4 MARINE WATER QUALITY

4.1 Introduction

Earlier reports in this series have presented the findings of an Initial Assessment and an examination of Key Issues pertinent to the Lantau Port Study. Modelling has played a large part in these studies and the previous reports were produced on the basis of an incomplete programme of investigation. This Final Report benefits from having a full set of model output on which to base interpretation and conclusions relating to the fully dredged and the dredge-drained reclamation options. The model output includes 347 different plots and tables produced from the various scenarios investigated. Readers wishing to inspect the model output should refer to CED or EPD. Key figures and tables from the model output have been incorporated here as a means of illustration or as a synopsis of scenario comparisons.

The Brief requires *inter alia* that the Final Assessment Report fully satisfies the requirements in respect to the prediction and assessment of impacts including all findings, conclusions and recommendations. As the study has been phased in so far as different scenarios have been assessed and presented in the Initial Assessment and Key Issues Reports, this Draft Final Assessment therefore incorporates some material taken from the former reports and readers familiar with them will recognise this. However, some statements have been modified in light of new information and/or due to the availability of a complete set of model output. As the Final Assessment may receive a wider readership than the previous reports, much of the technical data is presented as appendices to the main text. This has been done in an attempt to produce a more readable document by the wider audience yet still providing technical detail required by Government Departments and informed readers.

4.2 Objectives of this Report

As all planned modelling has been completed it has been necessary to review previous findings in order to present an overview of all factors assessed to date. The major issues have been the impacts of dredging and filling on suspended solids, dissolved oxygen and nutrients during the reclamation process together with the permanent impacts of stormwater from Penny's Bay and the terminals, and the transfer of sewage from Discovery Bay and Peng Chau to Siu Ho Wan. Methods of placing fill have been assessed by DEMAS with respect to their likely contribution to suspended solids and their comments are incorporated in the following sections.

It should be noted that assessments of impacts at the marine borrow or mud disposal areas are not part of the Brief for the present study and will not therefore be addressed. However, comment is made regarding the environmental resource implications with respect to these issues.

The reader is reminded that technical discussion is largely presented in Appendix form and these include :

Appendix A1	Review of Lantau Port Studies
Appendix A2	Physicochemical Aspects of Contaminant Desorption from Resuspended Sediments
Appendix A3	Approach to Modelling Studies
Appendix A4	Near Field Assessments for Sediment Plumes

The main conclusions of the appendices have been incorporated into the following text which focuses on summaries of the study findings, conclusions and recommendations. Where work has been completed subsequent to submission of the Draft Key Issues Report this is presented in detail under the Results section or incorporated into Appendices A3 and A4.

4.3 Summary of Previous Studies

Three environmental studies relating to Lantau Port have been conducted during the last few years, namely ;

- Lantau Port and Western Harbour Development Studies (LAPH) published in March 1993
- LPD Stage I Container Terminals 10 & 11 Ancillary Works (Design) published in December 1994
- LPD Stage I Container Terminals 10 & 11 Preliminary Design (January 1995)

The foregoing studies are reviewed in Appendix A1 and summarised here. All three studies arrived at essentially similar conclusions, notwithstanding the different scenarios investigated. The primary impacts will be produced as a consequence of the physical presence of the reclamations for the terminals and breakwater and it is the fundamental location of CT10&11 in all scenarios that is responsible for the similarity of, in particular, near field impacts. These may be summarised as temporary or permanent.

4.3.1 Temporary Impacts

Modelled impacts of nutrients desorbed from suspended sediments during dredging are predicted to be small in comparison with the high background concentrations but this remained a key issue as any increase must be viewed with concern and measures should be taken to minimise these impacts as far as is practicable. Dissolved oxygen demand of suspended sediments will be small and within acceptable limits except in the immediate vicinity of dredgers. Bunds and settlement lagoons will reduce suspended sediment impacts during filling. The mariculture zone at Ma Wan should not be subject to greatly elevated suspended solids concentrations as a result of the Port Development.

4.3.2 Permanent Impacts

Circulation rates within Discovery Bay will be changed as a result of the construction of CT10&11 and a quiescent zone will develop close to the Breakwater. Flows immediately outside Discovery Bay will reduce by up to approximately 20% and in the mouth of the Bay will reduce almost to zero. Sedimentation will increase in the vicinity of the Breakwater due to reduced water velocities. Far field changes in sediment deposition are greatest to the west of Lamma. Early implementation of diversion of sewage loads from Discovery Bay and Peng Chau to Siu Ho Wan will mitigate most effectively against eutrophication. If the latter is implemented, water quality in Discovery Bay should not deteriorate from that which exists at present and may actually improve. If sewage diversion is not implemented, water quality will deteriorate, particularly within Discovery Bay, with increased eutrophication and the possibility of algal blooms. Impacts from stormwater runoff from CT10 & 11 should be within acceptable limits.

4.4 Previous Reports in this Series

The primary objective of the present studies has been to compare the impacts of a fully dredged and a dredge-drained construction option. The approach to these studies has been one of looking at worst case scenarios for the fully dredged option as a priority, on the assumption that if water quality objectives could not be met then subsequent evaluation of mitigation measures would be required. In view of the short reporting deadlines, only limited modelling was possible at the Initial Assessment Report stage. At that time, only dredging impacts had been evaluated for both options. Model output indicated that, based on maximum dredging rates for the fully dredged option, there would be no exceedance of Statutory Water Quality Objectives at sensitive receivers for dissolved oxygen and suspended solids. Nutrient and stormwater impacts had not been modelled at that stage.

For the Key Issues Report, approximately 80% of projected modelling had been completed. Worst case scenarios for combined dredging and filling operations had been given priority and it was concluded that for both the fully dredged and the drained options, suspended solids at Ma Wan would exceed the Water Quality Objective of 30% increase over background, although the actual concentration of suspended solids *per se* was low. The fully dredged option produced a greater exceedance of this environmental objective (7.8 mg l^{-1} = 60% increase over background) than the drained option, the latter exceedance being marginal (34%). This same Objective was exceeded at Peng Chau for the fully dredged option (4.2 mg l^{-1} = 50% increase over background) but not for the drained option. Suspended solids at Discovery Bay were low for all scenarios. This assessment was conducted on worst case assumptions and therefore real effects were concluded as probably being less than predicted.

The last statement also applied to nutrient assessments. In this respect, it was considered that the scenario involving a nutrient concentration proportional to the mass of sediment in suspension represented a more realistic, yet still conservative approach, than one in which all nitrogen compounds were instantaneously desorbed and retained in solution. On the former basis, it was concluded that there should not be any measurable impact resulting from nutrients desorbed from sediments during dredging and filling, and on the latter basis, maximum predicted increases were of the order of 10% to 16% over background as total nitrogen. Nonetheless, any potential for increase in nutrients correctly attracts the precautionary principle and in terms of the Lantau Port reclamation, it was recommended that dredging proceeds as slow as is practicable.

Long term changes in water quality off East Lantau as a result of changes in hydrodynamics brought about by the physical presence of the terminals were not predicted to be cause for concern. There will be changes in the pattern of sedimentation with some areas receiving less and some areas receiving more than at present. The general result of the constriction of flow by the eastern arm of the terminals was to shift the pattern of sedimentation more to the south, with less in the north.

Modelling of stormwater impacts and near field suspended sediment assessments had not been completed at the time of producing the Key Issues Report.

4.5 Results of Recent Work

Work completed since submission of the Draft Key Issues Report includes :

- additional plots of nutrient assessment allowing no settling plus additional plots of tide averaged suspended sediment plumes for all scenarios. This output is complementary to those produced for the Key Issues Report.
- bacterial plume modelling for the completed terminals incorporating stormwater
- water quality plots for the completed terminals incorporating stormwater
- near field assessment of sediment plumes

A summary listing of all model output is provided in Table 4.1 and provided in full in Appendix A3.

Table No 4.1 : Summary Listing of Model Output

CASE	DETAILS	OUTPUT	No.Pages
1) HYDRODYNAMICS		Layout of reclamation for each case Location of stations for each case	3 3
BASELINE	- includes reclamations and dredging likely to be in place such as CT7, 8, 9, Western Kowloon Reclamation and South Tsing Yi borrow pit	Current Vector plots for Wet/dry, spring /neap, Surface & Bed layers, flood/ebb Time History Plot	16 4
CONSTRUCTION	- includes noise bunds and entrustment at the rear of CT11	ditto	16 4
COMPLETED	- completed stage of CT 10 and CT11 with the port breakwater in place	ditto	16 4
2) SEDIMENT PLUME SCENARIO 1	BASELINE CONDITION WITH DREDGING ONLY FOR FULLY DREDGED OPTION Each for Wet and Dry, Spring and Neap Total 44	Time series for SS Contour plots for SS (ebb/flood for each layer) Contour for DO (2 layer) Contour for Nutrient (2 layer) Contour for Mud Deposit	8 16 8 8 4
SCENARIO 2	ditto, but DRAINED OPTION Wet and Dry, Spring only	Time series Contour plots	4 18
SCENARIO 3	same as Scenario 1, but worst case for DEDGING and FILLING Wet and Dry, Spring	Time series Contour plots	4 18
SCENARIO 4	same as Scenario 3, but DRAINED OPTION Wet and Dry, Spring	Time series Contour plots	4 18
SCENARIO 5	same as Scenario 3, using CONSTRUCTION PHASE LAYOUT Wet and Dry, Spring	Time series Contour plots	4 18
SCENARIO 1	Extra Plots, for Surface and Bed Layer Extra Plots, for Surface and Bed Layer Each for Wet and Dry, Spring and Neap	Contour for Nutrient - No Settling Contour plots for Tide Averaged SS Concs.	2 8
SCENARIOS 2, 3, 4 AND 5	Extra Plots, for Surface and Bed Layer Each for Wet and Dry, Spring	Contour plots for Tide Averaged SS Concs.	16
3) BACTERIAL PLUME BASELINE	Wet and Dry, Neap Raw sewage discharge from DB and PC	Contour plots of E.coli conc. 2 layes, ebb/flood Time series of E.coli Baseline and Senario 1	4 2
CONSTRUCTION	Wet and Dry, Neap Senario 1 - Discharge at DB disinfected	Contour plots of E.coli conc. 2 layers, ebb/flood	4
COMPLETED	Wet and Dry, Neap Storms in Senario 3	Contour plots of E.coli conc. 2 layers, Start release and Ebb Tide	4
COMPLETED + PENG CHAU	Wet and Dry, Neap Storms in Senario 3	Contour plots of E.coli conc. 2 layers, ebb/ flood	4
4) FLUSHING OF DB BASELINE	Wet and Dry Neap	Distribution of source Concentration plots of pollutant at : 0.5, 12, 24, 36, and 48 hr after release	1 10
CONSTRUCTION	ditto	ditto	10
COMPLETED	ditto	dito	10
5) WATER QUALITY		Location of stations	2
BASELINE & CONSTRUCTION	Wet and Dry Neap	Time series for Baseline & Scen. 1 for DO, BOD, E.coli, Chorophyll NH3-N and organic N (15 stations)	36
BASELINE & COMPLETE	ditto	Time series for Baseline & Storm S3 for DO, BOD, E.coli, Chorophyll NH3-N and organic N (15 stations)	36
		Total Location maps Total Vector plots Total Contour plots Total Concentration plots Total Time Series plots	9 48 150 30 110
		TOTAL	347

4.5.1 General Water Quality

The water quality model provides predictions of water quality throughout the modelled area based on the influence of changes in coastline and/or bathymetry on hydrodynamic flow and includes locations and inputs of sewage and stormwater outfalls. Thus for Lantau Port, the major changes are the reclamation itself, reduction/diversion of Discovery Bay sewage and the introduction of stormwater discharges at specific locations (see Figure 4.1) in the port area. In view of these changes and the different degree of impingement in different areas of the study area, it is convenient to look at different groups of sensitive receivers.

The data output for the sixteen stations modelled can be divided into four geographical subgroups for ease of comparison :

- Ma Wan
- Penny's Bay to Discovery Bay
- Peng Chau to Kau Yi Chau
- Silvermine Bay to Hei Ling Chau

Summaries of tide averaged water quality parameters are given in Table 4.2 The same data expressed as proportional increases or decreases relative to baseline are presented for the construction and completed phases in Table 4.3 Neap tides were assumed to represent worst case as contaminants would receive minimum dilution under this condition. The main impacts in each sub-area may be summarised as follows :

Ma Wan

For wet season neap tides, the model predicts relatively low suspended solids (8 mg l^{-1}) and dissolved oxygen (68% saturation) for the baseline case. Construction of the terminals indicates a decrease in dissolved oxygen to 64% and a small increase in oxidised nitrogen from 0.11 to 0.13 mg l^{-1}. Little change is predicted for suspended solids (maximum 1 mg l^{-1}), BOD, ammonia, organic nitrogen, chlorophyll and *E.coli*.

