6 WATER QUALITY

6.1 GENERAL

Container Terminal (CT)10 and CT11 will be located on reclaimed land extending south east from the Tsing Chau Tsai (TCT) peninsula and Pennys Bay in the north east of Lantau Island. The terminals will be situated across the boundary between the Southern Water Control Zones (WCZ) and Western Buffer WCZ. Standards for effluent discharged into marine waters are the same for both WCZs. The principal source of impact from the terminal developments will be suspended solids from dredging and reclamation activities, uncontrolled site runoff, sewage discharges and spillage.

In the following sections the key cumulative water quality impacts of CT10 and CT11 developments are identified and discussed.

6.2 STATUTORY AND GUIDELINE CRITERIA

The Water Pollution Control Ordinance (WPCO) Cap. 358 (1980) lays down the framework for designation of Water Control Zones (WCZ's) throughout the Territory. Each such zone is characterised by specific water quality objectives (Table 6.1). Principle features of the WPCO and its subsidiary legislation are as follows:

- The Ordinance specifies prohibited discharges and deposits.
- This is reinforced by the Technical Memorandum to the WPCO which further provides standards for effluent discharged into drainage and sewerage systems, inland waters and coastal waters.
- The Water Pollution Control (Amendment) Ordinance 1990 made various changes to the WPCO including the removal of the 'right to discharge' certain pollutants taking place prior to the gazetting of a Water Pollution Control Zone.
- The relevant legislation pertinent to water quality includes:

  Water Pollution Control Ordinance : Cap 358 (1993)
  Water Pollution Control General Regulations (1988)
  Water Pollution Control (Southern Water Control Zone) Order (1988)
  Water Pollution Control (North Western Water Control Zone) Order (1992)
  Water Pollution Control (Western Buffer Water Control Zone) Order (1993)
  Legal Supplement No.2 1990:Water Pollution Control (Amendment) Regulations 1990
  Special Supplement N°5:Technical Memorandum standards for Effluent Discharged into Drains and Sewerage Systems, Inland and coastal waters.
  Dumping at Sea Act 1974 (Overseas Territories Order (1975).

Table 6.1 Summary of Marine Water Quality Objectives for the Southern Water Control Zone

Parameters	Objectives	Sub-Zone
Offensive Odour, Colour, Tints	Not to be present	Whole Zone
Visible foam, oil, scum, litter	Not to be present	Whole Zone
E. coli	Annual geometric mean not to exceed 610/100 ml Annual (March to October) geometric mean not to exceed 180/100 ml	Secondary contact Recreation sub-zone Bathing beaches
DO within 2.0 m of bottom Depth average DO	Not less than 2.0 mg/l for 90% of samples Not less than 4.0 mg/l for 90% of samples Not less than 5.0mg/l for 90% of samples	Whole Zone Whole Zone except Fish culture zones Fish Culture Zones
pH	To be in the range 6.5-8.5, change due to waste discharge not to exceed 0.2	Whole zone except bathing beaches
Salinity	Change due to waste discharge not to exceed 10% of ambient	Whole zone
Temperature	Change due to waste discharge not to exceed 2.0°C	Whole Zone
Suspended Solids	Not to raise the ambient level by 30%	Whole zone
Toxicants	Not to be present	Whole Zone
Ammonia	Annual mean not to exceed 0.021 mg/l calculated as unionised form	Whole Zone
Nutrients	Shall not cause excessive algal growth Annual mean depth average inorganic N not to exceed 0.1 mg/l	Whole Zone

Table 6.2 Standards for Effluent Discharged into the inshore waters of the Southern Water Control Zone (All units in mg.l^{-1} unless otherwise stated; all figures are upper limits unless otherwise indicated)

Flow rate (m^3/day) / Determinand	≤10	>10 and ≤200	>200 and ≤400	>400 and ≤600	>600 and ≤800	>800 and ≤1000	>1000 and ≤1500	>1500 and ≤2000	>2000 and ≤3000	>3000 and ≤4000	>4000 and ≤5000	>5000 and ≤6000
pH (pH units)	6-9	6-9	6-9	6-9	6-9	6-9	6-9	6-9	6-9	6- 9	6-9	6-9
Temperature (°C)	40	40	40	40	40	40	40	40	40	40	40	40
Colour (lovibond units) (25 mm cell length)	1	1	1	1	1	1	1	1	1	1	1	1
Suspended solids	50	30	30	30	30	30	30	30	30	30	30	30
BOD	50	20	20	20	20	20	20	20	20	20	20	20
COD	100	80	80	80	80	80	80	80	80	80	80	80
Oil & Grease	30	20	20	20	20	20	20	20	20	20	20	10
Iron	15	10	10	7	5	4	3	2	1	1	0.8	0.6
Boron	5	4	3	2	2	1.5	1.1	0.8	0.5	0.4	0.3	0.2
Barium	5	4	3	2	2	1.5	1.1	0.8	0.5	0.4	0.3	0.2
Mercury	0.1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cadmium	0.1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Other toxic metals individually	1	1	0.8	0.7	0.5	0.4	0.3	0.2	0.15	0.1	0.1	0.1
Total toxic metals	2	2	1.6	1.4	1	0.4	0.3	0.2	0.15	0.1	0.1	0.1
Cyanide	0.2	0.1	0.1	0.1	0.1	0.1	0.05	0.05	0.03	0.02	0.02	0.01
Phenols	0.5	0.5	0.5	0.3	0.25	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Sulphide	5	5	5	5	5	5	2.5	2.5	1.5	1	1	0.5
Total residual chlorine	1	1	1	1	1	1	1	1	1	1	1	1
Total nitrogen	100	100	80	80	80	80	50	50	50	50	50	50
Total phosphorus	10	10	8	8	8	8	5	5	5	5	5	5
Surfactant (total)	20	15	15	15	15	15	10	10	10	10	10	10
E. coli (count/100 ml)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

Source : EPD Technical Memorandum on Effluent Standards, Table 10a

Table 6.3 **Standards for Effluent Discharged into the marine waters of Southern, Mirs Bay, Junk Bay, North Western, Eastern Buffer and Western Buffer Water Control Zones** (All units in mg/L unless otherwise stated; all figures are upper limits unless otherwise indicated)

Flow rate (m^3/day) Determinand	≤10	>10 and ≤200	>200 and ≤400	>400 and ≤600	>600 and ≤800	>800 and ≤1000	>1000 and ≤1500	>1500 and ≤2000	>2000 and ≤3000	>3000 and ≤4000	>4000 and ≤5000	>5000 and ≤6000
pH (pH units)	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10
Temperature (°C)	45	45	45	45	45	45	45	45	45	45	45	45
Colour (lovibond units) (25 mm cell length)	4	1	1	1	1	1	1	1	1	1	1	1
Suspended solids	500	500	500	300	200	200	100	100	50	50	40	30
BOD	500	500	500	300	200	200	100	100	50	50	40	30
COD	1000	1000	1000	700	500	400	300	200	150	100	80	80
Oil & Grease	50	50	50	30	25	20	20	20	20	20	20	20
Iron	20	15	13	10	7	6	4	3	2	1.5	1.2	1
Boron	6	5	4	3.5	2.5	2	1.5	1	0.7	0.5	0.4	0.3
Barium	6	5	4	3.5	2.5	2	1.5	1	0.7	0.5	0.4	0.3
Mercury	0.1	0.1	0.1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cadmium	0.1	0.1	0.1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Other toxic metals individually	2	1.5	1.2	0.8	0.6	0.5	0.32	0.24	0.16	0.12	0.1	0.1
Total toxic metals	4	3	2.4	1.6	1.2	1	0.64	0.48	0.32	0.24	0.2	0.14
Cyanide	1	0.5	0.5	0.5	0.4	0.3	0.2	0.15	0.1	0.08	0.06	0.04
Phenols	0.5	0.5	0.5	0.3	0.25	0.2	0.13	0.1	0.1	0.1	0.1	0.1
Sulphide	5	5	5	5	5	5	2.5	2.5	1.5	1	1	0.5
Total residual chlorine	1	1	1	1	1	1	1	1	1	1	1	1
Total nitrogen	100	100	80	80	80	80	50	50	50	50	50	50
Total phosphorus	10	10	8	8	8	8	5	5	5	5	5	5
Surfactant (total)	30	20	20	20	15	15	15	15	15	15	15	15
E. coli (count/100 ml)	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000

Source : EPD Technical Memorandum on Effluent Standard, Table 10b.

The mechanism that will regulate discharges from the site including run off from storm drains and any liquid effluent is the Technical Memorandum (TM), 'Standards for Effluent Discharged into Drainage and Sewerage Systems, Inland and Coastal Waters'. The Memorandum establishes effluent standards that apply to different receiving water bodies (Table 6.2 & 6.3). All such effluent covered by this TM are required to be licensed. For the purposes of this legislation, inshore waters refer to all waters of less than 6m depth at mean low water (MLW) or within 200 metres of the low water mark.

