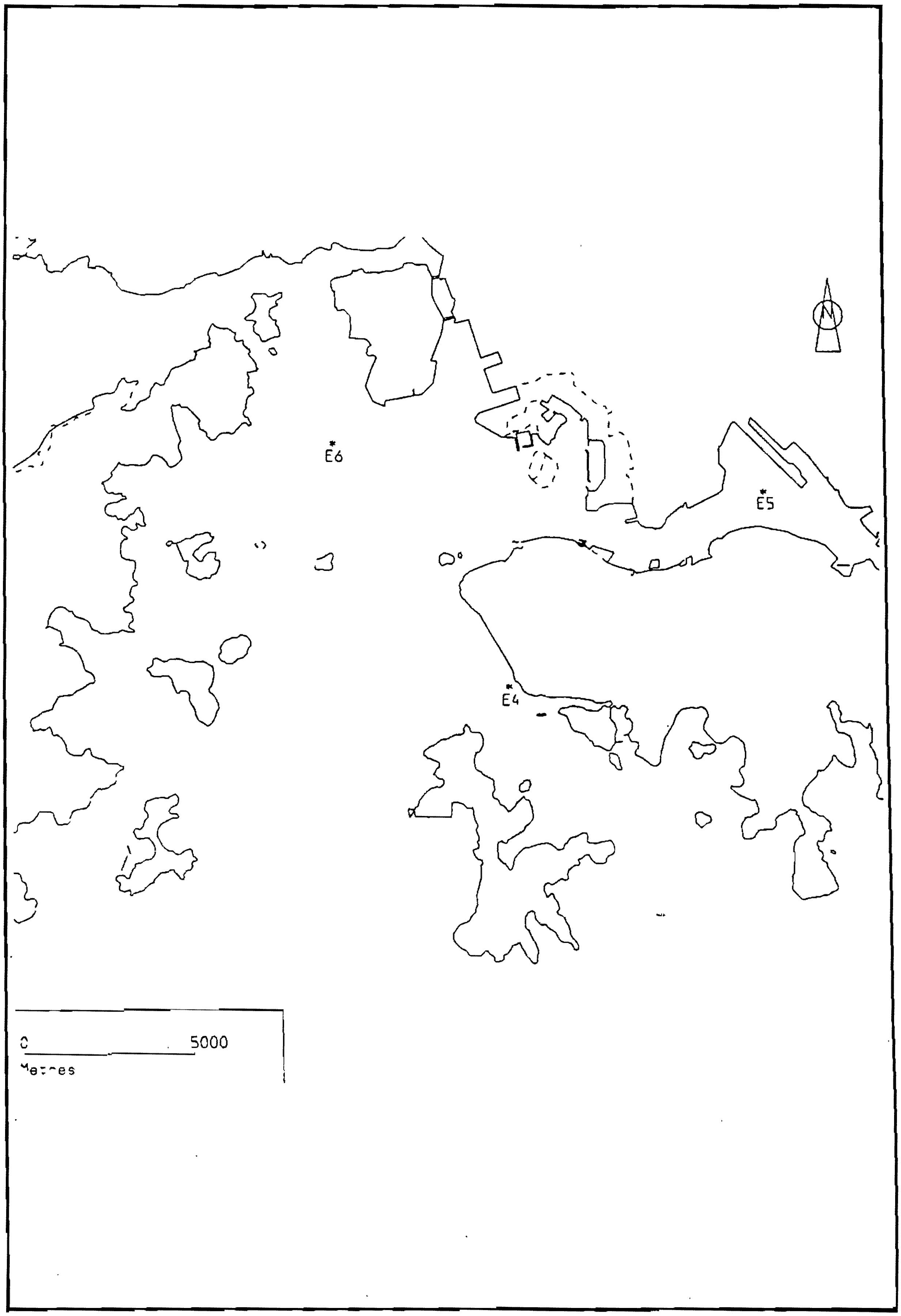


Figure 5.3
Locations of 1995 Validation Stations

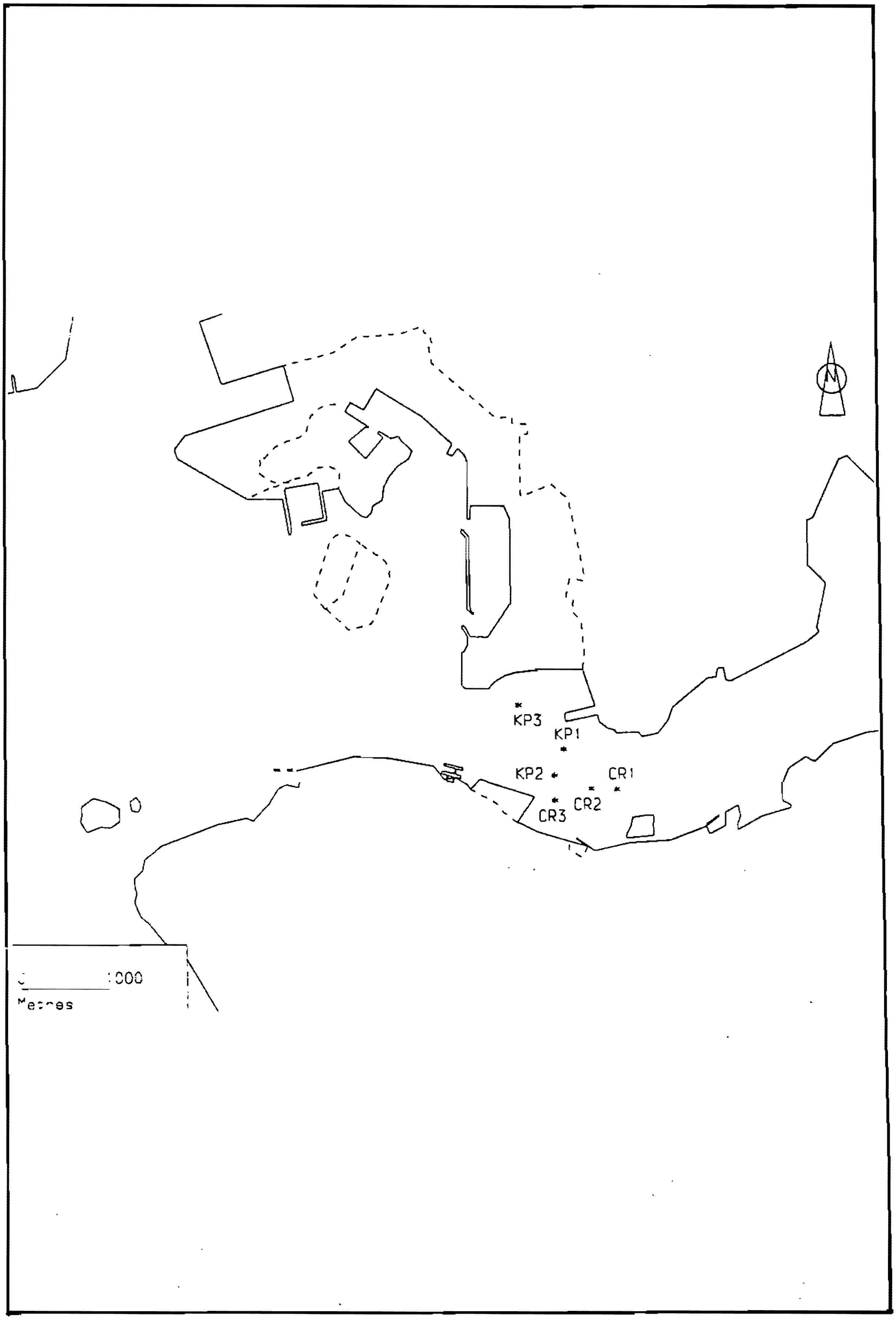
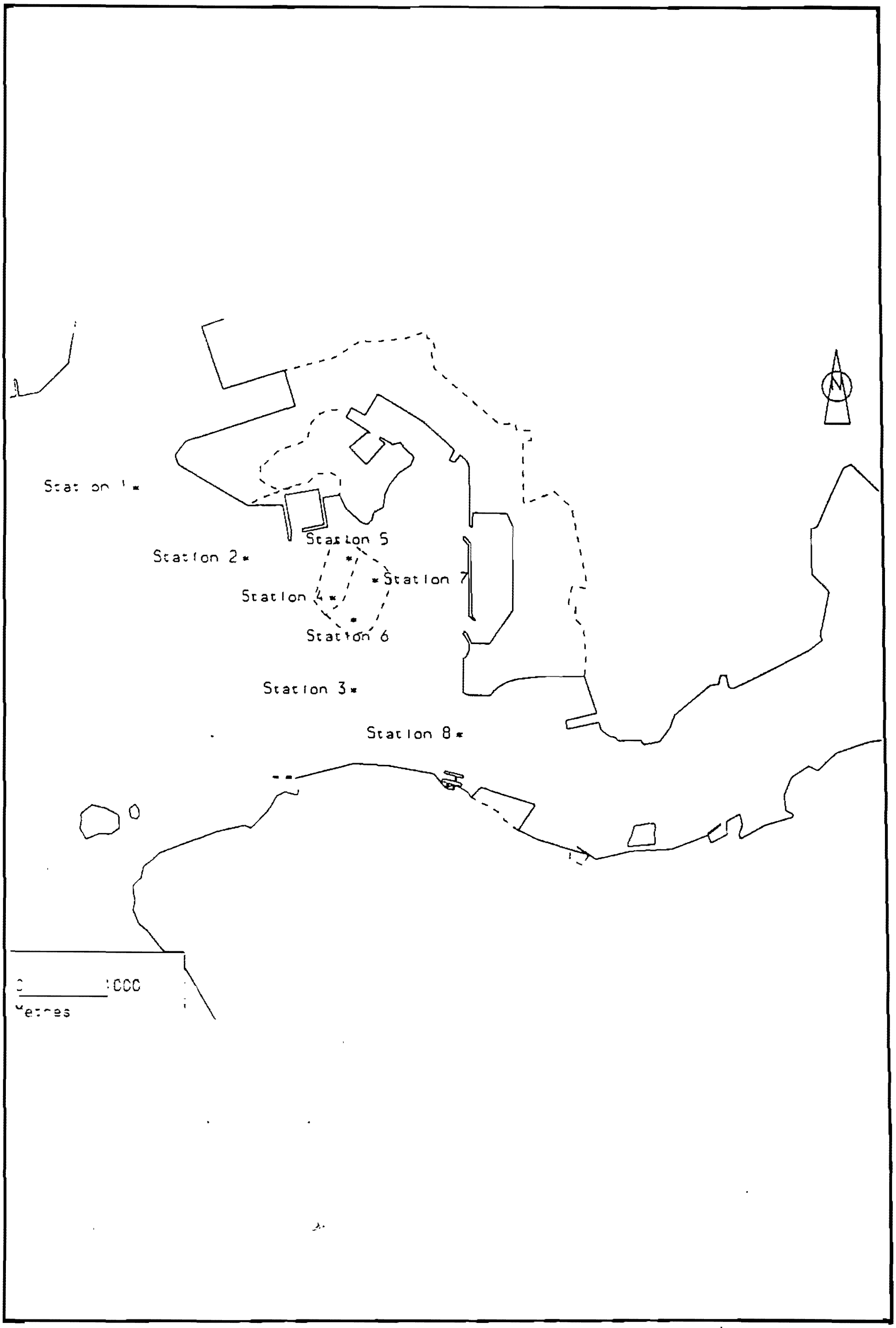


Figure 5.4
Locations of Flow Model Results Stations



APPENDIX A

Sediment Sampling and Testing Programme
(includes Figure A1 Location of Vibrocores for Elutriate Testing)

Table A.1 Sampling and Analyses to be conducted

Sampling

<table>
<tr><th>Sampling of Vibrocores</th><th>Sampling of Seawater for Elutriate Testing</th></tr>
<tr><td>30 Sample locations, 6m length of vibrocore at each location
5 Subsamples per 6m length of vibrocore

Total number of subsamples for testing is 150</td><td>3 Sample locations to be tested at 3m above seabed

2 Water samples to be collected at each location for the purpose of conducting elutriate tests. One additional sample to be collected at each location to determine the composition of seawater (ie without release of contaminants from sediment). A total of 9 (ie 3 x 3 no.) water samples to be collected.

Each suite of tests requires 4.375l (5l for convenience) of seawater therefore a total of 45 l of water to be collected.</td></tr>
<tr><th colspan="2">Analysis of Samples</th></tr>
<tr><th>Sediment</th><th>Seawater & Elutriate</th></tr>
<tr><td>A. Heavy Metal Contamination of Sediment (all sediment samples)

Cu
Cr
Cd
Pb
Ni
Zn
Hg</td><td rowspan="2">Tests to be conducted on seawater (3 samples) and Elutriate Samples (6 samples)

Redox potential
pH
Heavy Metals: Cu
Cr
Cd
Pb
Ni
Zn
Hg

Total Inorganic Nitrogen
Ammoniacal Nitrogen Content
Organic Nitrogen content
Total Organic carbon
Tributyl Tin (TBT)
DDT
PCB</td></tr>
<tr><td>B. Other tests on sediment for Elutriate Analysis (6 samples only)

Redox potential
pH
Total Organic Carbon
TBT
DDT
PCB</td></tr>
</table>

SHEET 1

Bottle requirements for seawater analysis provided by two different laboratories:

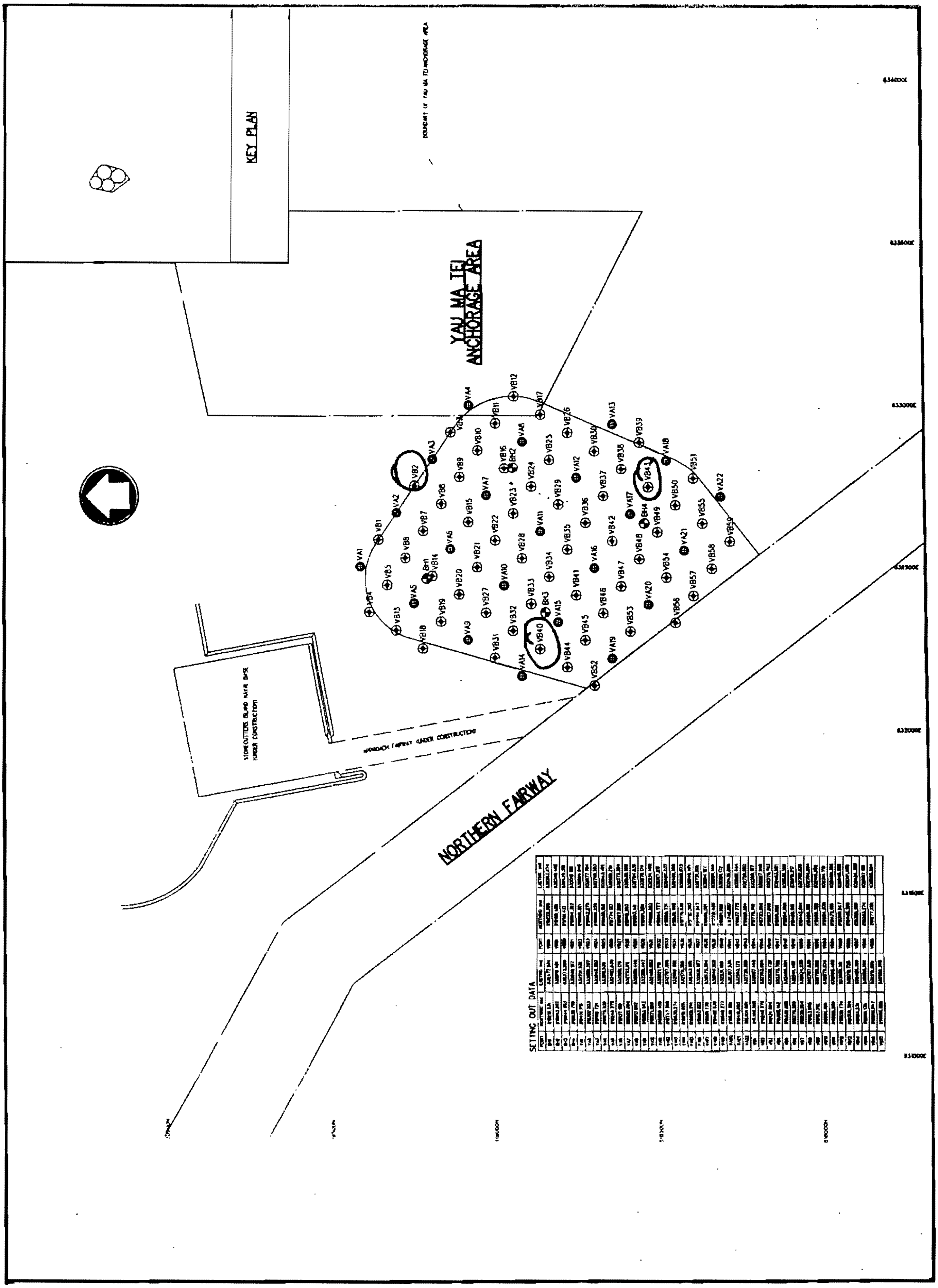
Redox potential	)	
pH	)	
TON	)	1 litre plastic
Ammonia	)	
Organic N	)	
TOC	)	
Tributyl Tin		2 litre glass
DDT + PCB's		1 litre glass
Cu, Cr, Cd, Pb, Ni, Zn		125 ml plastic
Hg		250 ml glass
Total Quality of Sample	=	<u>4 litre 375 ml</u>

Sample Description

Sample identification	:	1)	E1 Seawater	2)	E2 Seawater
		3)	E3 Seawater	4)	E1 Elutriate (I)
		5)	E1 Elutriate (II)	6)	E2 Elutriate (I)
		7)	E2 Elutriate (II)	8)	E3 Elutriate (I)
		9)	E3 Elutriate (II)		

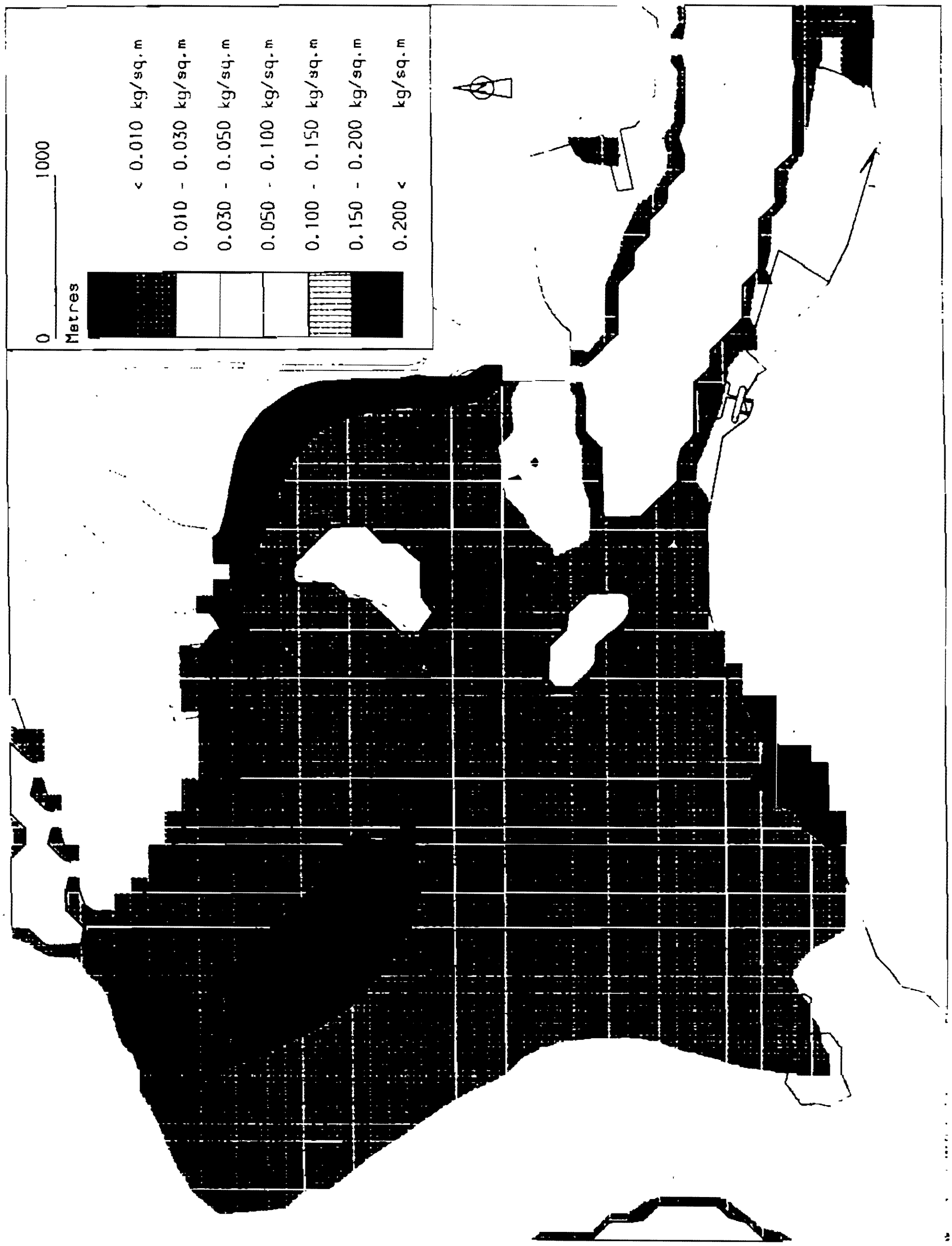
Test required	:	1)	pH value
		2)	Redox potential
		3)	Total organic carbon content
		4)	Copper content
		5)	Nickel content
		6)	Zinc content
		7)	Lead content
		8)	Cadmium content
		9)	Chronium content
		10)	Mercury content
		11)	Ammoniacal nitrogen content
		12)	Organic nitrogen content
		13)	Total inorganic nitrogen content
Date received	:	16/02/96	
Date completed	:	28/02/96	
Methods used	:	1)	APHA 17ed 4500 - H^+
		2)	ASTM D 1998 = 1976 excludes clause 8
		3)	APHA 17ed 5310C
		4), 5) & 7) - 9)	APHA 17ed 3113
		6)	APHA 17ed 3030A, 3030F3b & 3111B
		10)	In house method E-T-022D
		11)	APHA 17ed 4500 - NH_3 B&E
		12)	APHA 17ed 4500 - NH_3 B&E & 4500 - Norg B
		13)	APHA 17ed 4500-NO_3^-E & 4500-NO_2^-B

Figure A.1
Location of the Vibrocores for Elutriate Testing



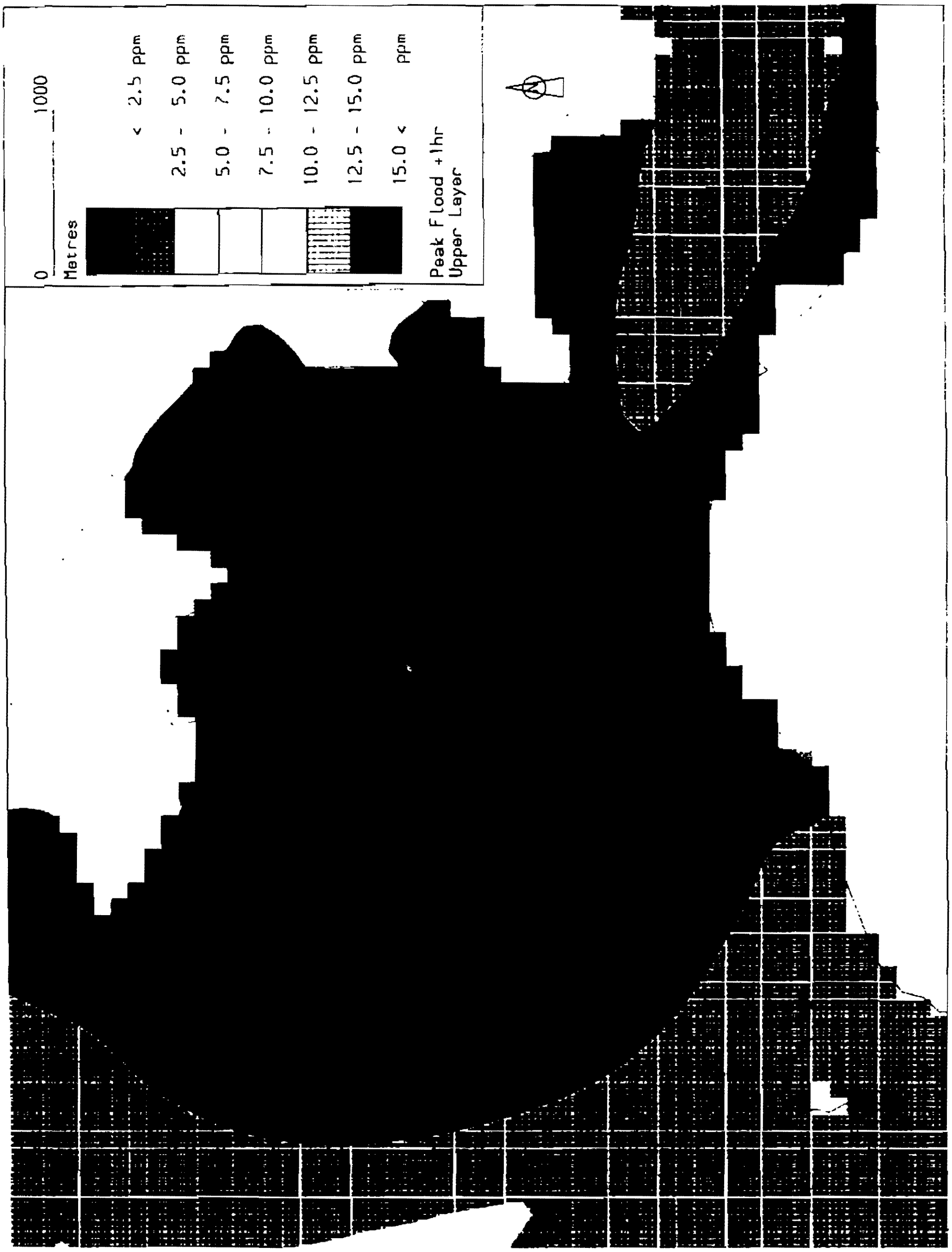
APPENDIX B

Sediment Quality Study

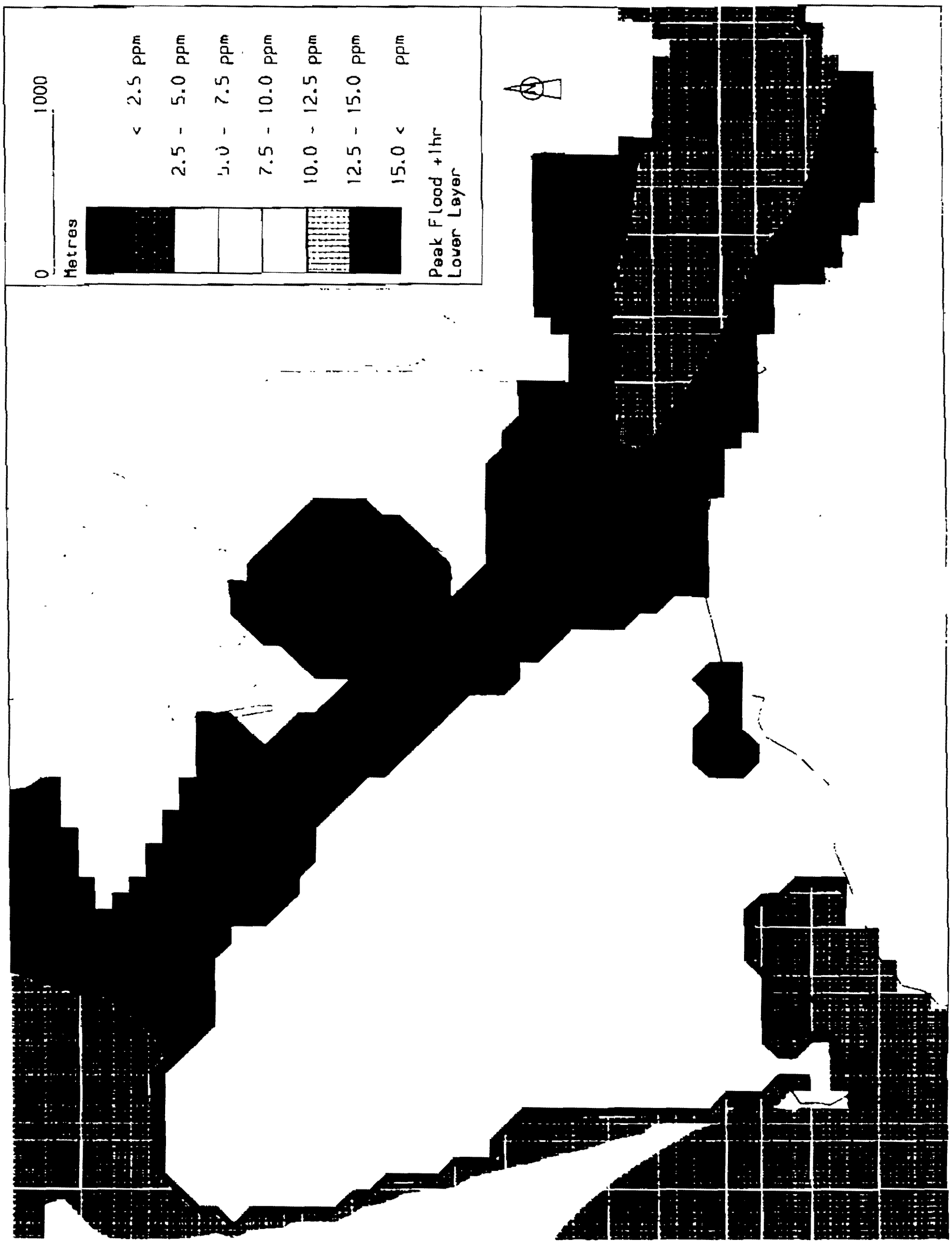


Stonecutters Naval Base Anchorage Area
Completed Scenario
Mud Deposits over 1 Tide
Wet Season Neap Tide

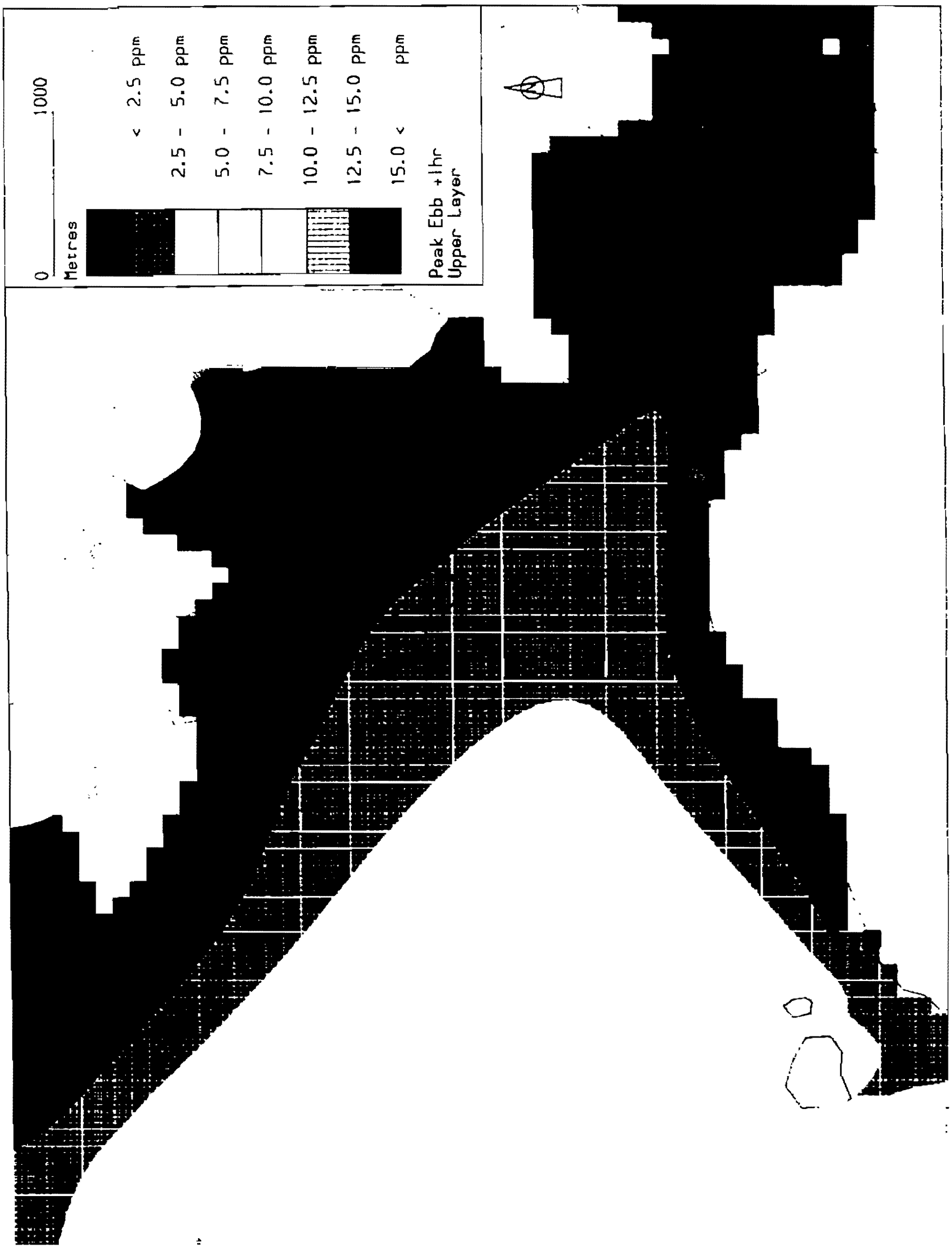
DRY SEASON SPRING TIDE



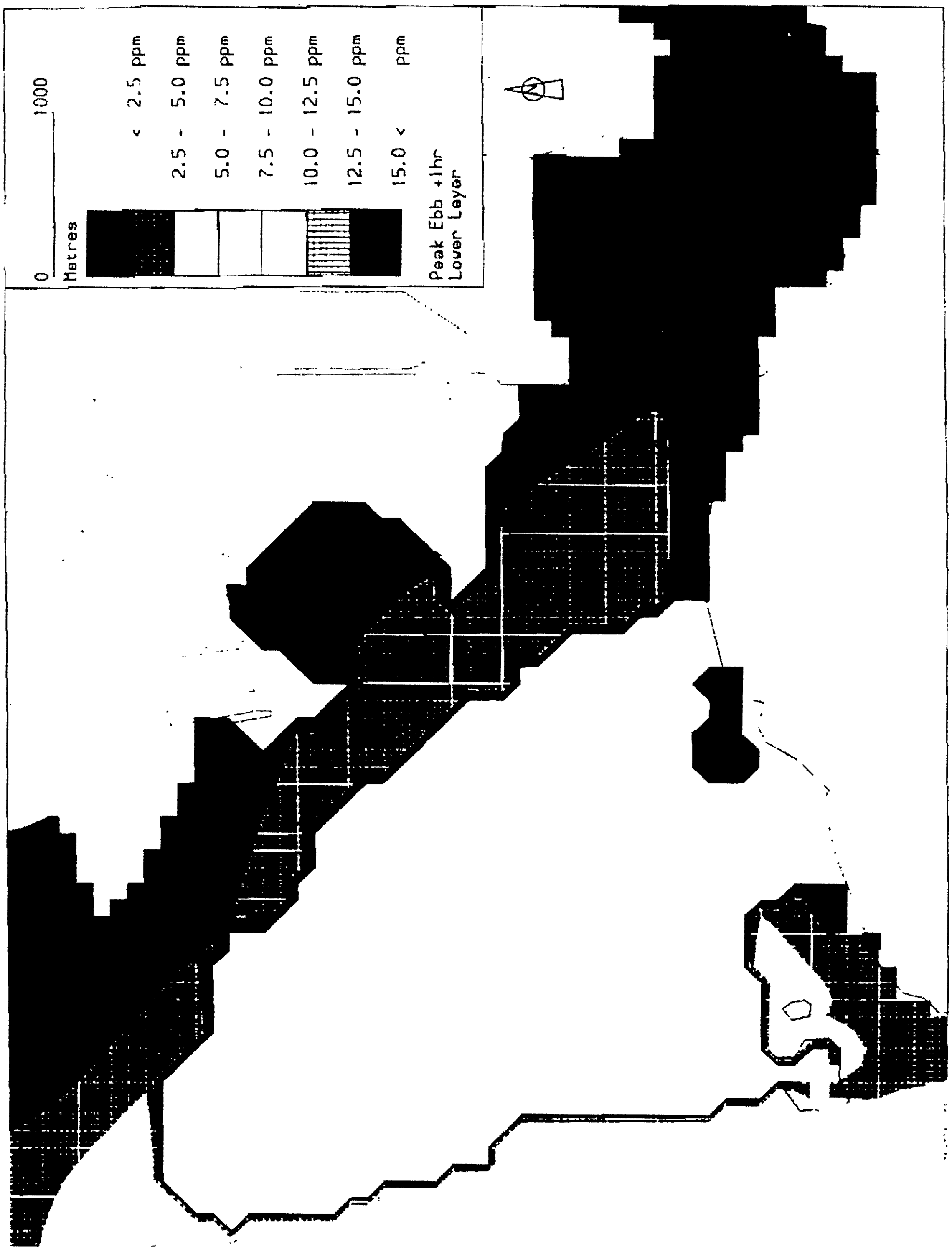
Stonecutters Naval Base Anchorage Area
Completed Scenario
Suspended Sediment Concentrations
Dry Season Spring Tide



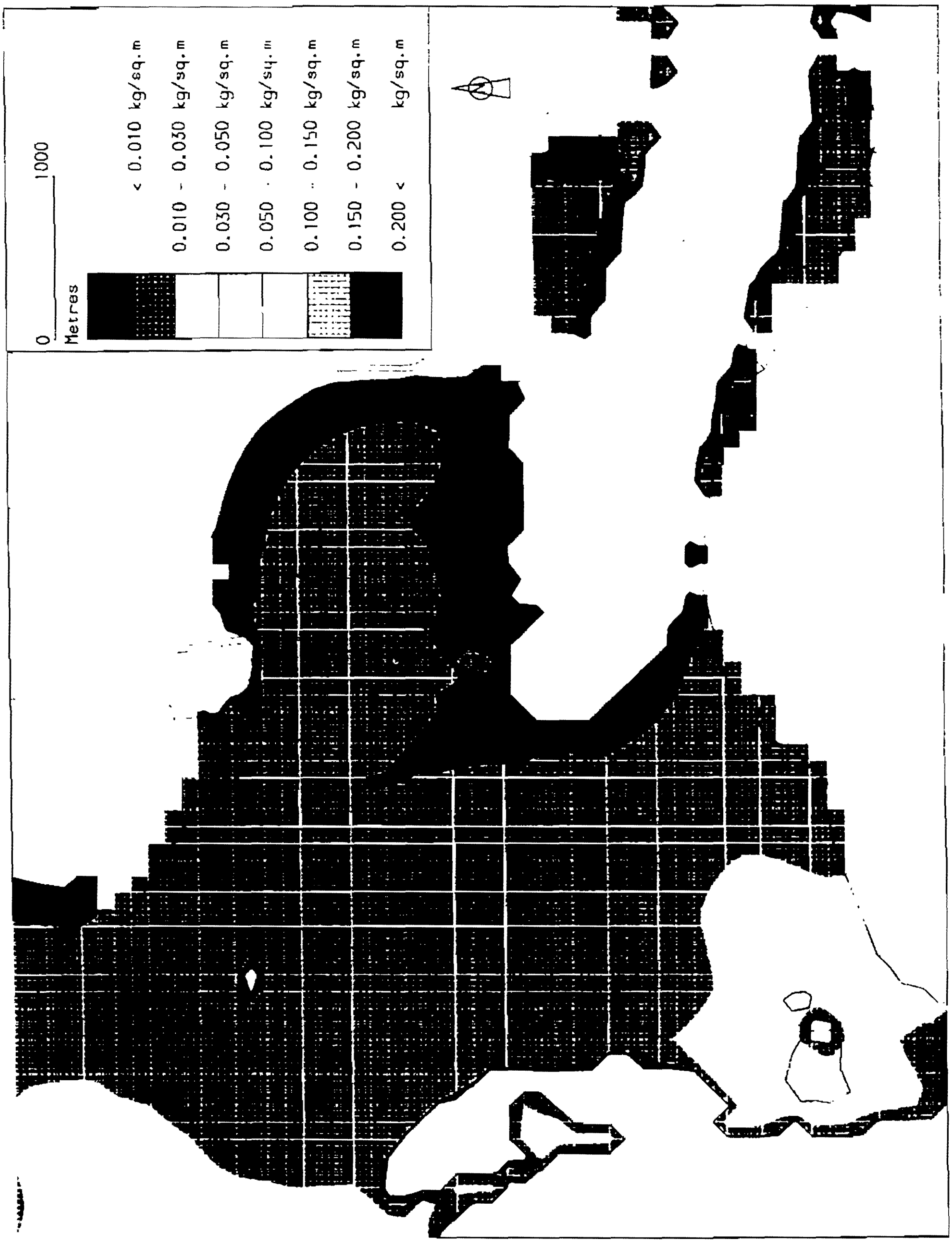
Stonecutters Naval Base Anchorage Area
Completed Scenario
Suspended Sediment Concentrations
Dry Season Spring Tide



Stonecutters Naval Base Anchorage Area
Completed Scenario
Suspended Sediment Concentrations
Dry Season Spring Tide

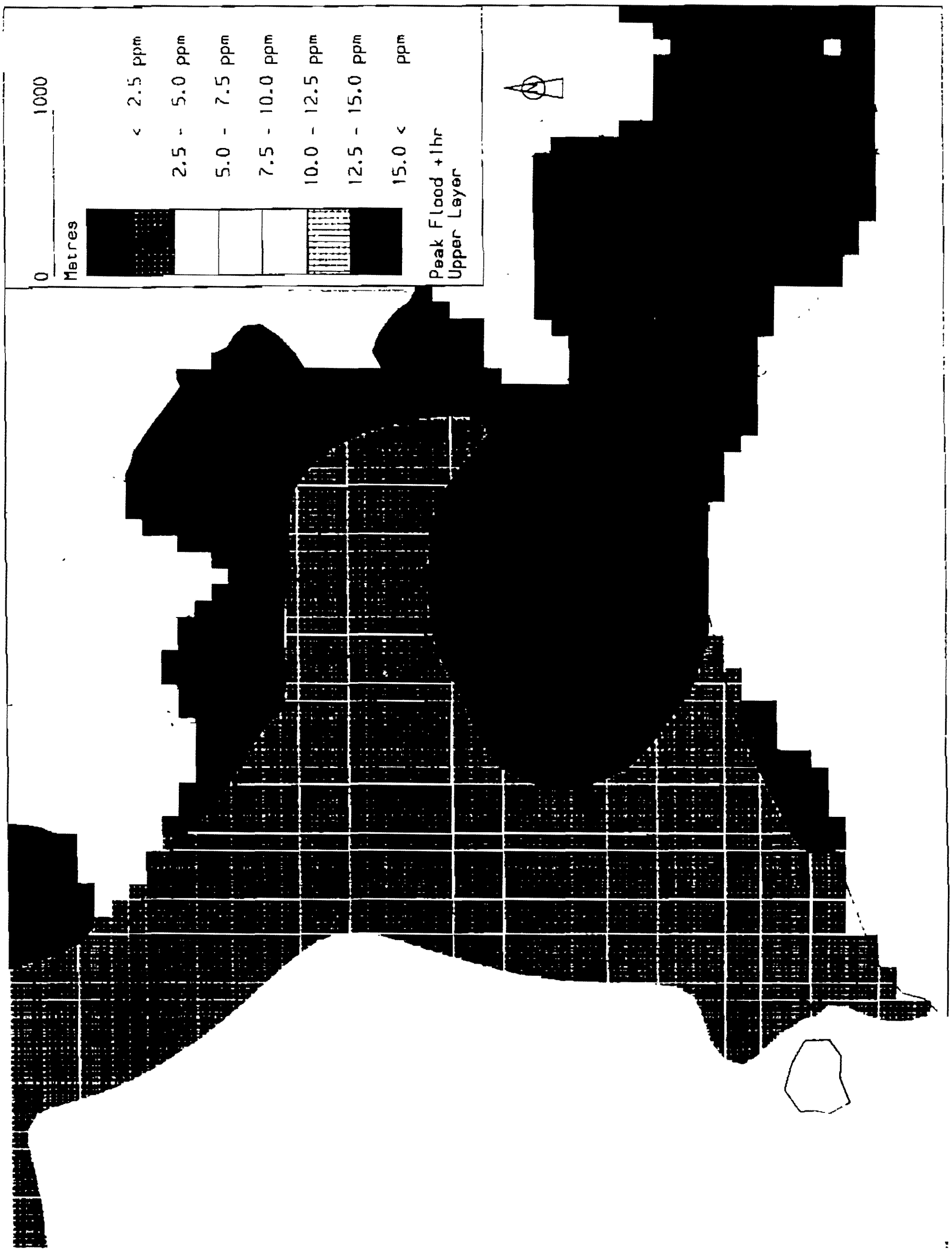


Stonecutters Naval Base Anchorage Area
Completed Scenario
Suspended Sediment Concentrations
Dry Season Spring Tide

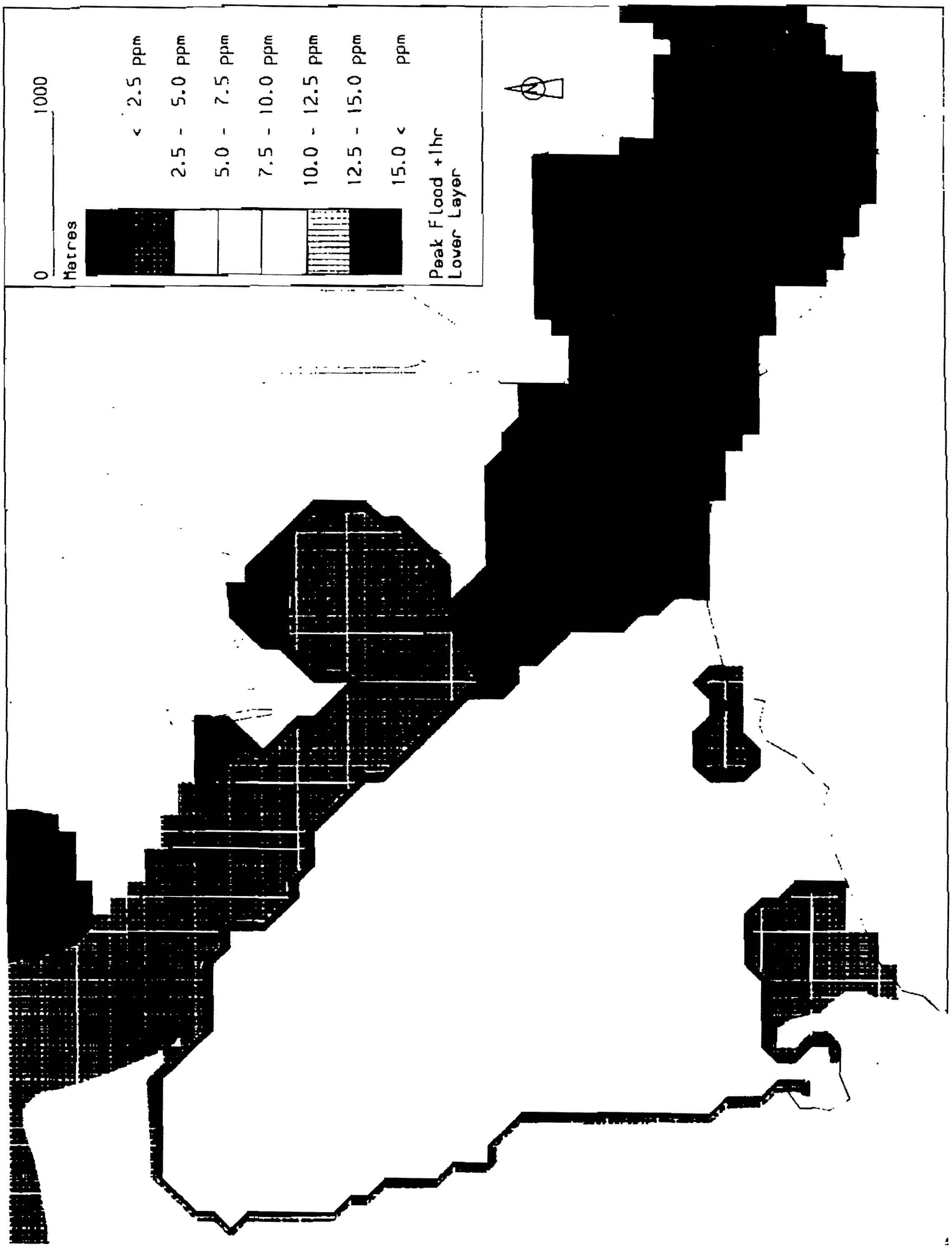


Stonecutters Naval Base Anchorage Area
Completed Scenario
Mud Deposits over 1 Tide
Dry Season Spring Tide

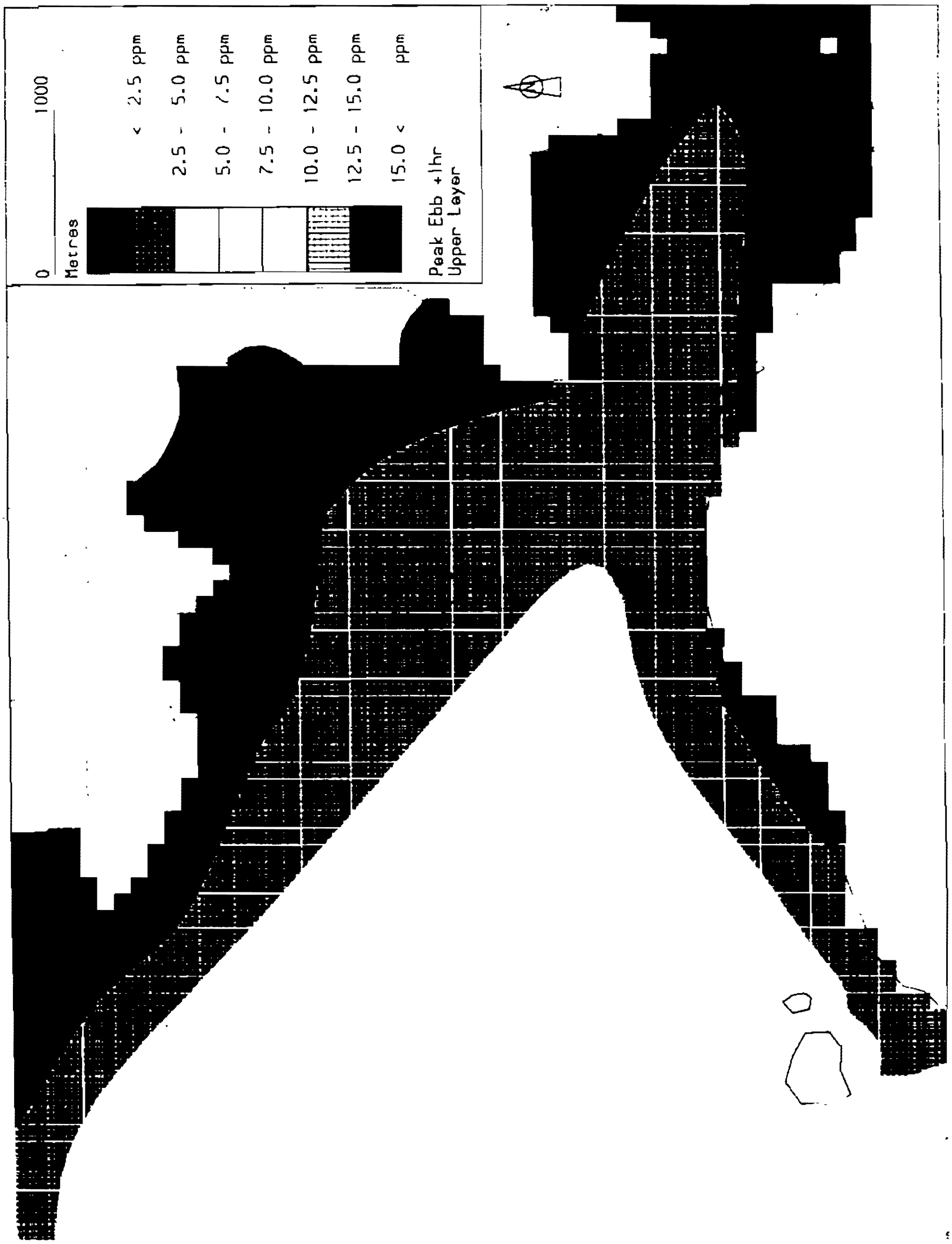
DRY SEASON NEAP TIDE



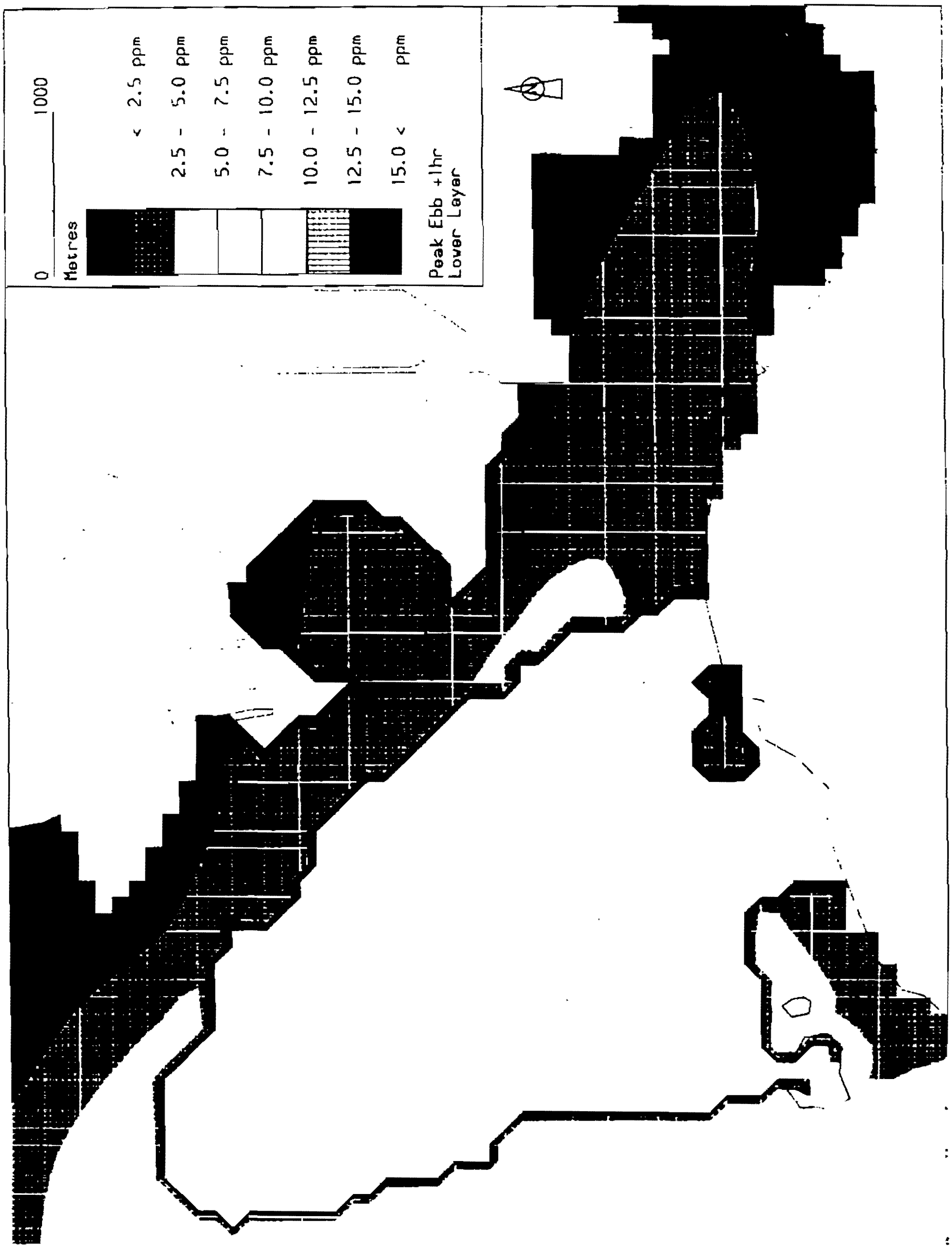
Stonecutters Naval Base Anchorage Area
Completed Scenario
Suspended Sediment Concentrations
Dry Season Neap Tide



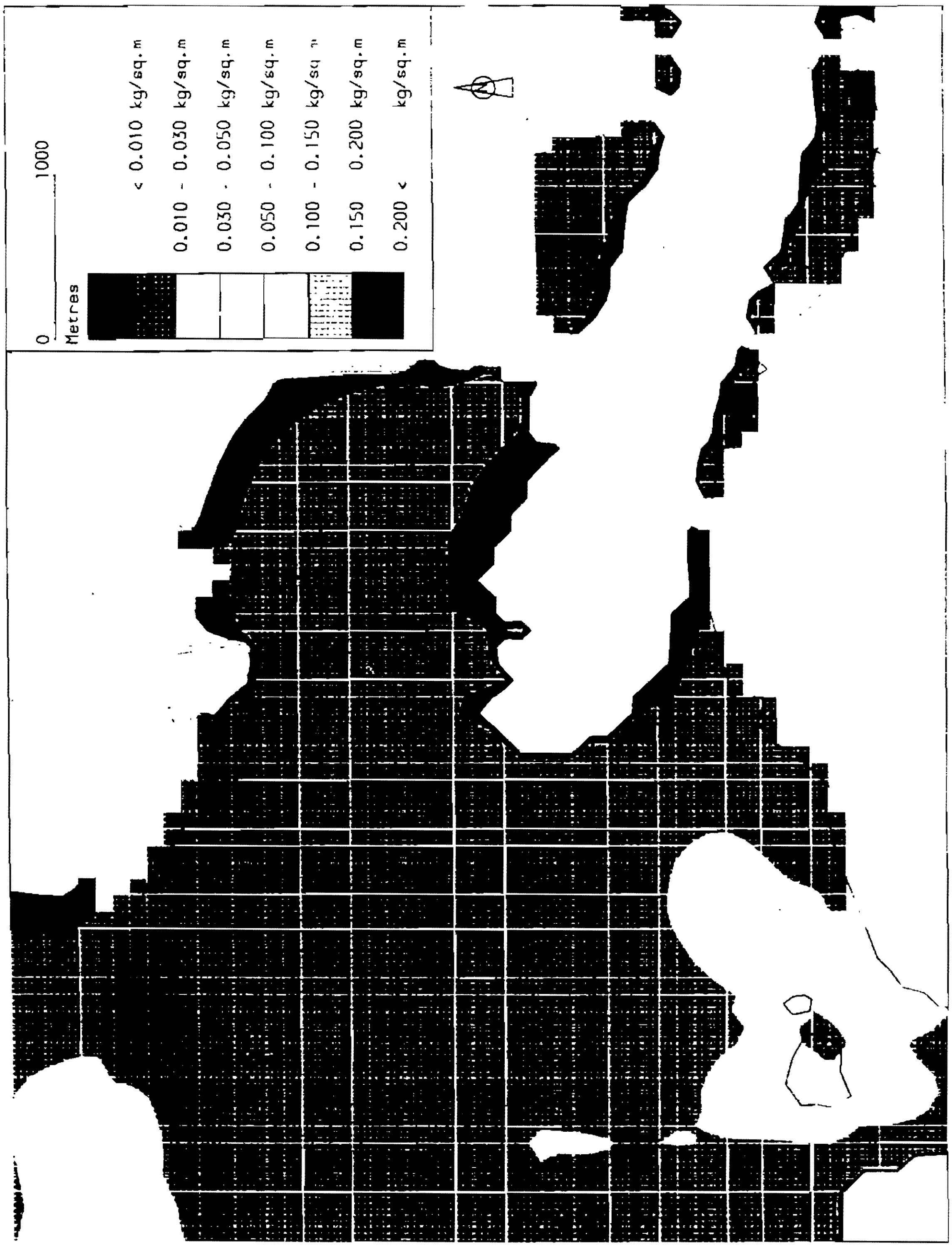
Stonecutters Naval Base Anchorage Area
Completed Scenario
Suspended Sediment Concentrations
Dry Season Neap Tide



Stonecutters Naval Base Anchorage Area
Completed Scenario
Suspended Sediment Concentrations
Dry Season Neap Tide

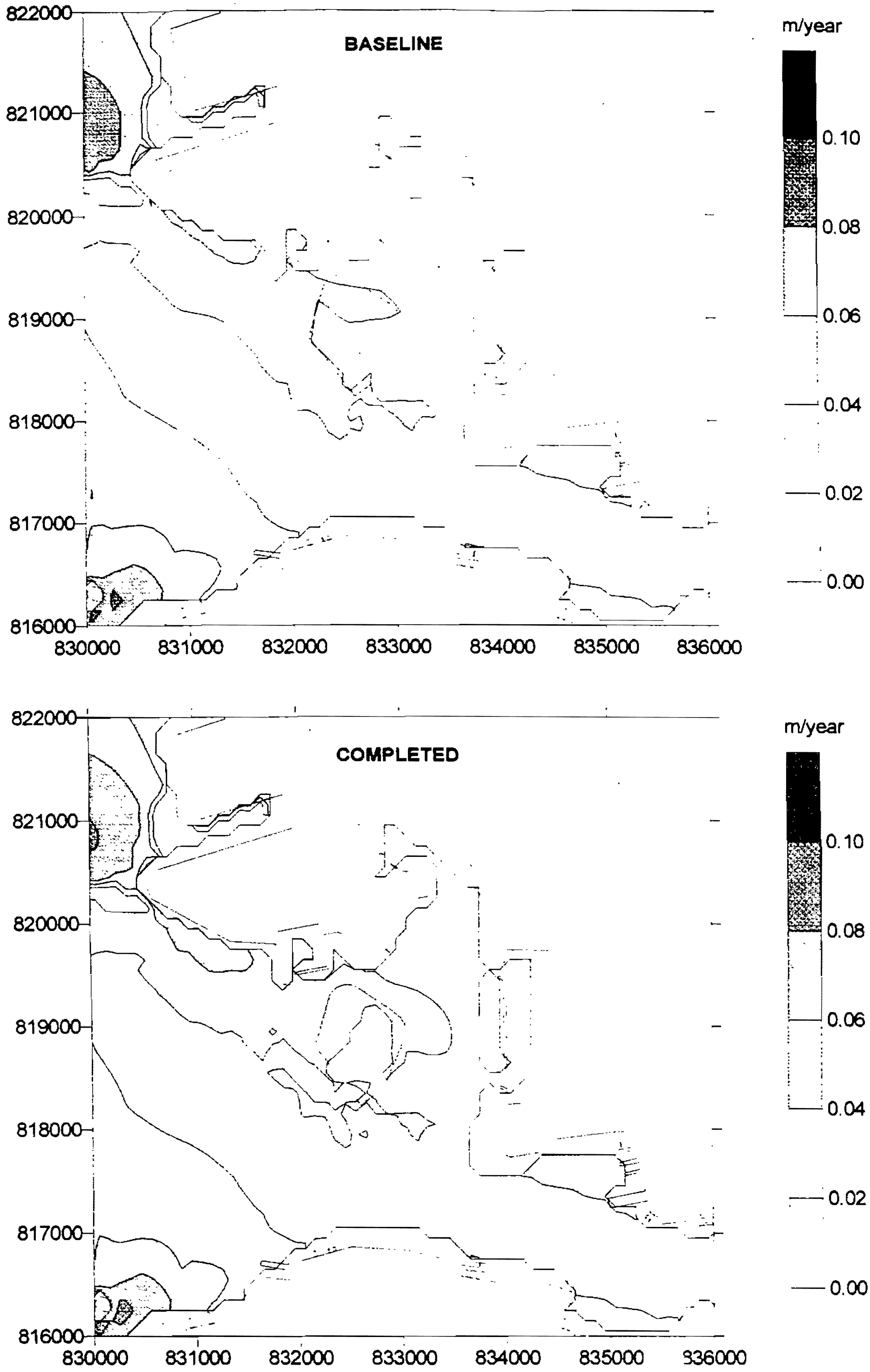


Stonecutters Naval Base Anchorage Area
Completed Scenario
Suspended Sediment Concentrations
Dry Season Neap Tide



Stonecutters Naval Base Anchorage Area
Completed Scenario
Mud Deposits over 1 Tide
Dry Season Neap Tide

APPENDIX L
PREDICTION OF ANNUAL SILTATION RATES

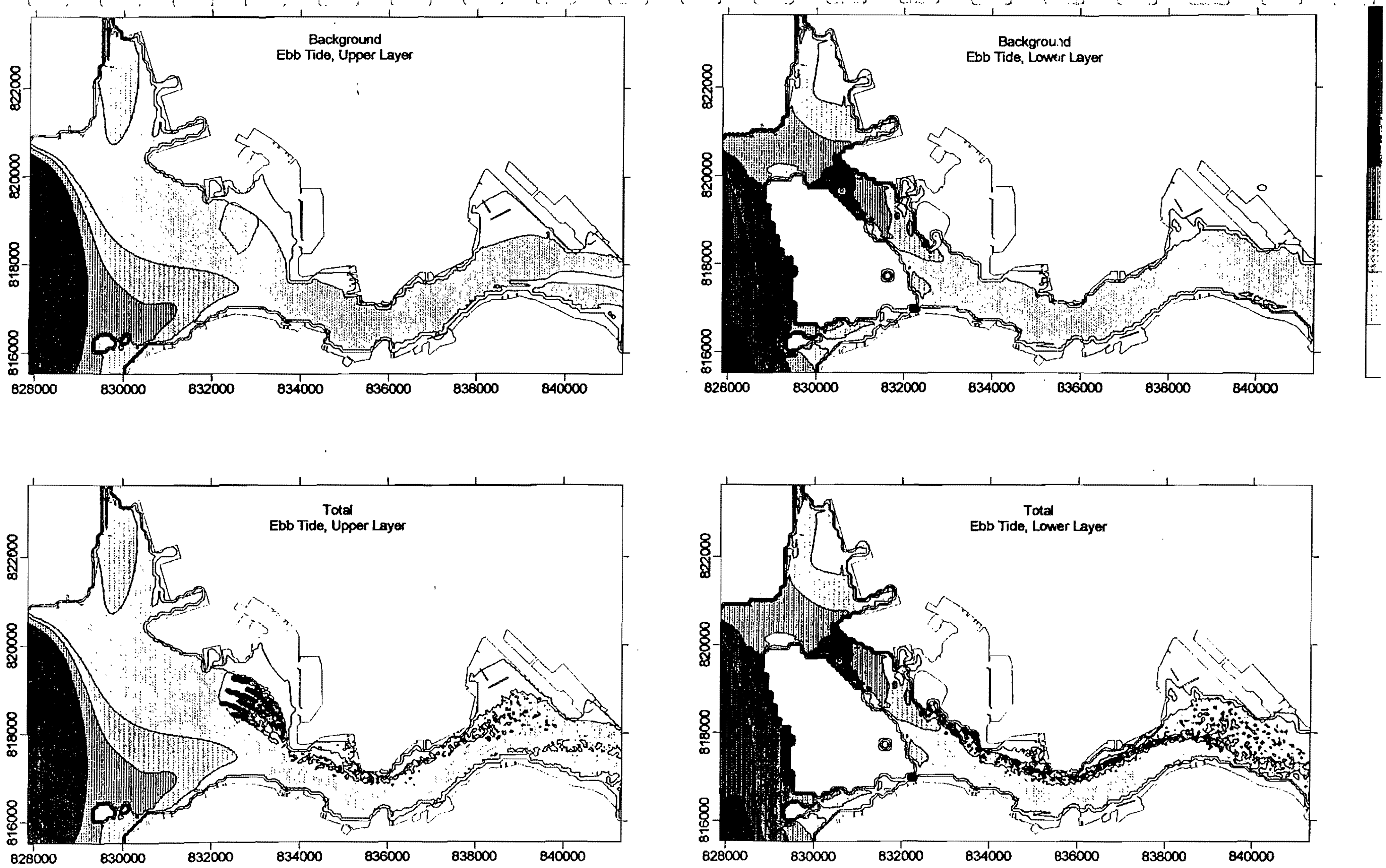


Stonecutters Naval Base Anchorage Area
Predicted Annual Siltation Rates

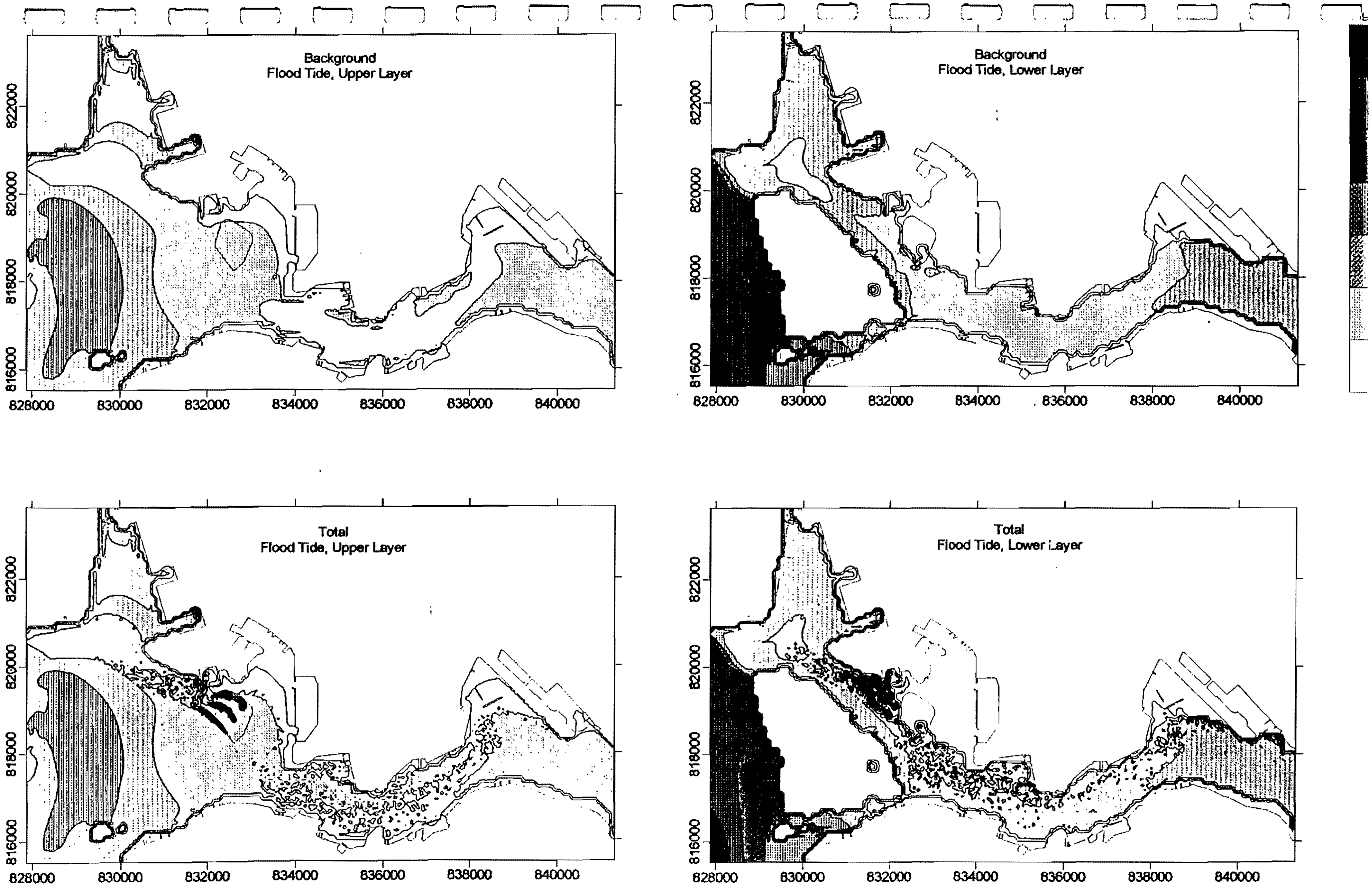
APPENDIX M
COMBINED SEDIMENT PLUME AND SEDIMENT TRANSPORT MODEL RESULTS

Appendix K

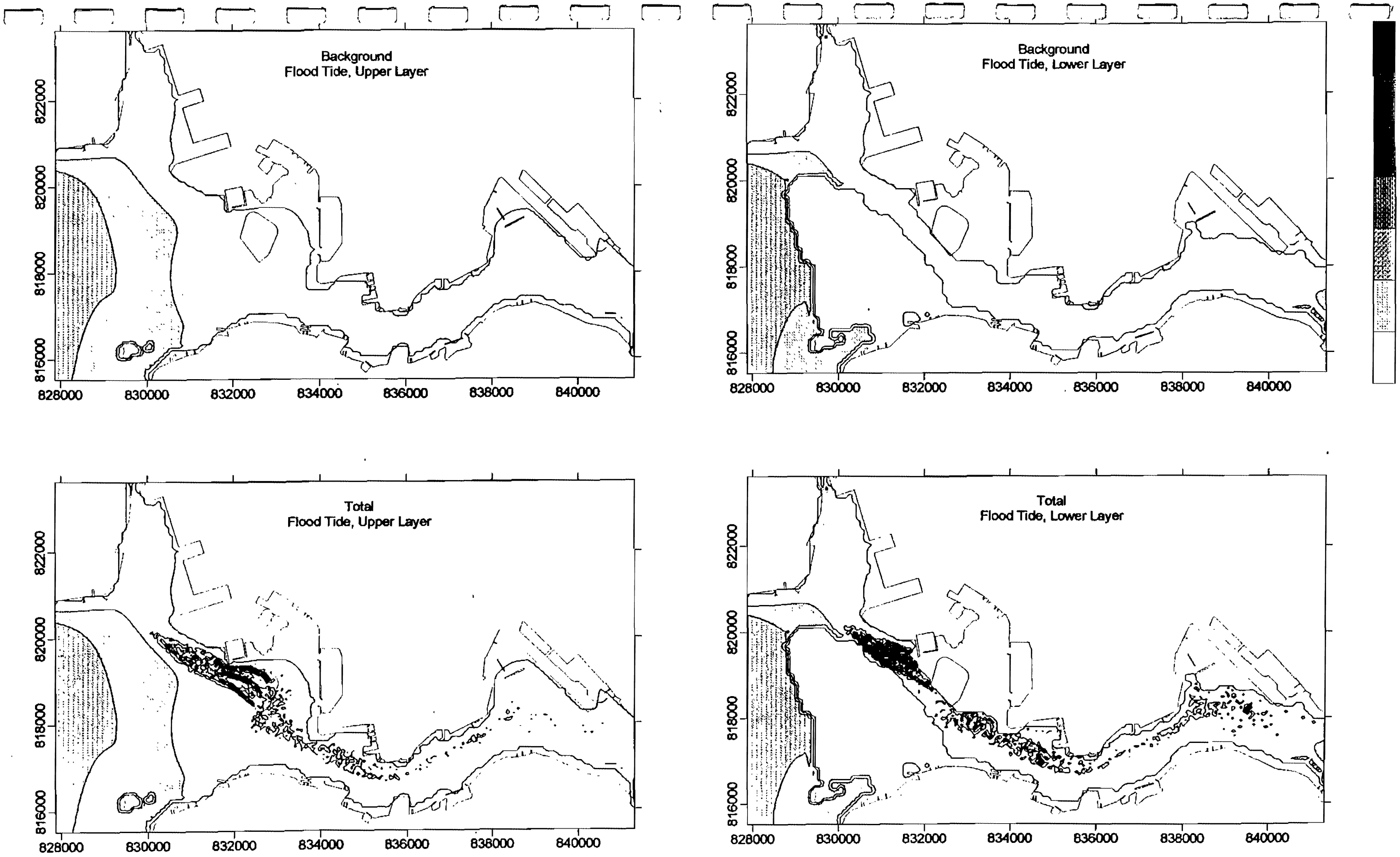
Combined Suspended Sediment Concentrations



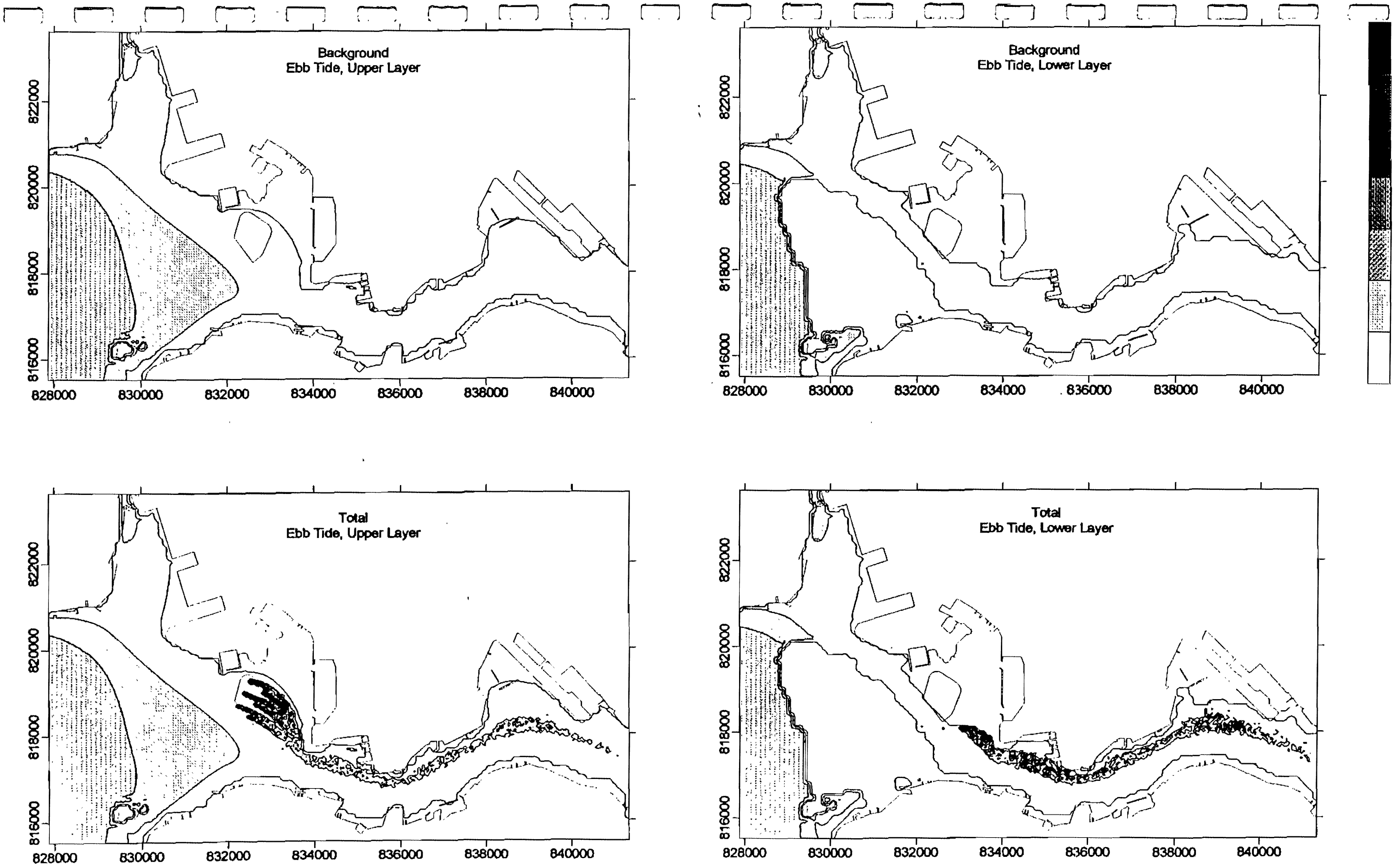
Stonecutters Naval Base Anchorage Area
Background and Total Suspended Sediment Concentrations
Scenario 1, Wet Season Spring Tide



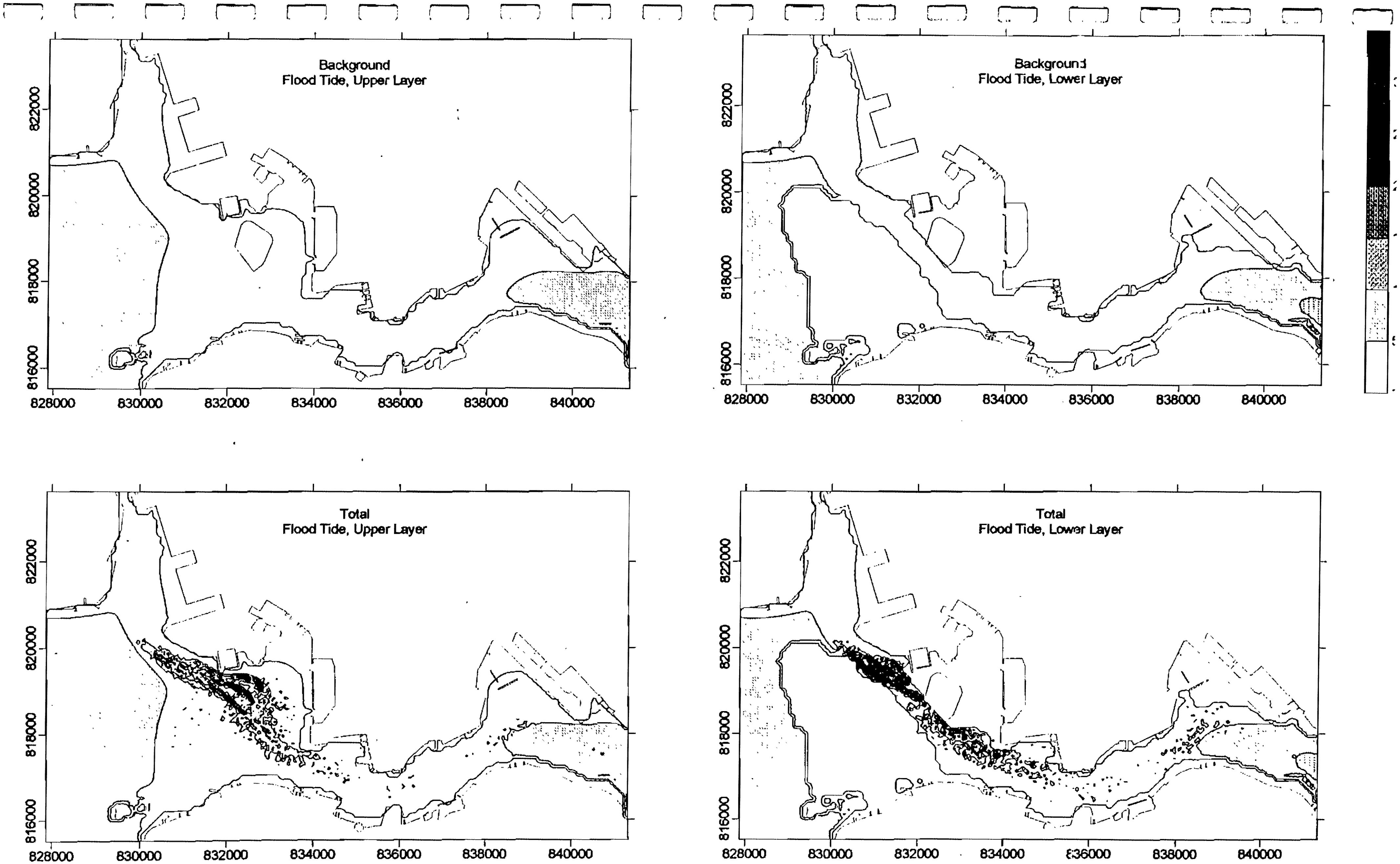
Stonecutters Naval Base Anchorage Area
Background and Total Suspended Sediment Concentrations
Scenario 1, Wet Season Spring Tide



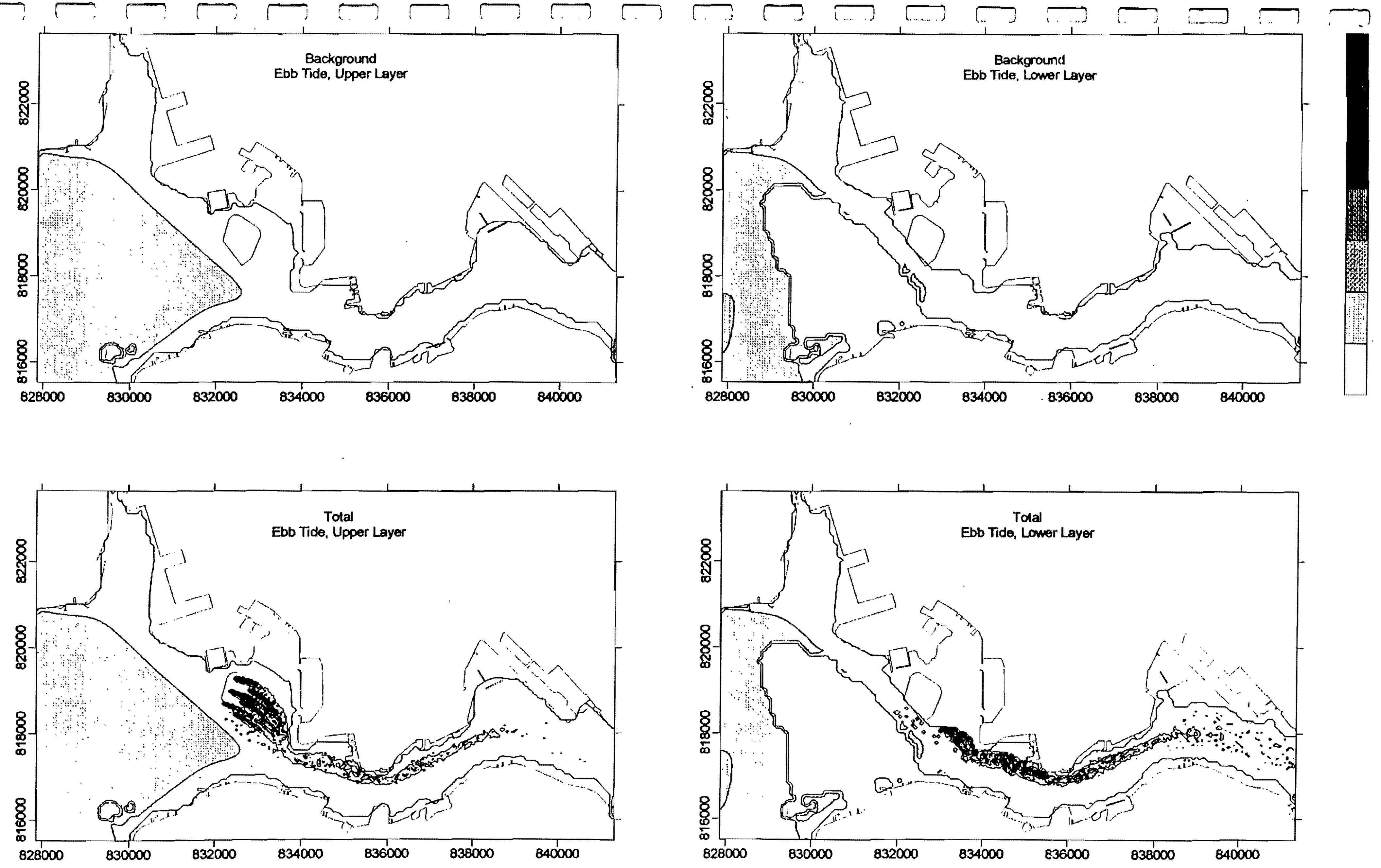
Stonecutters Naval Base Anchorage Area
Background and Total Suspended Sediment Concentrations
Scenario 1, Dry Season Spring Tide



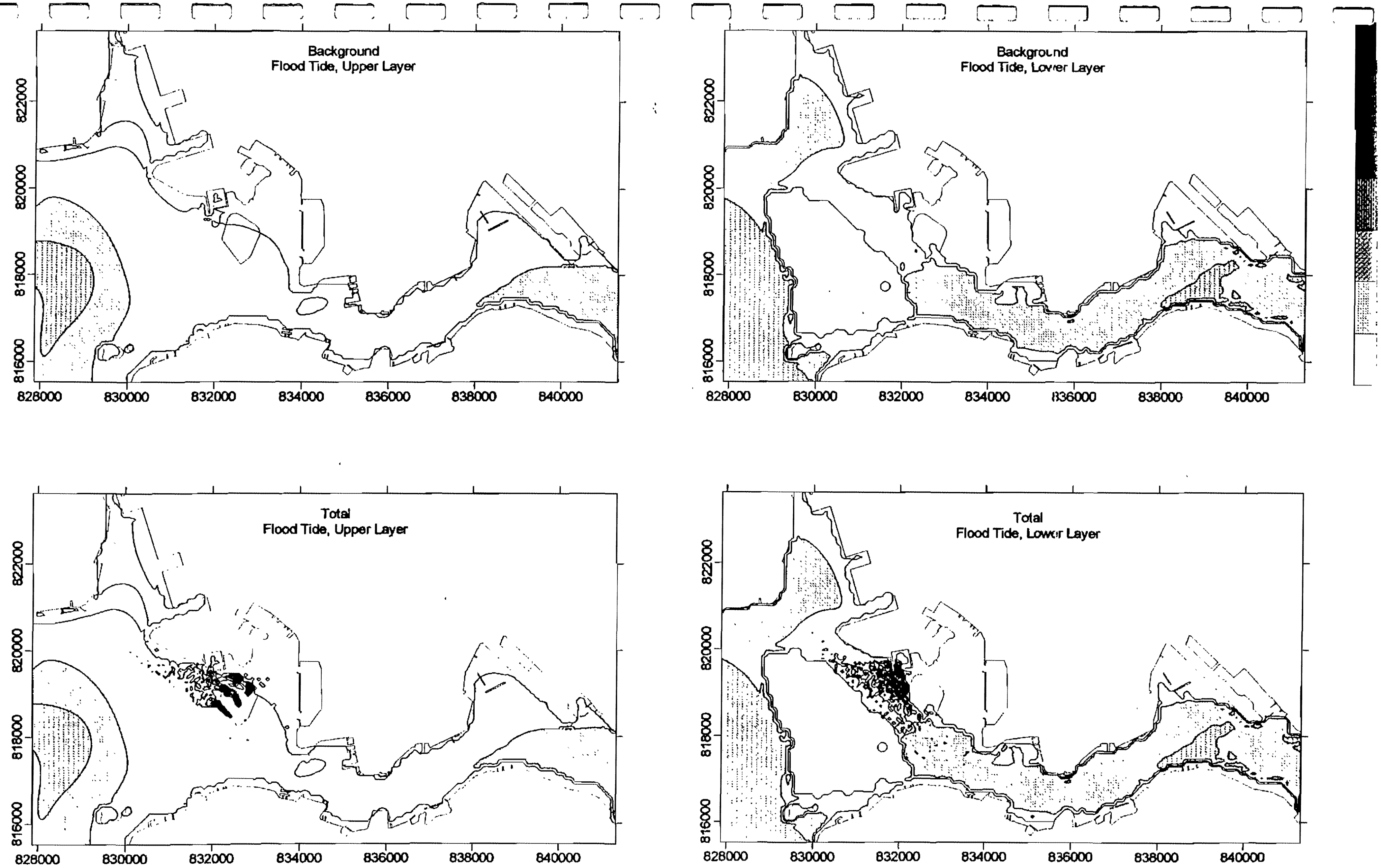
Stonecutters Naval Base Anchorage Area
Background and Total Suspended Sediment Concentrations
Scenario 1, Dry Season Spring Tide



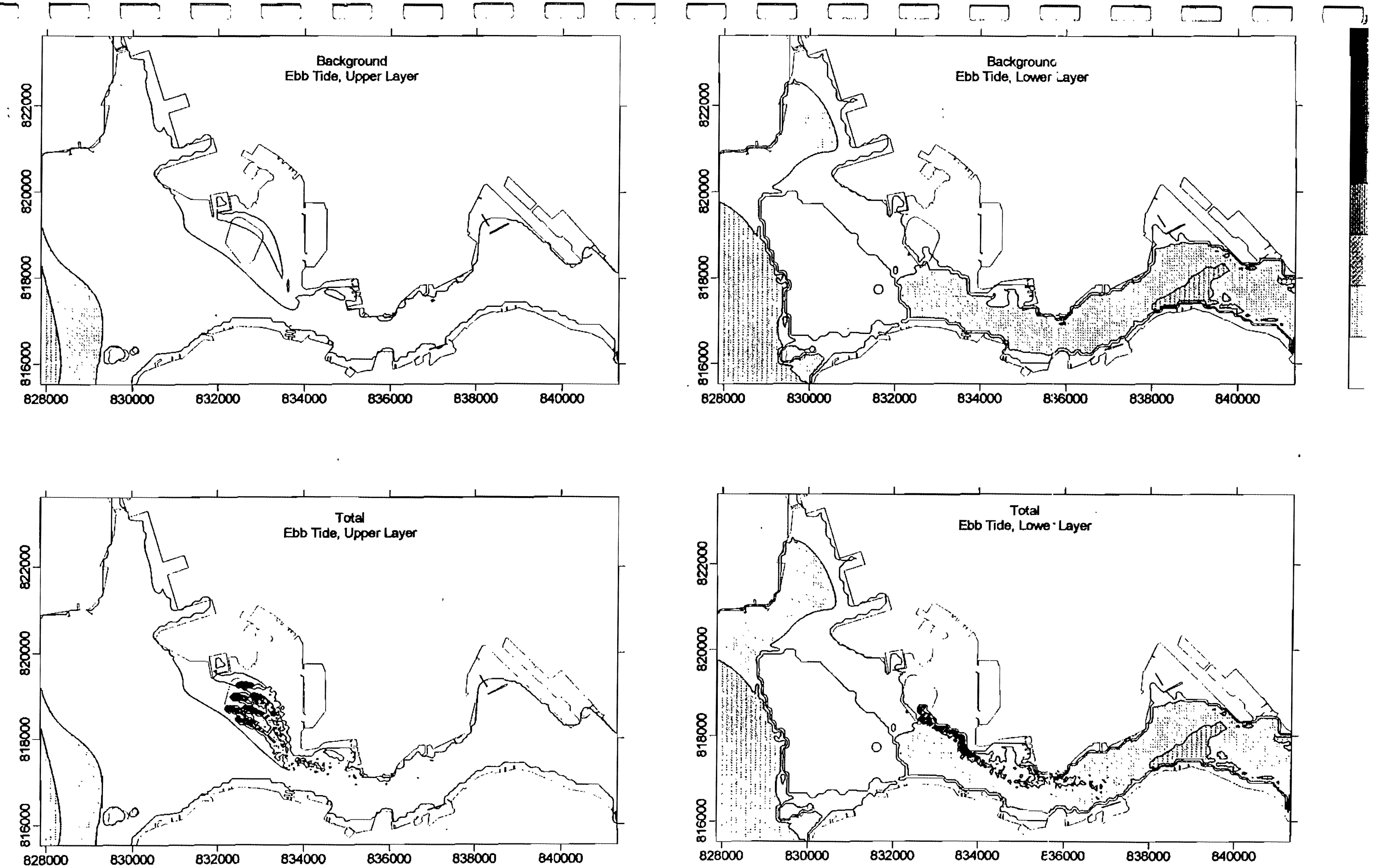
Stonecutters Naval Base Anchorage Area
Background and Total Suspended Sediment Concentrations
Scenario 1, Dry Season Neap Tide