For the dry season neap tide, suspended solids were generally higher than for the wet season (25 mg l^{-1}) and dissolved oxygen had a higher saturation at 86-88% with negligible difference between these parameters for all three phases. The dry season had slightly higher ammonia and BOD but lower oxidised nitrogen, organic nitrogen and chlorophyll, all of which were in relatively low concentrations.

Penny's Bay to Discovery Bay

The wet season neap tide baseline condition was typified by very low suspended solids (<5 mg l^{-1}), high dissolved oxygen (99%), low BOD, ammonia and oxidised nitrogen but moderate organic nitrogen (0.39 mg l^{-1}) and chlorophyll (8.6 mg l^{-1}). *E.coli* is generally low throughout the area (<25 counts per 100 ml) except in Discovery Bay where counts are of the order of 2,000 per 100 ml. There is little difference during the construction stage but marked changes are predicted for the completed stage. Concentrations of organic nitrogen and chlorophyll are predicted to double and BOD to increase by a factor of three throughout the general area. Dissolved oxygen is predicted to decrease from 99% to approximately 70% saturation. There is a reversal in *E.coli* distribution with Discovery Bay having very low counts (<10 per 100 ml) and Sz Pak increased to 475 per 100 ml.

For the dry season neap there is also little difference between the baseline and construction phases with respect to water quality parameters but there are differences arising from the completed phase. Dissolved oxygen is lower than during the wet season at 48-63% saturation, BOD and oxidised nitrogen are three to four times higher with maxima of 8.2 and 0.36 mg l^{-1} respectively. Organic nitrogen and chlorophyll at 0.58 and 5.8 mg l^{-1} respectively are approximately double, compared to the baseline case. However, these maxima are lower than for the wet season. *E.coli* at Discovery Bay are predicted to reduce from 2,700 to <25 counts per 100 ml and Sz Pak to increase from <16 to 554 per 100 ml.

Inspection of Figure 4.1 shows the reason for these changes to be related to the location of proposed stormwater outfalls serving the Penny's Bay development which discharge to the west of the terminals. The results of stormwater assessments are detailed below.

Peng Chau to Kau Yi Chau

There is little difference between baseline and construction phases on wet season neap tides but the completed phase demonstrates lower dissolved oxygen (85-89% saturation) and slightly higher BOD, organic nitrogen and chlorophyll. A similar pattern is predicted for the dry season neap tide which also has generally higher suspended solids and lower dissolved oxygen, organic nitrogen and chlorophyll than the wet season.

Silvermine Bay to Hei Ling Chau

The influence of the completed phase is less marked in this area for both wet and dry neap tides. Dissolved oxygen is predicted to be not less than 92% saturation, suspended solids <5 mg l^{-1} and BOD <1.7 mg l^{-1}. Organic nitrogen and chlorophyll demonstrate highest concentrations for the completed phase (0.41 and 8.6 mg l^{-1} respectively) although this represents a smaller proportionate increase over baseline compared to the Peng Chau and Discovery Bay areas. Silvermine Bay has high *E.coli* (3,800 counts per 100 ml) derived from local sewage inputs.

Table No 4.2 : Summary of Tide Averaged WQ Parameters

TABLE 4.2 CT10 & 11 Detailed Design - Summary of Water Quality Results

I : BASELINE
II : CONSTRUCTION
III : COMPLETED

Wet Season Neap Tide

Station	Temperature (deg C)			Salinity (ppt)			D.O. (% sat)			BOD (mg/l)			NH3-N (mg/l)			Oxidised N (mg/l)			Organic N (mg/l)			Chlorophyll (mg/l)			SS (mg/l)			E.coli (count/100ml)		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Pak Wan Beach	26.4	26.4	26.4	28.3	28.2	28.2	68.4	67.1	64.6	1.4	1.4	1.5	0.02	0.03	0.03	0.11	0.12	0.13	0.31	0.30	0.32	3.8	3.4	3.7	7.1	7.7	7.7	217	224	231
Ma Wan Mariculture (S)	26.8	26.8	26.8	26.6	26.6	26.5	68.9	67.6	64.9	1.3	1.3	1.4	0.03	0.03	0.04	0.11	0.12	0.13	0.28	0.27	0.28	2.9	2.6	2.5	7.7	8.3	8.4	205	225	251
Ma Wan Mariculture (B)	26.3	26.4	26.4	28.4	28.2	28.2	64.5	64.0	60.3	1.3	1.3	1.5	0.03	0.03	0.04	0.11	0.11	0.12	0.30	0.29	0.30	3.3	2.9	3.0	6.9	7.9	7.9	651	663	696
Ma Wan Fishery	26.4	26.4	26.4	28.3	28.2	28.3	68.5	67.1	64.3	1.4	1.4	1.6	0.02	0.03	0.00	0.11	0.12	0.10	0.31	0.30	0.32	3.9	3.5	3.7	6.9	7.6	7.6	175	190	193
Penny's Bay	26.5	26.7	-	28.9	28.9	-	99.2	97.5	-	1.5	1.2	-	0.01	0.01	-	0.01	0.00	-	0.40	0.36	-	8.6	8.0	-	1.2	0.1	-	1	1	-
Sz Pak Beach	26.6	26.7	26.8	28.9	29.2	29.8	99.0	98.4	74.3	1.4	1.3	8.2	0.01	0.01	0.01	0.01	0.00	0.12	0.39	0.38	0.88	8.6	8.3	17.7	0.7	0.4	5.2	9	6	475
Sam Pak Beach	26.7	26.7	26.8	28.9	29.1	29.7	99.1	98.6	70.4	1.3	1.3	4.8	0.01	0.01	0.00	0.00	0.00	0.02	0.39	0.38	0.79	8.6	8.4	16.3	0.4	0.3	1.7	19	17	17
Tai Pak Wan	26.7	26.7	26.8	28.9	29.1	29.7	99.1	98.6	69.9	1.3	1.3	4.7	0.01	0.01	0.00	0.00	0.00	0.01	0.39	0.38	0.79	8.6	8.4	16.2	0.3	0.3	1.6	24	22	13
Discovery Bay	26.7	26.7	26.7	28.9	29.1	29.7	99.7	99.3	69.5	1.3	1.3	4.0	0.01	0.01	0.01	0.00	0.00	0.01	0.39	0.39	0.75	8.7	8.5	15.3	0.3	0.3	1.2	2020	2011	6
Peng Chau Beach North	26.4	26.4	26.4	29.1	29.3	30.0	96.9	96.3	87.6	1.5	1.5	2.4	0.01	0.01	0.01	0.02	0.02	0.02	0.39	0.39	0.51	8.3	8.0	10.4	2.6	3.0	3.0	6	4	13
Peng Chau Beach West	26.6	26.5	26.5	29.2	29.5	30.1	97.9	97.8	89.4	1.3	1.4	1.9	0.01	0.01	0.01	0.01	0.01	0.01	0.38	0.38	0.47	8.4	8.3	9.9	0.7	0.8	0.9	170	158	177
Kau Yi Chau Fishery	26.2	26.1	26.0	29.6	29.7	30.2	90.0	87.8	85.7	1.6	1.6	1.8	0.01	0.01	0.01	0.04	0.05	0.06	0.38	0.37	0.40	7.3	6.7	7.3	5.3	6.0	6.0	6	6	4
Silver Mine Bay	26.8	26.7	26.7	29.2	29.6	29.9	98.1	97.8	95.6	1.2	1.3	1.4	0.01	0.01	0.01	0.00	0.00	0.00	0.37	0.37	0.40	8.1	8.1	8.7	0.2	0.2	0.2	3821	3807	3808
Silver Mine Bay Fishery	26.8	26.6	26.6	29.2	29.7	30.0	96.7	96.4	94.6	1.2	1.3	1.4	0.01	0.01	0.01	0.00	0.00	0.00	0.37	0.37	0.40	8.0	7.9	8.6	0.4	0.4	0.4	19	19	7
Hei Ling Chau Beach North	26.7	26.5	26.5	29.3	29.8	30.1	96.8	96.6	93.3	1.3	1.3	1.5	0.01	0.01	0.01	0.01	0.01	0.01	0.37	0.38	0.41	8.1	8.0	8.6	0.6	0.7	0.7	81	81	76
Hei Ling Chau Beach East	26.4	26.1	26.1	29.8	30.4	30.8	97.3	96.9	95.0	1.5	1.6	1.7	0.01	0.01	0.01	0.01	0.01	0.02	0.39	0.39	0.41	8.2	7.8	8.1	2.0	2.4	2.5	2	2	2

Dry Season Neap Tide

Station	Temperature (deg C)			Salinity (ppt)			D.O. (% sat)			BOD (mg/l)			NH3-N (mg/l)			Oxidised N (mg/l)			Organic N (mg/l)			Chlorophyll (mg/l)			SS (mg/l)			E.coli (count/100ml)		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Pak Wan Beach	18.8	18.8	18.8	31.1	31.1	31.1	86.9	87.3	86.7	1.7	1.8	1.8	0.06	0.06	0.06	0.09	0.09	0.10	0.27	0.27	0.27	1.2	1.2	1.2	25.7	25.7	25.8	606	571	594
Ma Wan Mariculture (S)	18.8	18.9	18.9	31.1	31.1	31.1	88.4	88.7	88.5	1.8	1.8	1.9	0.06	0.06	0.06	0.09	0.09	0.09	0.26	0.26	0.26	1.3	1.3	1.3	24.6	24.9	25.1	322	313	336
Ma Wan Mariculture (B)	18.8	18.9	18.9	31.1	31.1	31.1	88.3	88.6	88.4	1.8	1.8	1.9	0.06	0.06	0.06	0.09	0.09	0.09	0.26	0.26	0.26	1.3	1.2	1.3	24.1	24.5	24.6	204	198	216
Ma Wan Fishery	18.8	18.8	18.8	31.1	31.1	31.1	86.8	87.3	86.6	1.7	1.8	1.8	0.06	0.06	0.06	0.09	0.09	0.10	0.27	0.27	0.27	1.2	1.2	1.2	25.7	25.8	25.8	613	579	603
Penny's Bay	17.7	17.1	-	31.1	31.1	-	87.9	98.4	-	1.5	1.4	-	0.01	0.00	-	0.09	0.04	-	0.29	0.30	-	2.5	4.2	-	5.6	0.8	-	2	1	-
Sz Pak Beach	17.4	17.3	17.4	31.1	31.1	31.1	92.8	95.8	48.5	1.4	1.4	8.2	0.01	0.00	0.02	0.07	0.06	0.36	0.30	0.30	0.58	3.3	3.8	5.0	3.8	2.4	6.8	16	9	554
Sam Pak Beach	17.3	17.2	17.2	31.1	31.1	31.1	95.6	97.4	57.7	1.4	1.4	5.0	0.00	0.00	0.00	0.06	0.05	0.21	0.30	0.30	0.55	3.8	4.1	5.6	2.0	1.5	2.8	33	30	25
Tai Pak Wan	17.3	17.2	17.2	31.1	31.1	31.1	95.7	97.5	58.1	1.4	1.4	4.9	0.00	0.00	0.00	0.06	0.05	0.21	0.30	0.30	0.54	3.8	4.1	5.6	1.9	1.5	2.7	44	40	21
Discovery Bay	17.2	17.2	17.1	31.1	31.1	31.1	96.6	98.0	63.3	1.4	1.4	4.3	0.01	0.01	0.00	0.06	0.05	0.18	0.31	0.31	0.53	4.0	4.2	5.8	1.7	1.4	2.2	2722	2714	9
Peng Chau Beach North	17.9	18.0	17.8	31.1	31.1	31.1	86.3	85.6	72.2	1.5	1.5	2.4	0.02	0.03	0.01	0.09	0.09	0.13	0.28	0.28	0.35	2.2	2.0	2.7	12.2	14.1	10.8	20	15	32
Peng Chau Beach West	17.2	17.3	17.2	31.2	31.1	31.2	96.5	96.0	84.4	1.3	1.3	2.1	0.00	0.00	0.00	0.05	0.05	0.07	0.29	0.29	0.37	4.1	3.9	4.8	2.3	2.7	2.3	256	218	248
Kau Yi Chau Fishery	18.2	18.3	18.2	31.1	31.1	31.1	82.1	81.7	77.7	1.5	1.5	1.7	0.03	0.04	0.04	0.09	0.10	0.11	0.28	0.28	0.29	1.6	1.4	1.6	19.5	21.6	20.2	21	30	29
Silver Mine Bay	17.0	17.0	17.0	31.2	31.2	31.2	100.9	100.9	99.2	1.2	1.2	1.3	0.01	0.01	0.01	0.02	0.02	0.02	0.29	0.28	0.30	4.9	4.8	5.1	0.3	0.4	0.3	4517	4514	4503
Silver Mine Bay Fishery	17.2	17.2	17.2	31.2	31.2	31.2	100.1	99.8	97.8	1.2	1.2	1.3	0.00	0.00	0.00	0.02	0.02	0.02	0.28	0.28	0.29	4.6	4.5	4.9	0.7	0.8	0.7	29	29	11
Hei Ling Chau Beach North	17.3	17.2	17.2	31.2	31.2	31.2	99.6	99.2	96.7	1.2	1.2	1.3	0.00	0.00	0.00	0.03	0.03	0.03	0.28	0.28	0.30	4.5	4.4	4.8	1.0	1.2	1.0	89	94	87
Hei Ling Chau Beach East	17.4	17.4	17.4	31.2	31.2	31.2	97.2	95.3	92.7	1.2	1.2	1.4	0.00	0.00	0.00	0.04	0.05	0.05	0.28	0.28	0.30	4.1	3.8	4.2	2.8	4.1	3.5	5	6	5