Restrictions are placed on the location of new discharges. According to the TM, no new effluent will be allowed:

- within 100 m of the boundaries of a gazetted beach in any direction;
- within 200 m of the seaward boundary of a marine fish culture zone or an SSSI, and within 100 m of the landward boundary;
- in any typhoon shelter;
- in any marina;
- within 100 m of a seawater intake point.

6.3 SENSITIVE RECEIVERS

Water-based sensitive receivers in the study area are identified in Figure 6.1 and include:

- Fish Culture Zone at Ma Wan Island
- Fishing communities operating in the area
- Gazetted beach on Ma Wan
- Non- Gazetted bathing beach and shallow embayment at Discovery Bay

The Pennys Bay Power Station, identified in the LAPH Studies as being potentially sensitive, is a gas fired station which does not require cooling water. There are no seawater intakes or outlets in the study area.

The Fish Culture Zone (FCZ) at Ma Wan Island is approximately 3.0 km to the north of the subject site. Eighty-five operators and an estimated labour force of 270 are engaged in polyculture (multi-species) production at Ma Wan, and produce an estimated output of 120 - 140 tonnes of fish from 14,557 m^2 out of a total licensed area of approximately 46,000 m^2. The high unit rate of production from the site, compared to a number of other gazetted fish culture zones in this part of the Territory, reflects the good flushing capacity attributable to the tidal currents in the area and well oxygenated water quality conditions.

The potential for currents in the area to draw waters with high turbidities around the headland to Ma Wan on flood tides warrants consideration. EPD water quality monitoring data (depth averaged) for 1991 to 1993 recorded suspended solids at Station NM1 (west of Ma Wan) which ranged from 3 to 49 mg/l, with a mean of 11.6 mg/l. This water will pass through the channel between Lantau and Ma Wan on the ebb tide and directly impinge on the mariculture area. It is apparent therefore that the mariculture zone is at present periodically exposed to relatively high suspended solids concentrations originating from the Pearl River on ebb tides. Any suspended solids transported from Pennys Bay on the flood tide are unlikely to attain as high values at Ma Wan as those on the ebb tide due to the effective transit distance of 3 km between the two locations and the weak currents along the east Lantau coast which would facilitate settling out of the particulates. It is therefore considered that the occurrence of significant adverse impacts associated with elevated levels of suspended solids on the mariculture zone originating from the

Pennys Bay area is unlikely.

Fishing activities in the area may also be affected by runoff, dredging and associated changes in marine water quality. Limited information is available on the extent and distribution of fishing activity in the immediate area. Although data on fishing effort is available from the port surveys conducted by AFD on vessels of less than 15 metres in length, these surveys do not necessarily provide locally-specific information appropriate to the estimation of catch rates, species composition, biomass and annual fishing effort in the project area. Although a large number of vessels are based at Cheung Chau, the fishing effort of most of these boats is directed towards waters south of Hong Kong, as catch rates for trawlers in the northern part of the project area are unlikely to be economically viable. In the immediate project area small inshore vessels are engaged primarily in gill netting and hand line fishing, and AFD have advised that in 1991 up to 600 vessels of this type were fishing intermittently in the development area, plus a small number of larger vessels. The Consultants are aware of no previous resource assessment in the area by AFD or conducted in the course of other studies.

The non-gazetted beach at Discovery Bay faces eastward and will be approximately 2.5 km from the western edge of the CT11 development. WAHMO modelling for LAPH studies indicate that CT developments would have an impact on the water circulation within Discovery Bay from an early stage of reclamation works. The associated reduced rates of flushing would allow settling of suspended solids generated by reclamation activities but would conversely result in a deterioration in the water quality of Discovery Bay. The cumulative effect of associated LPD construction activities and the proposed development of CT12 and CT13 are expected to have a significant impact on Discovery Bay and may have an impact on the water quality experienced by the beach.

The gazetted beach at Ma Wan is located on the eastern shore of the island approximately 3.5 km from CT10. Due to the distance from the reclamation site and low flow rates associated with Tung Wan Bay, water quality impacts from CT developments at Tung Wan beach are not expected to be significant.

6.4 ASSESSMENT METHODOLOGY

Assessment of the water quality in the area has been based on information published in the LAPH Studies including WAHMO modelling, data collected by the EPD marine water quality monitoring programme and on-site by Consultants in Environmental Sciences (Asia) Ltd [CES] in December 1993. The work conducted by CES was limited to a one-day investigation of current speed and direction at two stations and physical profiling of dissolved oxygen, suspended solids, temperature, pH and salinity at 21 stations in and adjacent to Pennys Bay. This was done in order to obtain site-specific data for comparison with the nearest EPD monitoring stations. The station locations are shown in Figure 6.2.

The potential water quality impacts of CT10 and CT11 reclamations and operations have been assessed in terms of Water Quality Objectives and evaluated against the background conditions in the Southern, North Western and Western Buffer Water Control Zones. Reference was also made to the Environmental Guidelines for Planning in Hong Kong.

Although the brief is constrained to developments related to the construction and operation of CT10 and CT11, other activities will have a bearing on water quality in the area eg construction of a breakwater offshore from CT10 and CT11, backup area and associated works. These activities will be cumulative if the work programmes proceed simultaneously and the discussion presented here for Pennys Bay, CT10 and CT11 should be read with this in mind.

6.5 EXISTING SITE CONDITIONS

6.5.1 BACKGROUND

Water quality in the waters around north Lantau is dominated by the influence of the Pearl River which brings high sediment and nutrient loadings to this area. Hong Kong waters, particularly around Victoria Harbour, are used as the principle disposal route for largely untreated sewage and industrial effluent which add to the suspended solids and nutrient loadings. Extensive dredging and reclamation works around the Territory also have a significant impact on water quality.

Strong tidal currents draw estuarine waters from the Pearl River Estuary and oceanic water into Hong Kong's coastal environs. At ebb tide estuarine waters are drawn eastward around the TCT peninsula achieving high current speeds through the channels between Lantau and Ma Wan, and Ma Wan and Tsing Yi. The bulk flow is through the latter channel which then continues in a south-southeasterly direction between Lamma and Hong Kong Island. Flow from the channel between Lantau and Ma Wan moves in a southerly direction, subsequently fanning out to the southwest and southeast, losing velocity in the process. Flood tide flow is generally the opposite of the ebb tide and brings Lamma Channel and Victoria Harbour waters north and west around the TCT peninsula. During the flood tide a gyre may form offshore of Pennys Bay and Discovery Bay to the north/northeast of Peng Chau (Morton and Morton, 1983). Output from WAHMO modelling runs has identified an area of slack water relative to the surrounding area in a similar vicinity to the gyre at approximately 2.5 hours before high water for wet season but not dry season spring tides. However, this would appear to be a transient phenomenon and is unlikely to be of significance for the present study. This feature will probably be affected by the construction of CT10 and CT11 resulting in a small increase in current speeds in the area.

Current velocities in the study area are not monitored by EPD. WAHMO model output predicts peak current velocity on spring flood tides offshore of Pennys Bay of 0.3 to 0.4 m/s with currents further inshore being less than this. Measurements of spring tide current speed made by CES in December 1993, at a location just offshore of Pennys Bay, gave a range of 0.13 to 0.25 m/s for the first part of the spring flood tide, whereas within Pennys Bay current velocities were lower, ranging from 0.02 to 0.13 m/s. These measurements were of limited duration and did not cover the whole of the tidal period but they are indicative of lower velocities within Pennys Bay relative to the open coast, which would be expected, and are also within the WAHMO predicted values.

6.5.2 MARINE WATER QUALITY

Existing water quality in Pennys Bay is influenced by flushing rates and present discharges into the Bay from Cheoy Lee shipyard, China Light Power Station and a small existing quarry.

Discharges from the shipyard include canteen wastes and discharges from the workshops that may include oil, fuel, grease, lubricants and solvents. The total volume of daily discharges based on EPD discharge licence applications, is estimated to be around 15 m^3. Sewage effluent is directed to a septic tank and soakaway.

The power station has a secondary sewage treatment facility in the form of a Rotating Biological Contactor (RBC) and effluent discharges are under control of the Water Pollution Control Ordinance (WPCO), Licence Number EP52/W2/XG082. Maximum daily flow rate is 8 l/s to a 30/20 specification (suspended solids/BOD mg/l). Maximum *E.coli* allowed is 1000/100 mls. In addition to the sewage treatment facility there are three other facilities under the control of the WPCO licence ie two oil interceptors and a polishing treatment tank. Maximum flow rates from the oil separators are 55 l/s and 42 l/s, and for the polishing treatment tank, 10.5 m^3/s.

No information is available on the impact of the existing quarry on water quality in the area. However, it is likely that runoff containing suspended solids is discharged into the surrounding waters.