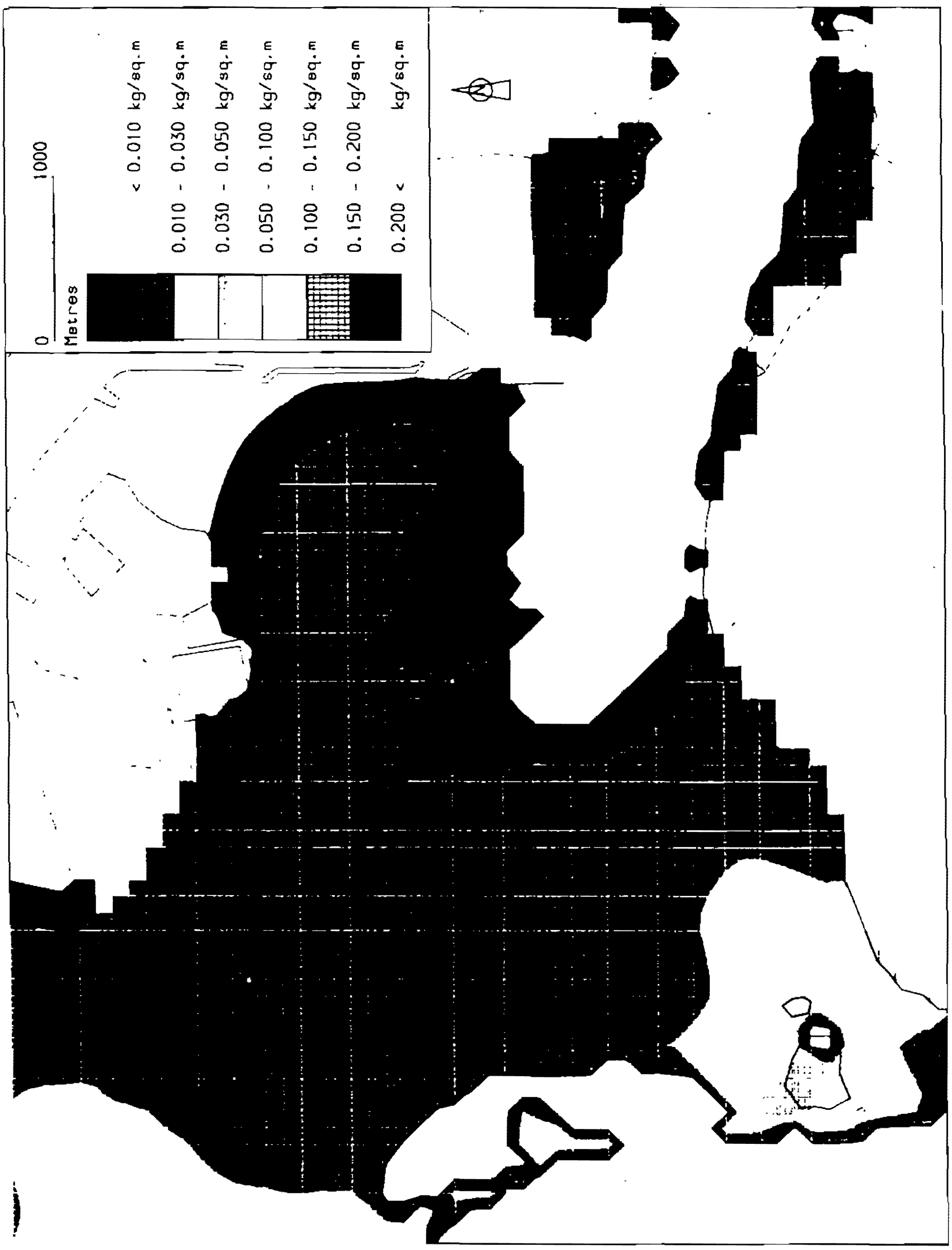
Stonecutters Naval Base Anchorage Area
Background and Total Suspended Sediment Concentrations
Scenario 1, Dry Season Neap Tide



Stonecutters Naval Base Anchorage Area
Background and Total Suspended Sediment Concentrations
Scenario 1, Wet Season Neap Tide

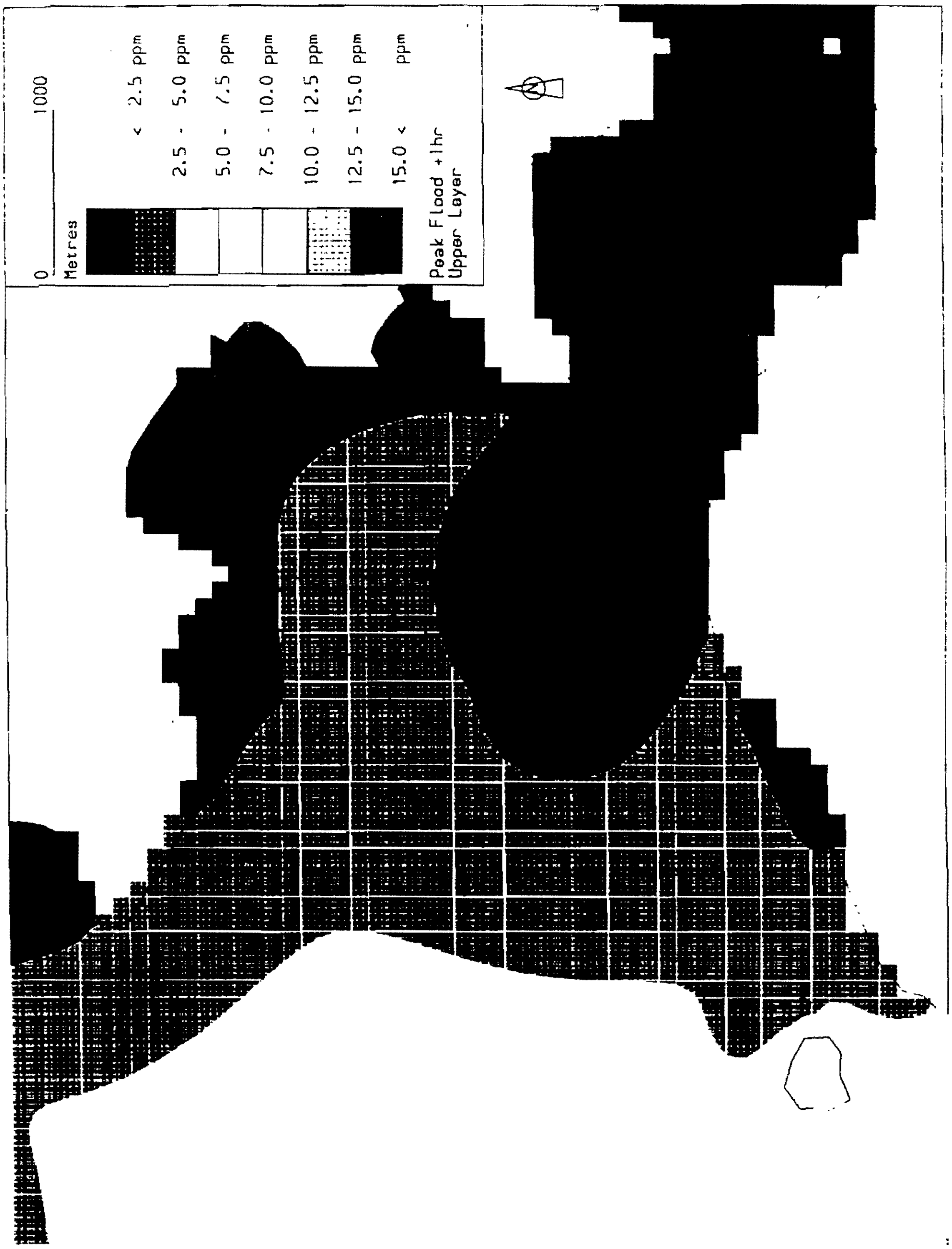


Stonecutters Naval Base Anchorage Area
Background and Total Suspended Sediment Concentrations
Scenario 1, Wet Season Neap Tide

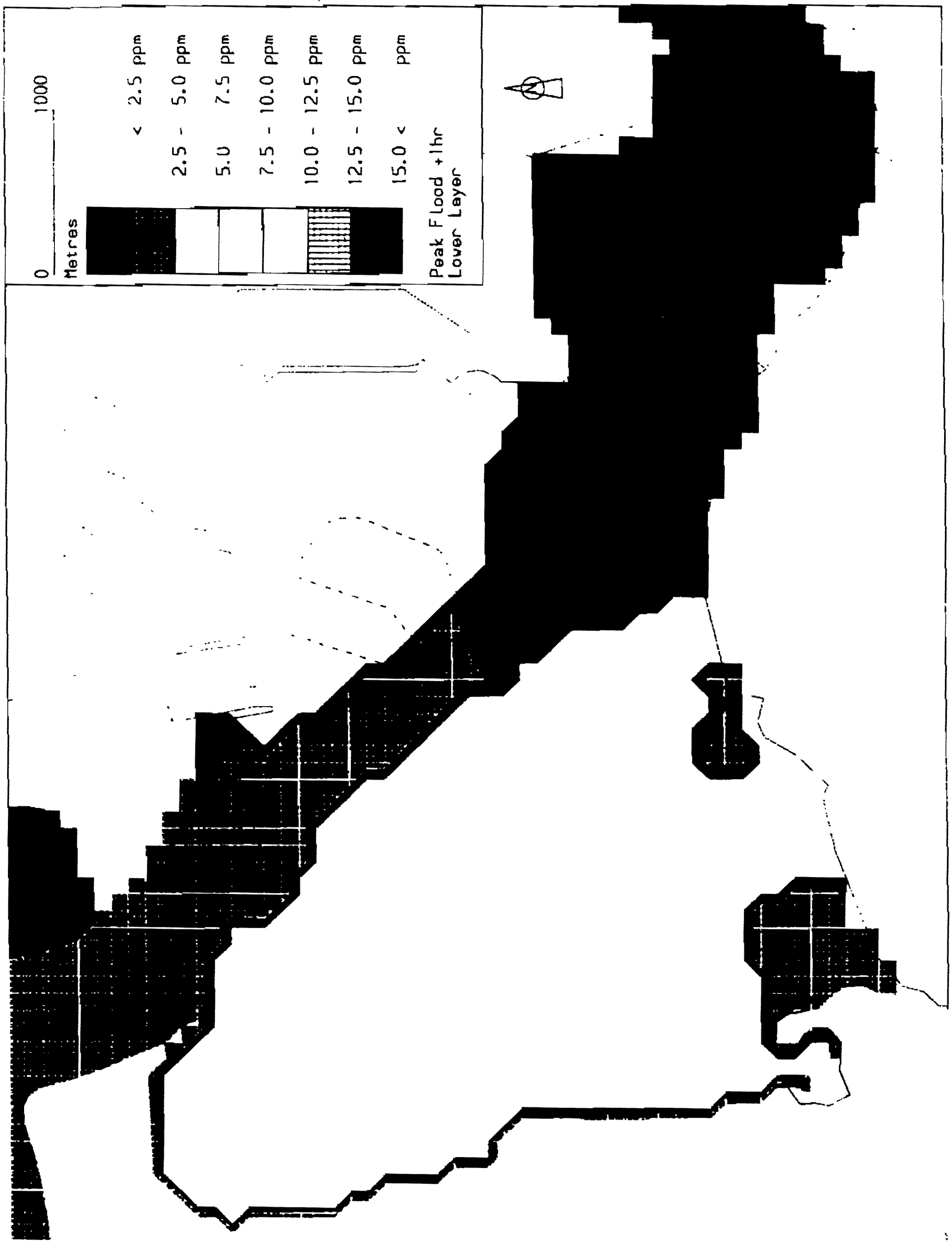


Stonecutters Naval Base Anchorage Area
Baseline Scenario
Mud Deposits over 1 Tide
Dry Season Spring Tide

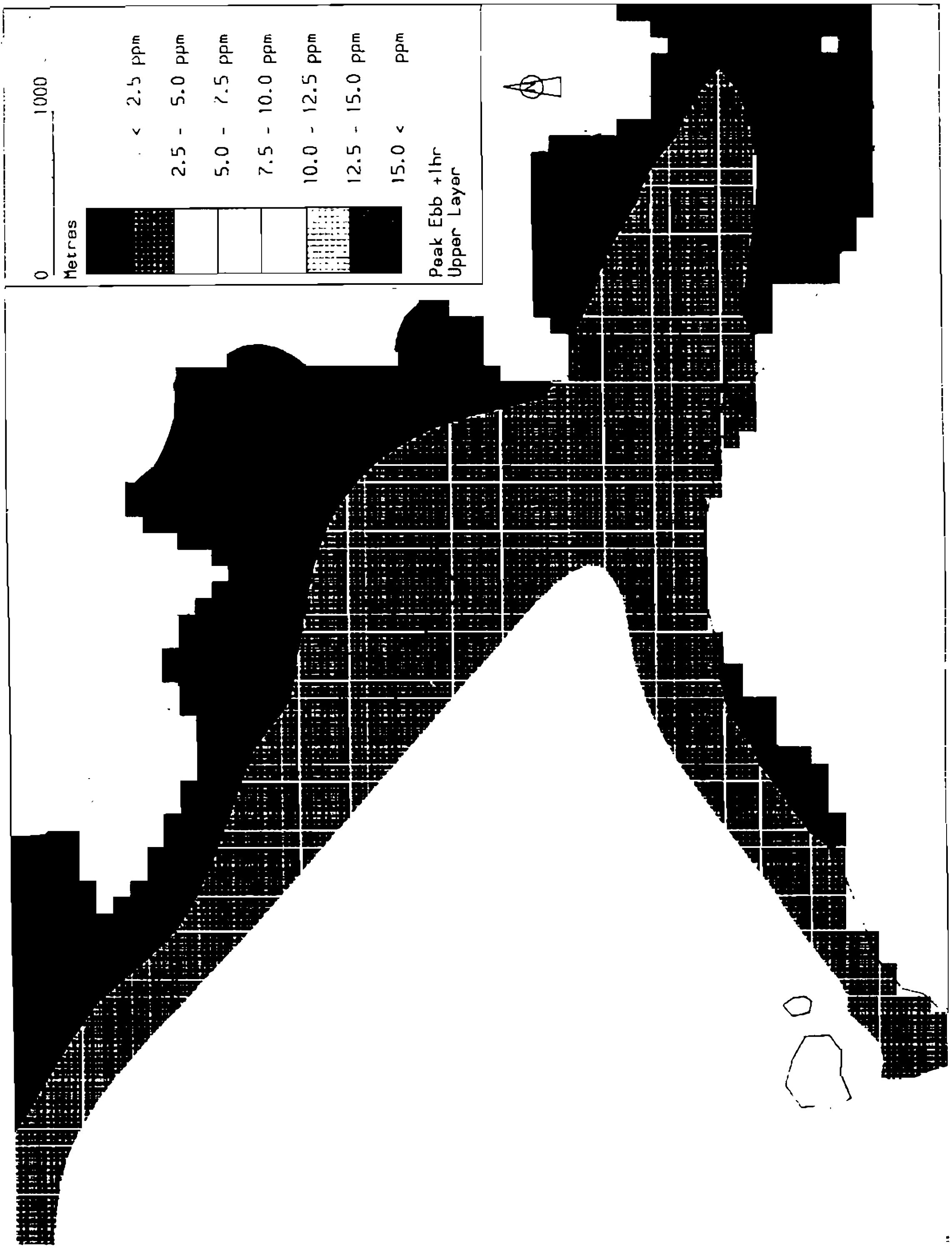
DRY SEASON NEAP TIDE



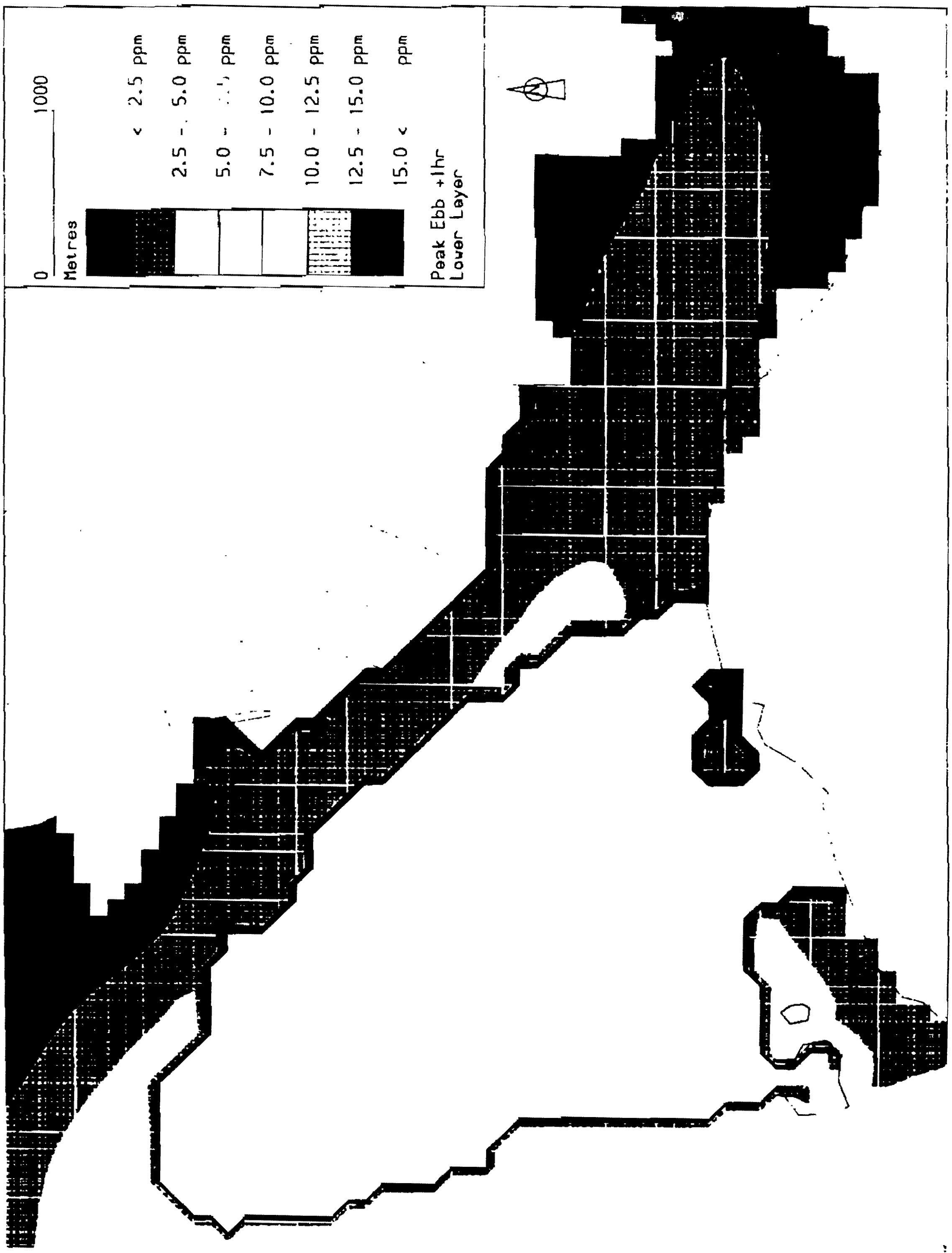
Stonecutters Naval Base Anchorage Area
Baseline Scenario
Suspended Sediment Concentrations
Dry Season Neap Tide



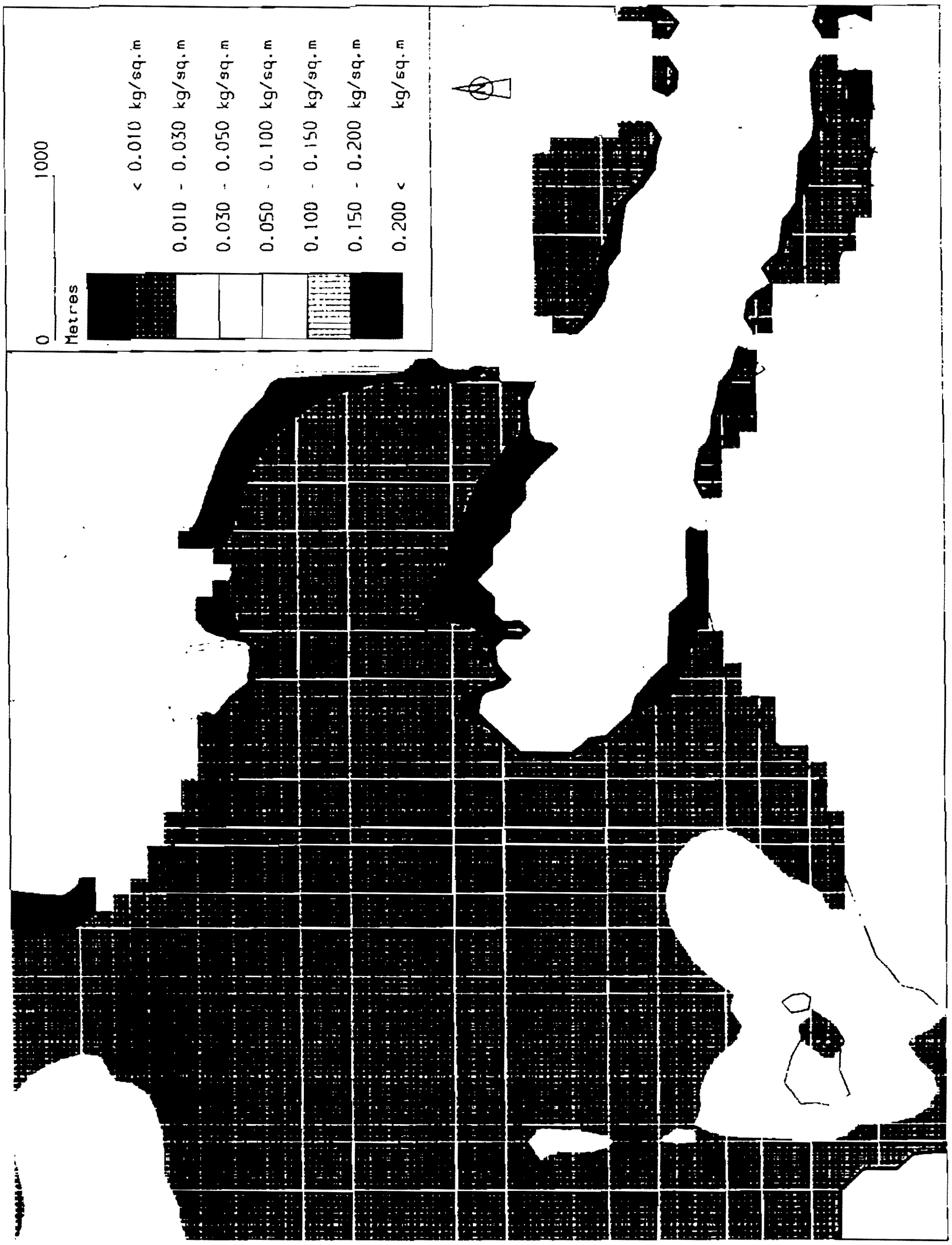
Stonecutters Naval Base Anchorage Area
Baseline Scenario
Suspended Sediment Concentrations
Dry Season Neap Tide



Stonecutters Naval Base Anchorage Area
Baseline Scenario
Suspended Sediment Concentrations
Dry Season Neap Tide



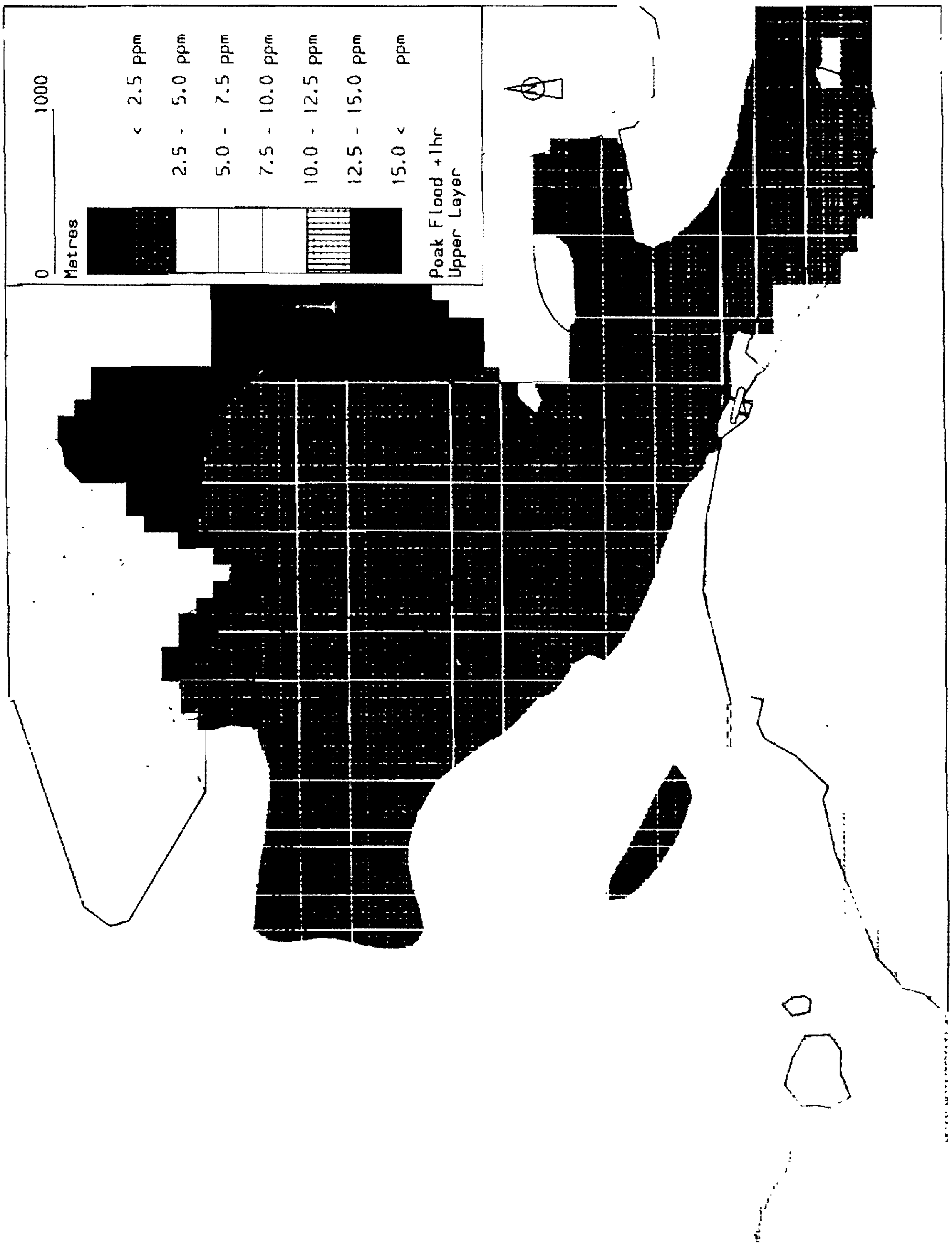
Stonecutters Naval Base Anchorage Area
Baseline Scenario
Suspended Sediment Concentrations
Dry Season Neap Tide



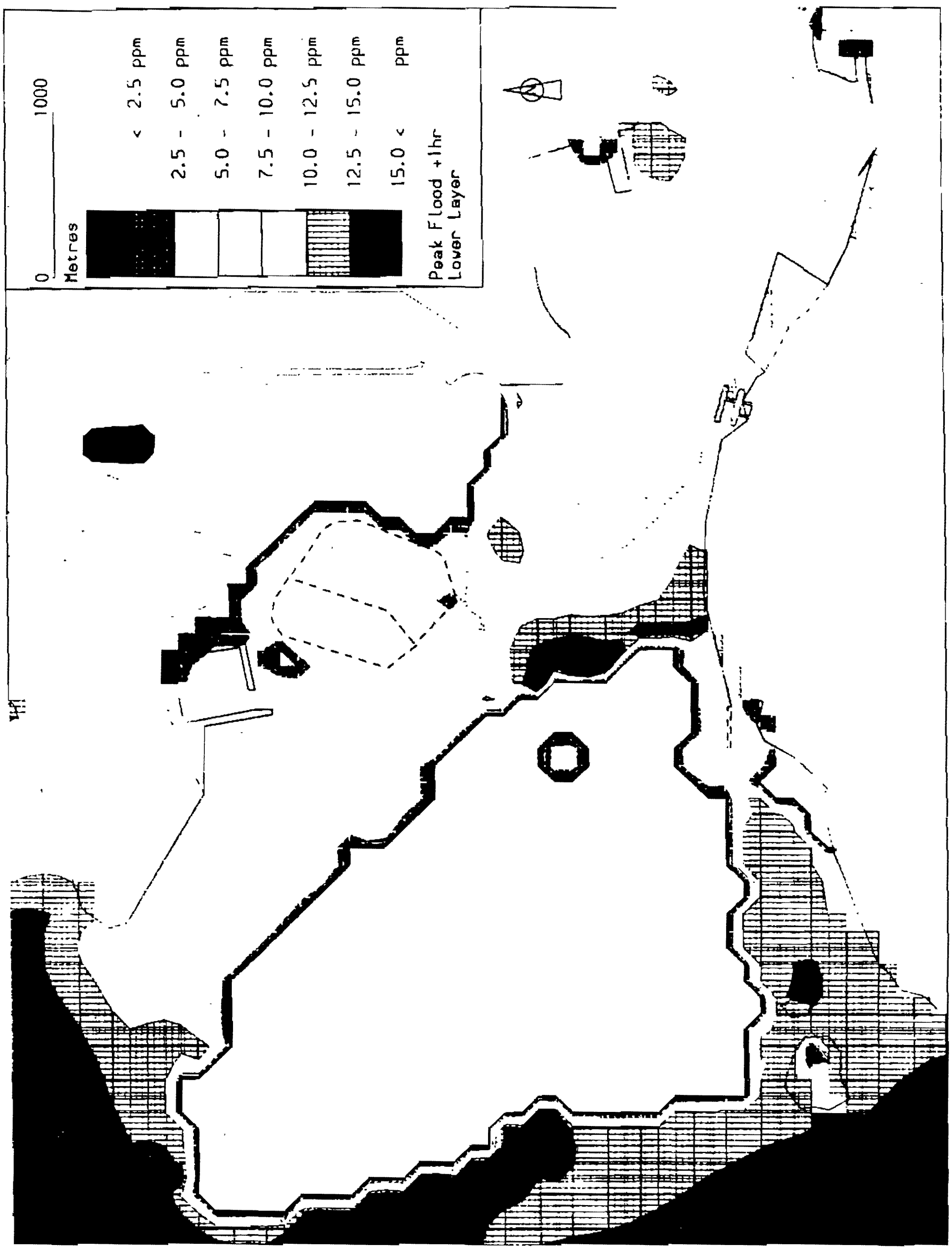
Stonecutters Naval Base Anchorage Area
Baseline Scenario
Mud Deposits over 1 Tide
Dry Season Neap Tide

APPENDIX K
SEDIMENT TRANSPORT MODEL RESULTS
COMPLETED SCENARIO

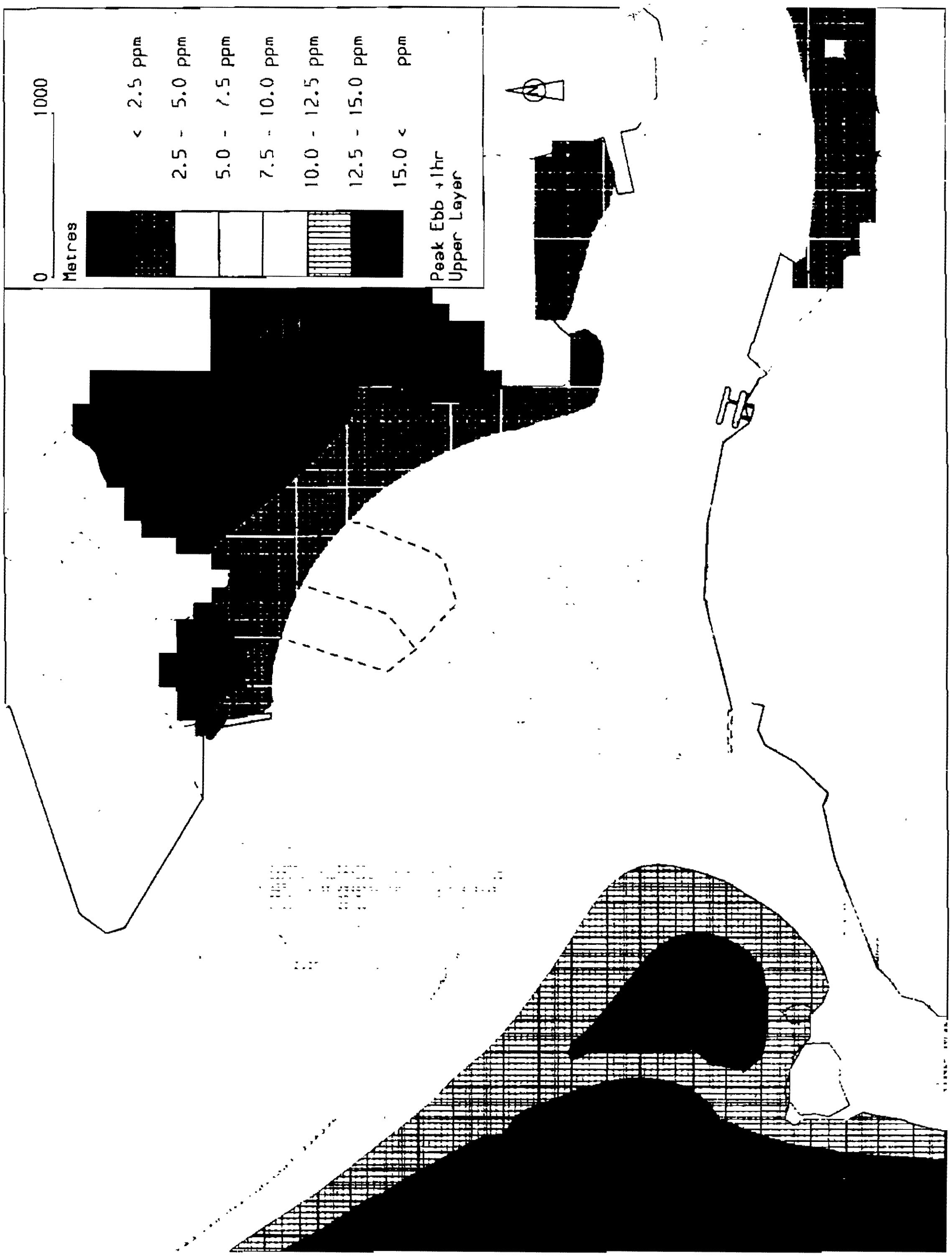
WET SEASON SPRING TIDE



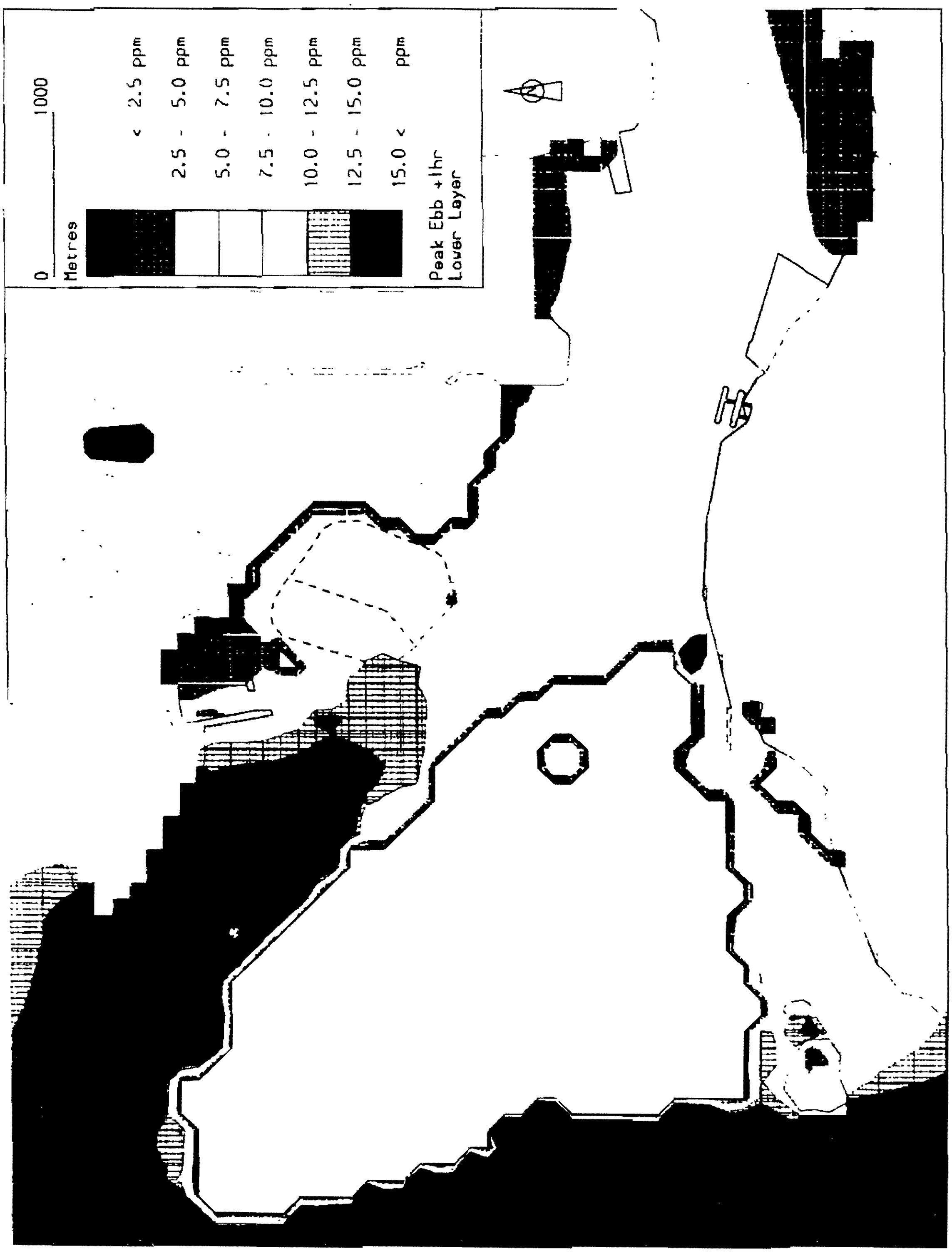
Stonecutters Naval Base Anchorage Area
Completed Scenario
Suspended Sediment Concentrations
Wet Season Spring Tide



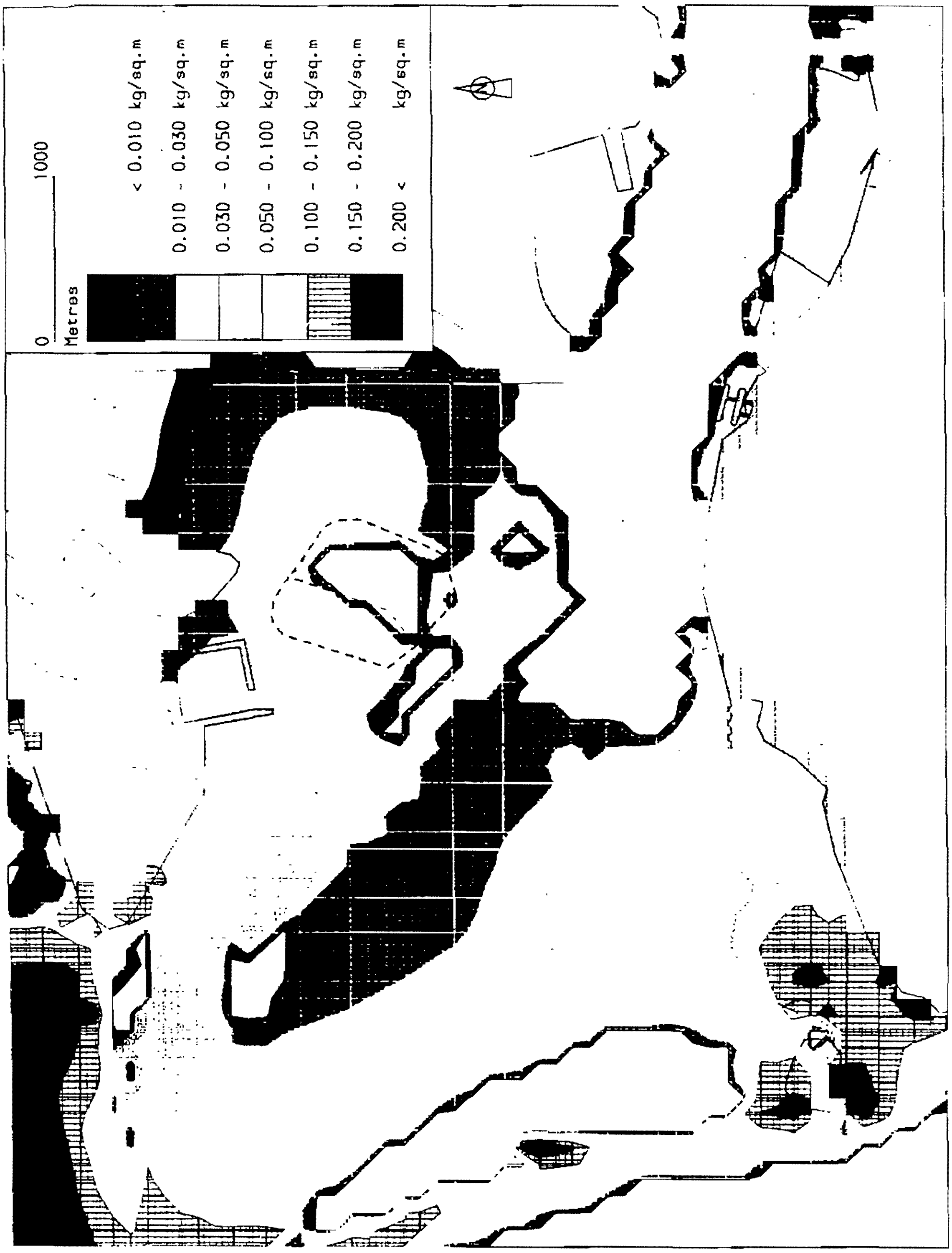
Stonecutters Naval Base Anchorage Area
Completed Scenario
Suspended Sediment Concentrations
Wet Season Spring Tide



Stonecutters Naval Base Anchorage Area
Completed Scenario
Suspended Sediment Concentrations
Wet Season Spring Tide

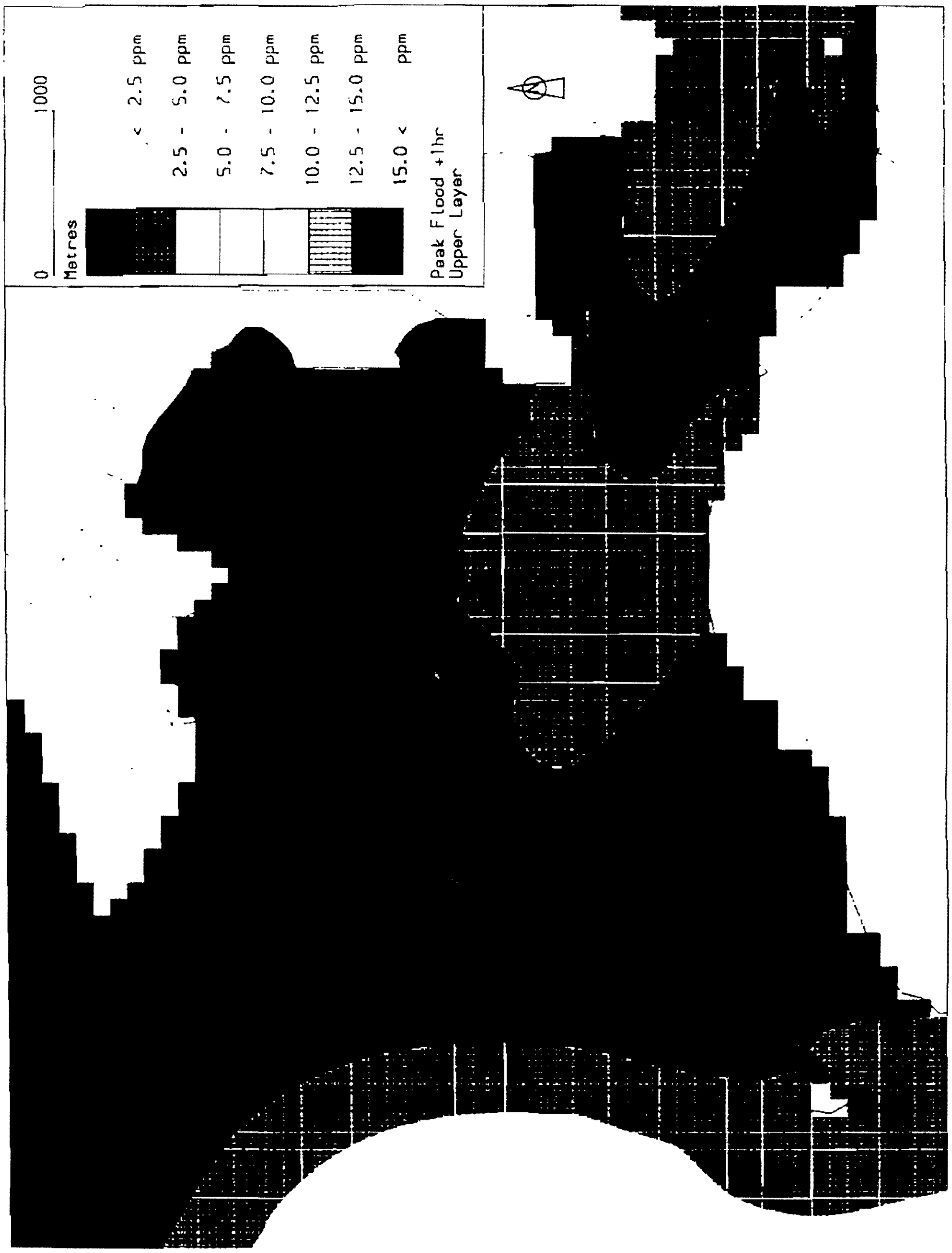


Stonecutters Naval Base Anchorage Area
Completed Scenario
Suspended Sediment Concentrations
Wet Season Spring Tide

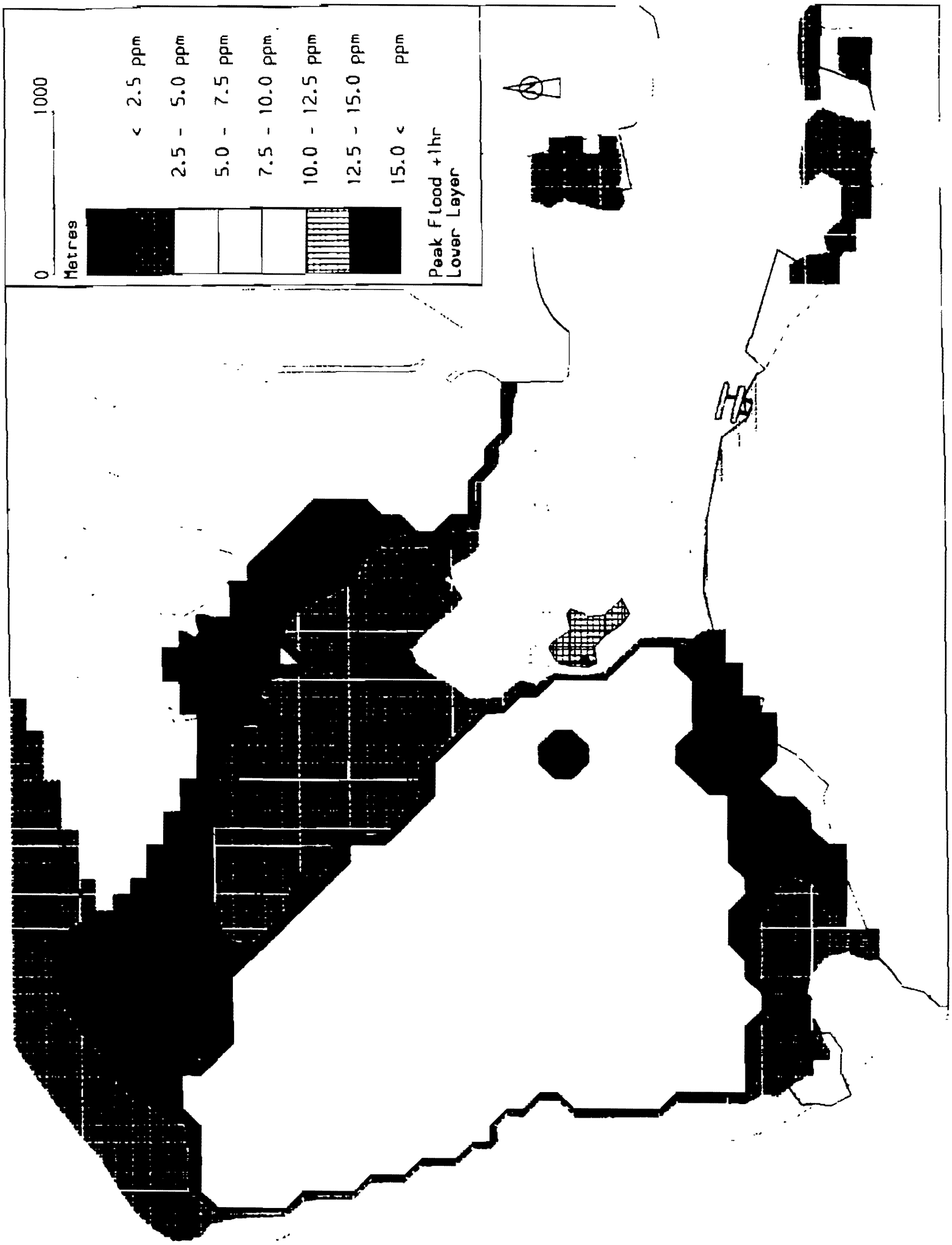


Stonecutters Naval Base Anchorage Area
Completed Scenario
Mud Deposits over 1 Tide
Wet Season Spring Tide

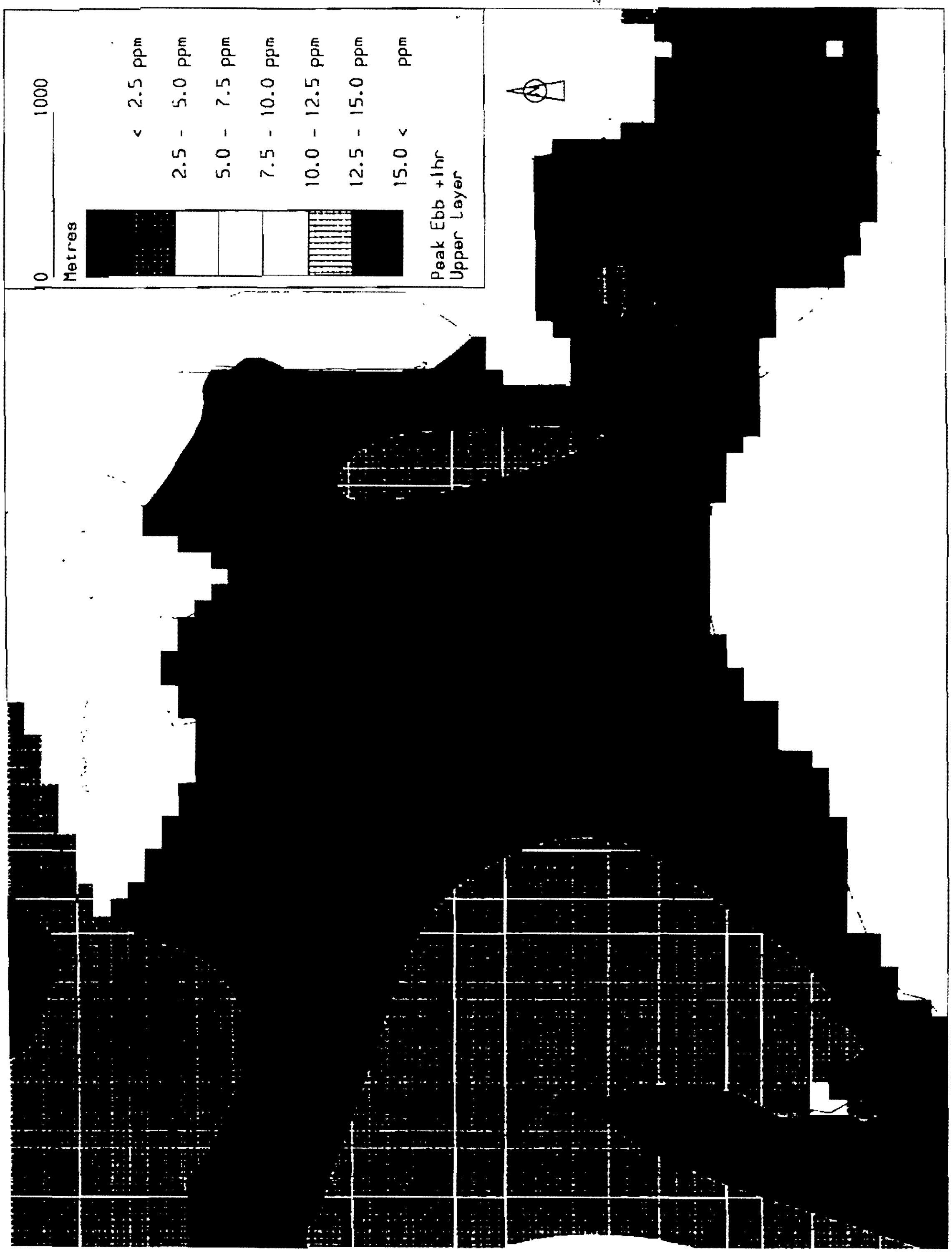
WET SEASON NEAP TIDE



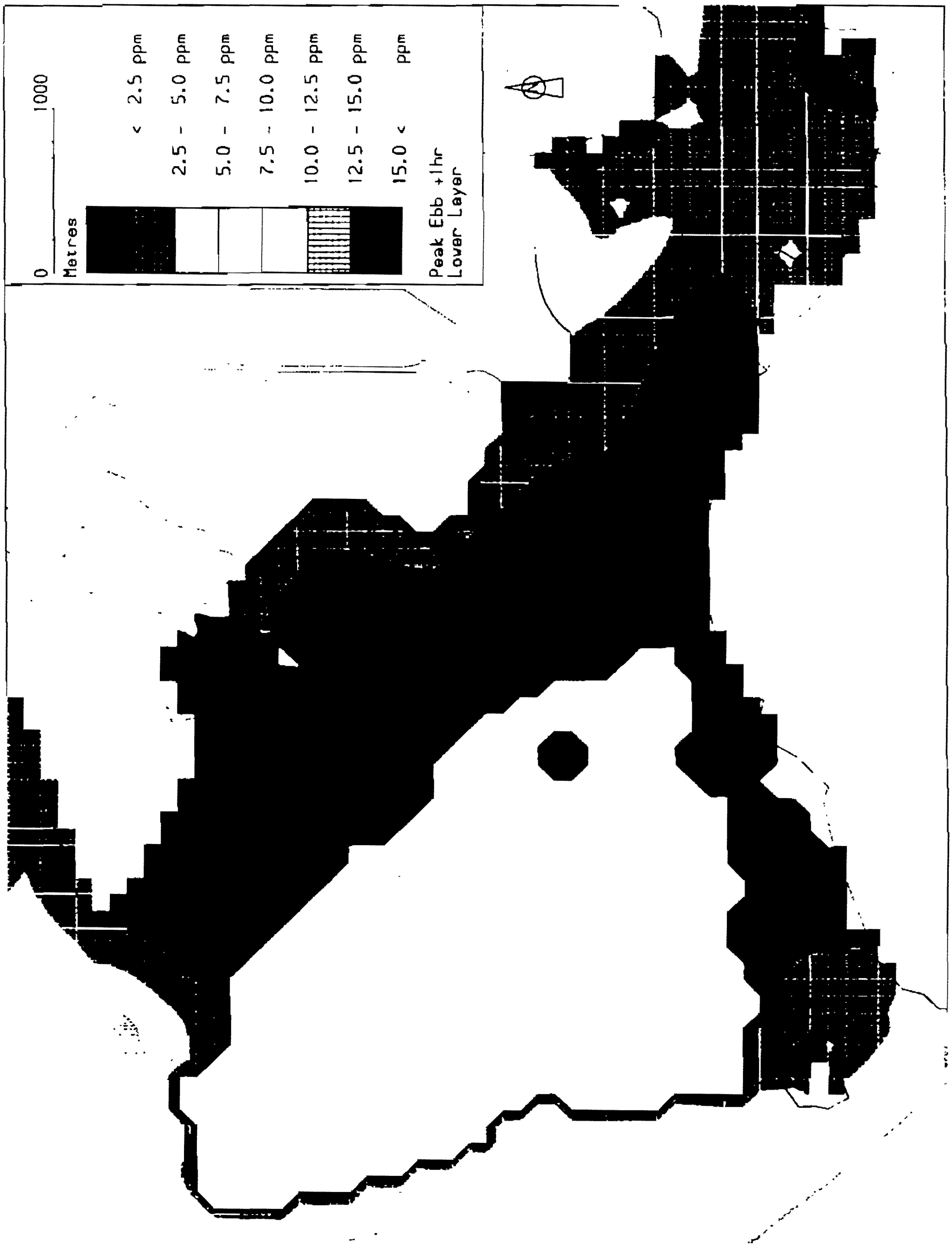
Stonecutters Naval Base Anchorage Area
Completed Scenario
Suspended Sediment Concentrations
Wet Season Neap Tide



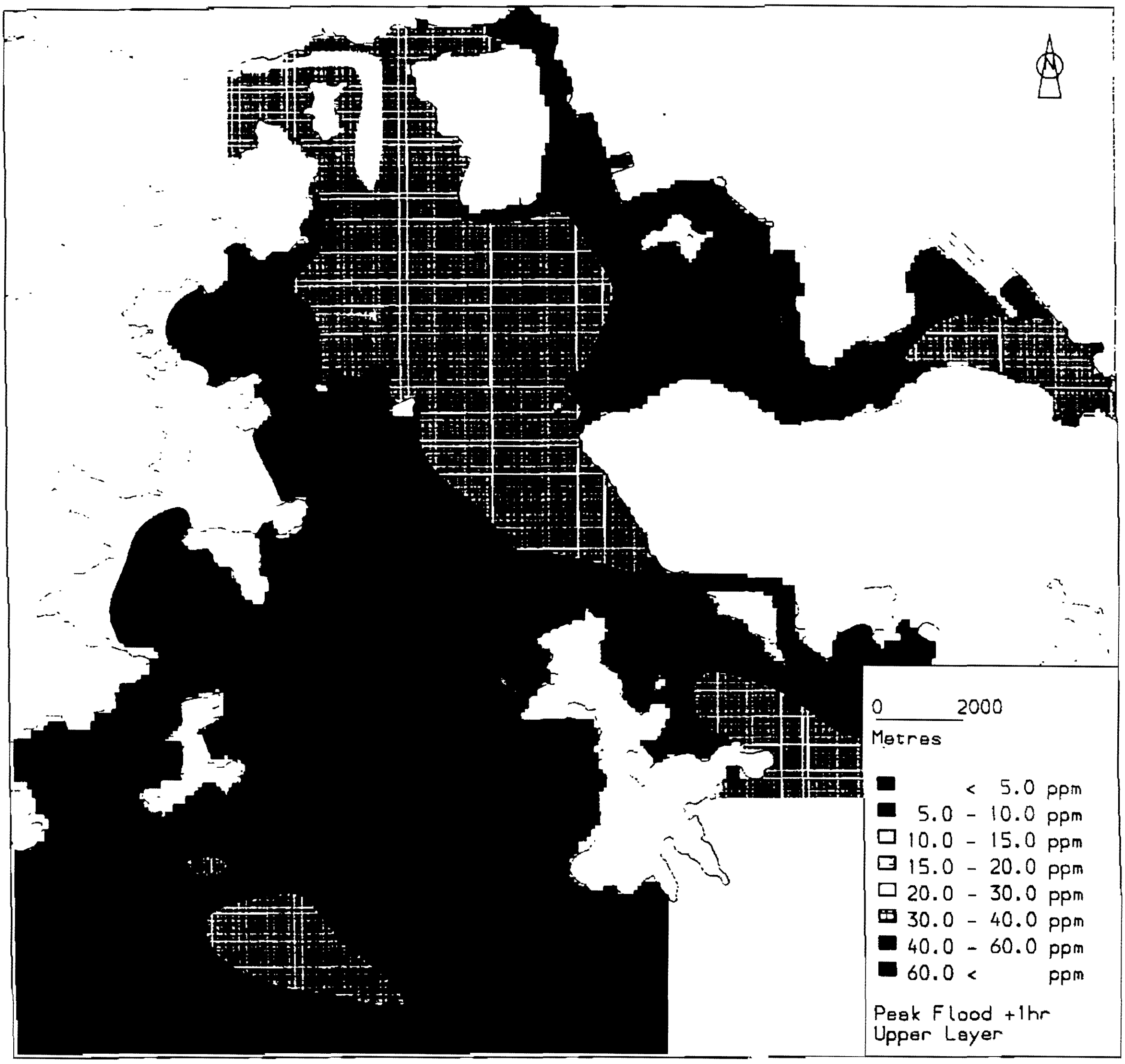
Stonecutters Naval Base Anchorage Area
Completed Scenario
Suspended Sediment Concentrations
Wet Season Neap Tide



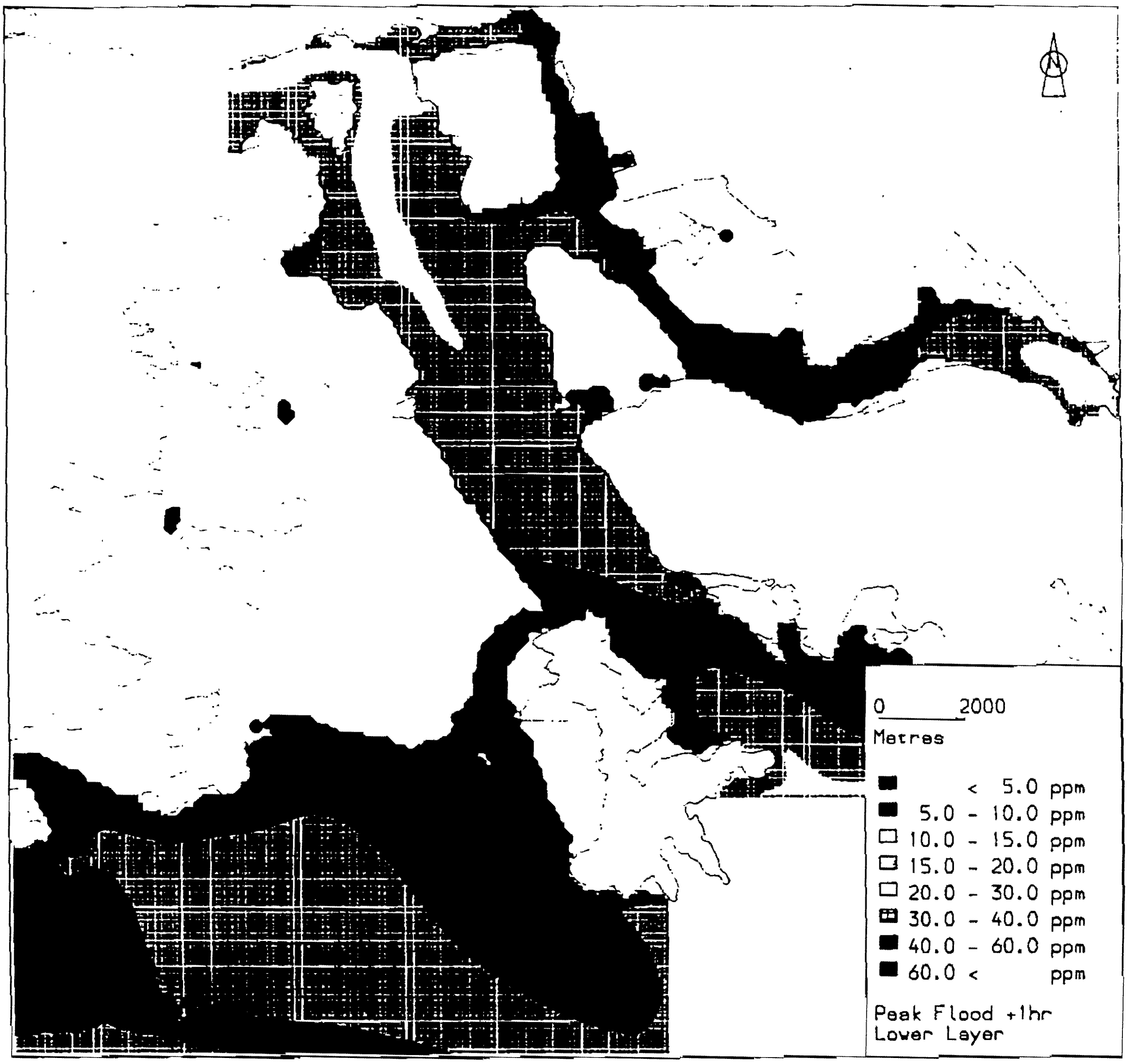
Stonecutters Naval Base Anchorage Area
Completed Scenario
Suspended Sediment Concentrations
Wet Season Neap Tide



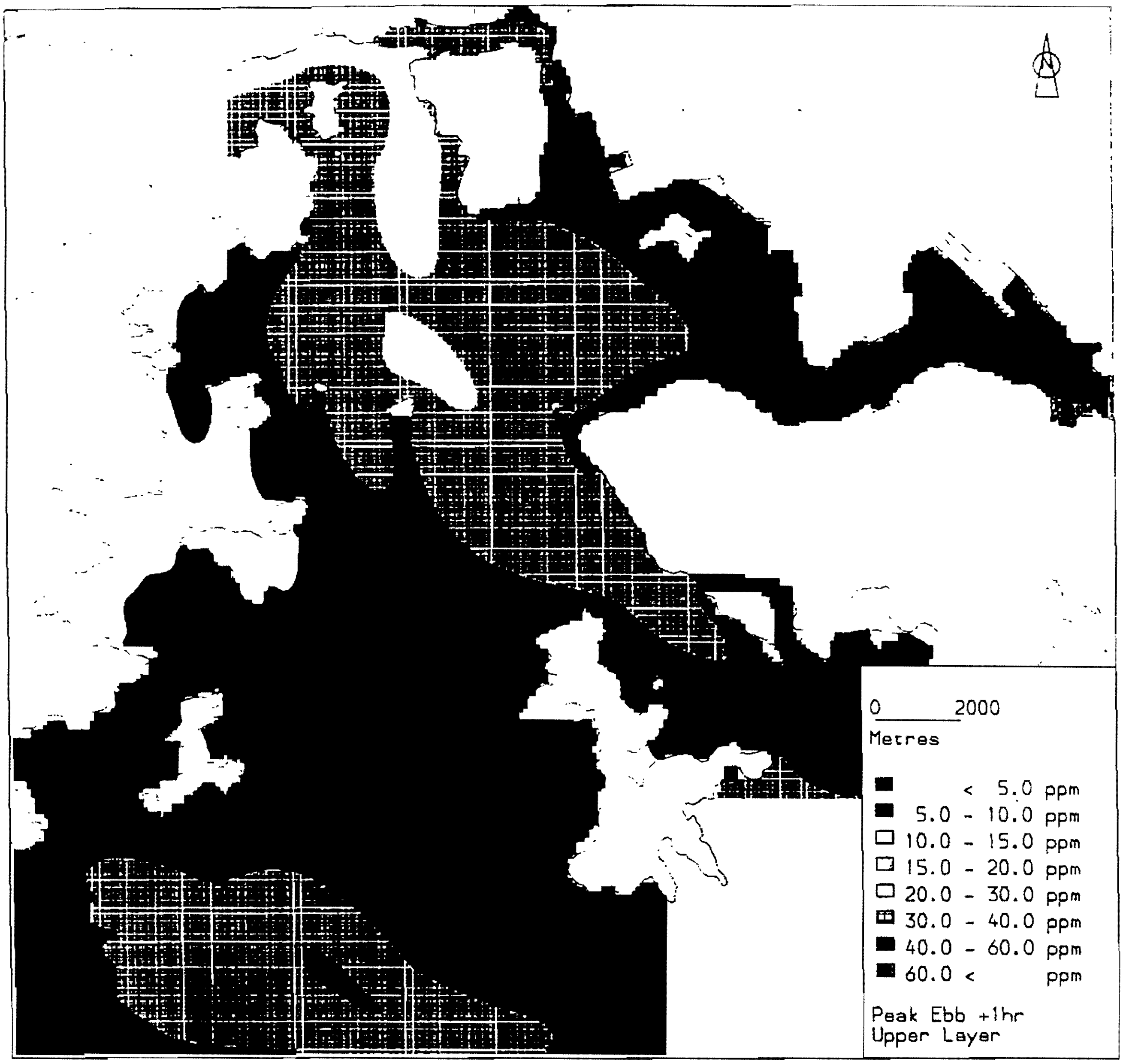
Stonecutters Naval Base Anchorage Area
Completed Scenario
Suspended Sediment Concentrations
Wet Season Neap Tide



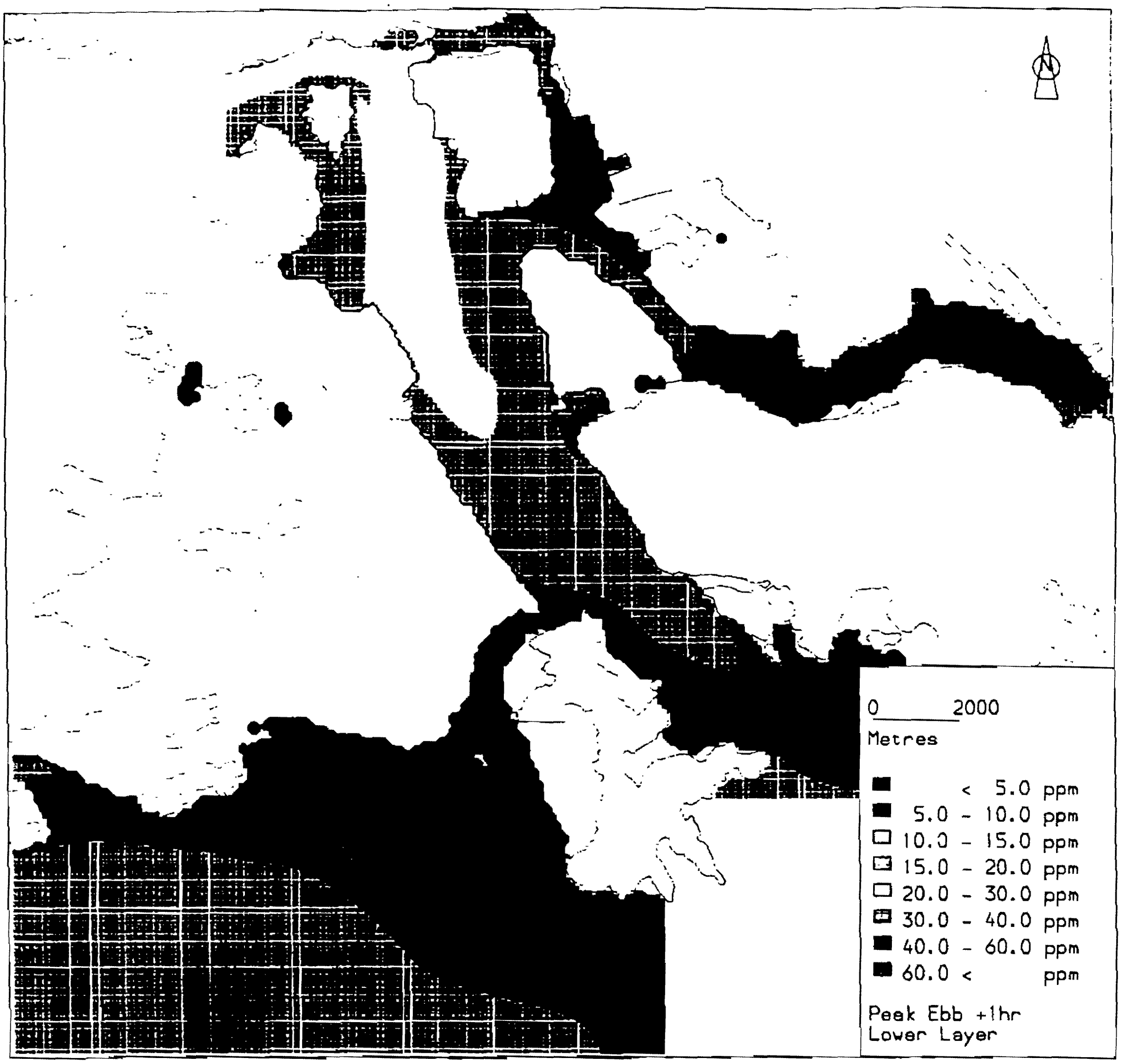
Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration
Suspended Sediment Concentrations
Dry Season Neap Tide



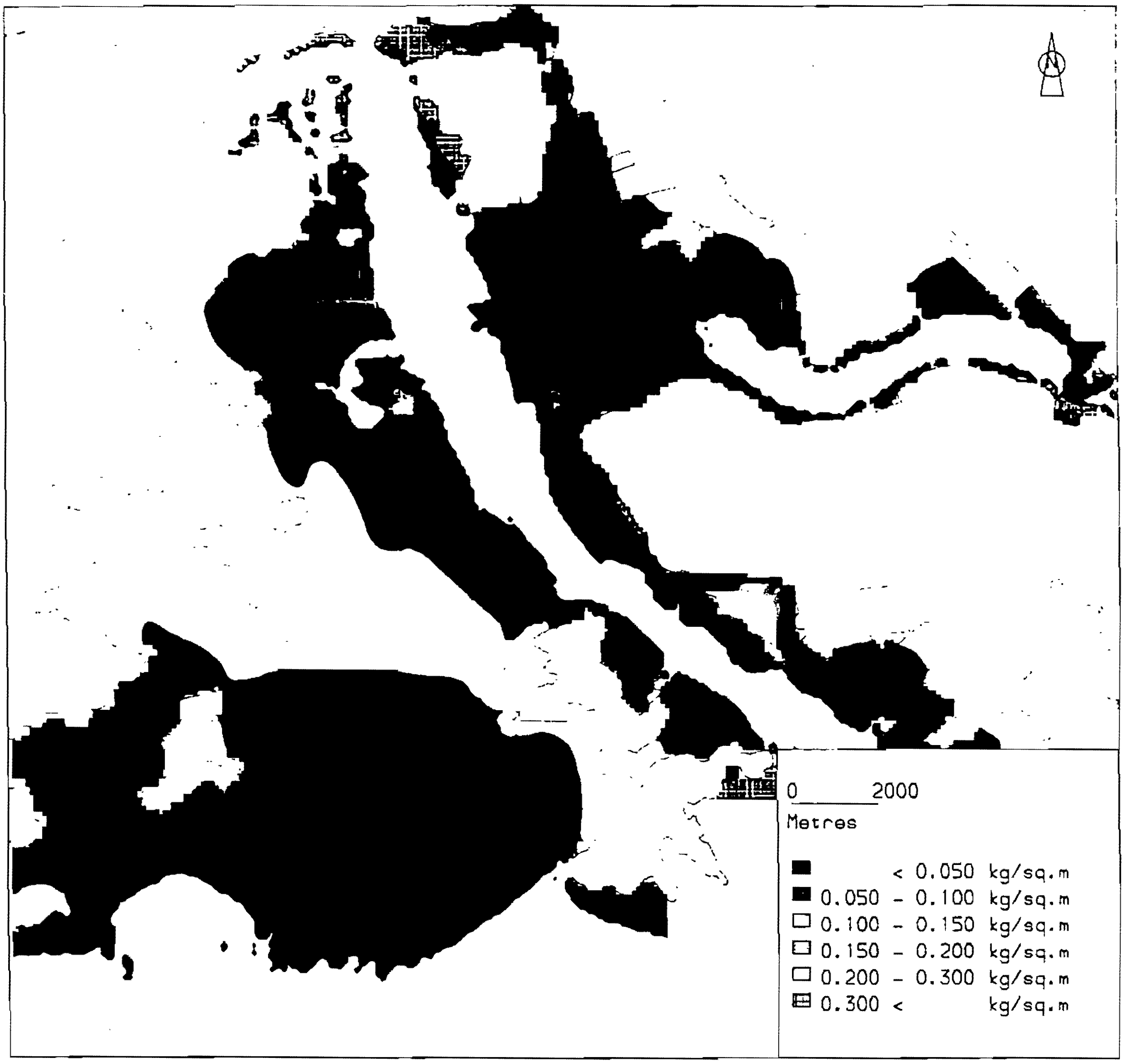
Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration
Suspended Sediment Concentrations
Dry Season Neap Tide



Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration
Suspended Sediment Concentrations
Dry Season Neap Tide



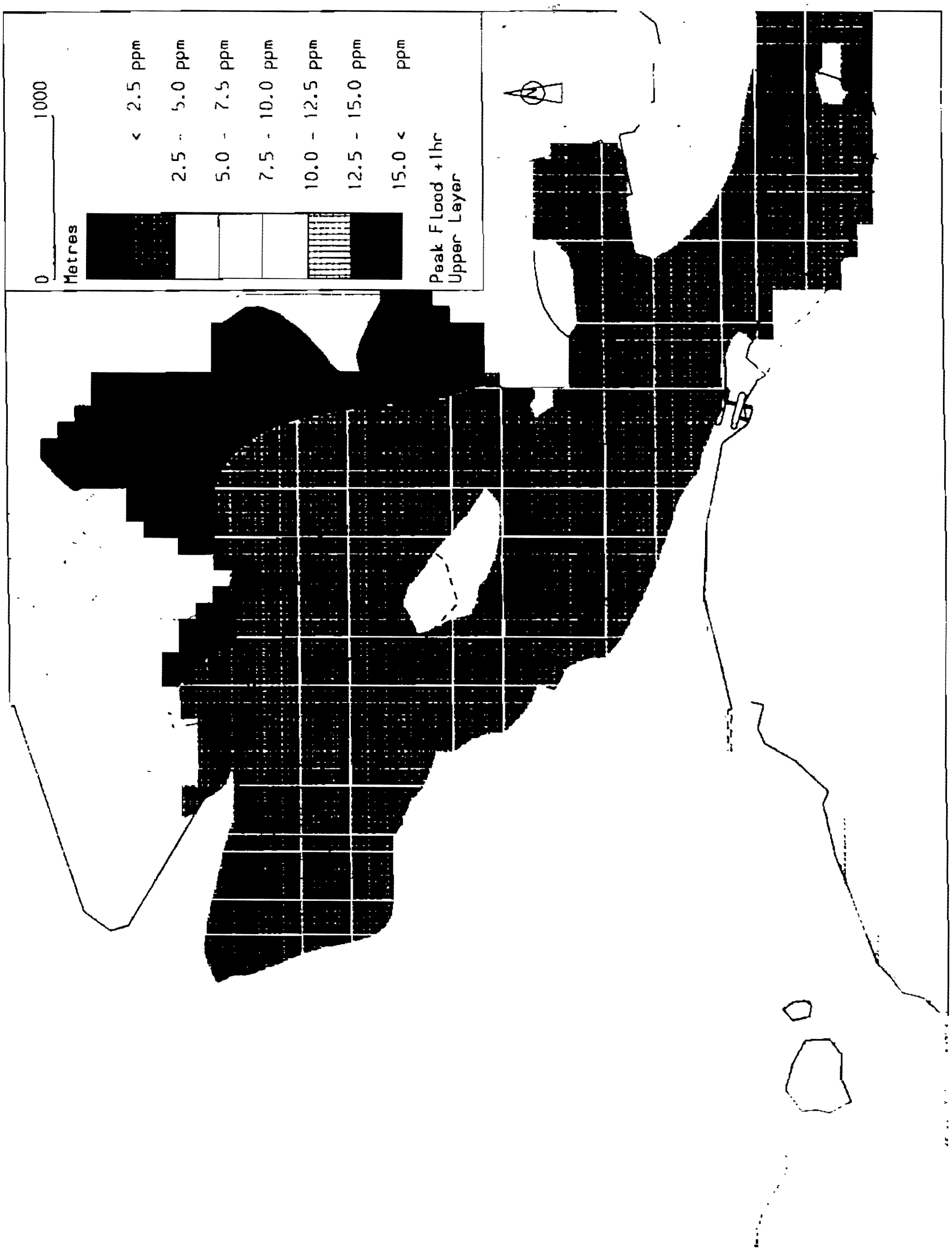
Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration
Suspended Sediment Concentrations
Dry Season Neap Tide



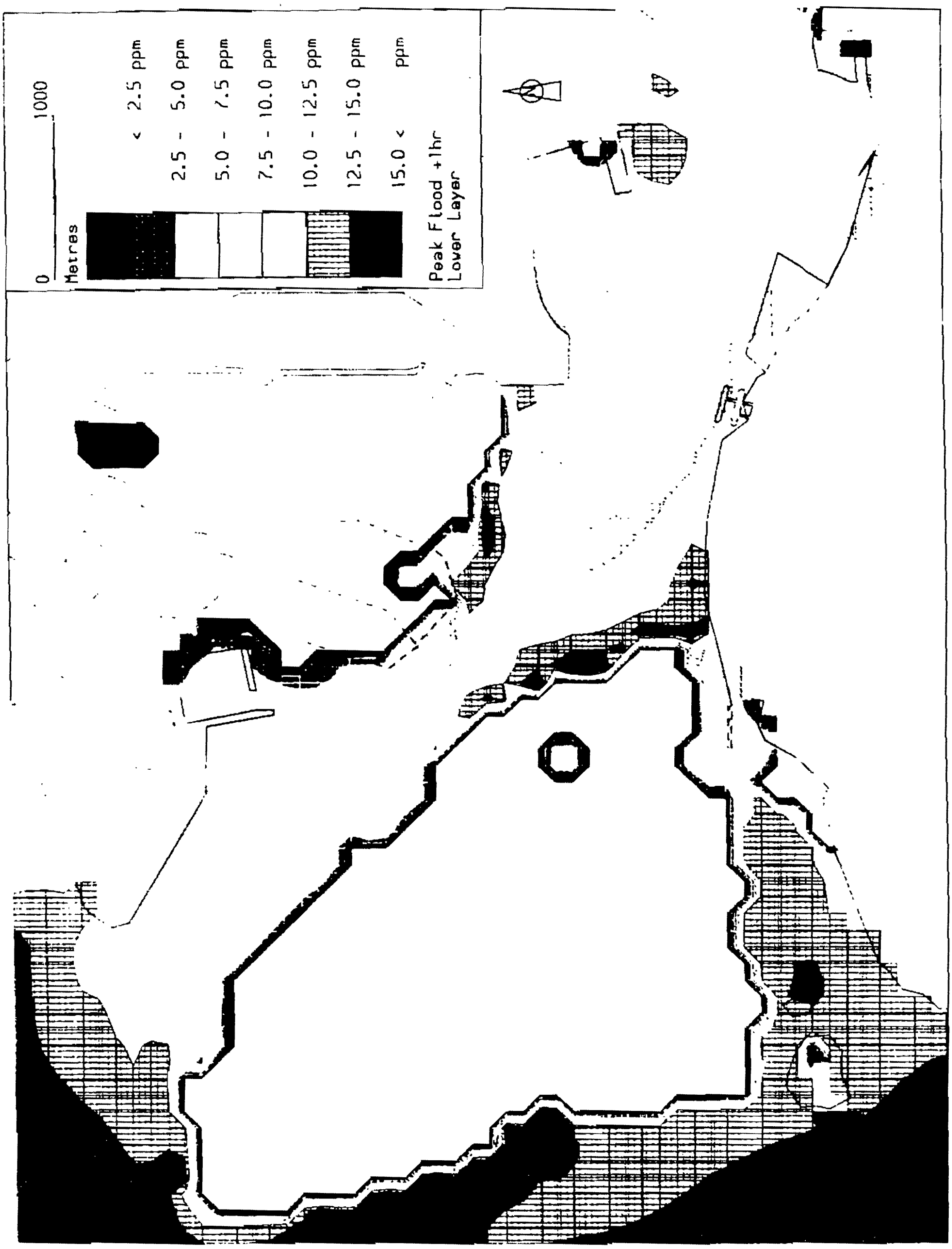
Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration
Mud Deposits over 1 Tide
Dry Season Neap Tide

APPENDIX J
SEDIMENT TRANSPORT MODEL RESULTS
BASELINE SCENARIO

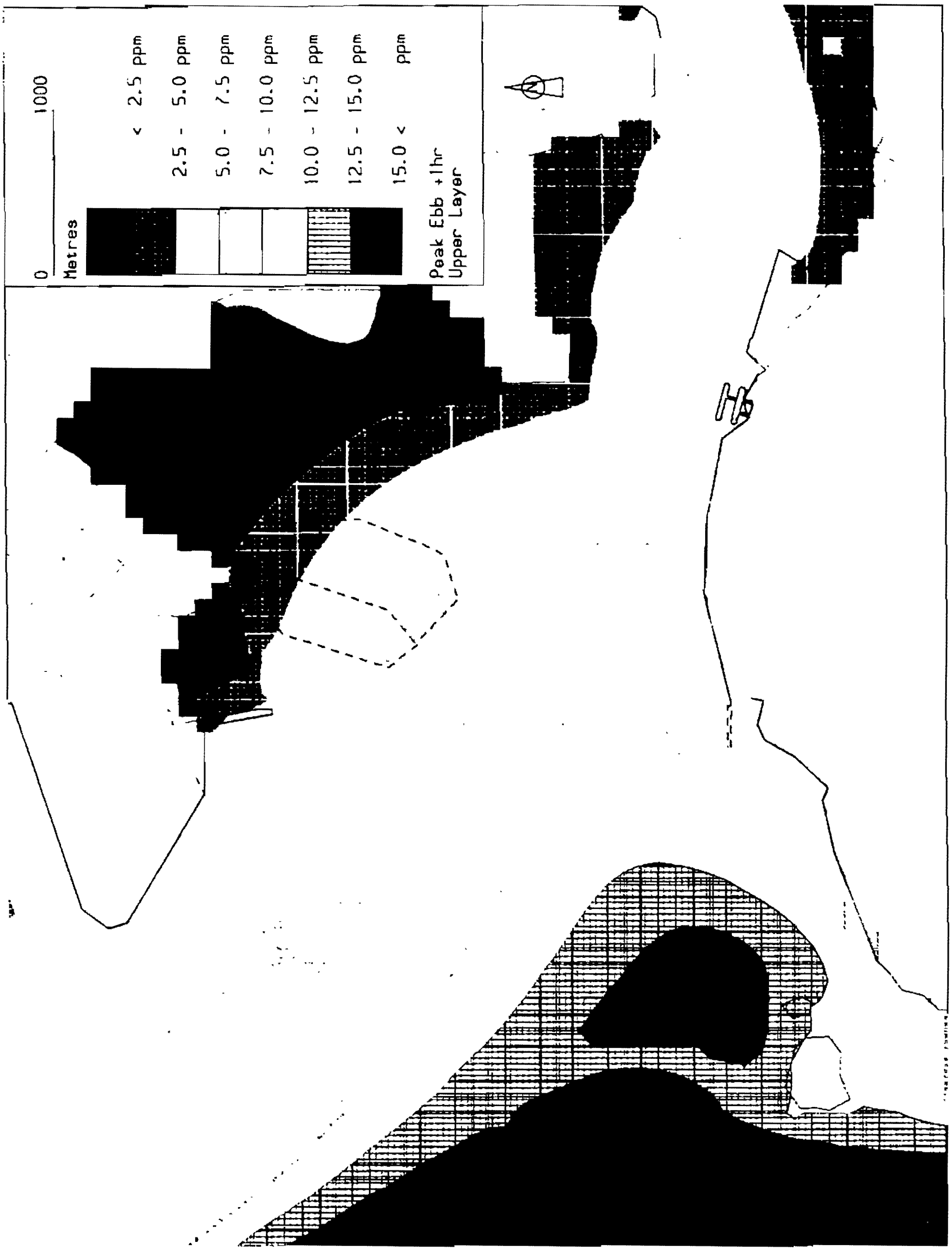
WET SEASON SPRING TIDE



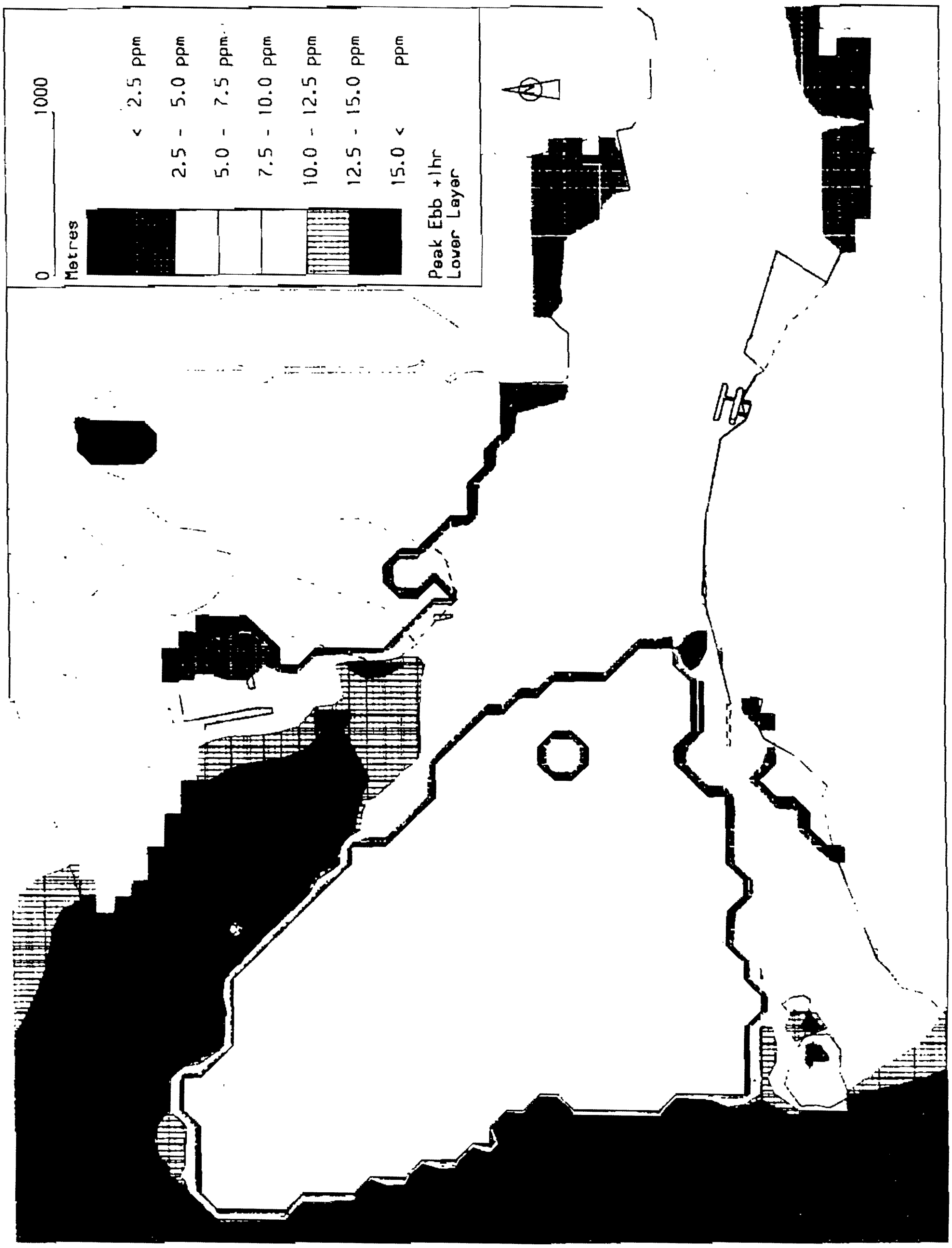
Stonecutters Naval Base Anchorage Area
Baseline Scenario
Suspended Sediment Concentrations
Wet Season Spring Tide