Table No 4.3 : WQ data as a proportional increases / decreases to baseline

TABLE 4.3 CT10 & 11 Detailed Design - Summary of Water Quality Results

I : BASELINE
II : CONSTRUCTION
III : COMPLETED

Wet Season Neap Tide

Station	Temperature (deg C)			Salinity (ppt)			D.O. (% sat)			BOD (mg/l)			NH3-N (mg/l)			Oxidised N (mg/l)			Organic N (mg/l)			Chlorophyll (mg/l)			SS (mg/l)			E.coli (count/100ml)		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Pak Wan Beach	26.35	1.00	1.00	28.27	1.00	1.00	68.35	0.98	0.95	1.40	0.99	1.10	0.02	1.50	1.50	0.11	1.09	1.18	0.31	0.97	1.03	3.80	0.90	0.96	7.06	1.09	1.09	217	1.03	1.06
Ma Wan Mariculture (S)	26.78	1.00	1.00	26.55	1.00	1.00	68.92	0.96	0.94	1.27	0.98	1.09	0.03	1.00	1.33	0.11	1.09	1.18	0.28	0.96	1.00	2.87	0.89	0.88	7.73	1.08	1.08	205	1.10	1.22
Ma Wan Mariculture (B)	26.32	1.00	1.00	28.43	0.99	0.99	64.52	0.99	0.93	1.34	0.98	1.11	0.03	1.00	1.33	0.11	1.00	1.09	0.30	0.97	1.00	3.32	0.89	0.91	6.93	1.14	1.14	651	1.02	1.07
Ma Wan Fishery	26.35	1.00	1.00	28.28	1.00	1.00	68.49	0.98	0.94	1.41	0.98	1.10	0.02	1.50	0.00	0.11	1.09	0.91	0.31	0.97	1.03	3.87	0.90	0.95	6.88	1.11	1.10	175	1.09	1.10
Penny's Bay	26.51	1.01		28.94	1.00		99.23	0.98		1.46	0.82		0.01	1.00		0.01	0.00		0.40	0.90		8.64	0.93		1.23	0.11		1	1.00	
Sz Pak Beach	26.63	1.00	1.01	28.92	1.01	1.03	99.00	0.99	0.75	1.36	0.96	6.00	0.01	1.00	1.00	0.01	0.00	12.00	0.39	0.97	2.26	8.61	0.97	2.05	0.68	0.59	7.60	9	0.67	52.78
Sam Pak Beach	26.68	1.00	1.00	28.89	1.01	1.03	99.07	1.00	0.71	1.33	0.97	3.61	0.01	1.00	0.00	0.00	######	######	0.39	0.97	2.03	8.61	0.97	1.89	0.35	0.74	4.97	19	0.89	0.89
Tai Pak Wan	26.69	1.00	1.00	28.89	1.01	1.03	99.08	1.00	0.71	1.32	0.98	3.55	0.01	1.00	0.00	0.00	######	######	0.39	0.97	2.03	8.61	0.97	1.88	0.34	0.74	4.82	24	0.92	0.54
Discovery Bay	26.70	1.00	1.00	28.87	1.01	1.03	99.72	1.00	0.70	1.34	0.99	2.99	0.01	1.00	1.00	0.00	######	######	0.39	1.00	1.92	8.73	0.97	1.76	0.33	0.79	3.70	2020	1.00	0.00
Peng Chau Beach North	26.44	1.00	1.00	29.14	1.01	1.03	96.86	0.99	0.90	1.47	1.01	1.65	0.01	1.00	1.00	0.02	1.00	1.00	0.39	1.00	1.31	8.30	0.96	1.26	2.55	1.18	1.18	6	0.67	2.17
Peng Chau Beach West	26.64	1.00	0.99	29.16	1.01	1.03	97.87	1.00	0.91	1.33	1.03	1.40	0.01	1.00	1.00	0.01	1.00	1.00	0.38	1.00	1.24	8.40	0.98	1.17	0.69	1.14	1.33	170	0.93	1.04
Kau Yi Chau Fishery	26.17	1.00	0.99	29.59	1.00	1.02	89.98	0.98	0.95	1.58	0.99	1.14	0.01	1.00	1.00	0.04	1.25	1.50	0.38	0.97	1.05	7.30	0.91	1.00	5.32	1.12	1.12	6	1.00	0.67
Silver Mine Bay	26.81	1.00	1.00	29.15	1.02	1.03	98.12	1.00	0.97	1.24	1.04	1.10	0.01	1.00	1.00	0.00	######	######	0.37	1.00	1.08	8.12	1.00	1.07	0.19	1.11	1.05	3821	1.00	1.00
Silver Mine Bay Fishery	26.75	0.99	0.99	29.22	1.02	1.03	96.74	1.00	0.98	1.24	1.04	1.12	0.01	1.00	1.00	0.00	######	######	0.37	1.00	1.08	8.01	0.99	1.07	0.37	1.19	1.11	19	1.00	0.37
Hei Ling Chau Beach North	26.69	0.99	0.99	29.29	1.02	1.03	96.81	1.00	0.96	1.29	1.04	1.14	0.01	1.00	1.00	0.01	1.00	1.00	0.37	1.03	1.11	8.09	0.99	1.07	0.60	1.22	1.13	81	1.00	0.94
Hei Ling Chau Beach East	26.38	0.99	0.99	29.84	1.02	1.03	97.27	1.00	0.98	1.48	1.05	1.12	0.01	1.00	1.00	0.01	1.00	2.00	0.39	1.00	1.05	8.24	0.95	0.99	1.97	1.23	1.28	2	1.00	1.00

Dry Season Neap Tide

Station	Temperature (deg C)			Salinity (ppt)			D.O. (% sat)			BOD (mg/l)			NH3-N (mg/l)			Oxidised N (mg/l)			Organic N (mg/l)			Chlorophyll (mg/l)			SS (mg/l)			E.coli (count/100ml)		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Pak Wan Beach	18.79	1.00	1.00	31.14	1.00	1.00	86.85	1.01	1.00	1.73	1.02	1.04	0.06	1.00	1.00	0.09	1.00	1.11	0.27	1.00	1.00	1.22	1.00	1.00	25.65	1.00	1.00	606	0.94	0.9802
Ma Wan Mariculture (S)	18.82	1.00	1.00	31.13	1.00	1.00	88.40	1.00	-1.00	1.80	1.01	1.06	0.06	1.00	1.00	0.09	1.00	1.00	0.26	1.00	1.00	1.26	0.99	0.99	24.58	1.01	1.02	322	0.97	1.0435
Ma Wan Mariculture (B)	18.83	1.00	1.00	31.14	1.00	1.00	88.28	1.00	1.00	1.80	1.01	1.05	0.06	1.00	1.00	0.09	1.00	1.00	0.26	1.00	1.00	1.25	0.99	1.00	24.14	1.01	1.02	204	0.97	1.0588
Ma Wan Fishery	18.79	1.00	1.00	31.14	1.00	1.00	86.79	1.01	1.00	1.73	1.01	1.04	0.06	1.00	1.00	0.09	1.00	1.11	0.27	1.00	1.00	1.22	1.00	1.00	25.70	1.00	1.00	613	0.94	0.9837
Penny's Bay	17.72	0.97		31.14	1.00		87.87	1.12		1.45	0.94		0.01	0.00		0.09	0.44		0.29	1.03		2.45	1.73		5.61	0.14		2	0.50	
Sz Pak Beach	17.44	0.99	0.99	31.14	1.00	1.00	92.80	1.03	0.52	1.42	0.99	5.78	0.01	0.00	2.00	0.07	0.86	5.14	0.30	1.00	1.93	3.34	1.15	1.51	3.77	0.63	1.80	16	0.56	34.625
Sam Pak Beach	17.29	0.99	0.99	31.14	1.00	1.00	95.57	1.02	0.60	1.41	0.99	3.55	0.00	######	######	0.06	0.83	3.50	0.30	1.00	1.83	3.79	1.08	1.47	1.97	0.75	1.41	33	0.91	0.7576
Tai Pak Wan	17.28	0.99	0.99	31.14	1.00	1.00	95.68	1.02	0.61	1.41	0.99	3.48	0.00	######	######	0.06	0.83	3.50	0.30	1.00	1.80	3.81	1.08	1.47	1.92	0.76	1.39	44	0.91	0.4773
Discovery Bay	17.23	1.00	0.99	31.14	1.00	1.00	96.56	1.01	0.66	1.43	1.00	3.00	0.01	1.00	0.00	0.06	0.83	3.00	0.31	1.00	1.71	3.99	1.06	1.46	1.74	0.81	1.25	2722	1.00	0.0033
Peng Chau Beach North	17.87	1.01	0.99	31.14	1.00	1.00	86.31	0.99	0.84	1.45	1.03	1.64	0.02	1.50	0.50	0.09	1.00	1.44	0.28	1.00	1.25	2.22	0.90	1.20	12.19	1.15	0.89	20	0.75	1.6
Peng Chau Beach West	17.24	1.00	1.00	31.15	1.00	1.00	96.52	0.99	0.87	1.31	1.01	1.57	0.00	######	######	0.05	1.00	1.40	0.29	1.00	1.28	4.06	0.97	1.18	2.32	1.15	0.98	256	0.85	0.9688
Kau Yi Chau Fishery	18.16	1.01	1.00	31.14	1.00	1.00	82.13	0.99	0.95	1.48	1.04	1.16	0.03	1.33	1.33	0.09	1.11	1.22	0.28	1.00	1.04	1.60	0.88	0.97	19.52	1.11	1.04	21	1.43	1.381
Silver Mine Bay	17.00	1.00	1.00	31.16	1.00	1.00	100.94	1.00	0.98	1.18	1.01	1.06	0.01	1.00	1.00	0.02	1.00	1.00	0.29	0.97	1.03	4.85	0.99	1.06	0.33	1.12	1.00	4517	1.00	0.9969
Silver Mine Bay Fishery	17.19	1.00	1.00	31.17	1.00	1.00	100.08	1.00	0.98	1.16	1.00	1.08	0.00	######	######	0.02	1.00	1.00	0.28	1.00	1.04	4.59	0.99	1.06	0.68	1.19	1.00	29	1.00	0.3793
Hei Ling Chau Beach North	17.26	1.00	1.00	31.17	1.00	1.00	99.60	1.00	0.97	1.18	1.01	1.11	0.00	######	######	0.03	1.00	1.00	0.28	1.00	1.07	4.47	0.98	1.07	1.02	1.21	0.98	89	1.06	0.9775
Hei Ling Chau Beach East	17.39	1.00	1.00	31.17	1.00	1.00	97.17	0.98	0.95	1.22	1.02	1.11	0.00	######	######	0.04	1.25	1.25	0.28	1.00	1.07	4.07	0.93	1.02	2.83	1.43	1.22	5	1.20	1

4.5.2 Stormwater Impact

The fifteen stormwater outfalls simulated are shown in Figure 4.1. Five outfalls for each of CT10 and CT11 serve the terminals area, two draining the Penny's Bay development discharge to the west of the terminals, and three serving the backup area discharge to the east of the terminals.

Figure 4.1 serves to illustrate that short term dispersion of stormwater-borne contaminants along the front of the terminals is relatively good. For *E.coli* for example, background concentrations are generally reached within 1 km after four hours of dispersion. Dispersion to the east of the terminals also appears to be effective. However, as anticipated in previous studies, dispersion to the west of the terminals in the Sz Pak embayment is not good and there are indications that little dispersion has occurred even after 24 hours. Use of the water quality model to predict tidal averaged increases in *E.coli* indicate concentrations of 475 and 554 counts per 100 ml for the wet and dry seasons respectively.