The nearest location to Penny's Bay at which marine water quality is regularly monitored is at EPD Station SM10, approximately 1.5 km offshore and equidistant from Discovery Bay and Pennys Bay. Inspection of the data for 1991 to 1993 indicates that there has been a trend towards increasing levels of *E.coli* (an indicator of sewage pollution) with depth average means of 61, 74 and 125 counts/100 ml for each respective year. However, due to the small number of samples and the natural variance in the data, the difference between the averages for 1991 and 1992 was not statistically significant ('t'-Test; $p>0.05$). At the time of writing, insufficient data were available for 1993 to make statistical comparisons with previous years. Domestic sewage is discharged from marine outfalls serving communities at Discovery Bay and Peng Chau. These are predominantly domestic discharges with small amounts of commercial and restaurant wastes. However, the *E.coli* at SM10 are not necessarily derived entirely from local sewage outfalls as water drained from Victoria Harbour during ebb tides, which is heavily contaminated with *E.coli* (exceeding 10^3 counts/100 ml), may contribute some bacteria to the count at SM10 during flood tides.

The EPD data for ammoniacal nitrogen also increased from 1991 to 1992 (1993 data not available at the time of writing) with depth average means of 0.109 and 0.138 mg/l and total inorganic nitrogen of 0.37 and 0.49 mg/l. As for *E.coli*, the difference between the averages for 1991 and 1992 was not statistically significant ('t'-Test; $p>0.05$). The WQO for inorganic nitrogen is 0.1 mg/l and a total inorganic nitrogen concentration of 0.3 mg/l in the water column is regarded as a typical concentration at which eutrophication effects can occur. Thus, the waters at SM10 exceed the WQO for inorganic nitrogen and may be considered as incipiently eutrophic. Ammoniacal nitrogen in its unionised form is potentially toxic to fish and the WQO for this radical is set at 0.021 mg/l. The unionised proportion of the reported ammoniacal nitrogen would closely approach the WQO value at a water temperature of 25°C and pH of 8.0. Actual water temperatures ranged from 15.4 to 26.3 according to time of year, and pH ranged from 7.9 to 8.4. Thus there is potential for exceedance of the unionised ammonia WQO under present conditions.

There is no WQO for phosphate, and phosphorus compounds are not normally a limiting nutrient in the marine environment. Concentrations for phosphate at SM10 ranged from 0.006 to 0.048 mg/l. This compares with depth average means of 0.06 mg/l in Western Victoria Harbour and 0.03 mg/l off North Lantau. The waters at SM10 are therefore midway between the latter two locations and are indicative of the source of water at SM10, on the ebb tide, being a mixture of the other two water masses, as would be expected, with the lower concentrations perhaps representing cleaner oceanic water prevalent on the flood tide.

Depth-averaged dissolved oxygen saturation was consistently high during 1991 to 1993 and ranged from 65% to 107% with increasing average values of 87.7%, 88.6% and 90.6% with each successive year. However, the ranges in dissolved oxygen were similar in each year. Dissolved oxygen concentrations measured by CES in December 1993 within Pennys Bay ranged from 3.5 to 4.3 mg/l (43.5% to 53.5% saturation). The criteria for marine water quality objectives require the depth average for dissolved oxygen to be not less than 4.0 mg/l for 90% of samples for the whole zone, with the exception of fish culture zones. Seven of the 19 stations sampled by CES failed to meet this criterion. Accepting that this sampling was restricted to one day, there is nonetheless an indication that the waters in and immediately adjacent to Pennys Bay are on some occasions susceptible to depletion in dissolved oxygen concentrations.

Salinity at SM10 ranged from 25.0 ppt to 33.1 ppt indicating that although it receives freshwater from the Pearl River, this area is primarily under the influence of oceanic water. Measurements of salinity conducted by CES in December 1993 in Pennys Bay and immediately offshore from it, were within the range of 32.0 to 33.0 ppt. The influence of the Pearl River is perhaps reflected in the slightly elevated suspended solids concentration (depth averaged mean of 8.2; range 3.7 to 16.3) over that typically found in essentially marine conditions eg Tai Tam Bay, where suspended solids range from 1.0 to 5.0 mg/l (EPD data station SM1). Biochemical Oxygen Demand (BOD) of the water column is low at Station SM10 with values generally less than 1.0 mg/l.

6.5.3 BENTHIC ECOLOGY

Broad coverage of the marine ecology for the area bounded by Ma Wan, Lamma, Lantau and Hong Kong Islands was performed and reported as part of the Lantau Port and Western Harbour Development Studies (LAPH) Environmental Survey Data Report (Section D). Of the 17 stations surveyed, Stations 5, 6 and 7 were closest to the Pennys Bay area and when ranked according to species diversity, were among the least diverse. However, species diversity throughout the whole of the 17 stations was generally very low.

Of the relatively few species present, polychaete worms were the most dominant comprising 80% of recorded species. The Report stated that no particular environmentally sensitive species were noted. This is taken as meaning there were no species particularly susceptible to environmental disturbance (eg increased sedimentation rates) nor any species of nature conservation significance. The marine ecology of the area was considered impoverished as indicated by diversity and abundance parameters.

Further survey work is not envisaged as the marine habitats in this area will be lost to the proposed backup area and container terminal reclamations. Burial of infaunal organisms will occur during reclamation and this is unavoidable. The loss of habitat due to the proposed development represents approximately 3% of the area studied in the LAPH Environmental Survey Data Report.

Government have provided the following information based on marine ecology surveys conducted by the Ancillary Works Consultant. "A survey on the activities of the Chinese white dolphin has been recently completed in the study area by the Ancillary Works Consultants. 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 World Wide Fund for Nature/Hong Kong (upto December 1993) and data collected during the current Swire Institute of Marine Science Study also suggest 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."

6.6 IMPACTS OF TERMINAL CONSTRUCTION

6.6.1 INTRODUCTION

The areas considered by this section are outer Pennys Bay bounded by CT10 and CT11 and associated entrusted works as shown in Figure 6.3 excluding reclamations in Pennys Bay which are designated as ancillary works developments. These areas are the remit of a separate study and will not be considered here, other than to point out that if these areas are not reclaimed at the same time as CT10 and CT11, an embayment will arise in Pennys Bay between CT11 and the present shoreline which could result in a deterioration in water quality within this enclosed water body. Similarly, the construction of the breakwater is also not part of the present brief but will have an influence on the hydrodynamics and quantity of contaminants in the study area.

During the construction phase potential sources of water quality impact are :

i) dispersion of fill and dredged material during reclamation activities leading to elevation in suspended solid concentrations in the surrounding water;
ii) dredging and disposal of potentially contaminated sediments;
iii) storm run-off carrying silt into receiving waters;
iv) run-off containing suspended solids from dust suppression waters;
v) sewage disposal;
vi) loss of marine flora and faunal habitats and damage to fish and filter feeder populations; and
vii) accidental discharges of fuel, oil, grease, lubricants and solvents.
viii) embayment formed in Pennys Bay.
ix) water circulation within Discovery Bay significantly affected at an early stage in the reclamation by affecting hydrodynamic characteristics of the area; and
x) eutrophication due to increased nutrient loading.

6.6.2 MARINE FILL

The source of marine fill to be used in the reclamation is currently being identified and it will most likely be dredged from different sites. Based on information contained in Technical Note 3/93 entitled 'Review of Specifications for Marine Fill Material for Reclamation' prepared by GEO in October 1993, reproduced here in Table 7.1, an average of 4.8% fines may be assumed for the purposes of the present assessment (this compares favourably with the 3.5% fines assumed for dust calculations in Section 6 of this report). It is understood that trailer suction hopper barges were used for the contracts listed in Table 7 and overflow was allowed during the dredging operations. The dredged material was composed of quartz particles and shell fragments.

Table 6.4 Summary of Some PSD Test Results on Marine Fill at Reclamation Sites

Contract No.	Marine Borrow Area	Dredging Method	Specified Max. Fines Content (%)	Average Fines Content from available representative PSD results (%)
CV/91/04	South Tathong	TSHD	30	3
TK 33/89	South Tathong	Grab	25 -35	14
TIE/1/91	South Tathong	TSHD	25 - 35	4
TK 34/91	South Tathong	TSHD	25 - 35	2
CV/90/09	East Tung Lung Chau	TSDH	20	4
ST 59/90	North Tathong	Grab	20	6
CV/91/02	South Tathong	TSHD	20	2
CT 8	South Tsing Yi	TSHD	20	4
NL 1/91	West Sokos	TSHD + Grab	16	8
UA 5/90	East Tung Lung Chau	TSHD	12	2
HY 91/07	North of Lantau	TSHD	5 - 10	5
HY 91/07	Kap Shui Mun	TSHD	5 - 10	2
HY 91/07	South Tathong	TSHD	5 - 10	7

Note: TSHD denotes trailer suction hopper dredger.

