7. WATER QUALITY IMPACT ASSESSMENT

7.1 Introduction

7.1.1 This chapter is to undertake a detailed assessment of the potential water quality impact from the construction and operation of the proposed drainage tunnel scheme. Predicted impacts have been assessed. Where appropriate, mitigation measures will be proposed and potential residual water quality impacts will be identified.

7.2 Relevant Legislation and Guidelines

7.2.1 The following Legislation and Guidelines are applicable to the evaluation of water quality impacts associated with the construction and operation of the Designated Project.

- *Water Pollution Control Ordinance* (WPCO).
- *Environmental Impact Assessment Ordinance (Cap.499. S.16), Technical Memorandum of Environmental Impact Assessment (EIAO-TM), Annexes 6 and 14.*
- Practice Note for Professional Persons, Construction Site Drainage (ProPECC PN 1/94), it provides useful guidelines on the management of construction site drainage and prevention of water pollutant associated and prevention of water pollution associated with construction activities.

7.3 Inland Water Quality Objectives

7.3.1 With regard to inland waters, there is no distinction between the Water Quality Objectives (WQOs) of the different Water Control Zones (WCZs) and the beneficial use of the inland waters is the only factor governing the quality and quantity of the effluent that should be met. Under the WPCO, inland waters are sub-divided into four beneficial uses. They are Group A-abstraction for portable water supply, Group B – Irrigation, Group C - Pond fish culture and Group D - general amenity and secondary contact recreation.

7.3.2 EPD has established a set of WQOs for each of the ten Water Control Zones (WCZs) and three supplementary WCZs. Compliance with the WQOs is calculated based on five key parameters: pH, suspended solids, DO, BOD_5 and COD.

7.3.3 For the proposed drainage tunnel, construction stage activities may affect the inland water of Victoria Harbour (Phase 3) and Western Buffer Water Control Zones. The WQOs are presented in Tables 7.1

Table 7.1
Inland Water Quality Objectives – Victoria Harbour and Western Buffer Water Control Zones

	pH		BOD_5	COD	SS	DO	E. coli
	> and <		(mg/L) <	(mg/L) <	(mg/L) <	(mg/L) >	(cfu/100mL) <
Western Buffer	6.0	9.0	5	30	25	4	1000#
Victoria Harbour (Phase 3)	6.0	9.0	5	30	25	4	1000#

#: *E. coli* level is calculated as the geometric mean of the 5 most recent consecutive samples taken at intervals between 7 and 21 days.

7.4 Marine Water Quality Objectives

7.4.1 The *Water Pollution Control Ordinance* (WPCO) is the legislation for the control of water pollution and water quality in Hong Kong. Under the WPCO, Hong Kong water is divided into 10 WCZs. Each WCZ has a designed set of statutory WQOs. The WQOs set limits for different parameters that should be achieved in order to maintain the water quality within the WCZs. The discharged point of the proposed drainage tunnel at Pok Fu Lam will fall into Western Buffer WCZs. The WQOs of Victoria Harbour (phase 3), Southern and Western Buffer WCZs are applicable for the water quality impact study from the proposed drainage tunnel discharge. The related WQOs are presented in Table 7.2.

Table 7.2
Marine Water Quality Objectives
Victoria Harbour (phase 3), Southern and Western Buffer Water Control Zones

Parameters	**Water Quality Objectives**	
Suspended Solids	Waste discharge shall neither cause the natural ambient level to be raised by more than 30% nor give rise to accumulation of suspended solids which may adversely affect aquatic communities.	Marine water
Dissolved oxygen (averaged-depth)	Waste discharges shall not cause the level of dissolved oxygen to fall below 4 mg/L (depth averaged) for 90% of the sampling occasions during the whole year	Marine water
Dissolved oxygen (2m from seabed)	Waste discharges shall not cause the level of dissolved oxygen to fall below 2 mg/L (depth averaged) for 90% of the sampling occasions during the whole year	Marine water
Dissolved oxygen	Depth-averaged DO shall not be less than 5mg/L for 90% of the samples collected in the year. In addition, the dissolved oxygen concentration should not be less than 2mg/L within bottom 2m of seabed for 90% of the sampling occasions during the whole year.	Fish Culture Subzones
pH	The pH of water should be within the range of 6.5-8.5 units. Changes due to waste discharges should not exceed 0.2 pH unit.	Marine water
Unionized ammonia	The annual ammonia nitrogen level should not be more than 0.021 mg/L as unionised form.	Marine Water
Nutrients	Annual depth averaged total inorganic nitrogen not to exceed 0.1 mg/L (Southern WQO) and 0.4 mg/L (Western buffer and Victoria harbour phase 3 WQOs).	Marine water
E. coli	Annual geometric mean should not exceed 610 cfu/100mL (For Southern and Western WQO only)	Secondary contact recreation Subzones and fish culture Subzones
	Annual geometric mean should not exceed 180 cfu/100mL (For Southern and Western WQO only)	Bathing Beach Subzones
Salinity	Waste discharge shall not cause the natural ambient salinity level to change by more than 10%	Marine Water
Temperature	Waste discharges shall not cause the natural daily temperature range to change by more than 2°C	Marine Water
Toxicants	Not to be present at levels producing significant toxic effect	Marine Water
Aesthetic appearance	(a) Waste discharges shall cause no objectionable odours or discolouration of the water.	Whole zone

Parameters	Water Quality Objectives	
	(b) Tarry residues, floating wood, articles made of glass, plastic, rubber or of any other substance should be absent.	Whole zone
	(c) Mineral oil should not be visible on the surface. Surfactants should not give rise to a lasting foam.	Whole zone
	(d) There should be no recognisable sewage-derived debris.	Whole zone
	(e) Floating, submerged and semi-submerged objects of a size likely to interfere with the free movement of vessels, or cause damage to vessels, should be absent.	Whole zone
	(f) Waste discharges shall not cause the water to contain substances which settle to form objectionable deposits.	Whole zone

7.4.2 WSD has water quality standards at seawater intake points for domestic toilet flushing. WSD standards are shown as following Table 7.3.

Table 7.3
Water Quality Objectives of sea water at intake point of salt water pumping stations for flushing

Parameter	Standard
Suspended solids	<10 mg/L
Dissolved Oxygen	> 2 mg/L
Ammonical Nitrogen	< 1 mg/L
E. coli	<20,000 per 100 mL
BOD_5	<10 mg/L
Synthetic Detergents	<5 mg/L
Colour	<20 HU
Turbidity	<10 NTU
Threshold Odour No.	<100

7.4.3 There are no water quality objectives for the cooling water intakes specified by the Government. The Sensitive Receivers (SRs) within the study area do not have specifications for the quality of the cooling water, although the threshold criteria of suspended sediments (SS) specified by users of several cooling water intakes (for example, Queen Mary Hospital Intake and Wah Fu Estate Intake) is 140 mg/L. This level should only be treated as recommended threshold level and could vary according to the requirements of different cooling water users.

7.4.4 The WQOs for SS in marine water of Southern and Western Buffer WCZs stipulated under WPCO that human activity should neither cause the natural ambient level to be raised by more than 30% or give rise to accumulation of suspended solids which may adversely affect aquatic communities. Following recent research by City University of Hong Kong[1], the water quality objectives applicable to fish culture zones (FCZs) are that the SS level should not exceed 50 mg/l or a 100% elevation above the maximum value recorded over the past five years whichever is the lower. Because FCZs span a large section of the water column, the water quality (WQ) is assessed as an average over the full water column (referred to as "depth-average").