The influence of stormwater derived organic nitrogen was predicted to increase concentrations in the Penny's Bay to Discovery Bay area to 0.75 to 0.88 mg l^{-1} in the wet season compared to 0.39 mg l^{-1} for the baseline condition. Increases in the dry season were smaller at 0.53 to 0.58 mg l^{-1}. Increases in BOD were similar for wet and dry season neaps and in the range of 4.0 to 8.2 mg l^{-1} compared to a baseline of 1.4 mg l^{-1}.

4.5.3 Near Field Assessment of Sediment Plumes

As the WAHMO model was based on a 100 m grid it was considered by EPD that alternative means to establish near field effects of dredging should be adopted and a number of references were provided. The results presented here were based on a method according to R E Watson[3] and calculations are presented in Appendix A4.

As dredge and fill activities at CT10 and CT11 will be approximately 1km apart, near field assessments for each terminal have been considered separately. Although the worst case scenario will be combined dredge and fill activities, all options were evaluated.

The calculations predicted that for the worst case, for CT11, suspended solids of 2,800 mg l^{-1} would result at a distance of 43 m from the source and would decrease to approximately background at a distance of 1 km. Based on a background of 8 mg l^{-1}, the WQO objective of an increase of 30% over background would be achieved within approximately 650 m of the source. For CT10, where rates of dredge and fill are lower than CT11, the WQO is predicted to be met within approximately 600 m.

Under the same assumptions as those made for the WAHMO modelling of nutrients, increases in total nitrogen concentrations at 250, 400 and 650 m from source are estimated as 0.1, 0.02 and 0.005 mg l^{-1} respectively.

4.5.4 Bacterial Plume

Dry season neap tides indicated poorer flushing than wet season neap tides. As described above for the stormwater modelling, in the absence of the Discovery Bay and

[3] 'A Model for the Estimation of the Concentrations and Spatial Extent of Suspended Sediment Plumes" in Estuarine and Coastal Marine Science (1979), Vol 9, pp65-78.

Peng Chau sewage outfalls, bacterial water quality in Discovery Bay and around Peng Chau is predicted to be good, with *E.coli* counts of less than 20 per 100 ml. The poorest bacterial situation will be in the Sz Pak area (*E.coli* up to approximately 500 per 100 ml) as a result of the proposed locations of two stormwater outfalls.

If the Peng Chau outfall is neither diverted nor treated, the area of its influence extends primarily along the east and north shores of Peng Chau and during the flood tide impinges on the western end of the reclamation area where counts of between 200 and 500 per 100 ml are predicted. Along the north shore of Peng Chau peak counts of 100 to 200 per 100 ml are predicted on the flood tide, reducing to 50 to 100 per 100 ml on the ebb tide. Worst case on eastern Peng Chau in the vicinity of Tung Wan is 20 to 50 *E.coli* per 100 ml. The beach at Discovery Bay is not affected but bacterial counts in the outer Bay are predicted to be of the order of 50 to 100 per 100 ml.

The above results indicate that in terms of bacteriological water quality, the general area should meet the Water Quality Objective for secondary water contact sports of 610 *E.coli* per 100 ml other than perhaps in the immediate vicinity of the proposed stormwater outfalls at Sz Pak. The bathing Water Quality Objective of 180 *E.coli* per 100 ml is predicted to be met at Discovery Bay, Yi Pak and Tung Wan.

4.6 Interpretation of Modelling Results

When interpreting the hydrodynamic results, it should be remembered that :

- Although the model is a two layer model, there are some shallow areas that have only one layer of fluid (ie. without the bottom layer). This is especially true in those areas of interest for the Lantau Port project. Besides the waters east of the TCT peninsula and on the two sides of Peng Chau, only one layer exists in the Lantau Port Area (relatively small in area and shallow when compared with the whole area modelled).
- The 100 m grid specified in the Brief may not have sufficient resolution to accurately simulate the flow within the enclosed bays such as Penny's Bay and Discovery Bay.
- As detailed in Appendices A2 and A3 the assessments have been undertaken on very much a worst case basis. Scenarios adopted have tended, in the absence of detailed research, known chemistry of the reactions involved or information, to assume worst case in each respect. Where multiple assumptions have been required, the resulting cumulative safety margins are probably large with an over-prediction of impact. The approximate magnitude of such overestimation is addressed for each relevant case in the Discussion section at the end of this report.

There are three situations which have been modelled which are :

- baseline;
- construction; and
- completed.

Table 4.1 outlines the model runs completed to date. Summaries of changes in hydrodynamics are provided here for the construction and completed phases, together with water quality overviews.

4.6.1 Construction Phase

The effect of the construction of the bunds on the hydrodynamics of the study area may be summarised as follows :

- There is not much difference to the flow pattern in the main water channel compared to baseline.

- Some enclosed or sheltered areas are created, where current speed is reduced. These areas are :

  1) Penny's Bay - the entrance to the Bay is blocked to a very large extent, leaving a very small channel connecting the bay and the marine waters.
  2) Noise Bund - an enclosed area is formed within the noise bund, which will be filled up at a later stage. Almost still water in this area.
  3) Area west of the western entrustment and noise bund for CT11 - During the baseline, water is flowing towards the northeast during flood tide and southwest during ebb tide. Due to the physical obstruction of the noise bund, the already low velocity is further reduced. This can be visualized as an enlargement of the enclosed waters in Discovery Bay.
  4) Area east of the noise bund for CT10 - after construction of the noise bund, a semi-enclosed area is formed by the noise bund and the southern coast of TCT Peninsula. The effect is more pronounced during flood tide, when water flows northeasterly at about 0.20 m s^{-1} before turning north at the east side of TCT Peninsula creating an area of reduced flow 'behind' the bund. There will probably be a back-eddy in this area but the model was of insufficient resolution to simulate this.

- Just outside Discovery Bay, the velocity is very small, as in the baseline situation.

- Just in front of CT10 and CT11, the velocity remains roughly the same as in the baseline (about 0.10 to 0.20 m s^{-1}). However, the direction of flow is altered to a certain extent due to the presence of the noise bund. For the baseline, the current turns gradually as the tide changes, whereas after the noise bund is constructed, the current direction remains quite constant (45 degrees during flood and 225 degrees during ebb) and turns around quickly as the tide changes.

4.6.2 Completed Phase

The final hydrodynamic regime as influenced by the presence of the full reclamation of CT10 and CT11 including the local breakwater may be summarised as follows :

- There is not much difference to the flow pattern in the main water channel compared to baseline.

- The enclosed area in Penny's Bay, within the noise bund and east of the noise bund for CT10 has been reclaimed.

- As in the construction case, a larger sheltered area is formed on the eastern side of the terminal.

- Dredging the access channel in front of CT10 and CT11 results in a very steady direction of flow during flood and ebb. Due to the increased depth, the maximum velocity is reduced to about 0.10 m s^{-1}.

- The breakwater alters the flow pattern in its vicinity. During baseline conditions, the flow is predominantly due north during flood and south during ebb. With the breakwater in place, water is forced to flow northeasterly during flood and southwesterly during ebb. Also a small region of still water is observed on the lee side of the breakwater.

4.6.3 Nutrients

For the scenario wherein nutrient availability was proportional to the mass of sediment in suspension, daily average nutrient levels derived from the sediment plume for the fully dredged option were less than 0.01 mg l^{-1} within approximately 250 m of the dredgers for both wet and dry season spring tides (Figure 4.2). Outside the area of the terminals, increases in nutrient concentration were less than 0.0025 mg l^{-1} at a distance of approximately 2 km from Discovery Bay beach and 1 km from the north shore of Peng Chau. Background concentrations are approximately 0.30 mg l^{-1}.

For the scenario wherein nutrient levels were derived by instantaneous desorption and exhibited fully conservative behaviour, the area of impact was greater as would be expected (Figure 4.3). In the vicinity of the terminals, increases in nutrient concentration were in the range 0.03 to 0.05 mg l^{-1} and the area from Fa Peng to the southern end of Peng Chau and inshore of this line to outer Discovery Bay, had increases in concentration in the range of 0.01 to 0.03 mg l^{-1}. For Inner Discovery Bay and off Yi Pak, nutrients were predicted to reach between 0.001 and 0.01 mg l^{-1} over background while Discovery Bay Beach was less than 0.001 mg l^{-1}. Background concentrations were predicted as being met in the vicinity of Ma Wan in the north and Hei Ling Chau in the south.

Calculations of near field impacts predict increases in total nitrogen concentrations at 250, 400 and 650 m from source of 0.1, 0.02 and 0.005 mg l^{-1} respectively. These results support the inference that impacts from nutrients derived from dredging and filling activities will not be a key issue. However, stormwater derived nutrients are predicted to contribute to adverse impacts in the vicinity of the proposed Sz Pak outfalls leading to higher chlorophyll concentrations ie increase in planktonic activity.

4.6.4 Sediment Transport

The general pattern of sediment transport was as follows :

- During flood tide, fine particles are carried away by the tidal current in a northeasterly direction along the coast of TCT Peninsula. The sediment plume turns north and travels around the peninsula towards Kap Shui Mun.

- During ebb tide, the fine particles flow south towards Peng Chau, and separate into different streams on the sides of Peng Chau and Siu Kau Yi Chau.

Far field effects for each scenario are shown in Table 4.4 :

Table No 4.4 : Max. increase in suspended solids concentration (mg l^{-1}) at key SRs (A), (B)

Scenario	Wet Season Spring Tide		Wet Season Neap Tide		Dry Season Spring Tide		Dry Season Neap Tide	
	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
I	1.1	2.3	1.7	0.2	2.7	1.9	2.2	1.0
II	0.3	1.0	-	-	1.1	0.8	-	-
III	4.9	4.2	-	-	7.8	3.1	-	-
IV	3.0	2.1	-	-	4.4	1.6	-	-
V	1.8	9.7	-	-	3.8	6.2	-	-

(A) Ma Wan Mariculture (susceptible to increased S.S. during flood tide)
(B) Peng Chau North Beach (susceptible during ebb tide)

Before the noise bund is constructed, the worst case will be Scenario III, ie., combined dredging and filling for the fully dredged option. The predicted maximum increase in suspended solids at Ma Wan mariculture is 7.8 ppm and Peng Chau north beach is 4.2 ppm. For all cases, the increase in suspended solids induced in Penny's Bay and Discovery Bay is comparatively negligible, less than 1 mg l^{-1}.

When the noise bund is in place, dispersion of the sediment plume to the west of the site is reduced due to the physical barrier. On the ebb tide this results in a higher increase in suspended solids to the south, and an increase of 9.7 ppm is predicted at Peng Chau north beach (non-gazetted) in the wet season. A similar concentration is predicted off Tung Wan, although the bay itself remains at less than 1.0 ppm. This may be due to a lack of resolution of the model in view of the small scale of Tung Wan, however, close inspection of the model output indicates a narrow band of suspended solids in the range of 1 to 5 ppm at the entrance to Tung Wan therefore it may be inferred that within the Bay concentrations of suspended solids may be in a similar range or less.

4.6.5 Sediment Deposition Due to Dredging

For combined dredging of Scenarios III and IV, since the rate of loss of fine particles into the water column has increased over Scenarios I and II, it is reasonable to expect the fine particles to settle over a larger extent and the area with a deposition rate exceeding 0.2 mg l^{-1} has increased. The major affected area will be the Access Channel and the areas on the two sides of the terminals. A small portion of the particles will settle within Penny's Bay. Impact is considerably less for the drained option than for the fully dredged option.

With the noise bund in place for Scenario V, most of the fine particles will be deposited within the bund, which will finally be reclaimed. Deposition is also observed on the eastern side of the noise bund, due to reduced flow in the sheltered area formed by the TCT Peninsula and the noise bund. Since sediment transport is increased towards the south, a higher deposition rate is also observed south of CT10 and 11, in the range 0.2

to 0.4 mg l^{-1}. Deposition is reduced to the west of the site.

4.6.6 Water Quality Modelling

The water quality model was used to simulate the long term behaviour of the marine environment. Stormwater discharges from Discovery Bay and the terminal, and sewage from the Discovery Bay and Peng Chau outfalls were included in the model for certain scenarios only (see Appendix A3 for details). Scenarios were simulated for Baseline, Construction, and Completed phases.

Water Quality (WQ) results at fifteen receivers were presented in Section 4.5 of this report and summarized in Table 4.2. For Ma Wan mariculture, results are presented for both surface (S) and bottom layer (B). For other stations, there is no bottom layer due to the shallowness of the water. An overview of all water quality modelling is presented in Table 4.5 below. It will be noted that the major impacts identified are consistently related to discharges from the proposed stormwater outfalls to the west of the terminals at Sz Pak.