Water quality impacts from the reclamation works will primarily result from the suspension of fine particulate material. The suspension of fine material will result in an increase in water turbidity and a concomitant decrease in light transmission which will result in a lowering of planktonic productivity through a reduction in photosynthesis. The extent of this effect is dependent upon how far the fine suspended material is transported from the site before settling to the seabed. This in turn is dependent upon the strength of water currents in the study area and the grain size of the particulates.

As previously mentioned, 4.8% percent fines content of the marine fill has been assumed. Fines are made up of silt and clay fractions, Sheldrick B H and Wang C (1993)[4] defined silt particle size as smaller than 0.06 mm. Using Stoke's Law, the settling velocity for this particle size was calculated to be 3.6 mm sec^{-1}. Assuming the worst case where all sediment losses occur at the water surface and that near-shore water depths at CT10 average approximately 15 m, the fine particle settling time would be in the order of just

[4] Sheldrick B H and Wang C (1993). Particle Size Distribution. pp499-511 in: *Soil Sampling and Methods of Analysis*. (M R Carter, Ed. for the Canadian Society of Soil Science). Lewis Publ., Boca Raton.

over an hour (71 minutes). However, fines are kept in suspension by turbulent water movements and assuming that for the study site, tidal water speeds vary sinusoidally with a peak speed of approximately 0.35 m sec^{-1} on both northeast and southwest flowing tides, the sediment lost to suspension could resettle over an area estimated to be 4.0 km per tidal excursion. In practise, because the greatest proportion of sediment lost to suspension enters the water column close to the bed, where water currents are very low, localised resettlement will occur, and very little sediment is expected to actually travel 4.0 km.

As the marine fill is likely to have a higher content of nitrogen and phosphorus compounds than granitic rockfill, there is potential for eutrophication. A nitrogen concentration of 0.3 mg/l in the water column is regarded as a typical concentration at which significant eutrophication effects occur, the increased nutrient loading will depend on the sources of marine fill and until these have been identified it is not possible to assess the full impact on water quality. Furthermore, the dynamics of nutrient desorption will be difficult to assess. If clean sand is used, it will be unlikely that there will be a problem with nutrients. However, if the fill contains a proportion of fines (mud) the potential for nutrient contamination will be dependent on the actual proportion of fines and the actual content of nutrients. It would be dangerous to assume an approximate nutrient content for the present assessment as this could lead to an erroneous conclusion, perhaps to the detriment of the project. Hence it is recommended that such information be sought once the borrow area has been decided upon.

6.6.3 FILL PLACEMENT

The Advance Works will first have been completed by the Government, to form the platform from which CT10 and CT11 will be constructed. CT10 and CT11 are programmed to start simultaneously after the beginning of the second quarter of 1996.

The present seabed level is an average of -15.4 m PD on the CT10 site and -5.8 m PD at CT11. A trench will first be dredged along the edge of the footprint for the construction of the main quay seawall. The seawall will be built progressively as the reclamation advances, to allow access to the area for barges and dredgers. Both container ports will be built from west to east, CT10 will extend south from the TCT peninsula then east along the southern tip of the peninsula. The back wall for CT11 will be built first, followed by the western side, the area to the east will then be reclaimed as far as CT10.

The existing sediments will be covered with a geotextile layer of matted plastic. The filling of the area will begin remote from the edge while the seawall is being built. Due to the nature of the underlying sediment, the sand will initially be pumped into the area in 1 m layers. When the fill reaches 2 m in depth, wick drains will be driven into the fill and underlying mud in a triangular grid over the whole area at distances of 1.5 m apart. The wick drains will quickly remove interstitial water expelled from the sediments during consolidation. The filling will then continue in 1m layers until there are 4 m of fill, after which filling will progress in 2 m layers. Rainbowing will be used to infill the area once the filling is above the water level. The slopes at the edges of the layers are required to be no greater than 1:15.

The sand will be transported from the marine borrow area by trailer suction dredgers, and will be bottom dumped into rehandling basins. The cutter suction dredgers will then lower a suction head into the sediment and it will be pumped into the reclamation area to reduce disturbances to the marine foundation layer. If the sand has to be pumped further than 1.5

km, boosters will be used to assist the pumping. The pumped sand will consist of 50% marine sediment from the marine borrow area and 50% water, to liquify it so that it spreads evenly. The trenches dredged for the seawalls will probably serve as temporary rehandling basins for the marine sediment. The trench will generally be dredged 200m ahead of the wall construction and the rehandling basin will move as the wall construction advances.

Since the reclamation of the two container ports will take place over such an extended period and the volume of fill required is so great, the impact from the resettling fines has potential to be cumulatively very significant. The total estimated fill required for the reclamation is 80.71 M cu. m, and assuming a 4.8% percent fines content, the total input of fines will be up to 3.9 M cu. m. However, the release of fines to the surrounding water will be greatest during the initial reclamation, until the water surface is broken. Escape of high suspended solids water from the site should decrease significantly during the rainbowing process which will proceed by backfilling. By directing the jet towards the back of the reclamation onto the newly-formed beach, as the liquid drains through the beach an increasing proportion of solids are trapped. The initial infilling will also be contained at all times by the seawall which will advance ahead of the reclamation.

6.6.4 EROSION OF RECLAMATION AND SILTY RUNOFF

As previously stated, the area including the advance works, CT10 and CT11 will require 80M cu. m of fill. The maximum projected rate of fill will be 2.3M cu. m per month for CT10, and 1.0 M cu m per month for CT11. It is anticipated that filling will commence in the second quarter of 1996 and continue until the first quarter of 2000. Reclamations for CT10 and CT11 will therefore result in a period of approximately 2 years of sustained input of suspended solids. The commissioning of the berths at CT10 and CT11 is scheduled for the same dates.

Water quality impacts from the reclamation works will primarily result from the suspension of fine particulate material, therefore mitigation options will include :

- o constraining the dispersion of the particulates by water currents eg by use of a silt curtain

- o filling to above highest tide level (+2.6m PD) as quickly and in as a controlled manner as possible

The rate at which the level of fill can be raised will depend upon engineering requirements for slope stability. However, if it is feasible to concentrate on a smaller rather than a larger area in filling the berth area, to minimise the area of fill exposed underwater at any one time, this would be advantageous.

During the later stages of construction, run-off from rainfall and the loss of oil and grease from trucks also have potential for affecting water quality. This can be mitigated against if a bund is placed around the perimeter of the reclamation with drainage collection ditches leading the run-off to oil interceptors before discharge to the sea. Freshwater run-off is a natural process in coastal areas and discharge of this water from settlement pits should not create a problem as long as contaminants are removed.

Impacts of construction on marine life in the area will include loss of marine habitats to reclamation activities as discussed earlier.

In the absence of modelling, our qualitative assessment of the impact from marine fill on suspended solids is that due to relatively low current velocities expected in the study area, impacts will tend to be localised at the study site. 'Acceptable' limits of increases in suspended solids are usually defined by EPD and an increase of 30% over background has been applied to other reclamation sites in Hong Kong. This is an overall requirement applicable to any water column (except at dumping and dredging sites) where various construction activities may be taking place concurrently; thus the cumulative impact should not exceed the limit. This performance specification is likely to be included in contract documents and it will be the contractors responsibility to maintain water quality within this limit. Other studies in Hong Kong have shown that this should not present a major hurdle to the progress of the works.

6.6.5 DREDGING

Dredging of marine mud for the development will be restricted to the southern edge of the reclamation area where the quay decks are sited and the northern edge structure adjacent to the Pennys Bay access channel. Uncontaminated mud dredged from the seawall and channel sites will be conveyed provisionally, to a disposal area located south of Shek Kwu Chau Island, the Cheng Chau marine spoil ground.

Dredging and dumping will be carried out by trailer-suction hopper dredger which employs a trailer-suction head to dislodge and remove marine deposits. Material is drawn up via a pipeline to the dredger hoppers by hydraulic pump. Dredged mud from the reclamation will be discharged by bottom dumping at the designated spoil grounds. Sandfill is likely to be pumped onto the reclamation to reduce disturbances to the marine foundation layer. Placement of rockfill by bottom dumping barges will be carried out upto a reclamation level -2.5 m PD.

Dredging for the foundations of the southern quay seawall trench to the base of marine deposits and placement of sandfill will be carried out in 3 stages, requirements are identified in the following table.