[1] City University of Hong Kong (2001), Agreement No.CE62/98, Consultancy Study on Fisheries and Marine Ecological Criteria for Impact Assessment - Final Report

7.4.5 Following the EIAs prepared for a 1,800 MW Gas-fired Power Station[2] and the Lamma Power Station Navigation Channel Improvement[3], the maximum SS level allowed for Kennedy Town WSD intakes, Cyberport and Ap Lei Chau WSD seawater intakes is 10 mg/L. For Queen Mary Hospital and Wah Fu Estate, the maximum SS levels allowed is 20 mg/L at flushing and cooling water intakes. These levels have been used for a number of other projects in and around Victoria Harbour and therefore they will be used to assess the WQ for the present EIA.

7.4.6 As the seawater intakes are normally located in the mid-depth or above, the assessment criteria for the seawater intakes has been based on the pollution levels at the surface layer.

7.4.7 The WQO in terms of other WQ parameters for the marine water SRs have been taken as the same as those for the respective WCZs. Following an EIA for Sand Dredging at the West Po Toi Marine Borrow Area[4], a limit on the sedimentation rate of 0.1 kg/m²/day was applied to this EIA in view of ecological interests found in and around area. As an objective the present EIA will assume the same rate for assessing the impacts of sedimentation at coral SRs which are located at the bottom of the water column. For the assessment of water quality impacts on ecological sensitive receivers (e.g. corals) sedimentation rate as well as suspended solid level and salinity should be evaluated.

7.5 Inland Water Quality Conditions

7.5.1 The potential SRs within the Study Area are mainly situated at the northwest urban area of Hong Kong Island comprising the fringes of the urban area and Country Parks. The project area is surrounded by a series of hills including Jardine's Lookout, Mount Nicholson, Mount Cameron, Wan Chai Gap, Mount Gough and Victoria Peak with peaks ranging from 300 m to 550 m. Most of the proposed intake locations are located on concrete and polluted nullah with a minor portion of them located near natural streams. The EPD published report "River Water Quality - 2003", the typical source of information on water quality in Hong Kong does not discuss the quality of Hong Kong Island's rivers and therefore baseline sampling results was carried out to represent wet and dry seasons of this year. Selective stream locations for monitoring streams during the dry and wet seasons are summarized in Appendix G. Detailed interpretation will be further discussed later in Section 7.17.

7.6 Marine Water Quality Conditions

7.6.1 The proposed Hong Kong West Drainage Tunnel uses intakes and drop shafts to collect and divert upland runoff to an east-west running stormwater tunnel. The diverted runoff will be conveyed via the tunnel and discharged to the sea at the Western Portal located at Kong Sin Wan, Hong Kong Island.

7.6.2 The operation phase of the proposed drainage tunnel outfall has potential impact on the Western Buffer, Southern and Victoria Harbour WCZs. There are five routine EPD marine water quality monitoring locations located in the vicinity of the Project area. For general information only a summary of water quality data for each of the stations is

[2] ERM(1999). 1,800 MW Gas-fired Power Station at Lamma Extension – Final EIA Report

[3] Hyder (2003) Lamma Power Station Navigation Channel Improvement

[4] ERM (2001). Focused Cumulative Water Quality Impact Assessment of Sand Dredging at the West Po Toi Marine Borrow Area

presented in Table 7.4. These data were measured in 2002 (the most recently published data). Note that these values are not used to estimate the cumulative impact of the tunnel project shown in Tables 7.8 to 7.9 (refer to Paragraph 7.14.15 for discussion on background concentrations for assessment purposes).

7.6.3 The Western Buffer has strong tidal flushing capacity and is heavily utilized for the disposal of treated sewage effluent (Stonecutters Island outlfall). Since the commissioning of Harbour Area Treatment Scheme (HATS) Stage I in 2002, the water near the Stonecutters Island Sewage Treatment Works (SCISTW) Outfall has experienced a mark increase of faecal bacteria. The *E. coli* level at WM2 (west of the Hong Kong Island) increased moderately by 40% (200 cfu/100mL) in 2003. WM1 is located at the northern end of the East Lamma Channel where a cluster of five sewage outfalls (Sandy Bay, Cyberport, Wah Fu, Aberdeen and Ap Lei Chau Sewage Treatment Works) are located.

7.6.4 The Western Buffer WCZ experienced a slight but general increase of dissolved oxygen (DO) by 6-11% in 2003. which may due to natural fluctuation in the seawater. The suspended solids and turbidity in the WCZ showed a reduction of 25-70% which could be related to the decrease of marine works around South Tsing Yi Island and sand dredging activity was ceased in 2003. Moreover, the amount of materials dumped at the two marine disposal sites in South Tsing Yi has also been reduced significantly.

7.6.5 The water quality in the Southern WCZ is affected by local pollutant sources such as submarine outfalls from sewage treatment works in the near-field and the Pearl River flow in the far-field. It is largely an open water affected by Pearl River flow, local discharges and marine works in the southern part of Hong Kong Island. Similar to the Western Buffer WCZ, the DO concentration decreased in 2003. A widespread increase in Salinity (by 1.0-5.6%) was also observed in 2003.

7.6.6 There was a widespread decrease of nitrogen in 2003. The mean levels of ammonia nitrogen, total inorganic nitrogen (TIN) and total nitrogen in the WCZ were lowered by 0.009 mg/L (18%), 0.068 mg/L (33%) and 0.075 mg/L (22%) respectively. Similar to 2002, full compliance (100%) with the WQO for DO and unionised ammonia was achieved at all southern WCZ monitoring locations in 2003.

7.6.7 The implementation of HATS Stage I in 2002 has resulted in a very substantial water quality improvement at the Eastern end of the harbour while the overall water quality in the Western harbour has been maintained, except in the localized area near Green Island (VM8). All monitoring stations in the Victoria Harbour WCZ fully complied (100%) with the WQOs for DO and unionized ammonia in 2003. The compliance for the TIN WQO was 80%.

Table 7.4

Summary of Water Quality Statistics of the Victoria Harbour, Western Buffer and Southern WCZs in (2002 & 2003)