Table No 4.5 : Main impacts on WQ Parameters Arising from CT10 & 11 Reclamation

PARAMETER	COMMENTS
Temperature	Effects are seasonal and not related to CT10&11
Salinity	As above
Dissolved Oxygen	Marked decrease (min 48% saturation) in the completed phase in the Penny's Bay to Discovery Bay area and to a lesser extent at Peng Chau; probably due to storm input. All other areas illustrate little or no decrease.
BOD	Little difference between seasons or phases except for the completed phase at Penny's Bay to Discovery Bay (max 8.2 mg l^{-1}); probably due to stormwater input.
Ammonia	Consistently low throughout the area with highest concentrations at Ma Wan in the dry season (0.06 mg l^{-1}). No difference between scenarios.
Oxidised Nitrogen	Consistently low everywhere in the wet season except at Ma Wan (0.12 mg l^{-1}). Levels generally higher in the dry season except at Ma Wan which reduces to 0.09 mg l^{-1} but remains highest of all stations except for Penny's Bay to Discovery Bay for the completed phase (wet season 0.18 to 0.36 mg l^{-1}); probably due to stormwater input.
Organic Nitrogen	Generally consistent throughout the area with highest values in the wet season (0.3 to 0.4 mg l^{-1}). Completed phase has the highest concentrations at 0.75 to 0.88 mg l^{-1} in the Penny's Bay to Discovery Bay area; probably due to stormwater input
E.coli	Bacterial concentrations were highest in Silvermine Bay (4,500 counts per 100 ml) and Discovery Bay (2,000 per 100 ml). For the completed phase, counts at Discovery Bay reduced to almost zero but Silvermine Bay remained constant. Increased coliforms were also predicted at Sz Pak; probably due to stormwater input. There was little change between phases for all other stations.
Chlorophyll	Highest concentrations occur in the wet season. Generally consistent throughout the area and between phases except for Penny's Bay to Discovery Bay for the completed phase (wet season 15.3 to 17.7 mg l^{-1}); probably due to stormwater input.

4.6.7 Bacterial Plume

For the baseline condition, the bacterial plume is transported by the tidal current towards the mouth of Penny's Bay during flood tide and towards the south during ebb tide. The surface concentration of the bacterial plume is in the order of 1000 to 2000 counts / 100 ml (compared to WQO of 610 count per 100 ml for secondary contact and recreation sub-zone, and 180 counts per 100 ml for bathing beaches). In general, the *E.coli* concentration in early morning (7 am) is higher than that during day-time, with counts of approximately 100 to 200 per 100 ml, due to the natural diurnal loading pattern and the fact that the bacteria die quickly during day-time (mortality rate T_{90} = 4 hrs). Lowest counts typically occur around late evening to the early hours. A maximum count of about 400 per 100 ml is observed at Peng Chau Beach West for the dry season neap tide. At Discovery Bay Beach, a maximum count of 100 per 100 ml is observed for the wet season neap tide early in the morning. This compares well with EPD published data for 1992 and 1993 for seasonal geometric means of 84 and 47 counts per 100 ml at Discovery Bay.

During construction, since the bacterial load is greatly reduced from the Discovery Bay outfall, the concentration of the resulting bacterial plume is much lower than that for the baseline condition. The surface concentration of the plume is usually below 500 counts per 100 ml. At the sensitive receivers except Peng Chau Beach West, the bacterial count observed is less than 10 for most of the time. At Discovery Bay, the maximum count is 7 per 100 ml. At Peng Chau Beach West, the reduction in bacteria concentration is not as significant as the other receivers due to the close proximity to Peng Chau outfall. A maximum count of 200 per 100 ml is predicted for the dry season neap tide.

Bacterial modelling for the completed stage ie no sewage input but including stormwater, has been presented in Section 4.5 of this report. In summary, bacterial water quality at Discovery Bay Beach and Peng Chau is predicted to be well within the Bathing Water Quality Objective of 180 counts per 100 ml.

4.6.8 Flushing

The results of the simulation of flushing of Discovery Bay may be summarised as follows:

- For all cases, the majority of the pollutants generated in the Bay remain within the Bay for at least 48 Hours.
- Comparing the concentration distribution patterns after 12 and 48 hours, the following may be concluded :
    1) A concentration gradient existed within the Bay, with the higher concentrations in the inner part of Discovery Bay and Yi Pak. The concentration decreased towards the opening of the Bay area due to tidal flushing.
    2) Not much dilution is achieved in the inner Bay and the concentration of pollutants remained at roughly the same level for all cases. This reflects the low current speed within the inner bay.
- Comparing the concentration patterns at 48 hours for the three scenarios, the following can be concluded :
    1) Flushing is the strongest for the baseline situation. The pollutant is

carried away and transported to Peng Chau. At the mouth of the Bay, the dilution factor achieved is approximately 3.

2) The Bay is sheltered by the noise bund or the terminal itself. The dispersion of pollutant is comparatively poor at the construction phase and also for the completed phase. Although the concentration distribution remains roughly unchanged in the inner bay, all the pollutants are still trapped in the sheltered bay on the western side of the terminal 48 hours after release. This demonstrates that the flushing capacity of Discovery Bay, which is already poor during the baseline situation, will be further impaired by the formation of CT10 and 11.

4.7 Discussion

4.7.1 Introduction

Primary concerns regarding water quality relating to the Lantau Port development have been dredging and placement of fill, the use of fill rehandling basins, nutrients, dissolved oxygen and suspended solids. Notwithstanding that the proposed diversion of Discovery Bay and Peng Chau sewage will improve local water quality, the interim stages pending diversion are also of concern. These aspects are dealt with in the following paragraphs.

4.7.2 Dredging

Under combined dredging and filling for the *fully dredged option,* and before the bunds are in place, the increases in suspended solids at Ma Wan and Peng Chau are predicted as being 7.8 and 4.2 mg l^{-1} respectively. Expressed as percentages relative to background, based on annual average 1992 EPD data for locations near to the sensitive receivers, these figures equate to approximately 60% and 50% increases respectively. As the Water Quality Objective (WQO) for suspended solids stipulates a 30% increase over background, then this objective will be exceeded (strictly speaking, it is understood that dredging and filling activities are not covered by the Water Pollution Control Ordinance and therefore not strictly bound by its Objectives; however, it is common practice that the Objectives be applied as benchmarks). Although this WQO would be exceeded under the assumptions adopted for the assessment, the physical increase in concentration *per se* would not pose a threat to the mariculture industry at Ma Wan.

On placement of the bunds for the fully dredged option, the change in hydrodynamics will result in lower concentrations of suspended solids at Ma Wan such that the WQO would not be exceeded, whereas at Peng Chau in the wet season suspended solids would increase to 9.7 mg l^{-1} and therefore would still exceed the WQO. Increases at Discovery Bay would be less than 1 mg l^{-1} at all times and would therefore not exceed the WQO.

Normal variation in suspended solids at Ma Wan often greatly exceeds the predicted increase from CT10&11 and compensation levels are set at 80 mg l^{-1} suspended solids. Discussions with AFD with respect to monitoring at Ma Wan indicate that suspended solids for spring tides during the dry season attain concentrations of 80 to 100 mg l^{-1} and for neap tides in the same season, 50 mg l^{-1}. This is a regular natural phenomenon. During the wet season, suspended solids for the spring tides are typically 20 to 30 mg l^{-1} dropping to approximately 10 mg l^{-1} at other times. This is a regular natural phenomenon. Nonetheless, EPD confirmed with AFD that these SS were not collected by AFD but by the EM&A teams of adjacent infrastructure projects (North Lantau Expressway, Lantau Fixed Crossing and the South Tsing Yi Dumping Site of the PAA) during their activity phase. These monitoring data served to determine the impact of the marine construction activities on the Ma Wan FCZ. The high SS readings recorded were largely signals of excessive construction impacts which caused the initiation of mitigation to reduce impact. In this connection, EPD regarded that it was inappropriate to use those SS readings collected during 1993 to 1995 to be applied in this assessment exercise as they did not truly represent the natural ambient SS level at the Ma Wan FCZ. However, on the basis of these data, which are based on more frequent sampling than EPD data, the annual average for Ma Wan will be much higher than that based on historical EPD data. As the model predictions were run for spring tides in the two seasons, it would be more applicable to base the 30% estimate on the available corresponding seasonal tidal data. On this basis, the 30% criterion would not be exceeded at Ma Wan.

Notwithstanding the above, it should also be noted that the figures given for increases in suspended solids are peak values, not tidal averages. From the time history plots provided in Volume 2, even for the conservative EPD data, the length of time for which the WQO limit of 30% over background would be exceeded at Ma Wan is only 2 hours per wet season spring tide and 7.5 hours per dry season spring tide. At Peng Chau north beach, exceedance occurs for 5.5 hours on a wet season spring tide and approximately five hours on a dry season spring tide. Tidal duration is approximately 24 hours therefore tidal averages for the scenarios will be less than the predicted maxima. Based on the time history plots provided in Volume 2, for Ma Wan and Peng Chau increases in mean tidal suspended solids are less than 3 mg l^{-1} and 2 mg l^{-1} respectively for both seasons. On this basis, neither station would exceed the 30% Objective. Thus, to summarise; in terms of maximum tidal values, periodic short term exceedances of the WQO are predicted to occur, whereas on a mean tidal basis, the 30% increase over background would be complied with.

It has been necessary to present the above ways of interpreting the data because there are no statutory constraints which apply to water quality impacts derived from dredging activities. Although it has become practice to apply the 30% criterion as a guideline, the Legislation does not specify how it should be applied in those instances where it is applicable ie as a finite limit not to be exceeded at any time, or as a time averaged figure, unlike other parameters which, for example, are applied as annual averages (ammonia) or 90% compliances (dissolved oxygen). However, EPD have advised that the 30% criterion should be applied as a finite limit not to be exceeded at any time. Clearly, projects have to be treated on an individual basis. On the strength of the modelling predictions for Lantau Port dredging and filling operations, it is concluded that the finite increases at sensitive receivers will be small and cyclical in duration, such that peak values will only be experienced for a few hours in each tide or indeed in each month.

The increases predicted above were for the worst case at maximum combined rate of dredging and filling which, for the fully dredged option, has a duration of approximately 15 months. Bund construction will not be complete until the end of the 15 month period and will not therefore shorten the period of potentially increased suspended solids at Ma Wan.

For the *drained option,* maximum combined dredging and filling is predicted to produce increases at Ma Wan and Peng Chau of approximately 4.4 and 2.1 mg l^{-1} respectively. These figures represent increases over EPD background of 34% and 25%. Thus Ma Wan would marginally fail the WQO for suspended solids but Peng Chau would not. As for the fully dredged option, Discovery Bay would experience an increase in suspended solids of less than 1 mg l^{-1}. The same arguments presented above apply here.

In addition to the foregoing it must be borne in mind that the above assessments are likely to be overestimates and in particular for filling operations. For the latter, it was assumed that effectively all fines present in the fill material (3.7%) would be lost into suspension; this included surcharge. In this respect, comments in the following sections should be borne in mind.

4.7.3 Placement of Fill and the Use of Rehandling Basins

For the drained option, fill will have to be placed by rainbowing or using a barge spreader in order to ensure that fill is placed uniformly so as not to cause mud waves. Rainbowing and barge spreading are considered to be similar with respect to potential impact on water quality. Once fill has been placed for a depth of five or six metres, it may be possible to place fill above this by pumping. In fact, the Contractor will probably prefer the latter option from cost considerations, pumping being a quicker means for discharging the fill than rainbowing. As the reclamation advances from west to east however, the advancing edge will have to be formed by rainbowing or barge spreading in order to maintain an edge slope of about 1:20 (the edge will need to be maintained like a beach so as to avoid causing mud waves). This however, is not a requirement for the dredged scheme, where it would be possible to form the edge at a slope of 1:3. Modelling has been undertaken on the basis of sediment input at the sea surface and therefore is a fair representation of rainbowing.

In the Draft Key Issues Report it was stated that DEMAS had advised the Consultants of a potential alternative technique to rainbowing in which the rehandling of the fill material from the cutter suction dredgers (CSD) is discharged in thin layers through a special diffuser. The design of the diffuser is such that the material does not disturb the sea bed and the resulting density flow will remain close to the sea floor. DEMAS advise that in using the diffuser it is unlikely that a significant increase in the load of suspended solids could be measured. Any release of fines which does occur, will be trapped in the trench for the deck edge structure and/or part of the access channel when dredged. Further discussion with DEMAS has revealed that in laying the first 0.5 m of sand it would be advantageous to keep the diffuser outlet close to the water surface or just above the water surface to make sure that the material spreads out evenly and does not have too high an impact on the mud layer. Such a practice would probably have similar impacts to rainbowing. Furthermore, the rate of placing fill by this means is slower and filling could only progress at 40% of the scheduled rate. Additional equipment in the form of anchor pontoons would also be required, adding to congestion at the site. In view of these constraints, and the general results predicted by the modelling, this option does not appear to offer sufficient advantage to warrant recommendation.