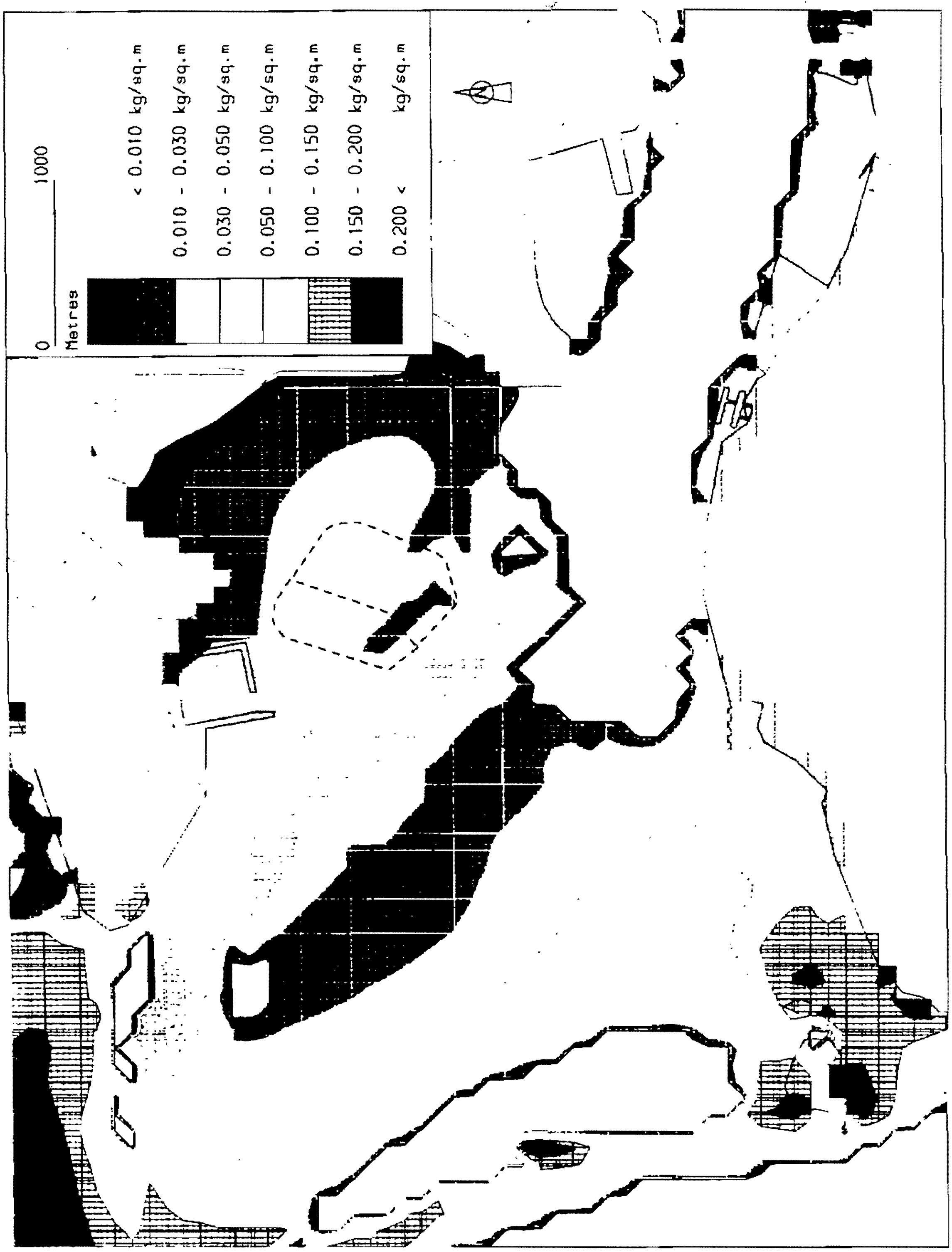
Stonecutters Naval Base Anchorage Area
Baseline Scenario
Suspended Sediment Concentrations
Wet Season Spring Tide



Stonecutters Naval Base Anchorage Area
Baseline Scenario
Suspended Sediment Concentrations
Wet Season Spring Tide

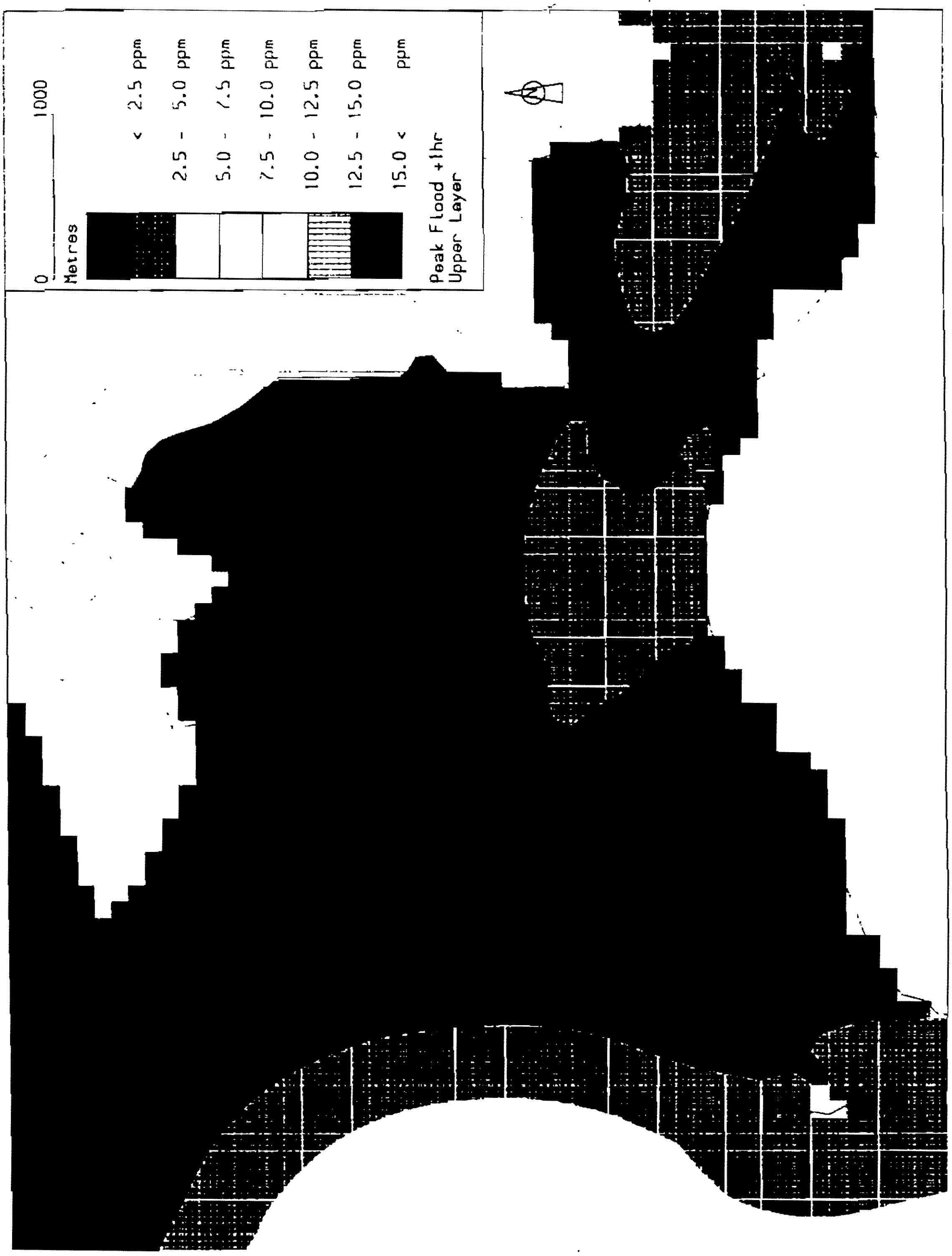


Stonecutters Naval Base Anchorage Area
Baseline Scenario
Suspended Sediment Concentrations
Wet Season Spring Tide

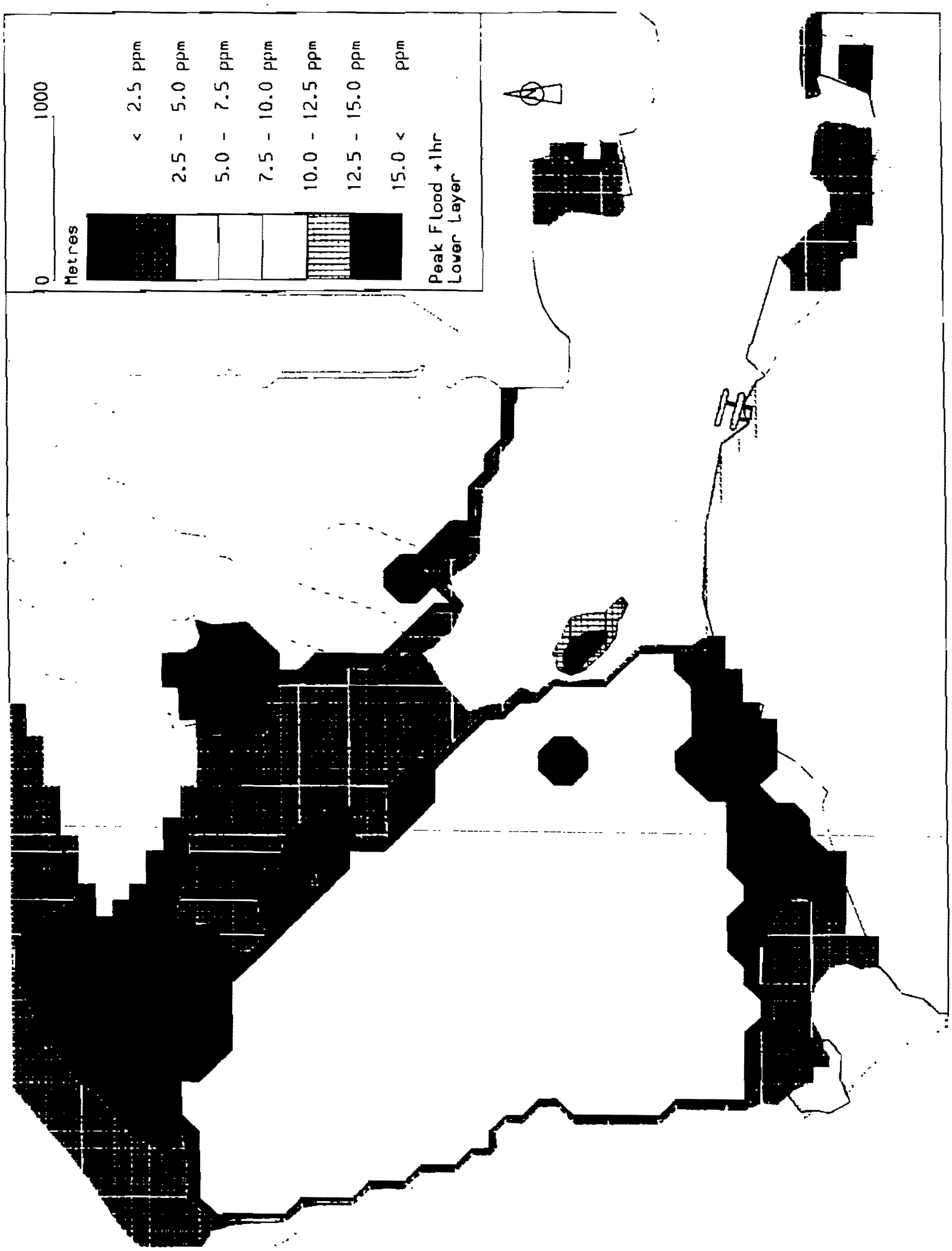


Stonecutters Naval Base Anchorage Area
Baseline Scenario
Mud Deposits over 1 Tide
Wet Season Spring Tide

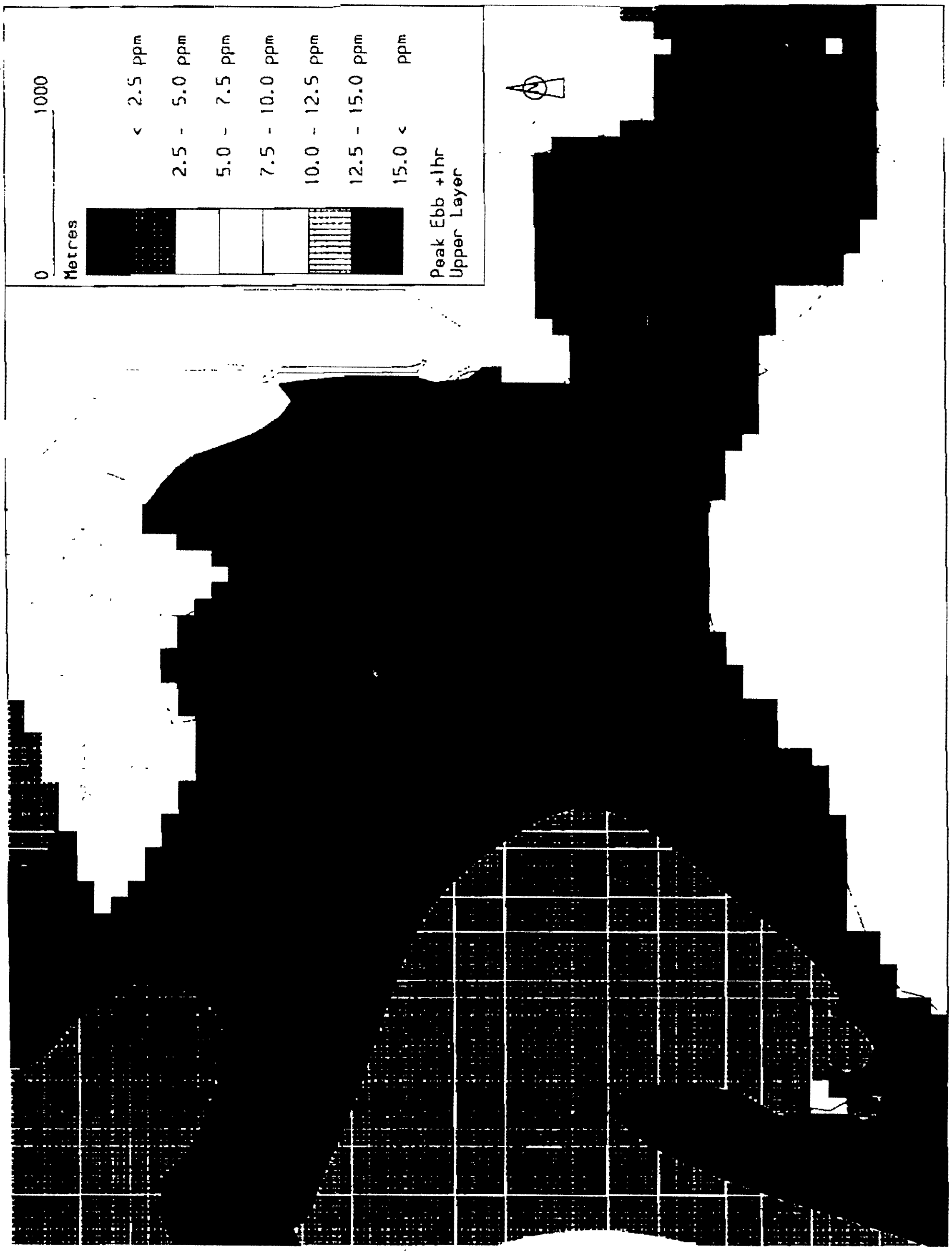
WET SEASON NEAP TIDE



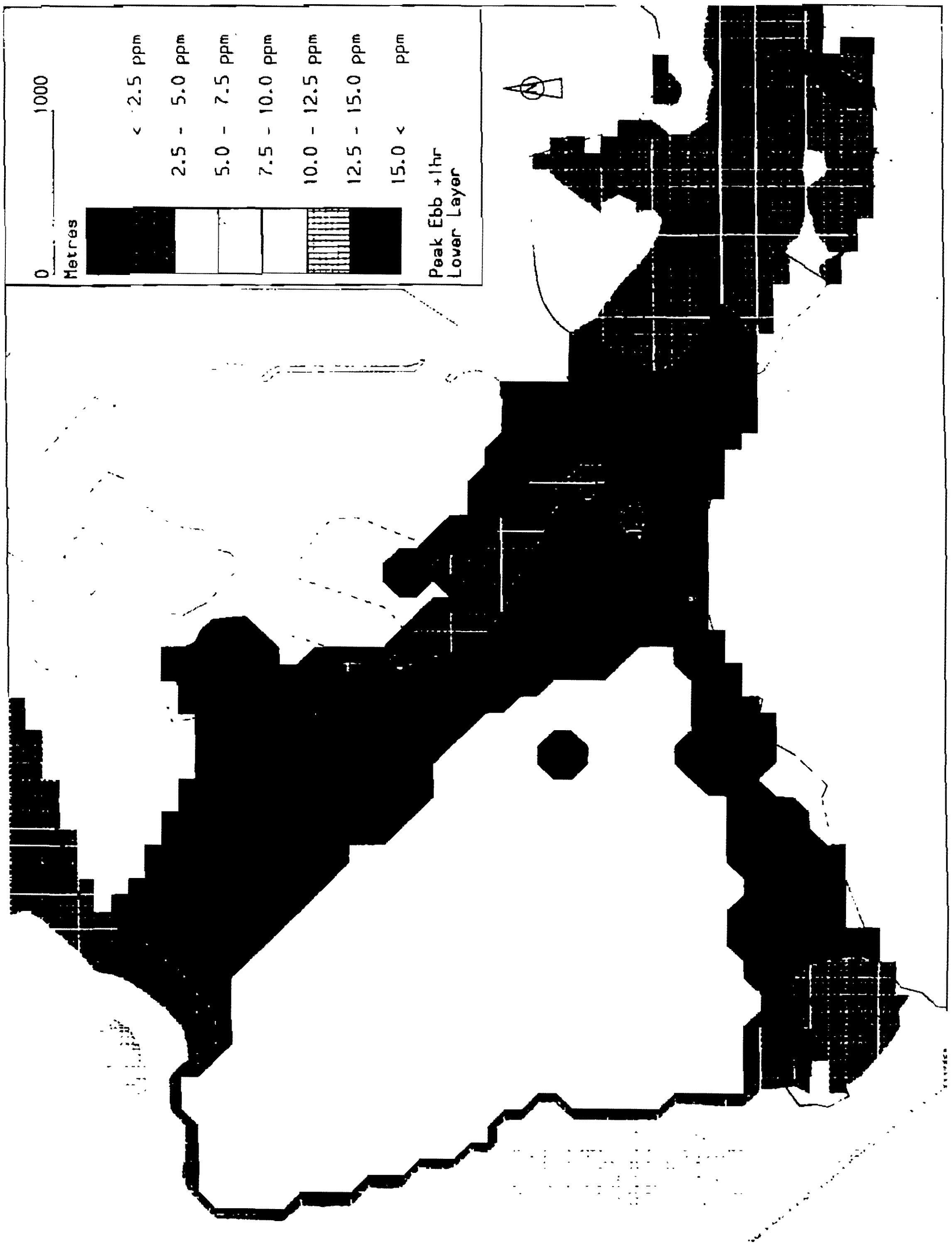
Stonecutters Naval Base Anchorage Area
Baseline Scenario
Suspended Sediment Concentrations
Wet Season Neap Tide



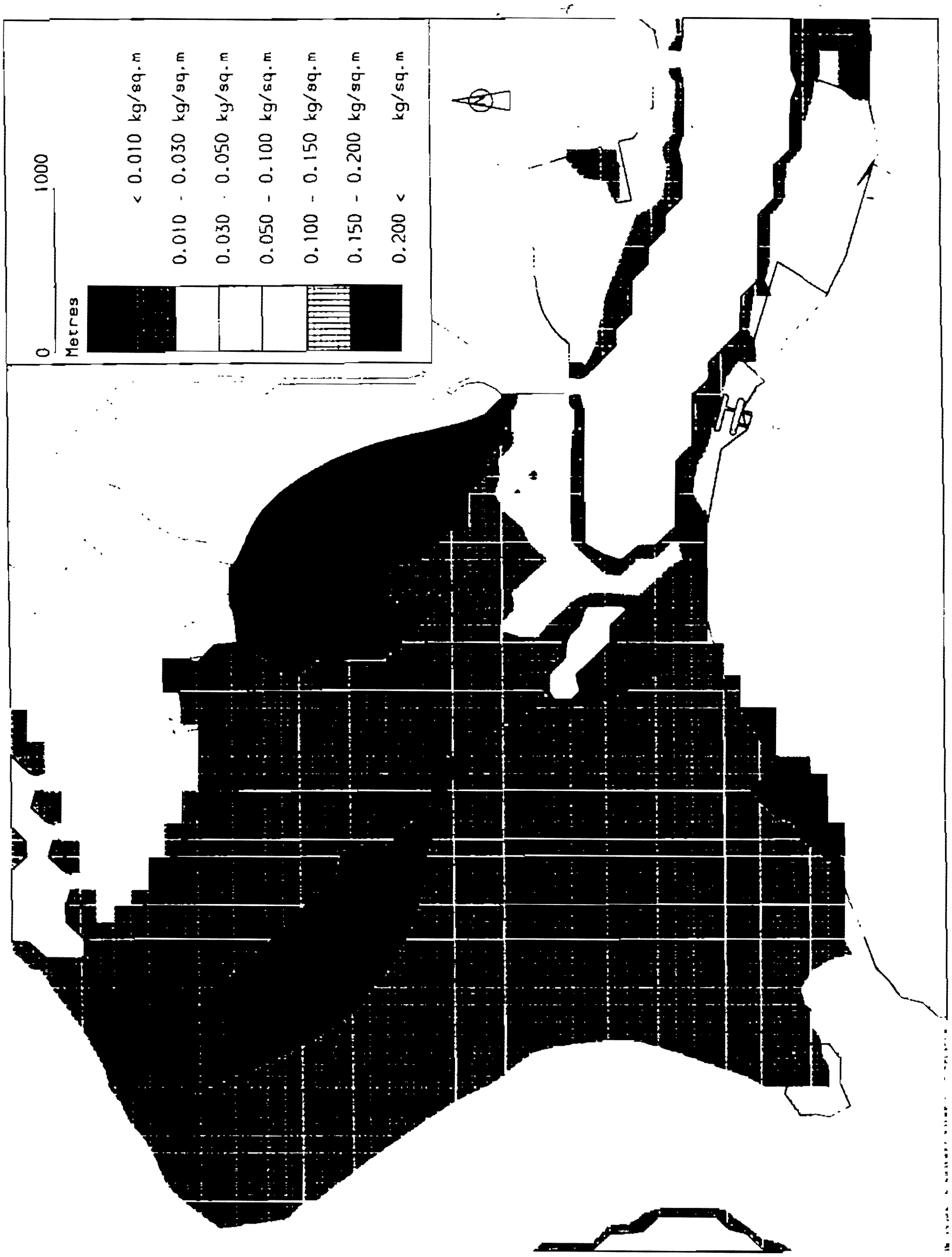
Stonecutters Naval Base Anchorage Area
Baseline Scenario
Suspended Sediment Concentrations
Wet Season Neap Tide



Stonecutters Naval Base Anchorage Area
Baseline Scenario
Suspended Sediment Concentrations
Wet Season Neap Tide

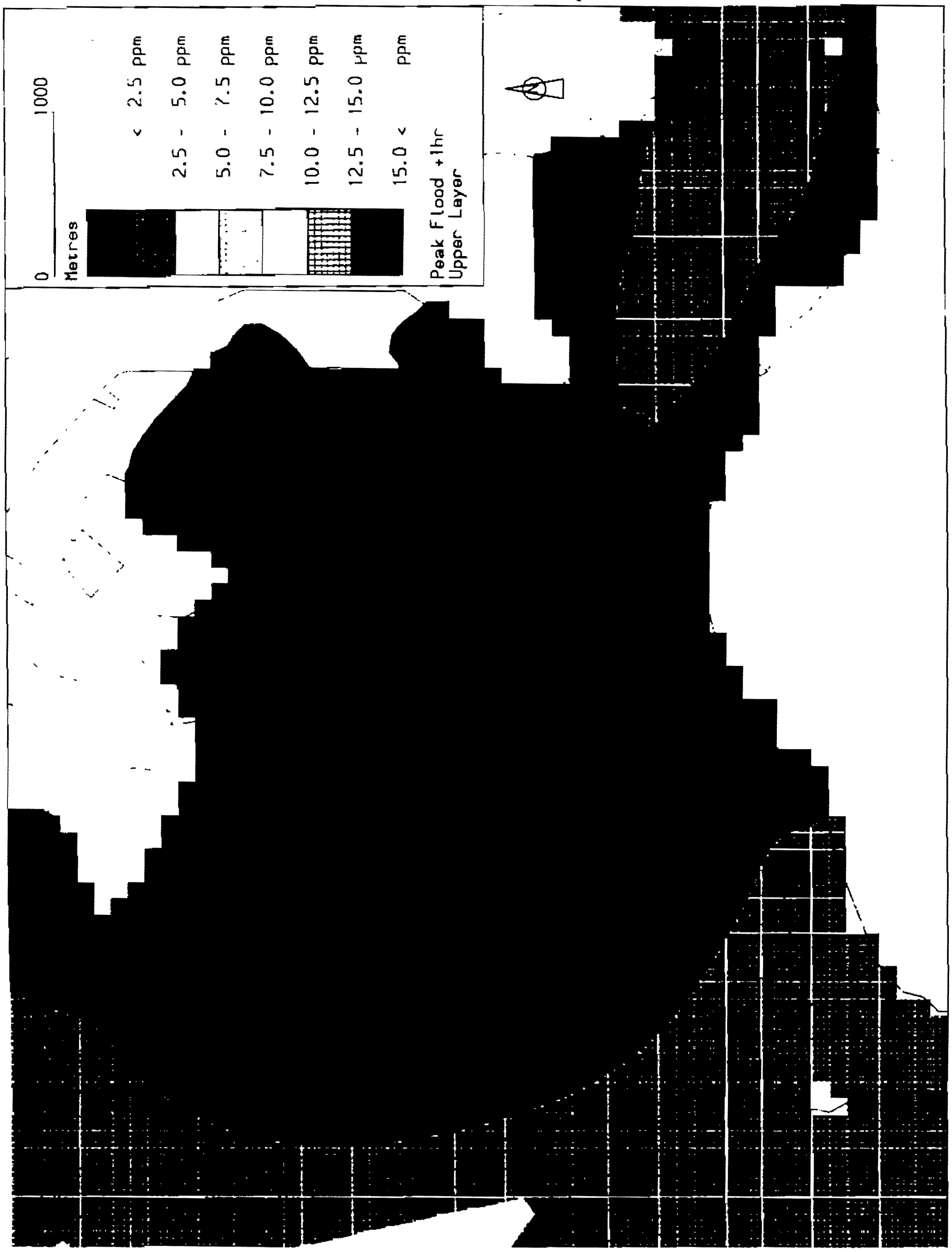


Stonecutters Naval Base Anchorage Area
Baseline Scenario
Suspended Sediment Concentrations
Wet Season Neap Tide

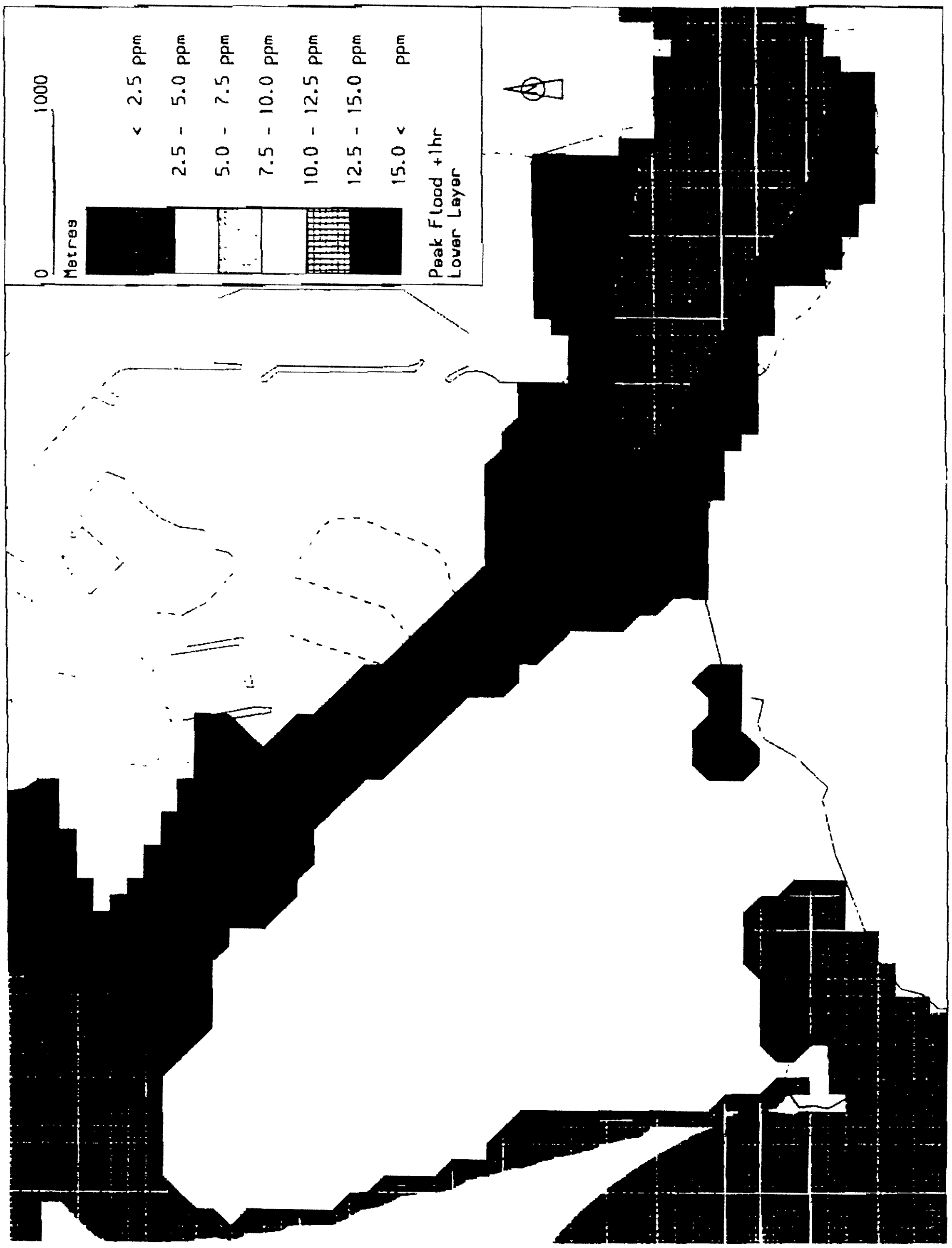


Stonecutters Naval Base Anchorage Area
Baseline Scenario
Mud Deposits over 1 Tide
Wet Season Neap Tide

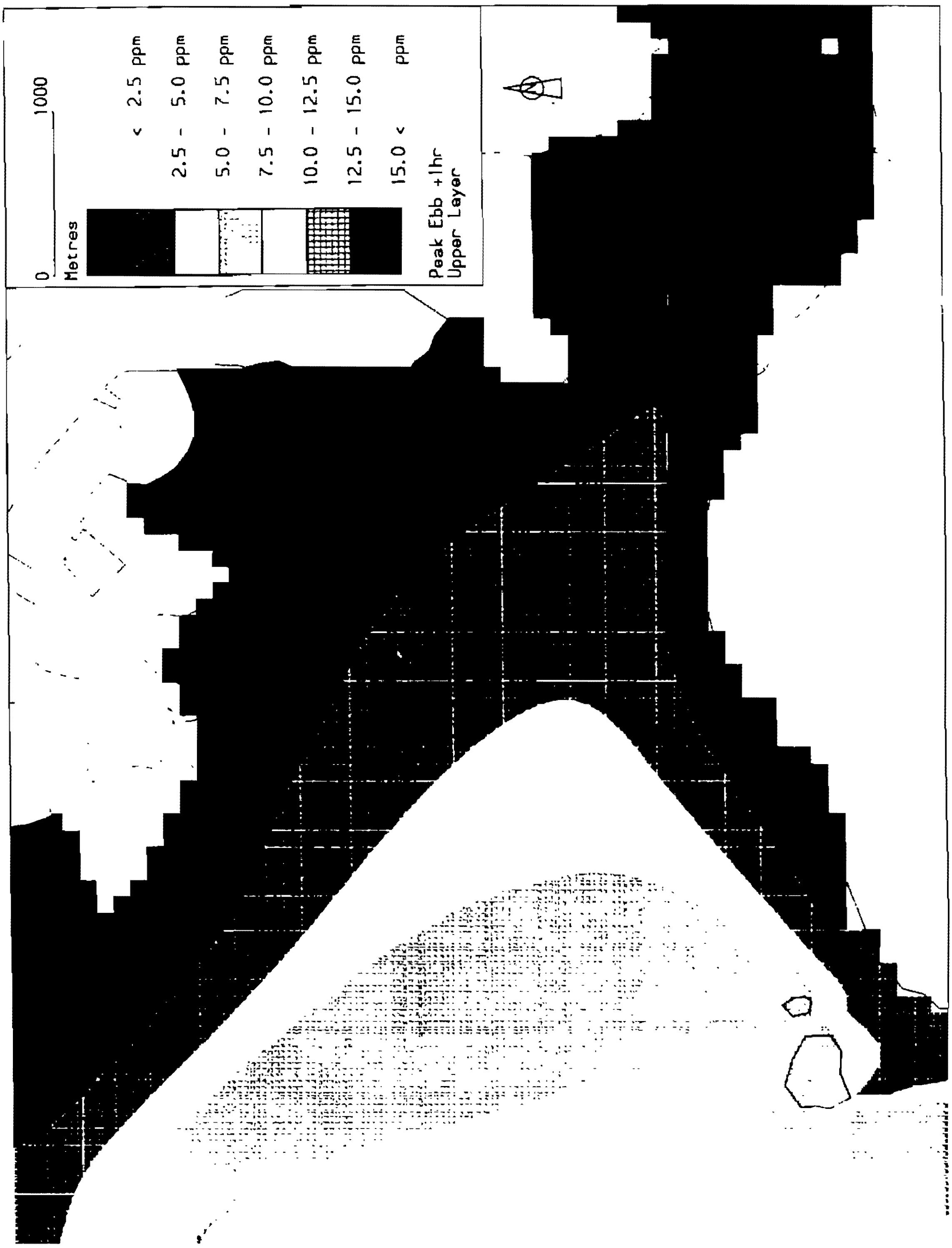
DRY SEASON SPRING TIDE



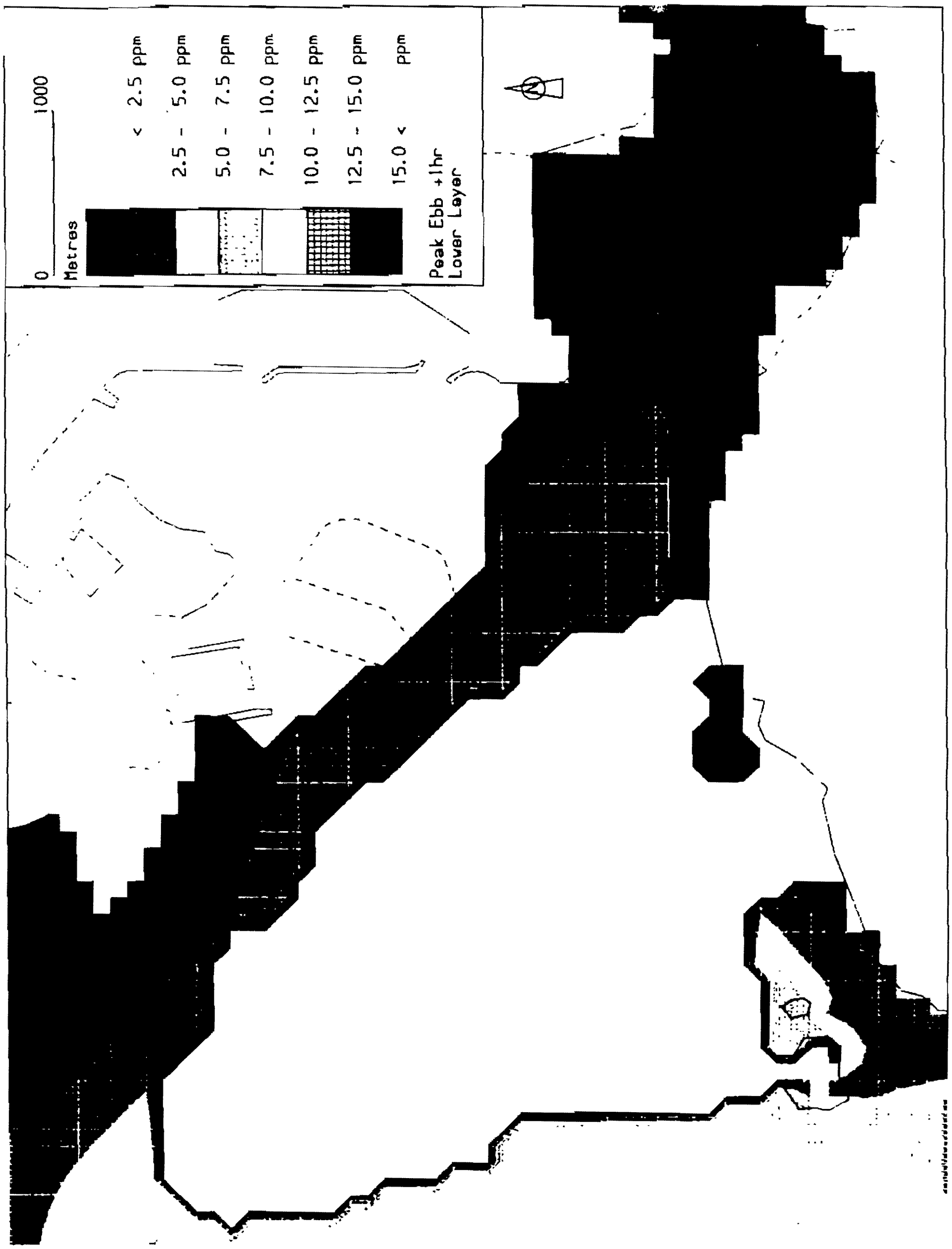
Stonecutters Naval Base Anchorage Area
Baseline Scenario
Suspended Sediment Concentrations
Dry Season Spring Tide



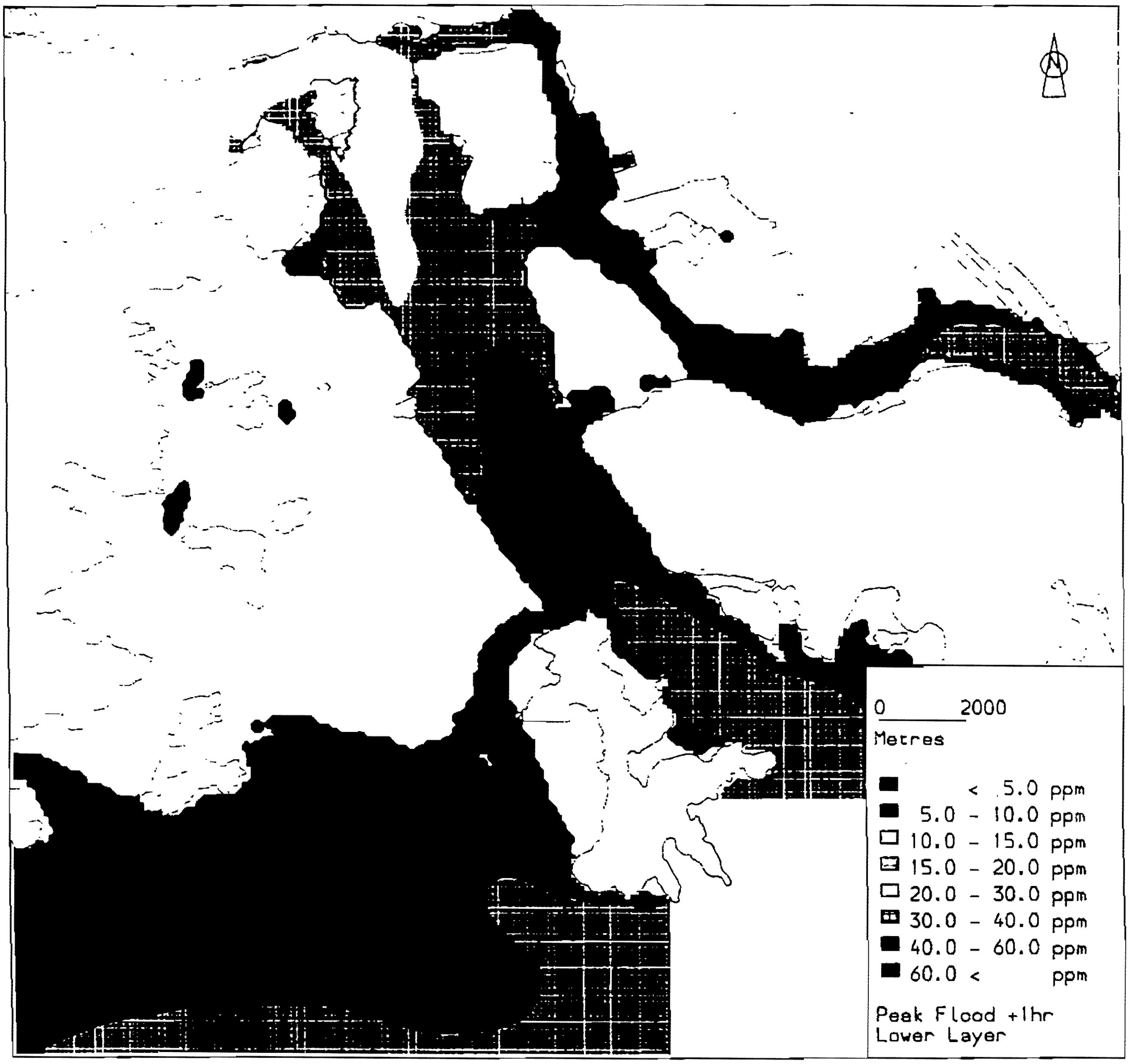
Stonecutters Naval Base Anchorage Area
Baseline Scenario
Suspended Sediment Concentrations
Dry Season Spring Tide



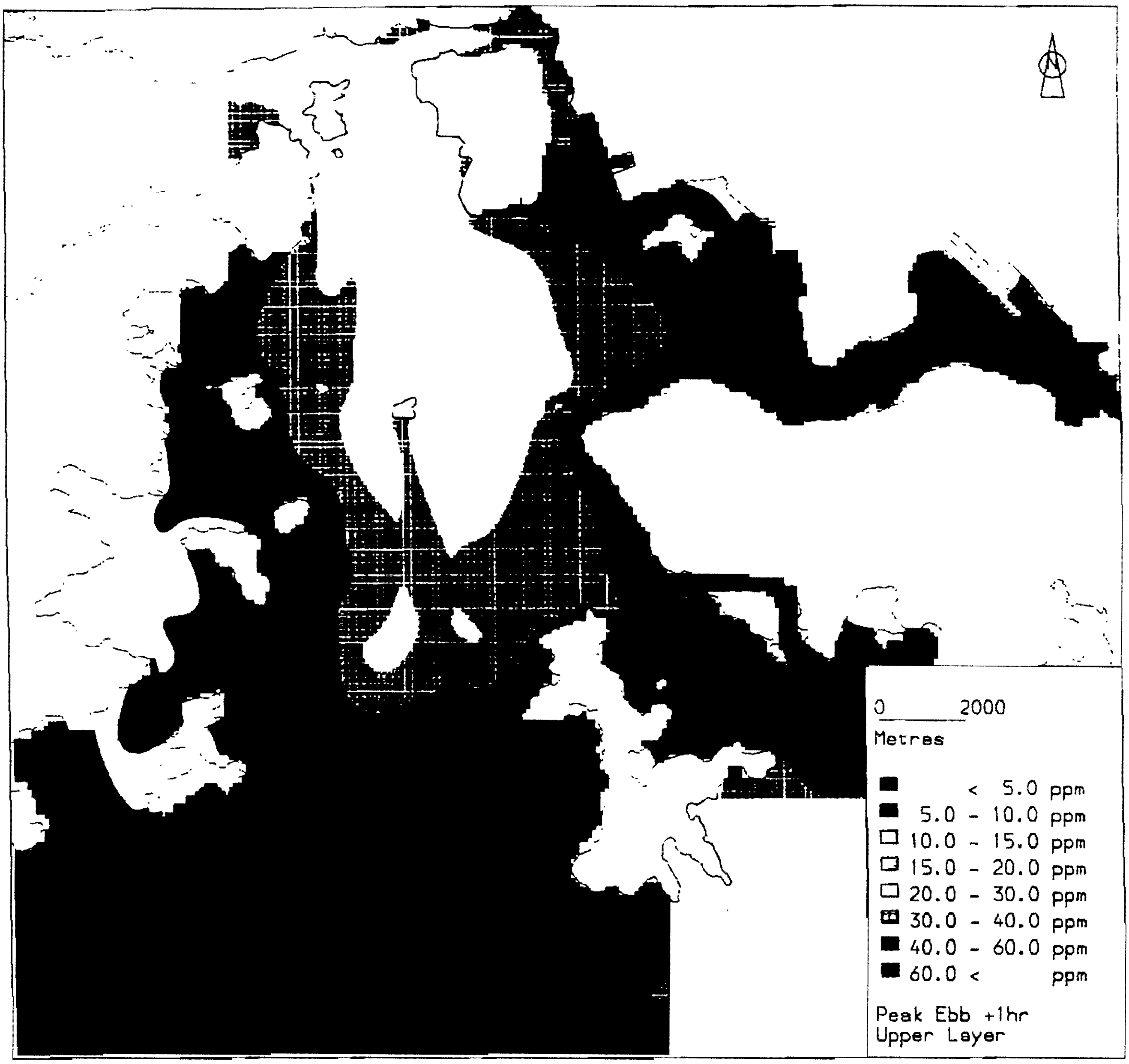
Stonecutters Naval Base Anchorage Area
Baseline Scenario
Suspended Sediment Concentrations
Dry Season Spring Tide



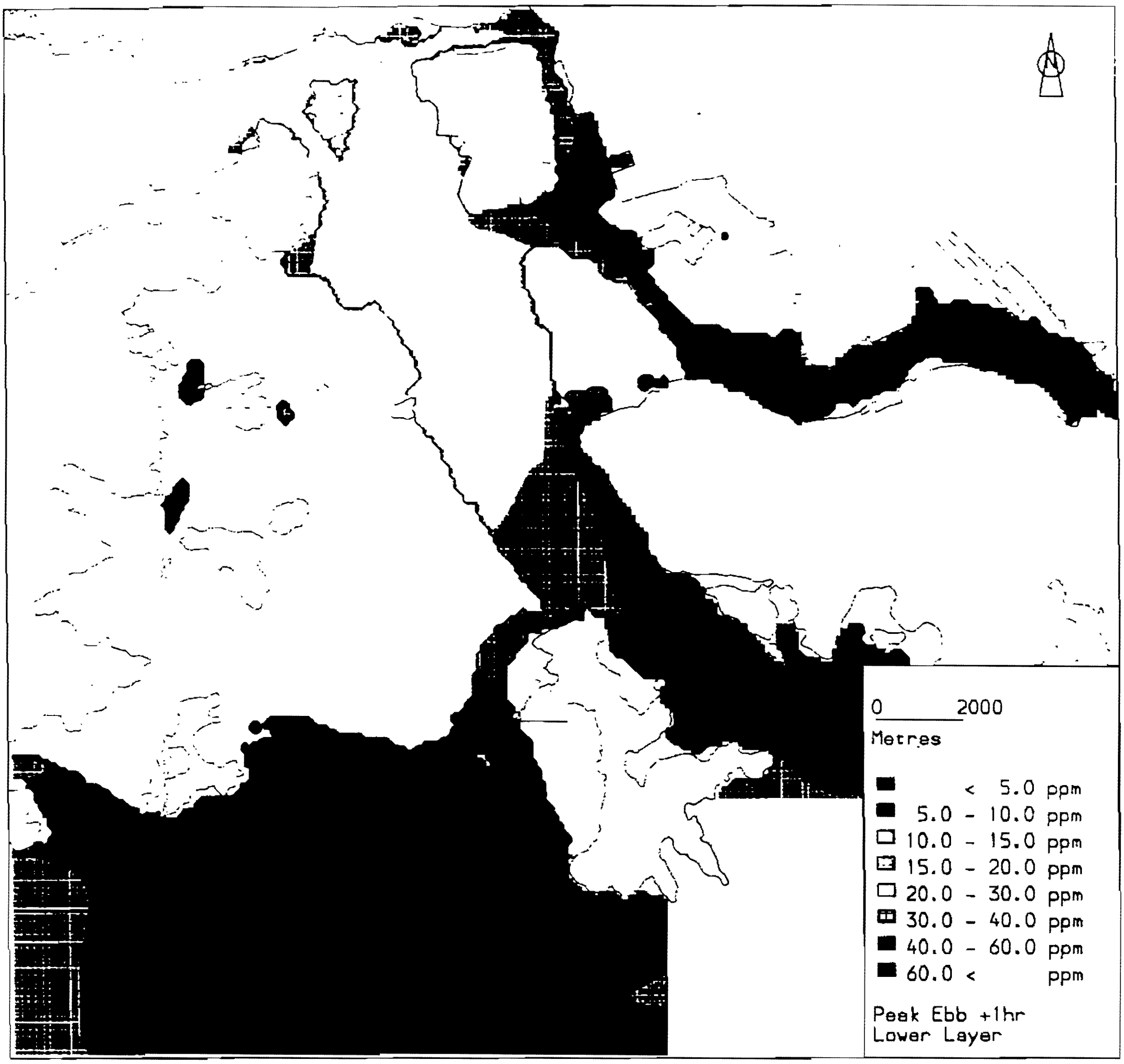
Stonecutters Naval Base Anchorage Area
Baseline Scenario
Suspended Sediment Concentrations
Dry Season Spring Tide



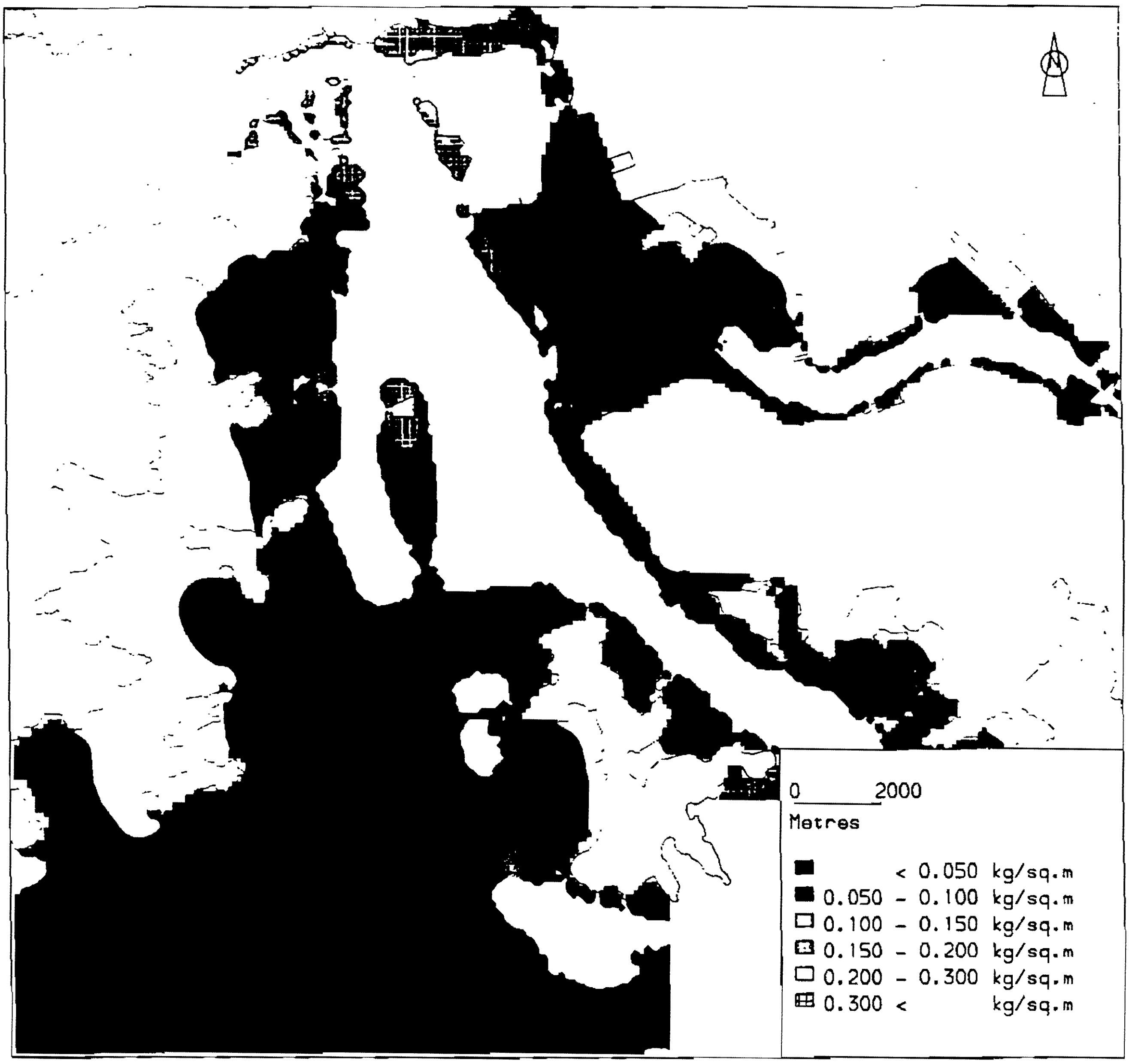
Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration
Suspended Sediment Concentrations
Dry Season Spring Tide



Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration
Suspended Sediment Concentrations
Dry Season Spring Tide

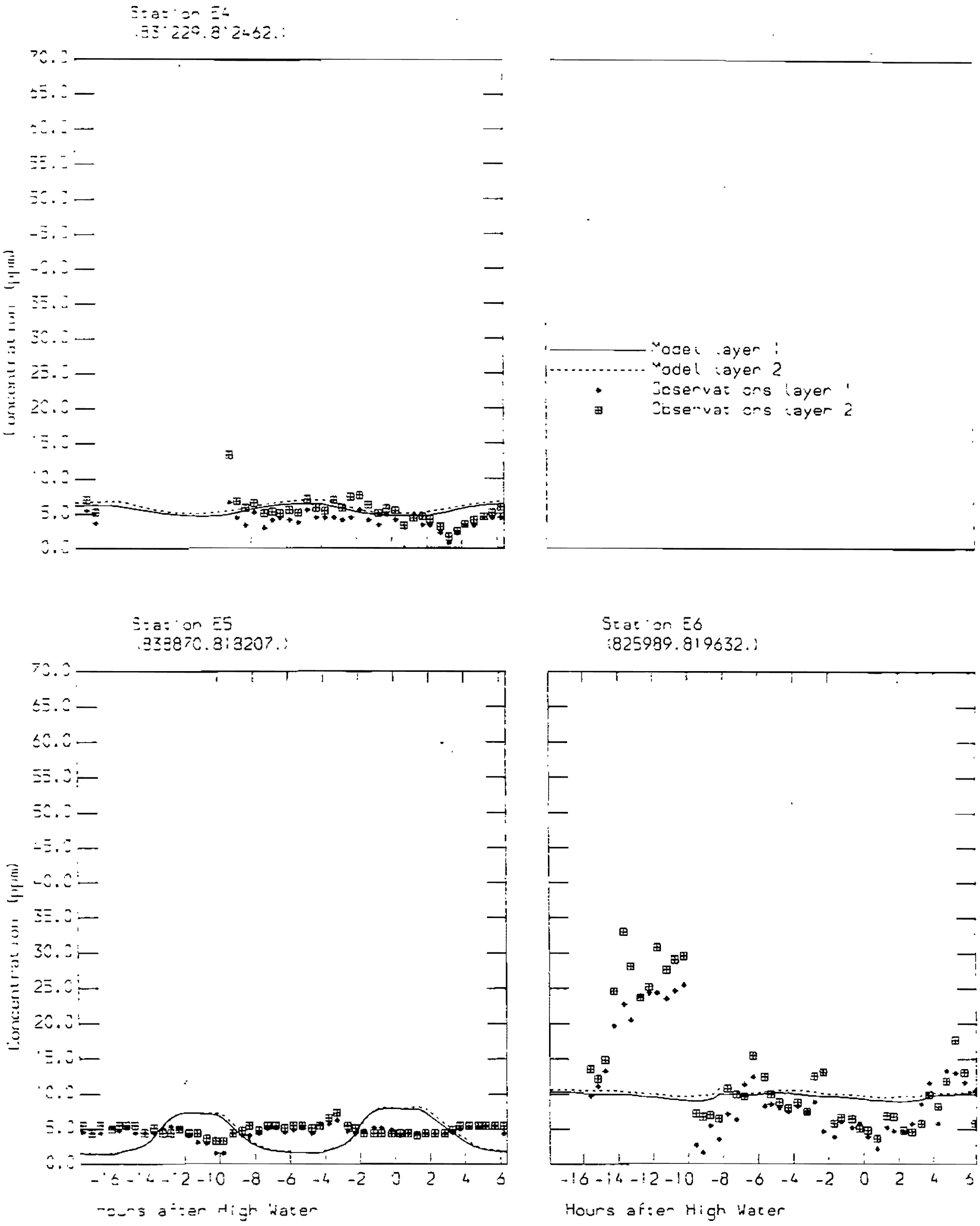


Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration
Suspended Sediment Concentrations
Dry Season Spring Tide

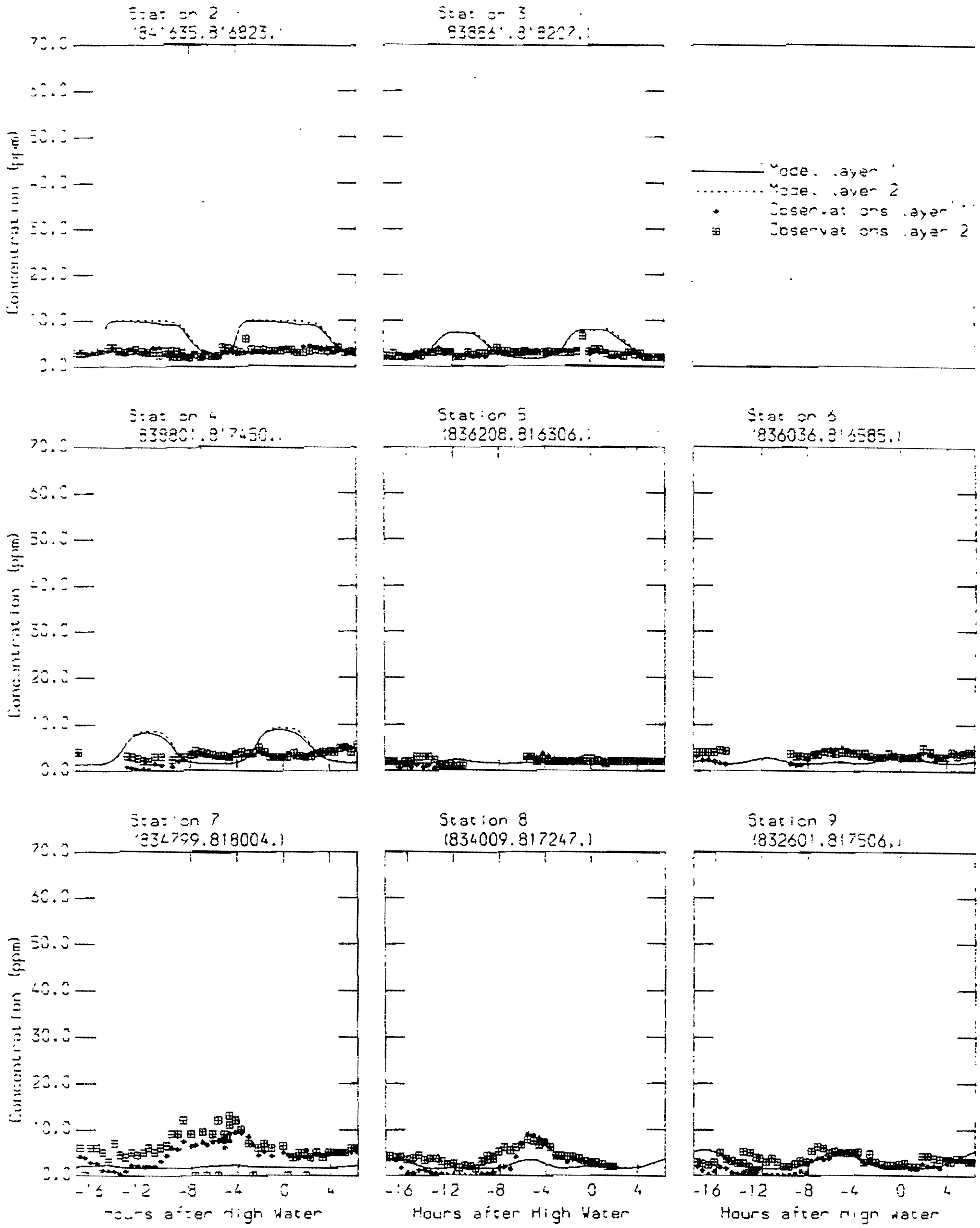


Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration
Mud Deposits over 1 Tide
Dry Season Spring Tide

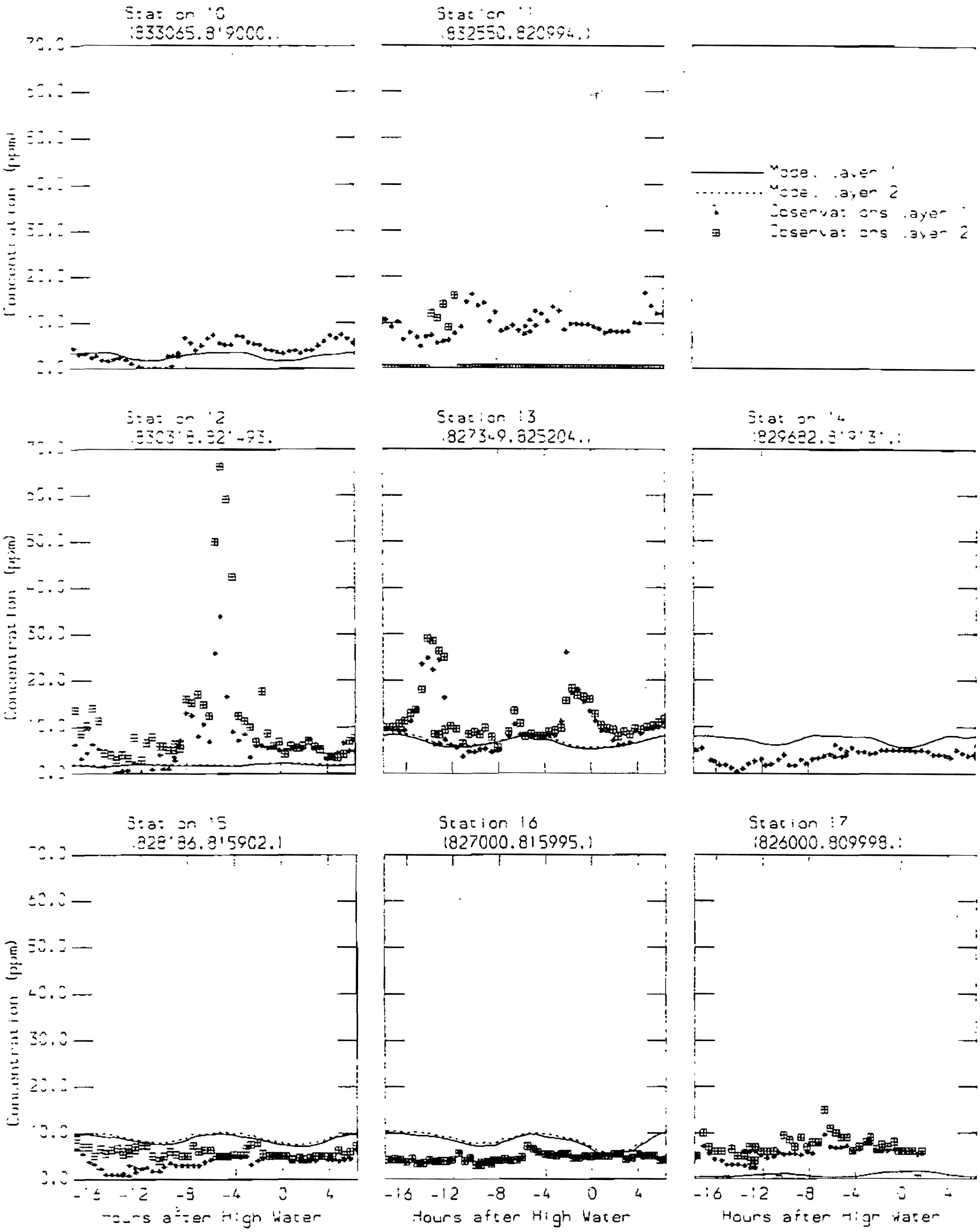
DRY SEASON NEAP TIDE



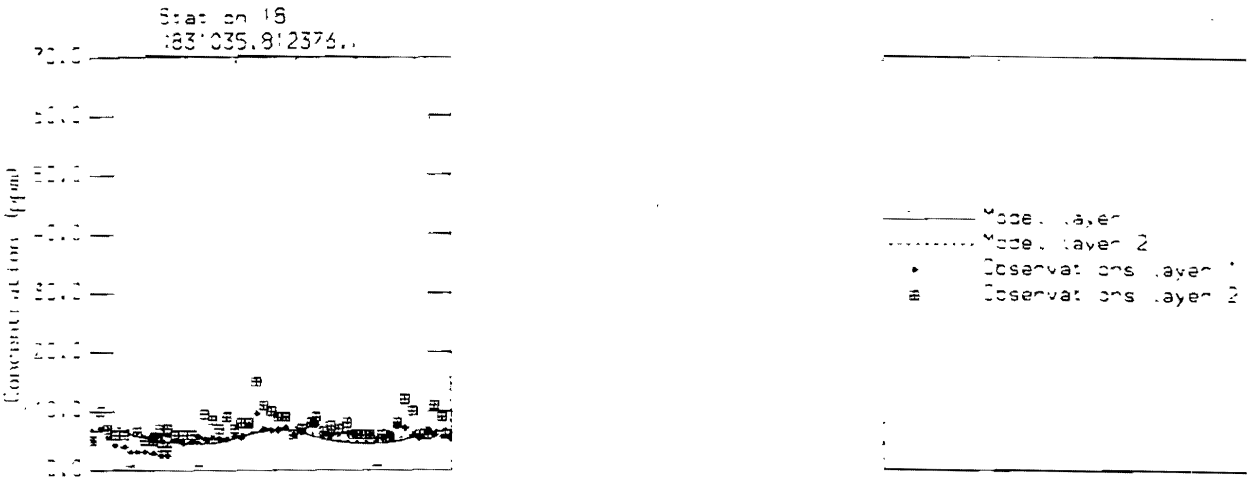
Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration (1990 Data)
Suspended Sediment Concentrations
Dry Season Neap Tide



Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration (1987 Data)
Suspended Sediment Concentrations
Dry Season Neap Tide



Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration (1987 Data)
Suspended Sediment Concentrations
Dry Season Neap Tide



Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration (1987 Data)
Suspended Sediment Concentrations
Dry Season Neap Tide

APPENDIX C

Analytical Results of Seawater and Elutriate Tests

MaterialLab

(W)

Lab. No. : -

Report No. : WA60122

Results :

	Testing items	E1 Seawater	E2 Seawater	E3 Seawater	E1 Elutriate (I)	E1 Elutriate (II)
1	pH value	7.8 at 25°C	7.8 at 25°C	7.8 at 25°C	7.6 at 25°C	7.9 at 25°C
2	Redox potential, mV at 25°C	-68	-62	-70	-72	-61
3	Total organic carbon content, mg C/L	<1	<1	<1	<1	<1
4	Copper content, µg/L	4	4	4	5	5
5	Nickel content, µg/L	87	60	60	91	88
6	Zinc content, mg/L	<0.05	<0.05	<0.05	<0.05	<0.05
7	Lead content, µg/L	11	<10	<10	12	13
8	Cadmium content, µg/L	0.4	0.4	0.4	0.4	0.6
9	Chromium content, µg/L	11	10	10	13	15
10	Mercury content, µg/L	<1	<1	<1	<1	<1
11	Ammoniacal nitrogen content, mg N/L	0.23	0.23	0.25	2.4	2.5
12	Organic nitrogen content, mg N/L	0.71	0.68	0.73	7.3	7.5
13	Total Inorganic nitrogen content, mg N/L	1.4	0.60	1.7	5.0	4.9

~~Tested~~ Prepared by : Monique Cho   Certified by : ______

Checked by : [signature]   Date : ______

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MateriaLab

Facsimile Transmission

To :	Civil Engineering Department	Ref. No. :	952399
Country :	(Please specify if overseas)	Fax No. :	2714 0113
Attn. :	Mr. K.C. Ng	Date :	1996-02-29
From :	Ms. Harriet H.Y. Lam	No. of Pages :	5 (incl. this page)
Subject :			

Contract No. GE/95/09
Laboratory Testing - Marine (Term Contract)
Works Order No. GE/95/09.2A

Attached please find the test results for the captioned.

Regards,

Authorized Signature

URGENT

Harriet H.Y. Lam
Senior Manager
Chemical & Environmental

(If you do not receive all pages, please fax response or phone 2450-8233.)

W

Lab. No. : –

Report No. : WA60122

Results :

	Testing items	E2 Elutriate (I)	E2 Elutriate (II)	E3 Elutriate (I)	E3 Elutriate (II)
1	pH value	7.7 at 25°C	7.8 at 25°C	7.9 at 25°C	8.0 at 25°C
2	Redox potential, mV at 25°C	-64	-56	-60	-63
3	Total organic carbon content, mg C/L	<1	<1	<1	<1
4	Copper content, µg/L	4	5	4	5
5	Nickel content, µg/L	92	76	73	64
6	Zinc content, mg/L	<0.05	<0.05	<0.05	<0.05
7	Lead content, µg/L	11	13	11	<10
8	Cadmium content, µg/L	0.6	0.8	0.6	0.6
9	Chromium content, µg/L	12	11	18	16
10	Mercury content, µg/L	<1	<1	<1	<1
11	Ammoniacal nitrogen content, mg N/L	0.65	0.62	2.8	3.0
12	Organic nitrogen content, mg N/L	1.6	1.6	7.9	8.2
13	Total inorganic nitrogen content, mg N/L	0.75	0.85	3.8	3.7

Prepared ~~Tested~~ by : Moriana Cho Certified by : ____________

Checked by : [signature] Date : ____________

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MateriaLab

Ref. No. : WA60122(1)
Client : Gammon Construction Ltd.
Project : Agreement No. CE 89/95 Supplementary EIA for Dredging of Archorage Area at Stonecutters Naval Base

Summary :

Test No.	Test item	Concentration, ug/L								
		E1-Sea water	E1-Elutiate I	E1-Elutiate II	E1-Sea water	E1-Elutiate I	E1-Elutiate II	E1-Sea water	E1-Elutiate I	E1-Elutiate II
1	TBT	<10	<10	<10	<10	<10	<10	<10	<10	<10
2	DDT	<1	<1	<1	<1	<1	<1	<1	<1	<1
3	PCB-1016	<1	<1	<1	<1	<1	<1	<1	<1	<1
	PCB-1221	<1	<1	<1	<1	<1	<1	<1	<1	<1
	PCB-1232	<1	<1	<1	<1	<1	<1	<1	<1	<1
	PCB-1242	<1	<1	<1	<1	<1	<1	<1	<1	<1
	PCB-1248	<1	<1	<1	<1	<1	<1	<1	<1	<1
	PCB-1254	<1	<1	<1	<1	<1	<1	<1	<1	<1
	PCB-1260	<1	<1	<1	<1	<1	<1	<1	<1	<1

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Our Ref. No. : 952399EN60155

IV. Results

IV.1. Analysis results of sediment, seawater and elutriate at location E1

Test item	E1 sediment
pH value, pH unit at 25°C	8.0
Redox potential, mV at 25°C	-86
Weight per 100cc, g wet mass/100cc	202.3
Moisture content, %	38
Copper, mg/kg	70
Cadmium, mg/kg	<0.2
Chromium, mg/kg	45
Lead, mg/kg	31
Nickel, mg/kg	19
Zinc, mg/kg	110
Mercury, mg/kg	0.24
Classification criteria of contamination level	C
TBT, µg/kg	<100
DDT, µg/kg	<10
PCB-1016, µg/kg	*
PCB-1221, µg/kg	*
PCB-1232, µg/kg	*
PCB-1242, µg/kg	*
PCB-1248, µg/kg	*
PCB-1254, µg/kg	*
PCB-1260, µg/kg	*
Total organic carbon content, mg/kg	430

Test item	E1 Seawater	Test item	E1 Elutriate I	E1 Elutriate II
pH value, pH unit at 25°C	7.8 at 25°C	pH value, pH unit at 25°C	7.6 at 25°C	7.9 at 25°C
Redox potential, mV at 25°C	-68	Redox potential, mV at 25°C	-72	-61
Copper, µg/L	4	Copper, µg/kg	16	18
Cadmium, µg/L	0.4	Cadmium, µg/kg	1.7	2.0
Chromium, µg/L	11	Chromium, µg/kg	45	52
Lead, µg/L	11	Lead, µg/kg	43	45
Nickel, µg/L	87	Nickel, µg/kg	320	310
Zinc, mg/L	<0.05	Zinc, mg/kg	<0.2	<0.2
Mercury, µg/L	<1	Mercury, µg/kg	<4	<4
TBT, µg/L	<10	TBT, µg/kg	<50	<50
DDT, µg/L	<1	DDT, µg/kg	<5	<5
PCB-1016, µg/L	<1	PCB-1016, µg/kg	<5	<5
PCB-1221, µg/L	<1	PCB-1221, µg/kg	<5	<5
PCB-1232, µg/L	<1	PCB-1232, µg/kg	<5	<5
PCB-1242, µg/L	<1	PCB-1242, µg/kg	<5	<5
PCB-1248, µg/L	<1	PCB-1248, µg/kg	<5	<5
PCB-1254, µg/L	<1	PCB-1254, µg/kg	<5	<5
PCB-1260, µg/L	<1	PCB-1260, µg/kg	<5	<5
Total organic carbon content, mgC/L	<1	Total organic carbon content, mg/kg	<3.5	<3.5
Ammoniacal nitrogen content, mgN/L	0.23	Ammoniacal nitrogen content, mgN/kg	8.4	8.7
Organic nitrogen content, mgN/L	0.25	Organic nitrogen content, mgN/kg	8.7	8.7
Total inorganic nitrogen content, mgN/L	1.4	Total inorganic nitrogen content, mgN/kg	1.7	1.7

"*" : After cleanup (according to USEPA 3620A Florsil column cleanup). Seroius interference are still present in sample E1 extract at retention time 6~20 min. part of PCB-1260 patten is found in samples E1 at other retention time. Therefore it is difficult to determine sample containing PCB or not.

Remark : Results of sediment and elutriate are based on mass of sediment dried at 103 to 105°C.

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IV.2. Analysis results of sediment, seawater and elutriate at location E2

Test item	E2 sediment
pH value, pH unit at 25°C	8.1
Redox potential, mV at 25°C	-120
Weight per 100cc, g wet mass/100cc	201.5
Moisture content, %	40
Copper, mg/kg	96
Cadmium, mg/kg	<0.2
Chromium, mg/kg	45
Lead, mg/kg	130
Nickel, mg/kg	12
Zinc, mg/kg	220
Mercury, mg/kg	0.73
Classification criteria of contamination level	C
TBT, µg/kg	<100
DDT, µg/kg	<10
PCB-1016, µg/kg	<50
PCB-1221, µg/kg	<50
PCB-1232, µg/kg	<50
PCB-1242, µg/kg	<50
PCB-1248, µg/kg	<50
PCB-1254, µg/kg	<50
PCB-1260, µg/kg	<50
Total organic carbon content, mg/kg	990

Test item	E2 Seawater	Test item	E2 Elutriate I	E2 Elutriate II
pH value, pH unit at 25°C	7.8 at 25°C	pH value, pH unit at 25°C	7.7 at 25°C	7.8 at 25°C
Redox potential, mV at 25°C	-62	Redox potential, mV at 25°C	-64	-56
Copper, µg/L	4	Copper, µg/kg	16	17
Cadmium, µg/L	0.4	Cadmium, µg/kg	2.2	2.9
Chromium, µg/L	10	Chromium, µg/kg	43	39
Lead, µg/L	<10	Lead, µg/kg	42	49
Nickel, µg/L	60	Nickel, µg/kg	330	280
Zinc, mg/L	<0.05	Zinc, mg/kg	<0.2	<0.2
Mercury, µg/L	<1	Mercury, µg/kg	<4	<4
TBT, µg/L	<10	TBT, µg/kg	<50	<50
DDT, µg/L	<1	DDT, µg/kg	<5	<5
PCB-1016, µg/L	<1	PCB-1016, µg/kg	<5	<5
PCB-1221, µg/L	<1	PCB-1221, µg/kg	<5	<5
PCB-1232, µg/L	<1	PCB-1232, µg/kg	<5	<5
PCB-1242, µg/L	<1	PCB-1242, µg/kg	<5	<5
PCB-1248, µg/L	<1	PCB-1248, µg/kg	<5	<5
PCB-1254, µg/L	<1	PCB-1254, µg/kg	<5	<5
PCB-1260, µg/L	<1	PCB-1260, µg/kg	<5	<5
Total organic carbon content, mgC/L	<1	Total organic carbon content, mg/kg	<3.6	<3.6
Ammoniacal nitrogen content, mgN/L	0.23	Ammoniacal nitrogen content, mgN/kg	2.4	2.3
Organic nitrogen content, mgN/L	0.22	Organic nitrogen content, mgN/kg	1.0	1.3
Total inorganic nitrogen content, mgN/L	0.66	Total inorganic nitrogen content, mgN/kg	2.7	3.1

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IV.3. Analysis results of sediment, seawater and elutriate at location E3

Test item	E3 sediment
pH value, pH unit at 25°C	8.1
Redox potential, mV at 25°C	-109
Weight per 100cc, g wet mass/100cc	202.7
Moisture content, %	47
Copper, mg/kg	220
Cadmium, mg/kg	0.27
Chromium, mg/kg	59
Lead, mg/kg	55
Nickel, mg/kg	19
Zinc, mg/kg	140
Mercury, mg/kg	0.34
Classification criteria of contamination level	C
TBT, µg/kg	<100
DDT, µg/kg	<10
PCB-1016, µg/kg	*
PCB-1221, µg/kg	*
PCB-1232, µg/kg	*
PCB-1242, µg/kg	*
PCB-1248, µg/kg	*
PCB-1254, µg/kg	*
PCB-1260, µg/kg	*
Total organic carbon content, mg/kg	820

Test item	E3 Seawater	Test item	E3 Elutriate I	E3 Elutriate II
pH value, pH unit at 25°C	7.8 at 25°C	pH value, pH unit at 25°C	7.9 at 25°C	8.0 at 25°C
Redox potential, mV at 25°C	-70	Redox potential, mV at 25°C	-60	-63
Copper, µg/L	4	Copper, µg/kg	17	20
Cadmium, µg/L	0.4	Cadmium, µg/kg	2.3	2.3
Chromium, µg/L	10	Chromium, µg/kg	74	66
Lead, µg/L	<10	Lead, µg/kg	43	<30
Nickel, µg/L	60	Nickel, µg/kg	300	270
Zinc, mg/L	<0.05	Zinc, mg/kg	<0.2	<0.2
Mercury, µg/L	<1	Mercury, µg/kg	<4	<4
TBT, µg/L	<10	TBT, µg/kg	<50	<50
DDT, µg/L	<1	DDT, µg/kg	<5	<5
PCB-1016, µg/L	<1	PCB-1016, µg/kg	<5	<5
PCB-1221, µg/L	<1	PCB-1221, µg/kg	<5	<5
PCB-1232, µg/L	<1	PCB-1232, µg/kg	<5	<5
PCB-1242, µg/L	<1	PCB-1242, µg/kg	<5	<5
PCB-1248, µg/L	<1	PCB-1248, µg/kg	<5	<5
PCB-1254, µg/L	<1	PCB-1254, µg/kg	<5	<5
PCB-1260, µg/L	<1	PCB-1260, µg/kg	<5	<5
Total organic carbon content, mgC/L	<1	Total organic carbon content, mg/kg	<4.2	<4.2
Ammoniacal nitrogen content, mgN/L	0.25	Ammoniacal nitrogen content, mgN/kg	12	12
Organic nitrogen content, mgN/L	0.23	Organic nitrogen content, mgN/kg	9.6	9.6
Total inorganic nitrogen content, mgN/L	1.7	Total inorganic nitrogen content, mgN/kg	16	15

"*" : After cleanup (according to USEPA 3620A Florsil column cleanup). Seroius interference are still present in sample E3 extract at retention time 6–20 min. part of PCB-1260 patten is found in samples E3 at other retention time. Therefore it is difficult to determine sample containing PCB or not.

Remark : Results of sediment and elutriate are based on mass of sediment dried at 103 to 105°C.

Preapred by : ____________________

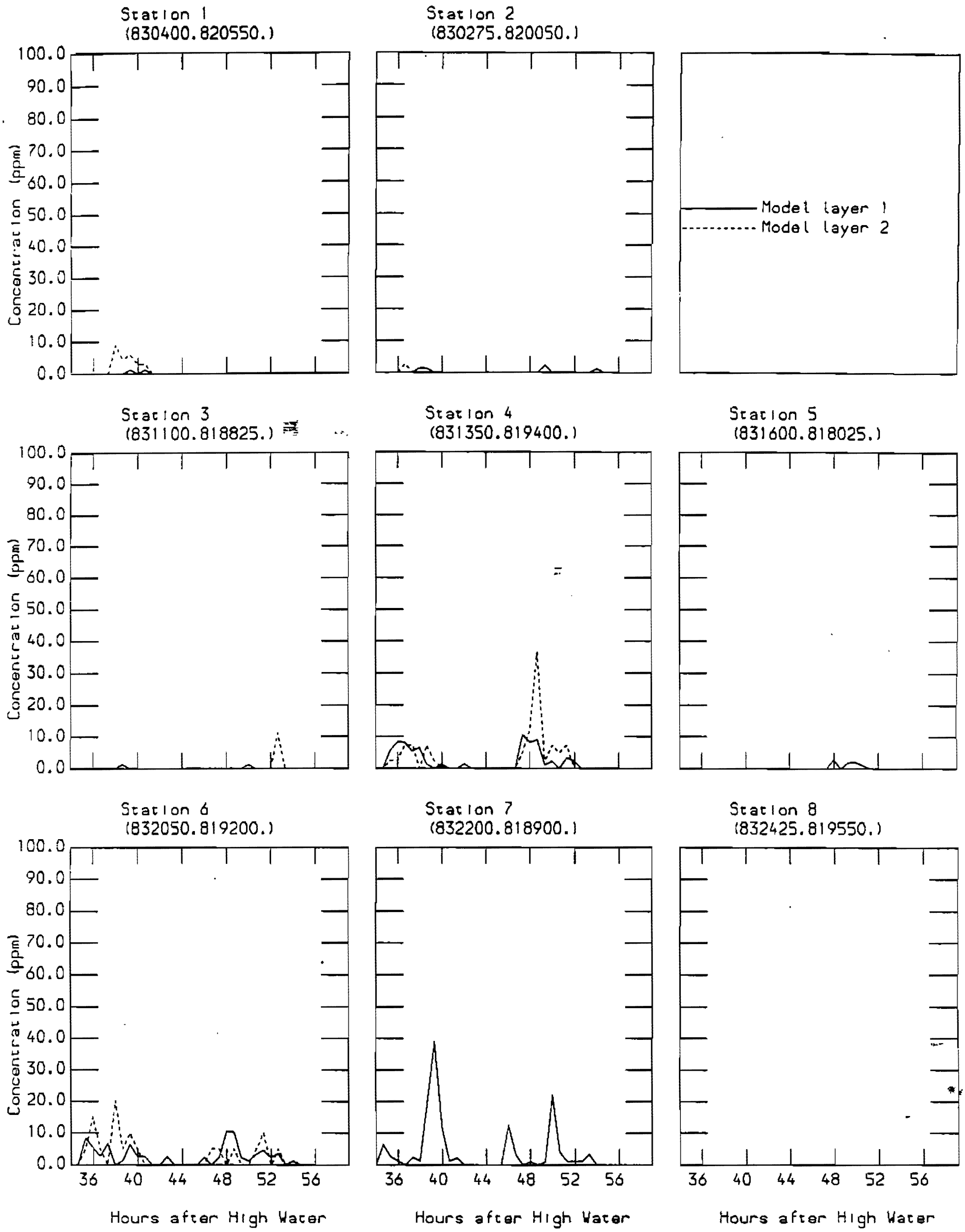
Approved Signatory : K.M. Ho

Date : ____________________

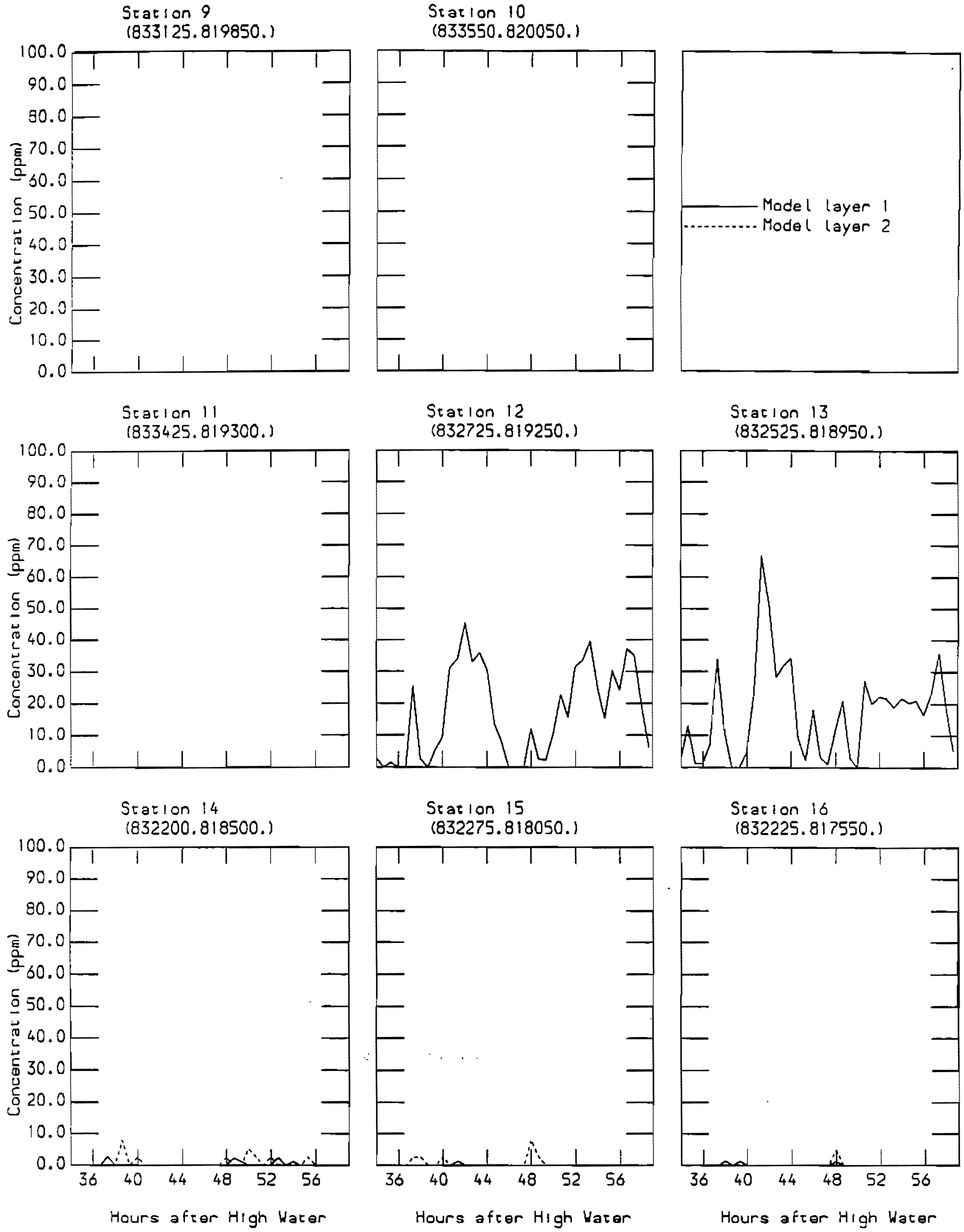
APPENDIX D

Sediment Plume Simulations	-	**Scenario 1 (Trailing Suction Dredgers)**
	-	**Scenario 2 (Grab Dredgers)**

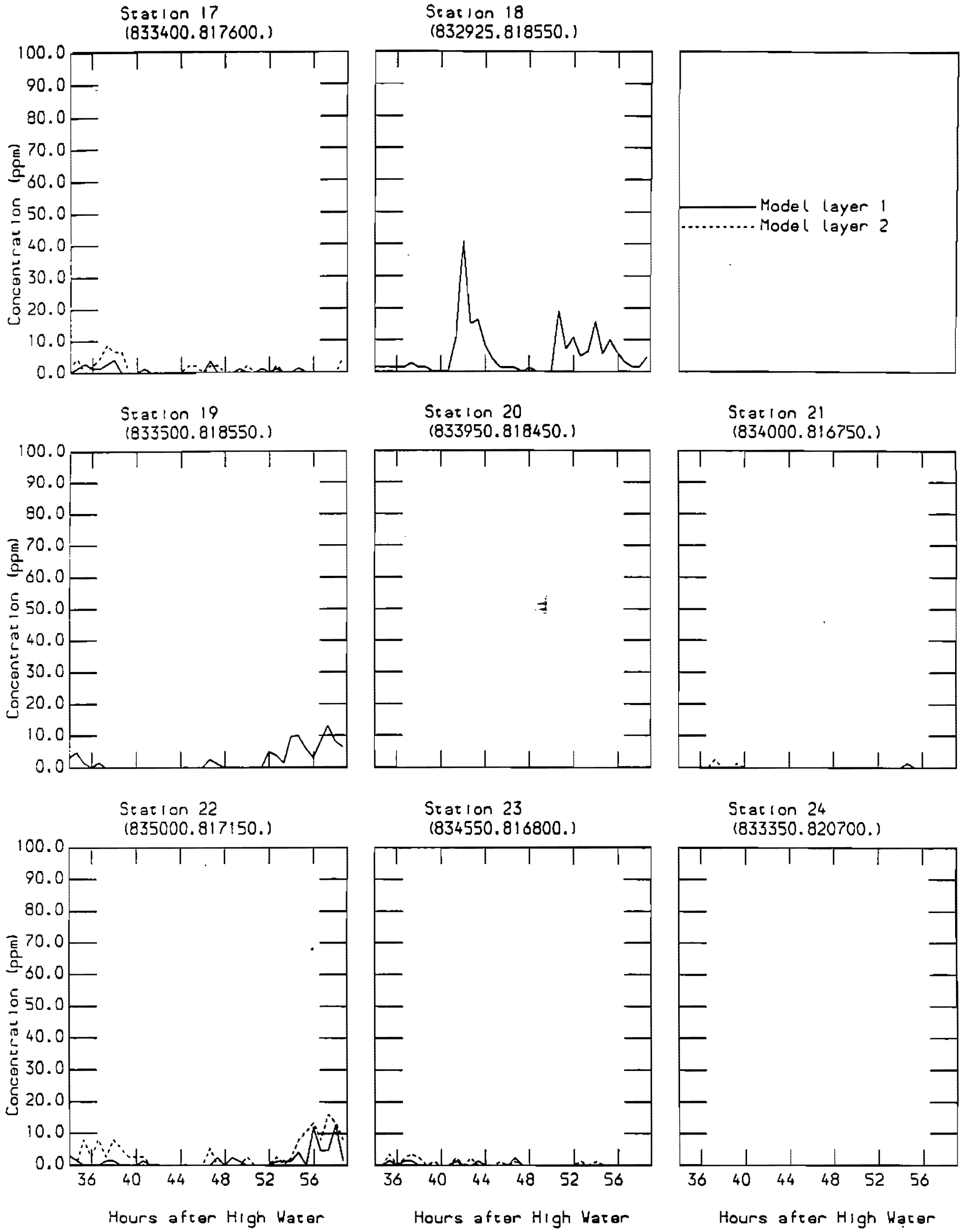
WET SEASON SPRING TIDE



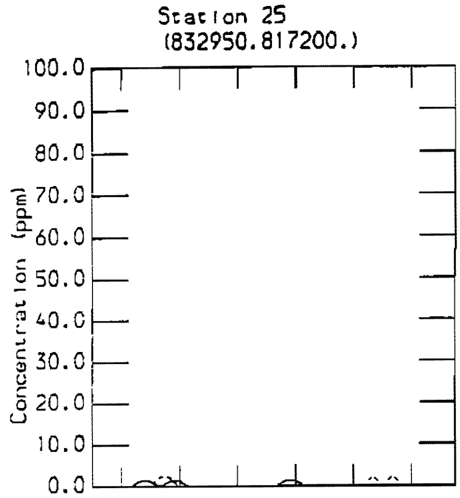
Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continous
Suspended Sediment at Sensitive Receiver
Wet Season Spring Tide

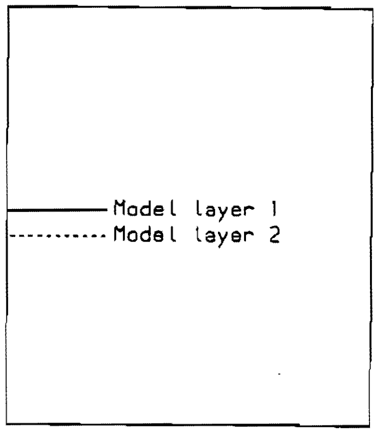


Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continous
Suspended Sediment at Sensitive Receiver
Wet Season Spring Tide



Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continous
Suspended Sediment at Sensitive Receiver
Wet Season Spring Tide





Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continous
Suspended Sediment at Sensitive Receiver
Wet Season Spring Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Suspended Sediment Concentrations
Wet Season Spring Tide

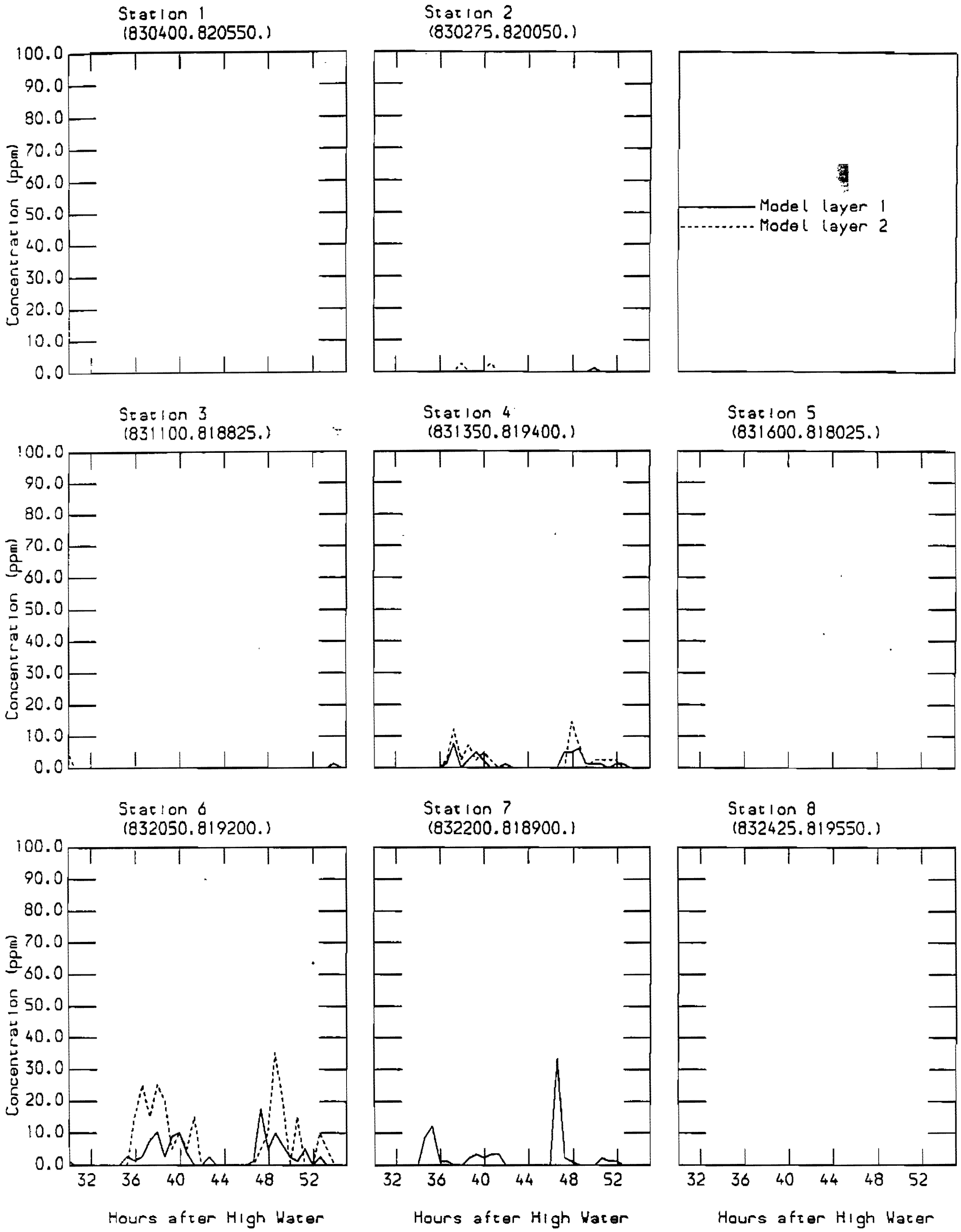
Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Suspended Sediment Concentrations
Wet Season Spring Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Suspended Sediment Concentrations
Wet Season Spring Tide

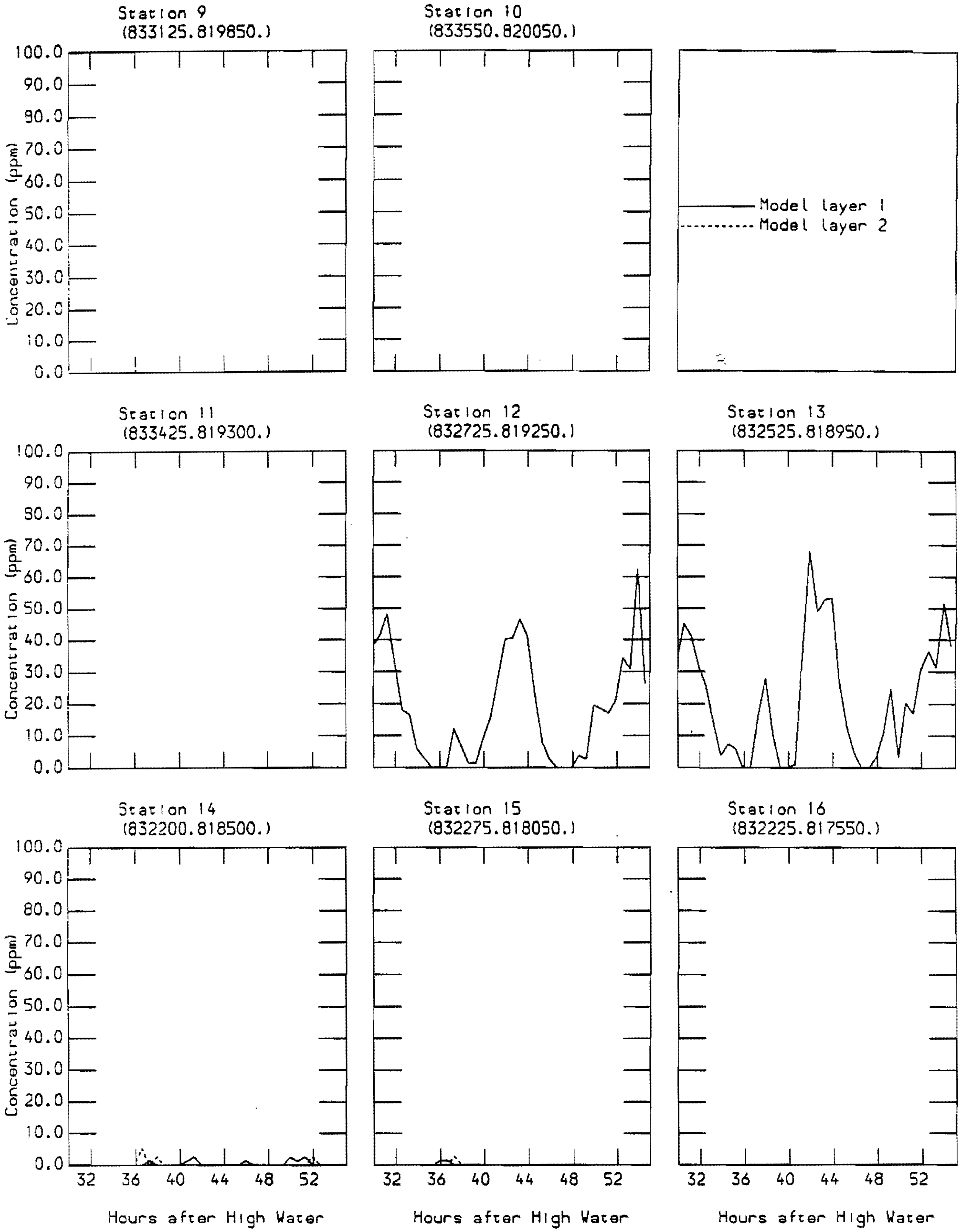
Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Suspended Sediment Concentrations
Wet Season Spring Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Mud Deposits for 1 Tide
Wet Season Spring Tide

WET SEASON NEAP TIDE



Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continous
Suspended Sediment at Sensitive Receiver
Wet Season Neap Tide



Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continous
Suspended Sediment at Sensitive Receiver
Wet Season Neap Tide

6. MITIGATION MEASURES

6.1 Construction Phase

From the interpretation of the results of the sediment plume study, it was concluded that no specific mitigation measures will be required to achieve the WQO's for dissolved oxygen, ammonia or nutrients when dredging is being carried out. As noted in Section 4.2 on the basis of the model results, it may be surmised that the WQO's for SS will be exceeded within the anchorage area.