	WM1		WM2		SM3		SM4		VM8	
	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Temperature (^oC)	22.9 (16.6-27.3)	23.3 (17.3-26.9)	23.2 (16.5-27.5)	23.6 (17.5-28.0)	23.5 (16.4-27.1)	23.4 (16.9-27.9)	23.8 (16.4-27.6)	23.5 (17.0-27.9)	23.1 (16.5-27.6)	23.5 (17.2-27.8)
Salinity (mg/L)	32.6 (30.6-33.7)	32.6 (29.2-33.8)	31.7 (28.4-33.4)	31.1 (23.7-33.5)	32.1 (28.9-33.9)	32.9 (31.5-33.9)	31.4 (26.5-34.0)	32.6 (30.5-33.8)	31.8 (28.4-33.5)	31.1 (24.0-33.4)
Dissolved Oxygen (mg/L)	6.1 (4.5-7.8)	5.6 (3.7-7.5)	6.2 (4.2-7.7)	5.5 (4.2-7.1)	6.1 (4.0-8.2)	5.8 (4.5-7.7)	6.7 (5.8-7.9)	5.8 (4.3-7.5)	5.9 (4.7-7.2)	5.6 (2.1-7.0)
pH	8.0 (7.8-8.3)	8.1 (7.9-8.3)	8.0 (7.8-8.2)	8.1 (7.9-8.3)	8.0 (7.8-8.3)	8.2 (8.0-8.3)	8.1 (7.8-8.3)	5.7 (3.7-7.4)	8.0 (7.8-8.2)	8.1 (8.0-8.2)
Turbidity (NTU)	11.0 (6.9-15.5)	10 (7.3-14.8)	12.8 (7.9-21.8)	9.7 (5.7-14.7)	10.2 (7.6-16.8)	9.6 (5.6-18.9)	9.5 (6.0-14.3)	8.2 (5.3-12.0)	12.7 (7.9-20.5)	9.9 (5.0-14.9)
Suspended Solids (mg/L)	6.5 (1.8-12.6)	6.7 (2.3-9.9)	8.5 (3.7-20.3)	6.5 (2.2-12.8)	5.3 (1.4-9.1)	6.0 (1.3-18.8)	4.4 (1.4-7.6)	4.5 (1.0-7.6)	9.1 (4.9-16.3)	7.9 (3.1-14.6)
BOD_5 (mg/L)	0.8 (0.3-1.3)	0.8 (0.4-1.2)	0.9 (0.3-2.1)	0.9 (0.4-1.5)	0.7 (0.3-1.4)	0.9 (0.4-2.2)	0.9 (0.2-1.7)	0.9 (0.4-1.8)	1.0 (0.4-2.2)	1.0 (0.4-1.9)
Unionised Ammonia (mg/L)	0.002 (0.001-0.006)	0.002 (<0.001-0.003)	0.003 (0.002-0.007)	0.004 (0.002-0.009)	0.002 (<0.001-0.004)	0.002 (<0.001-0.004)	0.003 (<0.001-0.006)	0.002 (0.001-0.006)	0.0006 (0.002-0.012)	0.007 (0.002-0.016)

	WM1		WM2		SM3		SM4		VM8	
	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Total inorganic nitrogen (mg/L)	0.14 (0.04-0.31)	0.14 (0.03-0.39)	0.24 (0.12-0.46)	0.29 (0.10-0.77)	0.15 (0.04-0.52)	0.09 (0.02-0.24)	0.19 (0.04-0.59)	0.11 (0.03-0.31)	0.29 (0.15-0.54)	0.34 (0.21-0.75)
Total Phosphorus (mg/L)	0.04 (0.02-0.14)	0.03 (0.02-0.03)	0.03 (0.02-0.05)	0.04 (0.02-0.05)	0.02 (0.02-0.04)	0.02 (0.02-0.03)	0.02 (0.02-0.03)	0.02 (0.02-0.03)	0.04 (0.03-0.08)	0.04 (0.03-0.07)
Chlorophyll a (mg/m^3)	3.5 (0.9-11.6)	2.8 (0.7-10.7)	4.6 (0.7-20.0)	3.4 (0.7-12.5)	83 (14-560)	2.0 (0.8-7.3)	63 (2-420)	2.6 (1.0-12.7)	4.0 (0.6-12.3)	3.4 (0.5-16.7)
E-coli (cfu/100ml)	89 (7-980)	84 (36-440)	690 (50-8900)	970 (110-9000)	46 (7-230)	15 (1-110)	33 (1-260)	21 (1-58)	4600 (670-31000)	3700 (390-22000)

Remarks:

(i) Data presented are annual arithmetic means of the depth-averaged results except for *E. coli* and faecal coliforms which are annual geometric means.

(ii) date in brackets indicate the ranges

(iii) Unless stated, data presented are depth-averaged values calculated by taking the means of the three depths: Surface, Mid-depth and Bottom.

7.7 Identification of Sensitive Receivers

7.7.1 As part of the ecological survey data (reported in Section 4) most of the proposed intake locations are located on concrete and polluted nullahs. A minor portion of them will be located near natural streams. They are THR(2), BR7(P), MA13(P) and MA14(P), TP789 (P), TP(5) and PFLR1(P). These locations will be identified as potential inland water SRs.

7.7.2 At all intake locations, base flow upstream of the diversion intakes will bypass the intakes and continue discharging into the downstream watercourses. When the capacities of the bypasses are exceeded during rainfall events, the excess runoff will enter the diversion intakes. The catchment areas are shown in Figure 7.1.

7.7.3 The operation of the tunnel system during rainfall events will have the potential to directly affect water quality in the waters along the western side of Hong Kong Island. SRs have been identified in these potentially affected areas which are seawater intakes, fish culture zones and sites of ecological interests. The relevant water SRs are shown in Figure 7.2. The identified SRs in each of these categories are as follows:

- **Water Intakes**:
  WSD Kennedy Town seawater intake, Queen Mary Hospital seawater intake, seawater intake at Wah Fu Estate, WSD water intakes at Cyperport.

- **Fish Culture Zones**:
  Lo Tik Wan and Sok Kwu Wan

- **Sites of Ecological Interests** (Corals):
  Pak Kok, Green Island, Luk Chau Wan and Sok Kwu Wan

7.7.4 As the results of the water quality modelling carried out for the present EIA clearly demonstrate, the discharge plume from the Western Portal does not affect any other marine SRs beyond those listed above and therefore only SRs listed above are considered by the present EIA.

7.7.5 In addition to the identified SRs, there is a number of open water monitoring stations including VM8, WM1, WM2, SM3 and SM4 which have been considered in this study to assess water quality in the marine waters potentially affected by the proposed Project operation activities.

7.8 Assessment Methodology

7.8.1 To assess the potential impacts on water quality and the associated risks to the marine environment, a comprehensive desktop study covering the following aspects has been carried out:

- Identify water SRs and users which may be impacted by the proposed work and the assessment criteria to be complied with.

- Identify potential sources of water quality impacts that may be generated during the construction and operation phases.

- Identify the baseline water quality at SR locations when the tunnel system becomes operation in 2012.

- Assess potential impacts upon the identified water SRs during the construction and operation phases.
- Provide actions/remedial measures that need to be implemented to reduce impacts to acceptable levels and best site management practices.
- Evaluate residual impacts and identify the requirement for the preparation of an Environmental Monitoring and Audit manual.

7.9 Potential Impacts during Construction

Source of Impacts

7.9.1 Siltation generated by different construction works can have a major impact on water quality. Construction of works for the proposed drainage tunnel will be finished approximate 4 years. The construction activities at tunnel portals and intake shafts will include site preparation and clearance, excavation, intake structure and tunnel portal structure construction, utilization of ancillary equipment at tunnel portals to support tunnel construction, material handling and rock drilling at portals and intakes, and drill and blasting at underground adits if unavoidable. For the Western Portal at Kong Sin Wan, a temporary berthing point will be constructed for transportation of excavated spoil during TBM tunnel construction and delivery of TBM-related materials and equipment by marine access. Also the construction of the stilling basin as a permanent structure at Western Portal may pose a source of impact.

Construction of Temporary Berthing Point at Western Outfall

7.9.2 In order to reduce the inland traffic, a temporary pier with dimensions of 11m wide, 40m long and about 15m deep will be constructed as an alternative marine access for barges. The pier will be built on rock boulders at Kong Sin Wan with a layer of paving on the top of the pier (Figure 7.3 shows the layout plan of the temporary pier). Construction of the temporary pier involves the placement of approximately 4,500 m^3 of imported rock fill material. Excavated spoil from the proposed drainage tunnel will be transported by conveyor belt systems to the barge for proper disposal (public fill areas or other projects if required). The conveyor belts shall be properly enclosed to prevent dispersion and dropping of material during the transportation process. The temporary pier will be constructed before work for the Western Portal begins. The method of construction is given in Attachment I to the Appendix H. Potential impacts may include disturbance of the sandy bottom and re-suspension of sediment during construction.