DEMAS have also advised on the potential for sediment resuspension during the rehandling process. During the initial placement of fill in a rehandling pit only the periphery of the density flow from the hopper to the sea floor is in contact with the water column and thus available for erosion of fines. If rehandling pits are chosen carefully with respect to currents (low in the study area) and distance within the working area, most of the material will settle in the rehandling pit. During rehandling, CSD will be moving sediment with effectively the same fines content as that deposited from the trailing suction hopper dredger (TSHD). Under such circumstances and assuming that fill material originated in the East Lamma Channel (*in situ* fines content 5 to 10%), DEMAS concluded that the maximum loss to the water column would be 1% of the fines contained in the fill material. It was considered that 1% may even be conservative because of the speed of dumping and the density of the material dumped. However, because some material will still flush out when the doors are being closed, 1% is considered applicable. In view of this experience, it was not likely that a significant increase in the load of suspended solids could be measured 100 m beyond the access channel due to rehandling of fill.

For the dredged option, fill will be placed by bottom dumping up to approximately -7 mPD. Above this level, fill will be placed by pumping. The initial stages of dumping will be done in deep water with the material falling onto a slope. The slope will reduce the impact of the material hitting the seabed and reduce the re-suspension of solids. After the initial stages, DEMAS are of the opinion that dumping of fill material inside the reclamation area will hardly generate any suspended solids outside the reclamation area since the TSHD tends to dump its load as close as possible to the existing shallow water in order to take maximum advantage of the reduction in draft of the ship to minimise sediment resuspension during dumping. At the edges of the reclamation some material will flow over the seabed to the trench and the access channel. Since the channel is more than 600 m wide it is unlikely that any fines will be detectable beyond the boundary.

The CSD rehandling the fill material in the later phase of reclamation will pump the material above water level. The reclamation by hydraulic fill results in a sloping surface of 1:10 to 1:20 depending on the grain size. The mixture runs over the surface and when reaching the edge of the reclamation continues as a density current down the underwater slope. The density flow will continue to the toe of the slope and 'still' after a certain distance. The whole process takes place very close to the sea floor with little or no fines brought into suspension as these are entrapped in the density flow and only erode at the edges of the flow, which on the top side is to the water column and on the lower side to the sand fill. Any material lost will be deposited on the sea bed adjacent to the reclamation area and certainly within the access channel area. DEMAS conclude that overall, it is not expected that the loss of fines into suspension into the water column will exceed 1% with the methods of reclamation considered for the project. Thus, a total loss of 2% of the fines content is considered reasonable (1% for each of dumping and rehandling). This represents a large difference (2% of 5% = 0.1%) from the sediment plume modelling where a loss of fines of 3.7% was assumed and serves to highlight the possible magnitude of overestimation of contribution to suspended sediments predicted by the modelling exercises.

When dredging unsuitable material from the reclamation site and when dredging for the access channel, no overflowing or use of Lean Mixture Overboard (LMOB) will be allowed except when starting, turning or finishing the dredging in the area. The LMOB will only be used for short periods when the dragheads are lifted or lowered from/to the sea floor. Since the dredger would restrict its manoeuvring in the dredging area as much as possible taking long hauls wherever feasible, it will only occur for approximately one minute in every twenty minute loading period. This equates to 5% of the time but during such periods pumps slow down and the mixture is leaner than average during the loading. Assuming that during the 1 minute period the flow of fines will be 10% of the normal flow when loading, (that is considering the flow of water and density of the mixture) only 0.5% of the material will be released into the water column.

Relevant field measurements in Hong Kong[4] are limited but dredging studies performed in the Ninepins area have measured suspended solids in the vicinity of overflowing TSHD's of up to 200 mg l^{-1} where the overflow consisted of up to 95% silt/clay fraction. Within 15 to 20 minutes suspended solids had decreased to less than 40 mg l^{-1}, and to 20 to 30 mg l^{-1} within half an hour. Although surface plumes were visible for up to 10 km, concentrations of suspended solids were only 1 to 2 mg l^{-1}. This serves to illustrate that the main impact from dredging and filling will probably be visual and therefore aesthetic, rather than one of the physical concentration of suspended sediments *per se*.

Modelled sediment plumes have indicated that with the construction of the bunds, the highest concentrations of suspended sediments will remain within the bunds and will rapidly decrease with distance. However it is reasonable to infer from the above studies that visual plumes will be evident outside the dredging area.

4.7.4 Nutrients

In previous reports, importance has correctly been placed on the potential for eutrophication in the vicinity of the Terminals and in particular, Discovery Bay, due to existing high levels of nutrient being supplemented by nitrogen compounds desorbed from sediments during dredging and filling activities. Discovery Bay, Silvermine Bay and the waters in mid-channel between these areas of Lantau and Hong Kong Island, have a typical inorganic nitrogen concentration of approximately 0.31 mg l^{-1} which reflects the influence of the relatively nutrient-rich waters of the Pearl River. Modelling has indicated that for the scenario wherein nutrient was proportional to suspended sediment concentration, increases in nitrogen based on the total availability of all nitrogen in resuspended sediments would be less than 0.01 mg l^{-1} (ie effectively undetectable above background) within approximately 250 m of the dredgers. It would appear unlikely therefore, that based on this scenario, that eutrophication would occur as a direct result of dredge and fill activities.

As stated previously, it has been necessary to adopt certain assumptions in conducting nutrient assessments which, in the Consultants opinion, have led to overestimates of impact. Given the general lack of available information regarding the subject of nutrient release from sediments, this has been to a certain extent unavoidable, if the precautionary principle is to be applied. However, it serves to attempt to give some indication of the possible magnitude of the overestimates. 'Nutrient' was assumed to be all nitrogen present in the sediment and an average figure for Hong Kong of 500 mg kg^{-1} was adopted. Elutriate tests (ie the concentration of nitrogenous compounds washed from sediment after mixing with seawater) performed for previous Lantau Port studies indicated a maximum of 5.54 mg l^{-1} for 'available' total inorganic nitrogen. This is approximately 1% of the figure actually used. Furthermore, although the fill to be obtained notionally from East Lamma Channel will have a very small nutrient content, the model input for cumulative dredge and fill activities cannot differentiate between nutrient-rich dredge and clean fill (because the sediment plume model was used to derive nutrient contours). Therefore all fill was assigned a nutrient content the same as for dredge material. Taking this into account, the nutrient input to the model would be approximately double than if dredge material alone had been provided for. Further overestimates will arise from the ultraconservative behaviour assigned to desorbed

[4] "Correlation of Water Appearance and Suspended Solids Concentration in Dredging Plumes" a report by DEMAS February 1994 to CED/GEO. Also, "Focused ADCP Studies West of Ninepins Marine Borrow Area" April 1994. a report by Binnie Consultants to CED.

nutrients but in view of the lack of knowledge concerning these processes, the magnitude of overestimation cannot be quantified in this instance but the following apply :

- The simulations assume that all nitrogen is in the form of nutrients which will be dissolved into solution, whereas a portion of the 'nutrient' content of the sediment will in fact be unavailable.

- The simulation assumes that the process whereby nutrients are dissolved happens instantaneously. In reality, the process of dissolution would be far from complete and certainly not instantaneous. Also, particularly in the vicinity of the dredging operations, sediment will settle rapidly to the seabed, aided by flocculation. In this way, there would not be sufficient time for all nutrients to be desorbed and some would remain trapped in the sediment falling to the seabed.

- It is further assumed that there is no uptake of nutrient by algae or loss by suspended sediment re-adsorption and flocculation. This is clearly not the case in natural systems, regardless of the source of nutrient.

- Models which have been used for calculating settling are limited in their ability to predict the equilibrium concentration or to entirely meet the underlying assumptions of the assessment. Transport processes for cohesive sediments such as silt and clay are much more complicated than those for cohesionless materials. Under the influence of physicochemical forces, cohesive materials form flocs and aggregates which can possess settling velocities which are orders of magnitude larger than those for constituent material. The properties of the flocs depend not only on the properties of the sediment but also on water chemistry, sediment concentration and hydrodynamic conditions.

The release of ammonia from resuspended sediments is a common phenomenon (see Appendix A2) and unionised ammonia is toxic to fish. As stated above, based on model output, total nitrogen concentration arising from dredging will be less than 0.01 mg l^{-1} within approximately 250 m of the dredgers. It is not known what proportion of this will be in the form of ammonia. Concentrations of unionised ammonia relative to total ammonia present are largely dependent on temperature and pH. The Water Quality Objective (WQO) for unionised ammonia nitrogen is 0.021 mg l^{-1} which would correspond approximately to 0.14 mg l^{-1} as total ammonia nitrogen for average temperature and pH conditions of Hong Kong marine waters (which incidentally is greater than the WQO for inorganic nitrogen of 0.10 mg l^{-1} which includes ammonia). It will be appreciated therefore, that even if all nitrogen available from dredging (0.01 mg l^{-1}) was in the form of ammonia, the concentration of unionised ammonia available to contribute towards exceedance of the WQO for this parameter would be so small as to be effectively negligible. As stated previously, the assumptions made in the above scenario are considered to be conservative and probably represent an overestimate of the impact.

For the ultra conservative scenario wherein all nitrogen is instantaneously desorbed from resuspended sediments and remains in solution indefinitely, predicted concentrations are of course higher than those described above. This simulation predicted increases in nutrient concentration within the area of the terminals of 0.03 to 0.05 mg l^{-1}. Existing concentrations of inorganic nitrogen in the study area are approximately 0.31 mg l^{-1} thus the predicted increase is of the order of 10 to 16 %. Notwithstanding the extreme conservatism of the assessment and even assuming that all the increase was in the form of ammonia, the increase in unionised ammonia would be less than 0.002 mg l^{-1} (WQO

= 0.021 mg l^{-1}). Again, this is unrealistic but serves to illustrate the low probability of unacceptable impact from nutrients derived from dredging operations on water quality.

It may be argued that within the 250 m distance described above, in the immediate vicinity of the dredgers, nitrogen concentrations in general, and ammonia in particular, could be much higher. Even if this were the case, it is considered likely that impacts on fisheries would be negligible for several reasons. In the first instance, due to the naturally high background concentrations of nitrogen compounds in the study area, it is probable that local marine organisms are adapted to concentrations of nutrients in excess of the WQO,s. Recent research and review of literature in the UK[5] concluded that good and moderate fisheries existed where the 95 percentile unionised ammonia concentration exceeded 0.021 mg l^{-1}. Also, a mixture of suspended solids and ammonia has been reported as being less toxic than the individual toxicities of the components, indicating ammonia adsorption onto suspended solids. In the vicinity of the dredgers, suspended solids will be at their greatest concentration therefore scavenging of ammonia may be anticipated. American reviewers cited in Appendix A2 concluded that (even when not normally exposed to elevated concentrations) "any aquatic organisms can be exposed to concentrations of ammonia in excess of WQO's for short periods of time without being significantly adversely affected. It should also be noted that the release of ammonia, or other contaminants for that matter, from resuspended sediments, is not greatly different from that which occurs naturally during storms. It would be rare that aquatic organisms in the water column could receive a lethal exposure to chemicals released to the water column as a result of dredging". Fishing (trawling) activities may also be added to storms as a means by which sediment resuspension regularly occurs, particularly in the vicinity of the study area. It may be concluded therefore, that given the probability of fish moving away from the immediate vicinity of dredging activities, plus the above factors regarding exposure to elevated concentrations of ammonia, and the very limited area of modelled increase in concentration of nitrogen compounds, it is probable that the proposed dredging activities will not have any measurable toxicological impact on fish.