Table 6.5 Requirements for Dredging and Marine Sand

Development Stage	Seawall Dredging (Volume-Million m^3)	Marine Sand (Volume-Million m^3)
Advanced Works	1.48	1.73
CT10	1.85	2.94
CT11	4.10*	4.40
Total	7.43	9.07

* Including dredging for the access channel to Pennys Bay

Under a separate contract a 650 m access channel adjacent to the quay seawall will be required to a minimum depth of -14.5 m CD, removing a total of approximately 14.4 million m^3 of material. The impact of access dredging and channel maintenance dredging in support of the CT development will be examined by others. Water quality during dredging could be affected by short term increases in turbidity which may have the following effects:

- o Impairment of water clarity;
- o Depletion of dissolved oxygen;
- o Release of nutrients from re-suspended sediments;
- o Possible release of contaminants, heavy metals and organic micro-pollutants from re-suspended sediments; and
- o Siltation, smothering marine flora and fauna.

To minimise potential impacts, the following general pollution avoidance measures would need to be followed during the dredging, transporting and disposal of dredged mud:

i) use of suction-heads on suction dredgers should minimise over-break and sedimentation around the head;

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

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

iv) excess material should be cleaned from the decks and exposed fittings before vessels are moved;

v) dredging should cause no visible foam, oil, grease, scum, litter or other objectionable matter to be present on the water;

vi) loading of hoppers should be controlled to prevent splashing of dredged material to the surrounding water and hoppers should not be filled to a level which would cause overflowing of material or polluted water during loading or transportation;

vii) adequate freeboard should be maintained to ensure that decks are not washed by wave action;

viii) 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;

ix) 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.

Water quality monitoring during dredging activities should be undertaken as detailed in the CT Environmental Monitoring & Audit Manual.

6.6.6 CONTAMINATED SEDIMENTS

A preliminary mud contamination survey was carried out to determine if there was actual or potential contamination of the mud related to the area to be dredged. Contaminated mud sampling was undertaken by Gammon Ltd under the supervision of Maunsell Consultants Asia Ltd. (MCAL). The subsequent laboratory analysis was conducted by Materialab Ltd in accordance with the testing procedure outlined in the Works Branch Technical Circular No. 22/92. Vibrocore locations were 100 m apart. Results indicate that Class B contamination (moderate contamination) has occurred at two locations and Class C contamination (severe contamination) at one location. The contamination is of the top 100 mm sediment and is limited to copper only.

MCAL speculates that copper contamination is due to the disused contaminated mud pit north and west of Kau Yi Chau located about 2.5 km away. A previous study[5] revealed that there was in fact some mercury contamination of the surface around this pit, but no evidence has been found for copper contamination. A much more possible cause of copper contamination is the small disused spoil ground (about 0.25 km^2) east of Chok Ko Wan Tsui. This disused pit is located almost directly on top of the vibrocore locations. Copper-contaminated materials such as copper-based paint waste from the boat yard of Pennys Bay might have been dumped at this pit prior to the regulation for disposal of contaminated mud had come into force.

MCAL estimated that the magnitude of quantity of Class C mud that will arise from the project (CT10 and CT11 combined) will be at least 30,000 m^3. The calculation assumed that one-sixth of the top 0.5 m sediment is Class C material, based on limited vibrocore data. It also assumed that it is feasible to confine the dredging to the top 0.5 m[6]. These assumptions need to be substantiated with: (i) further mud investigation with a refined sampling grid; and (ii) confirmation with the dredging contractor that this depth is feasible. In addition, surface grab samples taken every 200 m along the approach channel indicate that at least 50% will be categorised as Class B or Class C. This additional volume of contaminated mud is yet to be quantified.

As the preliminary results are indicative of metal contamination, further testing to verify the full extent of contamination is required. Vertical profiles of samples should be taken on a 100 x 100 m grid in accordance with WBTC No. 22/92. Agreement with EPD with respect to the sampling and testing programme must be obtained prior to the mud contamination survey in order to subsequently apply for a dumping license. This applies to both contaminated and uncontaminated mud. In conducting the contamination study, it is recommended that a specialist consultant be present on barge to supervise the mud sampling and subsequent laboratory testing so that the samples can be certified to be free from cross-contamination, and data thus obtained are indicative of the actual environment.

Marine disposal of Class C mud must be undertaken at specially dredged pits to be allocated by FMC and must be transported with great care as well as effectively isolated from the environment upon final disposal. The environmental conditions on disposal of contaminated marine mud at East Sha Chau Contaminated Mud Disposal Pits will apply.

5 Lantau Port & Western Harbour Development Studies - Environmental Baseline, Working Paper No. 12 A, Civil Engineering Port Development Office, February 1992.

6 Other dredging projects in Hong Kong have used 1 m to be the minimum practical dredging depth.

MCAL suggests that the idea of constructing a special pit beneath the advance works reclamation for the disposal of contaminated mud be explored. EPD was contacted about this issue (as a general case). EPD requires that a formal request of the proposed construction be submitted to the Director of Environmental Protection to seek approval[7]. It may be more cost-effective to undertake this step before the detailed design stage. Classes A and B mud may be disposed of at the gazetted spoil ground at South Cheung Chau Dumping Ground and no special dredging, transport or disposal methods are required beyond those which would normally be applied for the purpose of ensuring compliance with EPD's Water Quality Objectives, or for protection of sensitive receptors near the dredging or disposal areas.

6.6.7 SEWAGE DISPOSAL

At present there are no existing public sewers available for discharges from this project. The sewage generated by the LPD projects area will be directed to the main sewage disposal scheme at Siu Ho Wan. However, until this STW is in operation temporary facilities will be required for the LPD workforce. The Environmental Guidelines for Planning in Hong Kong state that major developments should be served by public sewerage and sewage treatment facilities and that construction should be programmed such that sewerage facilities are commissioned before occupation of the new developments.

It was proposed that for the workforce carrying out the reclamation work, and for those involved in the borrow area extraction, it would be most appropriate to tanker away the waste to a temporary facility located within the backup area. The predicted construction workforces are 500 for the borrow area and 1000 for each container terminal. The use of septic tanks and soakaways is not believed to be a viable approach as space limitations on the reclamation sites and lack of suitable soakaway sites precludes siting a treatment facility within the works area. It is proposed that the sewage is removed by tanker to a preliminary treatment plant located in the backup area.

Effluent discharged from this treatment works would require licensing under the Water Pollution Control Ordinance and would have to comply with the Technical Memorandum on Standards of Effluent Discharged into Drains and Sewage Systems, Inland and Coastal Waters. A suitable system would include screens, primary sedimentation, Rotating Biological Contractor (RBC) plant, final sedimentation and chlorination. With this arrangement a BOD/SS 20 : 30 (mg/l) could be achieved. The location of the outfall will also need careful consideration to ensure that the optimum dispersion of the effluent is achieved. The construction of the terminal will generate back-eddies and areas of poor circulation and it is important that the sewage effluent is not discharged into such areas.

6.6.8 PENNYS BAY IMPACT

Advance works reclamations will create a temporary embayment with access to the sea through a channel created on completion of construction of CT11. This will result from the southward progression of the Pennys Bay reclamation and the westward development of the first stages of CT11 across the mouth of the Bay. It is anticipated that this channel arrangement will be required for fill transfer throughout the lifetime of the quarry, upto 5 years if Stage 2 material is sourced from this borrow area.

[7] Correspondence should be made to Mr H C Chan, Solid Waste Control Group, EPD

With the partial enclosure of the outer part of Pennys Bay for the above facility, the circulation within the embayment and exchange of waters between the embayment and the open coast will be reduced. This will probably lead to a deterioration in water quality within the embayment. This could be exacerbated by the reclamation work proposed for the inner part of Pennys Bay which is under review by a separate consultant. Inputs of potential pollutants from that source cannot be estimated in this report as no information is available.

Dredging of marine mud may be necessary to install foundations for the borrow area fill transfer station quay, however, preliminary design and sediment sampling for this area is beyond the scope of this study. The impact of material placement during construction of advanced works in Pennys Bay CT10 and CT11 entrusted works may be significant. In addition to the dredging mitigation already discussed, washing rock to remove excess sediments and provision of silt curtains in reclamation areas could reduce suspended solids impacts to a minimum. Accepting that Pennys Bay will eventually be completely reclaimed, mitigation is still applicable in the interim to prevent water within the embayment becoming increasingly poorer to the extent that the working environment within the Bay is affected. Also, any effects within Pennys Bay should, wherever possible, be prevented from influencing the open waters immediately adjacent to the Bay.

6.7 OPERATION PHASE

During operation the key water quality impacts are identified as:

- o sewage discharge.
- o storm water discharge;
- o accidental spillage; and
- o embayment of Discovery Bay.

6.7.1 SEWAGE DISCHARGE

Sewage generated in the terminal will arise, in the main, from domestic type sources by the workforce at the administration building, Container Freight Station. Sewage will be collected and directed to the main sewer system in Container Port Road which will in turn be transferred to the new treatment works to be constructed at Siu Ho Wan on North Lantau. The proposed arrangement is shown in Figure 6.5.