Construction of Stilling Basin at Western Portal Outfall

7.9.3 The proposed Western Portal and associated features are located on the west coast of Hong Kong Island, beneath an existing multiple-span bridge which is part of the Northern Access Road. Immediately downstream of the Western Portal is the stilling basin (Figure 7.4).

7.9.4 There will be a discharge from the Western Portal during various storm events. Before discharging the diverted rainstorm water from intakes to the sea, the stilling basin will effectively reduce the flow's energy to avoid unnaturally high currents along the immediate coastline that may cause erosion and impact on sea life.

7.9.5 Blasting in combination with tunnel boring methods will be adopted for construction of the tunnel exit at Kong Sin Wan. The stilling basin will then be constructed after completion of the tunnel. The stilling basin will be constructed by open excavation

method. A temporary cofferdam in the form of sheet piles around the basin will first be constructed prior to bulk excavation for the basin. All construction for the basin will be carried out inside the temporary cofferdam.

7.9.6 The proposed invert level of the stilling basin is -5.4 mPD and therefore a watertight cofferdam in the form of sheet-pile wall outside the stilling basin will be constructed prior the construction of basin. The cofferdam will be dewatered to provide a working space for the construction of stilling basin. The boulders from the seawall will then be removed by landbased grabs. Upon completion of the construction of the Western Portal the cofferdam will be removed from site and the seawall will be reinstated.

7.9.7 Following the construction of stilling basin the temporary pier will be demolished and an armour rock panel (about 25m x 25m) outside the outlet of the stilling basin will be placed directly on the existing seabed without the need to carry out any dredging works. This panel is to enhance the protection of the seabed from scouring. The armour layer will consist of graded sizes of individually placed rock resting on muddy/sandy bottom. A dive survey showed that the present seabed is covered with rock or muddy/sandy bottom with imported boulders.

7.9.8 Details of the construction method for the stilling basin and temporary berthing point are shown in Appendix H (Attachment I).

Construction of Intakes

7.9.9 The main construction activities which have the potential to impact on the water bodies along the proposed drainage tunnel are those which may result in generation of silt. This is likely at all intakes owing to the construction of the intakes within rock however there is slightly more potential for silt to be generated at sites that are very shallow (<5m) because ground excavation techniques will be used to construct the drop shafts. The size of the intake structure is relatively small and all excavated spoil will be disposed by trucks including spoil from the shallow drop shafts. The remaining drop shafts will be constructed using a raised boring machine and all spoil will drop into the adit below and will be transported to the tunnel's portals for removal by barge or truck. The impacts at the intakes will be more likely limited to the dust generated during the excavation and the backfilling activities.

7.9.10 Most of the excavated spoil will be disposed at either portal. The estimated total quantity of excavated spoil from the proposed drainage tunnel will be about 524,000m³. It will then be removed through road access at Eastern Portal and by marine access at the Western Portal. Excavated spoil will be disposed of as separate waste materials to public fill and/or landfill properly, as described in the Waste Chapter.

7.9.11 Excavated spoil will be transported within the tunnel by using a conveyor system that terminates at either portal where the spoil will be immediately transported away or unloaded to a temporary stockpile area. The conveyor will be covered on 3 sides and the discharge point to the stockpile area will be fully enclosed. For the construction of intakes, many drop shafts will be excavated using the raised boring method, thus, most of the excavated spoil will not be stored or exposed to the surface of the construction sites.

7.9.12 Suspended solids run-off (turbidity) and nutrient loading may increase and enter adjacent watercourse due to the increase of site exposure, reducing light penetration and affecting aquatic organism in the waterbody and downstream. With the proper handling and disposal procedures, impacts from this source are likely to be minimal.

General Construction Activities and Workforce

7.9.13 Water quality may be affected during construction period as follows:

- Wash water from dust suppression activities and wheel washing facilities.
- Domestic sewage and waste generated by work force.
- Construction waste being washed off-site by surface runoff.
- Run-off and erosion from site surfaces, earth working areas, material stockpiles and drainage channels.
- Accidental chemical/fuel/oil spillages from vehicle and plant usage and maintenance.

7.10 Evaluation of Potential Impacts during Construction phase

Construction of Temporary Berthing Point at Western Outfall

7.10.1 The construction/demolition period for the temporary berthing point is short (less than 2 months) and no reclamation is required. However, the construction of a temporary pier may lead to the suspension of fine material which, if uncontrolled, can lead to a rise in the suspended solid level around the area. Removal activities can also disturb the bottom sediments. The water quality impact will likely be localised and temporary and no long term deterioration is expected.

Construction of Stilling Basin at Western Portal Outfall

7.10.2 A watertight cofferdam, in the form of a sheet-pile wall around the outside of the stilling basin, will be constructed prior to the construction of the stilling basin. So seawater is unlikely to be impacted by the stilling basin construction. After the cofferdam construction is completed and before the construction of stilling basin, dewatering the silty water within the cofferdam area is required. Water should be pumped to a sedimentation tank or settling devices before discharging to the sea in order to reduce the water quality impacts to seawater. The contractor should ensure discharge water from the sedimentation tank meet the WPCO/TM requirements before discharging to the sea.

Construction of Tunnel and Intakes

7.10.3 Ground excavation will be carried out at few shallow intakes with most drop shafts being excavated using the raise boring method. This means that most major works will be carried out at both portals. Potential impacts on water quality will depend on the nature of the material excavated and the runoff that can enter these watercourses. Other pollutants, such as oil and grease and chemicals, may also be present in the run-off where it flows over storage or maintenance areas. With proper implementation of mitigation measures and good site practices, no significant impact to the water quality is expected.

7.10.4 Volcanic rock will be encountered in most sections of the proposed drainage tunnel which may require more frequent maintenance of the TBM cutter head. Recycle water is also required for the cooling of the cutter head during boring. All discharge will be conveyed to sedimentation tanks for treatment prior to proper disposal. With implementation of mitigation measures, no significant impact to nearby water SR is expected. Sections of tunnel alignment will be underneath Country Parks. Prior to tunnel excavation, ground treatment works will be carried out. Therefore it will not cause unacceptable variation in underground watertable during tunnel construction.

7.10.5 As far as practicable, the construction of the intakes and drop shafts is planned to take place during the dry season when ground water levels are typically low. Also, volcanic rock will be encountered at most intake and drop shaft sites, which generally mean that the presence of groundwater should be minimal. Therefore, impact on the local groundwater is not expected during the construction phase. All intakes and drop shafts are located outside the Country Parks. Therefore variation of underground watertable during intakes and drop shaft construction is not expected.

General Construction Activities and Workforce

7.10.6 Unmitigated surface runoff can lead to incidents of increased levels of SS, oil and grease content, turbidity, BOD_5 and nutrient enrichment at nearby watercourses. This may result in a reduction of light penetration and dissolved oxygen which may reduce the assimilative capacity of the receiving waters for various organic and inorganic pollutants.

7.10.7 Potential floating refuse problems entering the water column, which may be aroused by site-generated debris and rubbish, would reduce the aesthetic quality of the receiving water body. However, with proper site waste management it can be well controlled and properly disposed. Also, with the appropriate storage and handling of chemicals/lubricants/oil and grease, the risk of accidental chemical losses to environment is expected to be low.