As noted in Section 4.2 the model indicates that the overall impacts on marine water quality are greater when a trailing suction dredger is used for dredging the anchorage area than for two grab dredgers. It should be noted that the dredging programme given in Figure 3.1 is actually based on a dredging rate of 20,000m^3. A rate of 40,000m^3 was used as input to the model to assess cumulative impacts if there was more than one dredging activity taking place in the area of influence during the programmed works. As noted in Section 3 this is not case and thus the results for the trailing suction dredger should be divided by 2. Even on this basis, it was predicted that suspended solids concentrations will exceed the WQO for the unmitigated scenario (20,000m^3).

It should however be noted that a sediment release rate of 5% is very conservative; in practice average release rates of about 1% are more common for trailing suction dredgers assuming good operating practices are adopted (as discussed later in the text). On the basis that 1% release rates are, on average easily achieveable using trailing suction dredgers the impacts within the anchorage area could be reduced to less than 7mg/l. The concentration around the dredger itself will naturally be higher but this should be confined to a small area.

If the construction programme needs to be compressed and trailing suction dredgers are used, the production rate could be between 20,000 and 40,000m^3 depending on the time available. The impact (and mitigation measures) would however need to be reassessed with respect to any changes in the construction programme.

For grab dredgers the rates used as input to the model correspond to the programme given in Figure 3.2.

The assumed sediment loss of 5% is also very high when relating this to field observations. A reduction of about 50% in the predicted losses (i.e. 2.5% loss rate) could easily be achieved through standard operating practices as discussed later in this section. If this reduction is taken into account the impacts associated with this dredging option will be significantly reduced. In the anchorage area, suspended solids concentrations still are forecast to be relatively high and mitigation measures will need to applied if the Contractor chooses to use grab dredgers throughout the construction phase.

It is worthy of note that about 1.8Mm^3 of mud is defined as being contaminated and will thus be dredged using closed end grab dredgers. The remaining 1.2Mm^3 is defined as uncontaminated and no such dredging restrictions apply. However, it is possible that the Contractor will choose to deploy only closed end grab dredgers on the site to carry out the entire dredging works as this could be more economical than changing plant part way through the dredging works. It is also worthy of note that the contaminated mud will be dredged out as the first activity (scheduled during the wet season). If the Contractor chooses to use trailing suction dredgers, impacts will be less as this will be carried out during the dry season.

Specific measures to reduce the impacts of dredging on the marine environment include:

- reduction of sediment losses through application of low impact dredging methods. Sediment losses estimated herein could be reduced by about 80% compared to the unmitigated scenario (ie 1% release rate compared to the it 5% which was assumed in the sediment plume model) through employment of trailing suction dredgers. Grab dredgers could reduce the impact by approximately 50% (compared to the unmitigated scenario). If closed end grabs are used the high vertical accuracy which can be attained will further reduce the sediment losses. Turbidity generation may still be high during closing and hoisting due to improper closing or debris/silt sticking to the sides of the grab.

- by controlling the dredging (and production) rates the impacts on the water column can be reduced. For trailing suction dredgers production rates should be controlled at 20,000m^3/day (as defined in the Construction Programme given in Figure 3.2), and for grab dredgers this should be 12,800m^3 per day on the basis of the foregoing assessments (as given in Figure 3.2);

- sediment losses during dredging should be controlled through the Conditions of Contract to less than 5% of the dredging rate; and

- residual impacts can be controlled through inter alia, dredging only on a slack or rising tide or by reducing the actual production rate.

Although the modelling study indicated there would be no need to use silt curtains to protect the sensitive receivers (seawater intakes), if these are found to be required the following conditions should apply:

- When dredging the Contractor shall surround any seawater intakes within the area of influence with suitable silt curtains to prevent excess silt contaminating the water drawn into the intakes. The Contractor shall be responsible for providing and installing silt curtains, where required, which shall be formed from tough, abrasion resistant, permeable membranes suitable for the purpose, supported on floating booms in such an a manner as to ensure that the ingress of turbid waters to the enclosed waters shall be restricted.

- The bottom of the curtain shall be formed and installed to accommodate the tidal rise and fall, and that ingress of turbid waters is limited. The Contractor shall regularly inspect the silt curtains and shall ensure that they are adequately moored and marked to avoid any danger to marine traffic.

6.2 Operation Phase

Examination of the calibrated sediment transport model results indicate that sedimentation rates within the anchorage area are likely to be up to 4cm per year. This calculation has been made on the assumption that the sediment will not consolidate and will have an average dry density of 94 kg/m^3. Maintenance dredging is likely, therefore to be required every ten years or so.

However, under extreme storm events, the soft seabed deposits are likely to be remobilised, forming a dense suspension of sediment and water close to the seabed. This mobilised material will tend to be deposited in the anchorage area where it will consolidate rapidly.

7. CONTRACT CLAUSES

7.1 General Environmental Protection Measures

On the basis of the foregoing assessments, it is apparent that specific controls will need to be applied to protect marine life and water quality, both at the Anchorage Area and at the spoil dumping grounds.

(1) The Contractor shall carry out the Works in such a manner as to minimize adverse impacts on the water quality during execution of the Works. Methods of working shall be arranged to minimize the effects on the water quality within the Site, adjacent to the Site, on transport routes and at loading, dredging and dumping areas.

(2) Methods of working shall be designed to minimize adverse impacts upon water quality in Hong Kong waters in terms of the WQO; experienced personnel with suitable training shall be employed to ensure that these methods are implemented.

(3) Particulars of proposed methods of working which are likely to cause adverse impacts upon water quality shall be submitted to the Engineer. The particulars shall be submitted before such work starts.

(4) Seawater intakes which may be affected by dredging shall be surrounded with suitable silt curtain systems to prevent excess silt contaminating the water drawn into the intakes if this is found to be necessary. The silt curtain systems shall be designed to ensure that the intake water shall contain less than 140 mg/l suspended solids (the water quality objective for WSD intakes is 10 mg/l, but note this is actually even less than ambient water quality).

(5) The Contractor shall comply with the provisions of the Summary Offences Ordinance, particularly with respect to marine littering.

(6) Sediment losses during dredging works shall not exceed 5% of the daily dredging rate or 1.2kg/s whichever is lowest and the sediment losses shall be confined within silt curtains if required.

(7) The Contractor shall agree with the Engineer the specific routes which shall be adopted for the disposal of spoil and shall adhere to these routes unless otherwise advised.

7.2 Protection of Marine Water Quality

(i) The Contractor shall design methods of working to minimise adverse impacts upon water quality stemming from his operations in Hong Kong waters in terms of the WQO, and shall provide experienced personnel with suitable training to ensure that these methods are implemented. Methods of working shall:

(a) minimize disturbance to the seabed while dredging;

(b) minimize leakage of dredged material during lifting;

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

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

(e) prevent the unacceptable reduction, due to the Works, of the dissolved oxygen content of the water affected by the Works; and

(f) prevent excess suspended solids from being present in intake waters.

(ii) Before the commencement of the Works, the Contractor shall submit to the Engineer the proposed methods of working.

(iii) After commencement of the Works if the plant or work methods are believed by the Engineer to be causing unacceptable levels of pollution, the plant or work methods shall be inspected and remedial proposals drawn up, approved and implemented. Where such remedial measures include the use of additional or alternative plant such plant shall not be used on the Works until agreed by the Engineer. Where remedial measures include maintenance or modification of previously approved plant such plant shall not be used on the Works until such maintenance or modification is completed and the adequacy of the maintenance or modification is demonstrated to the satisfaction of the Engineer.

(iv) When dredging the Contractor shall surround any seawater intakes which may be affected by such operations with suitable silt curtain systems, to prevent excess silt contaminating the water drawn into the intakes.

(v) The Contractor shall comply with the provisions of the Summary Offences Ordinance, particularly with respect to marine littering.

7.3 General Procedures for the Avoidance of Pollution During Dredging, Transporting and Dumping

(a) All Contractor's Equipment shall be designed and maintained to minimise the risk of silt and other contaminants being released into the water column or deposited in other than designated locations.

(b) Pollution avoidance measures shall include but are not limited to the following:-

(i) mechanical grabs shall be designed and maintained to avoid spillage and shall seal tightly while being lifted;

(ii) if trailing suction hopper dredgers for dredging of uncontaminated marine mud are proposed, overflow from the dredger and the operation of lean mixture overboard systems shall not be permitted, unless expressly approved by the Engineer in consultation with the EPD;

(iii) all vessels shall 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;

(iv) all pipe leakages are to be repaired promptly and plant is not to be operated with leaking pipes;

(v) the Works shall cause no visible foam, oil, grease, scum, litter or other objectionable matter to be present on the water within the Site or dumping grounds;

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

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

(viii) loading of barges and hoppers shall be controlled to prevent splashing of dredged material to the surrounding water and barges or hoppers shall not be filled to a level which will cause overflow of material or polluted water during loading or transportation;

(ix) adequate freeboard shall be maintained on barges to ensure that decks are not washed by wave action; and

(x) any other pollution avoidance measures deemed suitable and appropriate by the Contractor.

(c) The Engineer may monitor any or all vessels transporting material to ensure that no dumping outside the approved location takes place. The Contractor shall provide all reasonable assistance to the Engineer for this purpose.

(d) The Contractor shall ensure that all marine mud, contaminated marine mud and unsuitable material is disposed of at the approved locations. He will be required to ensure accurate positioning of vessels before discharge and will be required to submit and agree proposals with the Engineer for accurate positional control at disposal sites before commencing dredging. All disposal in designated marine dumping grounds shall be in accordance with the conditions of a licence issued by the DEP under the Dumping at Sea Act (Overseas Territories) Order 1975. Floatable and contaminated materials (as defined by the DEP) will not be acceptable at marine dumping grounds and will require other methods of disposal.

(e) The Contractor shall design methods of working to minimise pollution and shall provide both experienced personnel and suitable training to ensure that these methods are implemented.

7.4 Designated Contaminated Marine Mud

The locations and depths of the designated contaminated marine mud will be as directed by the Engineer on site. The Contractor is to ensure that the designated contaminated marine mud is dredged, transported and placed in approved special dumping grounds and in such a manner as to minimise the loss of material to the water column.

Special Procedures for the Avoidance of Pollution During Dredging, Transportation and Disposal of Designated Contaminated Marine Mud include:

(a) All contaminated material will be dredged and disposed of according to the requirements of the FMC and EPD.

(b) Uncontaminated mud shall not be dumped other than in dumping grounds as may be approved by the DEP and in accordance with the Dumping at Sea Act (Overseas Territories) Order 1975. Contaminated mud shall not be dumped in gazetted dumping grounds. If it cannot be left *in situ* it should be disposed of by specific methods as directed by the DEP. The Contractor shall be responsible for obtaining all necessary licences for these operations.

(c) 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 are not limited to the following:-

(i) The contractor shall obtain a disposal licence for disposal of contaminated mud at the East Sha Chau contaminated Mud Pits.

(ii) dredging of designated contaminated marine mud shall only be undertaken by a suitable grab dredger using a closed watertight grab;

(iii) transport of designated contaminated marine mud shall be by split barge of not less than $750m^3$ capacity; well maintained and capable of rapid opening and discharge at the disposal site;

(iv) the material will be placed in the pit by bottom dumping, at a location within the pit to be specified, from time to time, by the Secretary of Fill Management Committee;

(v) discharge shall be undertaken rapidly and the hoppers shall then immediately be closed; 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;

(vi) the Contractor must be able to position the dumping vessel to an accuracy of $\pm 10m$;

(vii) the Engineer for the Contract which is disposing of the contaminated mud will supervise and record the disposal operation. The Contractor shall provide assistance to the Engineer and the details of the supervision and record keeping are to be agreed beforehand by the Director of Environmental Protection; and

(viii) the Contractor shall ensure that the dumping vessel shall be stationary throughout the dumping operation.

In addition to the foregoing, the Fill Management Committee and the Environmental Protection Department may impose further restrictions when the Contractor applies for the licence.

8. ENVIRONMENTAL MONITORING AND AUDIT REQUIREMENTS

8.1 General

The Contractor will be required to schedule and design his works such that he:

- minimises disturbance to the seabed while dredging;
- minimises losses of dredged material during lifting and transportation of fill or dredged material;
- prevents discharge of pollutants, fill or dredged material at any location other that approved by the Director of Environmental Protection;
- prevents the unacceptable reduction in dissolved oxygen levels due to the dredging; and
- prevents release of excessive suspended solids to the water column.

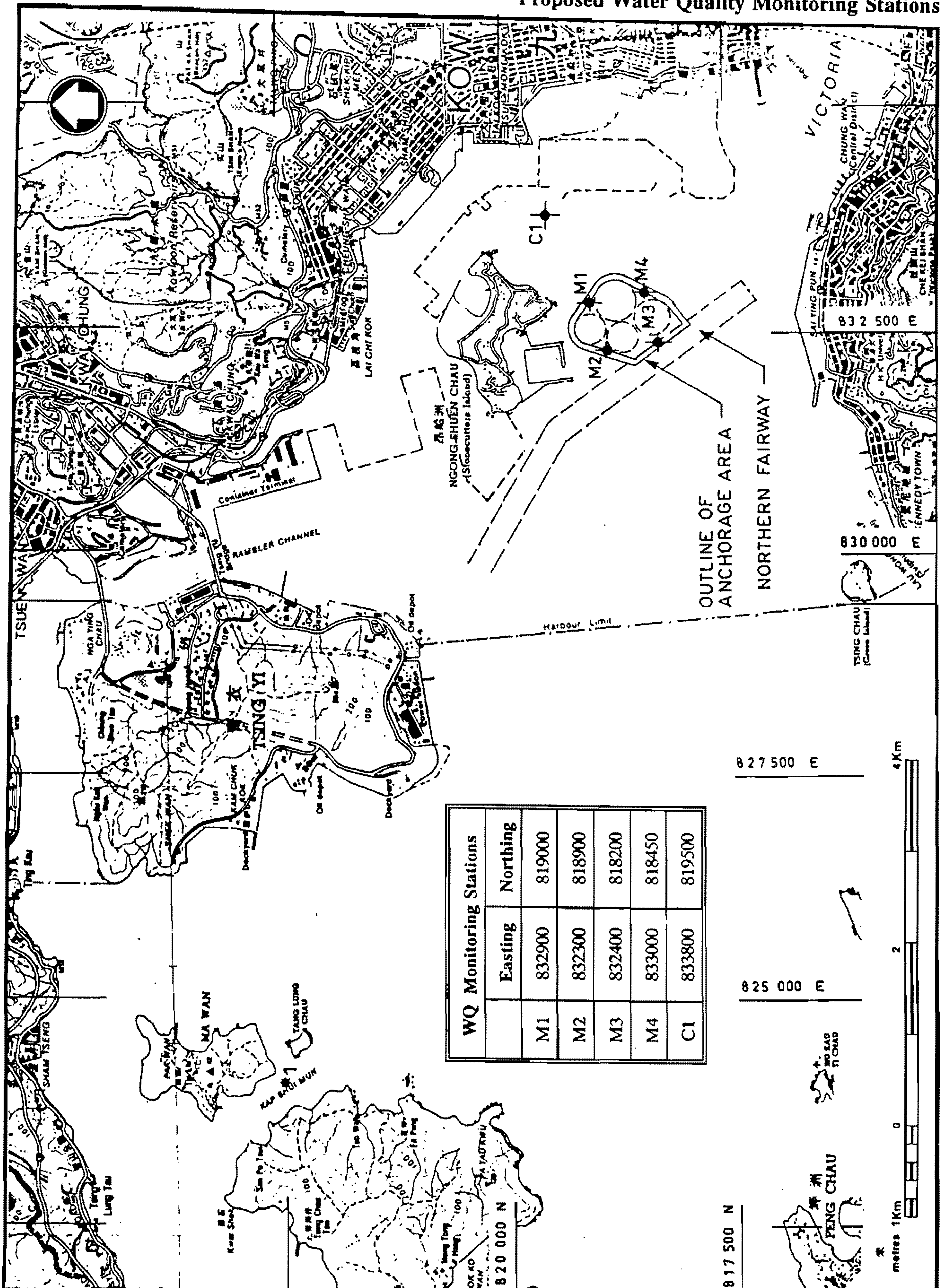
To ensure the Contractor is carrying out the Works in such a manner as to minimise adverse impacts on receiving water quality during execution of the Works, it is recommended that impact monitoring during the period when dredging and related marine works are undertaken to confirm the standards set are being achieved.

The Engineer should establish a series of Designated Monitoring Stations (as illustrated on Figure 8.1) with each station having a defined (measured) target limit for turbidity defined by the Engineer. One station will be located near any seawater intake within a 1km radius of the site. Two more stations will be located within the immediate Study Area, with a further two stations external to the embayment. It is proposed the 5 monitoring stations will be established around the Anchorage Area site to monitor the marine impacts of these works. These shall be defined in the Environmental Monitoring and Audit Manual.

8.2 Baseline Monitoring

Baseline conditions for water quality will be established at least four weeks prior to commencement of the marine works by insitu measurement of dissolved oxygen concentration (mg/l) (DO) and dissolved oxygen saturation (%) (DOS) and temperature (°C). No monitoring of heavy metals is proposed on account of the results provided and temperature (°C). Water samples will be taken for immediate onsite measurement of turbidity (NTU) and laboratory analysis of suspended solids (mg/L). Baseline monitoring will be undertaken for all other parameters at all Designated Monitoring Stations, for a period of one month prior to the commencement of the marine works on four days of each week. Monitoring shall be undertaken at each station on the mid flood and mid ebb tides at three depths, namely, one metre below the water surface (upper), mid water depth (middle) and one metre above the sea bed (lower). The baseline results and WQO shall form the basis for calculating trigger, action and target levels to be used in the impact monitoring. A framework for calculating TAT levels is shown in Table 8.1.

Figure 8.1
Proposed Water Quality Monitoring Stations



	Easting	Northing
M1	832900	819000
M2	832300	818900
M3	832400	818200
M4	833000	818450
C1	833800	819500

WQ Monitoring Stations

Table 8.1 Trigger, Action and Target Levels

Parameters	Trigger	Action	Target
Dissolved Oxygen, DO mg/L (Depth averaged)	DO<5%- ile of baseline data for surface and middle layers	DO<1%- ile of baseline data for surface and middle layers	<4mg/L (<5mg/L for MFCZ)
Dissolved Oxygen, DO mg/L (Bottom)	Bottom: DO<5%- ile of baseline data for bottom layer	Bottom: DO<1%- ile of baseline data for bottom layer	Bottom: <2 mg/L
Suspended Solid, SS mg/L (depth-averaged)	SS>90%- ile of baseline data and SS >110% upstream control station's SS at the same tide of the same day	SS>95%- ile of baseline data and SS >120% upstream control station's SS at the same tide of the same day	SS>99%- ile of baseline data and SS >130% upstream control station's SS at the same tide of the same day
Turbidity, Tby, NTU (depth-averaged)	Tby>90%- ile of baseline data and Tby >110% upstream control station's Tby at the same tide of the same day	Tby>95%- ile of baseline data and Tby >120% upstream control station's Tby at the same tide of the same day	Tby>99%- ile of baseline data and Tby >130% upstream control station's Tby at the same tide of the same day

8.3 Impact Monitoring

Impact monitoring will be undertaken, during the course of the Works, on three working days per week at each predefined Designated Monitoring Station. The interval between each sampling series (mid ebb and mid flood) will not be less than 36 hours where two sets of the turbidity, DO, DOS and temperature levels shall be measured and water samples for suspended solids taken at each depth. Where the difference in value between the first and second reading of each set is more than 25% the readings shall be discarded and further readings shall be taken. Suspended solids analysis will continue until such times as a clear relationship is determined with turbidity.

8.4 Event/Action Plan

If the monitoring data of turbidity or suspended solids or dissolved oxygen or ammoniacal nitrogen show a deteriorating trend or TAT levels for any of these parameters are exceeded, the Contractor shall take action in accordance with an Action Plan which shall be submitted to and agreed by the Engineer and EPD.

Action on detecting a deterioration in water quality shall include all necessary steps taken by the Contractor to stem the deterioration and re-establish the status quo. The steps taken will include but not be limited to:-

- checking of all marine plant and equipment;
- maintenance or replacement of any marine plant or equipment contributing to the deterioration;
- checking and maintenance of any silt screens; and

- review of all working methods.

An action plan for water quality monitoring has been drawn up and is included as Table 8.2 below.

Table 8.2 Action/Event Plan for Water Quality

Exceedance	Environmental Team (Monitoring Staff + Environmental Auditor)	Contractor	Engineer
Trigger Level being exceeded by one sampling day	Inform Contractor	Rectify unacceptable practice	
Trigger level being exceeded by more than two consecutive sampling days	Repeat in-situ measurement to confirm findings; Identify source(s) of impact; Inform Contractor; Checking monitoring data, all plant, equipment and contractor's working methods; Discuss mitigation measures with the Engineer and Contractor.	Inform the Engineer; Rectify unacceptable practice; Check all plant and equipment; Consider changes of working methods; Propose mitigation measures to Engineer and discuss with Environmental Team and the Engineer; Implement mitigation measures	Discuss with Environmental Team and the Contractor on the proposed mitigation measures; Make agreement on the mitigation measures to be implemented; Assess the effectiveness of the implemented mitigation measures.
Action level being exceeded by one sampling day	Repeat in-situ measurement to confirm findings; Identify source(s) of impact; Inform Contractor; Check monitoring data, all plant, equipment and contractor's working methods; Discuss mitigation measures with the Engineer and Contractor; Repeat measurement on the next day of exceedance.	Inform the Engineer and confirm notification of exceedance in writing; Rectify unacceptable practice; Check all plant and equipment; Consider changes of working methods; Propose mitigation measures to Engineer and discuss with Environmental Team and the Engineer, Implement the agreed mitigation measures.	Discuss with Environmental Team and the Contractor on the proposed mitigation measures; Make agreement on the mitigation measures to be implemented; Assess the effectiveness of the implemented mitigation measures.
Action level being exceeded by more than two consecutive sampling days	Repeat in-situ measurement to confirm findings; Identify source(s) of impact; Inform Contractor; Check monitoring data, all plant, equipment and contractor's working methods; Discuss mitigation measures with the Engineer and Contractor; Ensure mitigation measures are implemented; Prepare to increase the monitoring frequency to daily; Repeat measurement on the next day of exceedance.	Inform the Engineer and confirm notification of exceedance in writing; Rectify unacceptable practice; Check all plant and equipment; Consider changes of working methods; Propose mitigation measures to Engineer within 3 working days upon the notification and discuss with Environmental Team and the Engineer; Implement the agreed mitigation measures.	Discuss with Environmental Team and the Contractor on the proposed mitigation measures; Make agreement on the mitigation measures to be implemented; Assess the effectiveness of the implemented mitigation measures.
Target level being exceeded by one sampling day	Repeat in-situ measurement to confirm findings; Identify source(s) of impact; Inform Contractor and EPD; Check monitoring data, all plant, equipment and contractor's working methods; Discuss mitigation measures with the Engineer and Contractor; Ensure mitigation measures are implemented; Increase the monitoring frequency to daily until no exceedance of Target level.	Inform the Engineer and confirm notification of exceedance in writing; Rectify unacceptable practice; Check all plant and equipment; Consider changes of working methods; Propose mitigation measures to Engineer within 3 working days upon the notification and discuss with Environmental Team and the Engineer; Implement the agreed mitigation measures.	Discuss with Environmental Team and the Contractor on the proposed mitigation measures; Request Contractor to critically review the working methods; Make agreement on the mitigation measures to be implemented; Assess the effectiveness of the implemented mitigation measures;

Table 8.2 **Action/Event Plan for Water Quality (Cont'd)**

Exceedance	Environmental Team (Monitoring Staff + Environmental Auditor)	Contractor	Engineer
Target level being exceeded by more than two consecutive sampling days	Repeat in-situ measurement to confirm findings; Identify source(s) of impact; Inform Contractor and provide reports to EPD; Check monitoring data, all plant, equipment and contractor's working methods; Discuss mitigation measures with the Engineer and Contractor; Ensure mitigation measures are implemented; Increase the monitoring frequency to daily until no exceedance of Target level for two consecutive days.	Inform the Engineer and confirm notification of exceedance in writing; Rectify unacceptable practice; Check all plant and equipment; Review critically the working methods; Propose mitigation measures to Engineer within 3 working days upon the notification and discuss with Environmental Team and the Engineer; Implement the agreed mitigation measures; As directed by Engineer, to slow down or to STOP all or part of the marine work.	Discuss with Environmental Team and the Contractor on the proposed mitigation measures; Request Contractor to critically review the working methods; Make agreement on the mitigation measures to be implemented; Assess the effectiveness of the implemented mitigation measures; Consider and instruct, if necessary, the contractor to slow down or to STOP all or part of the marine work until no exceedance of Target level.

The general procedures to avoid pollution during dredging works include the requirement that the Contractor shall design his working methods and use equipment that shall minimise the risk of silt and other contaminants being released into the water column.

For the purposes of evaluating the water quality, all values shall be depth averaged. A monthly summary of all data will be prepared and will include at least the following:

- copy of all the monitoring results;
- highlighting whenever the trigger, action and target limits or WQO's are exceeded;
- implementation of the action plan whenever the trigger, action and target levels are exceeded;
- identification of reasons for non-compliance;
- identification of mitigation measures taken by the Contractor as a result of exceeding the trigger, action and/or target limits; and
- copy of all complaints received along with the responses and details of the action taken.

A copy of the summary data will be made available for inspection by the DEP at his request, and by the Contractor.

The Contractor shall provide a summary of any specific activities recently undertaken which may affect the water quality parameters, and any remedial measures deemed necessary as a result of non-compliance whenever target limits are exceeded. If, the Contractor has not taken appropriate and effective measures to reduce the water quality impacts, the Contractor may be required to take all measures necessary to improve the water quality. The trigger, action and target levels (TAT) will be endorsed by both the Engineer and EPD.

8.5 Monitoring of Spoil Disposal

The Contractor shall ensure that all marine mud, contaminated marine mud and unsuitable material is disposed of at the approved locations. He will be required to ensure accurate positioning of vessels before discharge and to submit and agree proposals with the Engineer for accurate positional control at disposal sites before commencing dredging. All disposal in designated marine dumping grounds shall be in accordance with the conditions of a licence issued by the DEP under the Dumping at Sea Ordinance (18 of 1995). Floating and contaminated materials (as defined by the DEP) will not be acceptable at marine dumping grounds and will require other methods of disposal as required by FMC.

The Engineer may monitor any vessel transporting material to ensure that loss of material does not take place during transportation. The Contractor shall provide all reasonable assistance to the Engineer for this purpose and shall design his methods of working to minimise pollution and shall provide experienced personnel with suitable training to ensure that these methods are implemented.

9. CONCLUSIONS

On the basis of the foregoing assessment, the following conclusions have been drawn:

(i) the water quality objectives for dissolved oxygen, ammonia, and nutrients can be achieved regardless of the dredging scenario considered;

(ii) the water quality objectives for suspended solids will be exceeded unless mitigation measures are applied as shown below:

	Contaminated Deposit	**Uncontaminated Deposit**
Total Volume	**1.8Mm^3**	**1.2Mm^3**
Mitigation Measures Proposed		
(a) Grab dredger	• closed grabs must be used for contaminated spoil • control production rate of 12,800m^3/day • low impact dredging can reduce sediment losses by 50% compared to unmitigated scenario • closed grabs further reduce sediment losses • ensuring proper closing and hoisting of grab will further reduce impacts • controlling dredging rates • sediment release rates no greater than 1.2kg/s	• control production rate of 12,800m^3/day • low impact dredging can reduce sediment losses by 50% compared to unmitigated scenario • closed grabs further reduce sediment losses • ensuring proper closing and hoisting of grab will further reduce impacts • controlling dredging rates • sediment release rates no greater than 1.2kg/s
(b) Trailing Suction Dredger	N/A	• controlling dredging rates to <20,000m^3/day • controlling sediment losses to 1% of dredging rate • use of trailing suction dredgers only during dry season • use of trailing suction dredgers only on slack or flooding tide • sediment release rates no greater than 1.2kg/s
Disposal Location	East Sha Chau Contaminated Mud Pits	East Ninepins or South Cheung Chau
Residual Impact	No residual impact outwith anchorage area	No residual impact outwith anchorage area

(iii) heavy metal and other organic pollutant releases from the solid to aqueous phase will be less than 0.1% of the source material in the sediment and will comply with all the Guidelines proposed for the protection of marine life as shown below:

Parameter	Guidelines for Protection of Marine Life	Average Concentration of Pollutant Released to Water Column During Dredging
pH	> 6.5 < 8.5	7.6 - 8.0
Cd	marine life : 0.005 mg/l (USEPA)	0.3 μg/l
Pb	marine life : 0.050 mg/l (USEPA)	1.5 μg/l
Hg	marine life: 0.10 μg/l (USEPA)	< 1 μg/l
Cr	marine life : 0.100mg/l (USEPA)	3.8 μg/l
Cu	marine life : 0.050mg/l (USEPA)	0.7 μg/l
Ni	marine life : 0.100mg/l (USEPA)	11.7 μg/l
Zn	marine life : 0.100 mg/l (USEPA)	<0.05 mg/l
Amm-N	marine life : 0.400 mg/l (unionised as NH_3) (USEPA)	5.45 mgN/l
DDT	marine life : 0.001ppm as 24 hour average with no exceedance of 0.13ppm (USEPA)	1 μg/l
Tributyl Tin	marine life : adverse impacts on gastropods and molluscs but levels for protection of marine life not included in the specification obtained.	10 μg/l
PCB's	marine life : <0.001ug/l (USEPA)	1 μg/l

(iv) no other sensitive receivers (seawater intakes) will be adversely affected either during or following construction;

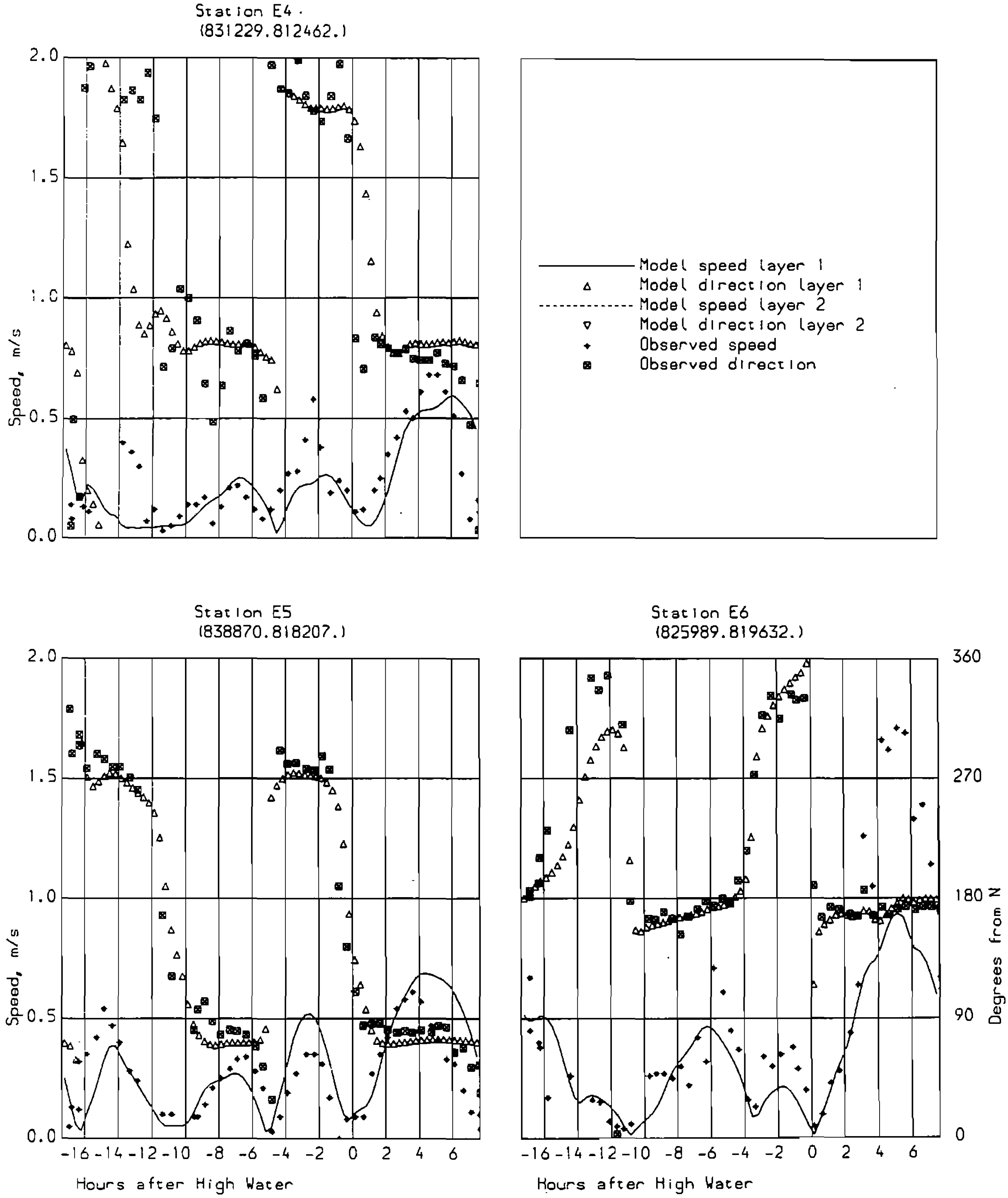
(v) an estimated 1.8Mm^3 of material to be dredged is contaminated, and will be disposed of at the East Sha Chau Contaminated Mud Pits. This material will be need to be dredged using a closed end grab dredger in accordance with the requirements of the Fill Management Committee and the Environmental Protection Department;

(vi) an estimated 1.2Mm^3 of material has been defined, through the sediment quality study, as being uncontaminated and will be disposed of at either East Ninepins of South Cheung Chau according to the requirements of the Fill Management Committee and the Environmental Protection Department; and

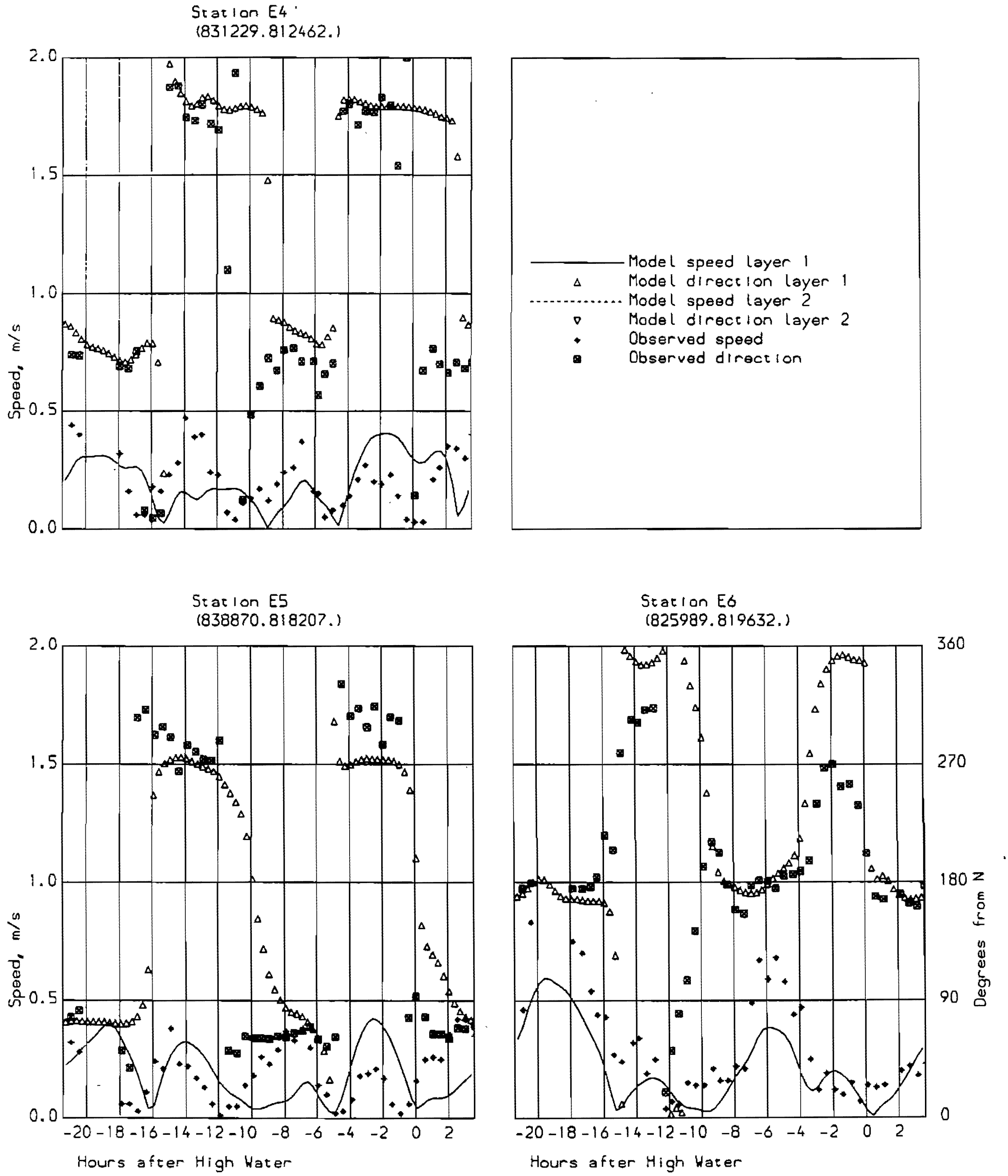
(viii) siltation rates to the west and east of the anchorage area are forecast to be 2cm and 4cm/year respectively. This means that maintenance dredging will on average be required every ten, or so, years to maintain the required clearance.

APPENDIX E

Tidal Flow Model Calibration



Stonecutters Naval Base Anchorage Area
Flow Model Calibration
Comparison with Original Field Data
Wet Season Spring Tide - Upper Layer



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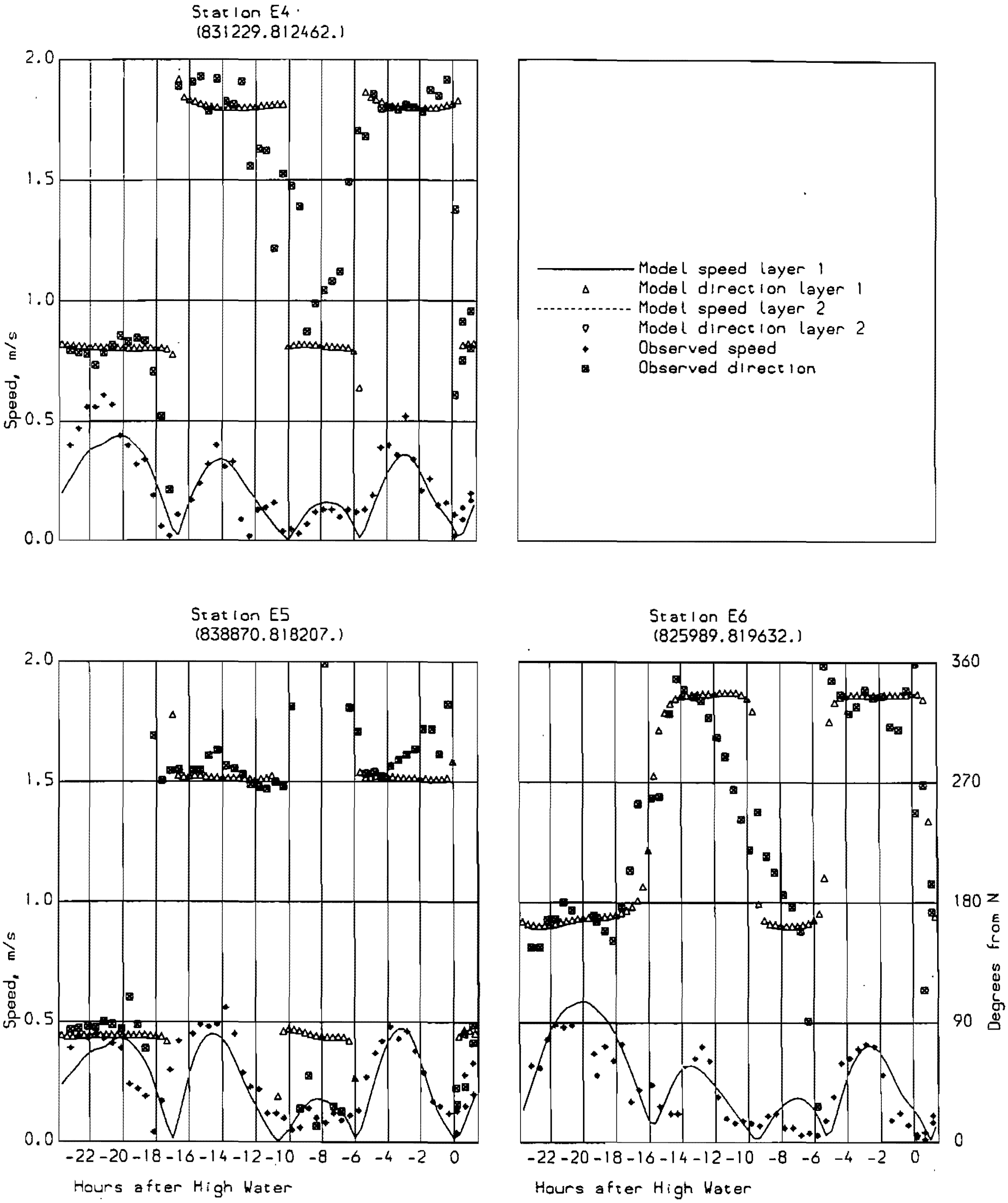
Flow Model Calibration
Comparison with Original Field Data
Wet Season Neap Tide - Upper Layer



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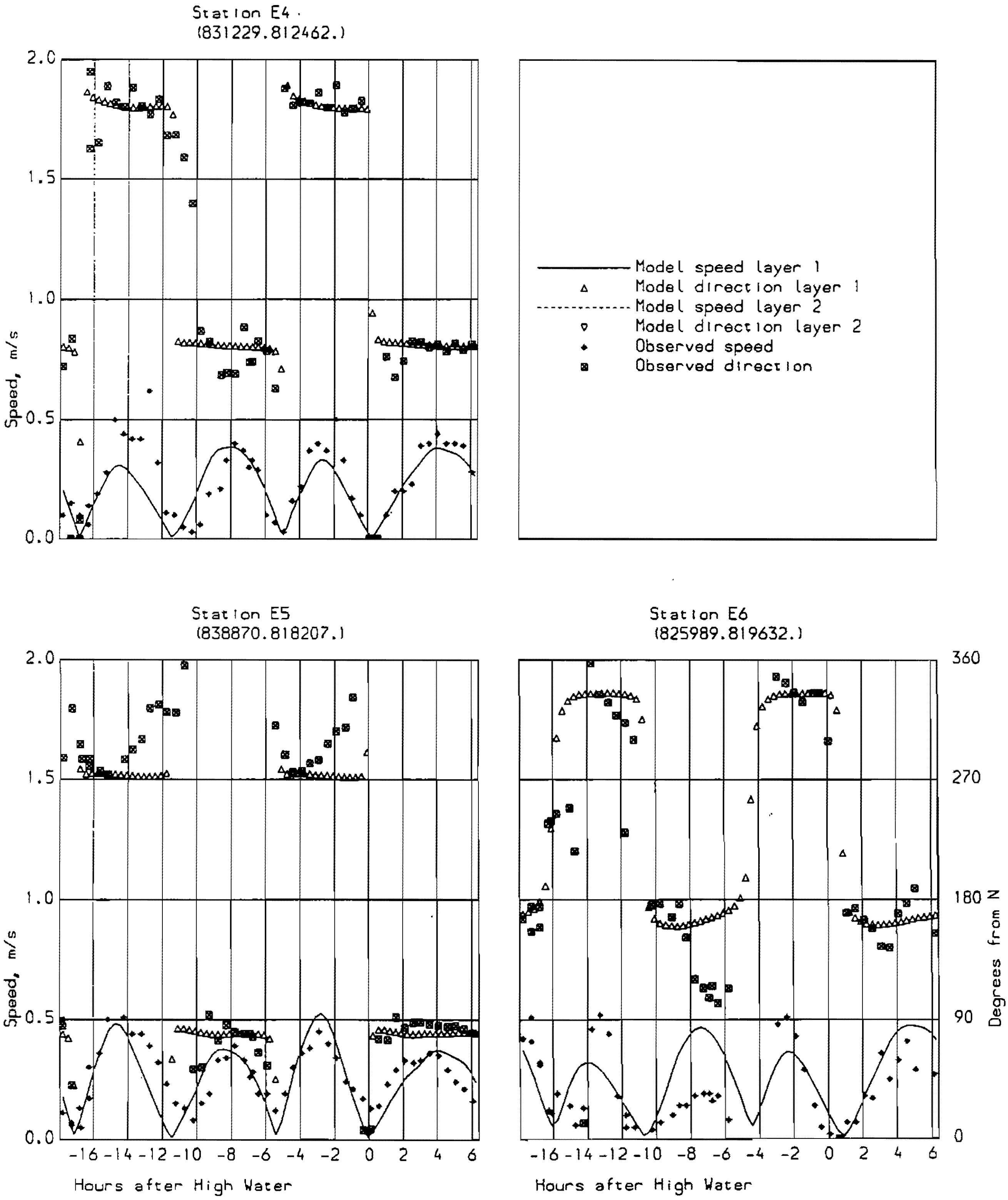
Flow Model Calibration
Comparison with Original Field Data
Dry Season Spring Tide - Upper Layer



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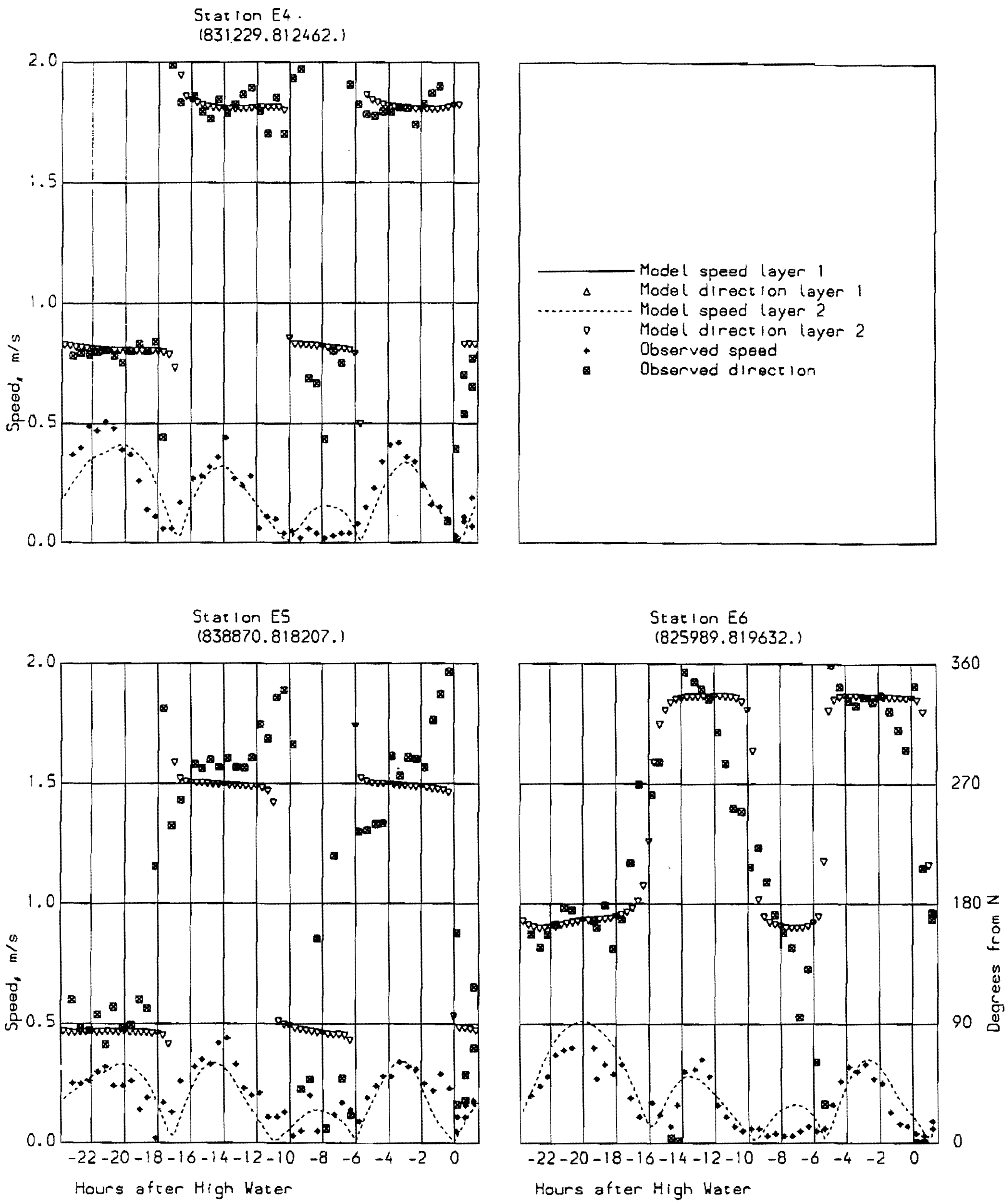
Flow Model Calibration
Comparison with Original Field Data
Dry Season Neap Tide - Upper Layer



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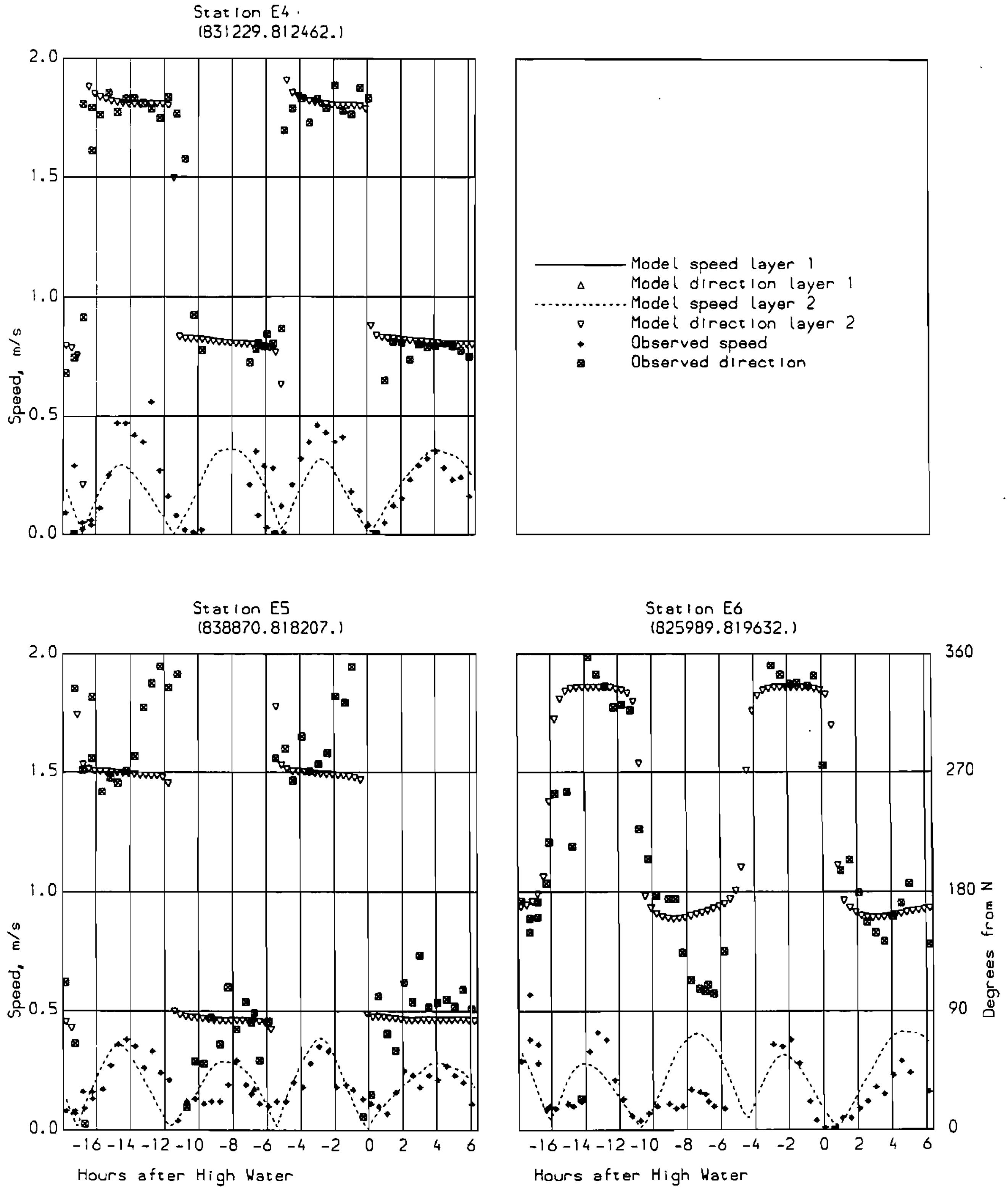
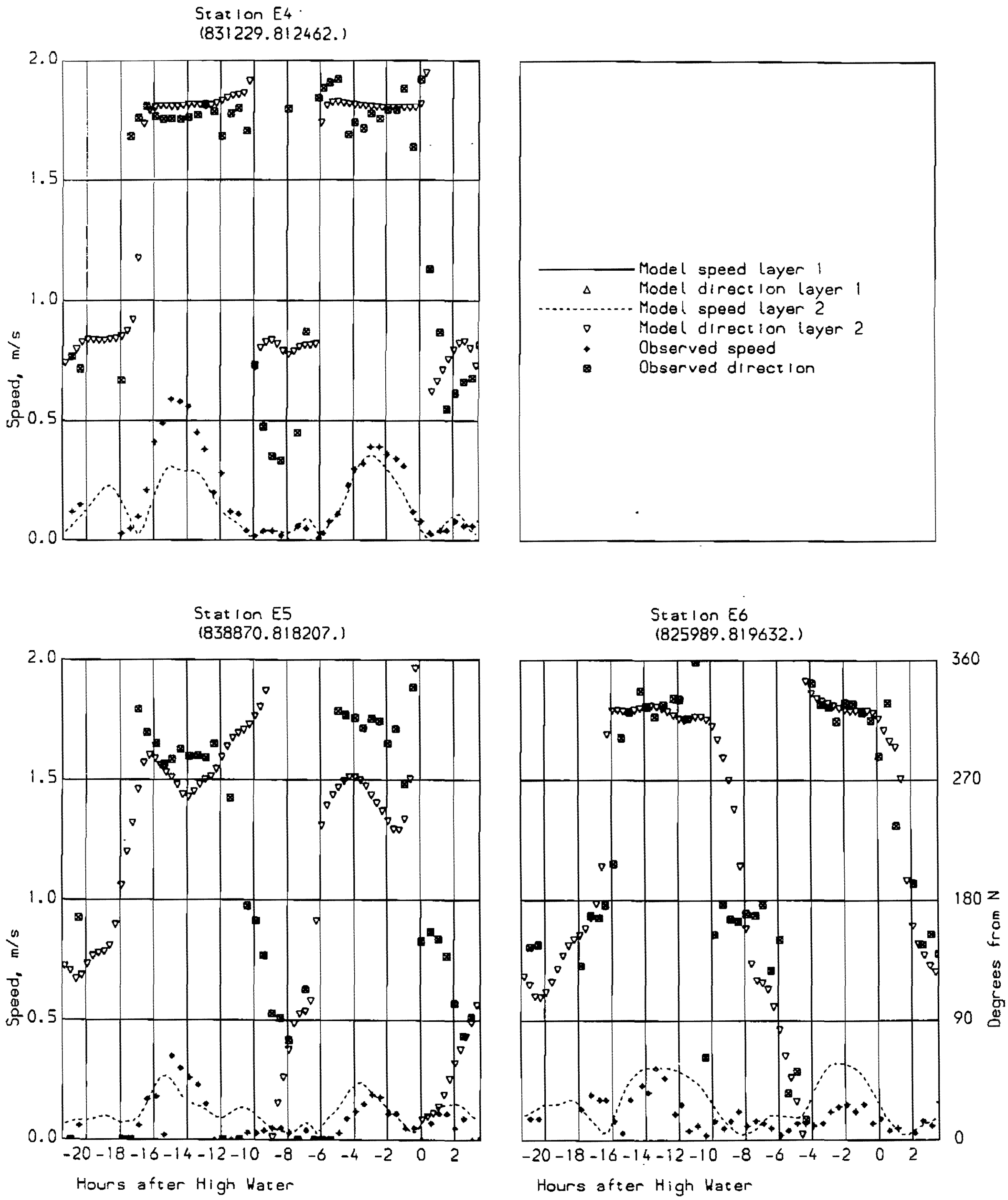
Flow Model Calibration
Comparison with Original Field Data
Dry Season Spring Tide - Lower Layer



Stonecutters Naval Base Anchorage Area
Flow Model Calibration
Comparison with Original Field Data
Dry Season Neap Tide - Lower Layer



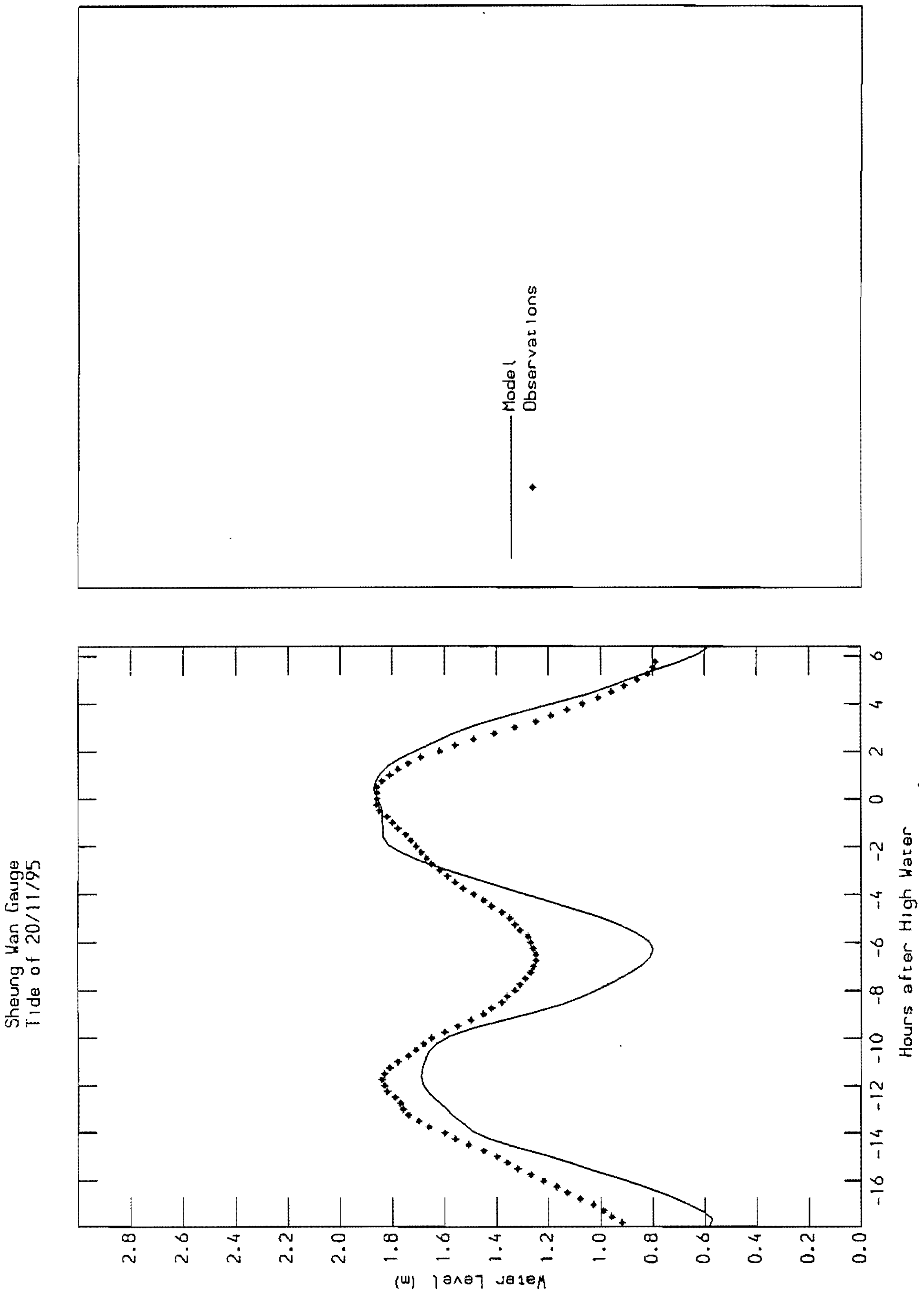
Stonecutters Naval Base Anchorage Area
Flow Model Calibration
Comparison with Original Field Data
Wet Season Neap Tide - Lower Layer

APPENDIX F

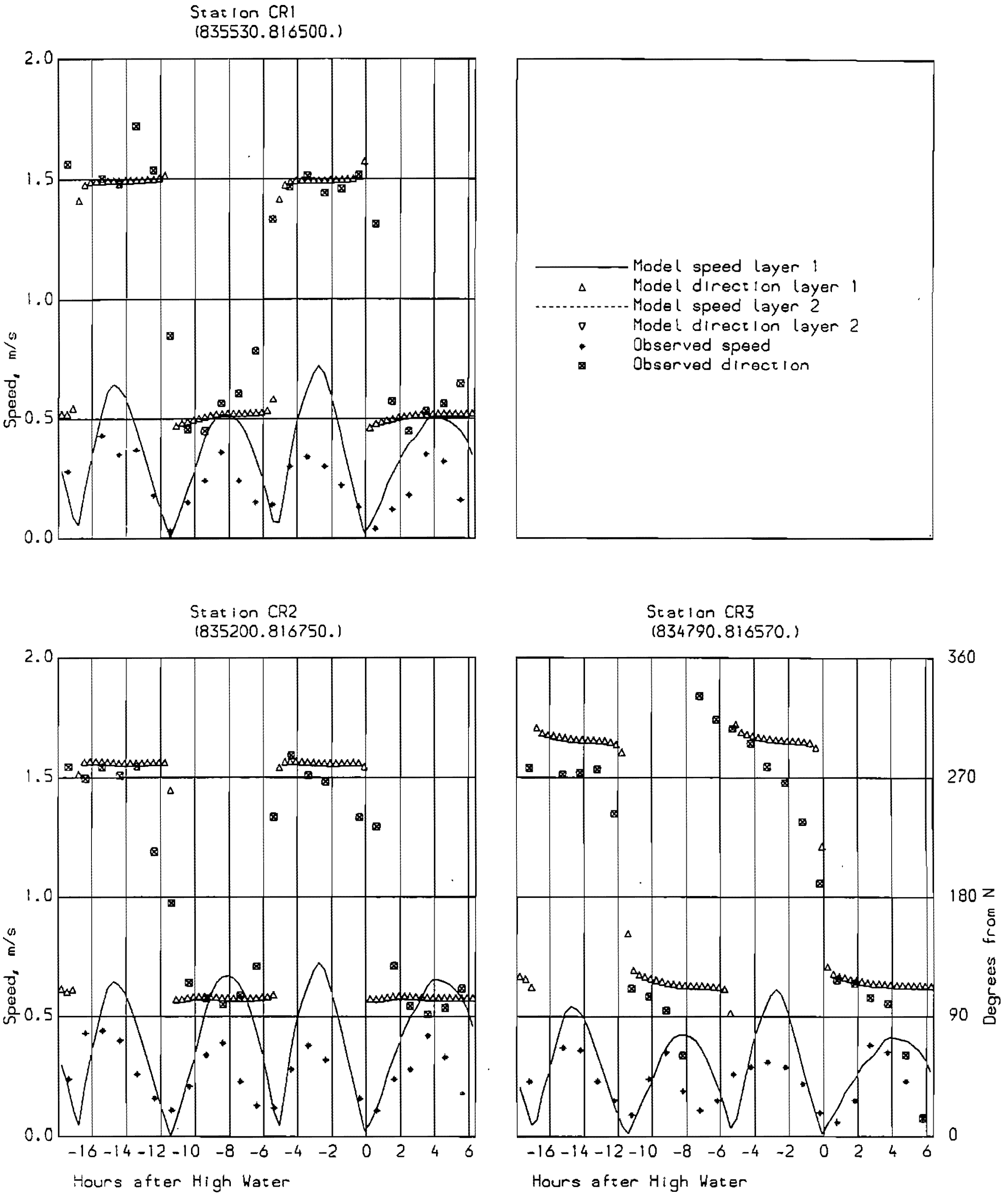
Tidal Flow Model Validation

TIDE OF 20/11/95

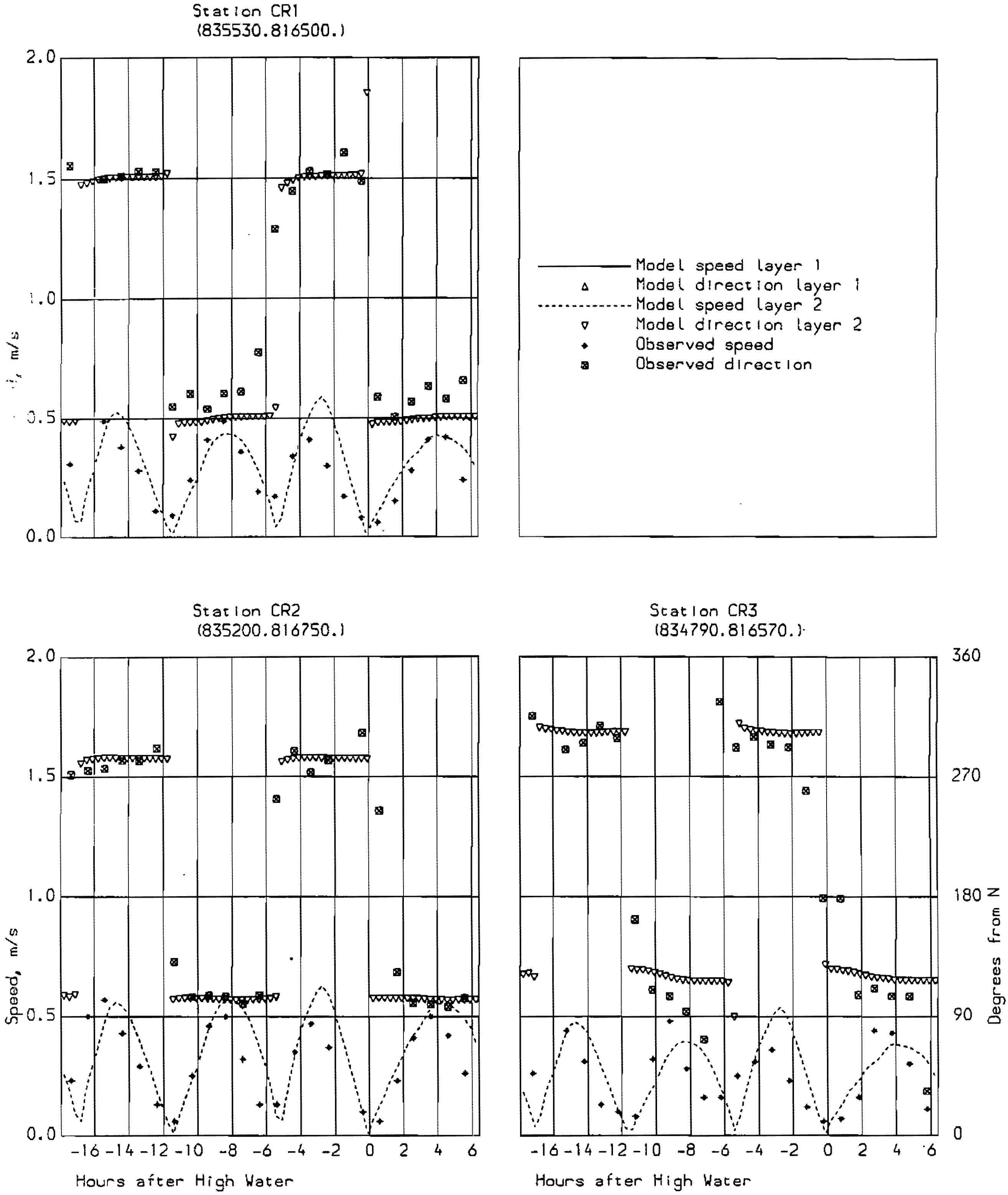
Fick



Stonecutters Naval Base Anchorage Area
Flow Model Validation
Tidal Elevations
Dry Season Neap Tide

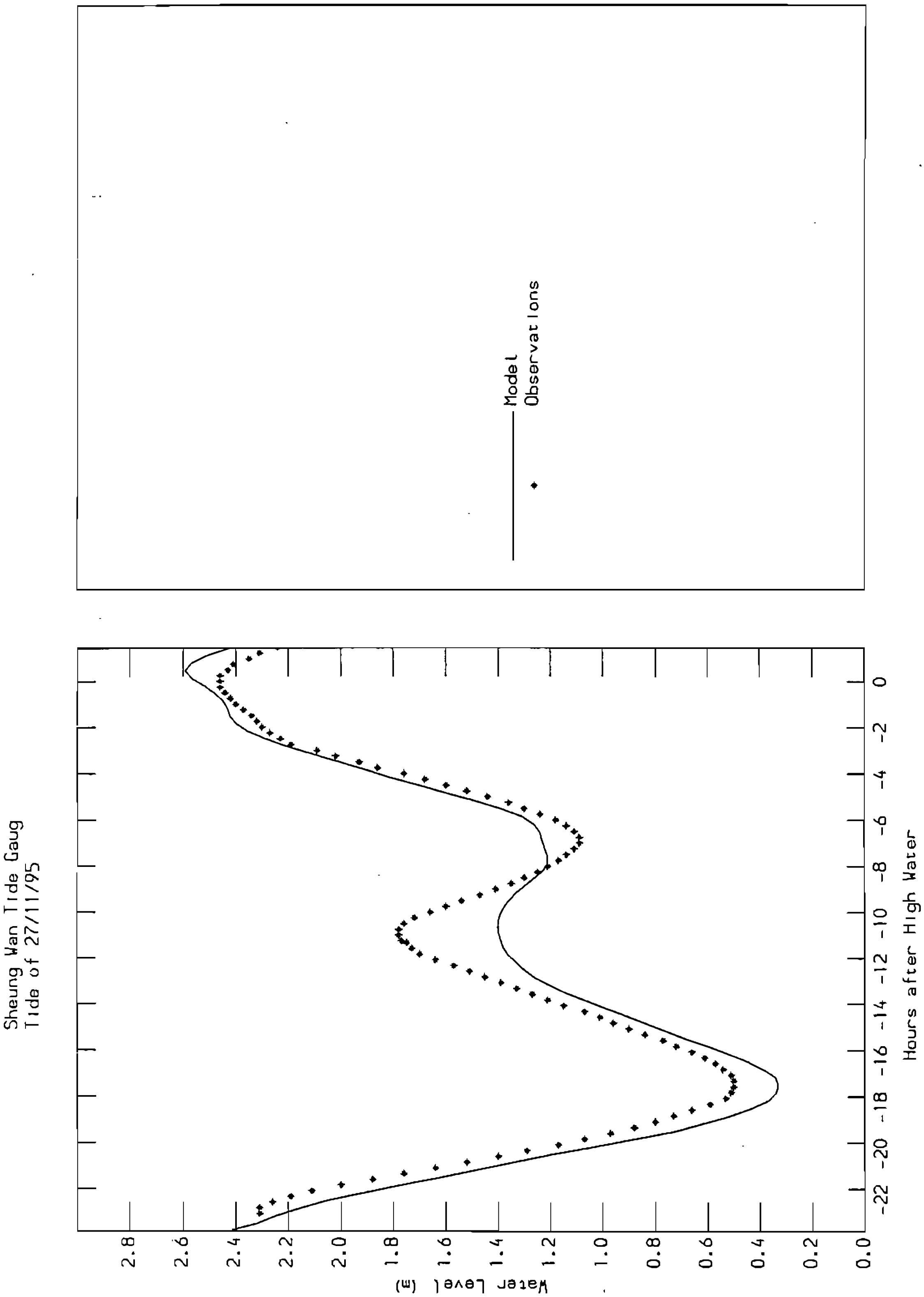


Stonecutters Naval Base Anchorage Area
Flow Model Validation
Current Speed & Direction
Dry Season Neap Tide - Upper Layer

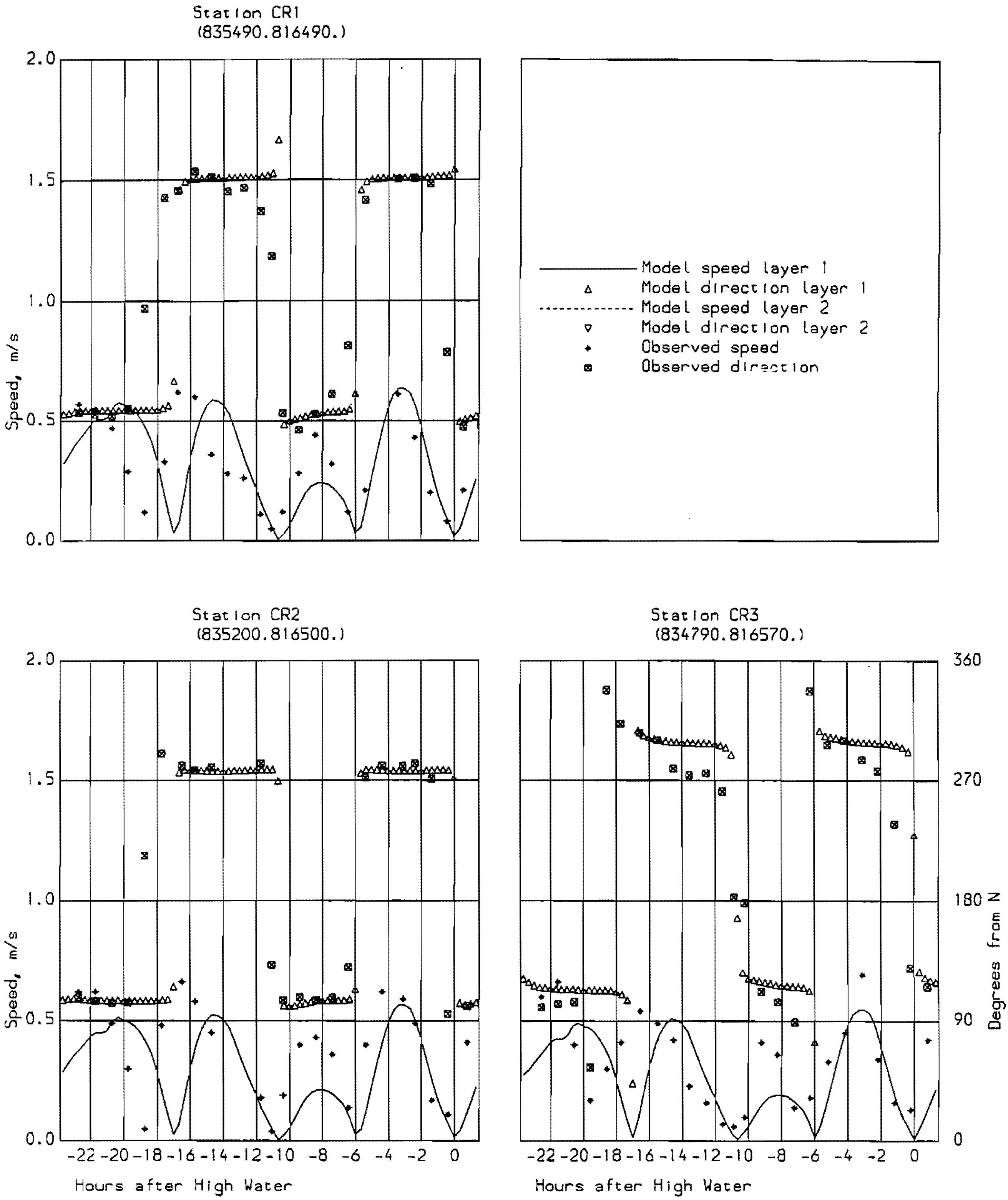


Stonecutters Naval Base Anchorage Area
Flow Model Validation
Current Speed & Direction
Dry Season Neap Tide - Lower Layer

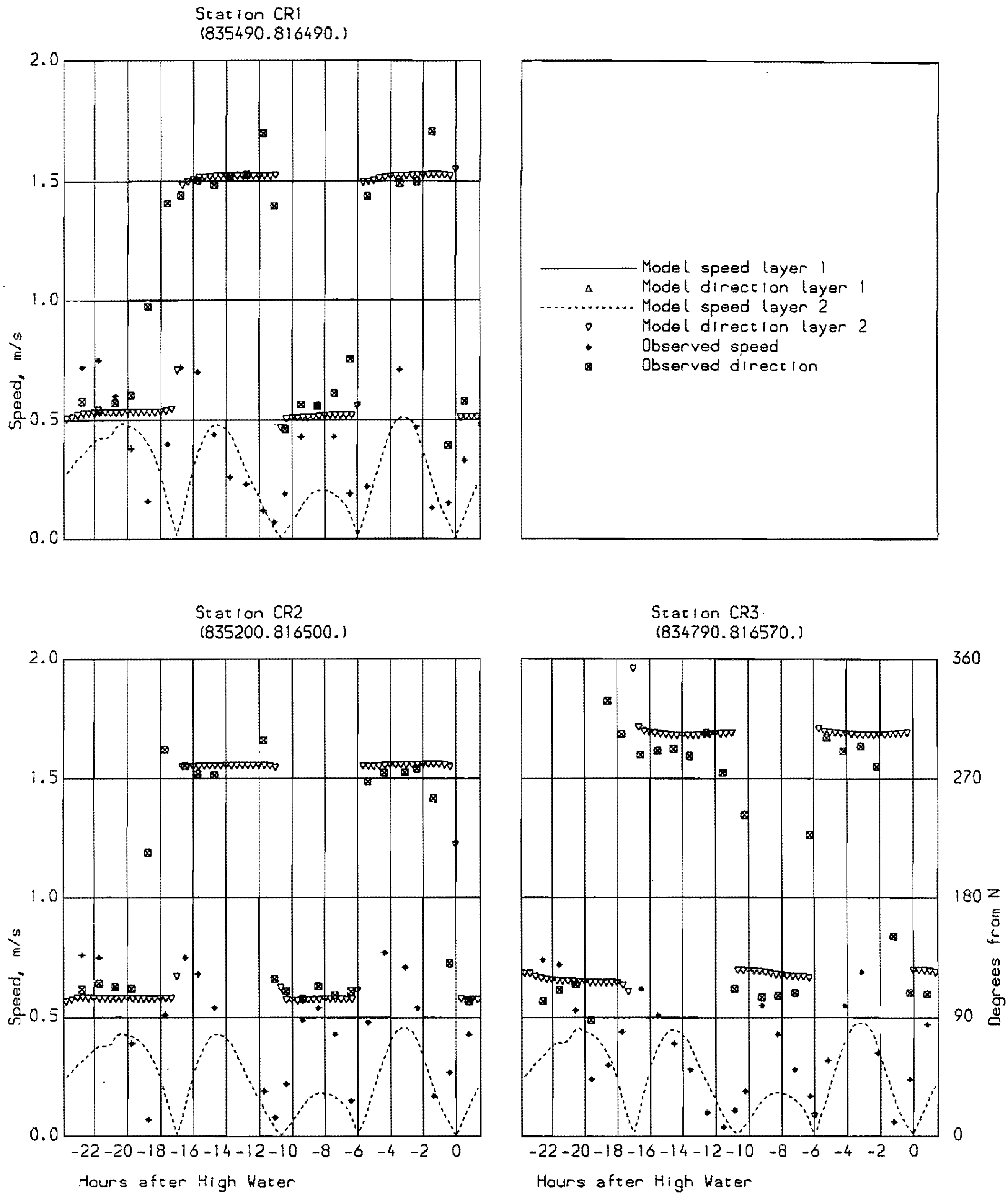
TIDE OF 27/11/95



Stonecutters Naval Base Anchorage Area
Flow Model Validation
Tidal Elevations
Dry Season Spring Tide

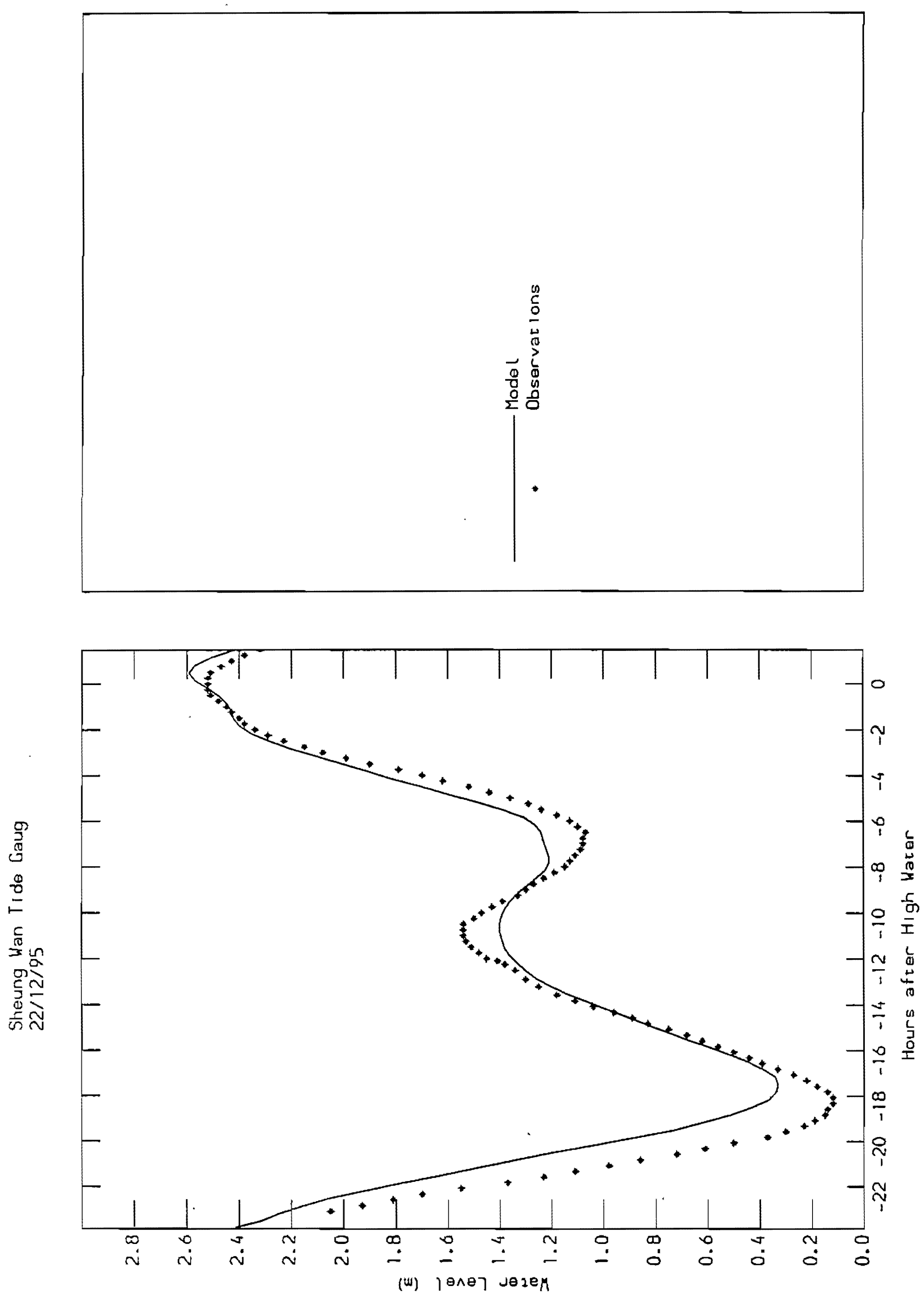


Stonecutters Naval Base Anchorage Area
Flow Model Validation
Current Speed & Direction
Dry Season Spring Tide - Upper Layer