For longer term operational impacts arising from the entire port development, WAHMO modelling undertaken as part of the Lantau Port & Western Harbour (LAPH) Development Studies Final EIA Report concluded that unless provision is made for sewage treatment of effluent arising from Discovery Bay, Yi Pak and Peng Chau, then water quality in Discovery Bay and eastern Lantau is at significant risk of eutrophication, algal blooms, hypoxia and unacceptable *E.coli* levels. Given a minimum of secondary treatment or relocation of the sewer outfalls outside of the embayment created by the port reclamation, the LAPH Report states that water quality is predicted to become acceptable. However, the foregoing Report also states that it is important to note that pollutant loads not included within WAHMO, and which could represent significant loading to the area, are surface run-off, spillage of oil and grease and the possible release of toxic materials from damaged or leaking containers. The impact of these inputs would be reduced by the provision of a bridge rather than a causeway linking Phases II and III which would improve flushing characteristics.

6.7.2 STORMWATER DISCHARGE

Storm water generated within Pennys Bay will be collected and discharged through one of two box culverts. One of which outfalls to the east of the terminals, the other discharges to the west into Discovery Bay. Storm water generated within the terminals will drain through storm drains to five discharge points in the southern edge structure of the terminal. The design assumes that oil interceptors will be incorporated to intercept the "first flush" of rainfall, that trapped gulleys are used to intercept engine oils entering the system and additionally, runoff from the lorry parking area passes through a 3-stage petrol interceptor prior to discharge into the storm water system. The arrangement of the stormwater drainage system is shown in Figure 6.6. Further discussion of this issue is presented in the operational waste management section.

6.7.3 DISCOVERY BAY IMPACT

Water circulation within Discovery Bay will be significantly affected at an early stage in the reclamation process by affecting hydrodynamic characteristics of the area. WAHMO modelling runs performed for the Lantau Port and Western Harbour Development Studies EIA Report clearly demonstrated two effects. Firstly, the mechanism of flushing would change which would result in cleaner, southern water, being entrained within the Bay. However, the second effect would be a much reduced rate of flushing which would result in accumulation of pollutants discharged to the Bay. The combined effect of these two factors would be a marked increase in concentrations of inorganic nitrogen, ammoniacal nitrogen, algal growth and coliform bacteria within Discovery Bay. These changes are brought about by the construction of a physical barrier (the terminal perimeter), placed across the present line of water flow, directing flow away from Discovery Bay.

It is envisaged that drainage from Pennys Bay area will be directed through a network of culverts and channels of the backup area drainage system to an outlet on the west of CT11. It has been demonstrated that Lantau Port Developments are likely to cause a deterioration of the water quality in Discovery Bay. Discharging drainage waters from the Pennys Bay area would aggravate this situation.

At normal discharge rates, the predicted water circulation within Discovery Bay would be expected to carry drainage waters southwards out into open waters. However local impacts affecting the circulation pattern could arise from release of large quantities of storm runoff into the Bay. It is likely that freshwater would stratify on the top of the water column, fanning out into Discovery Bay against the normal circulation flow, and the low flushing rates would mean that any contaminants contained in the discharges would tend to remain in the Bay.