7.11 Mitigation Measures

Precaution Measures for Construction Work Near Natural Streams

7.11.1 For the proposed drainage tunnel, most of the intakes are located in urban areas. Moreover, the small affected stream portion is located at the very downstream end of the natural stream (immediately near to residential/urban area). The government provides guidelines (ETWB TCW NO. 5/2005 and DSD TC 2/2004) to minimize impacts when there is construction work carried out at near natural streams course. Relevant mitigation measures for the intakes are summarised as follows:

- Temporary site access to the work sites should be carefully planned and located to minimize disturbance caused to the substrates of streams/rivers and riparian vegetation by construction plant.
- Locations well away from the rivers/streams for temporary storage of materials (e.g equipment, filling materials, chemicals and fuel) and temporary stockpile of construction debris and spoil should be identified before commencement of works.
- Proposed works areas inside, or in the proximity of, natural rivers and streams should be temporarily isolated to prevent adverse impacts on the stream water quality.
- Stockpiling of construction materials, if necessary, should be completely covered and located away from any natural stream/river.
- Construction debris and spoil should be covered up and/or disposed of as soon as possible to avoid being washed into nearby rivers/streams by rain and local runoff

7.11.2 For construction works to be carried out in the vicinity to natural stream course, any effluent generated including surface runoff shall be properly treated to WPCO-TM requirements and the effluent should be diverted away from the natural stream.

Construction of Temporary Berthing Point at the Western Portal

7.11.3 Throughout the construction works at the Western Portal (including stilling basin and temporary berthing point), the contractor shall implement mitigation measures and ensure that the impact on the water quality is within acceptable standard.

7.11.4 Prior to the construction of the temporary berthing point, a silt curtain shall be constructed to minimize sediment migration. The respective areas of the marine works will be completely enclosed by the silt curtain. The curtain shall be extended from water surface down to the seabed where it is anchored using sinker blocks. The Contractor shall inspect the silt curtain on regular basis to ensure its integrity and it is serviceable for all times. It is expected that there is no noticeable impact on water quality during construction.

7.11.5 Transfer of armour rock onto the seabed from barge at the temporary pier location should be conducted by careful grabbing and unloading to the seabed (to minimize sediment migration), thereby minimize impacts on water quality in the receiving waterbody and disturbance to the seabed.

7.11.6 During the construction of the proposed drainage tunnel, excavated spoil will be transported at the Western Portal to the temporary berthing point for disposal. The conveyor belt should be completely covered and muddy effluent from the temporary barge should be contained, treated and disposed of for compliance with WPCO requirements. Where there is transfer of excavated wastes, the Contractor should provide appropriate measures to ensure that the waste is free from floatables, putrescibes, organic wastes and toxic materials and when required a refuse collection vessel be provided to collect float refuse. With these measures and with the correct installation of the silt curtain, water quality impacts during construction phase should not be anticipated.

Construction of Stilling Basin at Western Portal Outlet

7.11.7 All construction for the basin should be carried out inside the temporary cofferdam which is a temporary watertight enclosure built in the water and pumped dry to expose the bottom so that construction of stilling basin can be undertaken. A cofferdam is composed of steel pilings driven into the seabed level to form a watertight structure around the stilling basin area. The cofferdam not only prevents water from entering the work area, but it prevents excavated and drilled material escaping to the open seawater. After excavating within the cofferdams, the seal courses would be placed to allow de-watering of the work area within the cofferdams. After the seal courses and cofferdams are in place, the water would be pumped from the cofferdams.

7.11.8 During the dewatering process, appropriate desilting/sedimentation devices should be provided on site for treatment before discharge. The Contractor should ensure discharge water from the sedimentation tank meet the WPCO/TM requirements before discharge.

7.11.9 The use of the cofferdam is essential to avoid impacts to the marine SRs. The cofferdam should be constructed to minimize contact of the works area with the surrounding water body. The cofferdam will remain on site until after the construction of stilling basin has been completed. The coffer dam shall be regularly inspected and maintained to ensure no spillage of waste or wastewater into the sea. Conveyance of dredged materials from the coffer dam shall be carried out cautiously to avoid spillage into the sea.

7.11.10 The filled material for the stilling basin should be contained inside the temporary cofferdam. The top level of the cofferdam shall be constructed higher than the final backfilled level. With this measure, potential spillage of fill material will be avoided.

7.11.11 In order to minimize any adverse impacts during construction of the cofferdam to identified SRs, where appropriate, silt curtains should be utilized to minimize sediment migration. The Contractor shall be responsible for the design, installation and maintenance of the silt curtains to minimize the impacts on the water quality and the protection of water quality. The design and specification of the silt curtains shall be submitted by the Contractor to the Engineer for approval.

7.11.12 Indicative locations and details of cofferdam and silt curtains are shown in Figures 7.4 and 7.5a. A typical suspended solids reduction of 75% can be achieved with the incorporation of silt curtain. Two-layer silt curtains have generally been used for dredging projects of larger scale to further ensure this reduction. However, as the scale of proposed project is relatively small, it is recommended to use only a single layer silt curtain.

7.11.13 Silt curtains shall be formed from tough, abrasion resistant, permeable membranes, suitable for the purpose, supported on floating booms in such a way as to ensure that the sediment plume shall be restricted to within the limit of the works area. The silt curtain shall be formed and installed in such a way that tidal rise and fall are accommodated, with the silt curtains always extending from the surface to the bottom of the water column and held with anchor blocks. The contractor shall regularly inspect the silt curtains and check that they are moored and marked to avoid danger to marine traffic. Any damage to the silt curtain shall be repaired by the Contractor promptly and the works shall be stopped until the repair is fixed to the satisfaction of the Engineer.

7.11.14 Although impacts from the construction of the armour rock based panel are likely to be minimal, care should be taken to avoid suspended solids re-suspension from the seabed during the construction process. Transfer of rock fill material (armour rock) from the barge onto the site location should be conducted by grabbing and placement on the seabed to minimize sediment migration. No free dropping of the material will be allowed.

7.11.15 Prior to the construction of armor rock based panel, a silt curtain shall also be installed prior to carry out any marine works as a preventive mitigation measure. It is expected that there is no noticeable impact on water quality during construction. The respective areas of the marine works will be completely enclosed by the silt curtain.

Construction of Tunnel at Both Portals and Intakes

7.11.16 The bored tunnel operation has been designed to minimize impacts on water quality. Recycled water will be used at the cutter face for cooling purposes. Used water will be collected and discharged to a settling tank for settlement. Excess water from the settling tank will be transferred to the water treatment plant on site where the addition of flocculants will assist in settlement of solids. The Contractor should ensure discharge water from the sedimentation tank meet the WPCO/TM requirements before discharge.

7.11.17 The intake shaft shall be constructed by raise boring machines. A typical intake layout structure is shown in Figure 7.5b. No works will commence until the completion of the tunnel construction. The main operation procedures for raise boring are:

- Set up the raise boring machine at ground level
- Sink down a pilot drill hole down and break through the soffit of tunnel/adit

- Dismantle the pilot bit and a reamer head is connected to the drill rod inside the tunnel/adit
- Up-reaming commences from the bottom and travel up-wards to the ground level
- During the up-reaming process, the excavated material is dropped to the tunnel/adit invert. The excavated material is transported by conveyor belt system inside the tunnel to the portals for proper disposal
- The up-reaming process ends when the whole intake drop shaft is formed

7.11.18 No storing of earth material on ground level is required by the raise boring method. During the drilling process, all flushing water will be recycled for use. Discharge of the treated water to nearby drainage system shall be allowed provided that it has been treated to a level meeting with statutory requirements.