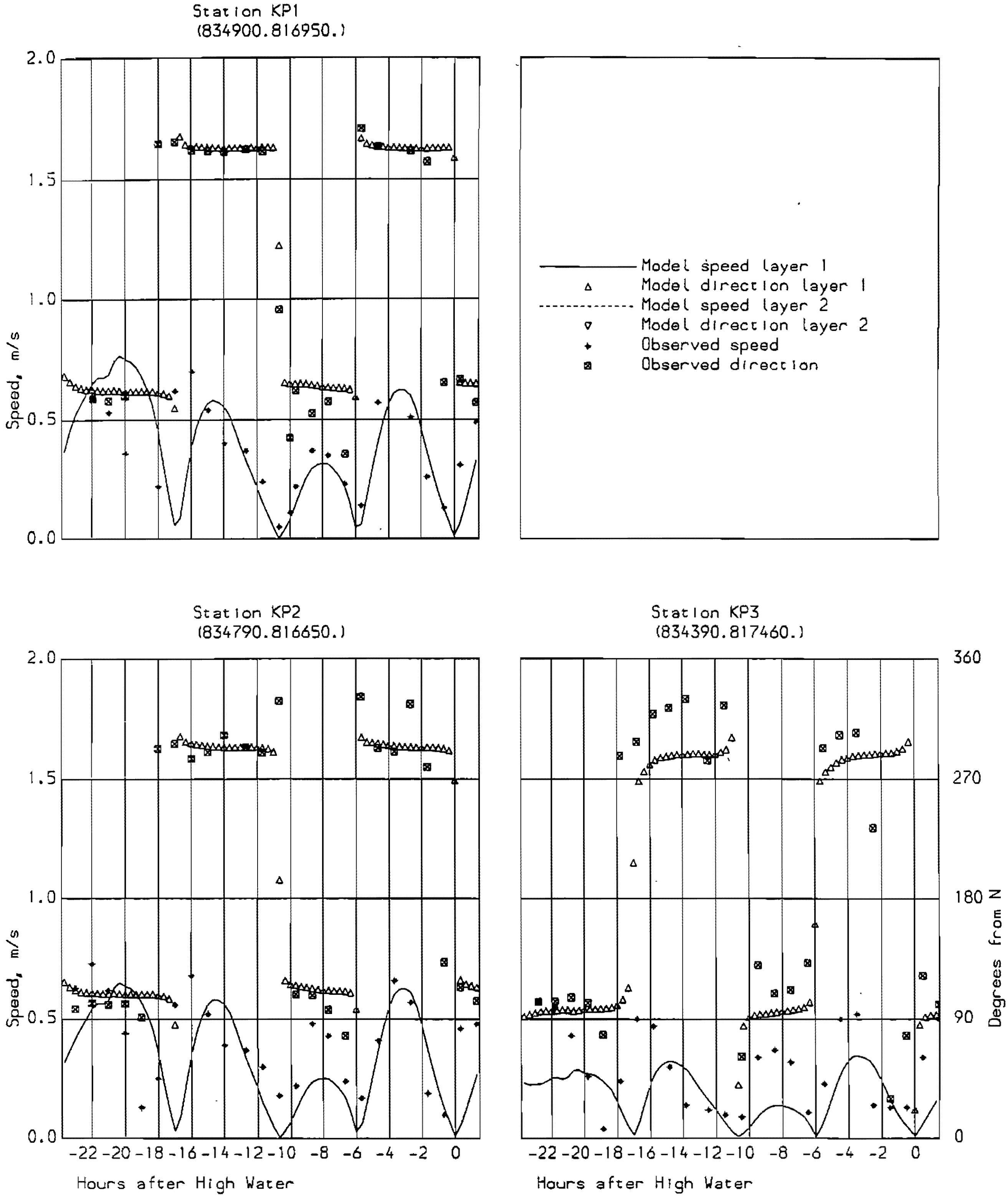


Stonecutters Naval Base Anchorage Area
Flow Model Validation
Current Speed & Direction
Dry Season Spring Tide - Lower Layer

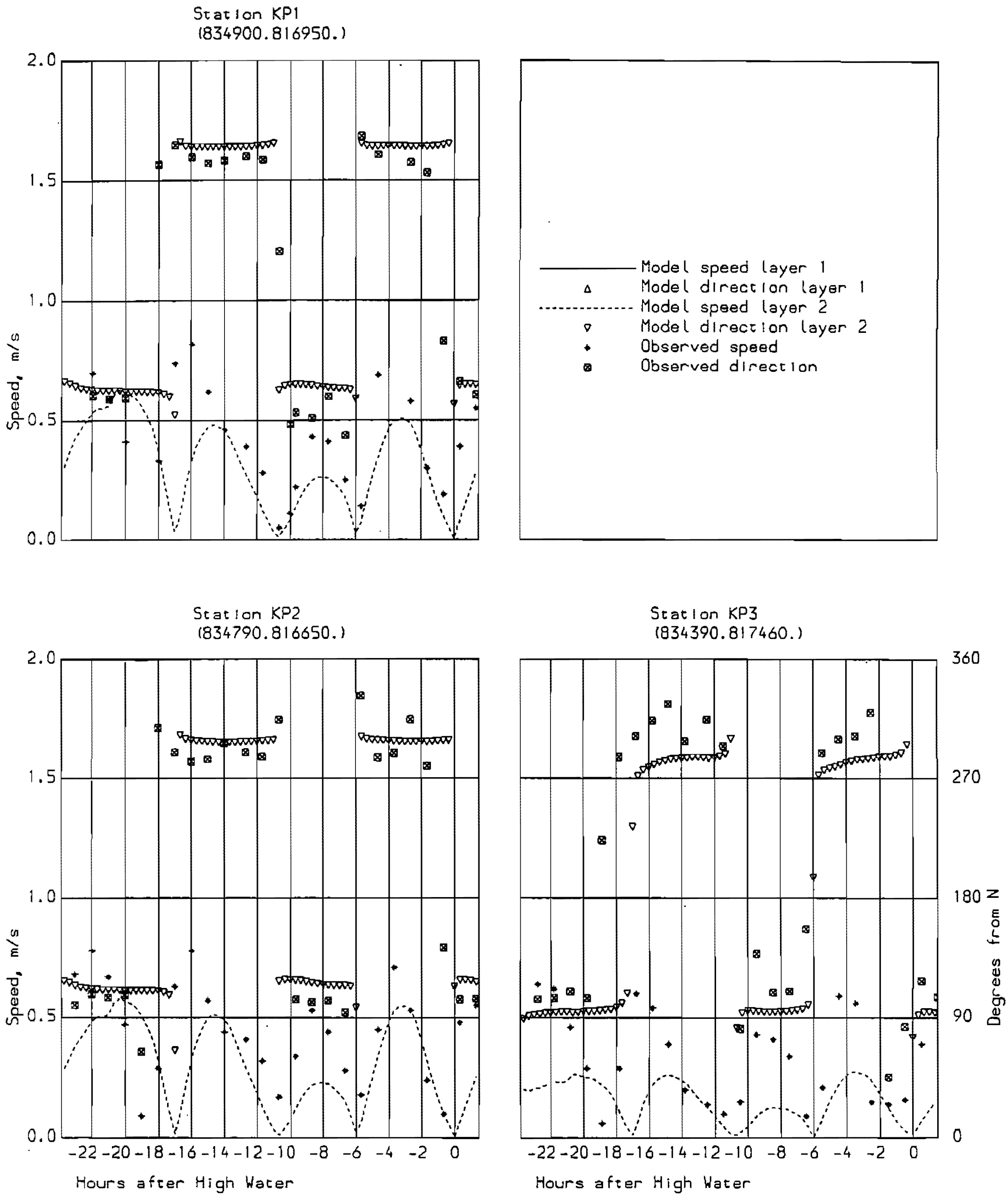
TIDE OF 22/12/95



Stonecutters Naval Base Anchorage Area
Flow Model Validation
Tidal Elevations
Dry Season Spring Tide



Stonecutters Naval Base Anchorage Area
Flow Model Validation
Current Speed & Direction
Dry Season Spring Tide - Upper Layer



Stonecutters Naval Base Anchorage Area
Flow Model Validation
Current Speed & Direction
Dry Season Spring Tide - Lower Layer

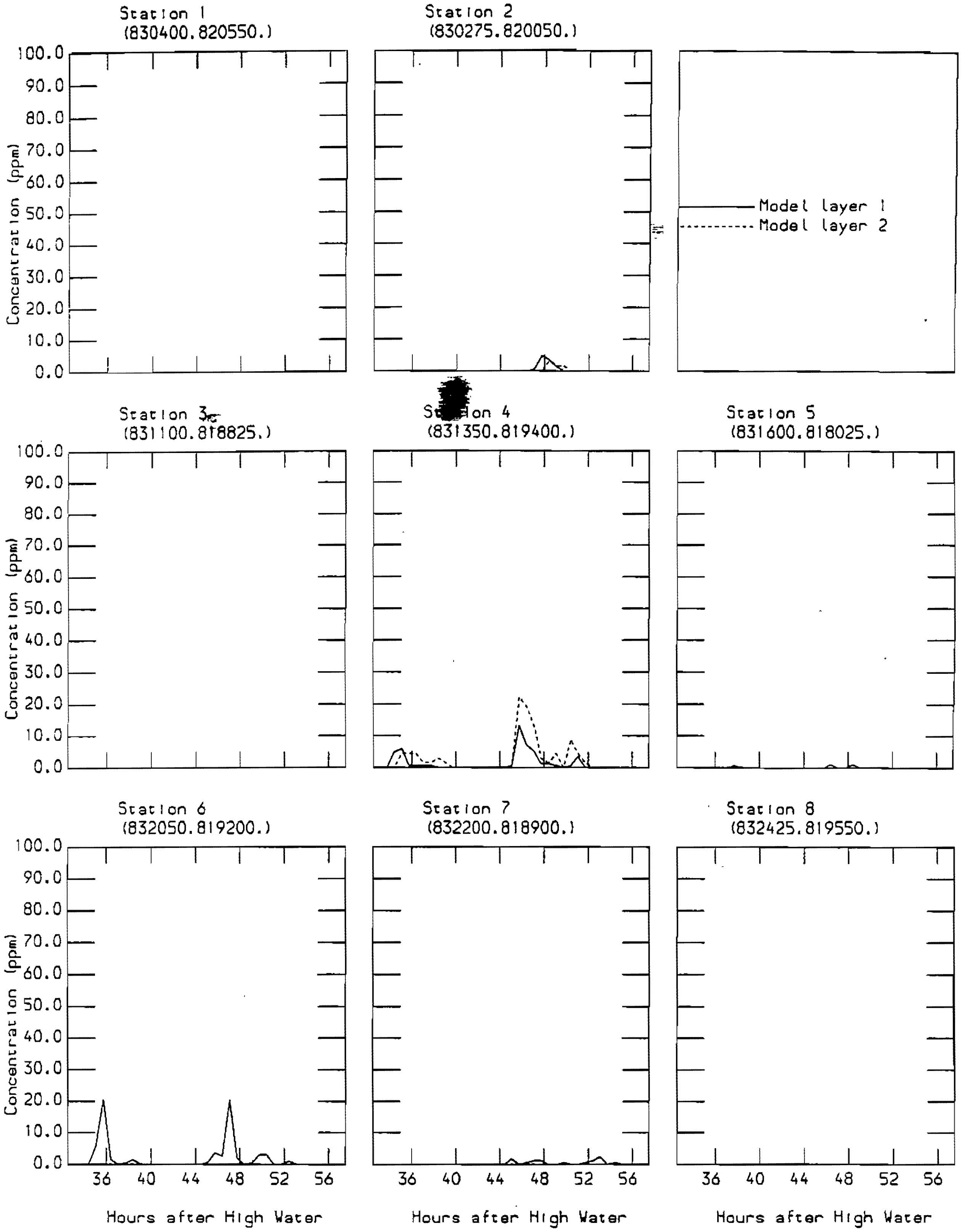
Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment Concentrations
Dry Season Spring Tide

Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Mud Deposits for 1 Tide
Dry Season Spring Tide

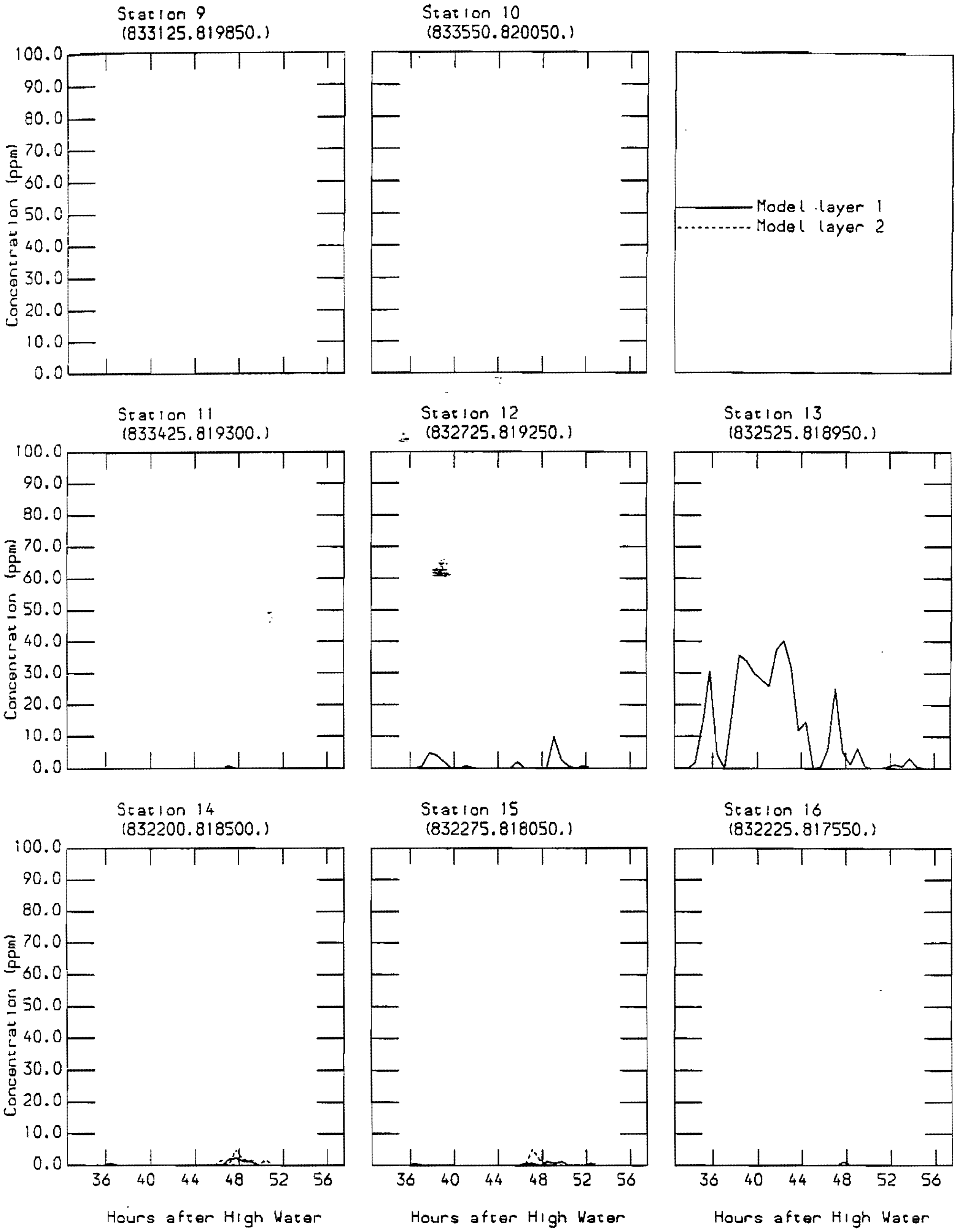
Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Daily Dissolved Oxygen Levels
Dry Season Spring Tide

Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Daily Dissolved Oxygen Levels
Dry Season Spring Tide

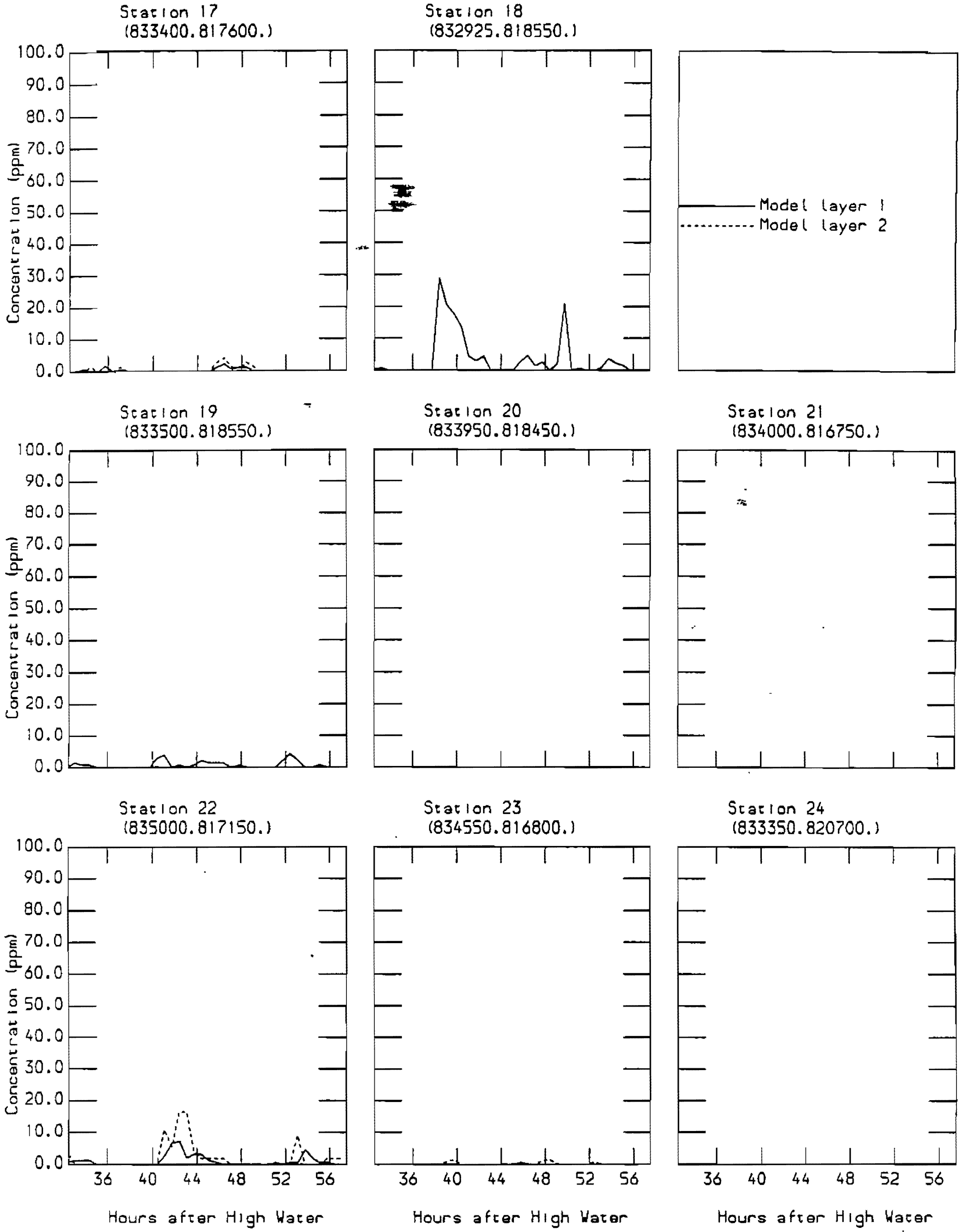
DRY SEASON NEAP TIDE



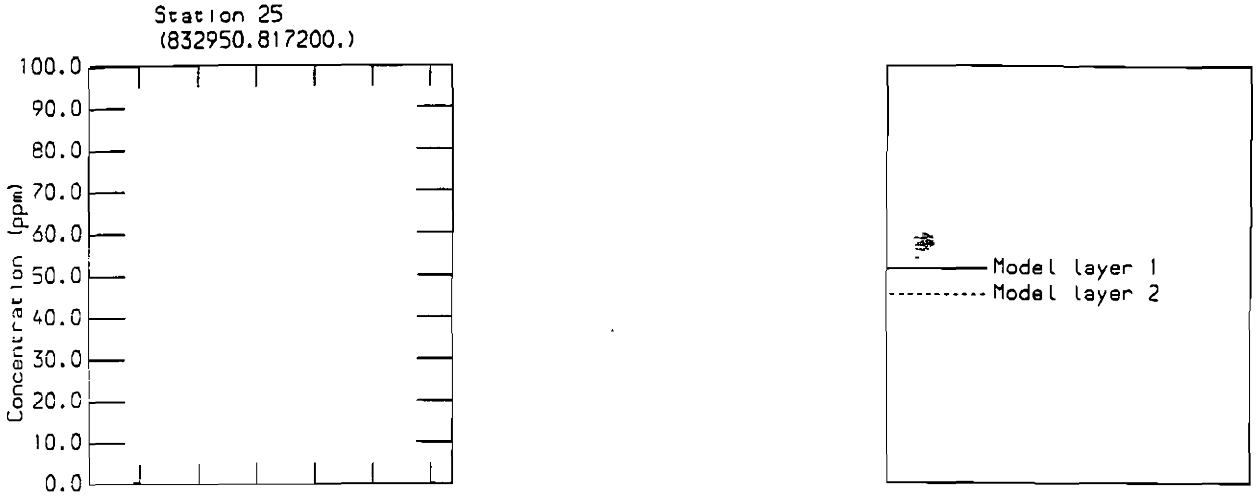
Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment at Monitoring Station
Dry Season Neap Tide



Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment at Monitoring Station
Dry Season Neap Tide



Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment at Monitoring Station
Dry Season Neap Tide



Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment at Monitoring Station
Dry Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment Concentrations
Dry Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment Concentrations
Dry Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment Concentrations
Dry Season Neap Tide

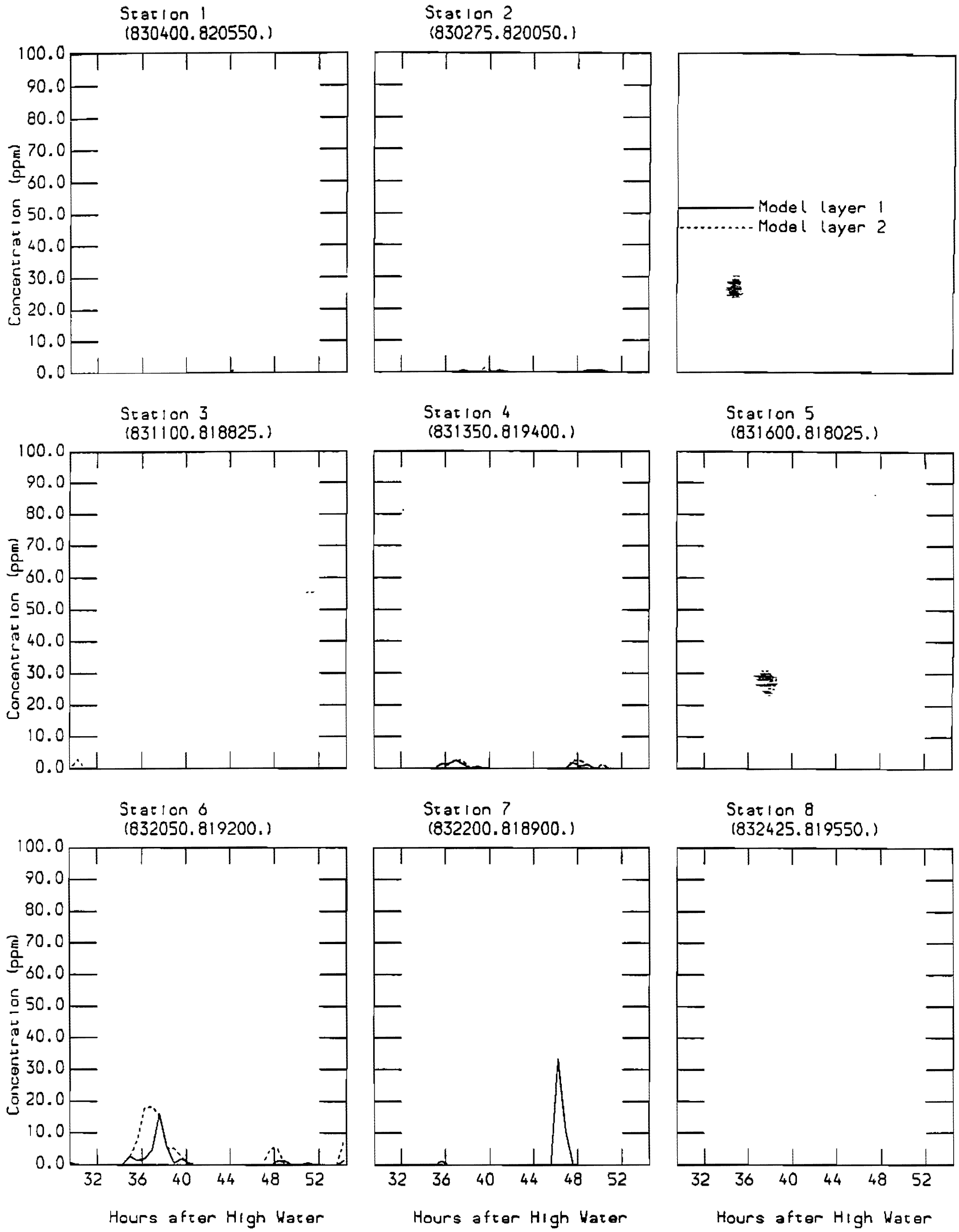
Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment Concentrations
Dry Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Mud Deposits for 1 Tide
Dry Season Neap Tide

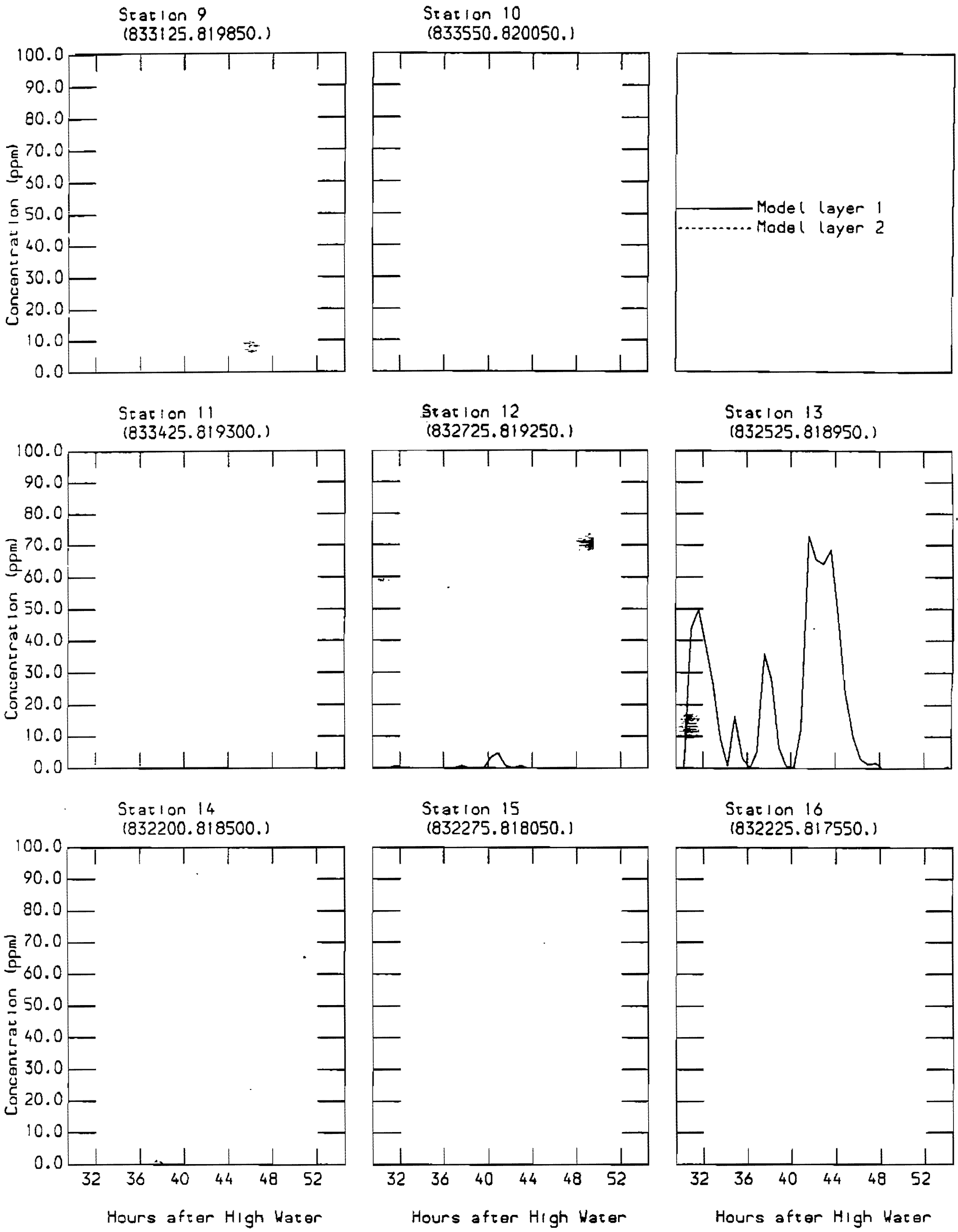
Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Daily Dissolved Oxygen Levels
Dry Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Daily Dissolved Oxygen Levels
Dry Season Neap Tide

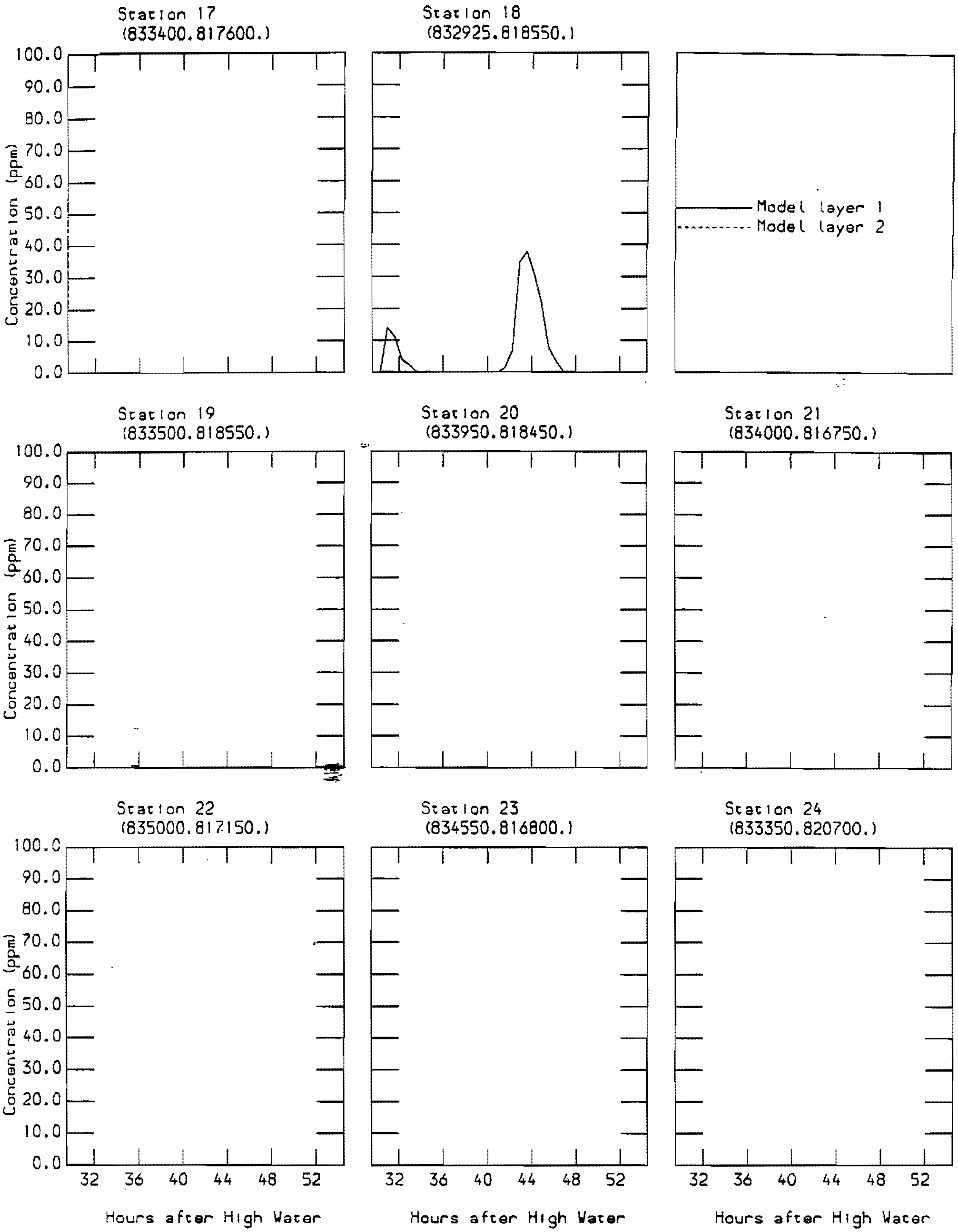
WET SEASON NEAP TIDE



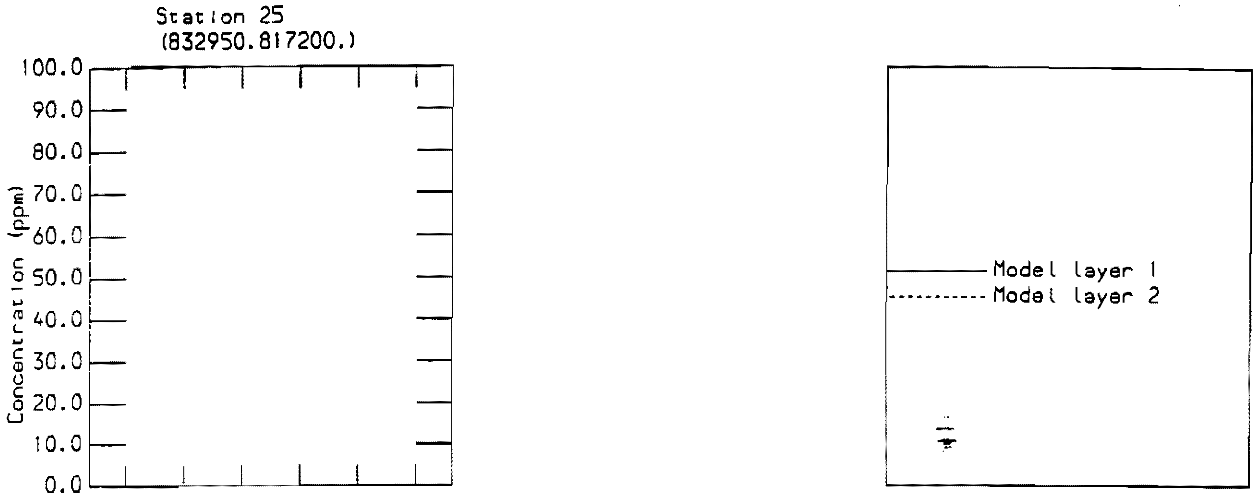
Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment at Monitoring Station
Wet Season Neap Tide



Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment at Monitoring Station
Wet Season Neap Tide



Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment at Monitoring Station
Wet Season Neap Tide



Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment at Monitoring Station
Wet Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment Concentrations
Wet Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment Concentrations
Wet Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment Concentrations
Wet Season Neap Tide

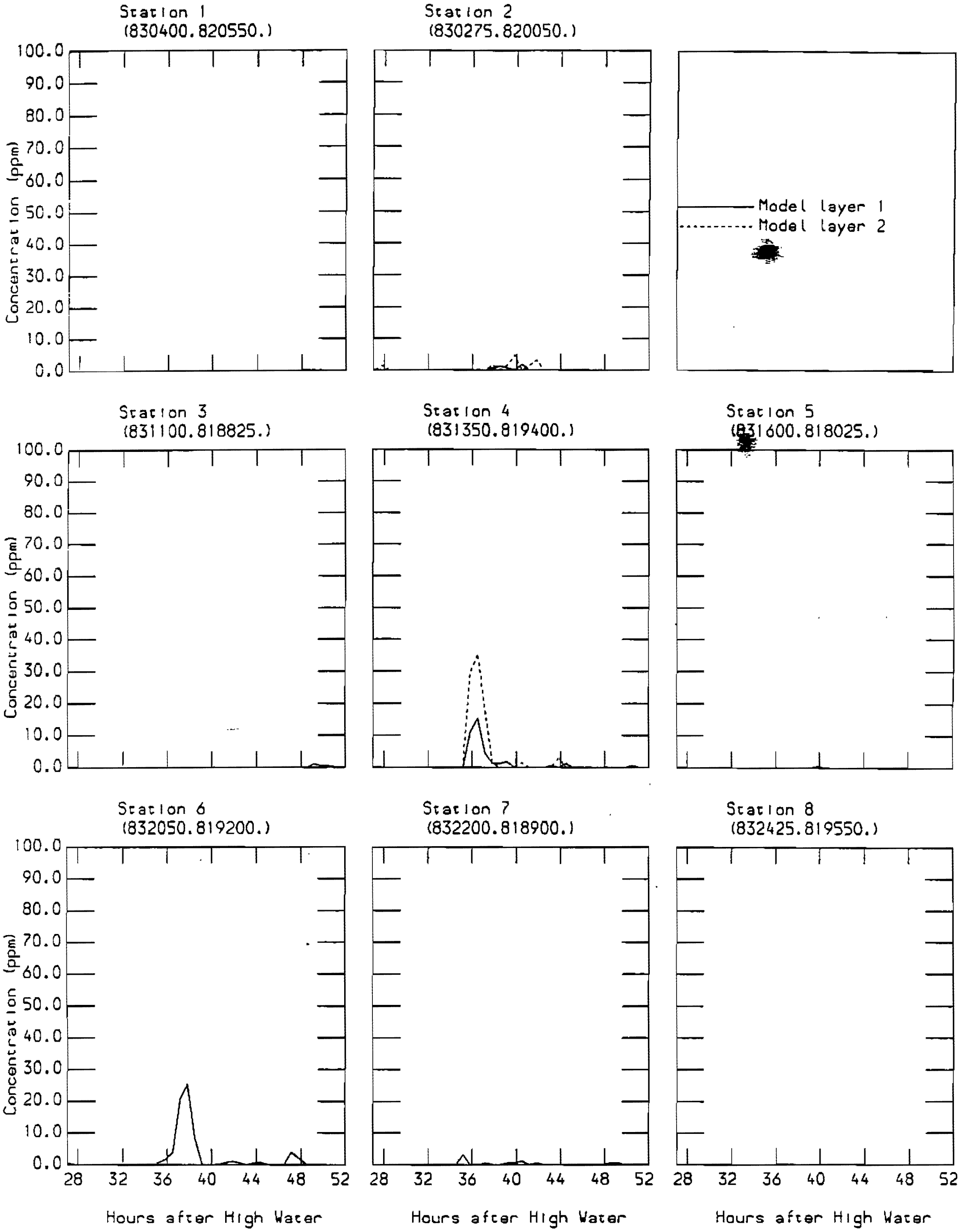
Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment Concentrations
Wet Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Mud Deposits for 1 Tide
Wet Season Neap Tide

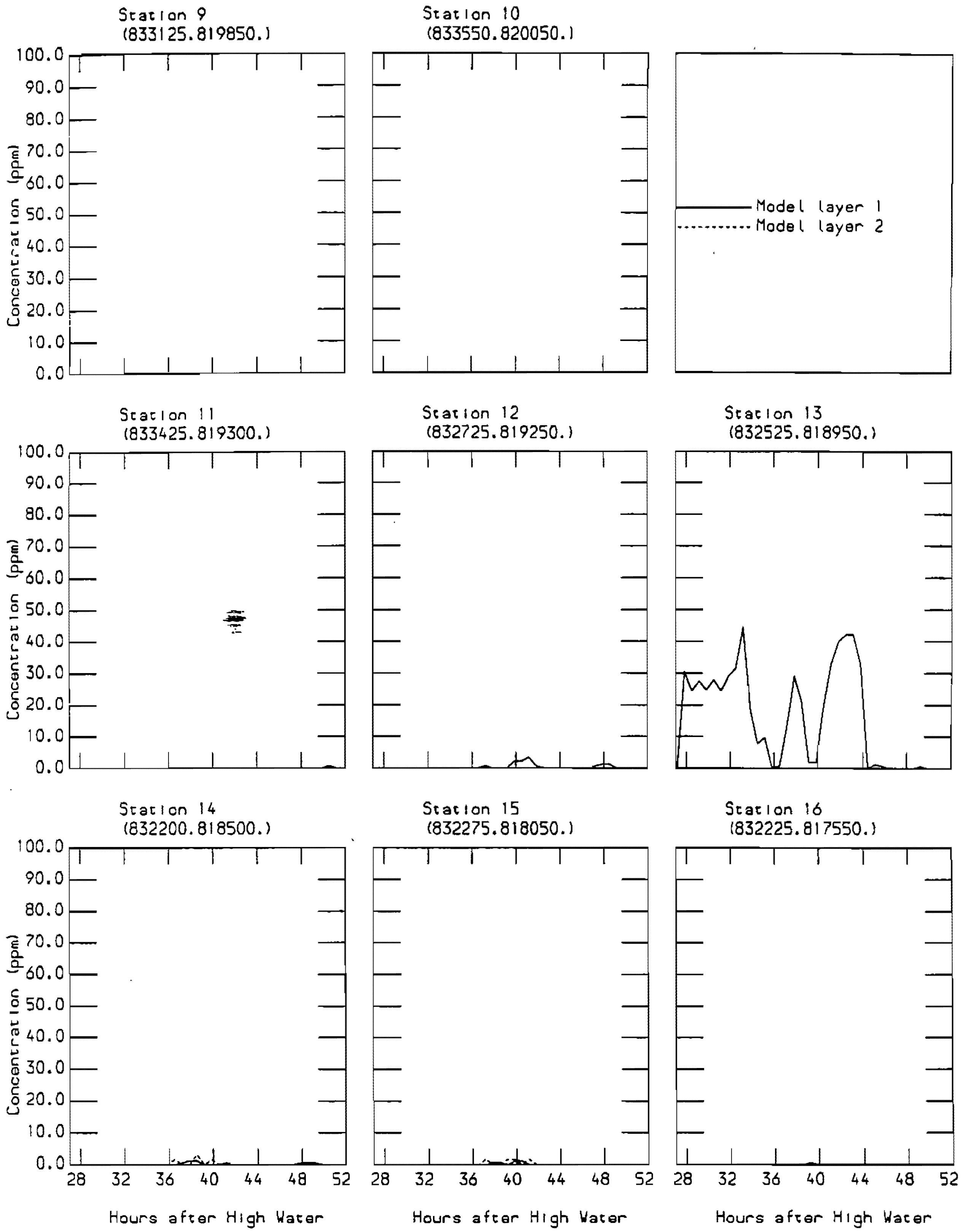
Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Daily Dissolved Oxygen Levels
Wet Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Daily Dissolved Oxygen Levels
Wet Season Neap Tide

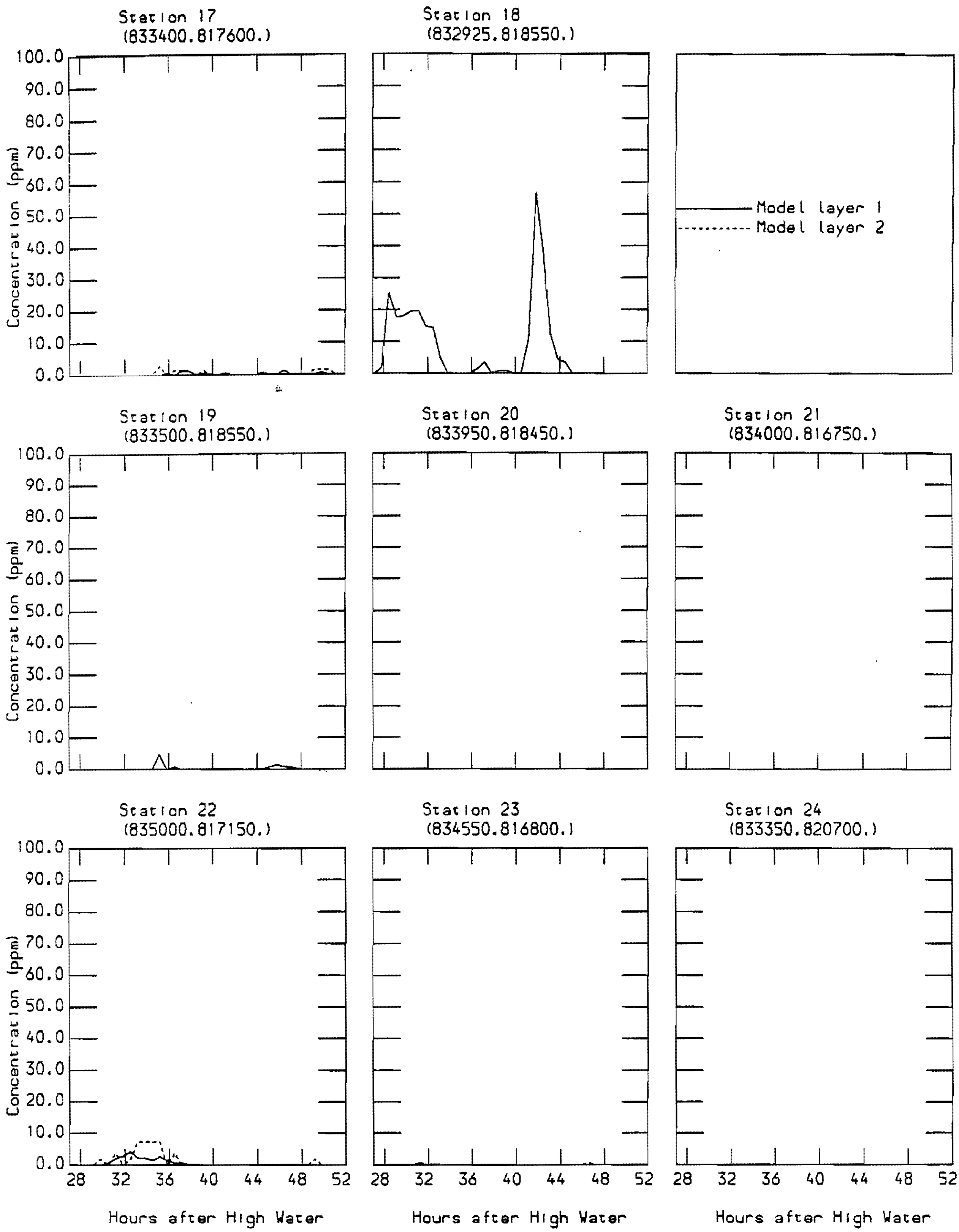
DRY SEASON SPRING TIDE



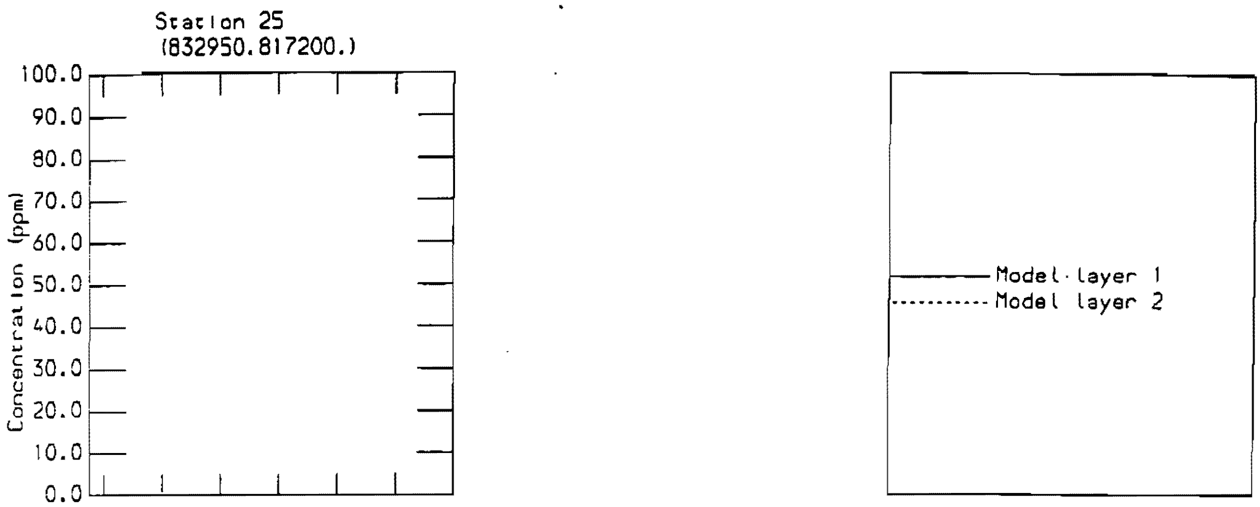
Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment at Monitoring Station
Dry Season Spring Tide



Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment at Monitoring Station
Dry Season Spring Tide



Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment at Monitoring Station
Dry Season Spring Tide



Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment at Monitoring Station
Dry Season Spring Tide

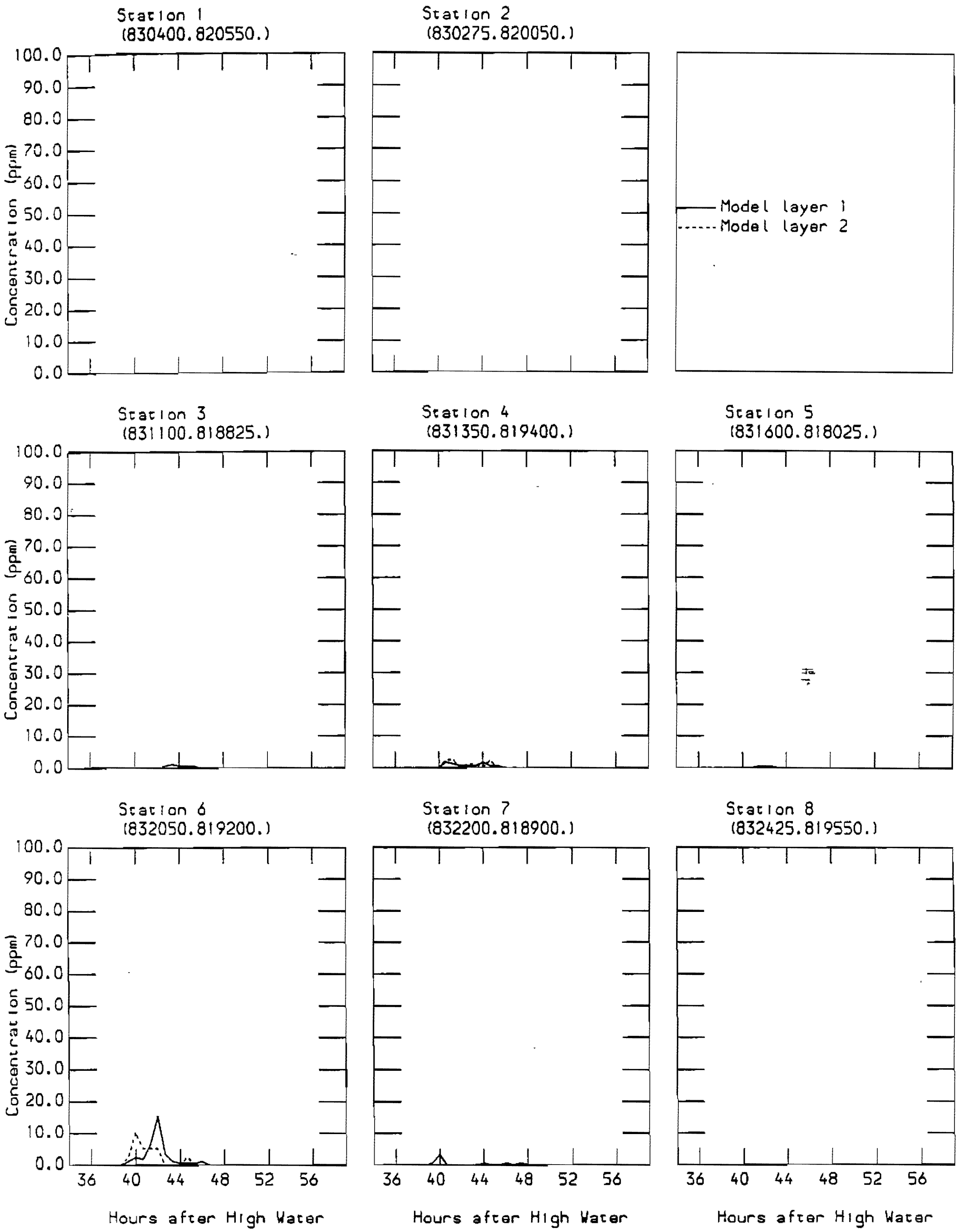
Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment Concentrations
Dry Season Spring Tide

Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment Concentrations
Dry Season Spring Tide

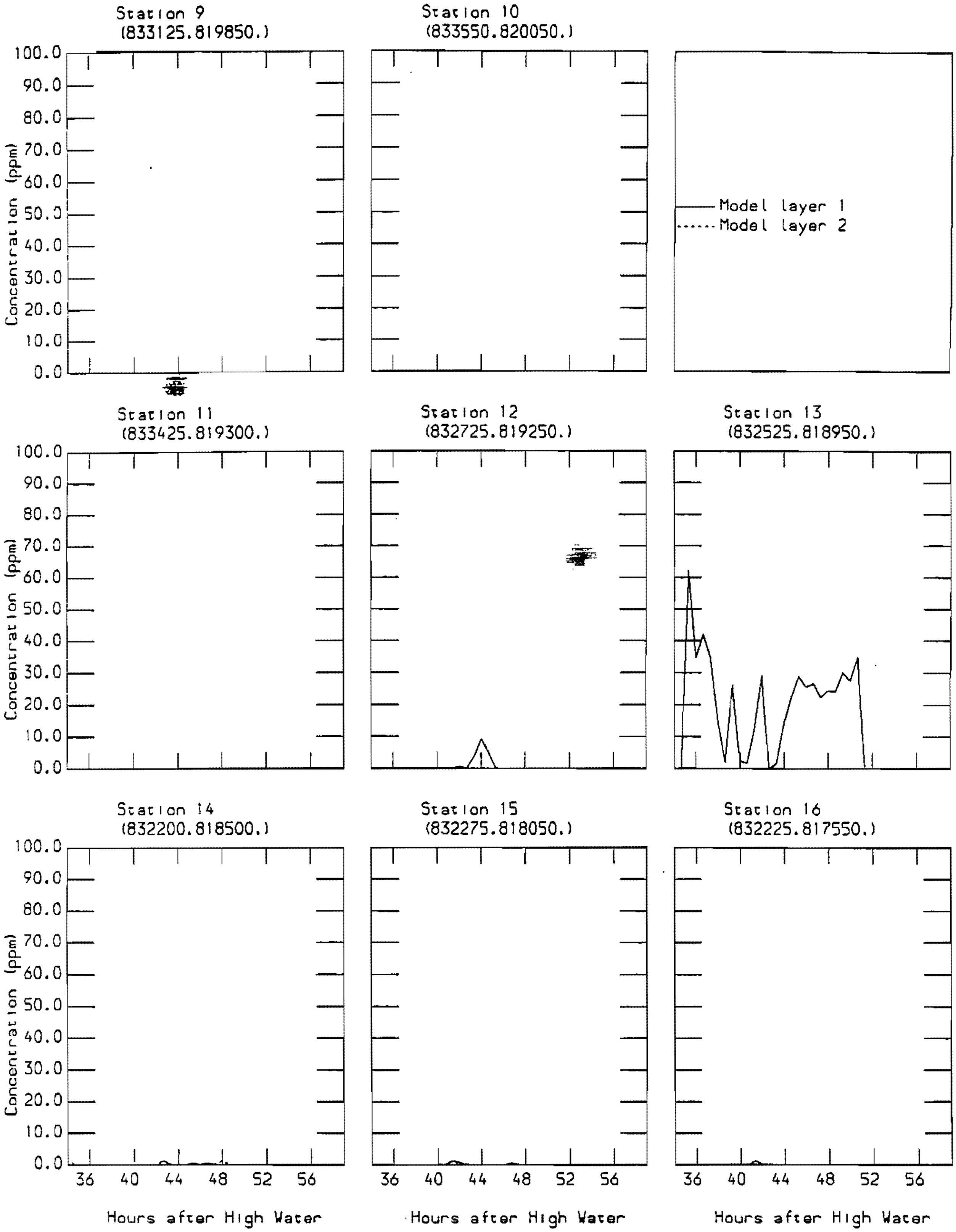
Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment Concentrations
Dry Season Spring Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Daily Inorganic Nitrogen Levels
Dry Season Neap Tide

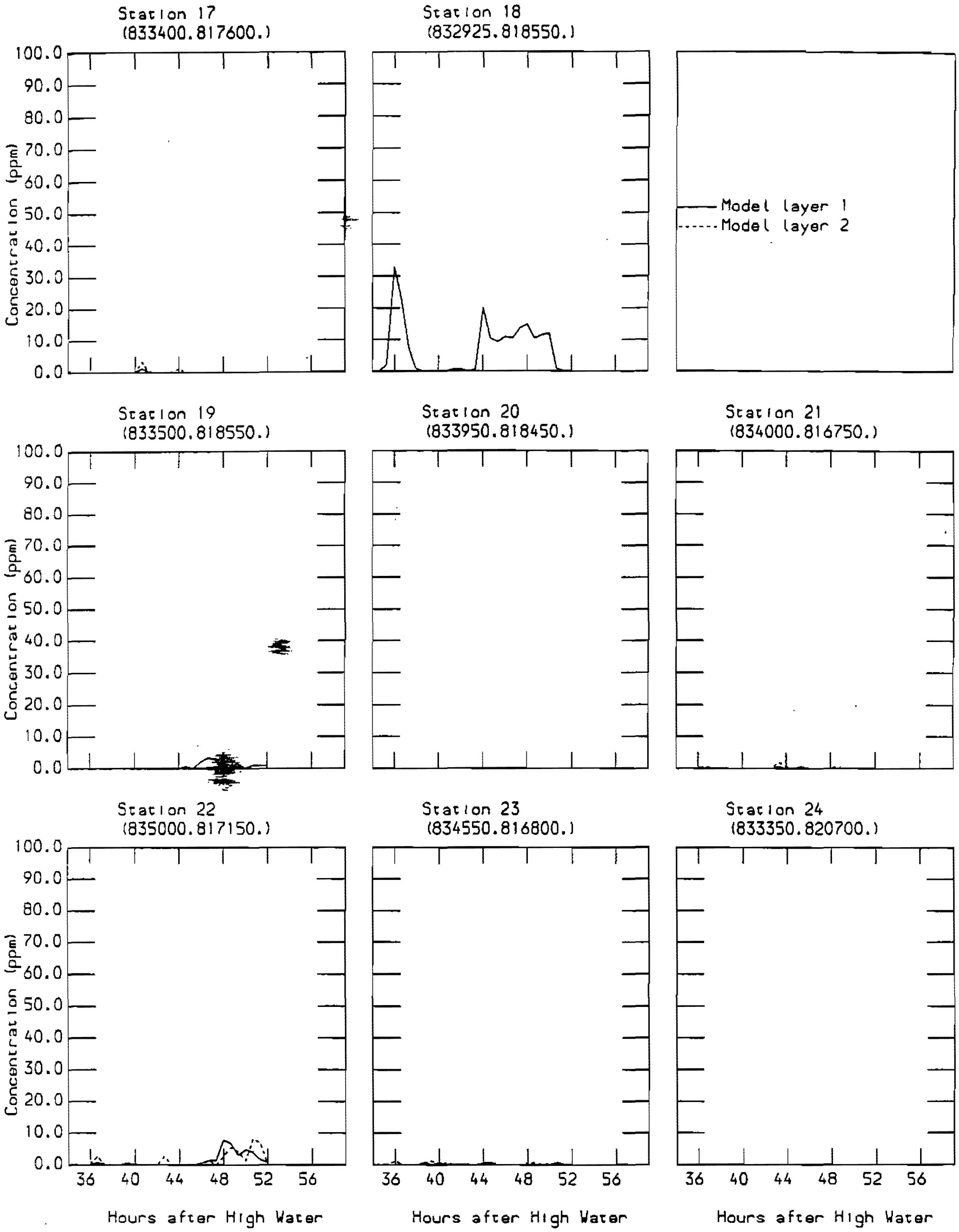
WET SEASON SPRING TIDE



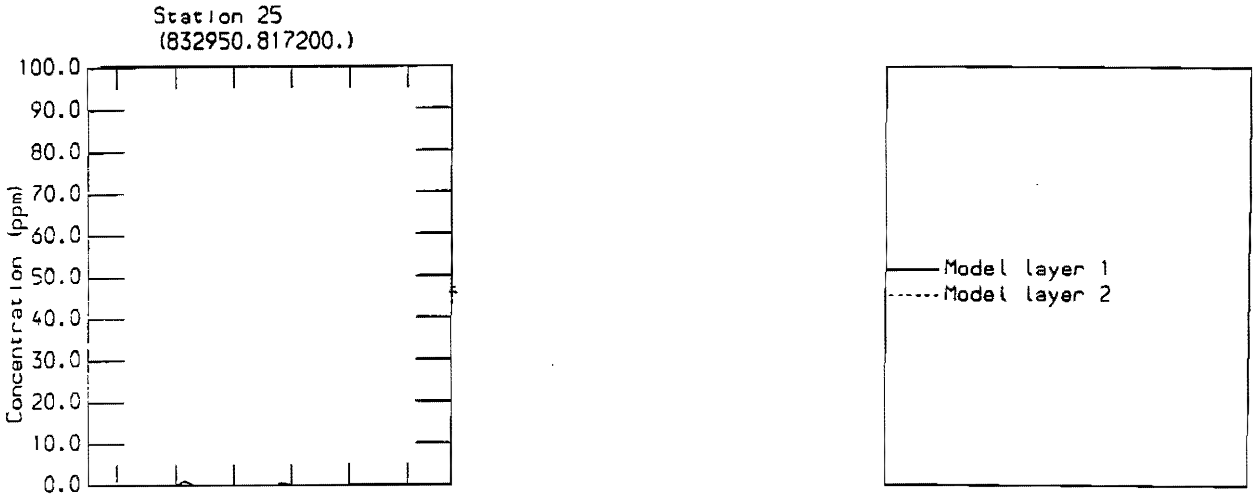
Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment at Monitoring Station
Wet Season Spring Tide



Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment at Monitoring Station
Wet Season Spring Tide



Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment at Monitoring Station
Wet Season Spring Tide



Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment at Monitoring Station
Wet Season Spring Tide

Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment Concentrations
Wet Season Spring Tide

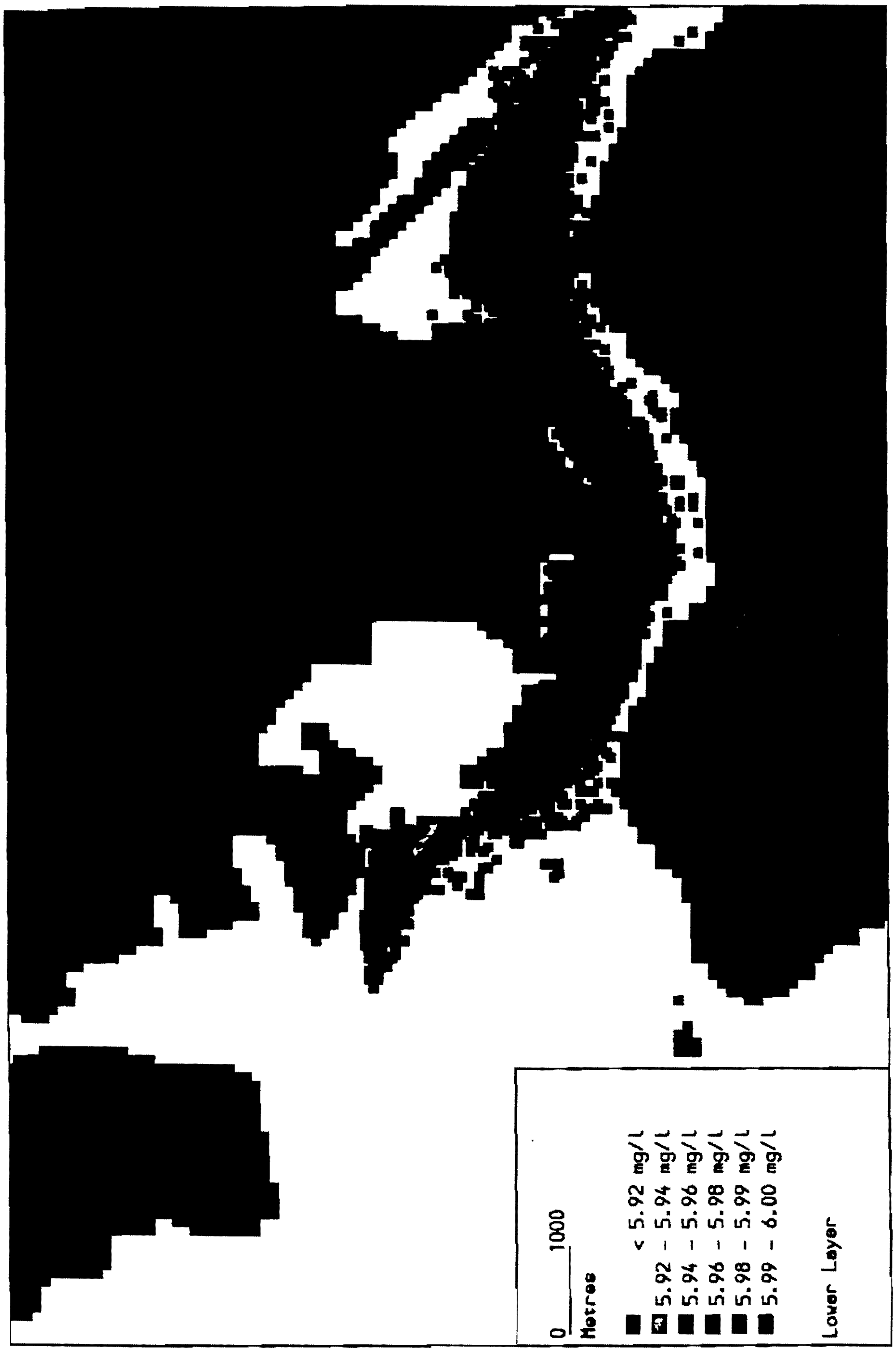
Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment Concentrations
Wet Season Spring Tide

Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment Concentrations
Wet Season Spring Tide

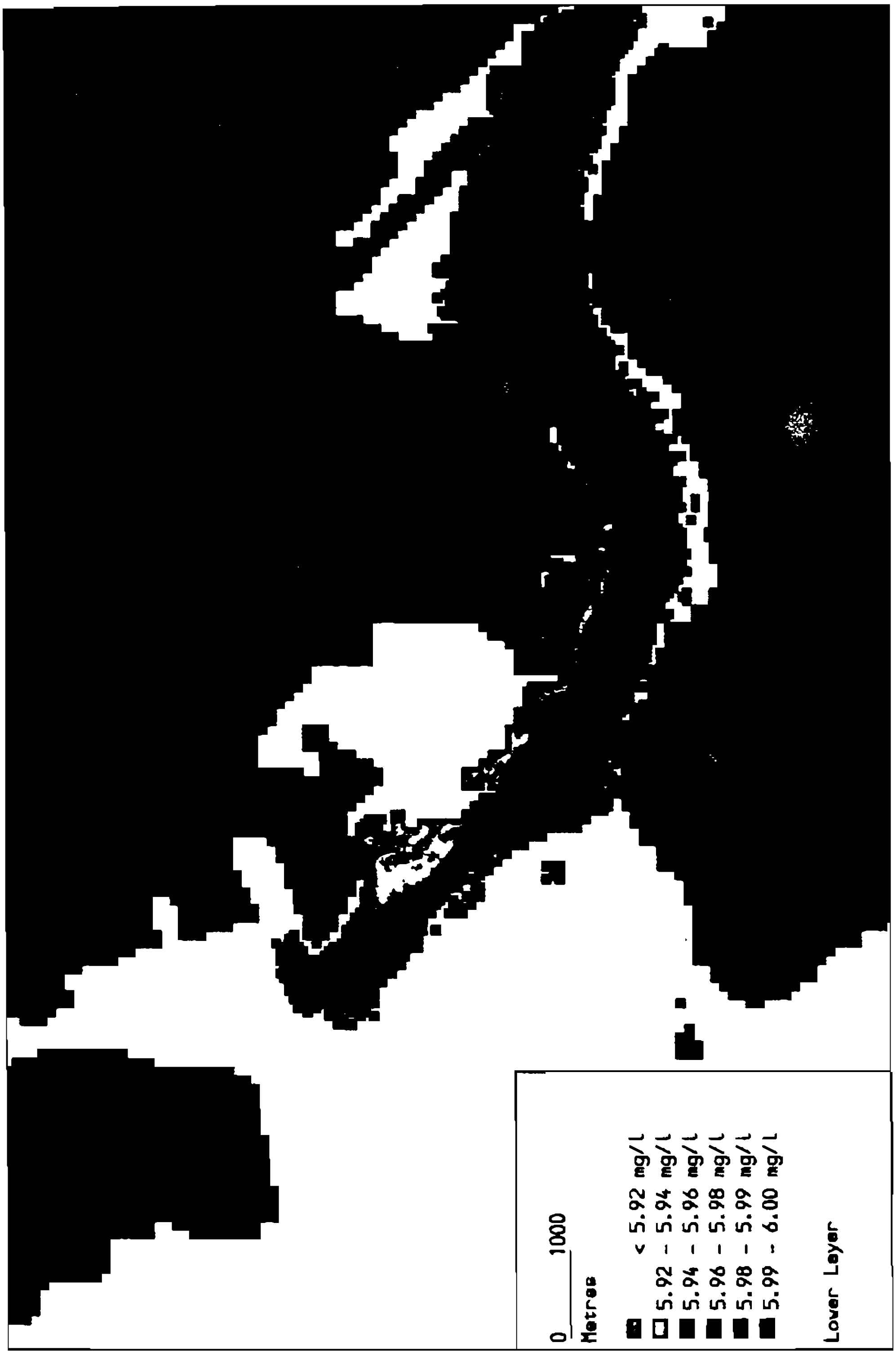
Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Suspended Sediment Concentrations
Wet Season Spring Tide

Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger Continuous
Mud Deposits for 1 Tide
Wet Season Spring Tide

Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Daily Dissolved Oxygen Levels
Wet Season Spring Tide



Stonecutters Naval Base Anchorage Area
Scenario 2 - Grab Dredger
Daily Dissolved Oxygen Levels
Wet Season Spring Tide



Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Daily Dissolved Oxygen Levels
Wet Season Spring Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Daily Ammoniacal Nitrogen Levels
Wet Season Spring Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Daily Ammoniacal Nitrogen Levels
Wet Season Spring Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Daily Inorganic Nitrogen Levels
Wet Season Spring Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Daily Inorganic Nitrogen Levels
Wet Season Spring Tide

WET SEASON NEAP TIDE

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Daily Dissolved Oxygen Levels
Wet Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Daily Dissolved Oxygen Levels
Wet Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Daily Ammoniacal Nitrogen Levels
Wet Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Daily Ammoniacal Nitrogen Levels
Wet Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Daily Inorganic Nitrogen Levels
Wet Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Daily Inorganic Nitrogen Levels
Wet Season Neap Tide

DRY SEASON SPRING TIDE

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Daily Dissolved Oxygen Levels
Dry Season Spring Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Daily Dissolved Oxygen Levels
Dry Season Spring Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Daily Ammoniacal Nitrogen Levels
Dry Season Spring Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Daily Ammoniacal Nitrogen Levels
Dry Season Spring Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Daily Inorganic Nitrogen Levels
Dry Season Spring Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Daily Inorganic Nitrogen Levels
Dry Season Spring Tide

DRY SEASON NEAP TIDE

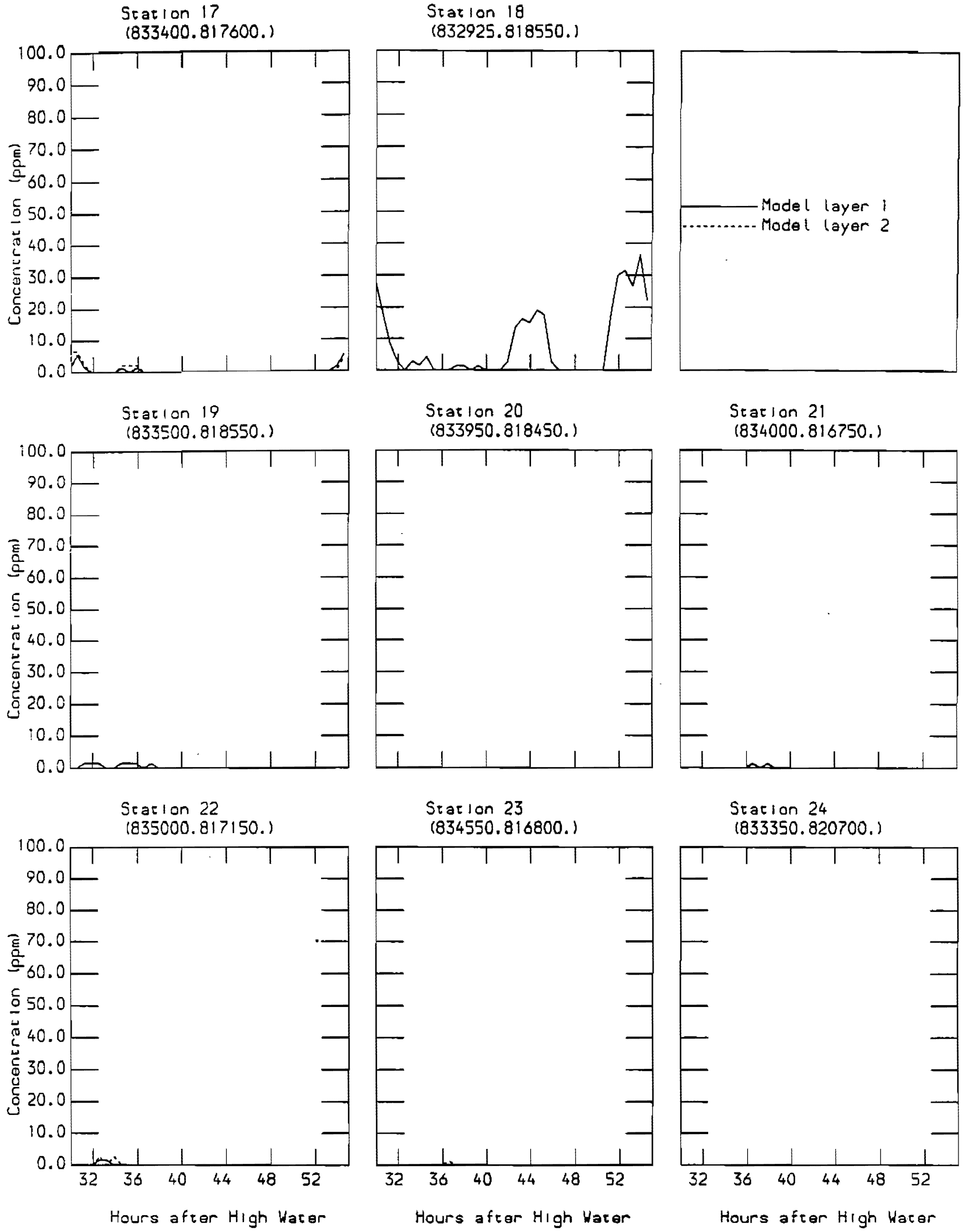
Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Daily Dissolved Oxygen Levels
Dry Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Daily Dissolved Oxygen Levels
Dry Season Neap Tide

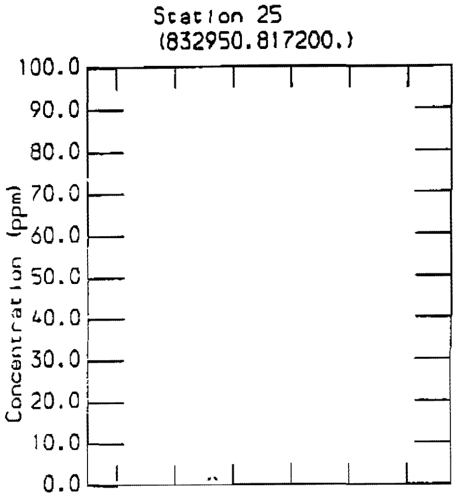
Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Daily Ammoniacal Nitrogen Levels
Dry Season Neap Tide

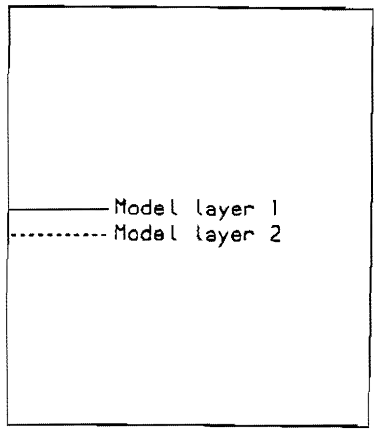
Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Daily Ammoniacal Nitrogen Levels
Dry Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Daily Inorganic Nitrogen Levels
Dry Season Neap Tide



Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continous
Suspended Sediment at Sensitive Receiver
Wet Season Neap Tide





Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continous
Suspended Sediment at Sensitive Receiver
Wet Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Suspended Sediment Concentrations
Wet Season Neap Tide

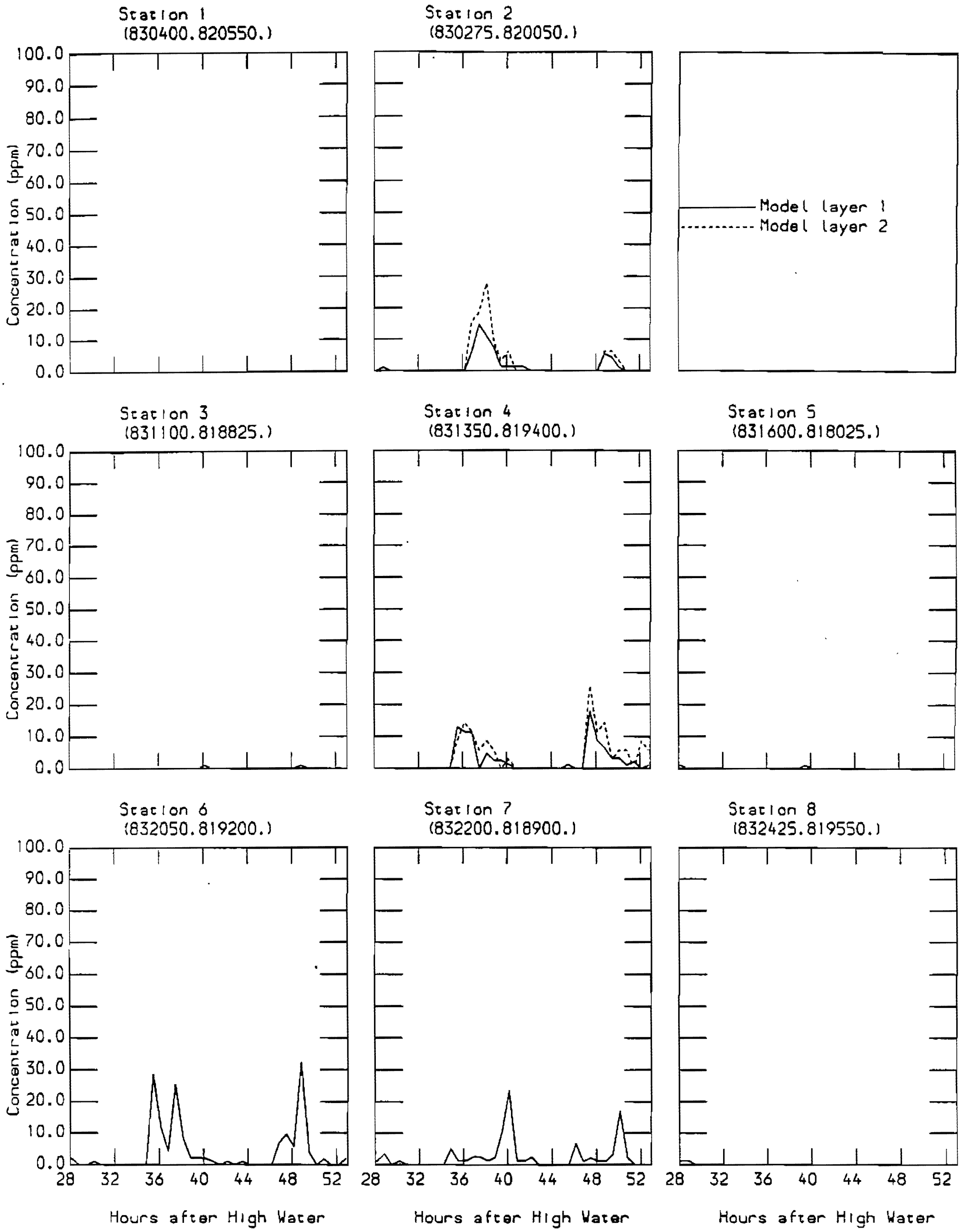
Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Suspended Sediment Concentrations
Wet Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Suspended Sediment Concentrations
Wet Season Neap Tide

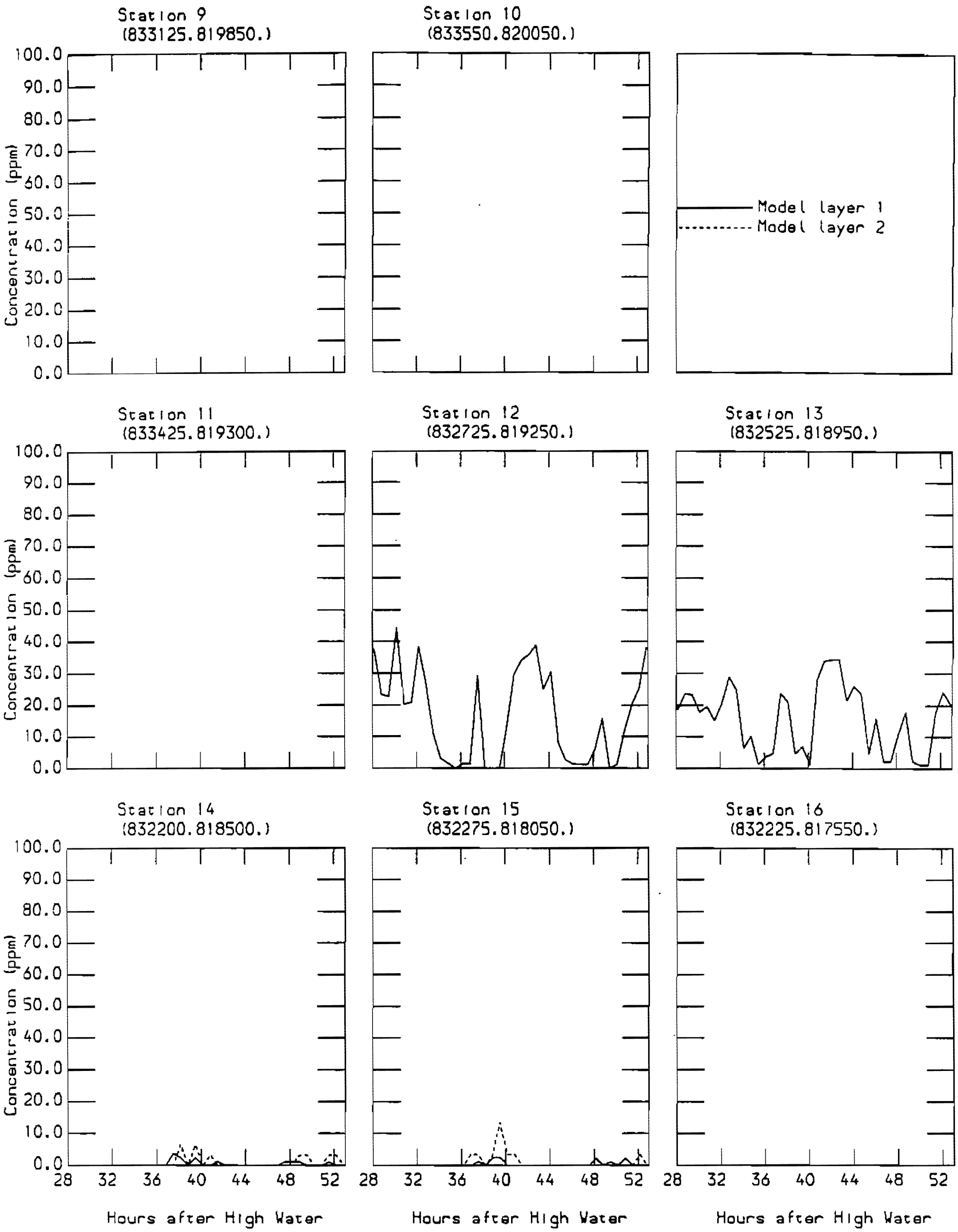
Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Suspended Sediment Concentrations
Wet Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Mud Deposits for 1 Tide
Wet Season Neap Tide

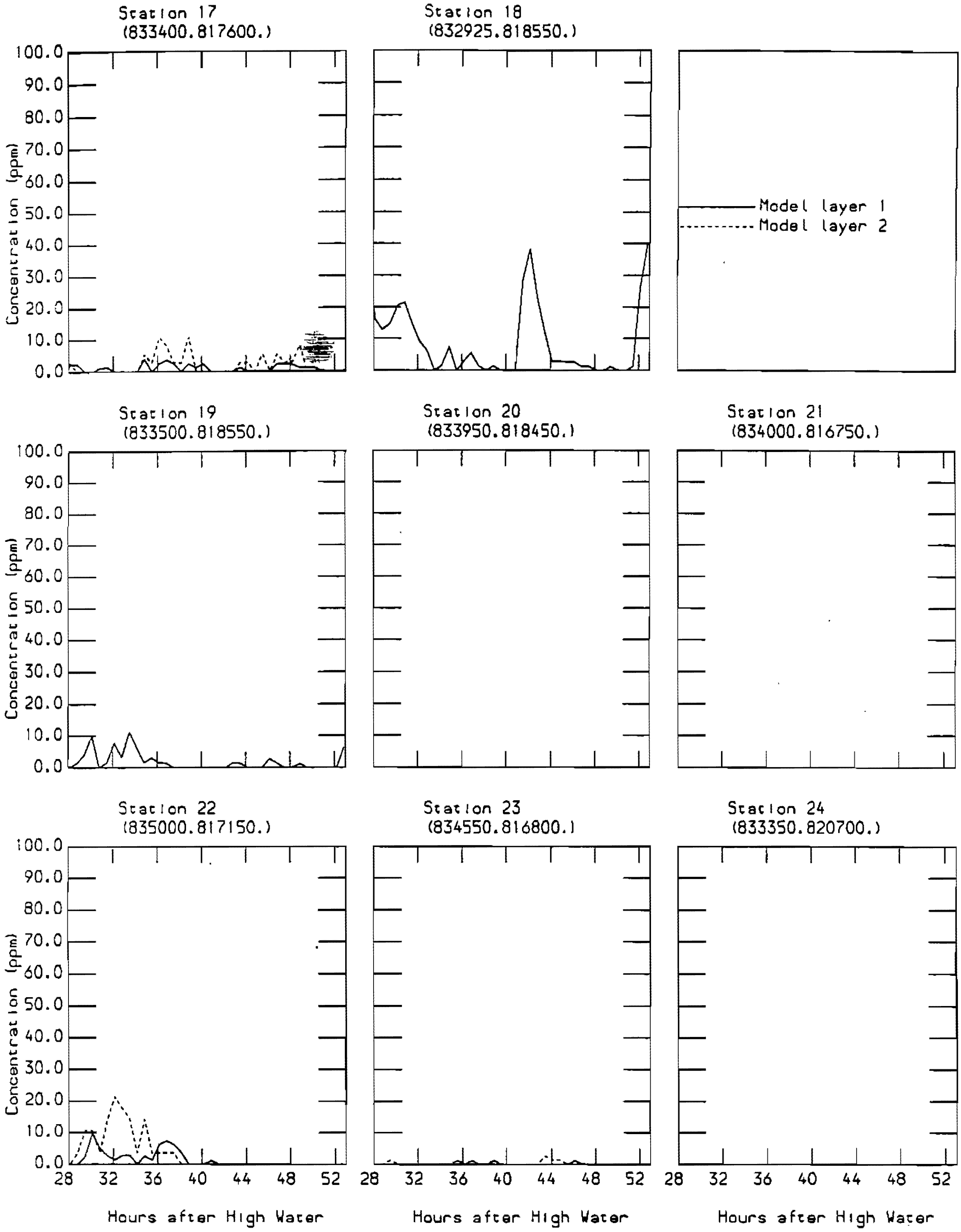
DRY SEASON SPRING TIDE



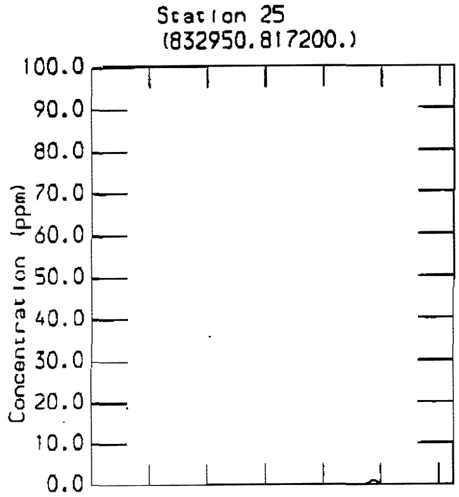
Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continous
Suspended Sediment at Sensitive Receiver
Dry Season Spring Tide

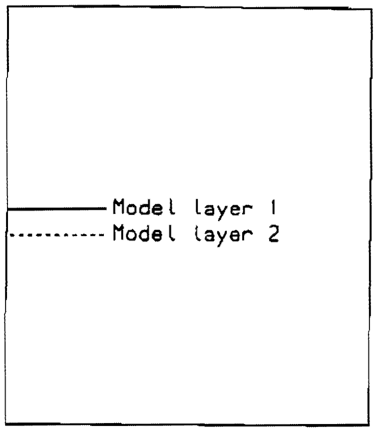


Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continous
Suspended Sediment at Sensitive Receiver
Dry Season Spring Tide



Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continous
Suspended Sediment at Sensitive Receiver
Dry Season Spring Tide





Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continous
Suspended Sediment at Sensitive Receiver
Dry Season Spring Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Suspended Sediment Concentrations
Dry Season Spring Tide

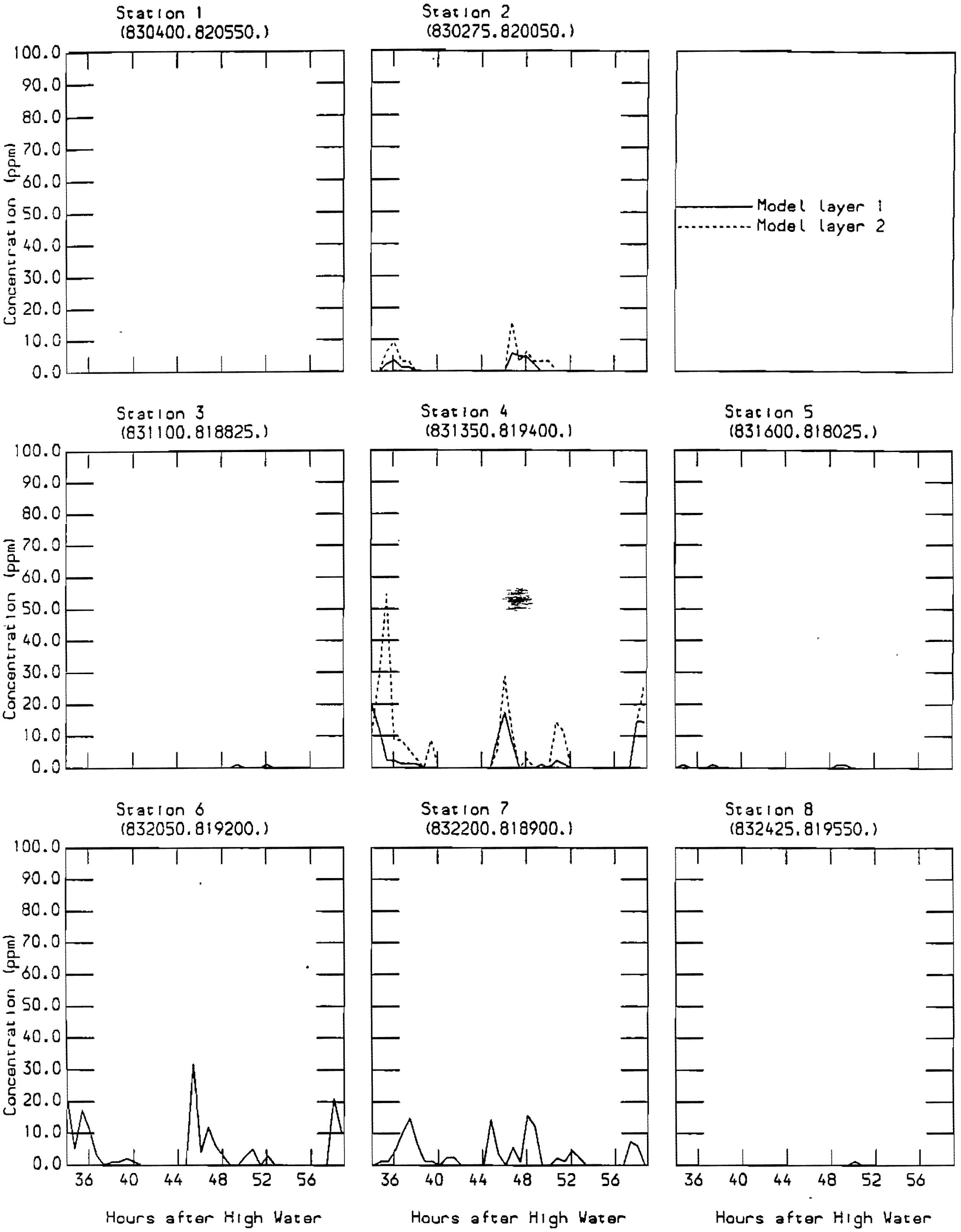
Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Suspended Sediment Concentrations
Dry Season Spring Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Suspended Sediment Concentrations
Dry Season Spring Tide