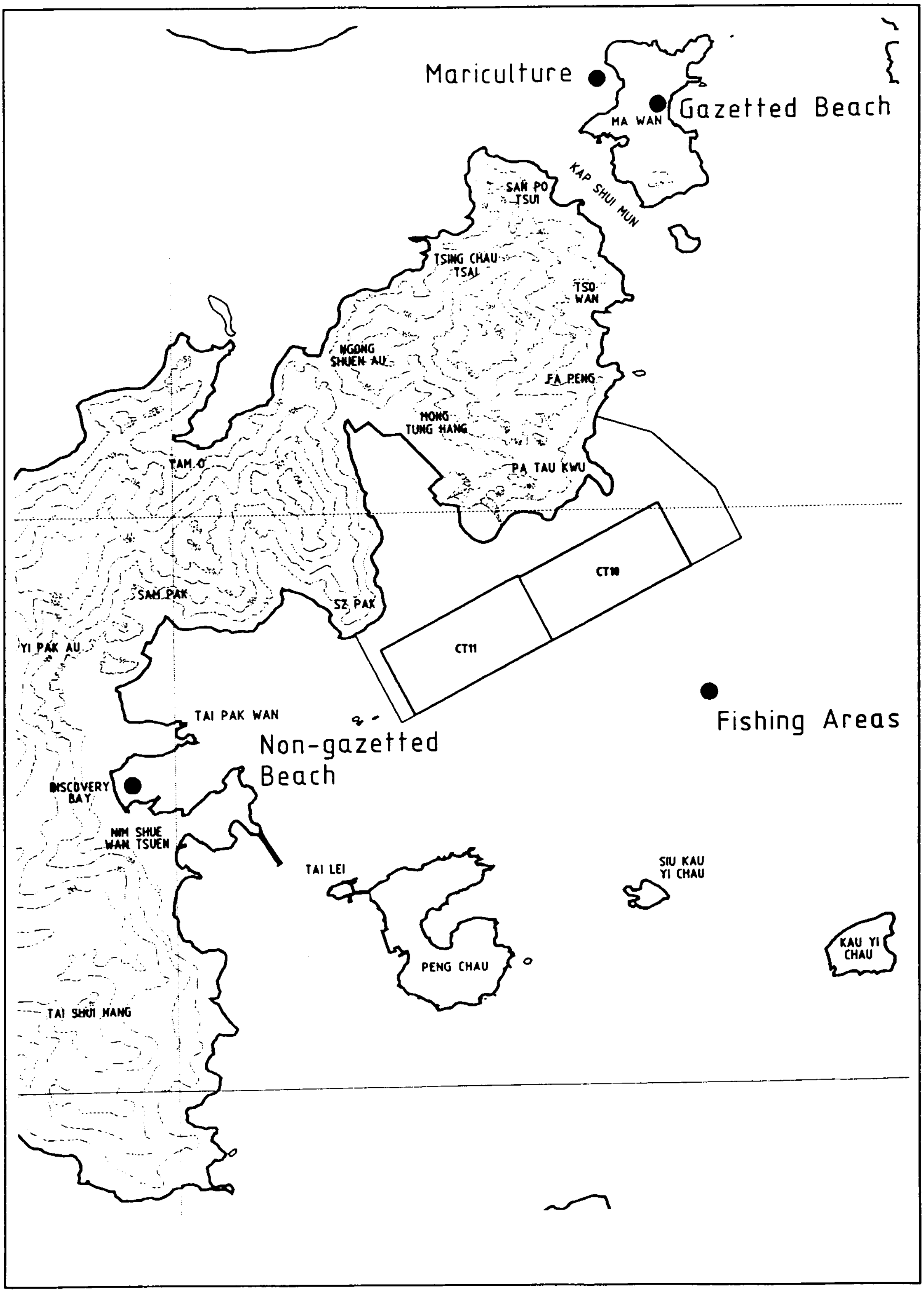

Figure 6.1 Water Based Sensitive Receivers

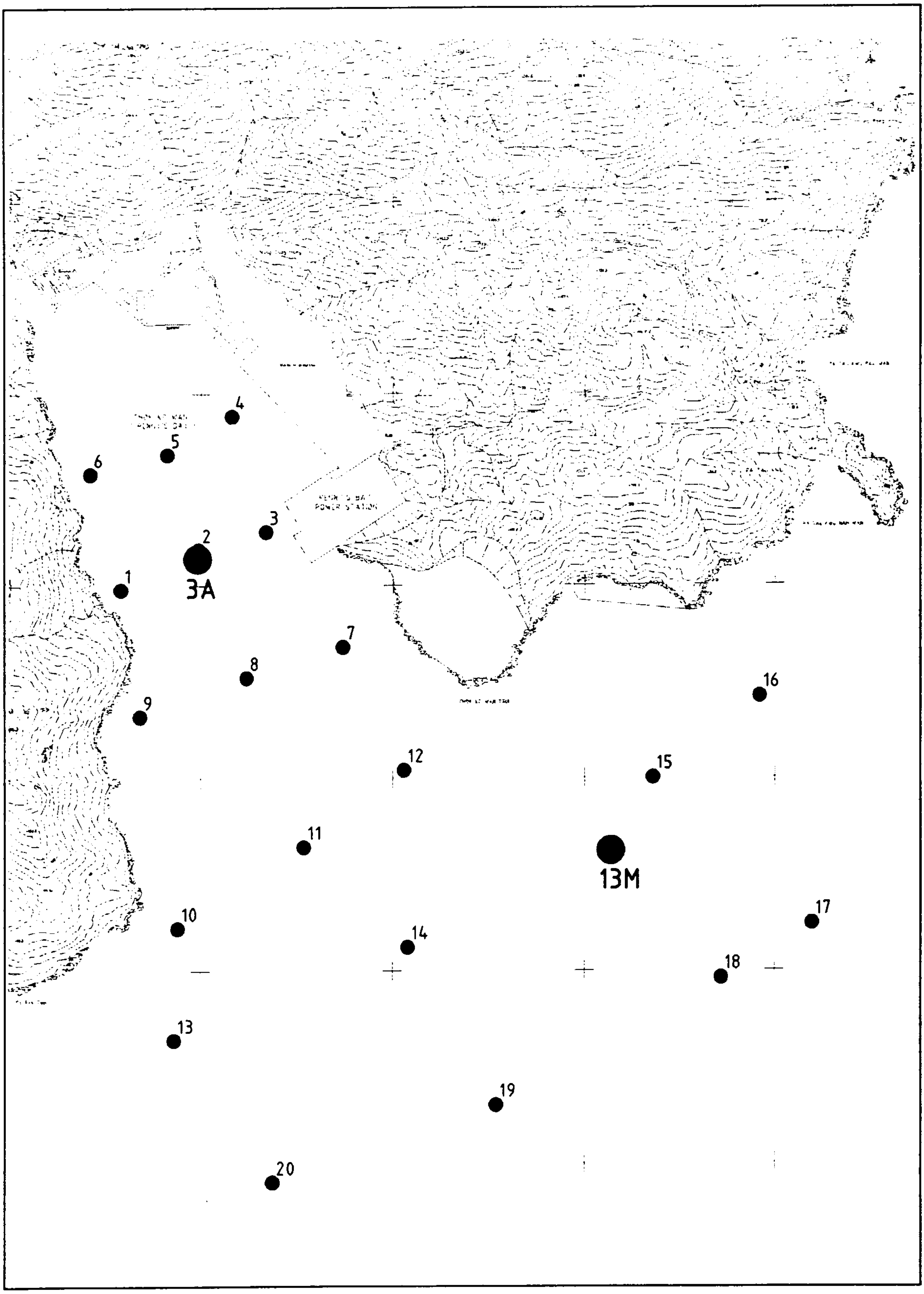

Figure 6.2 Monitoring Stations

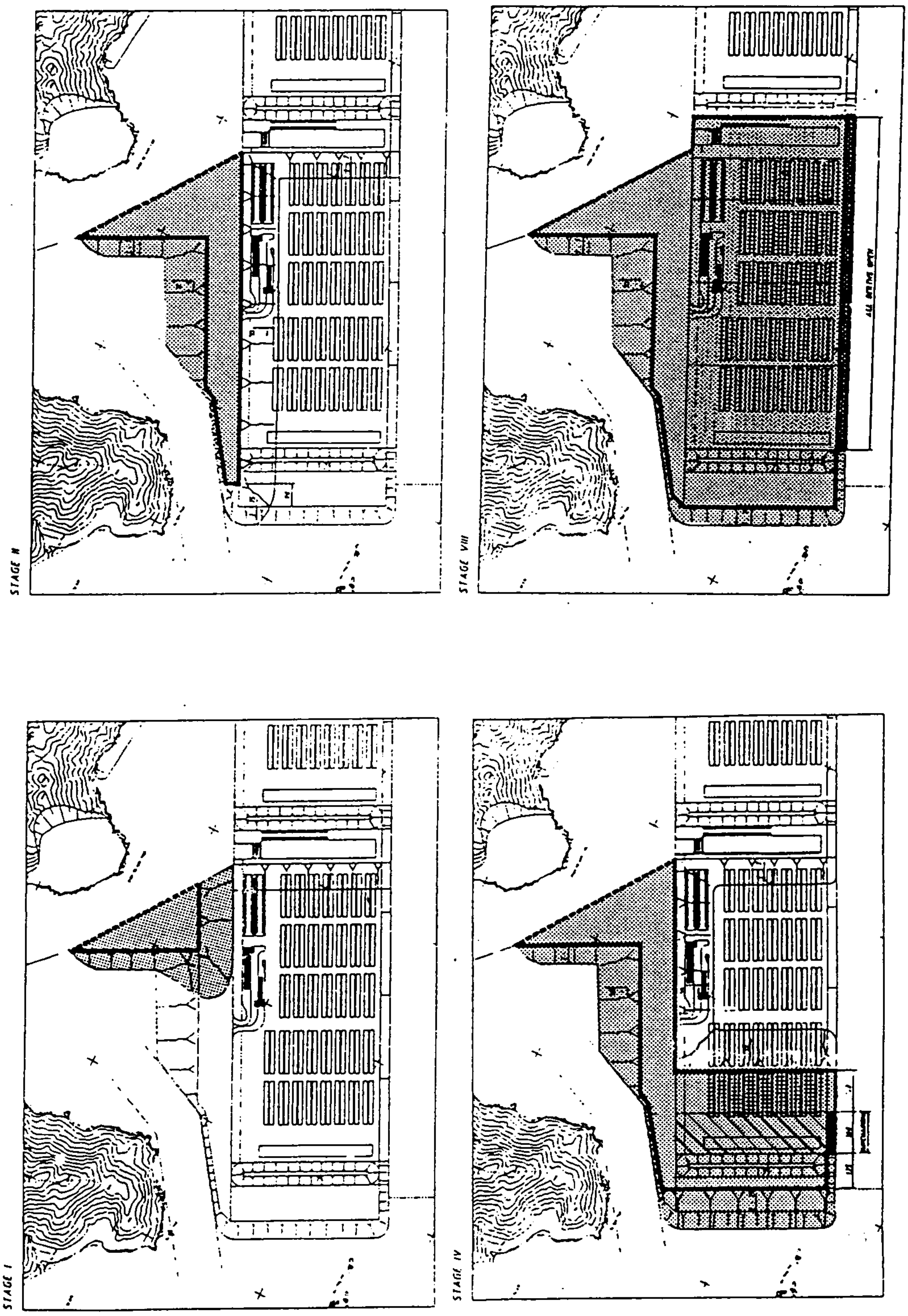