7.11.19 Water flow at streams should be maintained by a temporary diversion system during the construction phase of intakes and drop shafts. With the addition of appropriate site runoff control practices this should prevent construction effluent from entering the downstream watercourses.

7.11.20 Spent effluent arising from tunnel boring shall be treated with adequately designed and maintained sedimentation tank to WPCO-TM standards. Works carried out in the vicinity to natural stream courses shall be carried out cautiously to avoid disturbance to the natural habitats and the flora and fauna therein. All tunnel boring effluent shall be diverted away from the stream course.

General Construction Activities and Workforce

A. Surface Runoff

7.11.21 Effluent produced from construction activities are subjected to WPCO control. Effluent produced from sites would be treated before discharging to the nearby sewerage system. Where practicable, construction works near stream course should be scheduled in the dry season to avoid excessive site runoff discharge.

7.11.22 Potential run-off from construction activities (e.g. site formation and excavation mainly) must be minimized to avoid impacts on adjacent watercourses. Under the WPCO, turbid water from construction sites must be treated to minimize the solids content before being discharged into storm drains. The suspended solids load can be reduced by directing the runoff into temporary sand traps or other silt-removal facilities, and other good and appropriate site management practices. Where surface runoff or construction effluent is likely to be contaminated with oil, properly designed and maintained petrol interceptor shall be provided to meet WPCO-TM requirement. Advice on the handling and disposal of construction site discharge is provided in the ProPECC Paper (PN 1/94) on *Construction Site Drainage*.

7.11.23 A drainage system layout should be prepared by the Contractor for each of the works areas (portals and intakes), detailing the facilities and measures to manage pollution arising from surface runoff from those works areas. The drainage layout and an associated drainage management plan to reduce surface runoff sediments and pollutants entering watercourses, should be submitted to the Engineer for approval.

7.11.24 The system should be capable of handling stormwater from the site and directing it to sediment removal facilities before discharge. If oil and grease is used on the site or brought to the site, the stormwater should pass through oil interceptors before discharge. The interceptors should have a bypass to prevent washout in heavy storms.

7.11.25 A temporary channel system or earth bunds or sand barriers should be provided in works areas on site to direct stormwater to silt-removal facilities. Stockpiled materials, if susceptible to erosion of rain or wind, should be covered with tarpaulins (or similar fabric) or hydroseedings as far as practical especially during the wet season.

7.11.26 Silt removal facilities should be checked and the deposited silt and grit should be removed regularly to ensure these facilities are in good working condition and to prevent blockages.

7.11.27 Vehicle washing areas should be drained into a settlement basin to settle out the suspended solid before discharging to storm water drains. The water should be recycled on site whenever possible. It is suggested that the wash water from the wheel wash basin is either reused for road watering or pumped to the on-site settling tanks for treatment. Water used for dust depression purposes should be minimized as far as practicable; and an alternative soil holding agent should be considered.

B. Spillage, Oil and Solvents

7.11.28 Any contractor generating waste oil or other chemicals as a result of his activities should register as a chemical waste producer and provide a safe storage area for chemicals on site. Oil interceptors need to be regularly inspected and cleaned to avoid wash-out of oil during storm conditions. A bypass should be provided to avoid overload of the interceptor's capacity.

7.11.29 Any spillage of oils and chemicals shall be properly handled in accordance with the requirement stipulated under the Waste Disposal (Chemical Waste) (General) Regulation. Spills should be contained to avoid spreading and contaminating the water resources.

7.11.30 Oil and fuels should be used and stored properly in designated area. All fuel tanks and storage areas should be provided with locks and be sited within sealed areas surrounded by bunds with a capacity equal to 110% of the storage capacity of the largest tank.

7.11.31 Good housekeeping practices are required to minimize careless spillage and keep the work space in a tidy and clean condition. Appropriate training, including safety codes and relevant manuals, should be given to the personnel who regularly handle the chemicals on site.

C. On-Site Effluent Generation

7.11.32 Sewage arising from the additional population of workers on site should be collected in a suitable storage facility (chemical mobile toilets). Most of the work site locations are close to the public sewerage system and therefore the use of septic tanks are not encouraged. Portable toilets should be used coupled with tankering away services provided by a licensed collector. They should be positioned at appropriate locations across the site to ensure no direct discharge of foul water off-site.

D. Protection of Existing Flora and Fauna

7.11.33 The Contractor should provide details of the plant and operation organisation each site's for approval by the Engineer before commencing construction. The plans should include how the existing flora and fauna will be protected. As part of the groundwater monitoring programme groundwater levels at intake sites on key natural watercourses shall be monitored both during the construction period and for the first year that the

tunnel scheme is operation, to ensure that the groundwater regime, and its interaction with existing flora and fauna, is not adversely affected.

7.12 Residual Impacts

7.12.1 With the appropriate adoption of proper mitigation measures during the construction for stilling basin, temporary pier, tunnel and intakes, any potential impacts should be minimized. Therefore, no significant impacts on the water quality are expected.

7.12.2 The construction and demolition of the temporary pier may create short term impacts on the local marine water quality. However, the situation will be restored once the work is finished. By proper phasing of the works programme and implementation of the adequate mitigation measures (e.g. silt curtain) the impacts will be minimized.

7.12.3 The water discharge from site is subject to the control of the WPCO. The Contractor must obtain a discharge license prior to the commencement of the construction who is obliged to comply with the standards set out in the license which specifies the maximum allowable limits for the parameters of concern in the discharge. The Contractor also has the responsibility to design, operate and monitor the performance of any on-site treatment systems.

7.12.4 If the identified mitigation measures are properly applied it is anticipated that impacts will be minor, temporary and localised. Moreover, no significant impacts upon the existing seawater intakes, drain outfalls or either marine or fresh water ecology are predicted.

7.13 Potential Impacts during Operation Phase

7.13.1 The proposed intakes to the tunnel scheme include provision for the bypass of baseflows to the existing downstream drainage system. This means that the tunnel is only operation during storm events when runoff will be diverted into the tunnel system and consequentially discharge to the Western Portal during storm events (preliminary design of the proposed intake structure is presented in Appendix G).

7.13.2 The operation of the proposed drainage tunnel will result in pollutant laden stormwater discharging to the marine water at the Western Portal outfall. It should be noted that the overall water and pollutant fluxes to the Hong Kong marine waters will not be changed, but they will be released in one point (proposed Western Portal at Kong Sin Wan), rather than in a diffuse way (across the lower catchment of northern Hong Kong Island). The concentrations of pollutants that are likely to discharge to the Western Portal are discussed further in Appendix G where there are details on the estimation of the pollutant and sediment loads.