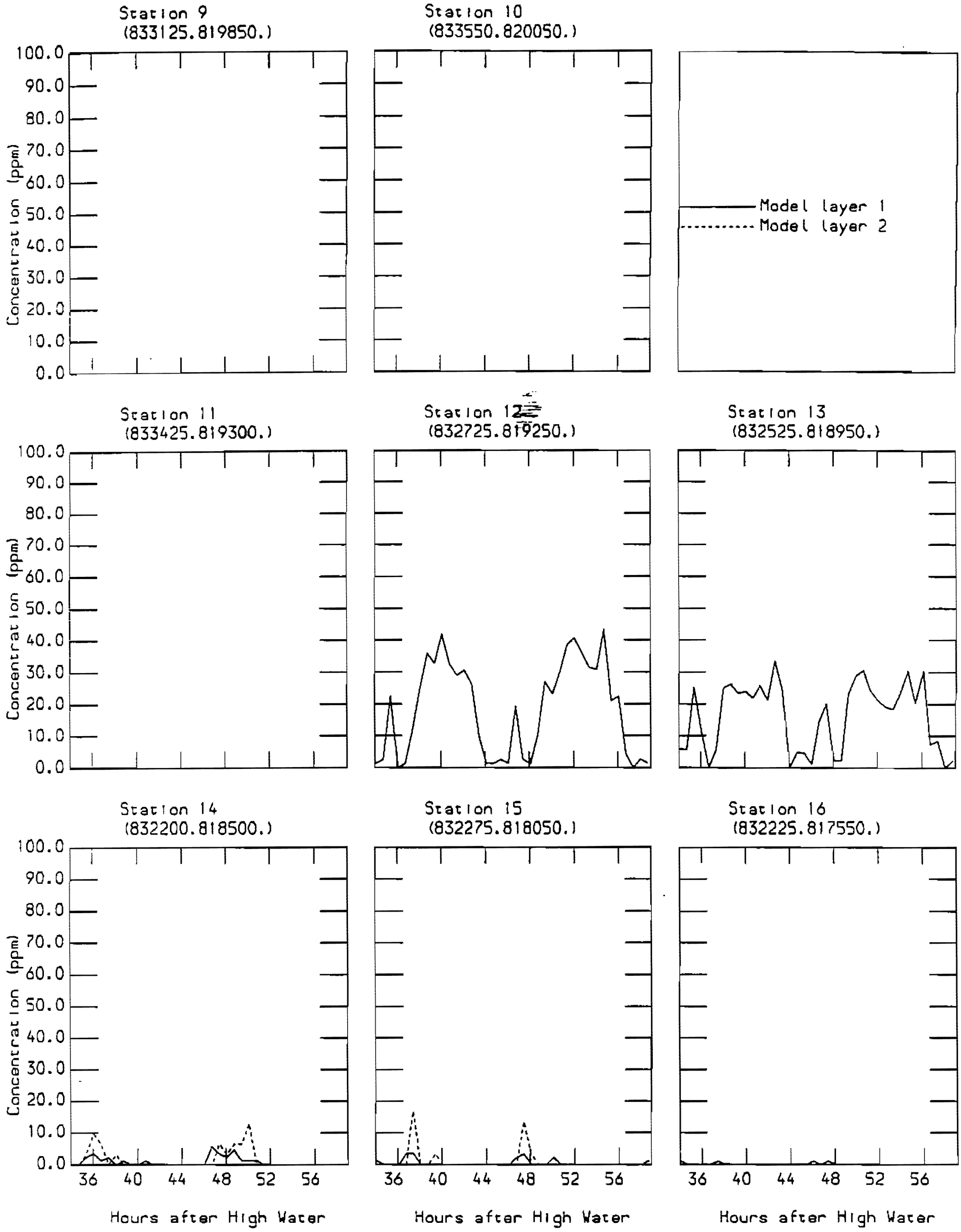
Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Suspended Sediment Concentrations
Dry Season Spring Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Mud Deposits for 1 Tide
Dry Season Spring Tide

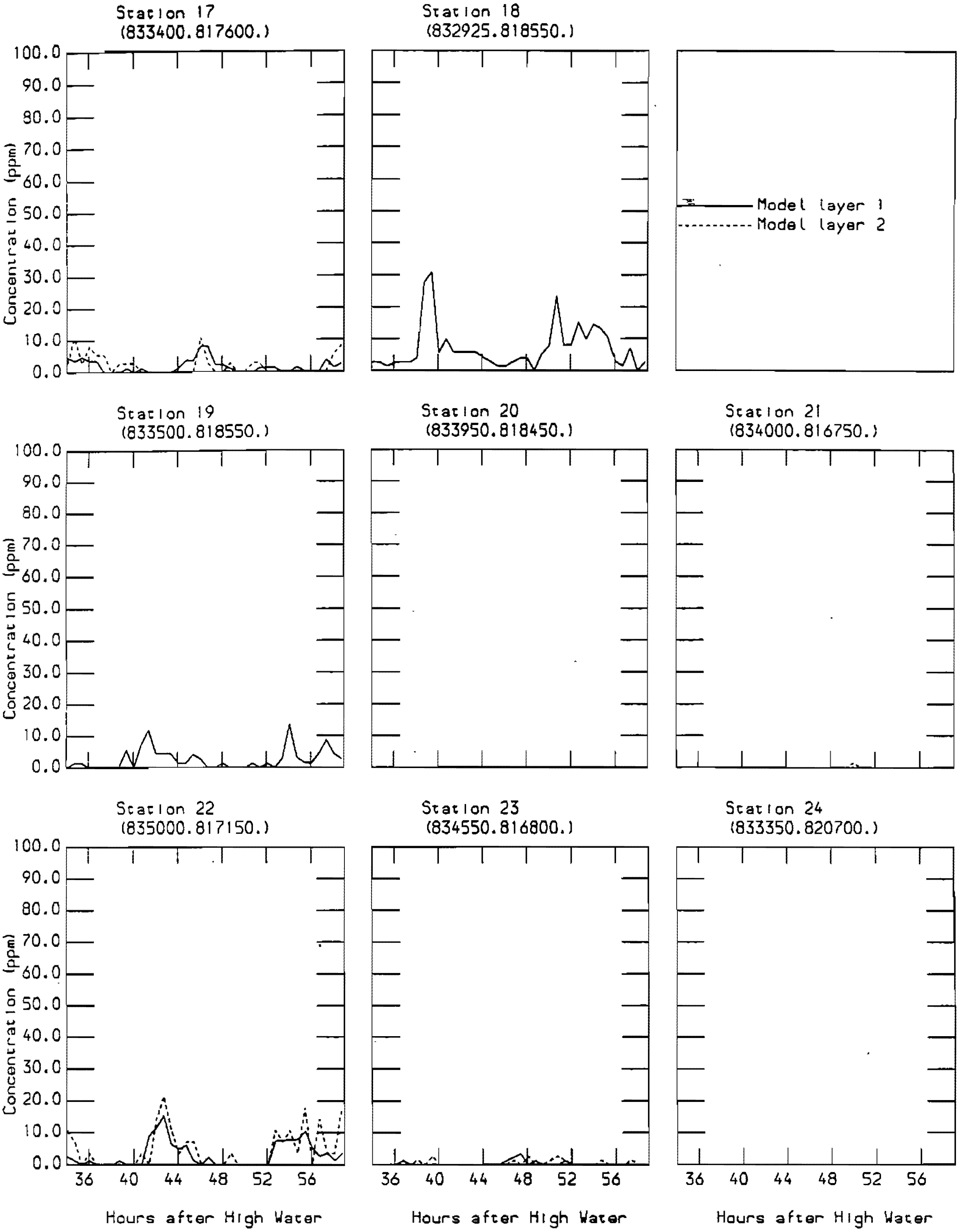
DRY SEASON NEAP TIDE



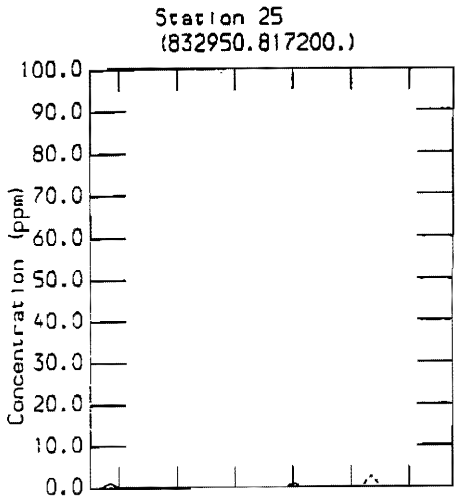
Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continous
Suspended Sediment at Sensitive Receiver
Dry Season Neap Tide

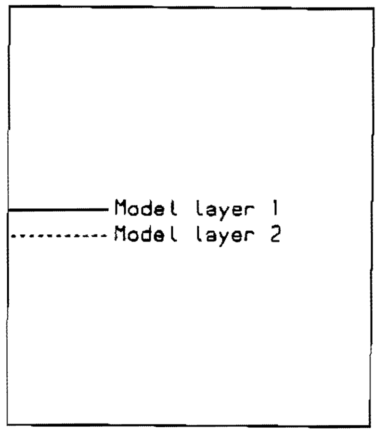


Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continous
Suspended Sediment at Sensitive Receiver
Dry Season Neap Tide



Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continous
Suspended Sediment at Sensitive Receiver
Dry Season Neap Tide





Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continous
Suspended Sediment at Sensitive Receiver
Dry Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Suspended Sediment Concentrations
Dry Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Suspended Sediment Concentrations
Dry Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Suspended Sediment Concentrations
Dry Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Suspended Sediment Concentrations
Dry Season Neap Tide

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Mud Deposits for 1 Tide
Dry Season Neap Tide

WET SEASON SPRING TIDE

Stonecutters Naval Base Anchorage Area
Scenario 1 - Trailer Dredger Continuous
Daily Dissolved Oxygen Levels
Wet Season Spring Tide

APPENDIX B.1.1 HEAVY METAL CONTAMINATION LEVELS

Vibrocore No	Seabed Level(mPD)	Sample Depth (m)		Level mPD	Cd mg/kg	Cr mg/kg	Cu mg/kg	Pb mg/kg	Ni mg/kg	Zn mg/kg	Hg mg/kg	Class	Class B Elements	Class C Elements
VA11	-8.60	00 -	0.1	-8 65	0 26	57	190	43	21	130	0.25	C	Cr	Cu
VA11		09 -	1 0	-9 55	0 29	63	210	59	18	170	0 49	C	Cr Zn	Cu
VA11		1 9 -	2 0	-10 55	< 0 2	33	9 8	18	17	72	< 0.05			
VA11		2 9 -	3 0	-11.55	< 0 2	38	10	18	19	71	< 0 05			
VA11		5 9 -	6 0	-14 55	< 0 2	33	11	35	17	66	< 0 05			
VA12	-8.59	0 0 -	0 1	-8 64	< 0 2	43	88	41	18	120	0 33	C		Cu
VA12		0 9 -	1 0	-9 54	< 0 2	31	12	21	17	81	< 0 05			
VA12		1 9 -	2 0	-10 54	< 0 2	33	9 6	18	18	74	< 0 05			
VA12		2 9 -	3 0	-11 54	< 0 2	33	9 5	18	18	68	< 0 05			
VA12		5 9 -	6 0	-14 54	< 0 2	34	9 8	24	17	65	< 0 05			
VA13	-8.48	0 0 -	0 1	-8 53	< 0 2	28	19	28	15	86	0 11			
VA13		0 1 -	0 2	-8 62	< 0 2	31	8 6	18	17	70	< 0 05			
VA13		1 9 -	2 0	-10 43	< 0 2	34	9 8	17	18	74	< 0 05			
VA13		2 9 -	3 0	-11 43	< 0 2	33	9 7	19	18	72	< 0 05			
VA13		5 9 -	6 0	-14 43	< 0 2	32	11	15	17	76	< 0 05			
VA14	-8.32	0 0 -	0 1	-8 37	0 32	58	220	310	19	160	0 36	C	Cr Zn	Cu Pb
VA14		0 9 -	1 0	-9 27	< 0 2	34	150	120	21	130	0 6	C		Cu Pb
VA14		1 9 -	2 0	-10 27	< 0 2	34	8 5	17	18	70	< 0 05			
VA14		2 9 -	3 0	-11 27	< 0 2	35	9.7	19	18	75	< 0 05			
VA14		5 9 -	6 0	-14 27	< 0 2	32	9 7	23	16	84	< 0 05			
VA15	-8.52	0 0 -	0 1	-8 57	< 0 2	29	290	50	15	100	0 15	C		Cu
VA15		0 9 -	1 0	-9 47	< 0 2	31	8.1	16	18	69	< 0 05			
VA15		1 9 -	2 0	-10 47	< 0 2	33	9	19	17	73	< 0 05			
VA15		2 9 -	3 0	-11 47	< 0 2	34	9 9	19	17	72	< 0 05			
VA15		5 9 -	6 0	-14 47	< 0 2	33	10	25	17	67	< 0 05			
VA16	-9.18	0.1 -	0 2	-9 33	< 0 2	38	120	42	15	120	0 28	C		Cu
VA16		0 9 -	1 0	-10 13	0 3	63	210	78	17	400	0 82	C	Cr Hg	Cu Pb Zn
VA16		1.9 -	2 0	-11.13	0.21	78	120	73	19	190	0 79	C	Cr Pb Zn	Cu
VA16		2 9 -	3 0	-12 13	< 0 2	35	9 6	20	17	70	< 0 05			
VA16		5 9 -	6 0	-15 13	< 0 2	33	9.9	26	17	63	< 0 05			
VA17	-9.25	0 1 -	0 2	-9 4	0 31	60	290	43	20	150	0 29	C	Cr Zn	Cu
VA17		0 9 -	1 0	-10 2	< 0 2	47	120	42	19	120	0 31	C		Cu
VA17		1 9 -	2 0	-11.2	0 36	110	350	74	24	230	0 74	C	Pb	Cr Cu Zn
VA17		2 9 -	3 0	-12.2	< 0 2	47	61	32	17	100	0 21	B	Cu	
VA17		5 9 -	6 0	-15 2	< 0 2	35	15	94	19	70	< 0 05	C		Pb
VA18	-10.22	0 1 -	0 2	-10 37	0 22	51	170	40	20	120	0 36	C	Cr	Cu
VA18		0 9 -	1 0	-11 17	< 0 2	38	70	34	18	94	0 22	C		Cu
VA18		1 9 -	2 0	-12 17	0 55	100	380	71	25	230	< 0 64	C	Pb	Cr Cu Zn
VA18		2 9 -	3 0	-13 17	< 0 2	35	9 5	20	18	67	< 0 05			
VA18		5 9 -	6 0	-16 17	< 0 2	32	12	110	16	62	< 0 05	C		Pb
VA19	-9.13	0 0 -	0 1	-9 18	< 0 2	37	15	37	18	74	< 0 05			
VA19		0.9 -	1 0	-10 08	< 0 2	36	10	36	18	72	< 0 05			
VA19		1 9 -	2 0	-11 08	< 0 2	36	10	19	18	74	< 0 05			
VA19		2 9 -	3 0	-12 08	< 0 2	35	10	19	18	71	< 0 05			
VA19		5 9 -	6 0	-15 08	< 0 2	31	10	28	16	64	< 0 05			
VA20	-8.85	0 0 -	0.1	-8.9	< 0 2	37	29	22	18	74	< 0 05			
VA20		0 9 -	1 0	-9.8	< 0 2	32	8 5	22	18	72	< 0 05			
VA20		1.9 -	2.0	-10 8	< 0 2	35	9 9	18	18	73	< 0 05			
VA20		2 9 -	3 0	-11 8	< 0 2	34	9 6	17	17	67	< 0 05			
VA20		5 9 -	6 0	-14.8	< 0 2	30	9.5	41	16	61	< 0 05			

1. According to WBTC 22/92

	Cd	Cr	Cu	Pb	Ni	Zn	Hg
Class A	0 0-0 9	0-49	0-54	0-64	0-34	0-140	0 0-0 7
Class B	1 0-1 4	50-79	55-64	65-74	35-39	150-190	0 8-0 9
Class C	>1 5	>80	>65	>75	>40	>200	>1 0

B

APPENDIX B.1.2 HEAVY METAL CONTAMINATION LEVELS (CONT'D)

Vibrocore No	Seabed Level(mPD)	Sample Depth (m)	Level mPD	Cd mg/kg	Cr mg/kg	Cu mg/kg	Pb mg/kg	Ni mg/kg	Zn mg/kg	Hg mg/kg	Class	Class B Elements	Class C Elements
VA01	-7.38	0 1 - 0 2	-7 53	0 24	48	55	43	17	150	0 37	B	Cu Zn	
VA01		0 9 - 1 0	-8 33	< 0 2	29	10	21	16	72	< 0 05			
VA01		1 9 - 2 0	-9 33	< 0 2	31	7 6	14	17	68	< 0 05			
VA01		2 9 - 3 0	-10 33	< 0 2	38	9	16	19	75	< 0 05			
VA01		5 9 - 6 0	-13 33	< 0 2	31	11	21	19	80	< 0 05			
VA02	-8 60	0 4 - 0 5	-9 05	< 0 2	46	71	30	19	110	< 0 25	C		Cu
VA02		0 9 - 1 0	-9 55	< 0 2	29	8 5	13	17	66	< 0 05			
VA02		1 9 - 2 0	-10 55	< 0 2	34	8 8	15	19	72	< 0 05			
VA02		2 9 - 3 0	-11.55	< 0 2	35	9 3	18	19	78	< 0 05			
VA02		5 9 - 6 0	-14 55	< 0 2	34	10	19	17	72	< 0 05			
VA03	-8.13	0 5 - 0 6	-8 68	< 0 2	28	7 3	15	18	87	< 0 05			
VA03		0 9 - 1 0	-9 08	< 0 2	29	7 3	15	17	68	< 0 05			
VA03		1 9 - 2 0	-10 08	< 0 2	33	8 6	15	17	66	< 0 05			
VA03		2 9 - 3 0	-11 08	< 0 2	34	9	18	18	73	< 0 05			
VA03		5 9 - 6 0	-14 08	< 0 2	34	10	18	18	74	< 0 05			
VA04	-7 64	0 0 - 0 1	-7 69	< 0 2	42	62	27	18	90	0 18	B	Cu	
VA04		0 9 - 1 0	-8 59	< 0 2	28	15	22	15	71	0 08			
VA04		1 9 - 2 0	-9 59	< 0 2	32	8 5	19	18	69	< 0 05			
VA04		2 9 - 3 0	-10 59	< 0 2	38	10	20	18	67	< 0 05			
VA04		5 9 - 6 0	-13 59	< 0 2	31	21	22	15	73	0 09			
VA05	-7.90	0 3 - 0 4	-8 25	< 0 2	48	84	32	20	140	0 19	C		Cu
VA05		0 9 - 1 0	-8 85	0 59	90	140	60	21	210	0 69	C		Cr Cu Zn
VA05		1.9 - 2 0	-9 85	< 0 2	32	7.9	15	17	87	< 0 05			
VA05		2 9 - 3 0	-10 85	< 0 2	33	8 3	17	17	70	< 0 05			
VA05		5 9 - 6 0	-13 85	< 0.2	38	12	23	18	78	< 0 05			
VA06	-8.03	0 0 - 0.1	-8 08	0 35	63	170	44	21	150	0 28	C	Cr Zn	Cu
VA06		0 9 - 1.0	-8 98	< 0 2	38	23	20	18	86	0 07			
VA06		1 9 - 2.0	-9 98	< 0.2	38	28	20	18	79	0 08			
VA06		2 9 - 3 0	-10 98	< 0 2	37	9 7	20	19	80	< 0 05			
VA06		5 9 - 6 0	-13 98	< 0 2	37	11	23	19	78	< 0 05			
VA07	-8.44	0 0 - 0.1	-8 49	0.36	63	210	40	22	160	0 32	C	Cr Zn	Cu
VA07		0 9 - 1 0	-8 98	< 0 2	29	7 3	14	17	68	< 0 05			
VA07		1 9 - 2 0	-9 98	< 0 2	33	9 3	18	18	73	< 0 05			
VA07		2 9 - 3 0	-10 98	< 0 2	38	9 9	19	18	75	< 0 05			
VA07		5 9 - 6 0	-13 98	< 0 2	33	9 7	21	16	65	< 0 05			
VA08	-7.58	0 0 - 0 1	-7 63	0 16	50	120	37	19	120	0 22	C	Cr	Cu
VA08		0 9 - 1 0	-8 53	< 0 2	29	7 4	15	17	76	< 0 05			
VA08		1.9 - 2 0	-9 53	< 0 2	34	8.7	16	19	73	< 0 05			
VA08		2.9 - 3.0	-10 53	< 0 2	35	9.7	19	19	80	< 0 05			
VA08		5 9 - 6 0	-13 53	< 0 2	32	11	28	16	88	< 0 05			
VA09	-8.44	0 2 - 0 3	-8 69	0 31	55	160	47	19	170	0 47	C	Cr Zn	Cu
VA09		0 9 - 1 0	-9.39	< 0 2	42	350	120	17	240	1	C		Cu Pb Zn Hg
VA09		1 9 - 2 0	-10 39	< 0 2	34	8 7	16	19	73	< 0 05			
VA09		2 9 - 3 0	-11 39	< 0 2	35	9 7	19	19	80	< 0 05			
VA09		5 9 - 6 0	-14 39	< 0 2	34	11	30	17	73	< 0 05			
VA10	-8.48	0 0 - 0 1	-8 53	0 21	55	130	38	21	130	0 27	C	Cr	Cu
VA10		0 9 - 1 0	-9 43	0 21	52	150	48	17	150	0 41	C	Cr Zn	Cu
VA10		1 9 - 2 0	-10 43	< 0 2	34	9 3	17	18	76	< 0 05			
VA10		2 9 - 3 0	-11 43	< 0 2	38	9 8	18	18	75	< 0 05			
VA10		5 9 - 6 0	-14 43	< 0 2	33	12	90	17	67	< 0 05	C		Pb

Remark :

1. According to WBTC 22/92

	Cd	Cr	Cu	Pb	Ni	Zn	Hg
Class A	0 0-0 9	0-49	0-54	0-64	0-34	0-140	0 0-0 7
Class B	1 0-1 4	50-79	55-64	65-74	35-39	150-190	0 8-0 9
Class C	>1 5	>80	>65	>75	>40	>200	>1 0

APPENDIX B.1.3 HEAVY METAL CONTAMINATION LEVELS (CONT'D)

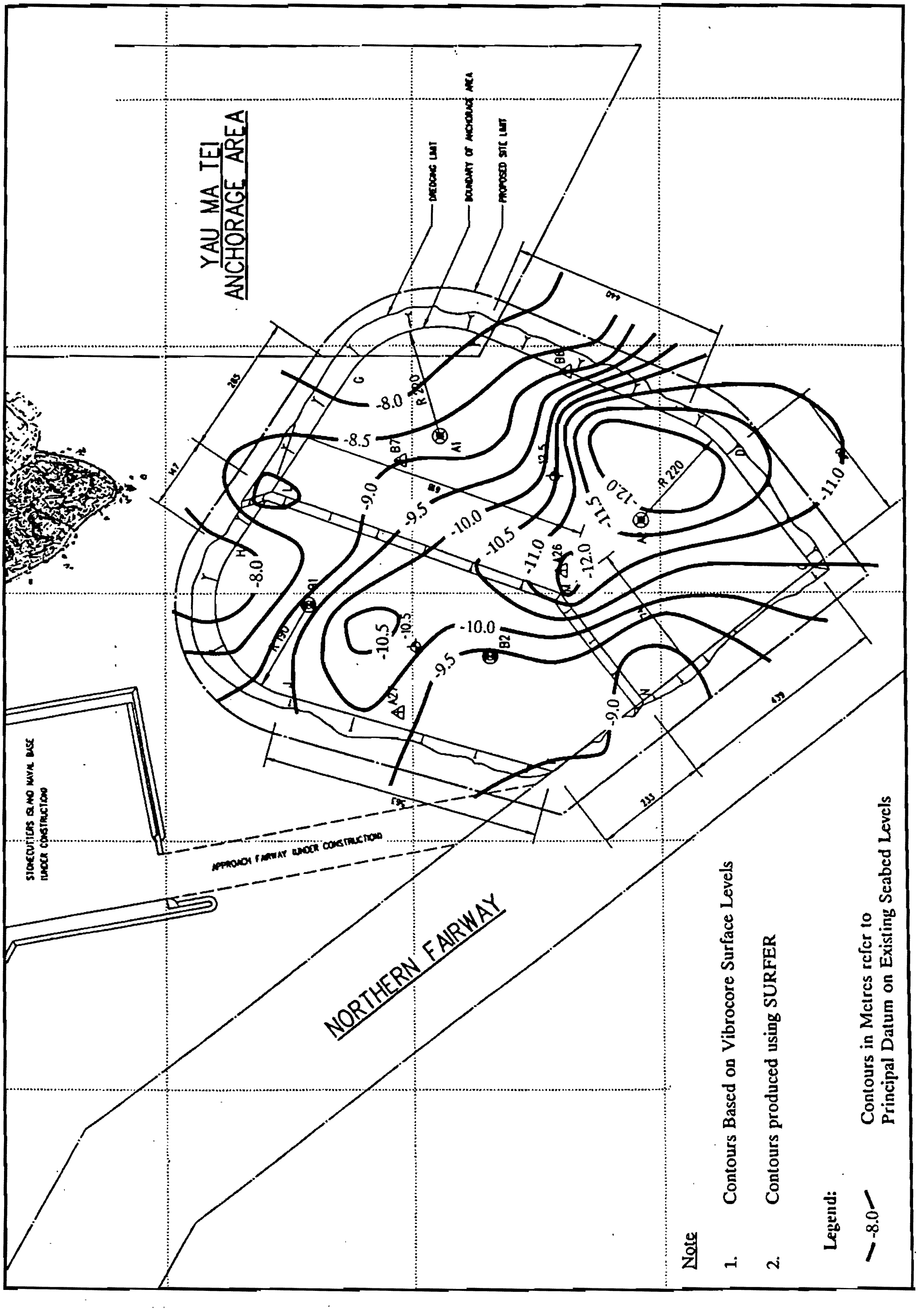
Vibrocore No	Seabed Level(mPD)	Sample Depth (m)	Level mPD	Cd mg/kg	Cr mg/kg	Cu mg/kg	Pb mg/kg	Ni mg/kg	Zn mg/kg	Hg mg/kg	Class	Class B Elements	Class C Elements
VA21	-9.82	0 0 - 0 1	-9 87	< 0 2	27	77	67	14	120	< 0 05	C	Pb	Cu
VA21		0 9 - 1 0	-10 77	< 0 2	32	9 6	17	18	64	< 0 05			
VA21		1 9 - 2 0	-11.77	< 0 2	33	9 7	17	17	67	< 0 05			
VA21		2 9 - 3 0	-12.77	< 0 2	30	9 4	19	18	83	< 0 05			
VA21		5 9 - 6 0	-15.77	< 0 2	32	9 9	26	17	66	< 0 05			
VA22	-9.94	0 0 - 0 1	-9 99	0 25	56	180	67	15	140	0 39	C	Cr Pb	Cu
VA22		0 9 - 1 0	-10 89	0 25	64	170	73	16	190	0 63	C	Cr Pb Zn	Cu
VA22		1 9 - 2 0	-11 89	< 0 2	28	8	15	15	61	< 0 05			
VA22		2 9 - 3 0	-12 89	< 0 2	31	9 2	17	16	64	< 0 05			
VA22		5 9 - 6 0	-15 89	< 0 2	31	10	43	17	60	< 0 05			
VB6	-7.10	0 0 - 0 1	-7.15	0 33	55	160	50	18	150	0 63	C	Cr Zn	Cu
VB6		0 9 - 1 0	-8 05	< 0 2	31	11	22	18	72	< 0 05			
VB6		1 9 - 2 0	-9 05	< 0 2	30	7.3	15	15	61	< 0 05			
VB6		2 9 - 3 0	-10 05	< 0 2	35	8 4	17	18	64	< 0 05			
VB6		5 9 - 6 0	-13 05	< 0 2	41	11	21	20	80	< 0 05			
VB10	-7.93	0 0 - 0.1	-7.98	< 0 2	32	8 6	16	18	77	< 0 05			
VB10		0 9 - 1 0	-8 88	< 0 2	33	9 2	18	17	68	< 0 05			
VB10		1.9 - 2.0	-9 88	< 0 2	36	10	19	18	71	< 0 05			
VB10		2.9 - 3 0	-10 88	< 0.2	35	10	21	18	69	< 0 05			
VB10		5 9 - 6 0	-13 88	< 0 2	35	11	28	18	69	< 0 05			
VB20	-8.18	0 0 - 0.1	-8 23	< 0 2	51	140	38	20	120	0 27	C	Cr	Cu
VB20		0.9 - 1 0	-9.13	< 0.2	40	90	43	15	100	0 3	C		Cu
VB20		1.9 - 2.0	-10.13	0.33	84	230	68	21	220	0 88	C	Pb Hg	Cr Cu Zn
VB20		2 9 - 3.0	-11 13	< 0.2	37	9 8	19	20	78	< 0 05			
VB20		5 9 - 6 0	-14.13	< 0.2	36	11	22	19	74	< 0 05			
VB24	-8.18	0 0 - 0 1	-8 21	< 0 2	49	130	36	20	120	0 23	C		Cu
VB24		0 9 - 1 0	-9 11	< 0 2	35	11	20	18	79	< 0 05			
VB24		1 9 - 2 0	-10 11	< 0 2	34	6 8	18	18	73	< 0 05			
VB24		2 9 - 3 0	-11.11	< 0 2	36	10	19	18	71	< 0 05			
VB24		5 9 - 6 0	-14.11	< 0 2	35	11	22	18	69	< 0 05			
VB32	-8.33	0 0 - 0 1	-8 38	< 0 2	43	94	75	15	160	0 7	C	Zn	Cu Pb
VB32		0 9 - 1 0	-9 28	< 0 2	31	8 5	15	17	67	< 0 05			
VB32		1 9 - 2 0	-10 28	< 0 2	36	9 7	19	19	75	< 0 05			
VB32		2 9 - 3 0	-11 28	< 0 2	35	9 9	19	18	74	< 0 05			
VB32		5 9 - 6 0	-14 28	< 0 2	33	11	22	17	67	< 0 05			
VB36	-8.66	0 0 - 0 1	-8 71	< 0 2	28	41	49	13	99	0 38			
VB36		0 9 - 1 0	-9 61	0 4	100	370	74	23	210	0 74	C	Pb	Cr Cu Zn
VB36		1 9 - 2 0	-10 61	< 0 2	37	11	20	19	74	< 0 05			
VB36		2.9 - 3 0	-11 61	< 0 2	33	10	20	18	72	< 0 05			
VB36		5 9 - 6 0	-14 61	< 0 2	33	9 4	21	17	63	< 0 05			
VB46	-8.70	0 0 - 0 1	-8 75	< 0 2	42	71	33	17	95	< 0 29	C		Cu
VB46		0 9 - 1 0	-9 65	< 0 2	32	8 9	15	17	69	< 0 05			
VB46		1.9 - 2.0	-10 65	< 0 2	34	9 6	19	17	70	< 0 05			
VB46		2 9 - 3 0	-11 65	< 0 2	32	9 1	18	17	70	< 0 05			
VB46		5 9 - 6 0	-14 65	< 0 2	35	11	22	17	65	< 0 05			
VB50	-9.67	0 0 - 0 1	-9 72	< 0 31	67	260	53	23	220	< 0 24	C	Cr	Cu Zn
VB50		0 9 - 1 0	-10 62	< 0 2	50	120	36	21	110	< 0 2	C	Cr	Cu
VB50		1 9 - 2 0	-11.62	< 0 2	34	32	80	12	140	< 0 76	C		Pb
VB50		2 9 - 3 0	-12.62	< 0 2	30	9 1	19	18	64	< 0 05			
VB50		5 9 - 6 0	-15 62	< 0 2	33	9 8	24	17	63	< 0 05			

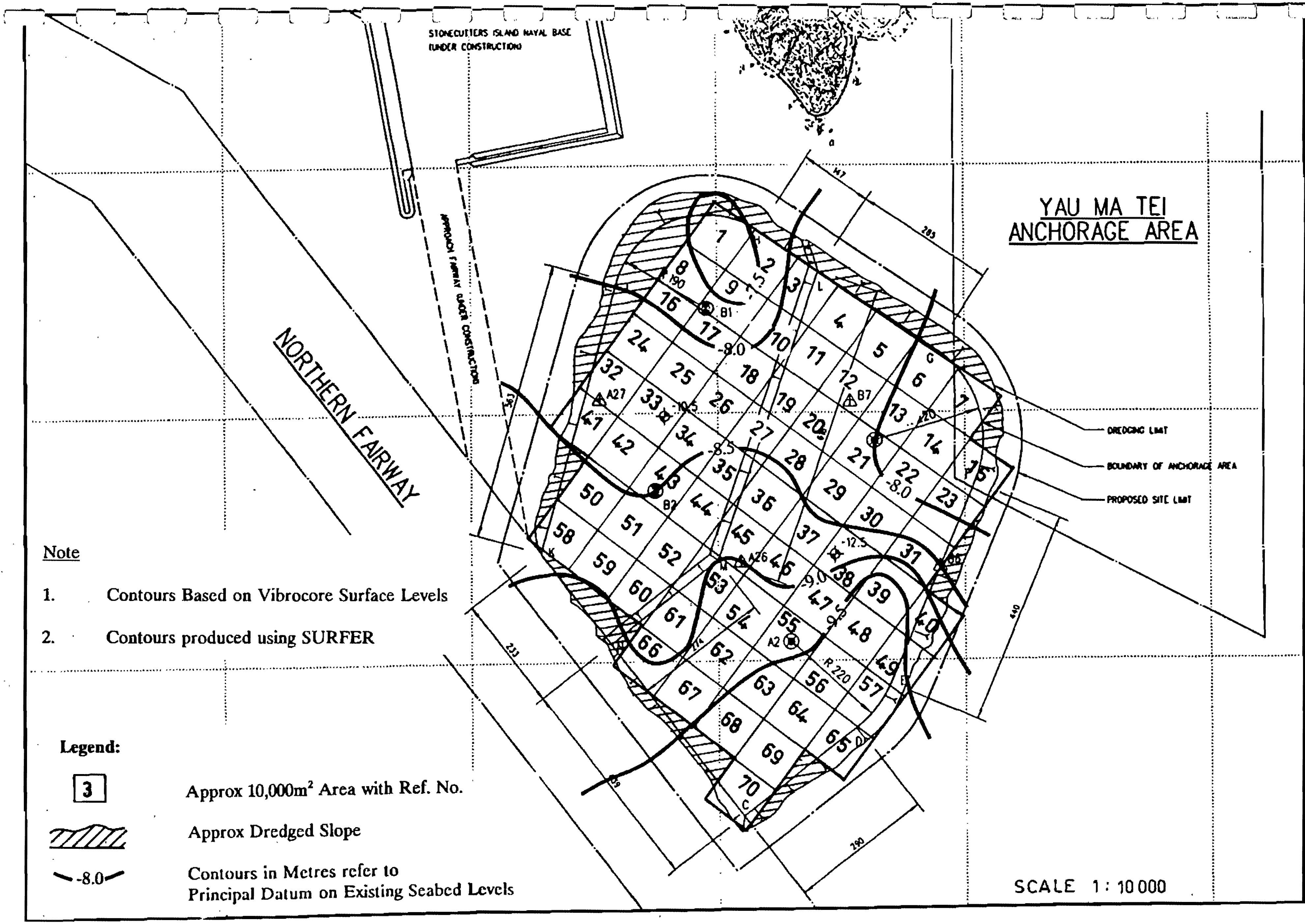
Remark :

1. According to WBTC 22/92

	Cd	Cr	Cu	Pb	Ni	Zn	Hg
Class A	0 0-0 9	0-49	0-54	0-64	0-34	0-140	0 0-0 7
Class B	1 0-1 4	50-79	55-64	65-74	35-39	150-190	0 8-0 9
Class C	>1 5	>80	>65	>75	>40	>200	>1 0

Contours of Class C Contamination





Note

1. Contours Based on Vibrocore Surface Levels
2. Contours produced using SURFER

Legend:

3 — Approx 10,000m² Area with Ref. No.

Approx Dredged Slope

-8.0 — Contours in Metres refer to Principal Datum on Existing Seabed Levels

Appendix B.1.5
Grid for Estimation to Total Dredging Volumes

Appendix B.1.6
Estimate of Total Volume of Material to be Dredged

	STONECUTTERS NAVAL BASE ANCHORAGE AREA				
	Estimate of Total Volume of Material to be Dredged				
Section	Area (m2)	Average Sea bed level (mPD)	Dredge Level (mPD)	Thickness Removed (m)	Dredge Volume (m3)
1	10,000	-7.5	-10.5	3	30000
2	10,000	-7.7	-10.5	3	30000
3	10,000	-8.2	-10.5	2.8	28000
4	10,000	-8.2	-11.5	2.3	23000
5	10,000	-8.2	-12.5	3.3	33000
6	10,000	-8	-12.5	4.3	43000
7	6,660	-7.7	-12.5	4.5	29970
8	10,000	-7.5	-10.5	4.8	48000
9	10,000	-7.3	-10.5	3	30000
10	10,000	-8.1	-11	3.2	32000
11	10,000	-8.2	-10.5	2.9	29000
12	10,000	-8.2	-10.5	2.3	23000
13	10,000	-8	-10.5	2.3	23000
14	10,000	-7.8	-10.5	2.5	25000
15	5,000	-7.8	-12.5	2.7	13500
16	10,000	-8	-12.5	4.7	47000
17	10,000	-8	-12.5	4.5	45000
18	10,000	-8	-12.5	4.5	45000
19	10,000	-8.2	-12	4.5	45000
20	10,000	-8.3	-12.5	3.8	38000
21	10,000	-8.1	-12.5	4.2	42000
22	10,000	-8	-12.5	4.4	44000
23	10,000	-8	-11	4.5	45000
24	10,000	-8.2	-10.5	3	30000
25	10,000	-8.2	-10.5	2.3	23000
26	10,000	-8.3	-10.5	2.3	23000
27	10,000	-8.4	-11.5	2.2	22000
28	10,000	-8.4	-10.5	3.1	31000
29	10,000	-8.4	-10.5	2.1	21000
30	10,000	-8.5	-10.5	2.1	21000
31	10,000	-8.5	-12.5	2	20000
32	10,000	-8.2	-12.5	4	40000
33	10,000	-8.3	-12.5	4.3	43000
34	10,000	-8.4	-12.5	4.2	42000
35	10,000	-8.7	-11.5	4.1	41000
36	10,000	-8.7	-12.5	2.8	28000
37	10,000	-8.7	-12.5	3.8	38000
38	10,000	-9	-12.5	3.8	38000
39	10,000	-9.5	-12.5	3.5	35000
40	3,330	-9.2	-12.5	3	9990
41	5,000	-8.4	-10.5	3.3	16500
42	10,000	-8.4	-10.5	2.1	21000
43	10,000	-8.5	-10.5	2.1	21000
44	10,000	-8.7	-10.5	2	20000
45	6,660	-8.8	-12.5	1.8	11988
46	10,000	-9	-12.5	3.7	37000
47	10,000	-9.2	-12.5	3.5	35000
48	10,000	-9.7	-12.5	3.3	33000
49	6,660	-9.7	-12.5	2.8	18648
50	10,000	-8.8	-10.5	2.8	28000
51	10,000	-8.8	-10.5	1.7	17000
52	10,000	-8.8	-10.5	1.7	17000
53	10,000	-9	-11.5	1.7	17000
54	10,000	-9.2	-12.5	2.5	25000
55	10,000	-9.4	-12.5	3.3	33000
56	10,000	-9.7	-12.5	3.1	31000
57	6,660	-9.7	-12.5	2.8	18648
58	8,000	-8.8	-10.5	2.8	22400
59	10,000	-8.8	-10.5	1.7	17000
60	10,000	-8.8	-10.5	1.7	17000
61	10,000	-9	-12.5	1.7	17000
62	10,000	-9.2	-12.5	3.5	35000
63	10,000	-9.5	-12.5	3.3	33000
64	10,000	-9.7	-12.5	3	30000
65	5,000	-9.8	-12.5	2.8	14000
66	10,000	-9.1	-12.5	2.7	27000
67	10,000	-9.4	-12.5	3.4	34000
68	10,000	-9.7	-12.5	3.1	31000
69	10,000	-9.8	-12.5	2.8	28000
70	6,660	-9.9	-12.5	2.7	17982
		Total Dredge Volume for Sections 1 to 70 (m3)			2021626
		Additional Volume From Dredging of Side Slopes			295,500
		Total volume of dredged material (m3)			2317126

Appendix B.1.7
Estimate of Total Volume of Contaminated Material to be Dredged

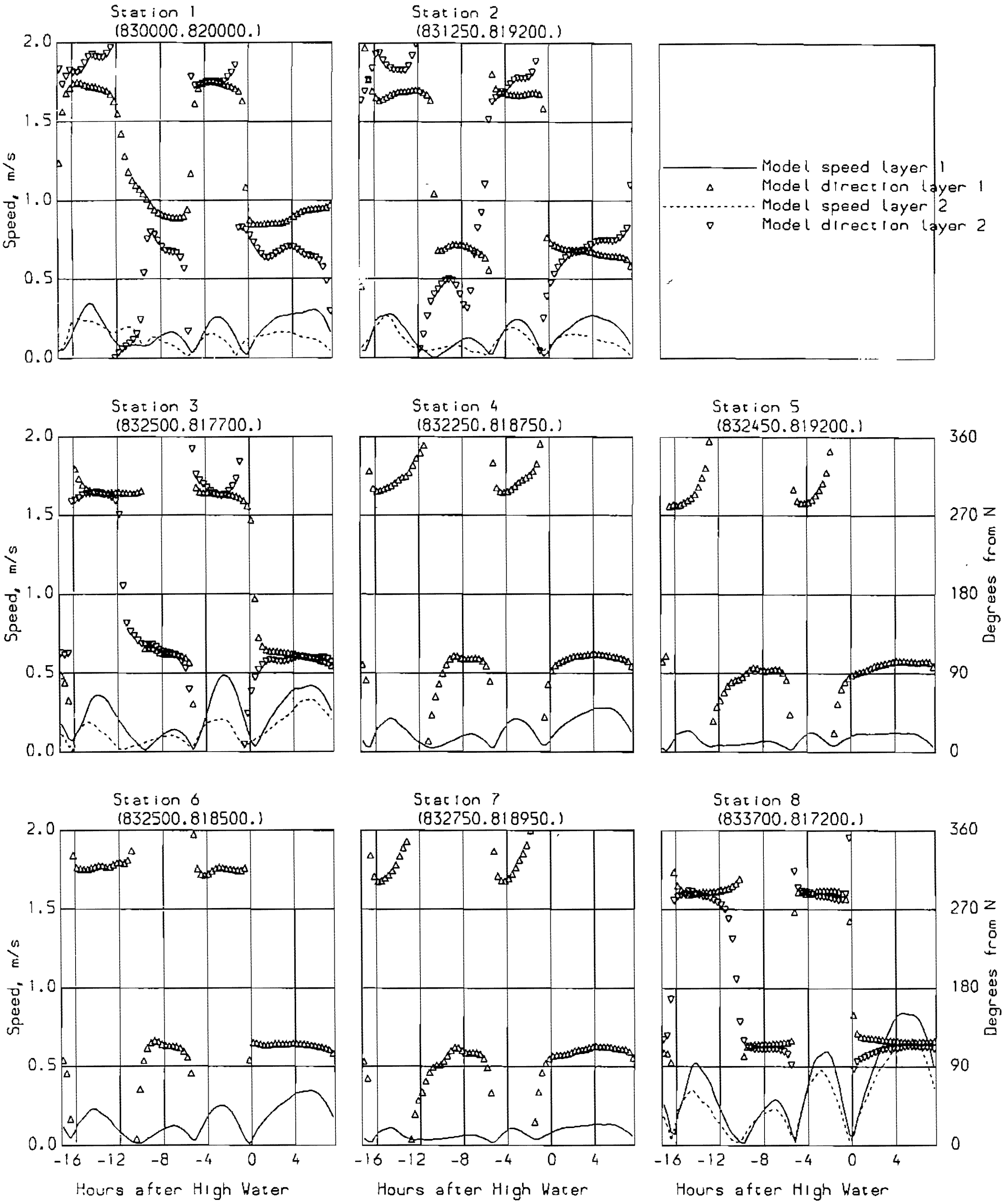
	STONECUTTERS NAVAL BASE ANCHORAGE AREA					
	Estimate of Total Volume of Contaminated Material to be Dredged					
					Thickness	Contaminated
	Section	Area (m2)	Average Seabed Level	Base of Class C Contamination	Contam. Mud	Dredge Volume
			(mPD)	(mPD)	Removed (m)	(m3)
	1	10,000	-7.5	-7.7	0	0
	2	10,000	-7.7	-7.9	0.2	2000
	3	10,000	-8.2	-8.7	0.5	5000
	4	10,000	-8.2	-9	0.8	8000
	5	10,000	-8.2	-8.4	0.2	2000
	6	10,000	-8	-8.2	0.2	2000
	7	6,660	-7.7	-8.8	1.1	7326
	8	10,000	-7.5	-8.6	1.1	11000
	9	10,000	-7.3	-8.9	1.6	16000
	10	10,000	-8.1	-8.9	0.8	8000
	11	10,000	-8.2	-9.2	1	10000
	12	10,000	-8.2	-10.7	2.5	25000
	13	10,000	-8	-8.5	0.5	5000
	14	10,000	-7.8	-8	0.2	2000
	15	5,000	-7.8	-8	0.2	1000
	16	10,000	-8	-9.7	1.7	17000
	17	10,000	-8	-9.7	1.7	17000
	18	10,000	-8	-9.7	1.7	17000
	19	10,000	-8.2	-9.5	1.3	13000
	20	10,000	-8.3	-9.5	1.2	12000
	21	10,000	-8.1	-8.9	0.8	8000
	22	10,000	-8	-8.8	0.8	8000
	23	10,000	-8	-9.1	1.1	11000
	24	10,000	-8.2	-10.4	2.2	22000
	25	10,000	-8.2	-10.7	2.5	25000
	26	10,000	-8.3	-10.5	2.2	22000
	27	10,000	-8.4	-10.2	1.8	18000
	28	10,000	-8.4	-10	1.6	16000
	29	10,000	-8.4	-9.6	1.2	12000
	30	10,000	-8.5	-9.6	1.1	11000
	31	10,000	-8.5	-10	1.5	15000
	32	10,000	-8.2	-10.2	2	20000
	33	10,000	-8.3	-10.2	1.9	19000
	34	10,000	-8.4	-10	1.6	16000
	35	10,000	-8.7	-10.4	1.7	17000
	36	10,000	-8.7	-10.7	2	20000
	37	10,000	-8.7	-10.4	1.7	17000
	38	10,000	-9	-10.8	1.8	18000
	39	10,000	-9.5	-11.7	2.2	22000
	40	3,330	-9.2	-10.4	1.2	3996
	41	5,000	-8.4	-9.8	1.4	7000
	42	10,000	-8.4	-9.9	1.5	15000
	43	10,000	-8.5	-9.6	1.1	11000
	44	10,000	-8.7	-10.6	1.9	19000
	45	6,660	-8.8	-11.4	2.6	17316
	46	10,000	-9	-11.4	2.4	24000
	47	10,000	-9.2	-11.8	2.6	26000
	48	10,000	-9.7	-12.4	2.7	27000
	49	6,660	-9.7	-12.7	3	19980
	50	10,000	-8.8	-9.8	1	10000
	51	10,000	-8.8	-10.4	1.6	16000
	52	10,000	-8.8	-10.2	1.4	14000
	53	10,000	-9	-11.2	2.2	22000
	54	10,000	-9.2	-12.2	3	30000
	55	10,000	-9.4	-11.8	2.4	24000
	56	10,000	-9.7	-12.4	2.7	27000
	57	6,660	-9.7	-12.2	2.5	16650
	58	8,000	-8.8	-9.7	0.9	7200
	59	10,000	-8.8	-9.7	0.9	9000
	60	10,000	-8.8	-10	1.2	12000
	61	10,000	-9	-10	1	10000
	62	10,000	-9.2	-10.6	1.4	14000
	63	10,000	-9.5	-11.2	1.7	17000
	64	10,000	-9.7	-11.7	2	20000
	65	5,000	-9.8	-11.9	2.1	10500
	66	10,000	-9.1	-9.5	0.4	4000
	67	10,000	-9.4	-9.6	0.2	2000
	68	10,000	-9.7	-10.6	0.9	9000
	69	10,000	-9.8	-11.2	1.4	14000
	70	6,660	-9.9	-10.7	0.8	5328
	Total Dredge Volume (Contaminated Mud) for Sections 1 to 70 (m3)					961296
	Additional Volume of Contaminated Mud From Dredging of Side Slopes (Shaded Area)					210,000
			Total volume of Contaminated Mud to be Dredged (m3)			1171296

APPENDIX G

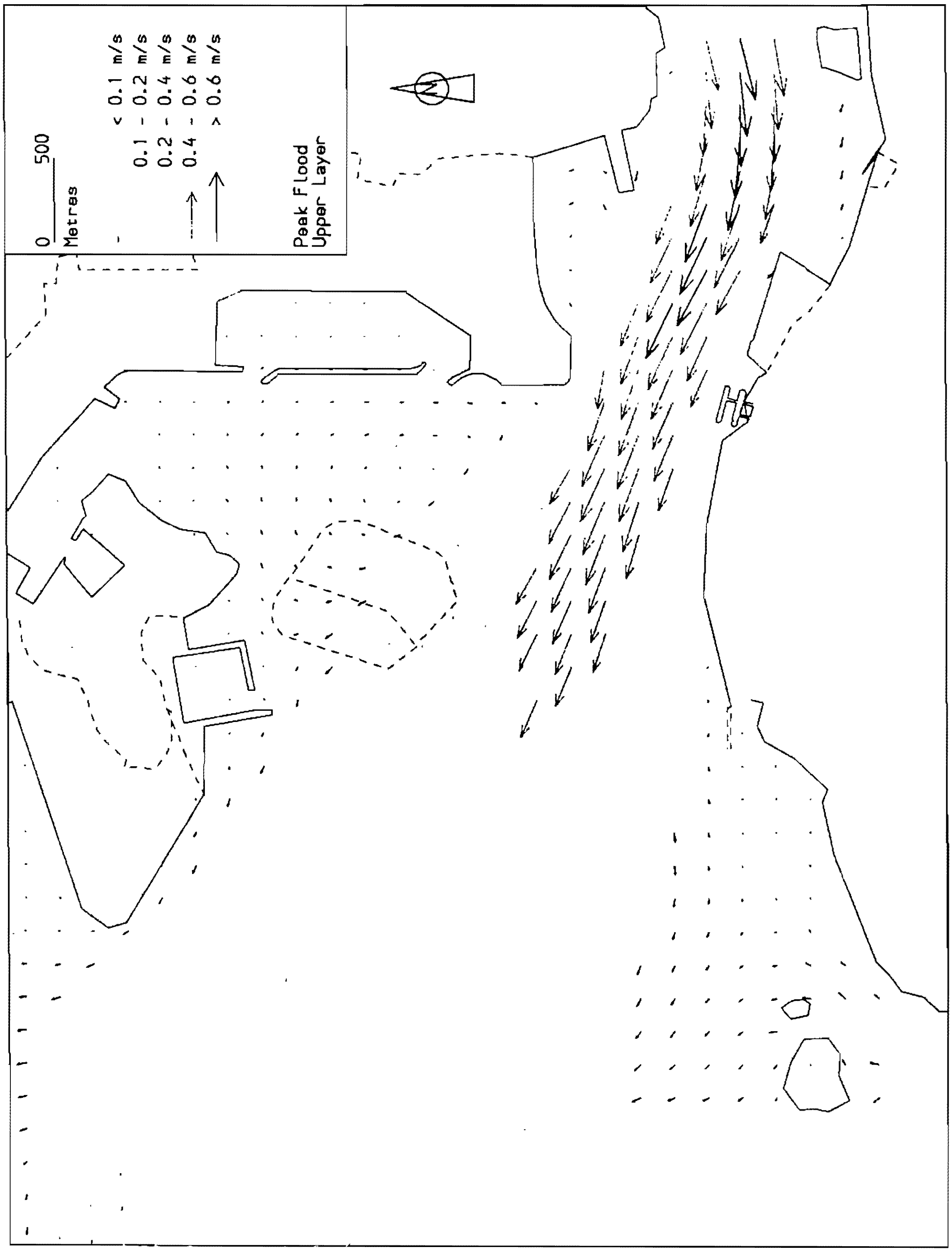
Tidal Flow Model Results : Baseline Scenario

WET SEASON SPRING TIDE

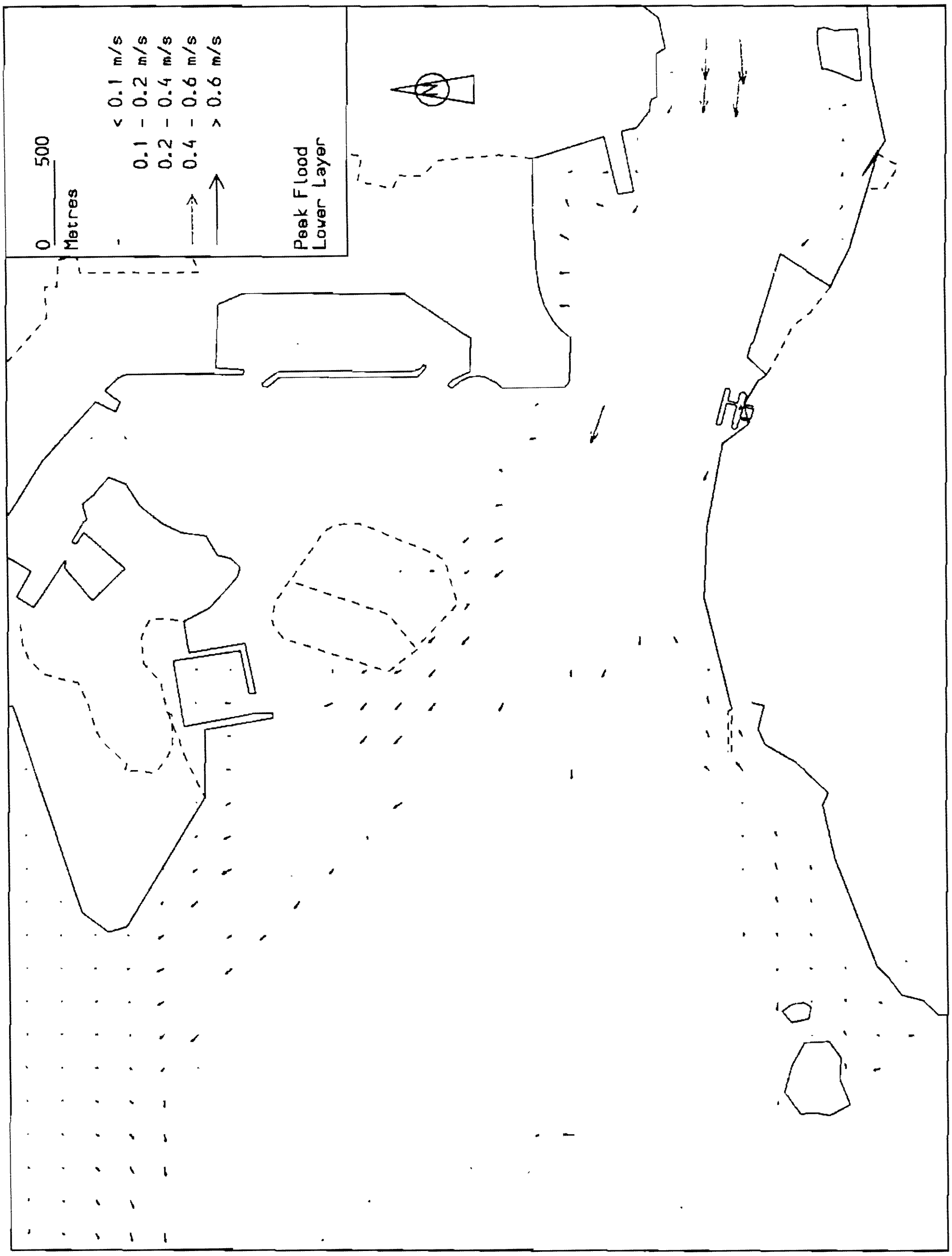
G



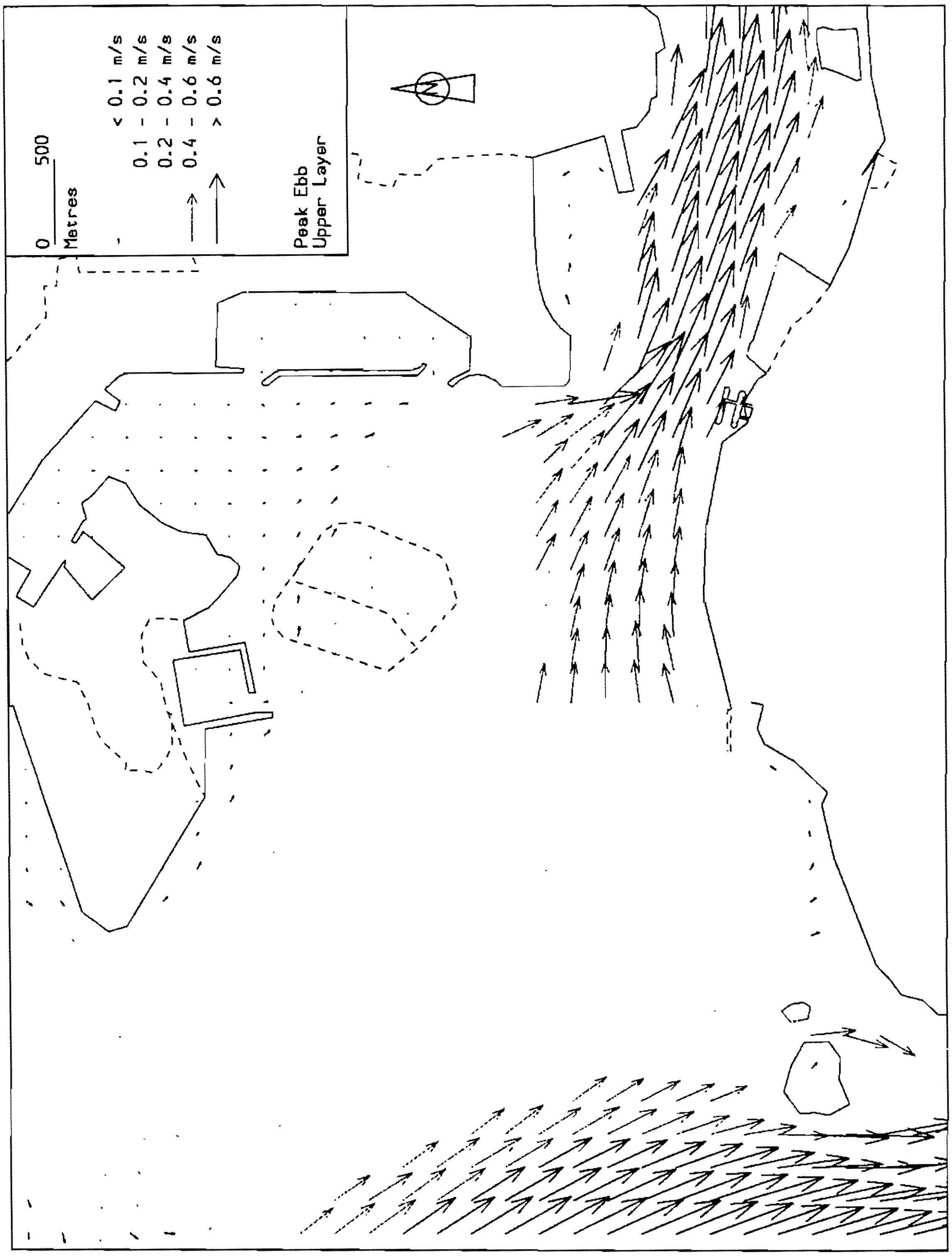
Stonecutters Naval Base Anchorage Area
Baseline Scenario
Current Speed & Direction
Wet Season Spring Tide



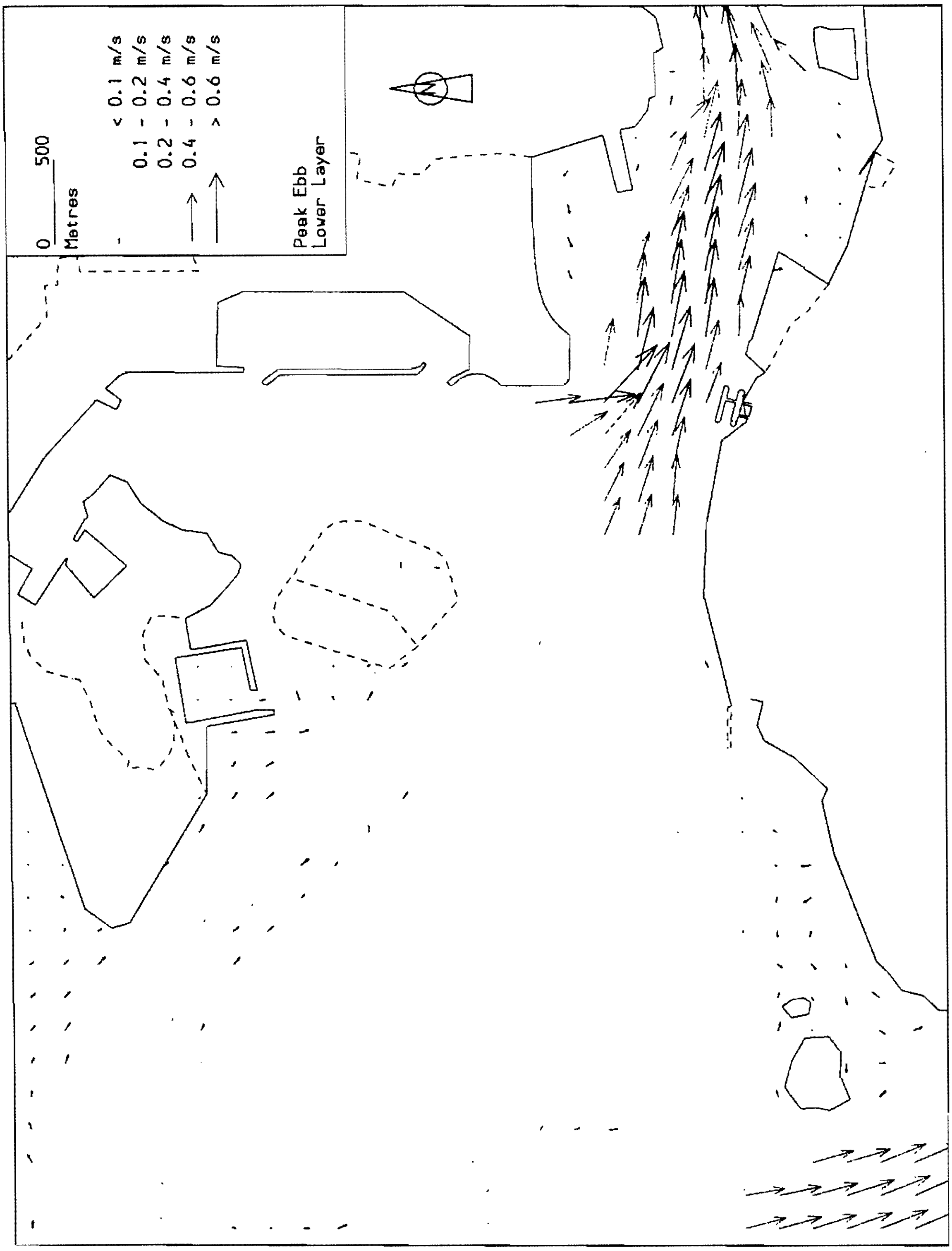
Stonecutters Naval Base Anchorage Area
Baseline Scenario
Velocity Vectors
Wet Season Spring Tide



Stonecutters Naval Base Anchorage Area
Baseline Scenario
Velocity Vectors
Wet Season Spring Tide

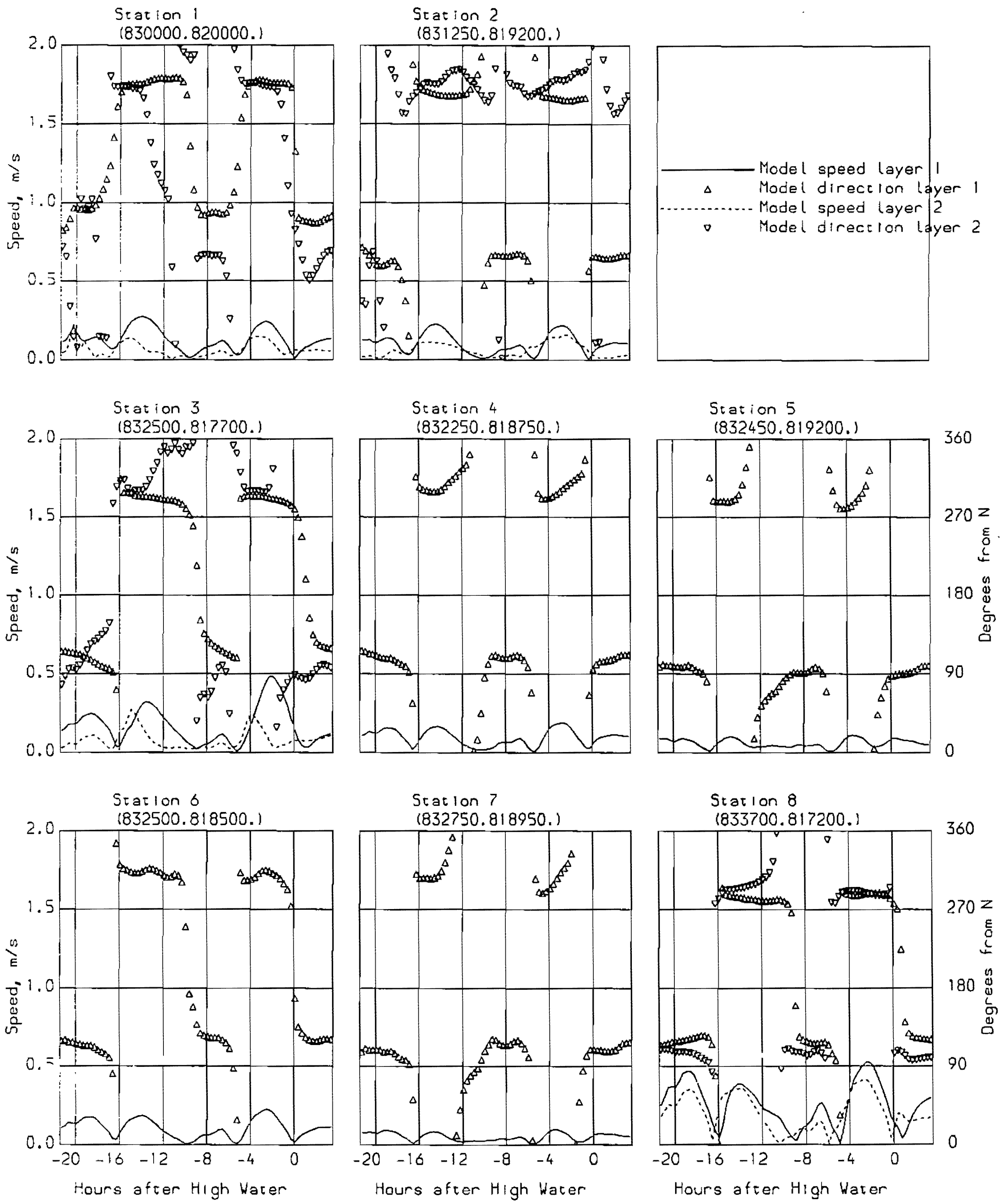


Stonecutters Naval Base Anchorage Area
Baseline Scenario
Velocity Vectors
Wet Season Spring Tide

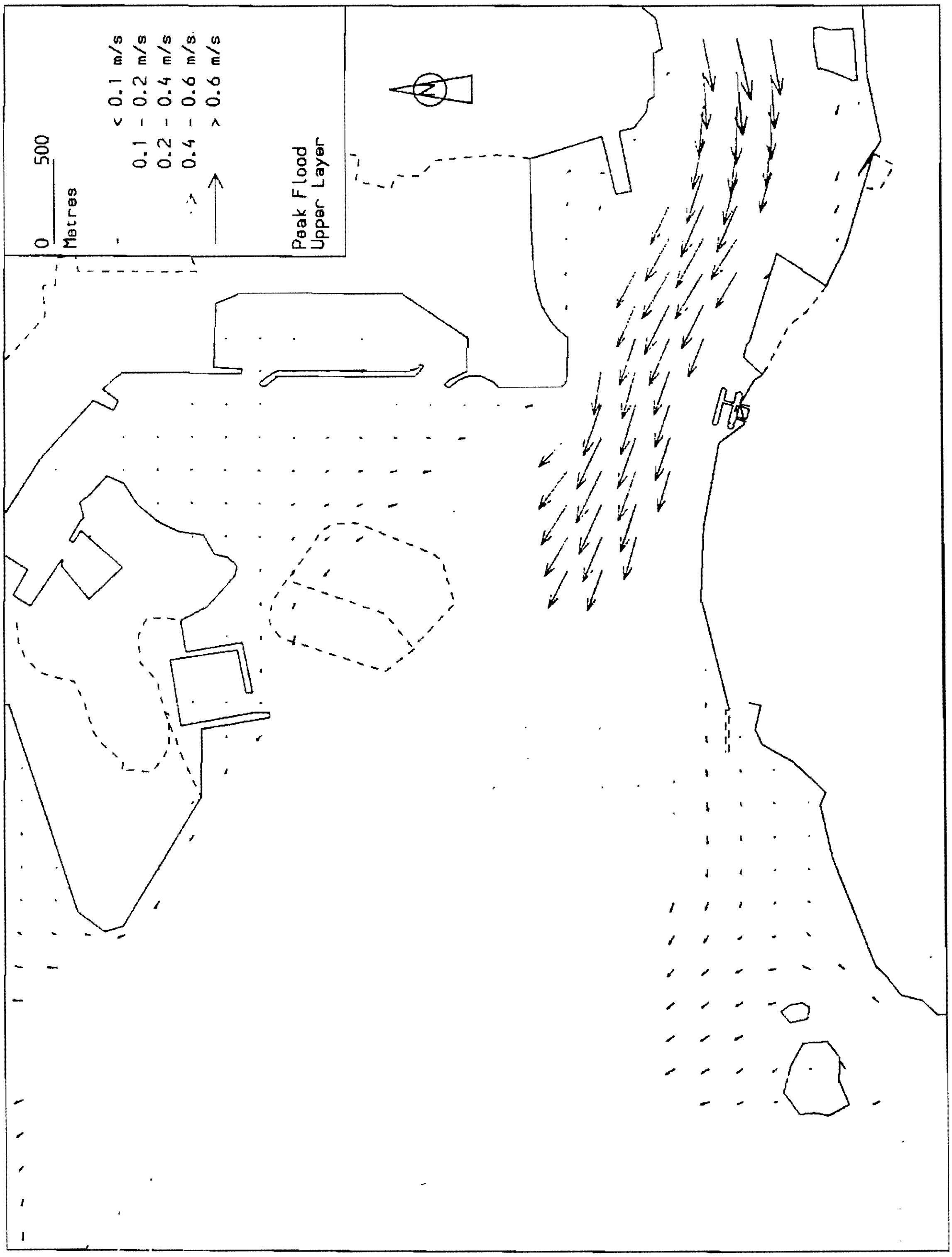


Stonecutters Naval Base Anchorage Area
Baseline Scenario
Velocity Vectors
Wet Season Spring Tide

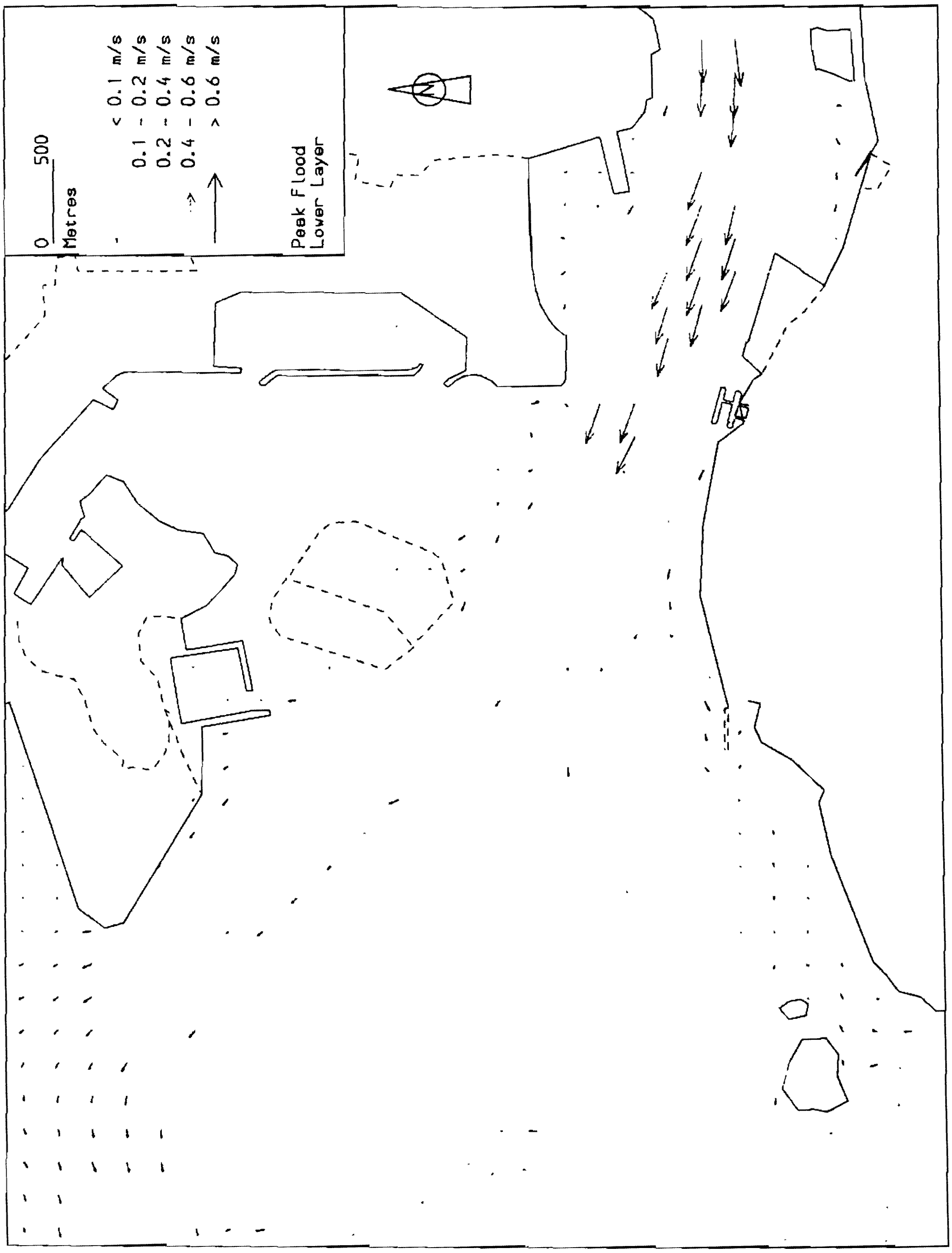
WET SEASON NEAP TIDE



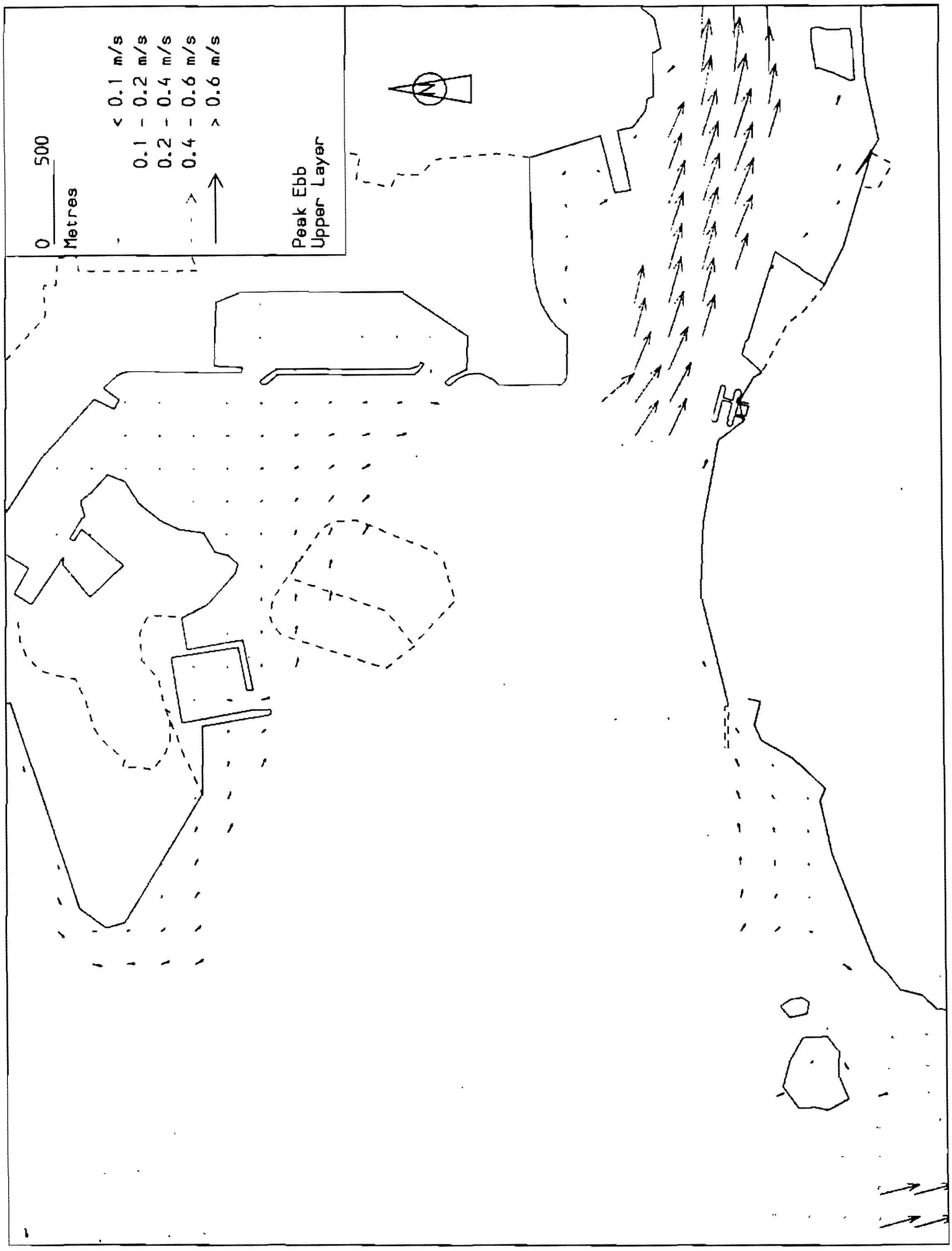
Stonecutters Naval Base Anchorage Area
Baseline Scenario
Current Speed & Direction
Wet Season Neap Tide



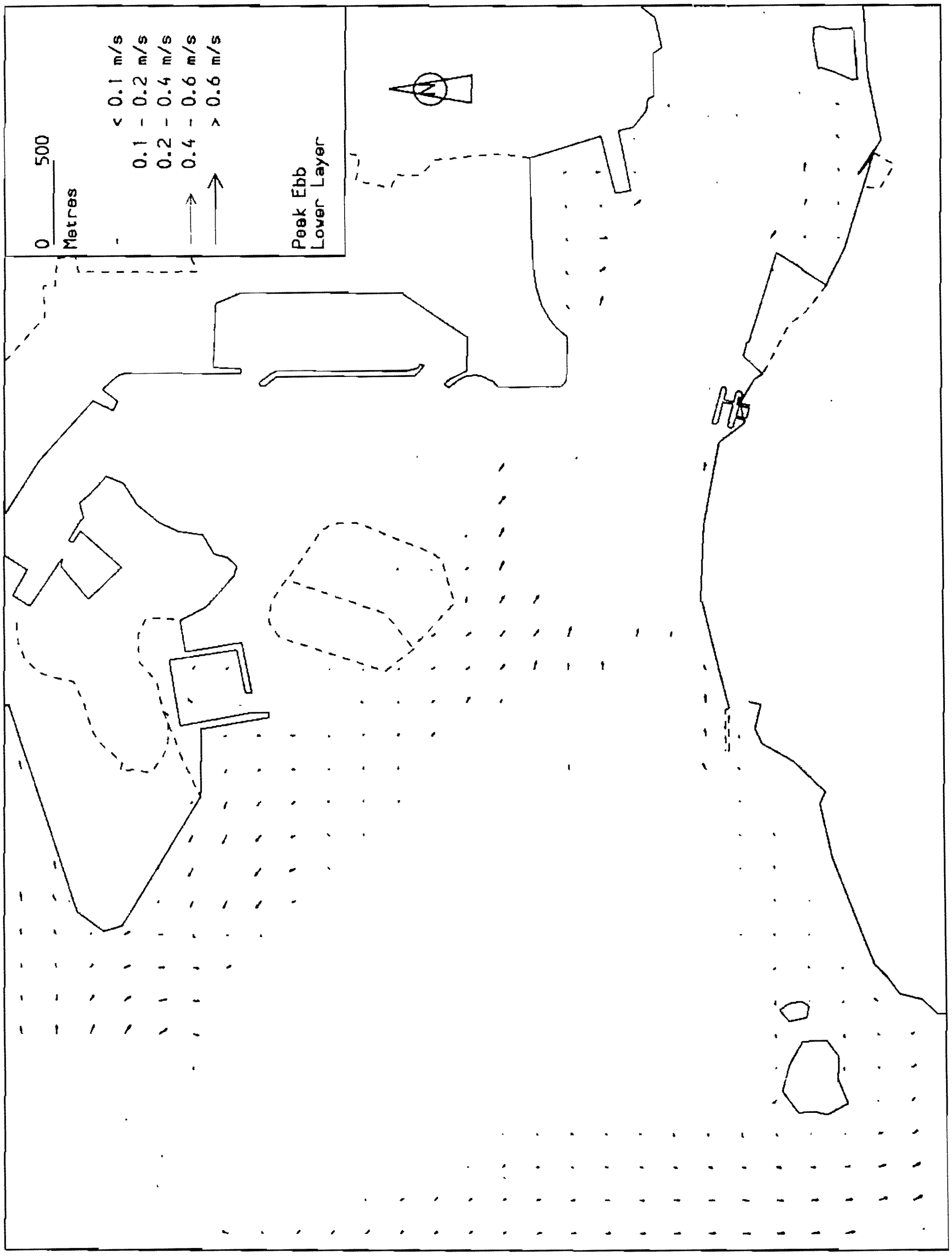
Stonecutters Naval Base Anchorage Area
Baseline Scenario
Velocity Vectors
Wet Season Neap Tide



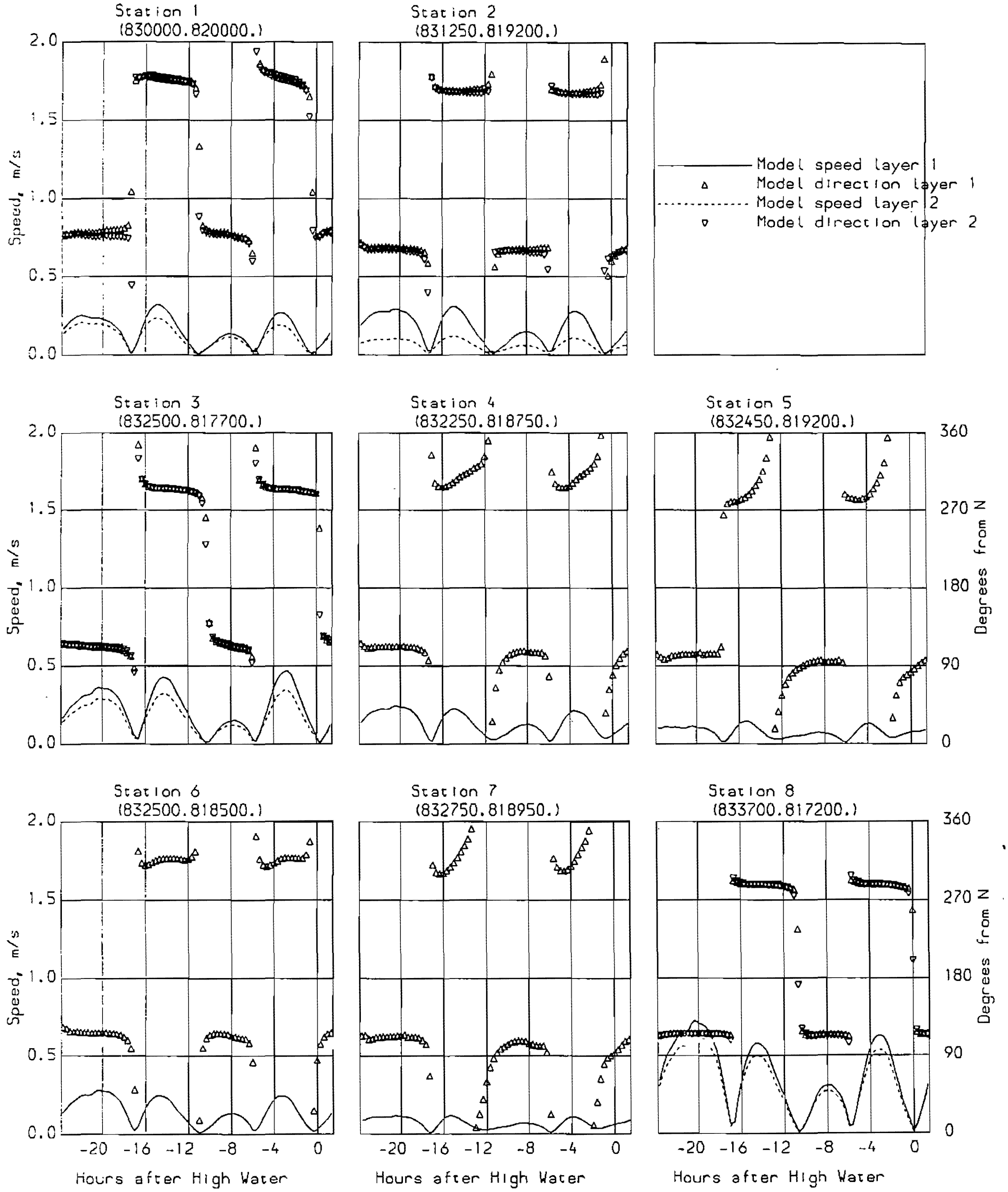
Stonecutters Naval Base Anchorage Area
Baseline Scenario
Velocity Vectors
Wet Season Neap Tide



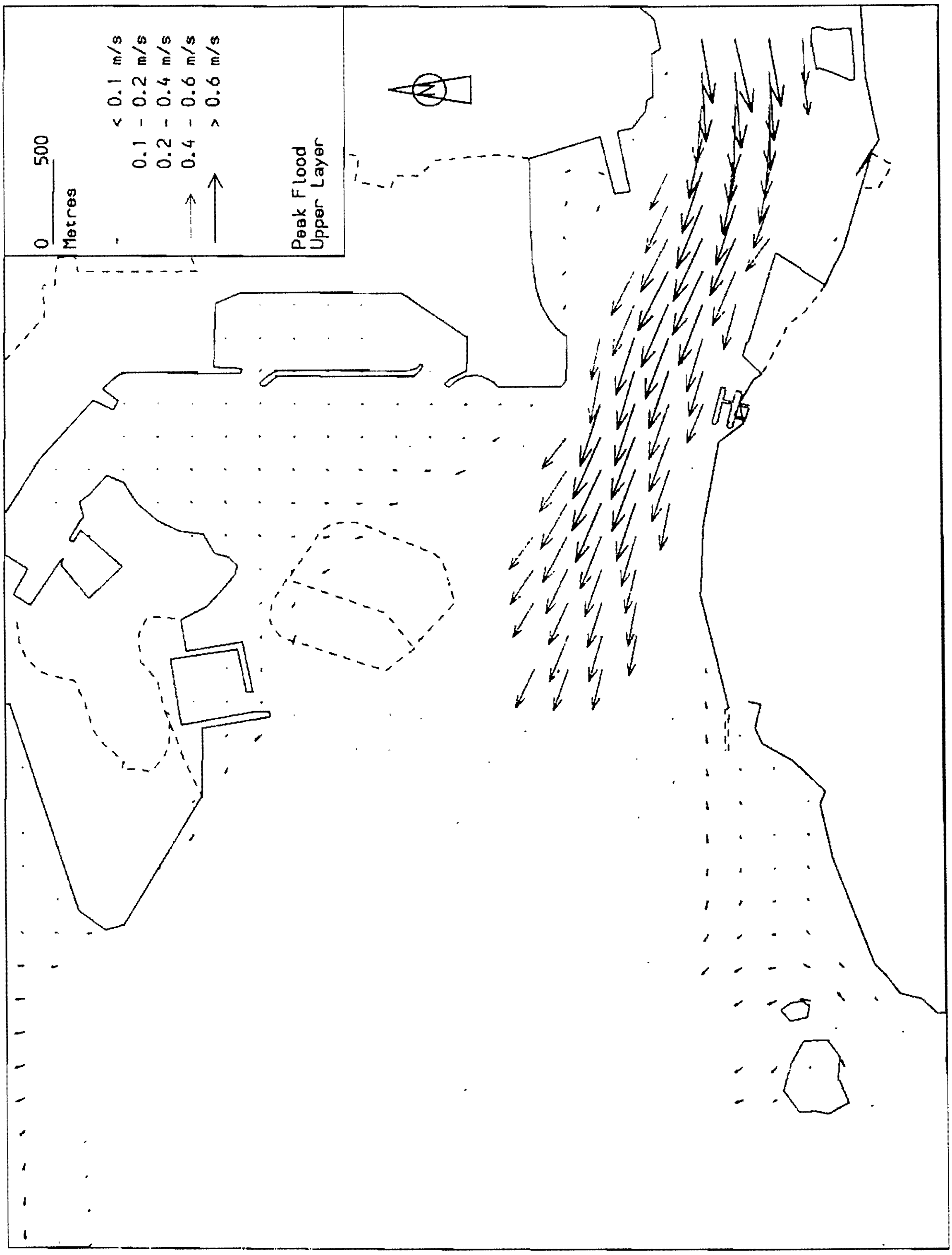
Stonecutters Naval Base Anchorage Area
Baseline Scenario
Velocity Vectors
Wet Season Neap Tide



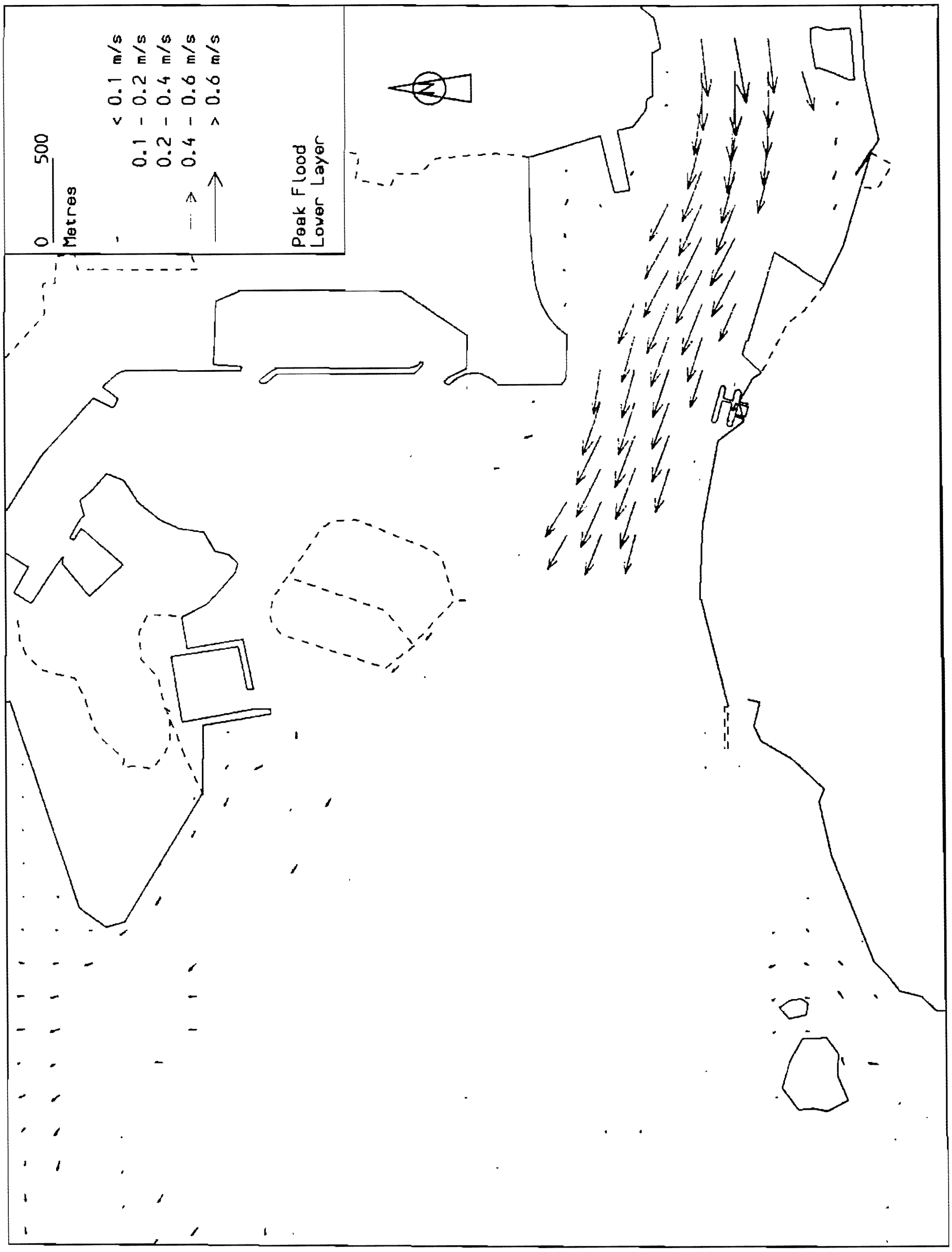
Stonecutters Naval Base Anchorage Area
Baseline Scenario
Velocity Vectors
Wet Season Neap Tide