In terms of nitrogenous compounds fuelling eutrophication, the maximum increase modelled represented an increase of between 10% and 16% over background. Given that the average background nutrient levels are relatively high with natural peak values of the order of 50% to 70% over background, then the increase predicted by the model does not necessarily imply that there will be harmful effects. It must be restated that the model assessments performed represented worst case scenarios and that impacts are likely to be much less than predicted. In this respect, it is considered that the scenario involving a nutrient concentration proportional to the mass of sediment in suspension represents the most realistic, yet conservative, approach. On this basis, it is concluded that there should not be any measurable impact resulting from nutrients desorbed from sediments during dredging. Nonetheless, any potential for increase in nutrients correctly attracts the precautionary principle and in terms of the Lantau Port reclamation, it must be recommended that dredging procedures adopt good working practice at all times to minimise sediment losses to the water column. The following are recommended :

- use of suction heads on suction dredgers should minimize over-break and sedimentation around the head;
- all pipe leakages should be repaired promptly and construction plant should not be operated with leaking pipes;

5 "Environmental Quality Standards to Protect Identified Uses of Controlled Waters." A report by WRc plc to the National Rivers Authority

- all barges and hopper dredgers should be fitted with tight fitting seals to their bottom openings to prevent leakage of material;
- excess material should be cleaned from the decks and exposed fittings before vessels are moved;
- dredging should cause no foam, oil, grease, scum, litter or other objectionable matter to be present on the water;
- loading of hoppers should be controlled to prevent splashing of dredging material to the surrounding water and hoppers should not be filled to a level which would cause overflow of material or polluted water during loading or transportation;
- adequate freeboard should be maintained to ensure that decks are not washed by wave action;
- all barges and dredgers should maintain adequate clearance between vessels and the sea bed at all states of the tide and reduce operating speeds, to ensure that undue turbidity is not generated by turbulence from vessel movement or propeller wash;
- when the dredged material has been unloaded at the disposal area, any material which has accumulated on the deck or other exposed parts of the vessel should be removed and placed in the hold or hopper. Under no circumstance should decks be washed clean in a way that permits material to be released overboard. Hoppers should not be flushed with water to remove any remaining material and should remain tightly closed at all times.

4.7.5 Water Quality

Long term water quality impacts arising from the change in hydrodynamics brought about by construction of the terminals are predicted to be very small. During the construction stage in the wet season dissolved oxygen concentrations will be marginally lower than in the baseline case with maximum decreases in concentration generally less than 1%. During the dry season this relationship is reversed. Similarly, for ammonia, oxidised nitrogen and organic nitrogen, differences in concentration between the two scenarios are generally zero or less than 0.01 mg l^{-1}. Non of the long term water quality parameters for the general study area appear to be significantly affected by the construction of the terminals.

Long term impacts arising during the operational stage of the Terminals are related to the proposed location of two stormwater oufalls to the west of the Terminals at Sz Pak. The very poor circulation and water exchange in this created embayment exacerbates the impact of nutrients and coliform bacteria washed out from the Port development during storm events. Although coliform bacteria levels were within the statutory criterion for secondary contact water sports, the nutrients were predicted to stimulate plankton growth and this would be an adverse development. Further consideration should therefore be given to diverting these two outfalls to the east of the terminals or to a location along the seaward edge of the Terminals to take advantage of better dispersion conditions. However, such a review of outfall relocation should be deliberated in the context that extreme storm events are infrequent and of short duration. A storm with a 24 hour duration may be considered conservative and that one hour durations of heavy intensity are more realistic. In the latter case, the 1 in 10 year event is approximately 17% the intensity of the 1 in 200 year event and this would obviously greatly reduce the magnitude of nutrient loading. However, the comparisons can only be outlined here and it will be for Government to decide which scenario and/or risk they find acceptable. In this respect, it should be borne in mind that WAHMO modelling of storm discharges cannot provide for the inherent velocity of the discharges which would themselves aid dispersion; instead, the low flow field in the vicinity of Sz Pak is imposed upon the discharges. Thus, again, the simulations of stormwater impact are conservative.

Potential mitigation measures which could be considered for reducing the impact from the Sz Pak stormwater outfalls include :

- attenuation of the first flush, with subsequent controlled discharge;
- split flows from the catchment area into urbanised and hillside discharges, with the former being discharged elsewhere or discharged in a controlled manner as for the above option;
- provision of swales and filter strips (practised at the Chek Lap Kok site);
- provision of pollutant traps and a regular desilting / cleaning programme; and
- physical relocation of the outfalls;

Decisions regarding the necessity for pursuing the above options in view of the small risk of nutrient enrichment at Sz Pak will have to be made in light of cost-benefit analyses taking into account engineering constraints.

Even if the above stormwater outfalls are not diverted, Discovery Bay should have reasonable water quality notwithstanding the poorer circulation resulting from the physical presence of the terminals. Peng Chau, and Tung Wan in particular, should not experience measurable decreases in water quality parameters. However, it must be stated that although elevations in the concentrations of suspended solids should be low in these areas, the very fine nature of particulates which remain in suspension for the longest time, will probably have a visual impact.

With respect to the suspended solids input from stormwater and runoff arising from the container terminals and their hinterland, the only additional input will be from the terminals themselves as there is already input of solids to the present water quality from the hinterland. Although the latter will in future be effectively discharged from a discrete location(s) rather than as a diffuse source as at present, this will not represent *additional* input. Applying criteria contained the final report for the LPD Ancillary Works EIA using the figure quoted for suspended solids content of stormwater (100 mg/l) and assuming the total solids content of a 24 hour, 1 in 200 year storm for the *whole* catchment would settle within the approach channel, this would result in an increase of less than 0.5mm in the depth of sediment[6]. In view of the vastly greater contribution to sediment accretion derived from the Pearl Estuary the additional input of solids from stormwater is not considered to be a key issue.

4.7.6 Sewage

In confirmation with previous studies, bacterial concentrations will be greatly reduced during the construction period with the introduction of disinfection of the Discovery Bay effluent. *E.coli* numbers at Discovery Bay beach are predicted to reduce from 50 to 80 per 100 ml to less than 10 per 100 ml. Reduction at Peng Chau West is not as great due to the close proximity of the Peng Chau outfall. However, if Peng Chau is also diverted to Siu Ho Wan or is provided with secondary treatment, bacterial numbers will drop to less than 20 per 100 ml. All beaches would therefore comply with statutory requirements for bathing water quality.

[6] Contained in fax from CES to EPD (SA) dated 8 June ref. 96620/fsh50605.01

4.7.7 Marine Ecological Issues

It has to be accepted that the area of reclamation will be permanently lost as a benthic resource. Previous studies (LAPH) have identified that the whole of the area to the east of Lantau between the proposed Port and Cheung Chau to be of low benthic diversity. However, the animals living in and on the sediments provide a food source for fisheries. It is not known how important the study area is in terms of its contribution to fisheries but it represents approximately 3% of the LAPH study area.

A survey of the activities of the Chinese White Dolphin has recently been undertaken as part of the Ancillary Works studies but the one month study could only achieve a cursory investigation to document the presence of the dolphins in the study area. It must be accepted that in order to adequately evaluate dolphin and fisheries statistics with any degree of scientific rigour or confidence, demands long term studies.

In recognition of the above constraints, CED are currently in the process of appointing Consultants to undertake longer term studies and these issues will not be discussed further in this report. However, the Ancillary Works studies concluded that "the number of dolphins sighted in the area was small and the area appeared to be less utilised by the dolphins than the waters to the north of Lantau Island. Sighting records of the World Wide Fund for Nature/Hong Kong (up to December 1993) and data collected during the Swire Institute of Marine Science Study also suggested that the area does not appear to be of major significance to the dolphins. Hence it was concluded that the Lantau Port Development is likely to have minimal impact on the dolphins. Nonetheless, monitoring during construction has been recommended to monitor the impact." The latter recommendation has been incorporated into the EM&A Manual produced as part of this study

4.8 Conclusion

Worst case scenarios have been given priority and it has been concluded that for both the fully dredged and the drained options, suspended solids at Ma Wan would exceed the Water Quality Objective (WQO) of 30% increase over background if the annual average of EPD 1992 data was used. The fully dredged option produced a greater exceedance of this environmental objective (60%) than the drained option, the latter exceedance being marginal (34%). This same Objective was exceeded at Peng Chau (maximum in the wet season) for the fully dredged option but not for the drained option. Exceedances were limited to a few hours per day. However, if seasonal values for background are used, based on recent monitoring data for the Ma Wan Mariculture area, then the WQO will be met at all times. Suspended solids at Discovery Bay were low for all scenarios. As this assessment has been conducted on worst case assumptions it is concluded that real effects will probably be less than predicted and that increases in suspended solids at sensitive receivers will not exceed water quality objectives. Calculations have indicated that in the near field area continually affected by dredging, the 30% over background increase should be met within a distance of approximately 650 m.

The statement regarding overestimation also applies to nutrient assessments. In this respect, it is considered that the scenario involving a nutrient concentration proportional to the mass of sediment in suspension represents the most realistic, yet still conservative, approach. On this basis, it is concluded that there should not be any measurable impact resulting from nutrients desorbed from sediments during dredging. Nonetheless, any potential for increase in nutrients correctly attracts the precautionary principle and in terms of the Lantau Port reclamation, it must be recommended that dredging proceeds in such a way as to minimise sediment losses to the water column at all times.

Long term changes in water quality as a result of changes in hydrodynamics brought about by the physical presence of the terminals are not predicted to be cause for concern. There will be changes in the pattern of sedimentation with some areas receiving less and some areas receiving more than at present. The general result of the constriction of flow by the eastern arm of the terminals is to shift the pattern of sedimentation more to the south, with less in the north.

It is recommended that the proposed locations of stormwater outfalls to the west of the Terminals are given further consideration with a view to relocate them to the seaward edge of the Terminals or engineering-based mitigation measures evaluated to avoid potential eutrophication problems in the Sz Pak embayment and outer Discovery Bay. It is further recommended that this area off Sz Pak not be used as a point of discharge for site effluents as far as is practicable.

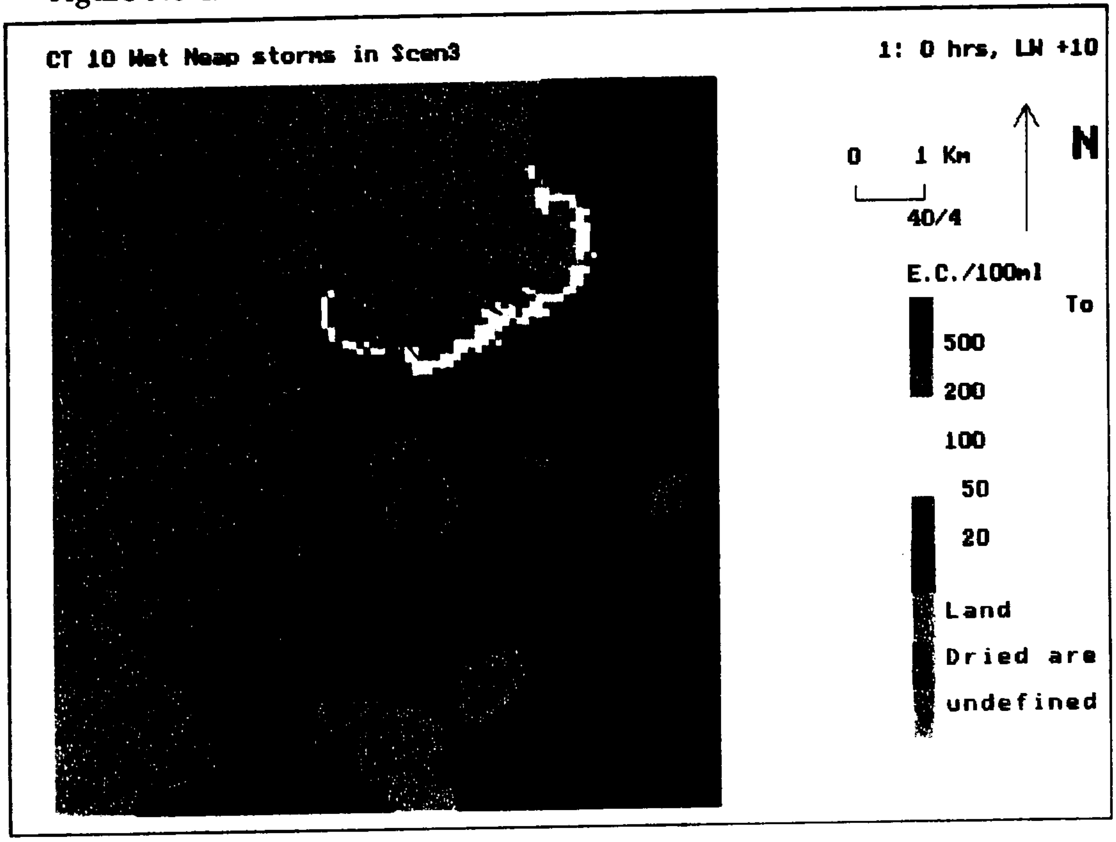
The environmental advantages and disadvantages for the dredge-drained and fully-dredged options in terms of resource consumption are summarised in Table 4.6