7.13.3 Based on the result of the estimated pollutant and sediment loads to the marine water at the Western Portal, only fresh water salinity, *E. coli* and suspended solids will be investigated using a Water Quality Model. Comparisons between the estimated pollutant loads against Water Quality Objectives will also be discussed in following section for pollutant parameters which are not quantitatively assessed by modelling,

7.13.4 The flow diverted into the tunnel system may also convey floating objects such as vegetation (including leaves), plastic bags and other forms of litter, although for plastic bags and litter there is unlikely to be large amount because the catchments are mostly natural or country parks. Care has been taken to minimise the amount of vegetation entering the tunnel system which may affect the aesthetic appearance WQO mentioned in Table 7.2. Note that vegetation will not cause objectionable odours or discolouration

of the water. Furthermore there should be no oil, surfactants, sewerage-derived debris, floating objects that are likely to interfere with the movement of vessels, or substances that settle to form objectionable deposits in the flow discharging from the Western Portal. Notwithstanding the aforementioned, some vegetation may discharge from the Western Portal which may create an adverse aesthetic impact.

7.13.5 During operation of the tunnel system the intakes will divert runoff from the upstream catchments that currently discharge into the existing downstream watercourses and drainage systems. To avoid these watercourses from drying and causing ecological and odour problems, the proposed intakes include a provision for the bypass of baseflow. This means that the intakes will only divert flow to the Western Portal during rainfall events.

7.14 Evaluation of Potential Impacts during Operation Phase

7.14.1 The mathematical modelling activities are intended to support the analysis of the effects on the marine water quality of storm water discharges during the operation phase of the proposed drainage tunnel at Western Portal.

7.14.2 During the operation phase of the proposed drainage tunnel, flood flow from streams within the study area will be diverted up to the 200-year storm event, conveyed by the proposed drainage tunnel system and discharged via the Western Portal outfall to the sea at Kong Sin Wan. The stream's base water flow (dry weather flow) will bypass the intakes, and continue flowing downstream along their existing watercourses. Most of the pollution loads together with the storm flow will be diverted from intakes to the Western Portal outfall only during rain storm events.

7.14.3 Many of the sampling points (proposed intake locations) are located at urban areas where are already channelised or affected by human activities to different extents. Some of the water samples contained relative high concentrations of *E. coli* and SS due to the vicinity of those intakes located within built up residential/school/community areas.

7.14.4 For estimation of pollutant loading to the Western Portal and to quantify the water quality impacts to marine environment, the present methodology assumes all stream flow is diverted into the proposed drainage tunnel and will be discharged at the Western Portal outfall during different rain storm events. Therefore, the water quality impact is assessed for the wet season only (the wet season occurs from April to September inclusive) when significant rainstorm events are expected to occur.

7.14.5 Stream sampling of a number of pollutants was carried out at 13 intake locations during dry-weather and wet-weather flows. The main pollutants that were identified for testing are suspended solids, Oil and Grease, BOD_5, Total Organic Carbon, Total Kjeldahl Nitrogen, Nitrate, Ammonia Nitrate, Total Phosphorus, Orthophosphorus, *E-coli* and Chlorophyll-a. Analysis of the sampling results indicates that both their dry-day and wet-day concentration loadings are low. The major reason being that about 80% of the catchment is located within both the Country Park and the water supply catchwaters.

7.14.6 Inherently, the water quality model will consider the relative changes in suspended solids, *E. coli* and salinity owing to the discharge of storm water (freshwater) from the Western Portal for the proposed drainage tunnel.

7.14.7 Very short term episodes and processes will predominantly determine the impact of the proposed drainage tunnel on the marine environment. Therefore, the focus of the water quality modelling will be on the transport and dispersion of the drainage water in the vicinity of the drainage tunnel outfall following individual storm events. The model

covers the Southern and Southern Supplementary, Victoria Harbour, Eastern and Western Buffer Water Control Zones as designated under the Water Pollution Control Ordinance.

7.14.8 Under the first phase of the Harbour Area Treatment Scheme (HATS) Stage 2A, a deep tunnel system is proposed to bring sewage from the northern and western areas of Hong Kong Island to the Stonecutters Island Sewage Treatment Works. Under the second phase (HATS Stage 2B), a new biological treatment plant will be placed on a site adjacent to the existing Stonecutters Island Sewage Treatment Works. The design of HATS Stage 2A could start in 2005 to enable the major construction works to commence in 2007/08. Such a timetable will enable completion of the Stage 2A works around 2013/14. The Cyperport Sewage Treatment Works (STWs) will be included in the Stage 2 HATS programme. According to the current preliminary implementation programme, the earliest completion date for the proposed drainage tunnel will be at the end of 2011. Therefore for the water quality assessment to consider the worst case scenario, it assumes that both the tunnel and Cyberport STW are both operation during the years 2012 to 2014.

7.14.9 The existing Western Harbour Model (WHM) was used for the modelling assessment. The application of the Delft3D modelling suite has been accepted by the HKSAR government in previous studies, and is available with WL | Delft Hydraulics. The WHM is based on and nested in the so called "Update Model" which was prepared by a consortium led by Hyder, including WL | Delft Hydraulics.

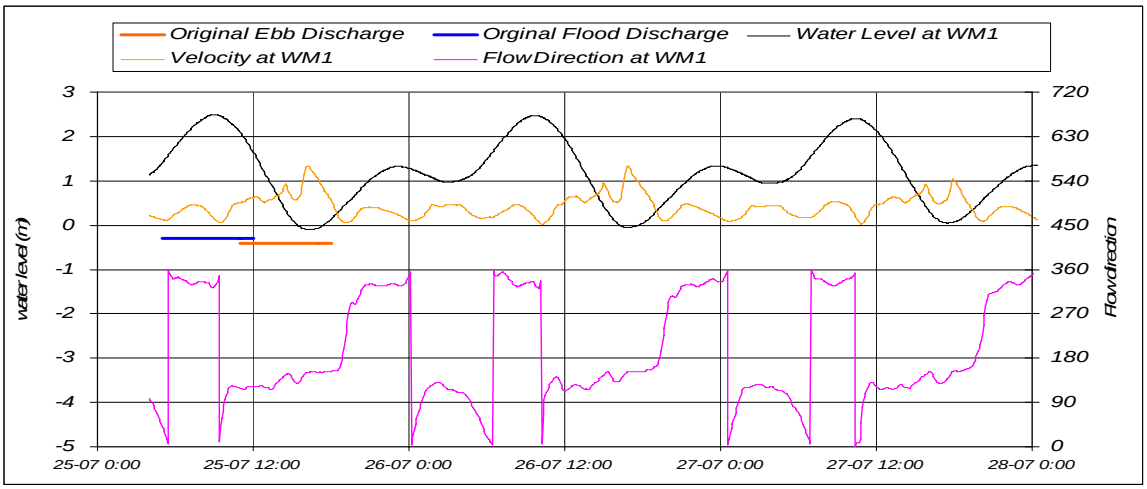
7.14.10 For the simulation of the spreading of the Drainage Tunnel's outfall plume, the particle tracking model Delft3D-PART was applied using the flow field produced with Delft3D-FLOW. The particle tracking model provides the trajectories and destinations of discharged pollutants. Both models use the same computational coordinate grid, assuring consistency and mass conservancy in their coupling. The proposed use of the PART model is made on the basis of the assumptions regarding the expected effects of the discharge mentioned above, and imposes limitations on the type of results that can be obtained. The model only considers relative changes in concentrations and results need to be added to baseline ambient values in order to assess absolute values. Details of the model set-up, input parameters and proposed scenarios were presented in Appendix H.

Water Levels and Currents at the Discharge Point

7.14.11 The definition of the "ebb" and "flood" discharges was based on a simulated tidal flow direction at a location (WM1) in the Lamma Channel, northwest of the discharge point. The "flood" discharge was started when the tide turns and flows in a northwest direction at location WM1 (25 July, 5.00h), while the "ebb" discharge was started when the tide turns and flows in a southeast direction at location WM1 (25 July,11.00h).