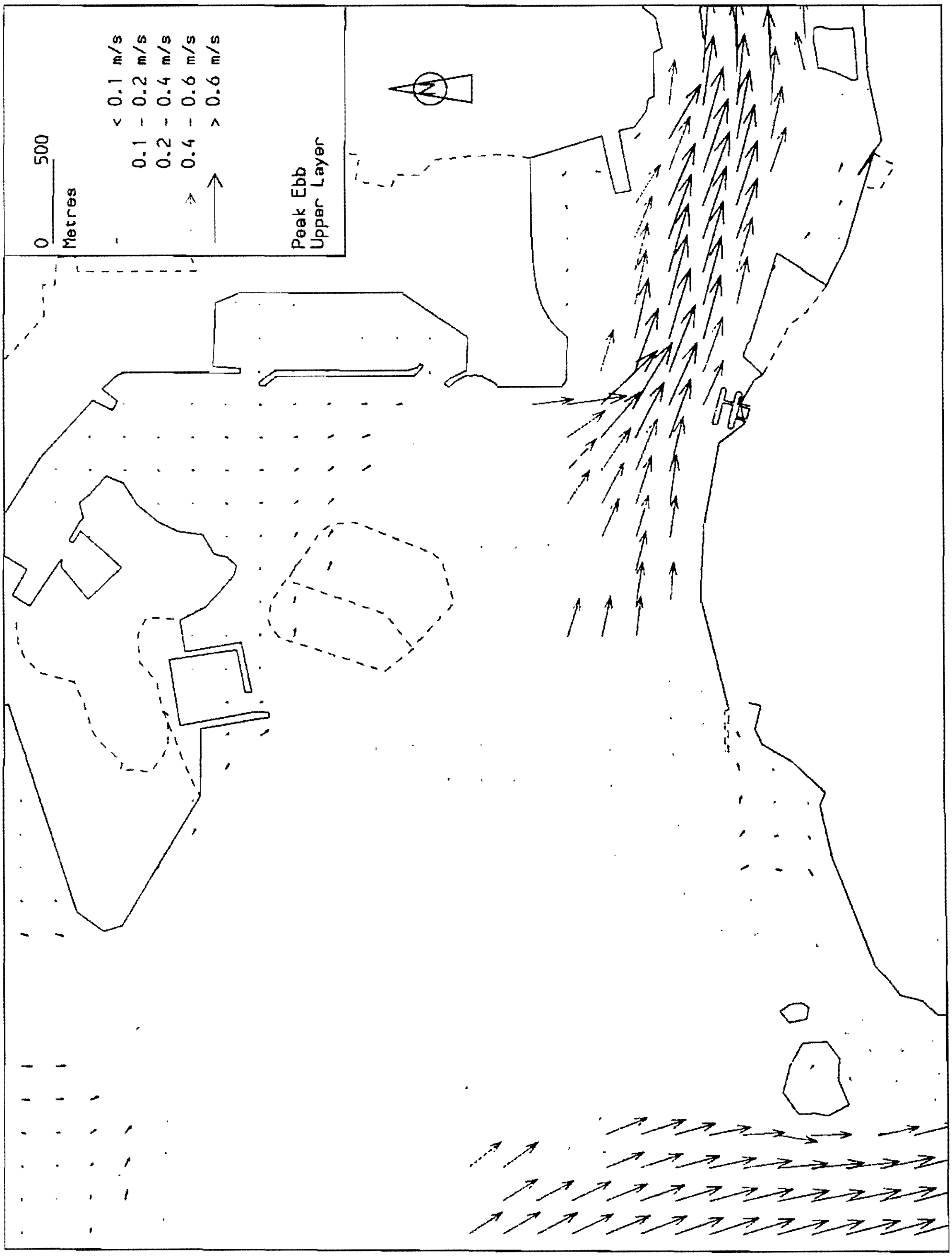
Stonecutters Naval Base Anchorage Area
Baseline Scenario
Current Speed & Direction
Dry Season Spring Tide



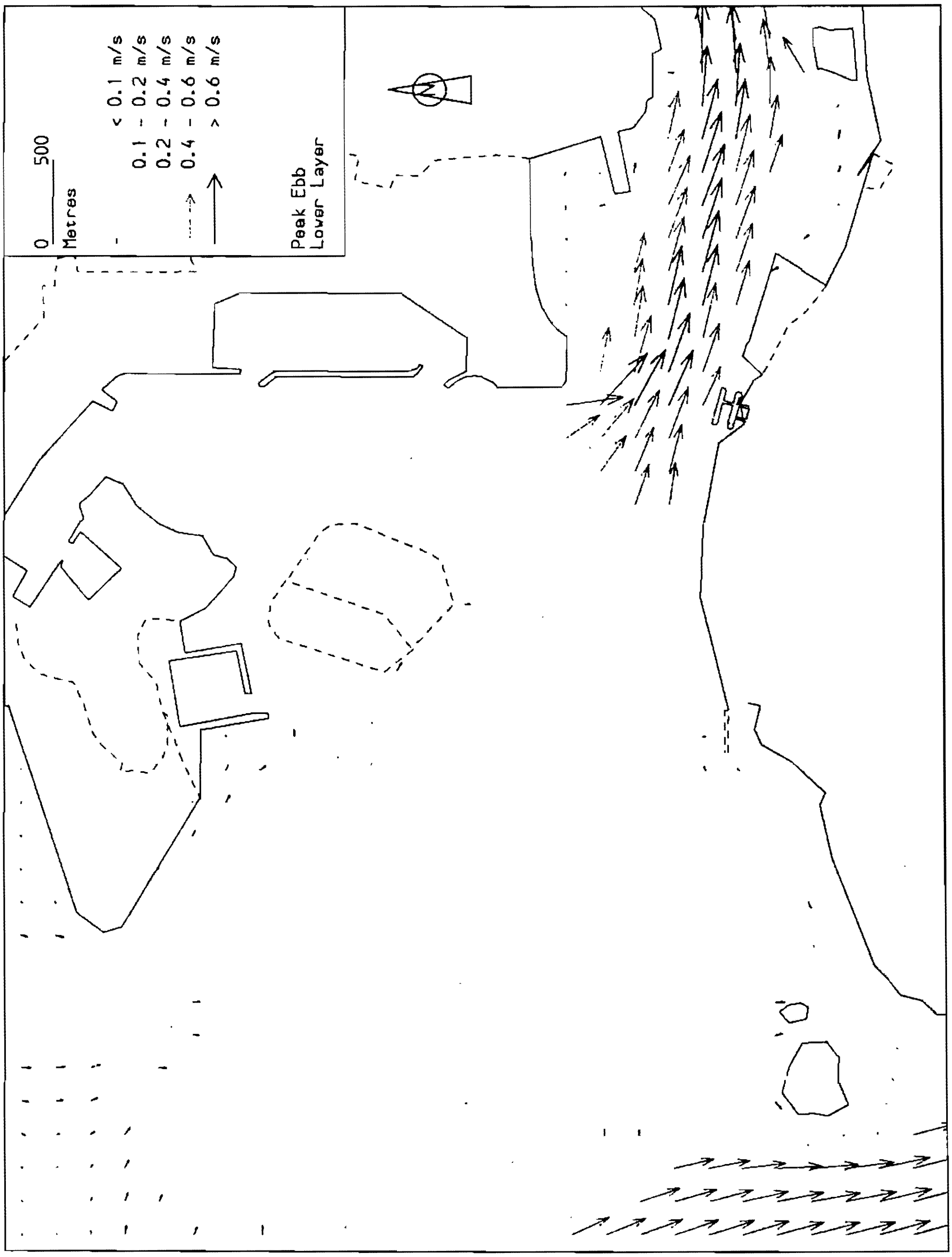
Stonecutters Naval Base Anchorage Area
Baseline Scenario
Velocity Vectors
Dry Season Spring Tide



Stonecutters Naval Base Anchorage Area
Baseline Scenario
Velocity Vectors
Dry Season Spring Tide

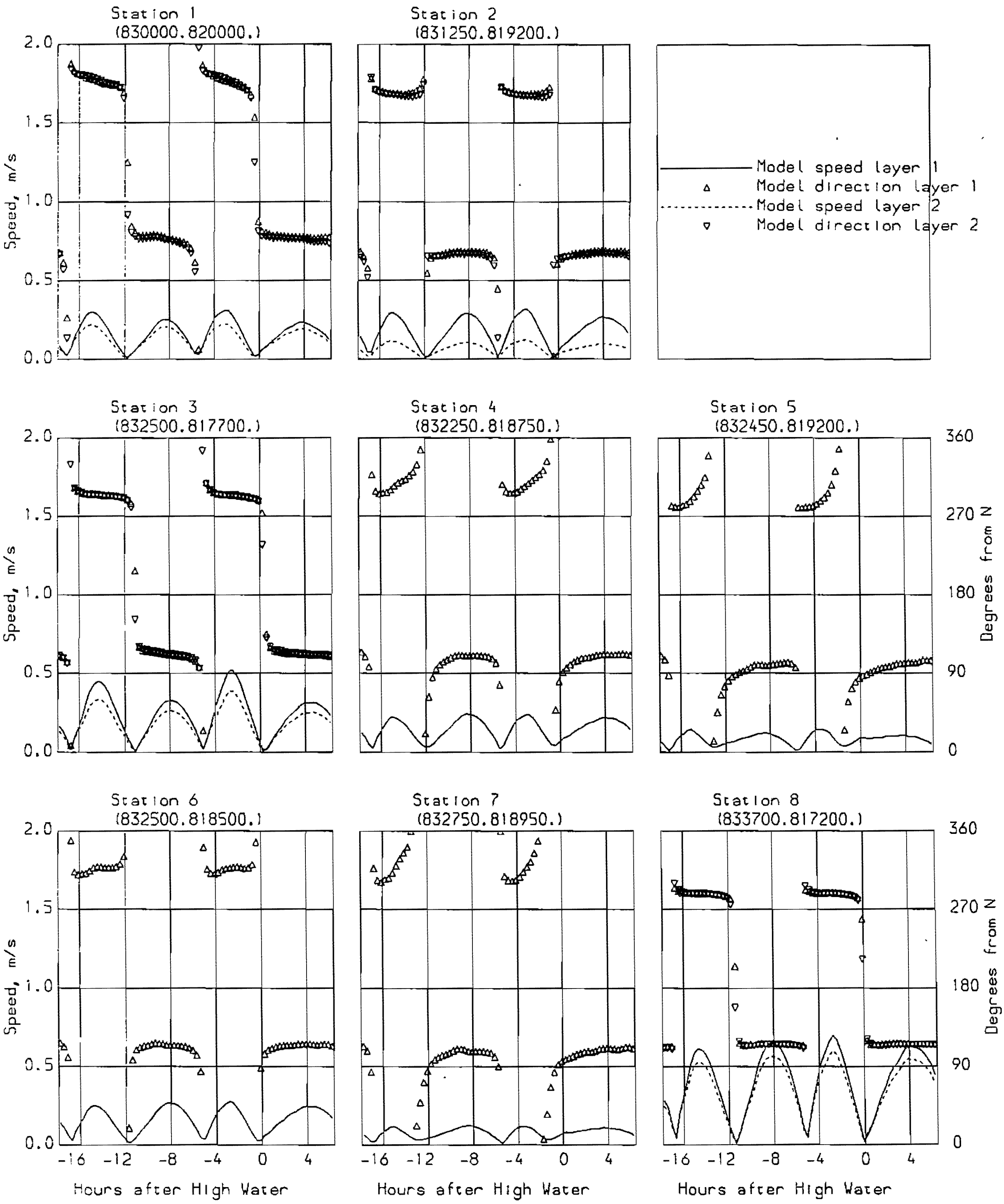


Stonecutters Naval Base Anchorage Area
Baseline Scenario
Velocity Vectors
Dry Season Spring Tide

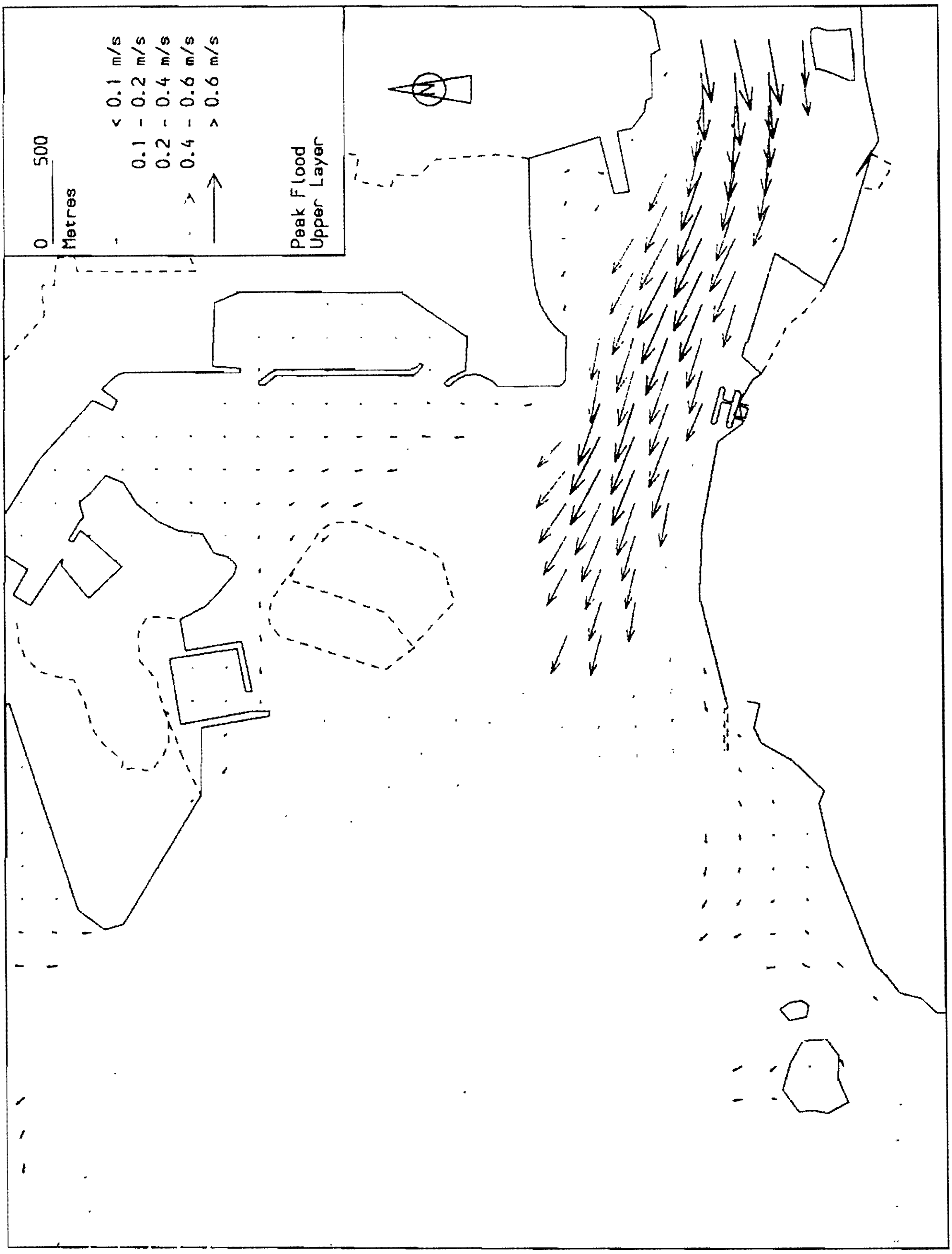


Stonecutters Naval Base Anchorage Area
Baseline Scenario
Velocity Vectors
Dry Season Spring Tide

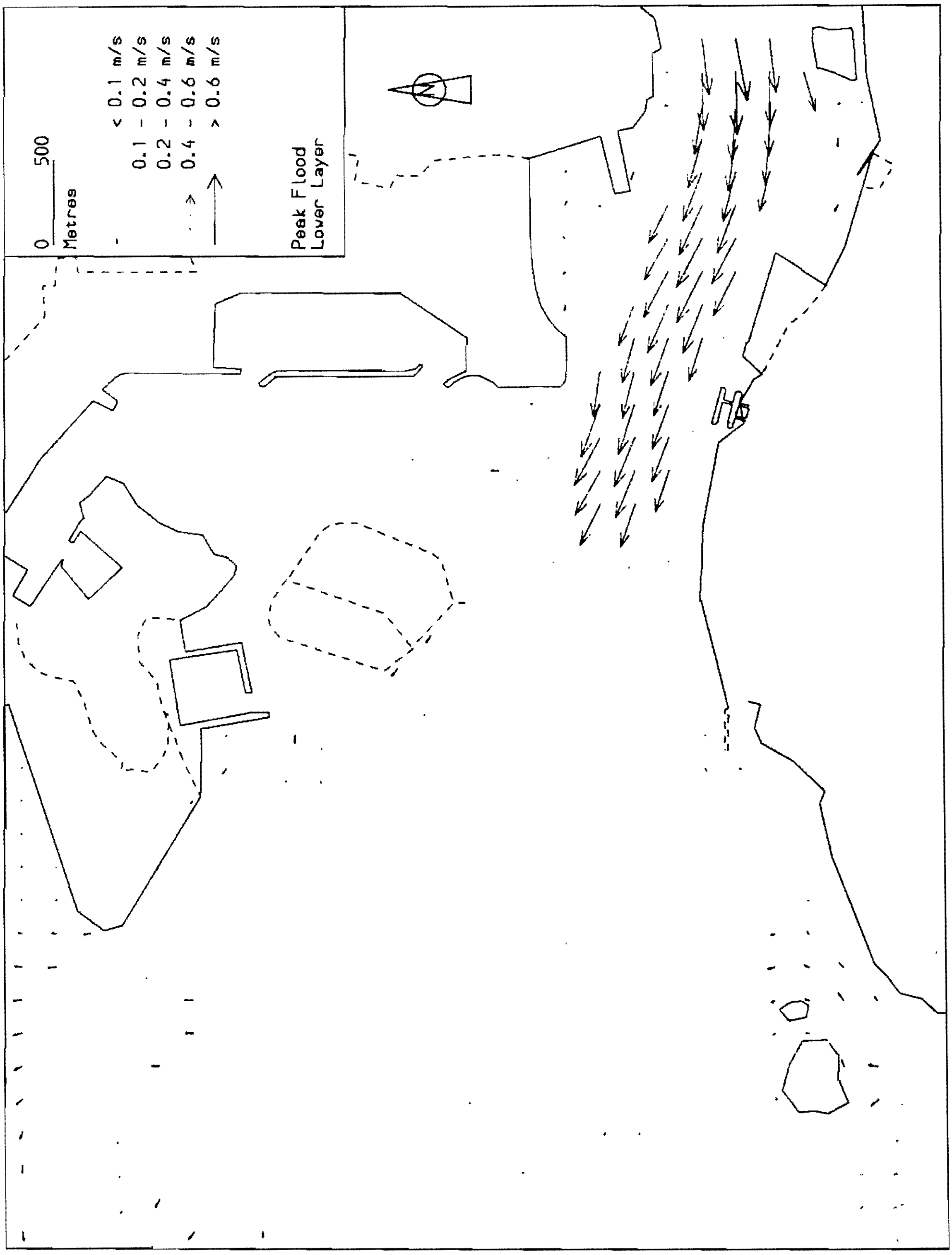
DRY SEASON NEAP TIDE



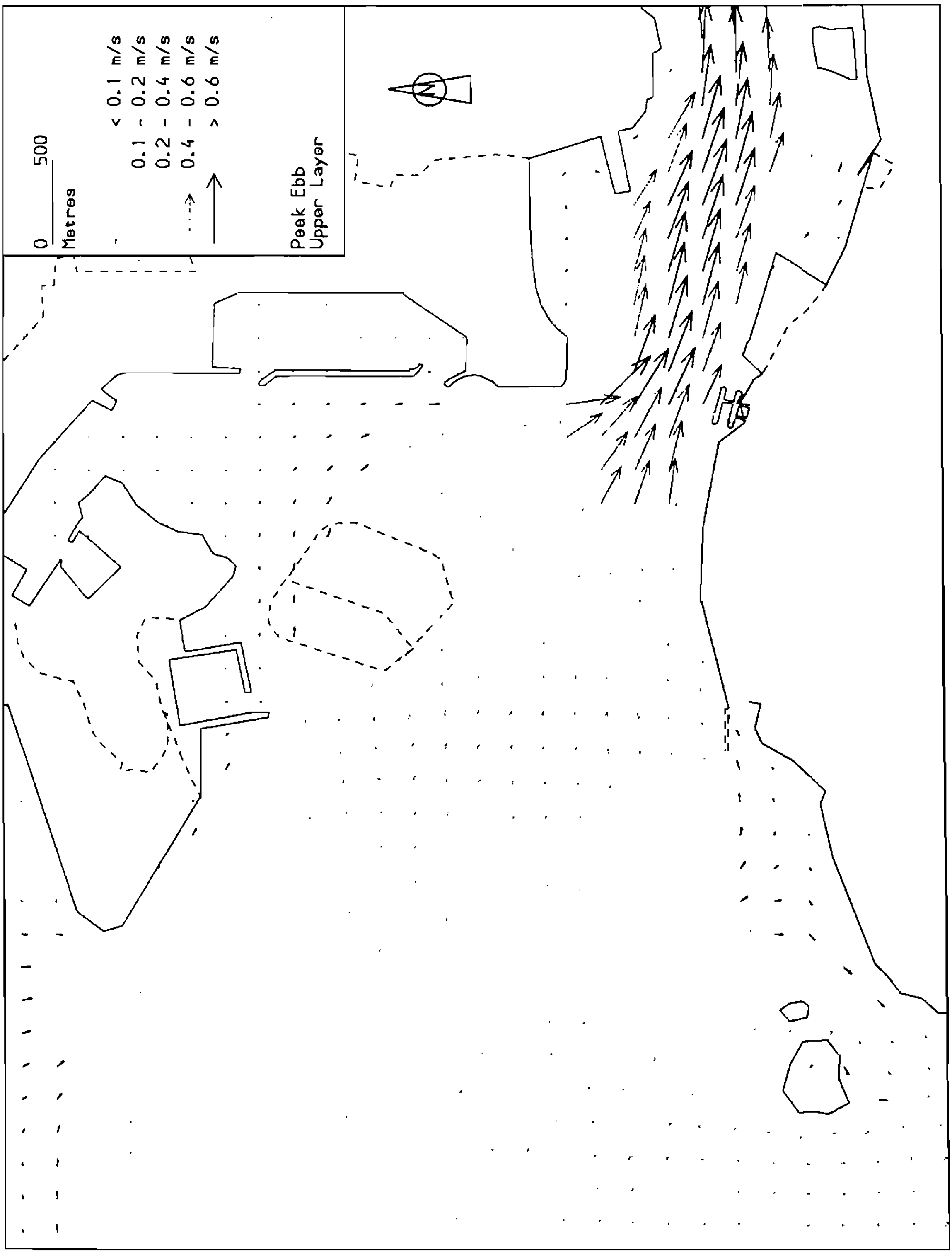
Stonecutters Naval Base Anchorage Area
Baseline Scenario
Current Speed & Direction
Dry Season Neap Tide



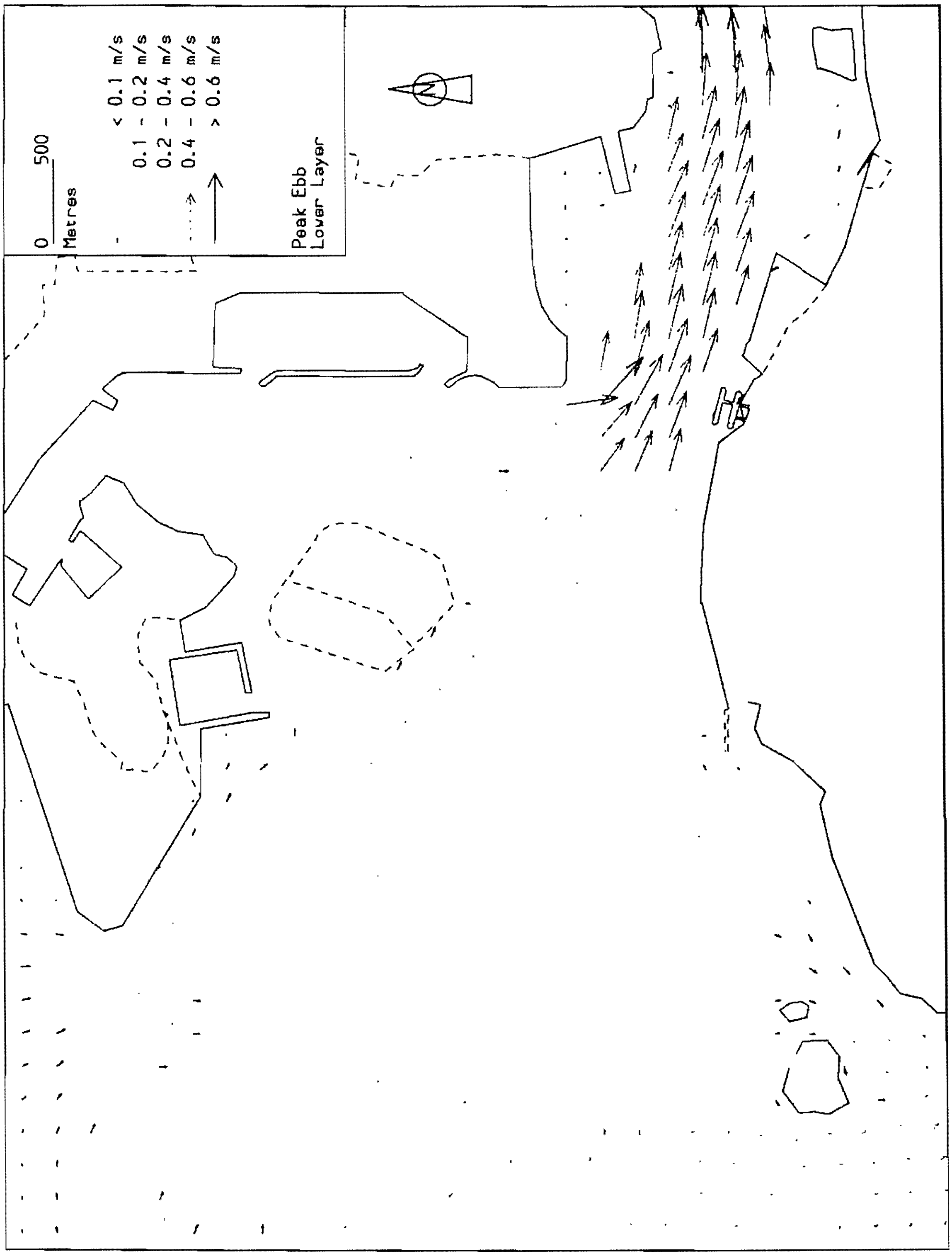
Stonecutters Naval Base Anchorage Area
Baseline Scenario
Velocity Vectors
Dry Season Neap Tide



Stonecutters Naval Base Anchorage Area
Baseline Scenario
Velocity Vectors
Dry Season Neap Tide



Stonecutters Naval Base Anchorage Area
Baseline Scenario
Velocity Vectors
Dry Season Neap Tide

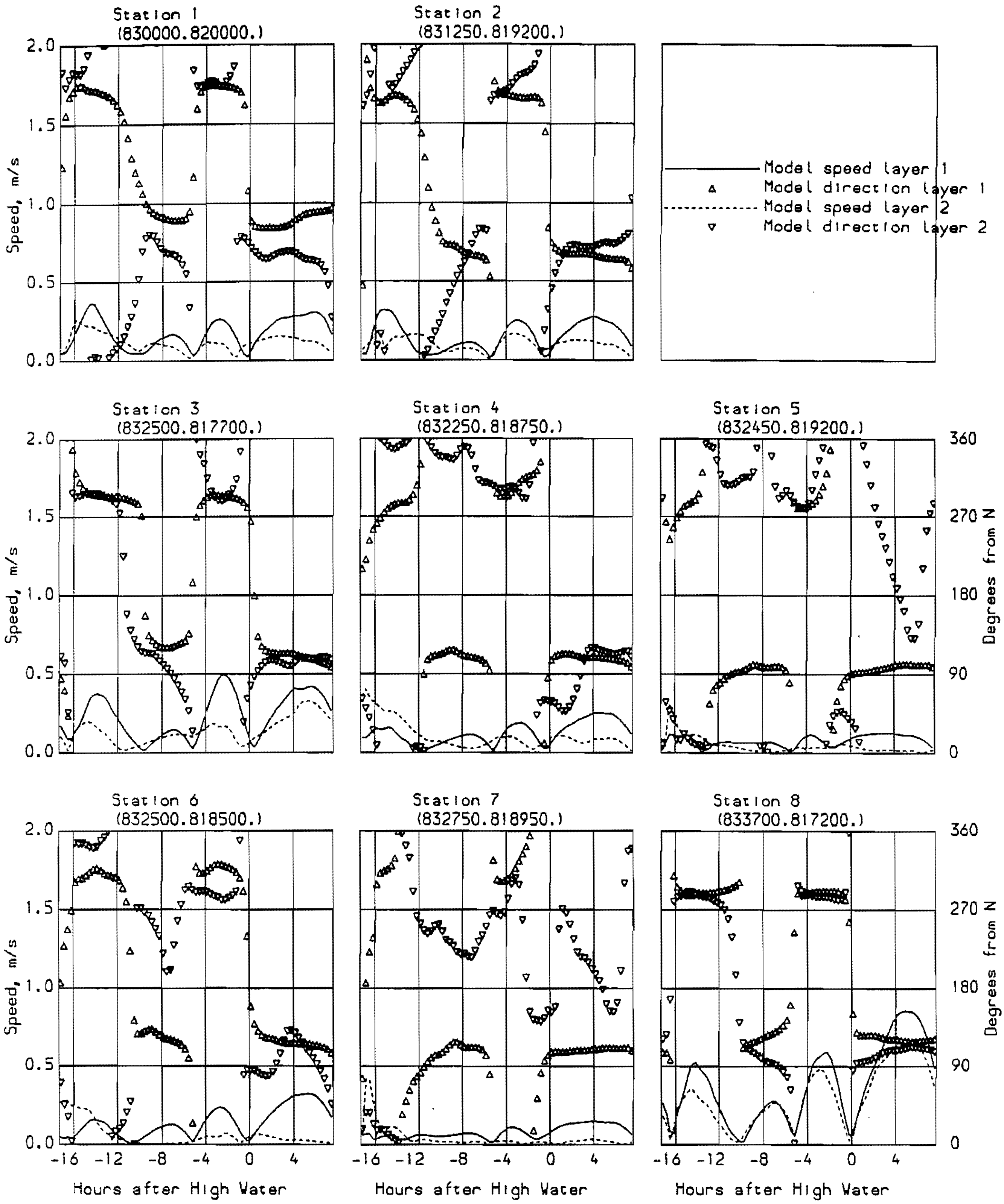


Stonecutters Naval Base Anchorage Area
Baseline Scenario
Velocity Vectors
Dry Season Neap Tide

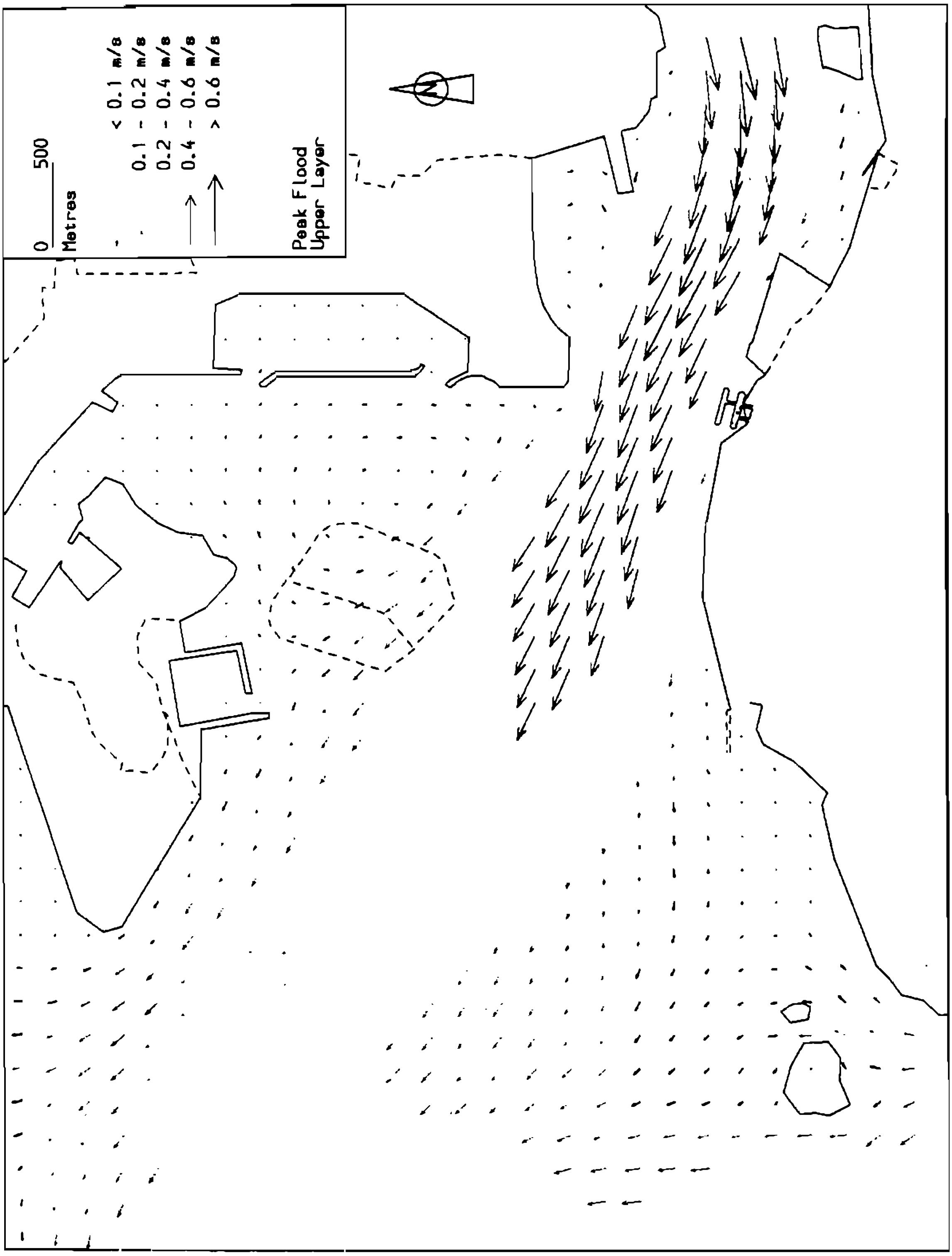
APPENDIX H

Tidal Flow Model Results : Completed Scenario

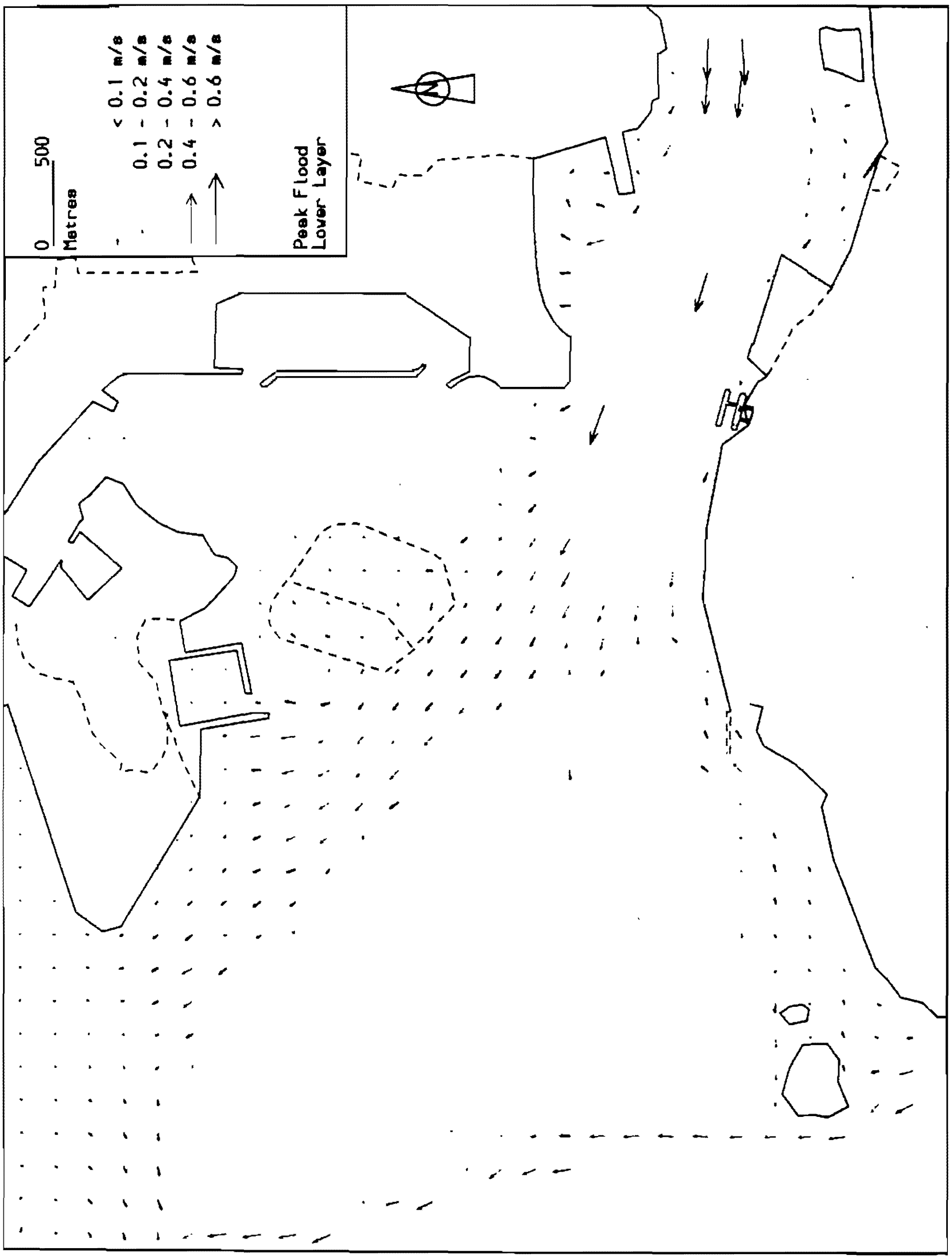
WET SEASON SPRING TIDE



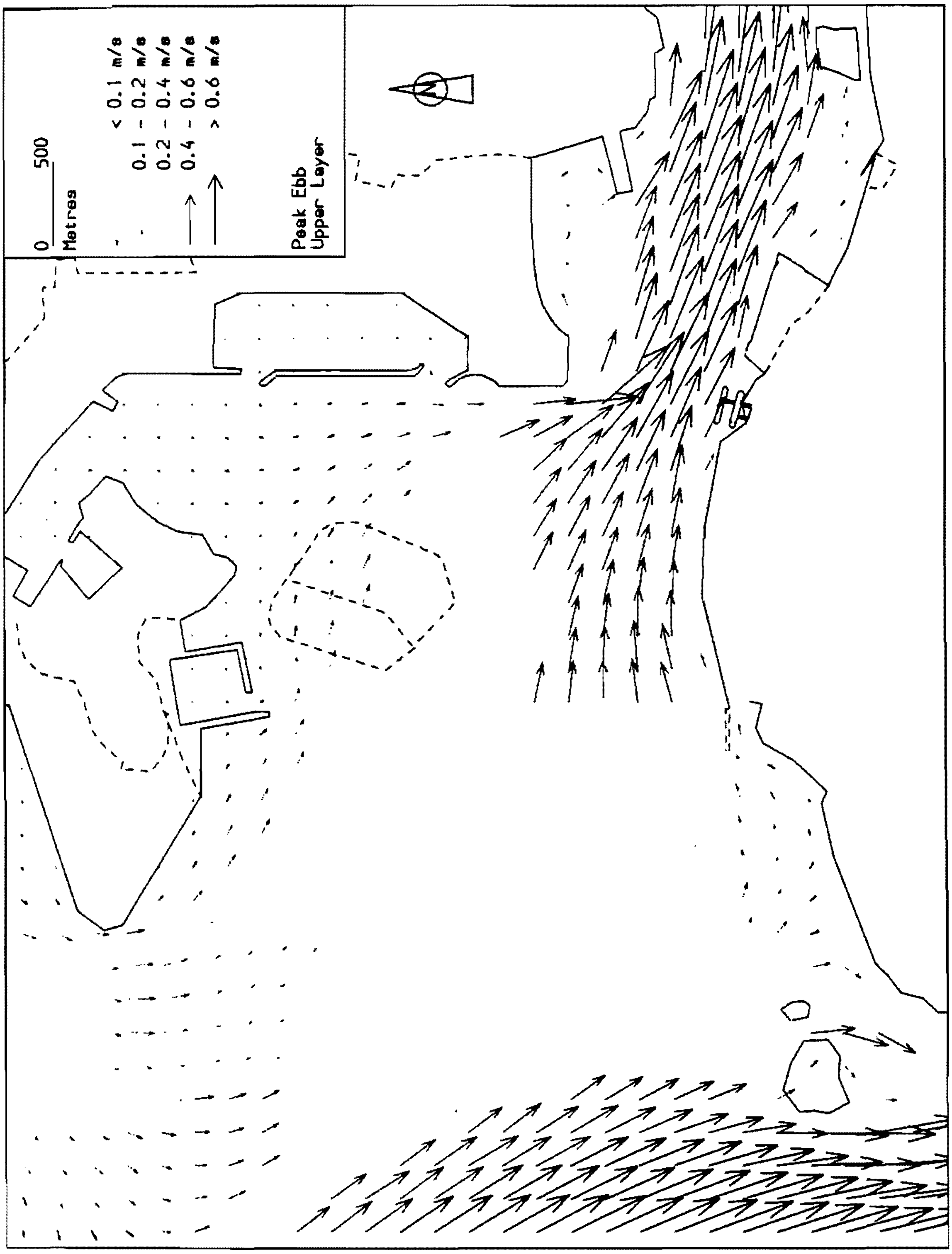
Stonecutters Naval Base Anchorage Area
Completed Scenario
Current Speed & Direction
Wet Season Spring Tide



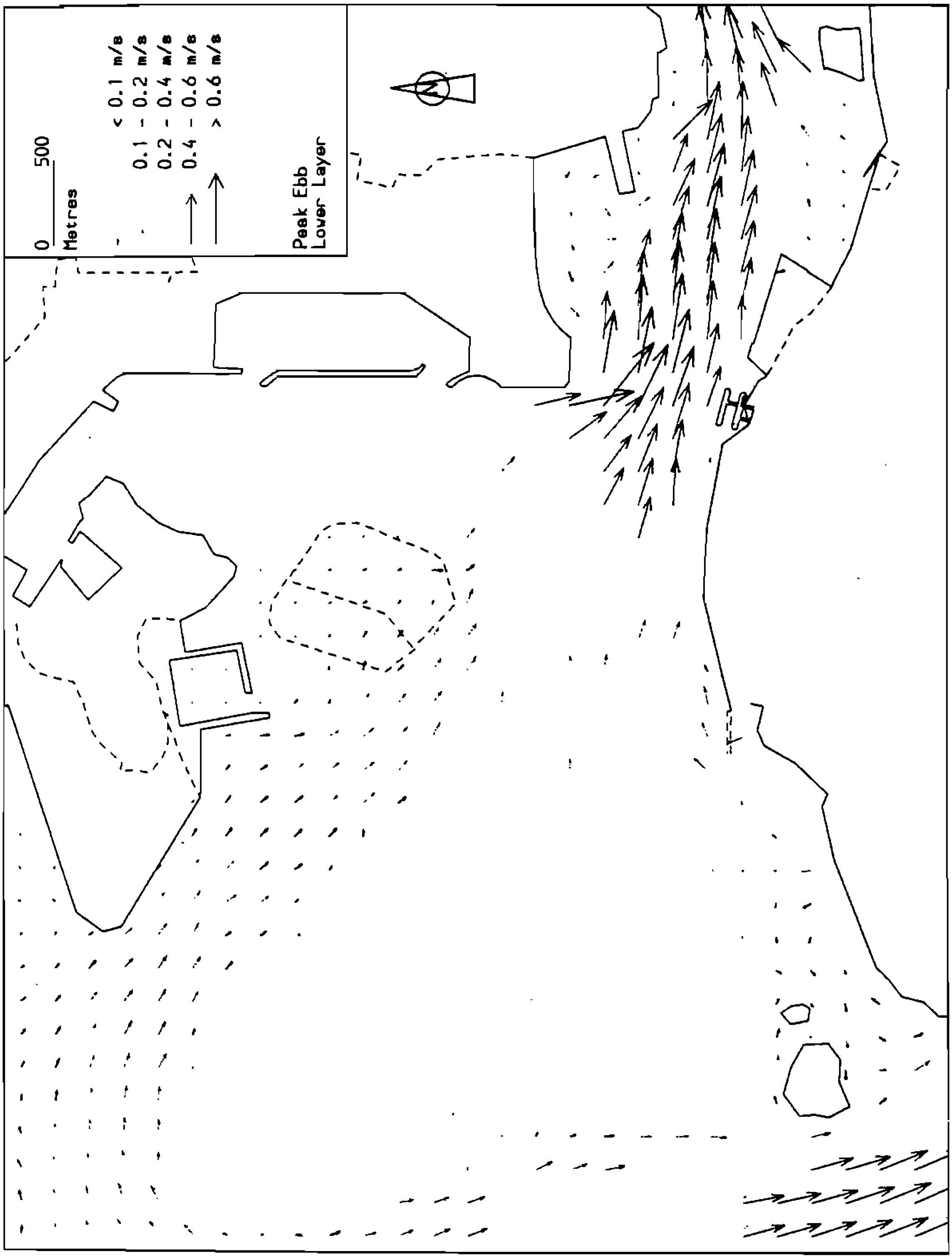
Stonecutters Naval Base Anchorage Area
Completed Scenario
Velocity Vectors
Wet Season Spring Tide



Stonecutters Naval Base Anchorage Area
Completed Scenario
Velocity Vectors
Wet Season Spring Tide

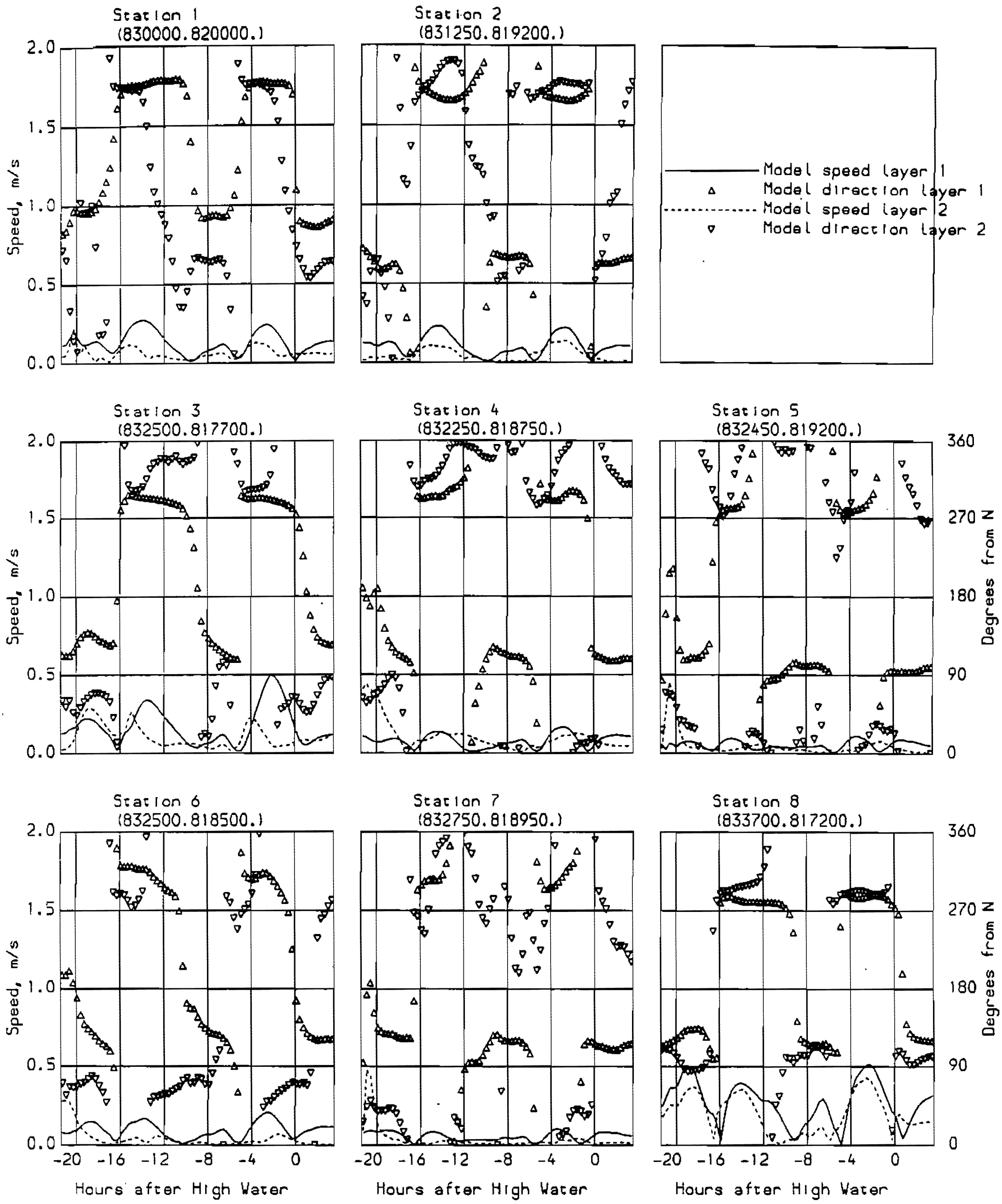


Stonecutters Naval Base Anchorage Area
Completed Scenario
Velocity Vectors
Wet Season Spring Tide

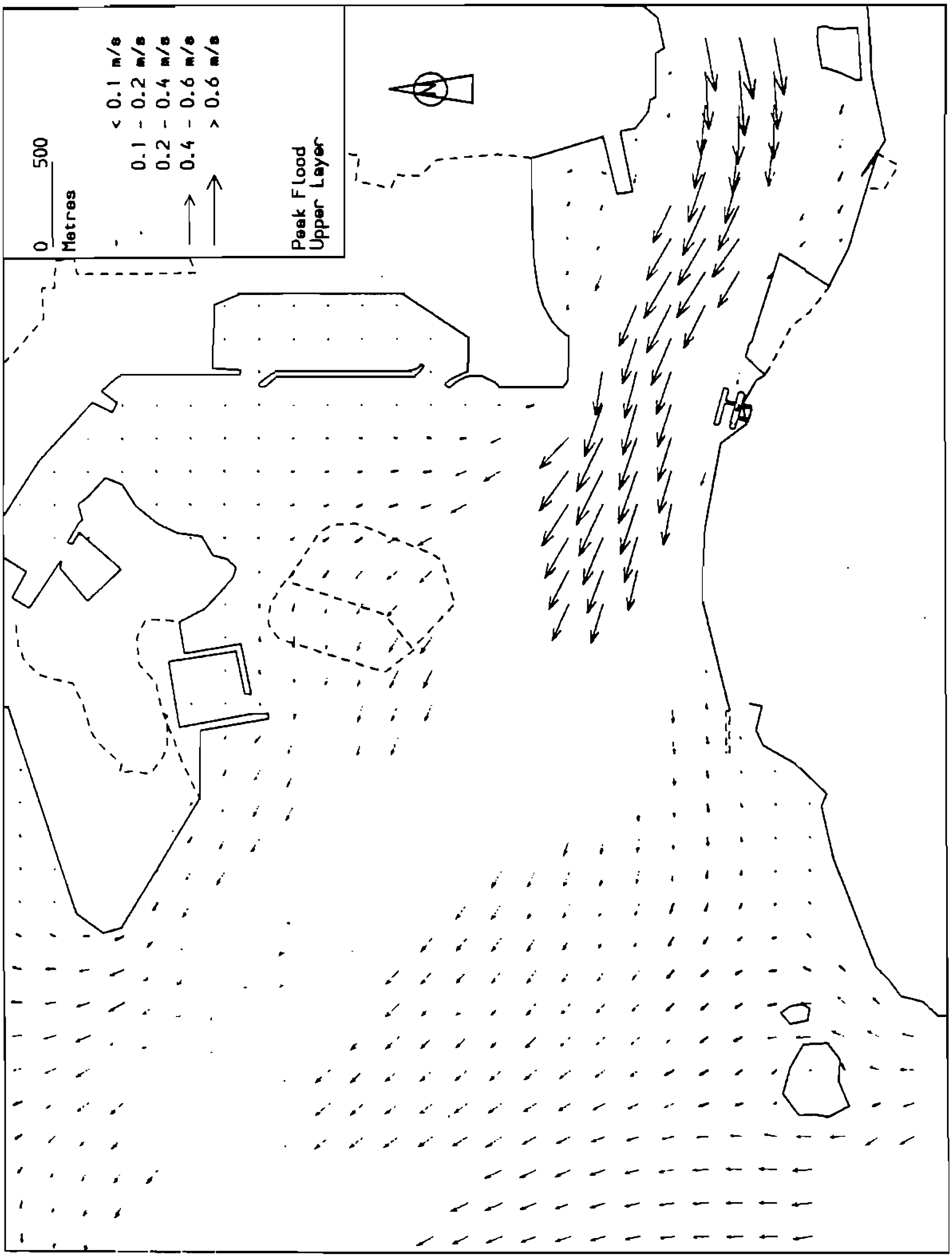


Stonecutters Naval Base Anchorage Area
Completed Scenario
Velocity Vectors
Wet Season Spring Tide

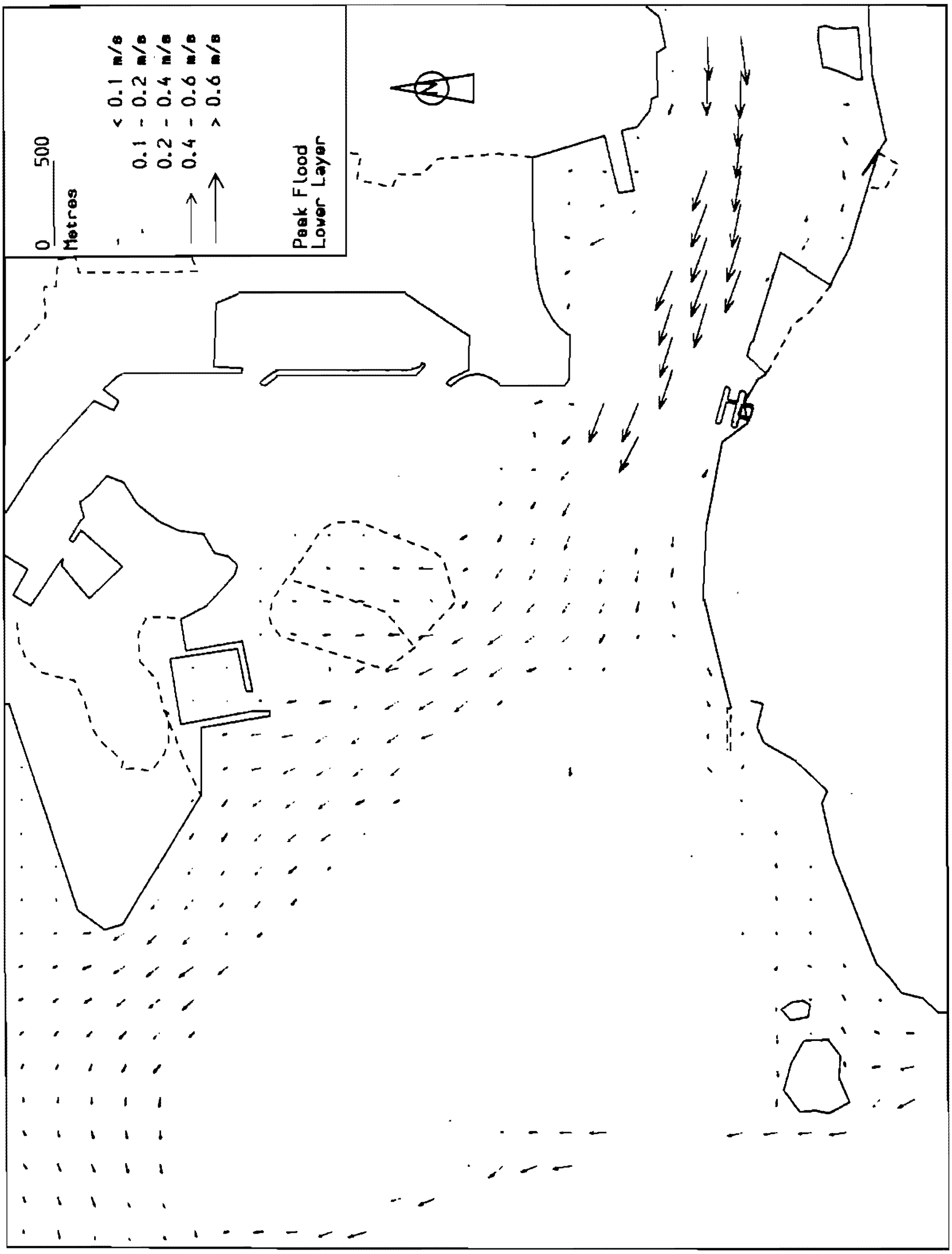
WET SEASON NEAP TIDE



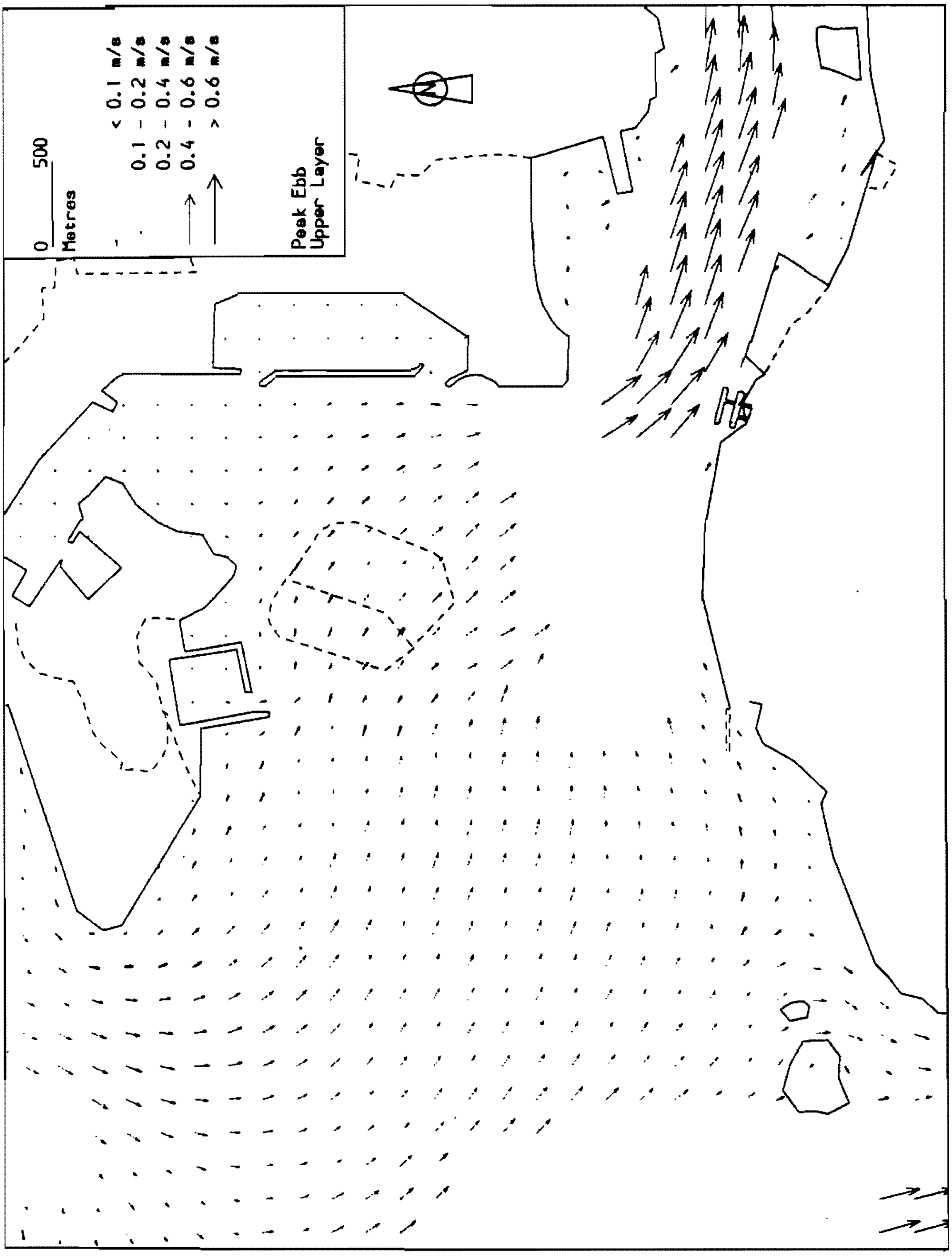
Stonecutters Naval Base Anchorage Area
Completed Scenario
Current Speed & Direction
Wet Season Neap Tide



Stonecutters Naval Base Anchorage Area
Completed Scenario
Velocity Vectors
Wet Season Neap Tide



Stonecutters Naval Base Anchorage Area
Completed Scenario
Velocity Vectors
Wet Season Neap Tide

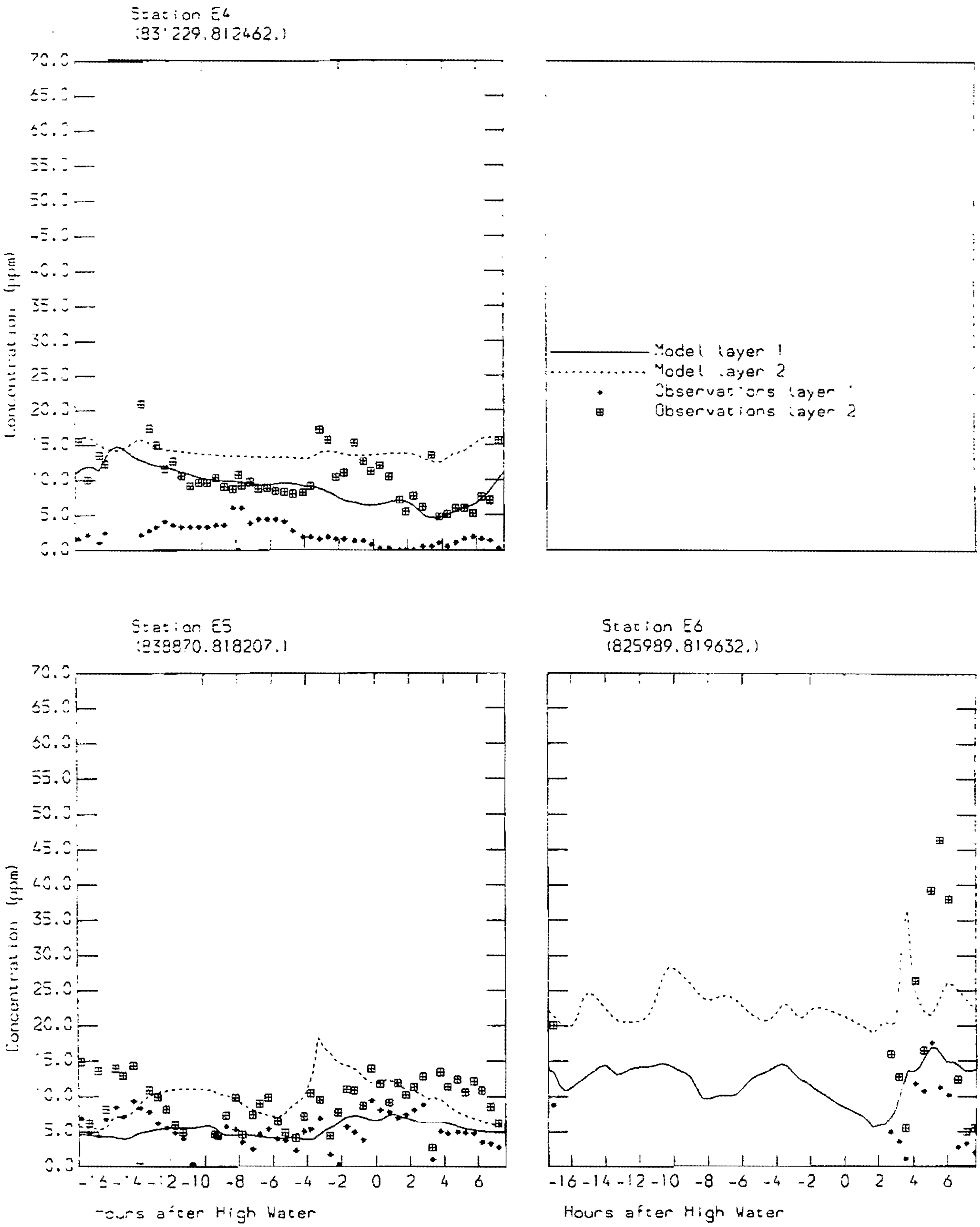


Stonecutters Naval Base Anchorage Area
Completed Scenario
Velocity Vectors
Wet Season Neap Tide

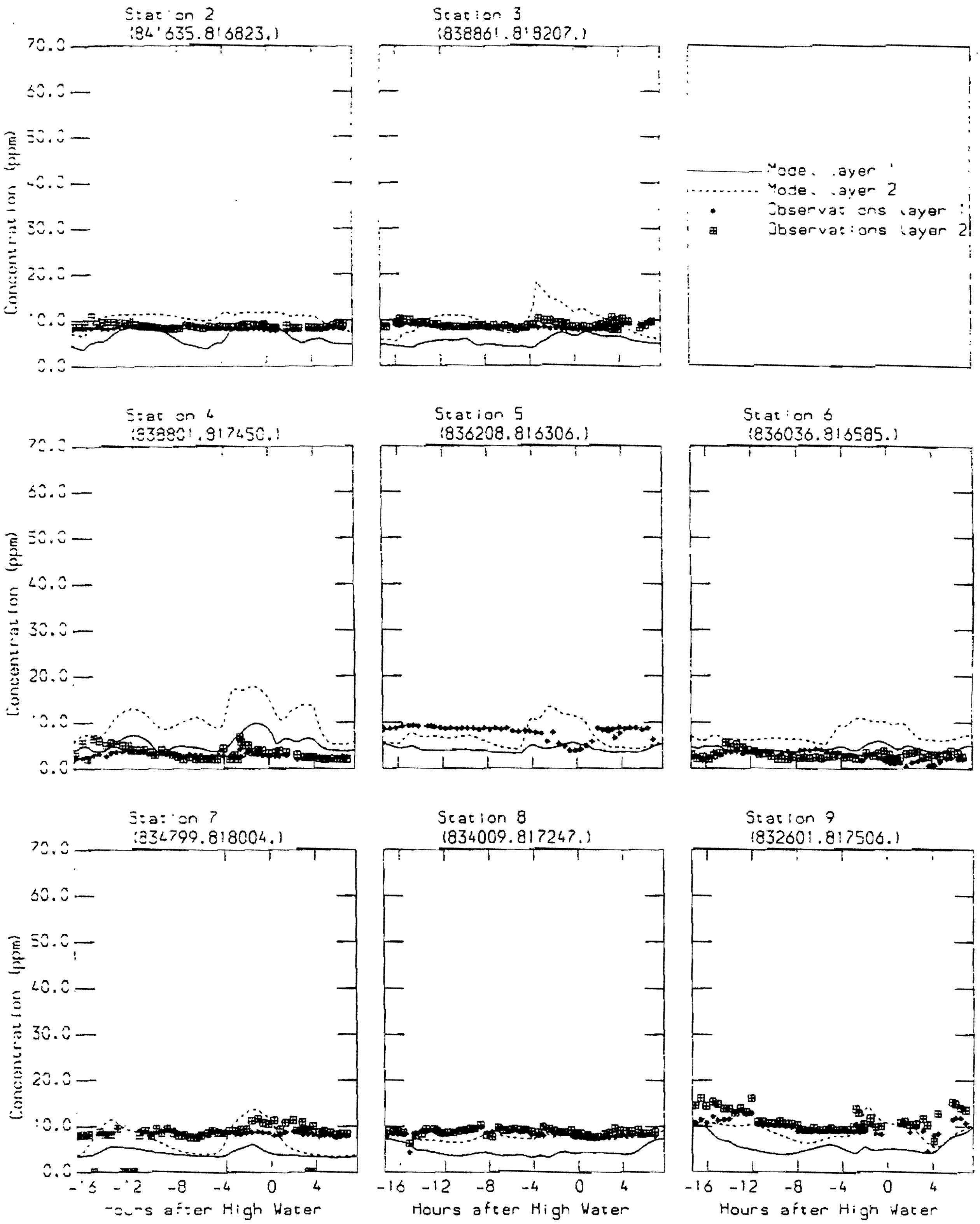
APPENDIX I

Sediment Transport Model Results

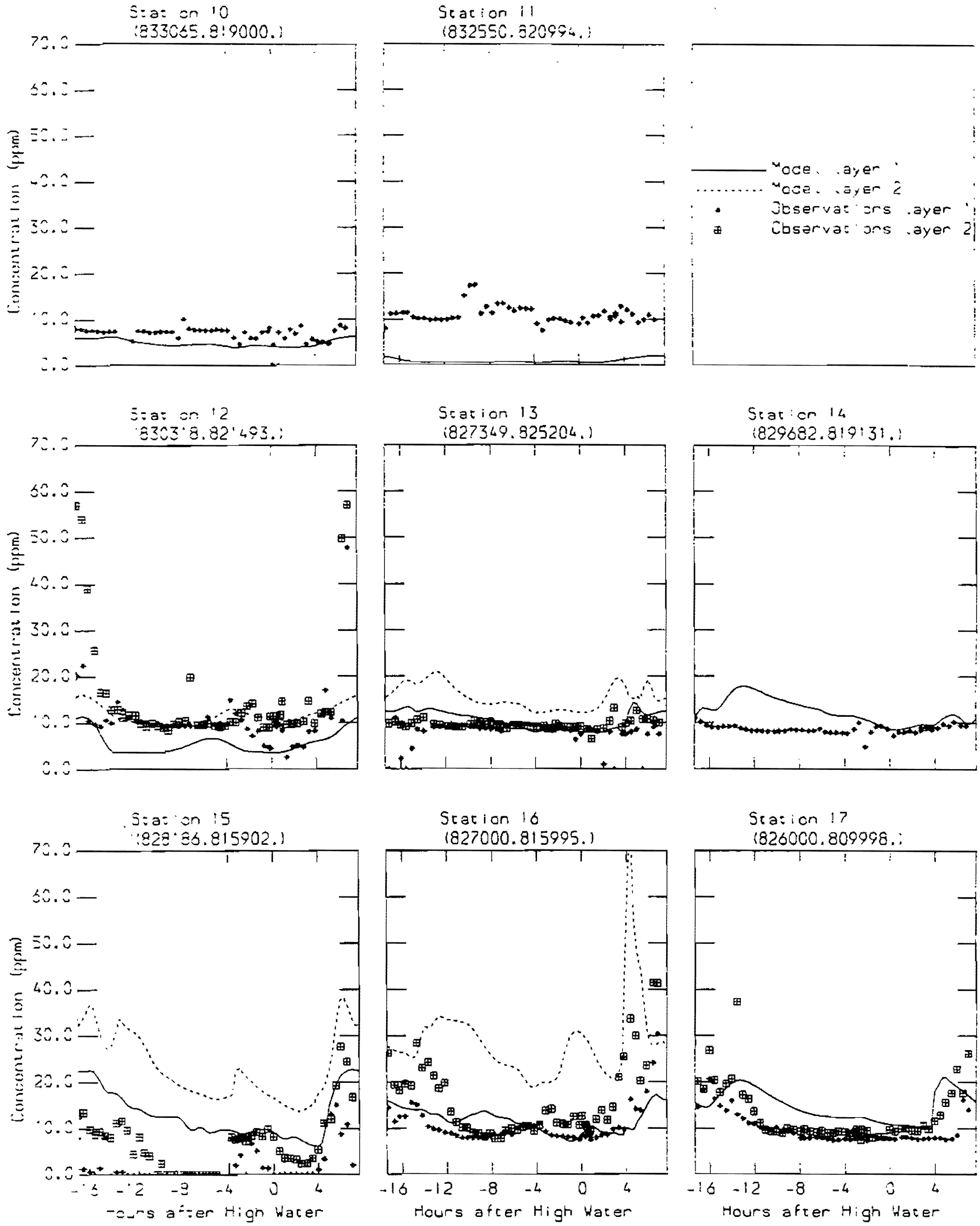
WET SEASON SPRING TIDE



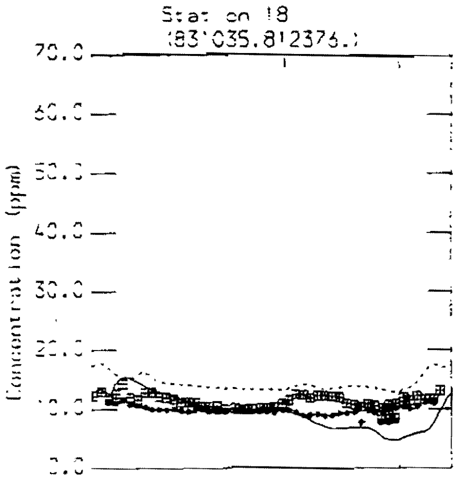
Stonecutters Naval Base Anchorage Area
WODFLOW Calibration (1990 Data)
Suspended Sediment Concentrations
Wet Season Spring Tide

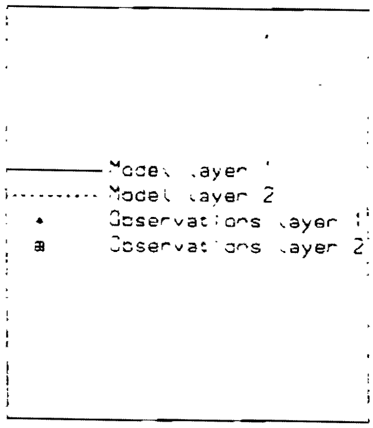


Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration (1987 Data)
Suspended Sediment Concentrations
Wet Season Spring Tide

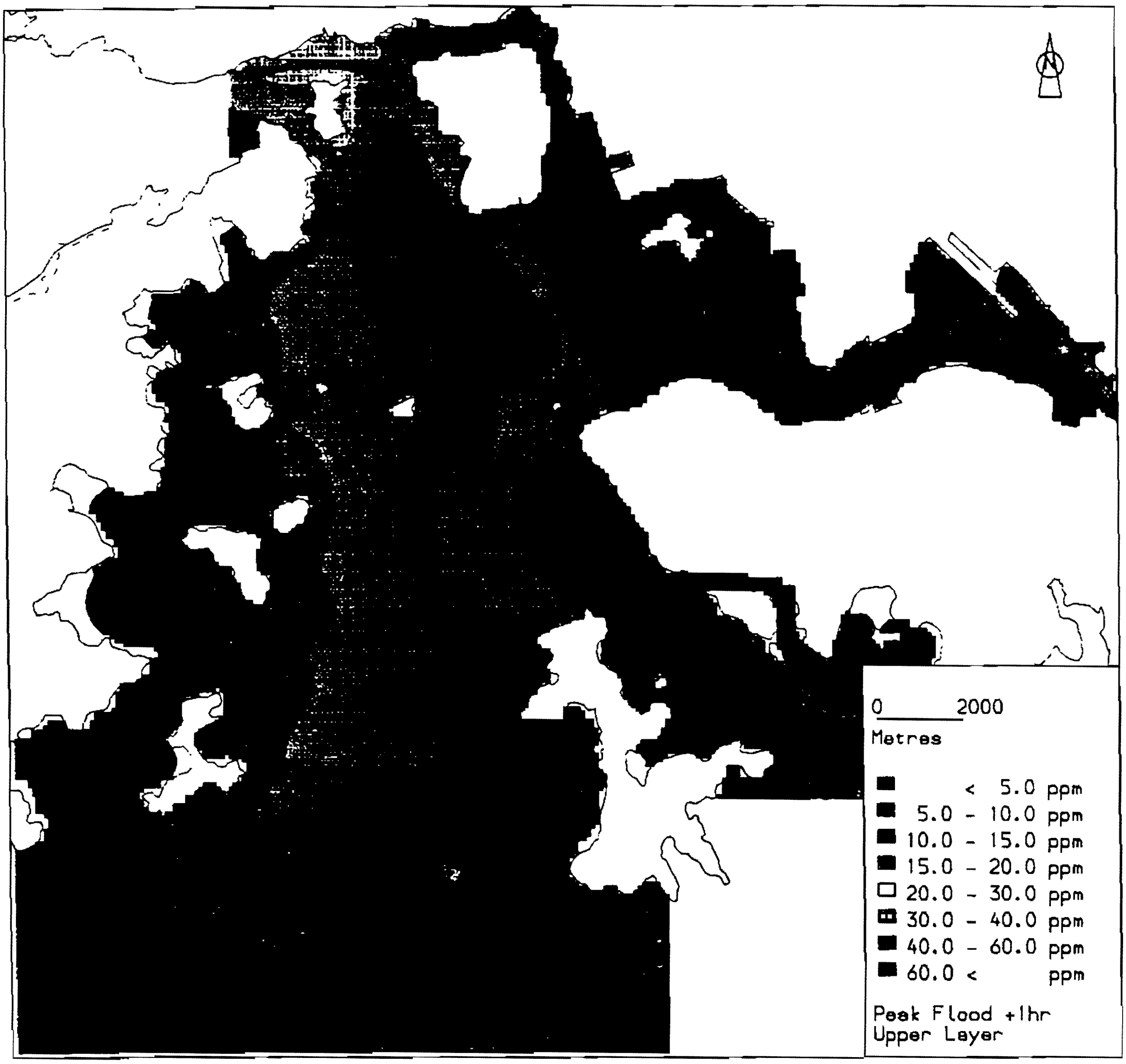


Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration (1987 Data)
Suspended Sediment Concentrations
Wet Season Spring Tide

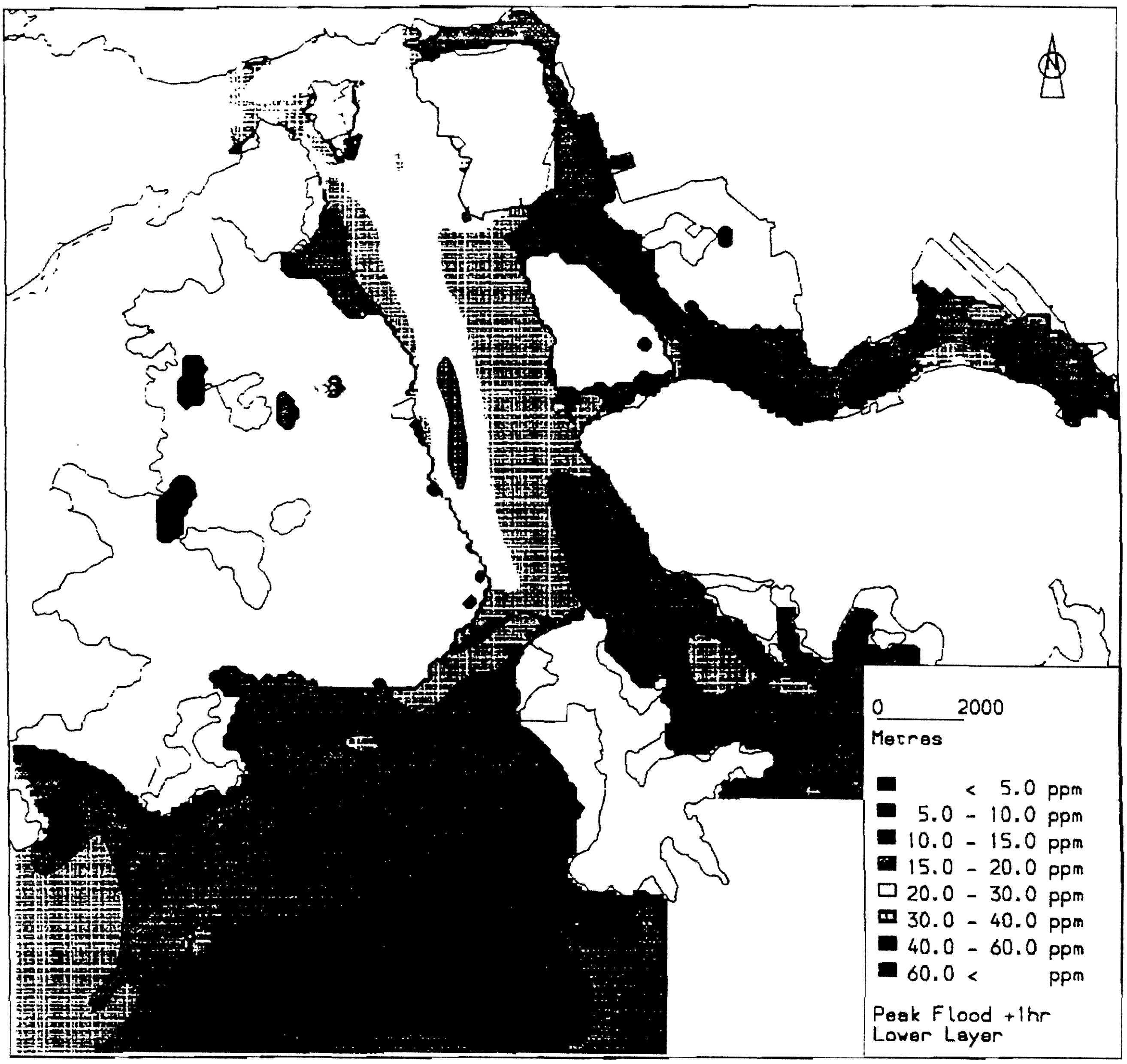




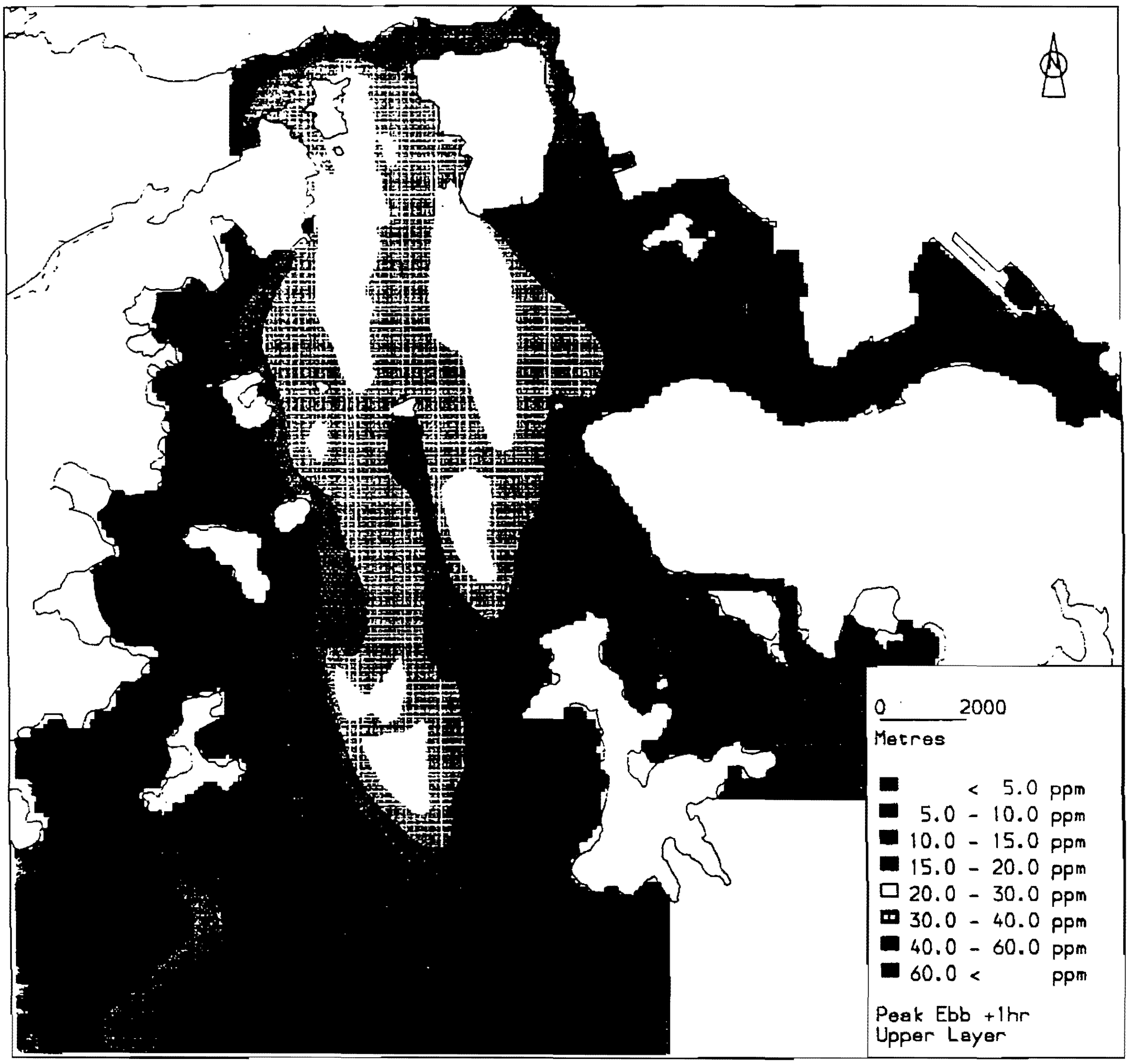
Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration (1987 Data)
Suspended Sediment Concentrations
Wet Season Spring Tide



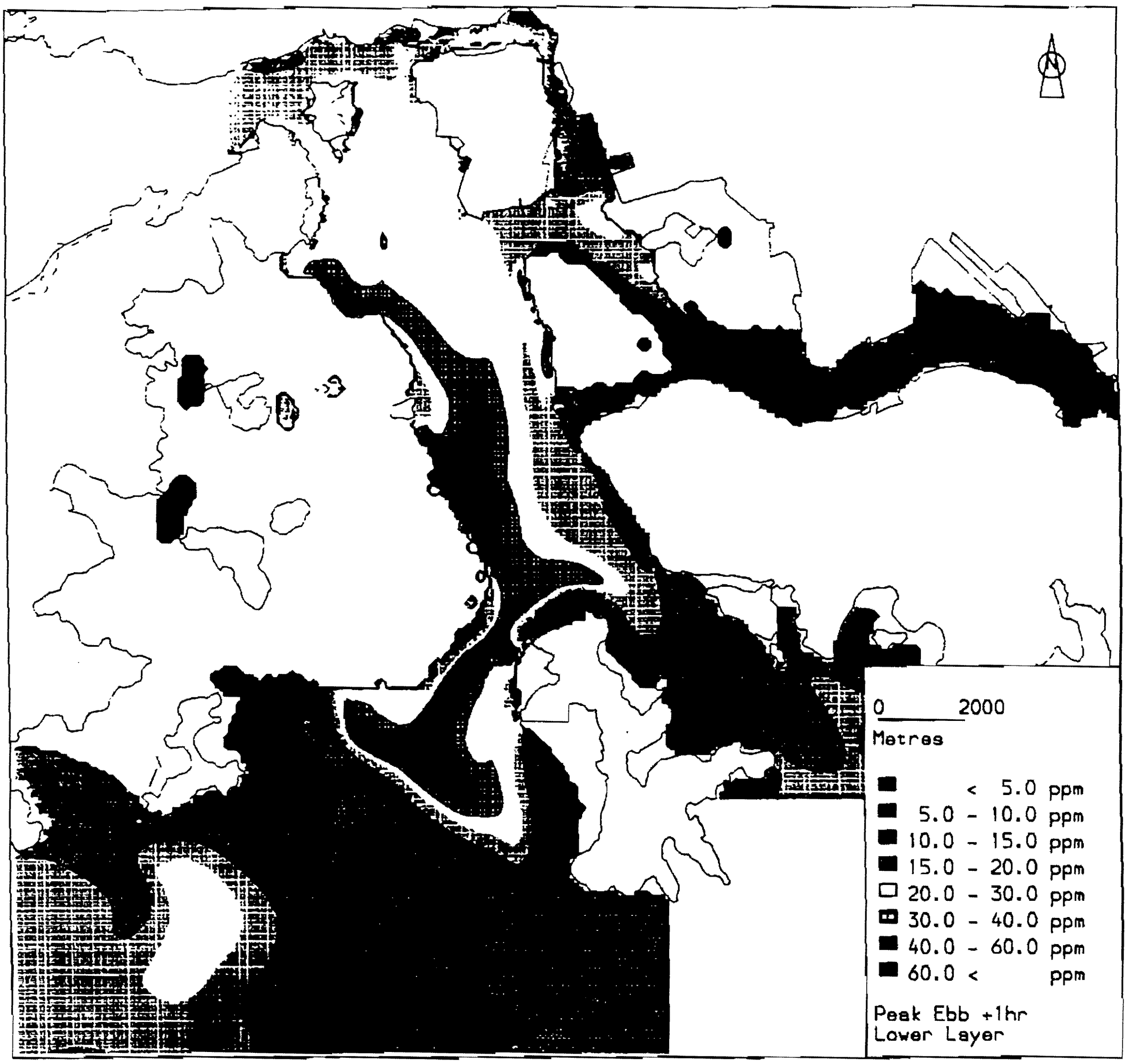
Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration
Suspended Sediment Concentrations
Wet Season Spring Tide



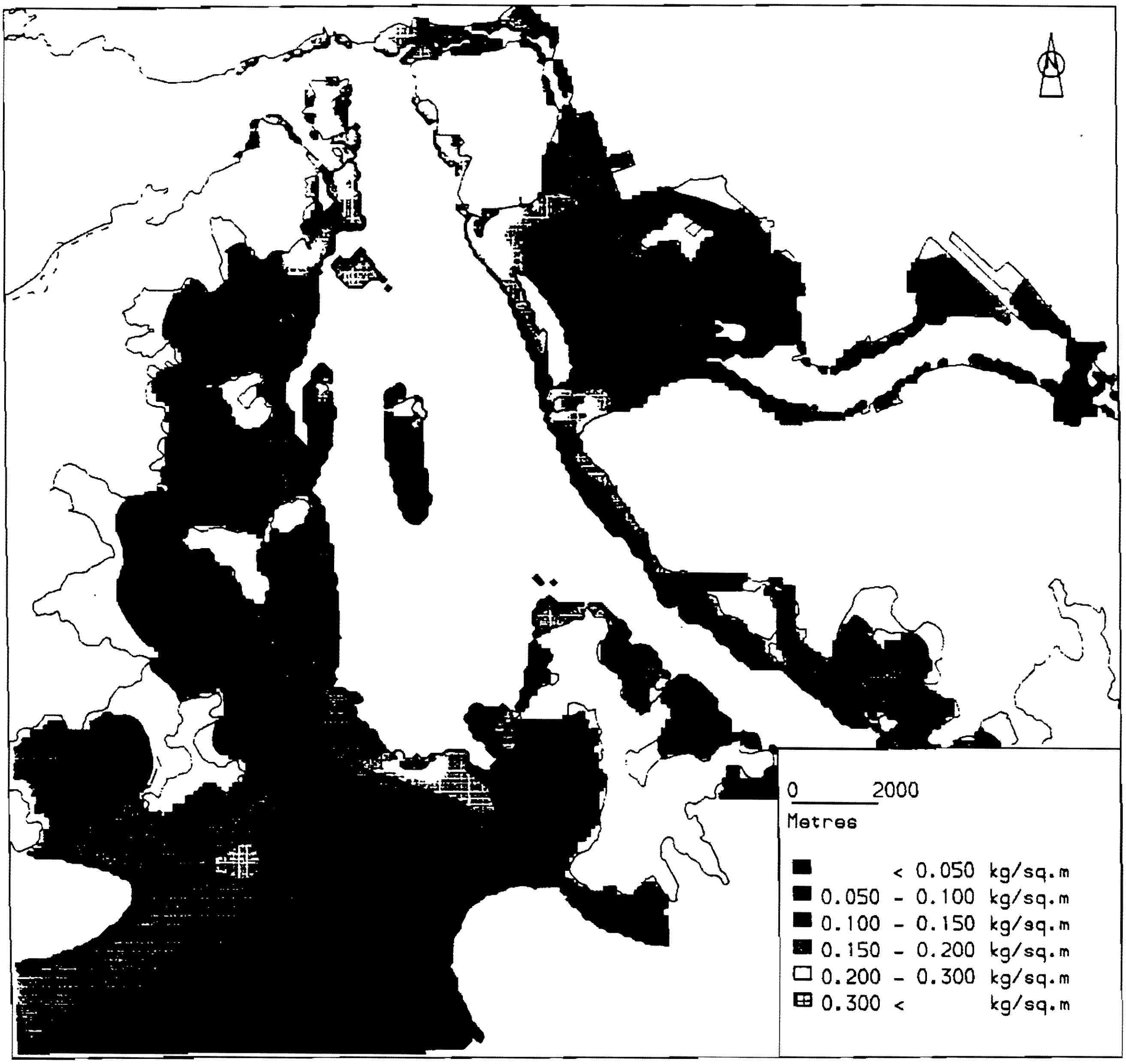
Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration
Suspended Sediment Concentrations
Wet Season Spring Tide



Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration
Suspended Sediment Concentrations
Wet Season Spring Tide

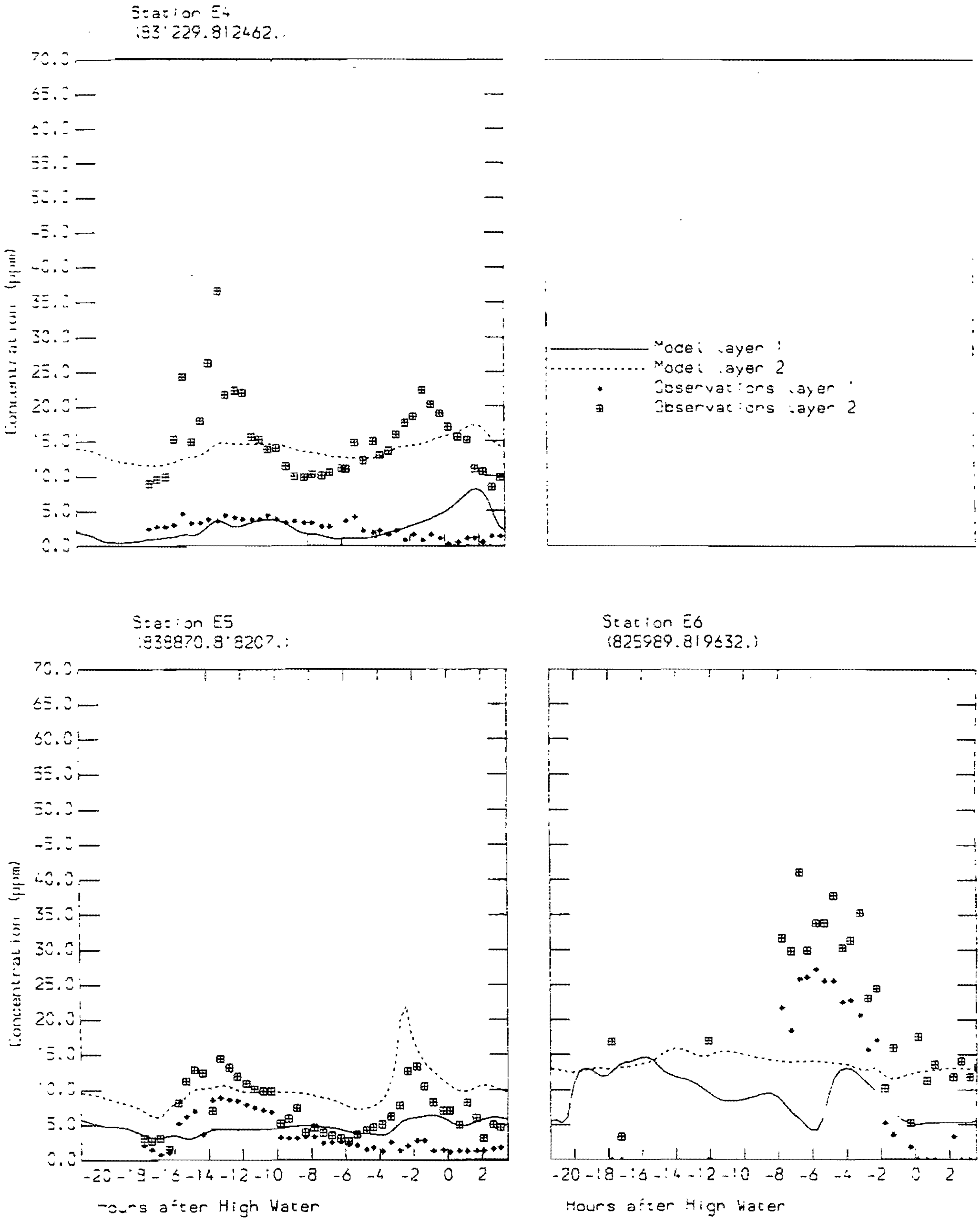


Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration
Suspended Sediment Concentrations
Wet Season Spring Tide

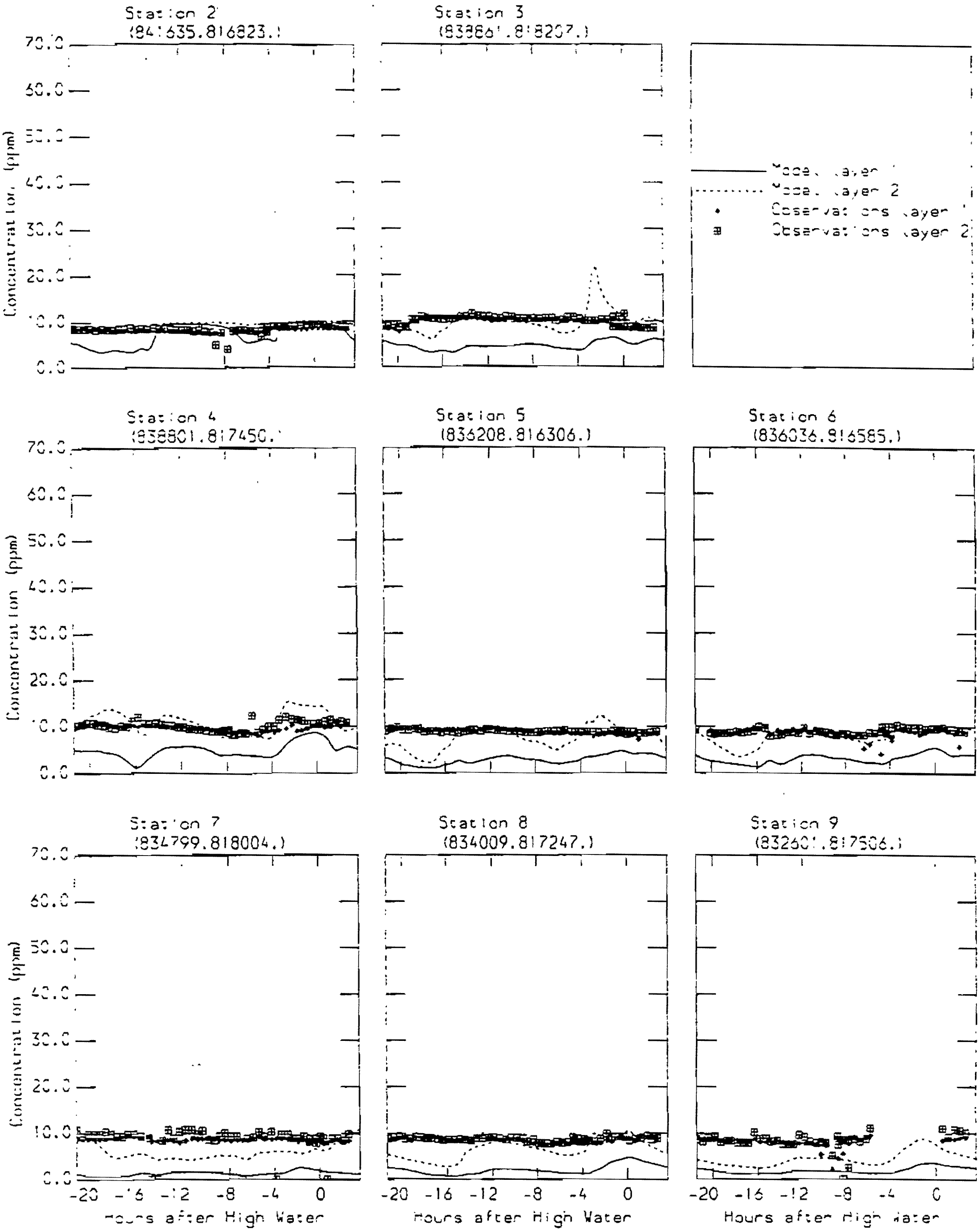


Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration
Mud Deposits over 1 Tide
Wet Season Spring Tide

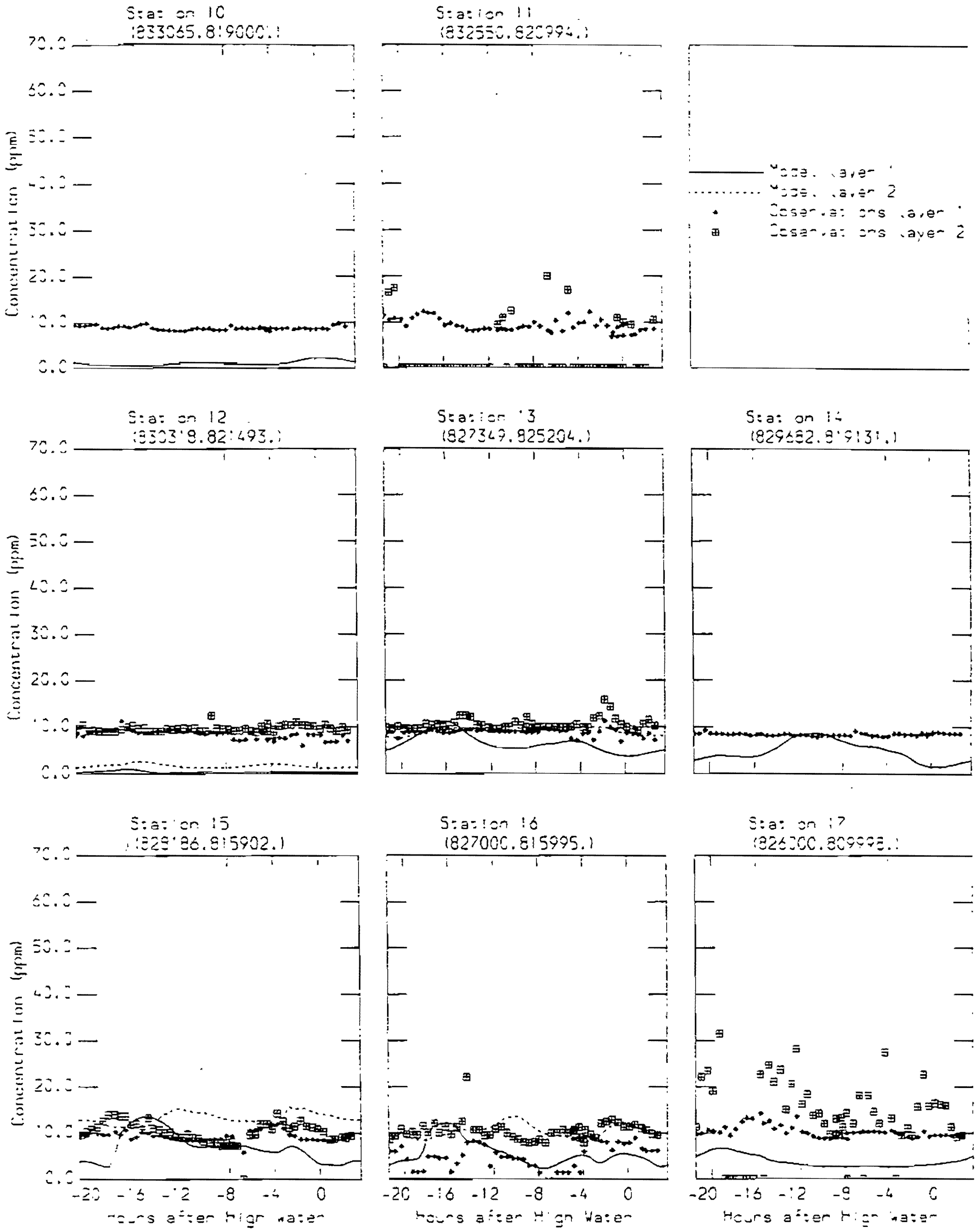
WET SEASON NEAP TIDE



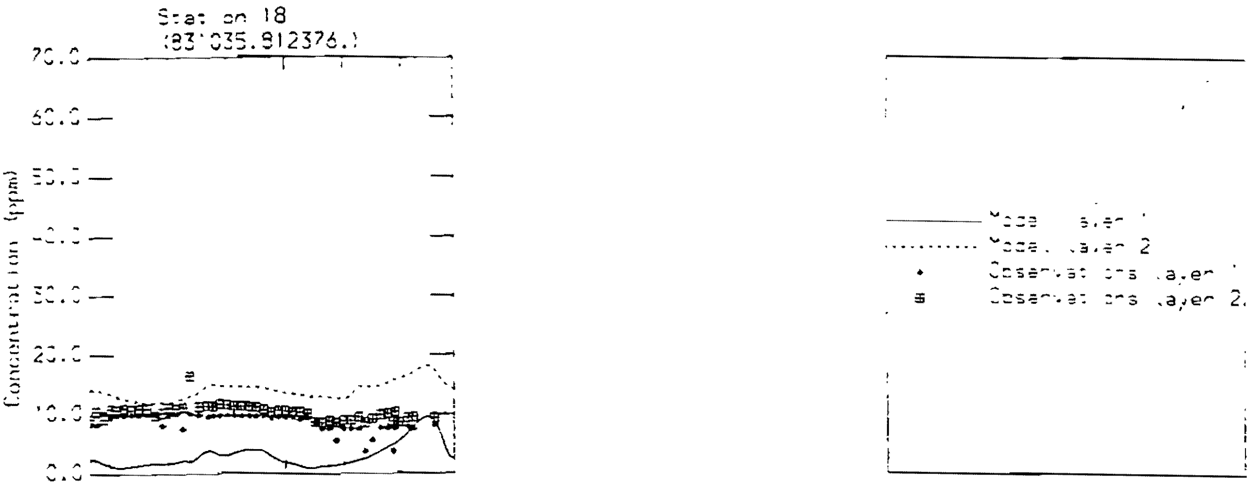
Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration (1990 Data)
Suspended Sediment Concentrations
Wet Season Neap Tide



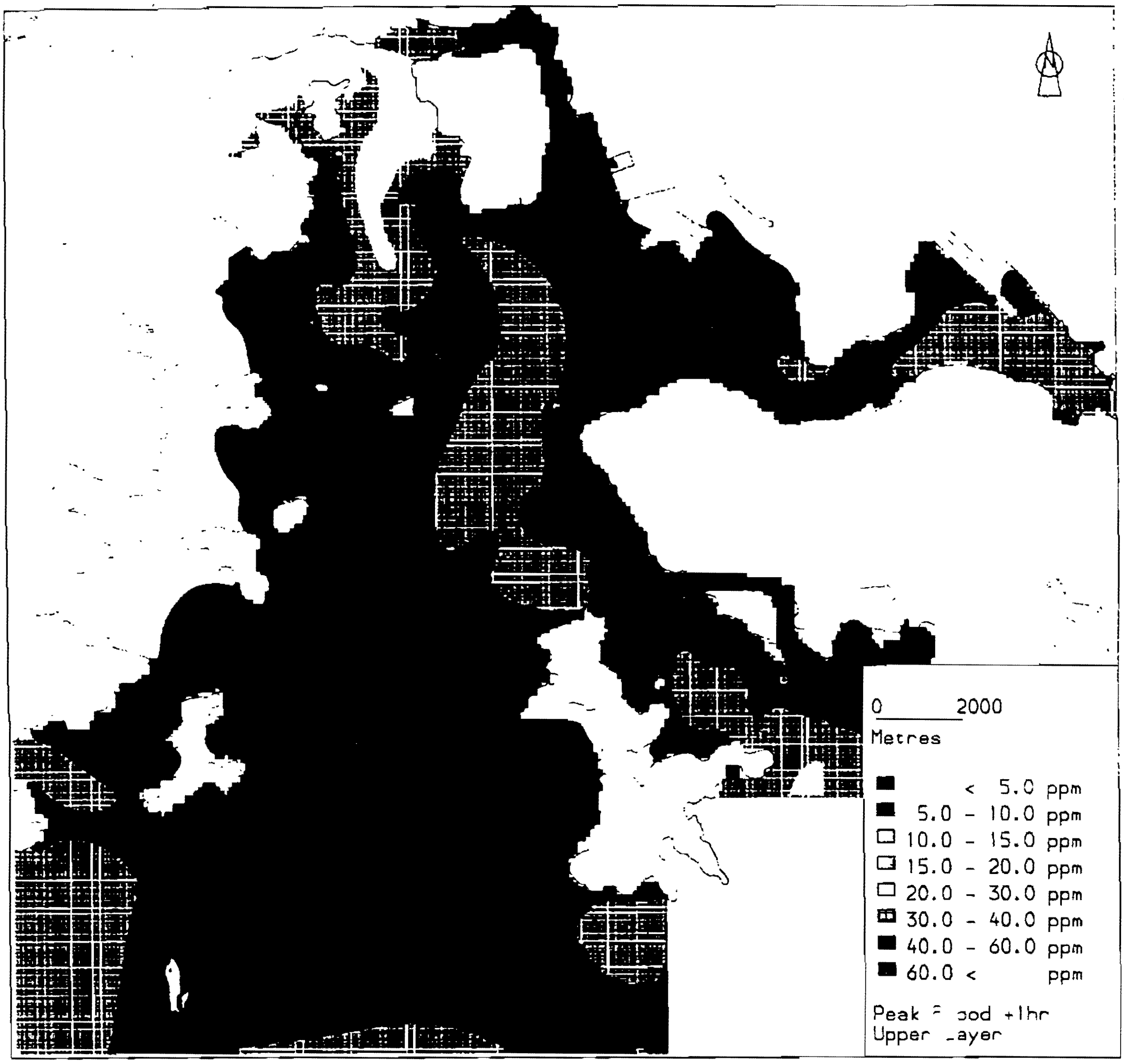
Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration (1987 Data)
Suspended Sediment Concentrations
Wet Season Neap Tide



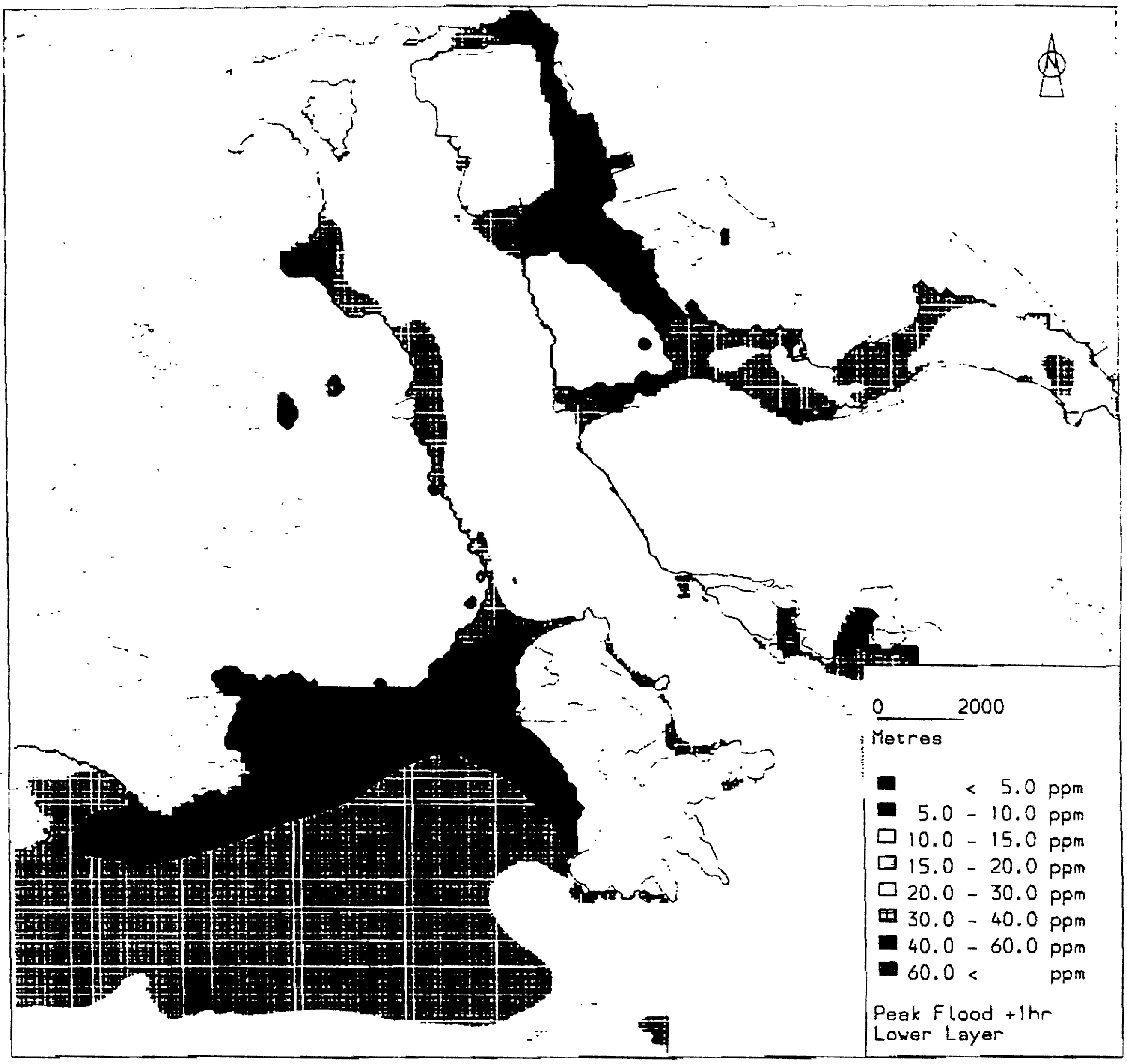
Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration (1987 Data)
Suspended Sediment Concentrations
Wet Season Neap Tide



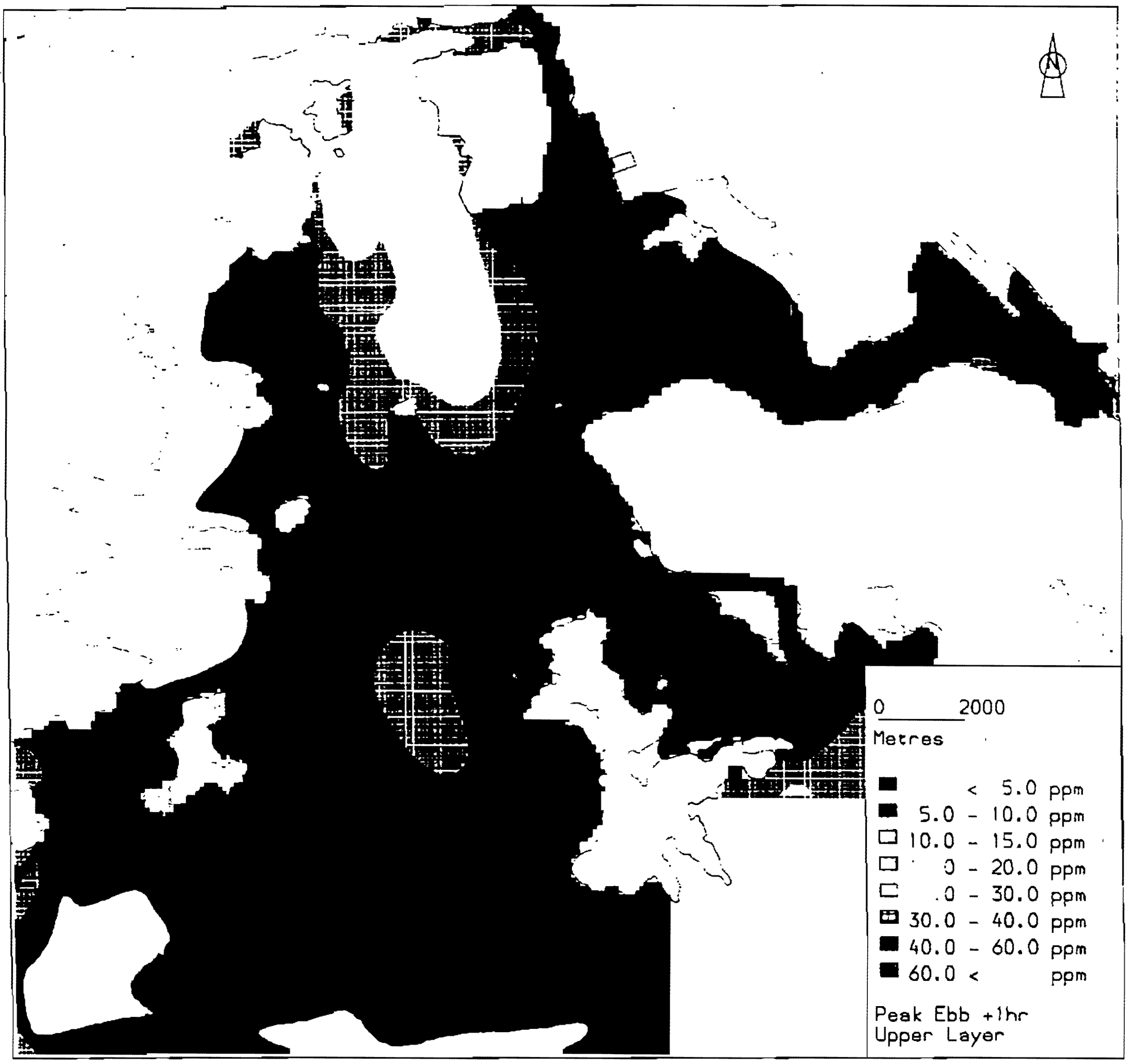
Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration (1987 Data)
Suspended Sediment Concentrations
Wet Season Neap Tide



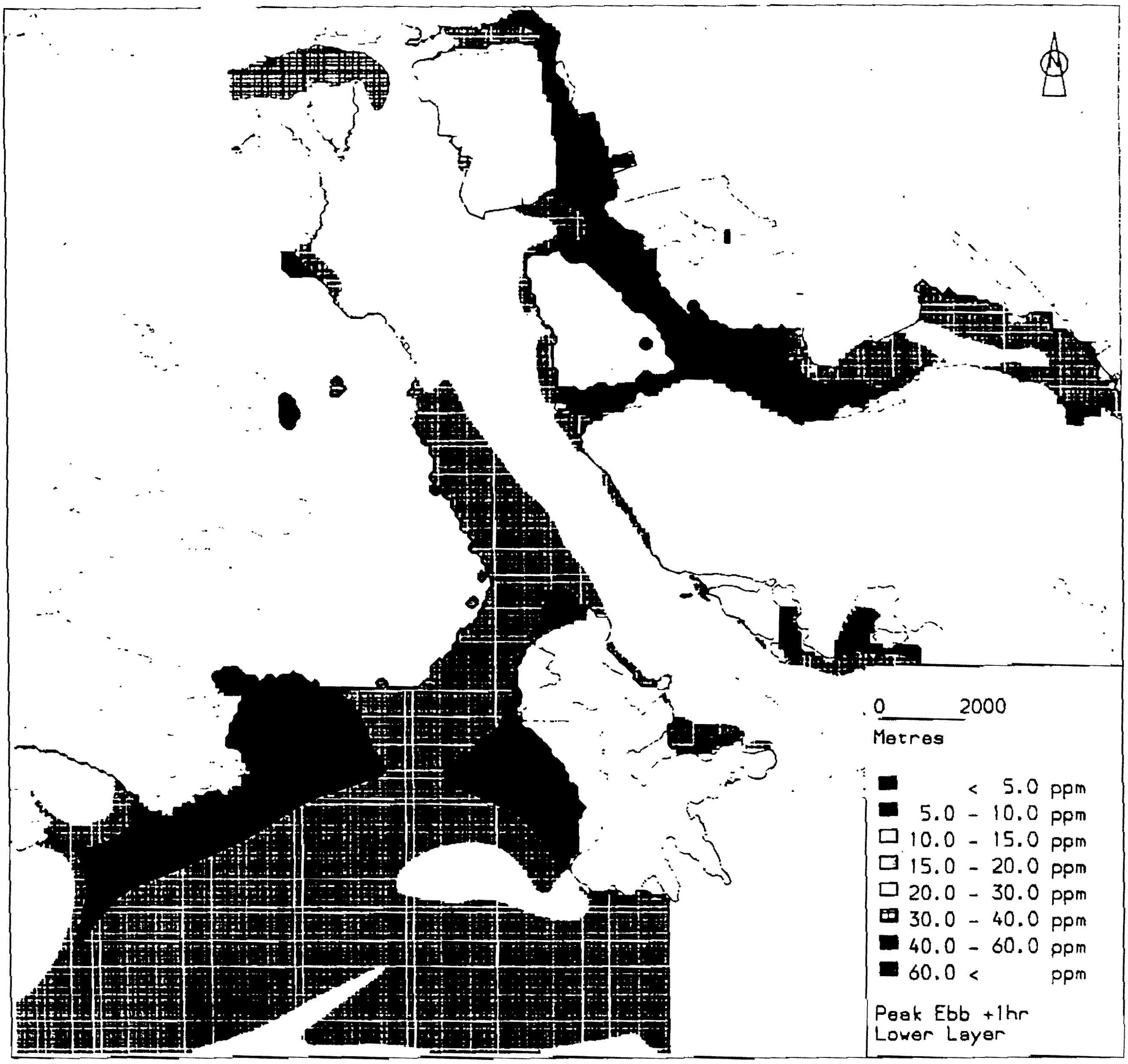
Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration
Suspended Sediment Concentrations
Wet Season Neap Tide



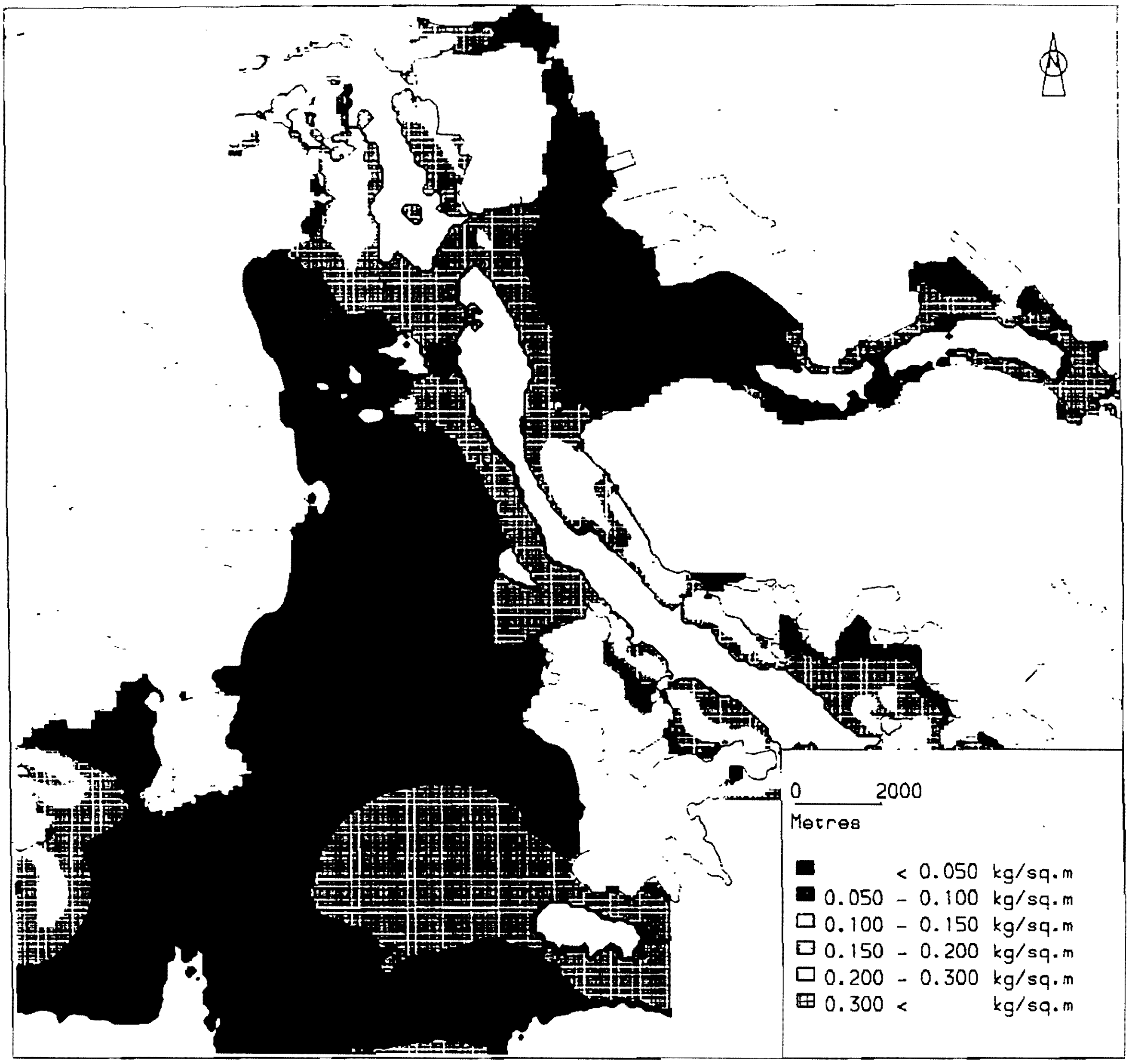
Stonecutters Na   Base Anchorage Area
MUDFLOW Calibrat .on
Suspended Sediment Concentrations
Wet Season Neap Tide



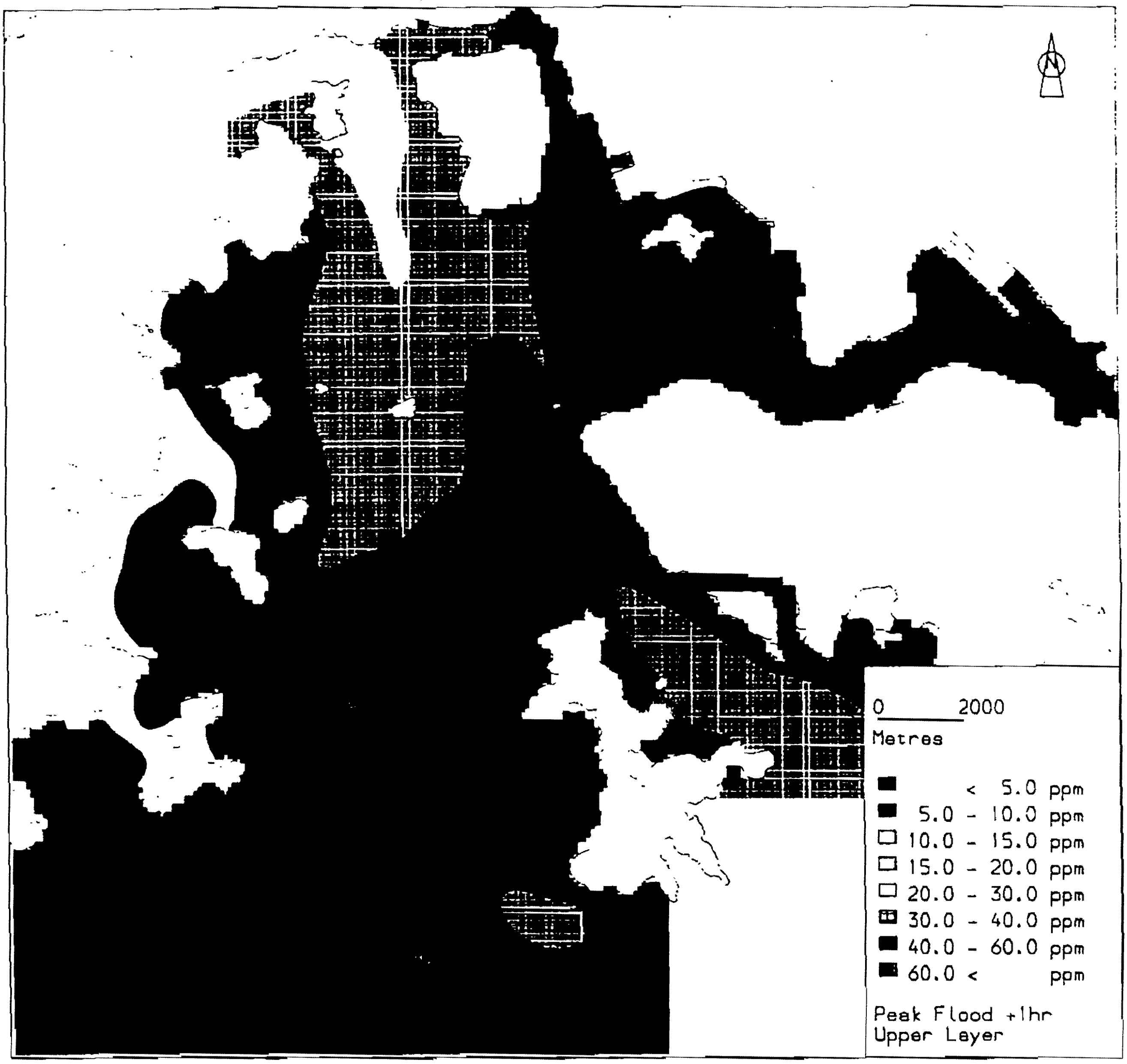
Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration
Suspended Sediment Concentrations
Wet Season Neap Tide



Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration
Suspended Sediment Concentrations
Wet Season Neap Tide

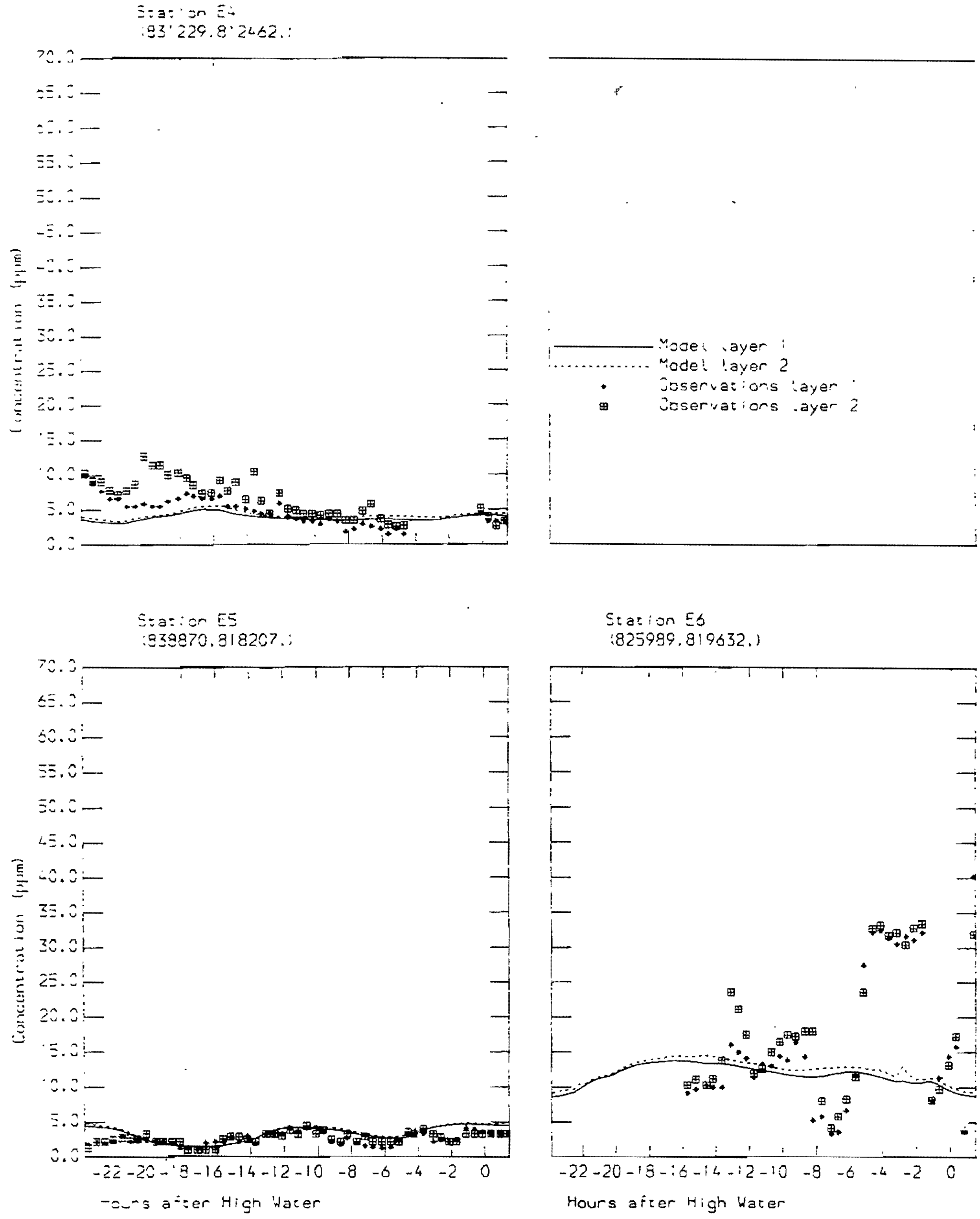


Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration
Mud Deposits over 1 Tide
Wet Season Neap Tide

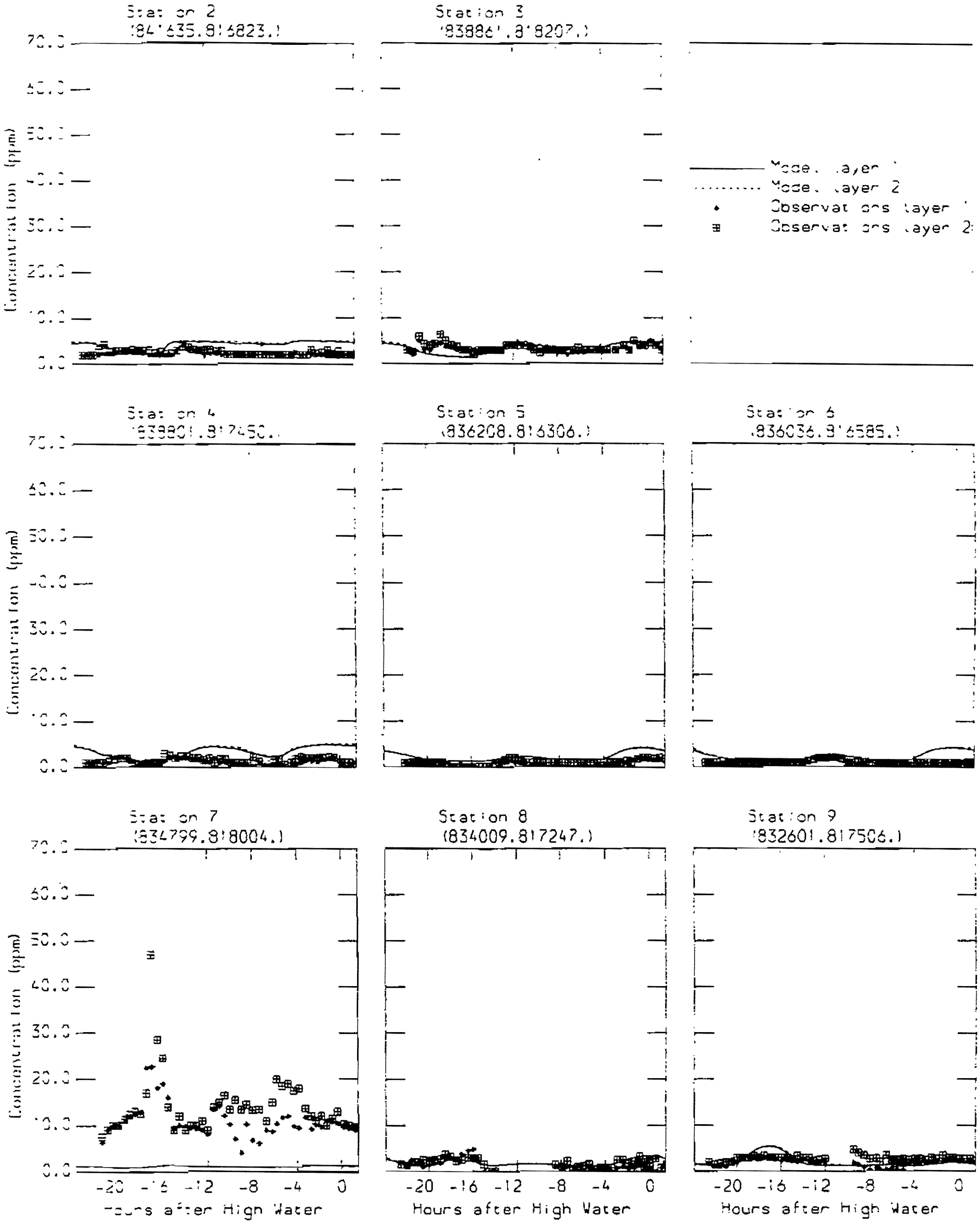


Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration
Suspended Sediment Concentrations
Dry Season Spring Tide

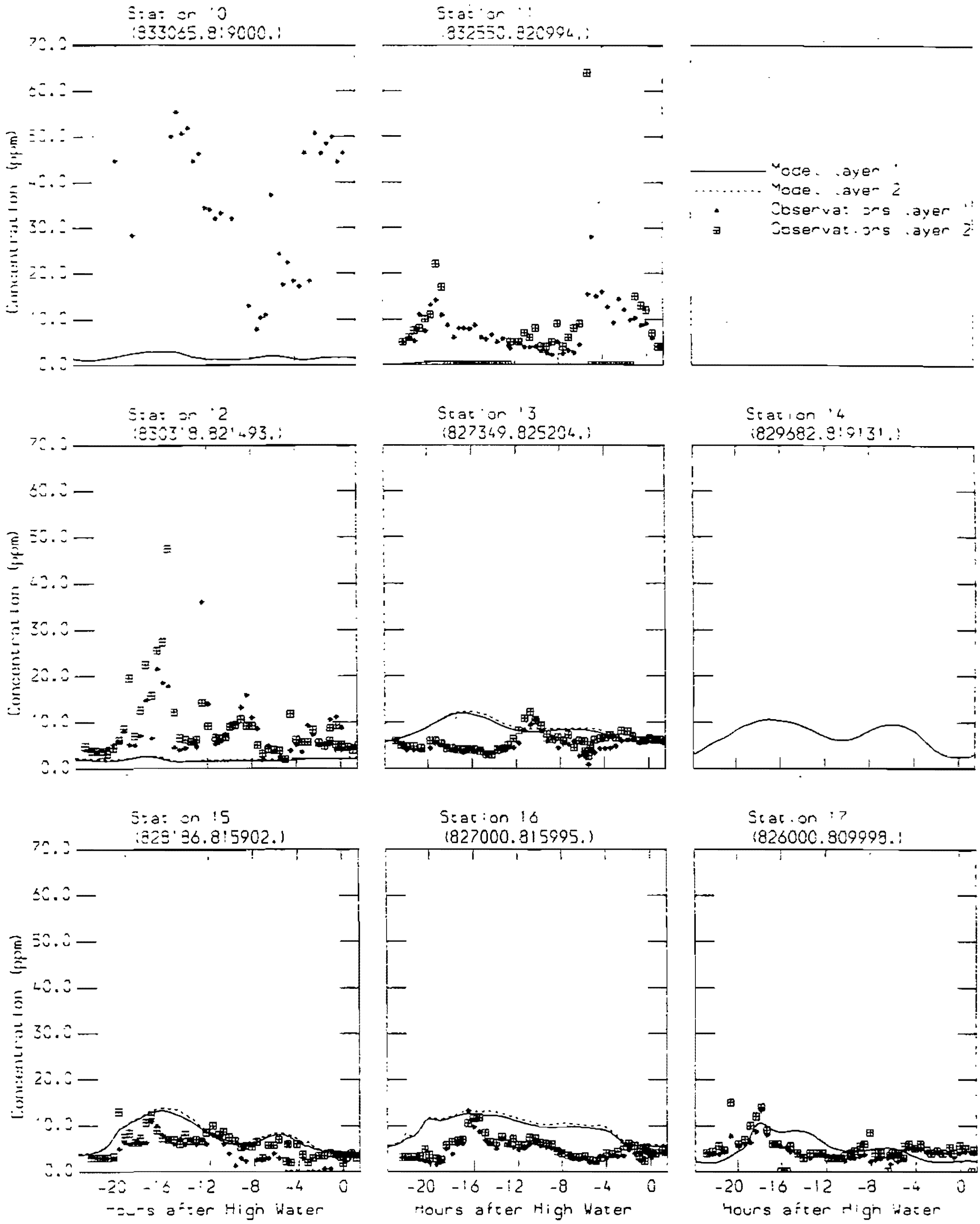
DRY SEASON SPRING TIDE



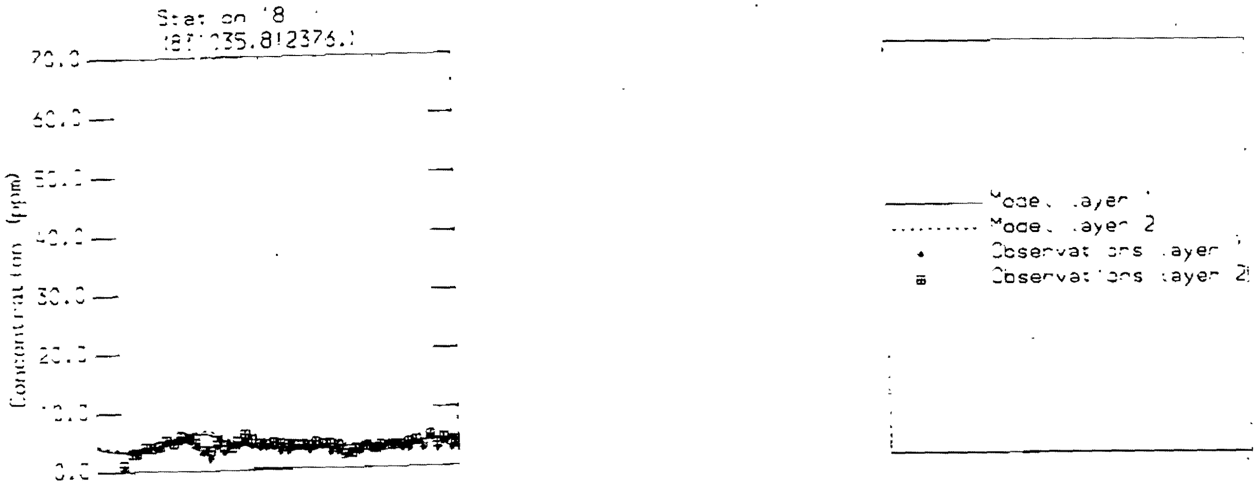
Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration (1990 Data)
Suspended Sediment Concentrations
Dry Season Spring Tide



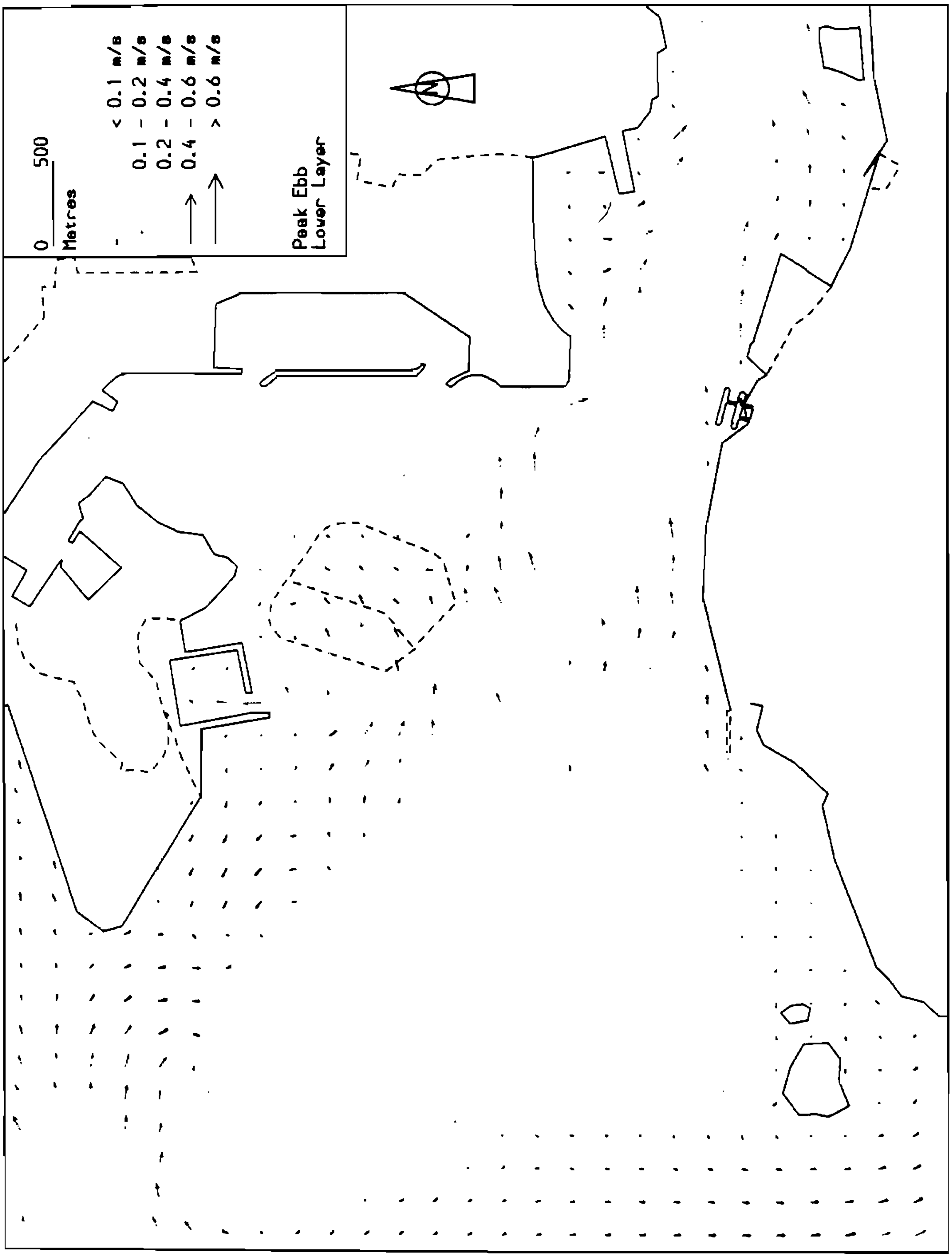
Stonecutters Naval Base Anchorage Area
WAQFLOW Calibration (1987 Data)
Suspended Sediment Concentrations
Dry Season Spring Tide



Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration (1987 Data)
Suspended Sediment Concentrations
Dry Season Spring Tide

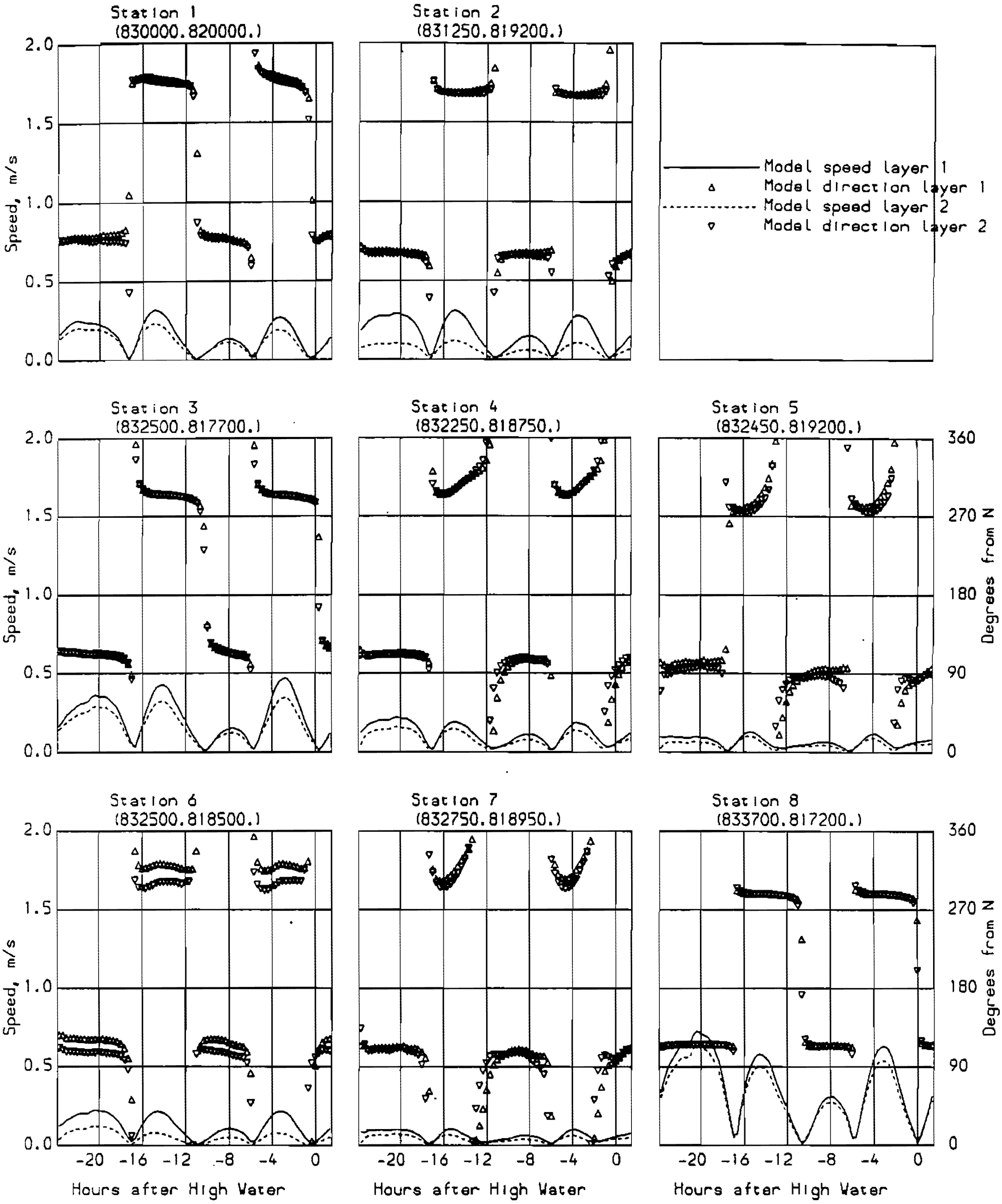


Stonecutters Naval Base Anchorage Area
MUDFLOW Calibration (1987 Data)
Suspended Sediment Concentrations
Dry Season Spring Tide

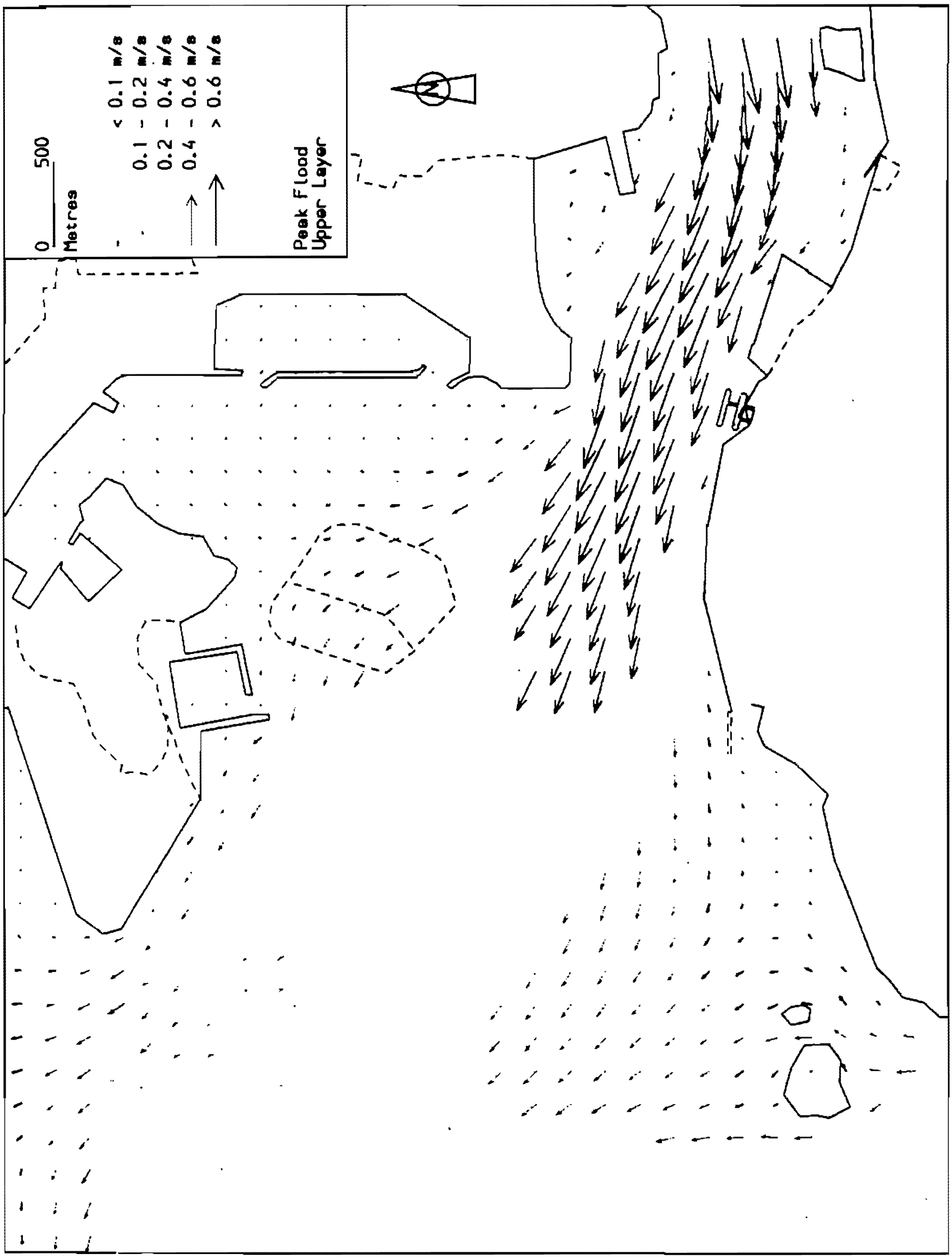


Stonecutters Naval Base Anchorage Area
Completed Scenario
Velocity Vectors
Wet Season Neap Tide

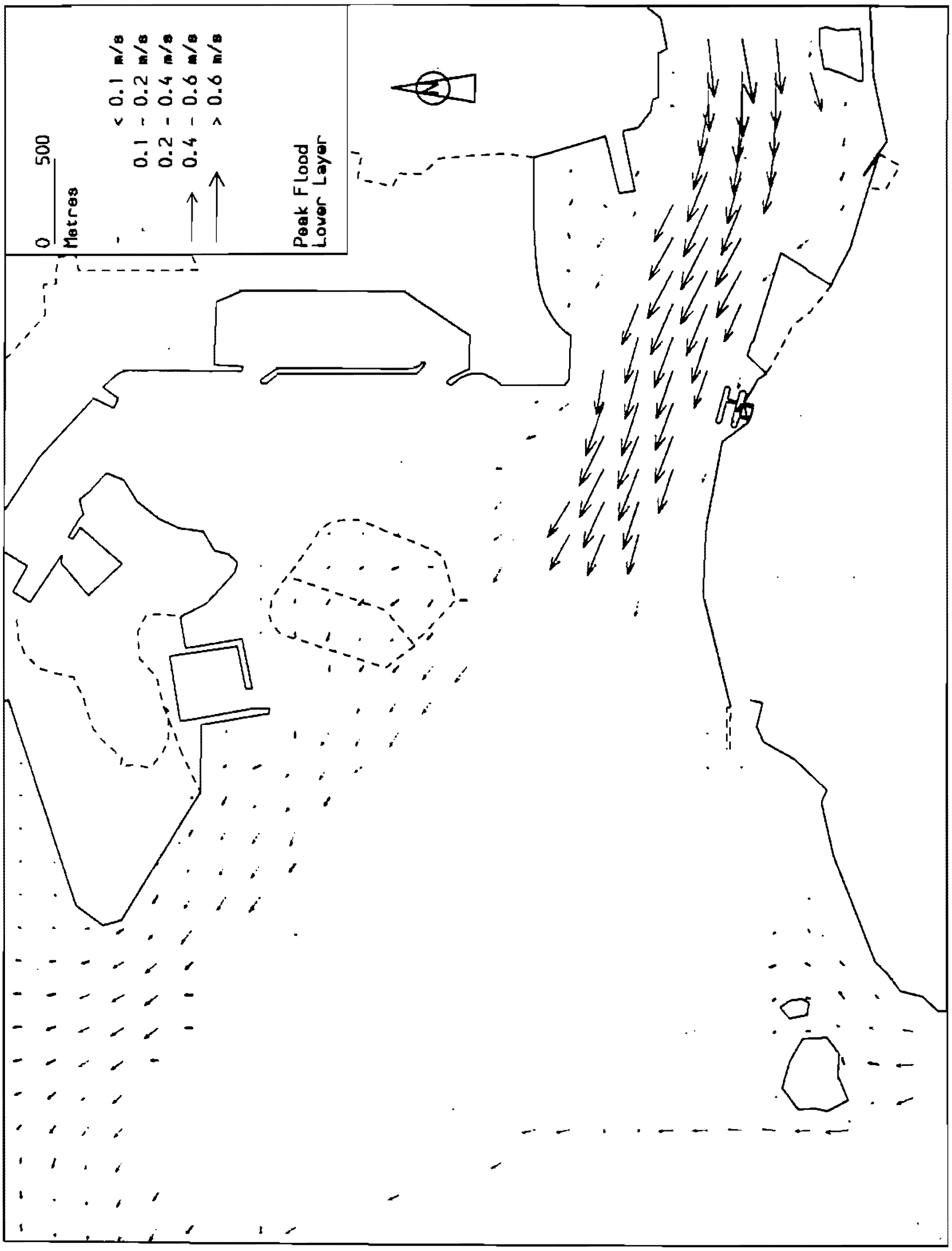
DRY SEASON SPRING TIDE



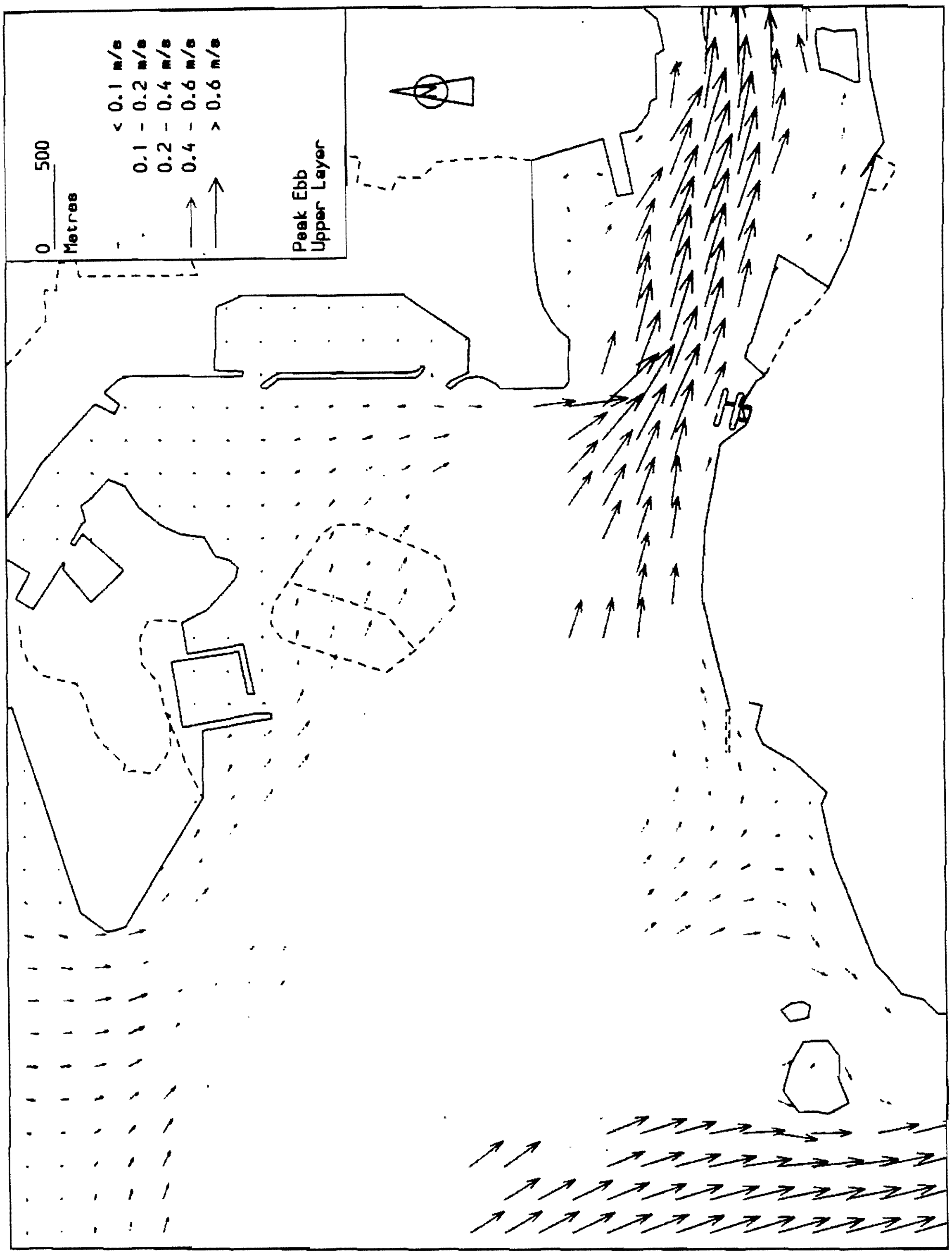
Stonecutters Naval Base Anchorage Area
Completed Scenario
Current Speed & Direction
Dry Season Spring Tide



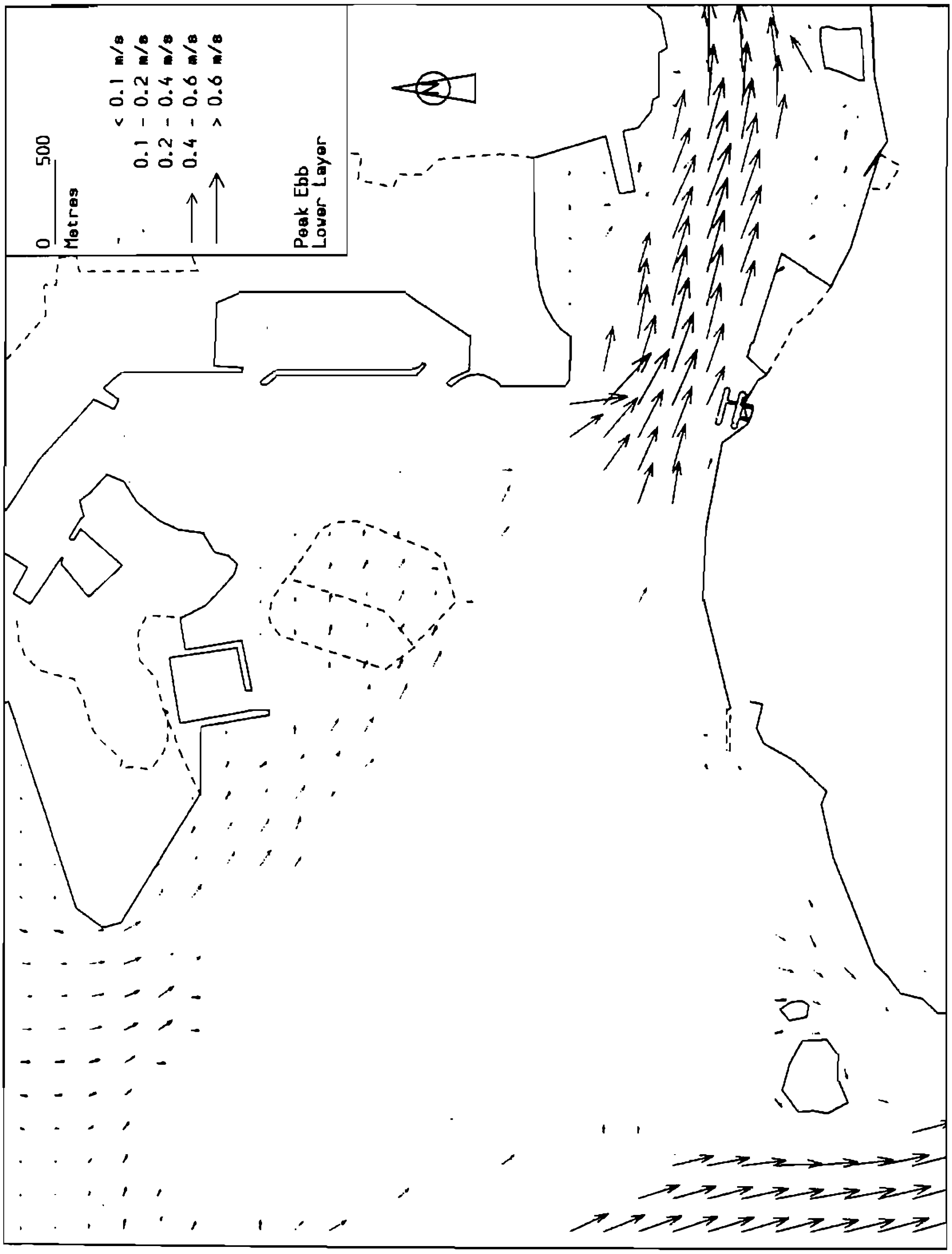
Stonecutters Naval Base Anchorage Area
Completed Scenario
Velocity Vectors
Dry Season Spring Tide



Stonecutters Naval Base Anchorage Area
Completed Scenario
Velocity Vectors
Dry Season Spring Tide

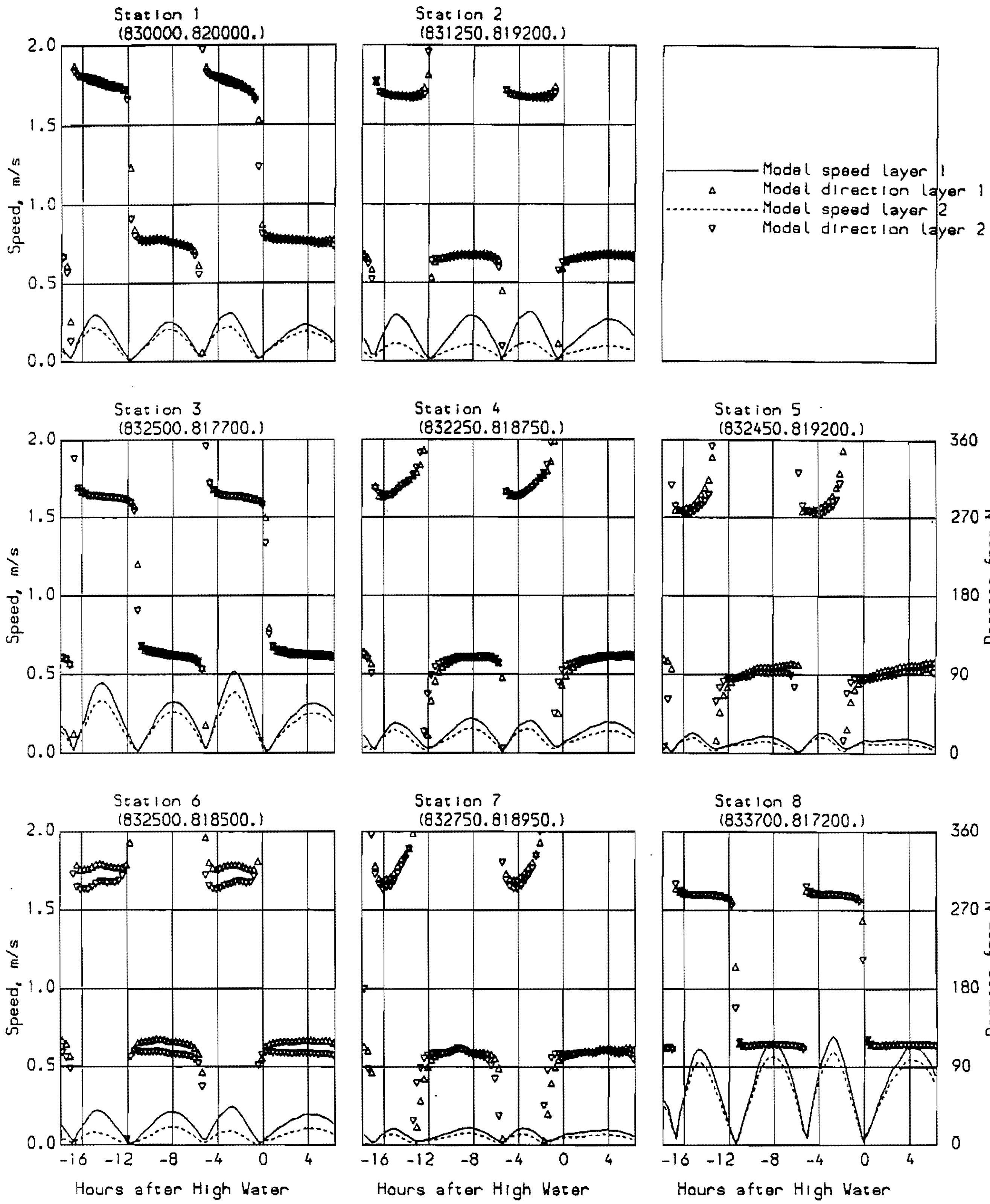


Stonecutters Naval Base Anchorage Area
Completed Scenario
Velocity Vectors
Dry Season Spring Tide

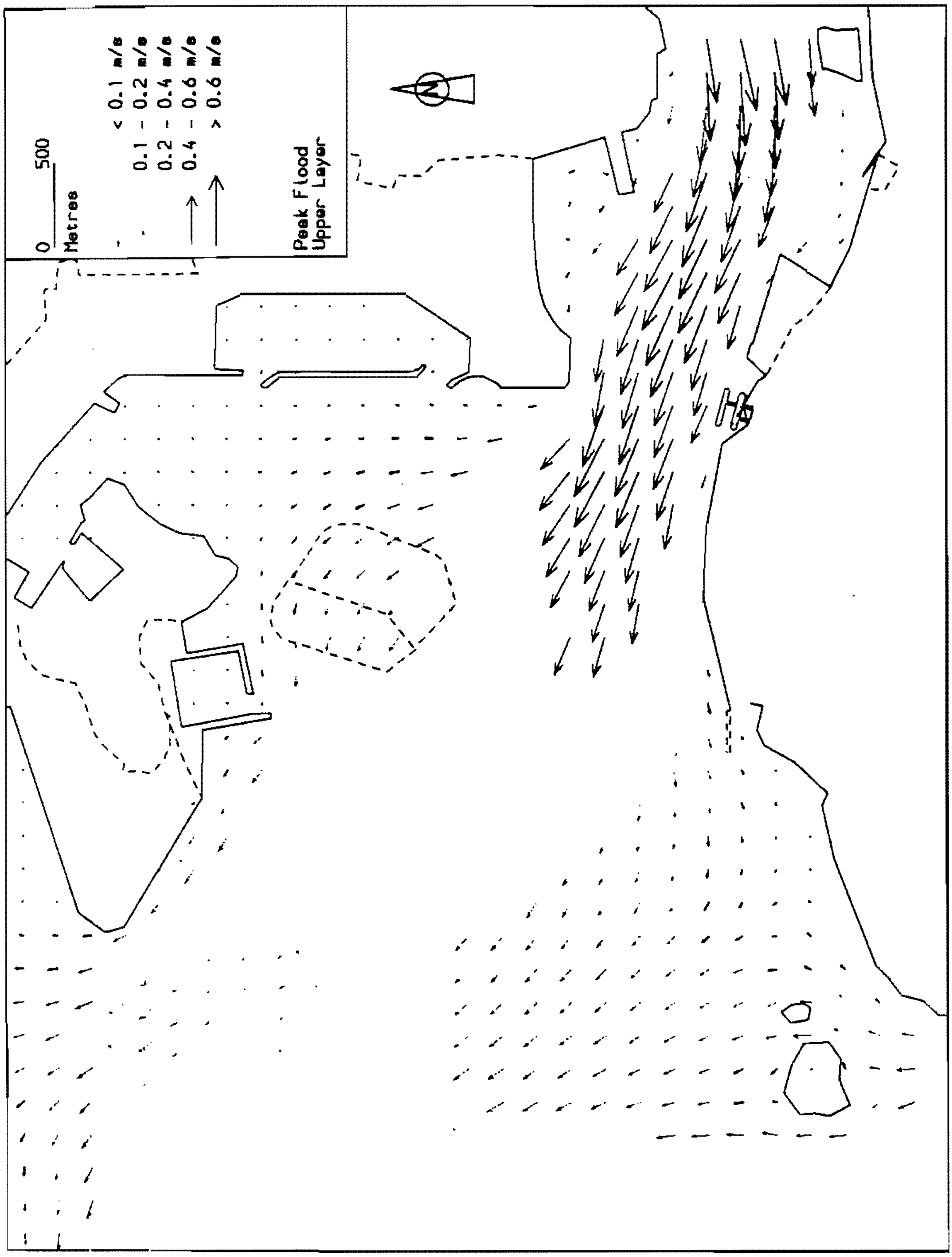


Stonecutters Naval Base Anchorage Area
Completed Scenario
Velocity Vectors
Dry Season Spring Tide

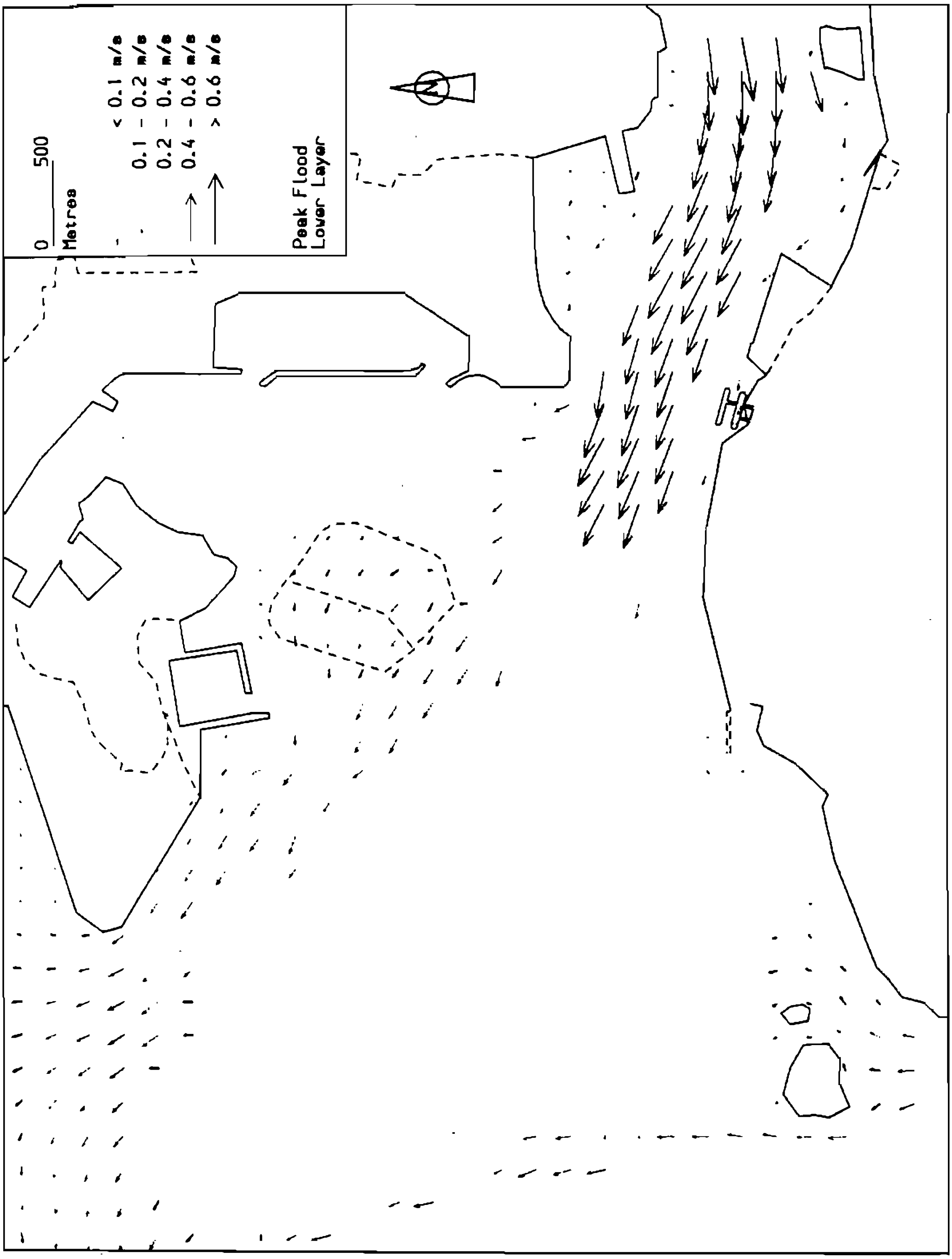
DRY SEASON NEAP TIDE



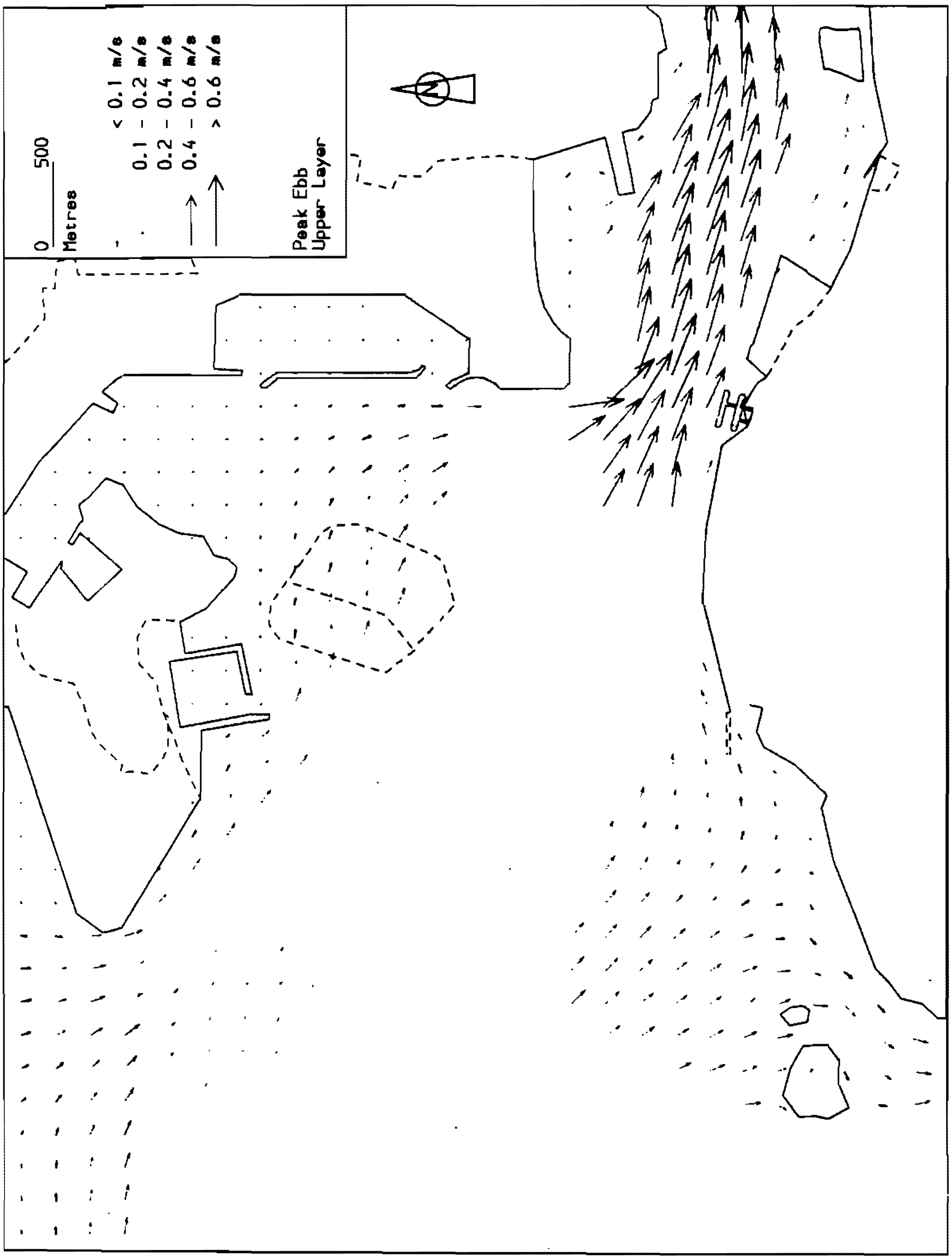
Stonecutters Naval Base Anchorage Area
Completed Scenario
Current Speed & Direction
Dry Season Neap Tide



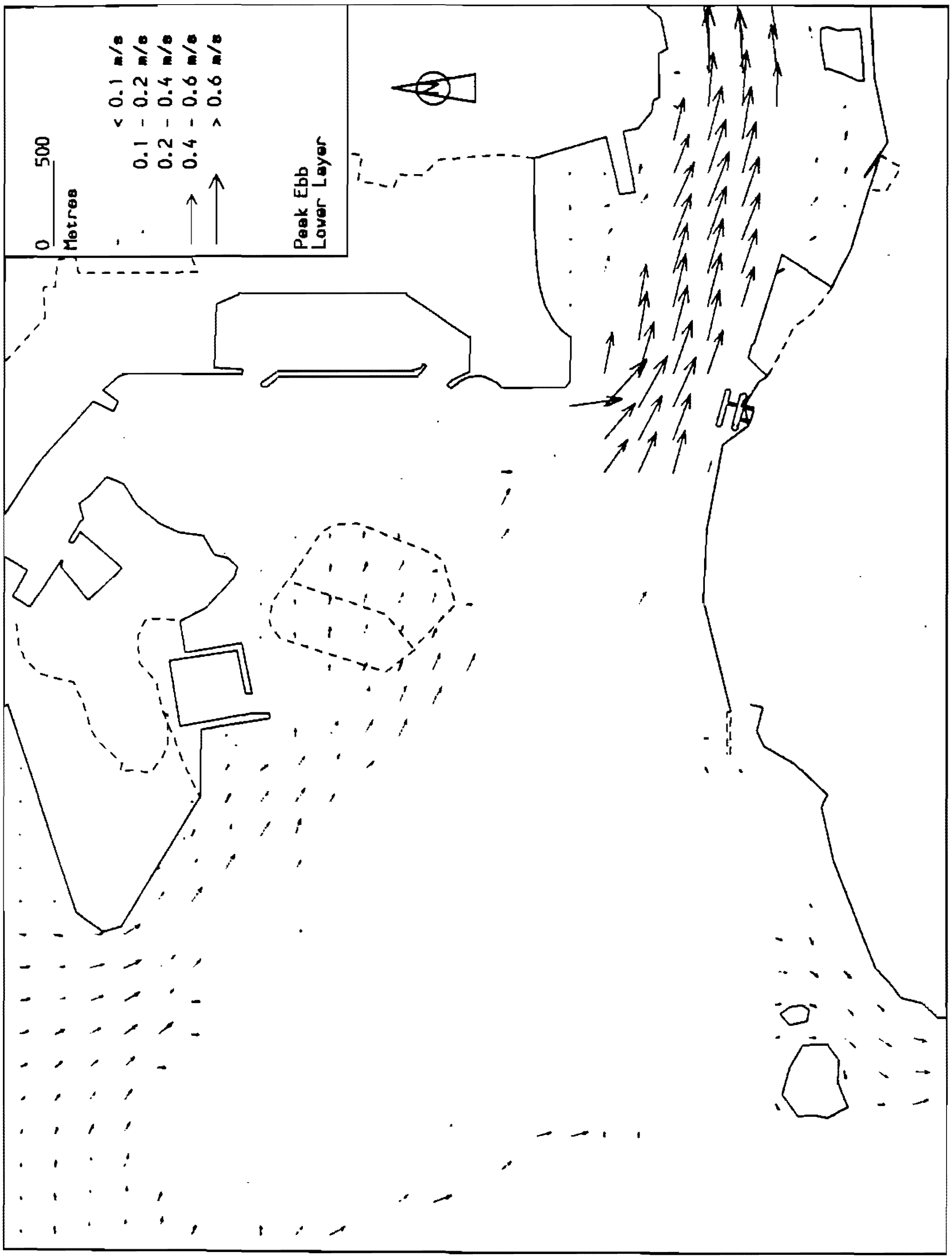
Stonecutters Naval Base Anchorage Area
Completed Scenario
Velocity Vectors
Dry Season Neap Tide



Stonecutters Naval Base Anchorage Area
Completed Scenario
Velocity Vectors
Dry Season Neap Tide



Stonecutters Naval Base Anchorage Area
Completed Scenario
Velocity Vectors
Dry Season Neap Tide



Stonecutters Naval Base Anchorage Area
Completed Scenario
Velocity Vectors
Dry Season Neap Tide

DRY SEASON SPRING TIDE