Table No 4.6 : Comparison of Impacts for the Drained and Fully-Dredged Options

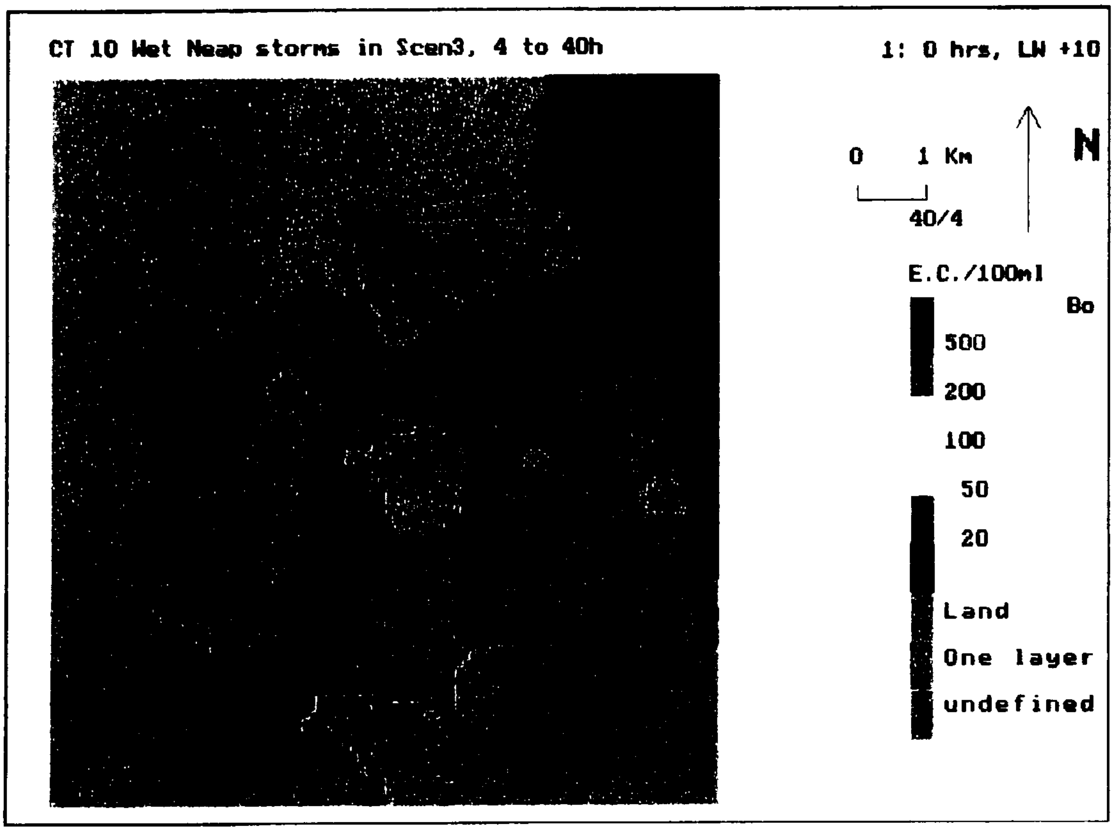
ITEM	DRAINED	FULLY DREDGED
Volume of Dredged Mud	8 Mm^3	43 Mm^3
Volume of Contaminated Mud (Terminals/approach channel/breakwater)	1.114 Mm^3	1.136 Mm^3
Volume of Fill Required	71 Mm^3	99 Mm^3
Rate of Dredging	1.0 Mm^3 per month	3.4 Mm^3 per month
Duration of Dredging	9 months	27 months
Rate of Filling	2.66 Mm^3 per month	3.94 Mm^3 per month
Duration of Filling	27 months	25 months
Fill Method	Rainbowing, bottom dumping, pumping	Bottom dumping, pumping

In terms of *water quality* and marine resource utilisation, it is apparent that the drained option would be preferable in all respects except for the duration and method of fill placement. The drained option has only approximately one fifth of the dredging and disposal of mud required by the fully-dredged option, and approximately 70% of the fill requirement. The volumes of contaminated mud are virtually the same. Given that dredging will probably generate more suspended solids in the water column than filling, the drained option offers a reduction of 66% on the duration of this activity for the fully-dredged scheme. The duration of filling is similar at just over two years, but the drained option necessitates the use of rainbowing. In view of the fact that dredging will be required for 18 months longer for the fully-dredged option, and that rainbowing will not be used to place all the fill for the drained option, it is concluded that in overall terms the drained option offers the least impact to the marine environment.

Figure No 4.1 : Location of Stormwater Outfalls



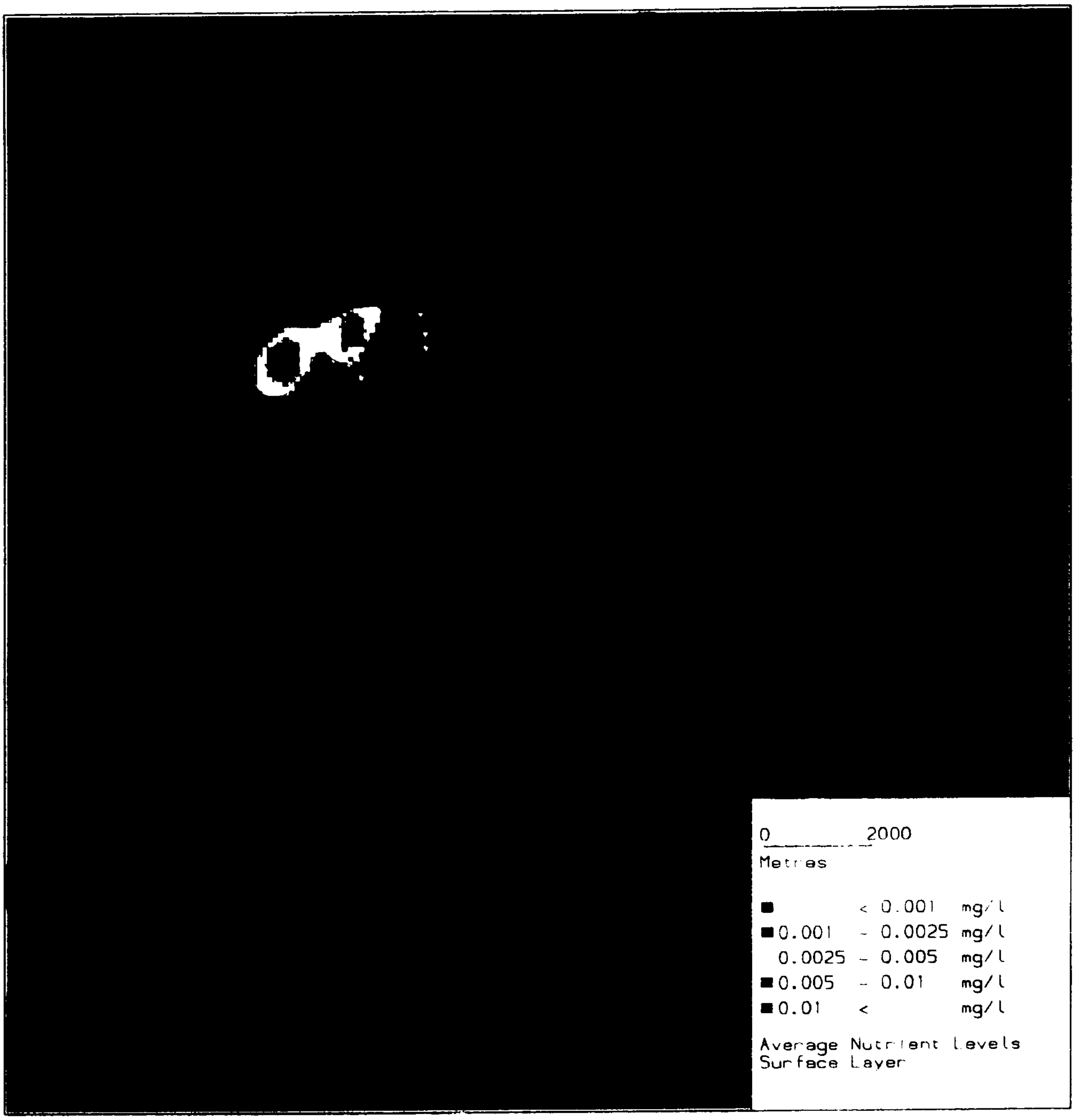
Upper - Start Release



Lower - Start Release

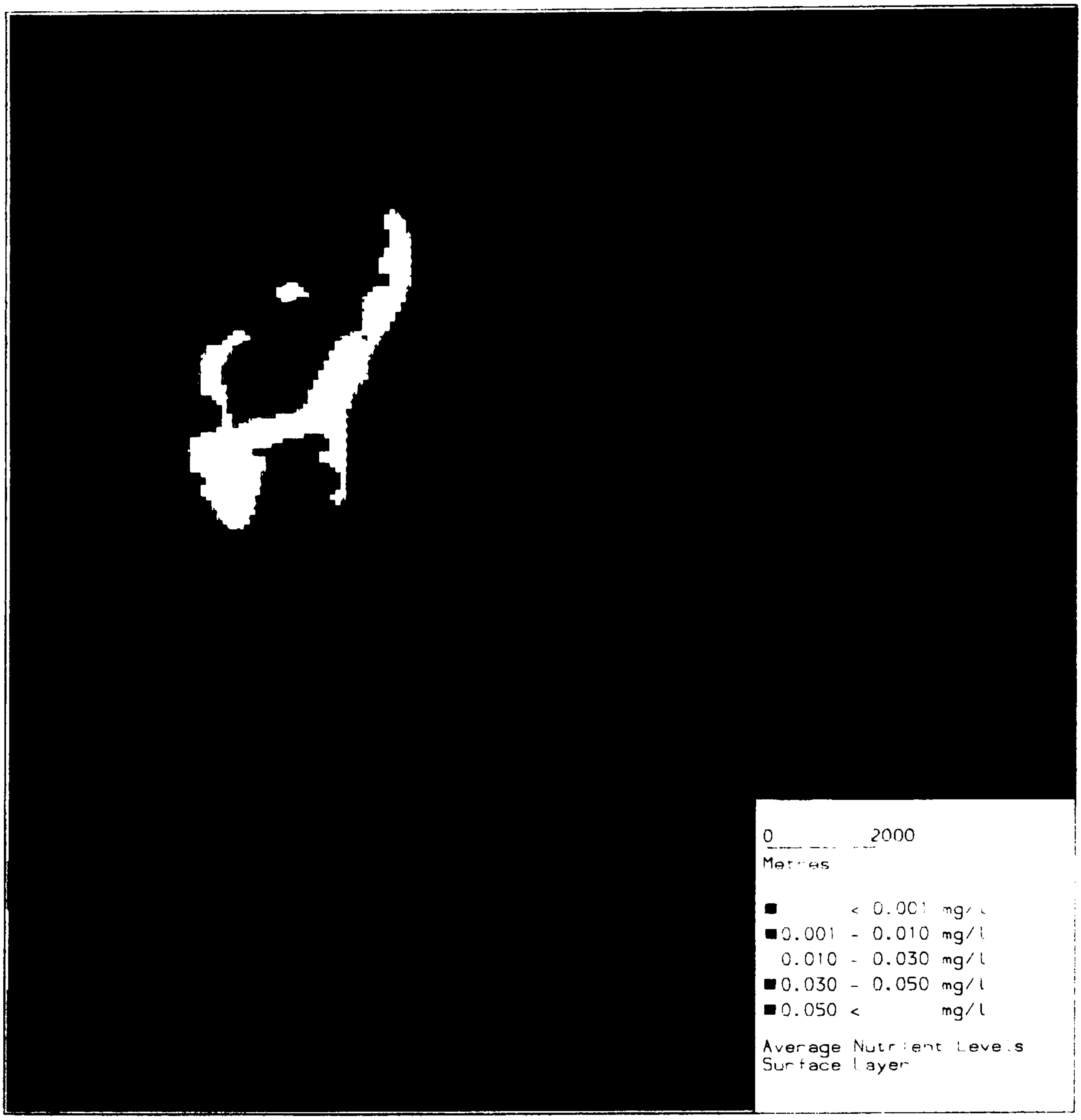
Completed Case - Wet Season Neap Tide

Figure No 4.2 : Nutrient levels derived by the Sediment Plume



CT10 & 11 Detailed Design
Scenario 1 - Fully Dredged Option
Daily Average Nutrient Levels
Dry Season Spring Tide

Figure No 4.3 : Nutrient levels derived by the Sediment Plume (instant desorption)



CT10 & 11 Detailed Design
Scenario 1 - Fully Dredged Option
Average Nutrient Levels - No Settling
Dry Season Spring Tide

Figure No 4.4 : WAHMO Output Points