Figure 6.3 Reclamation progress

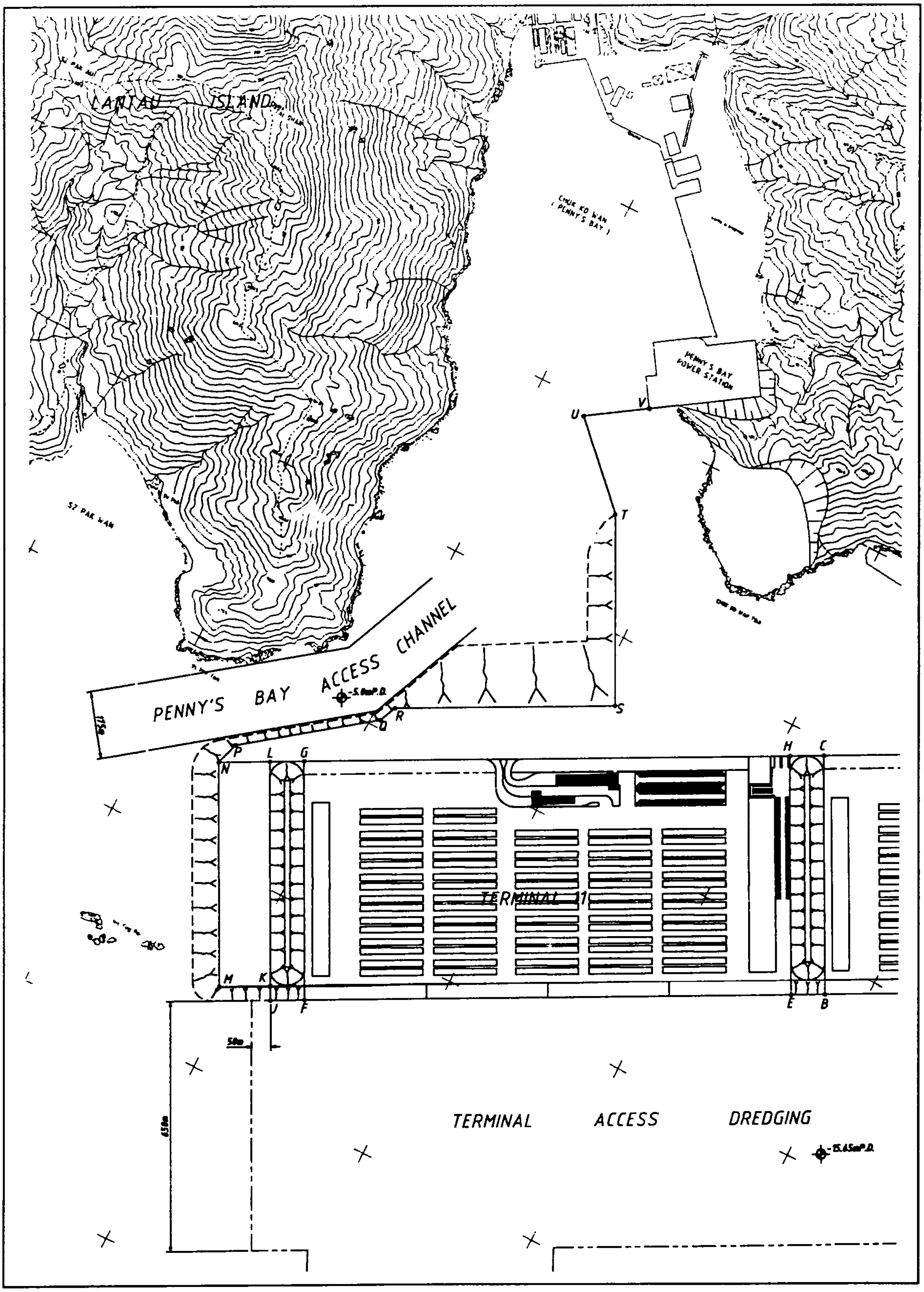

Figure 6.4 Penny's Bay Access

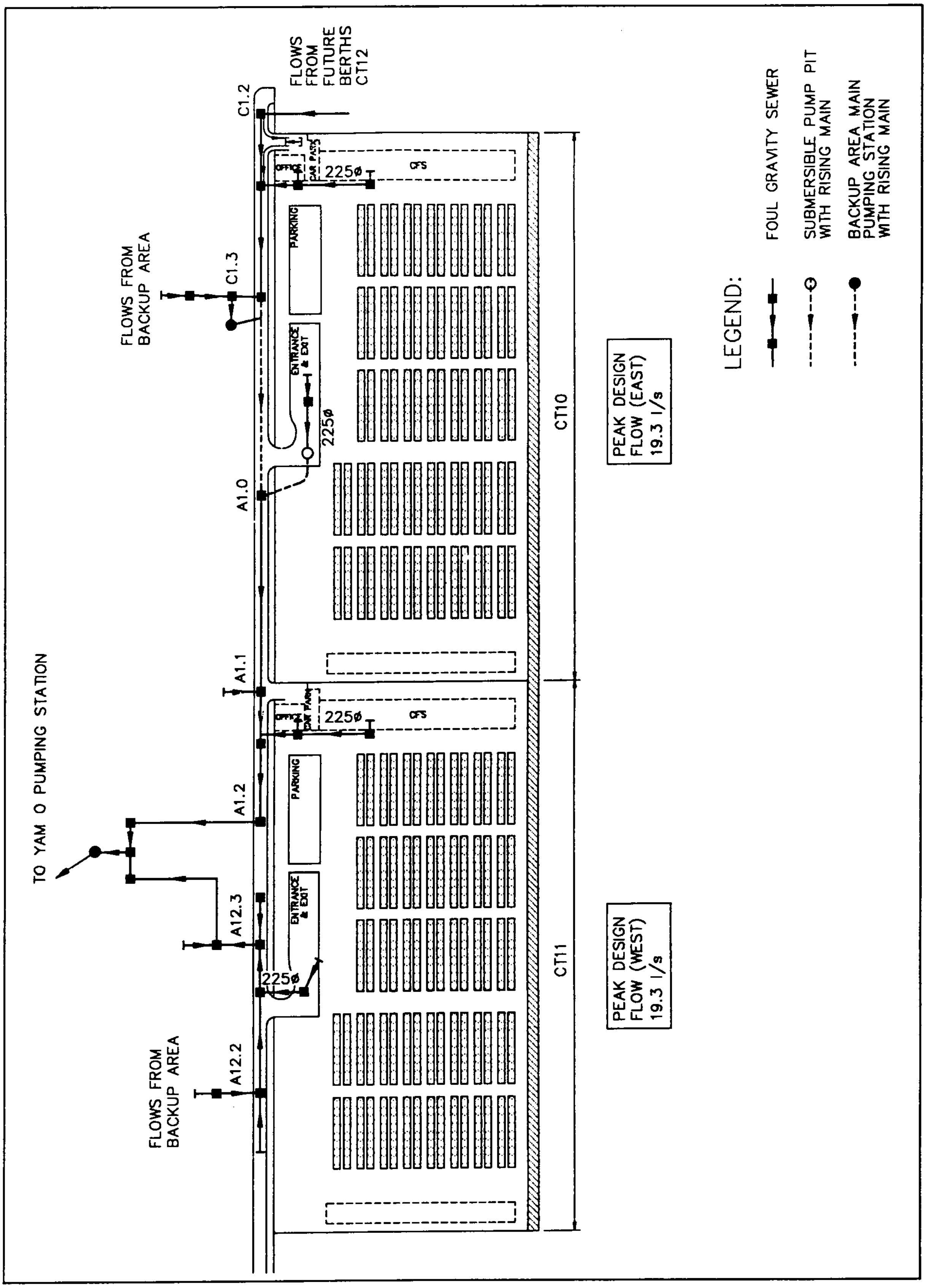

Figure 6.5 Sewerage

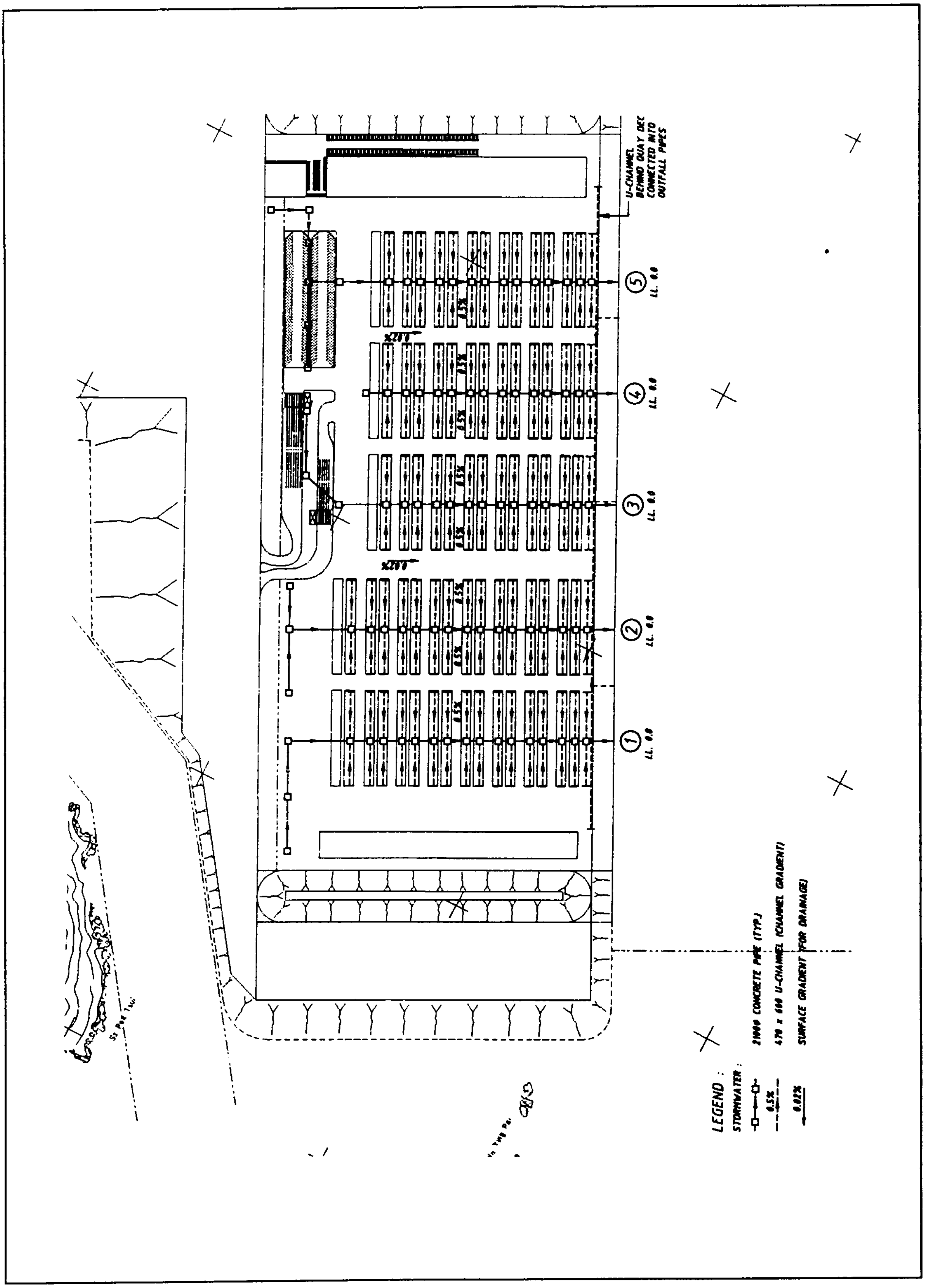

Figure 6.6 Stormwater