7.14.12 The water levels at the location of the discharge show a small phase shift as compared to location WM1. The precise timing of the discharges in relation to the local water level is shown in Figure 7.6 along with the tidal velocity and direction.

Figure 7.6 Flood and Ebb Water levels



7.14.13 The direction of current at the discharge point during the discharge event is also shown in Table 7.5. The ebb tide discharges are characterised by a southeast current during the initial stage of the discharge, followed by predominantly northwest current from 13.00h onwards, which is just before the peak flow of the discharge.

7.14.14 The flood tide discharges are characterised by a northwest current during the initial stage of the discharge, followed by southeast currents from about 8.00h onwards, which is just after the peak flow of the discharge.

Table 7.5 Characteristic of Ebb and Flood Discharges

	Ebb-discharge			Flood-discharge	
	1/2 year	1/50 year		1/2 year	1/50 year
25-07-25 11:00	SE	SE	25-07-25 5:00	NW	NW
25-07-25 12:00	SE	SE	25-07-25 6:00	NW	NW
25-07-25 13:00	NW	NW	25-07-25 7:00	NW	NW
25-07-25 14:00	NW	NW	25-07-25 8:00	SE	NW
25-07-25 15:00	NW	NW	25-07-25 9:00	SE	SE
25-07-25 16:00	NW	NW	25-07-25 10:00	SE	SE
25-07-25 17:00	SE	SE	25-07-25 11:00	SE	SE
25-07-25 18:00	NW	NW	25-07-25 12:00	SE	SE

Baseline Conditions

7.14.15 There is a period of about 2 years between 2012 and 2014 when both the tunnel scheme and the Cyberport STW plant will be both operation and discharging into the sea at Kong Sin Wan. The latter will be operating near its projected maximum capacity before it is diverted to the Stonecutters STP as part of the HATS scheme which will not become operation until 2013/2014. Therefore, the baseline WQ is based on this two year period which is considered the likely worst case.

7.14.16 The working paper "Performance Verification of Cyberport Sewage Outfall – Investigation: Working Paper on Effluent Plume Modelling (Final)"[5] has modelled the likely WQ of the Lamma Channel in the vicinity of the Western Portal and provides WQ information on SS and *E.coli* near the SRs identified under the present study. This information is used in the present EIA as the baseline conditions and these values appear in Tables 7.8a&b and 7.9a&b. The absolute concentration loadings modelled as part of the present EIA are added to the baseline conditions to assess the cumulative concentration loadings. Note that the baseline concentration values taken from the report "Performance Verification of Cyberport Sewage Outfall – Investigation, Working Paper on Effluent Plume Modelling (Final)" in which year 2016's (HATS Year X) bathymetry and coastline were assumed with effluent loadings of the then SSDS Stage 1 outfall, Tathong Channel, Rambler Channel and sewage outfalls near the western outfall incorporated. This baseline is not exactly the 'natural ambient level' as stipulated under the WQO/WPCO.

7.14.17 The following is a brief summary of the estimated Cyberport STW submarine discharge in the Year 2016:

- The maximum discharge flow rate of the Cyberport STWs is 9,807 m^3 per day which will be discharged through a diffuser on the sea floor.
- The estimated *E.Coli* concentration discharging from the Cyberport STW is 2.0 x 10^4 cfu/100mL.
- The estimated concentration of Total Suspended Solids within the daily discharge of the Cyberport STW is 73.9 mg/L

Suspended Sediments

7.14.18 Impacts from SS may be caused by sediment plumes being transported to sensitive areas, such as water intakes, FCZ and areas of high ecological values (corals). There may be a possibility of those SRs which are likely to be affected by increased SS concentrations from the proposed drainage tunnel during its operation phase.

7.14.19 The Delft model predicts the extent and movement of the sediment plumes along with the concentration of SS. The model will determine the impact to those SRs.

7.14.20 The WQOs of the waste discharge shall neither cause the natural ambient level to be raised by more than 30% nor give rise to accumulation of SS which may adversely affect aquatic communities. The predicted maximum values from the water quality model of those SRs will be compared with 30% tolerance values to determine acceptability of the impacts.

7.14.21 In addition to the above criteria for suspended solids, the seawater intakes which have been defined as SRs have specified SS criteria to protect abstraction systems and maintain appropriate water quality for the designated use. The SS concentration should be maintained below 10 mg/L for WSD seawater intakes. In addition, a pragmatic guideline of controlling SS concentrations to below 20 mg/L at flushing and cooling water intakes has been used on a number of other EIA projects in and around Victoria Harbour.

[5] A report prepared in January 2005 by Meinhardt Mouchel Ltd for the EPD. Relevant sections are shown in Appendix G.

7.14.22 As the seawater intakes are normally located at mid-depth or above, the assessment criteria for the seawater intakes has been based on the pollution levels at the surface layer.

Sediment Deposition

7.14.23 Impacts from SS may be caused by sediment plumes being transported to the SRs, leading to the elevation of the SS levels at the SRs. Following an EIA prepared for Sand Dredging at the West Po Toi Marine Borrow Area, a limit on the coral sedimentation rate of 0.1 kg/m²/day is applied to this EIA. Sediment deposition can adversely impact on ecological SRs, namely corals that are located at the bottom of the water column. Therefore, the results of the WQ model consider the concentration of SS at the sea floor and the rates of deposition.

Bacteriological Indicator, *Escherichia Coli*

7.14.24 The presence of *E.coli* in the seawater is considered as a clear indication of faecal contamination and the possible presence of other pathogens. The WQO standard of *E. coli* is an annual geometric mean that should not exceed 610 cfu/100mL in secondary contact recreation area and fish culture zones. Both of these are located across the full extent of the water column and therefore the WQ modelling results consider the depth-average results. In addition, *E. coli* levels of seawater intakes for flushing should not exceed 20,000 cfu/100mL which is measured at the surface layer.

Salinity

7.14.25 For general information only Table 7.6 represents the background salinity at 5 regular EPD monitoring stations during the wet season in the vicinity of the project area (1996-2000). The number of observations varies between 14 and 20, and consequently a period of 5 years provides a reasonable image of the variability of water quality. Note that these values are not directly used to estimate the cumulative impact of the tunnel project shown in Tables 7.11a and 7.11b (refer to Paragraph 7.15.6 for discussion on background concentrations for assessment purposes) however the values shown in Table 7.6 are indicative of the baseline model used to assess the change in salinity.

Table 7.6
Pre-project Background Water Quality (Salinity) at Various Sensitive Receivers

Sensitive receivers (Relevant EPD Monitoring Station)		Depth Average ppt	Surface ppt
Pak Kok (Coral)	N*	20	20
Cyberport Intake	Average#	30.5	25.1
Wah Fu Estate Intake	Min^	26.7	13.0
(WM1)	Max^^	33.8	33.6
Green Island (Coral)	N*	20	20
Queen Mary Hospital Intake	Average#	28.9	24.9
	Min^	24.2	14.3
(WM2)	Max^^	33.5	33.1
Luk Chau Wan (Coral)	N*	14	14
Lo Tik Wan (FCZ)	Average#	31.5	27.8
(SM3)	Min^	29.8	21.1
	Max^^	33.7	33.6

Sensitive receivers (Relevant EPD Monitoring Station)		Depth Average ppt	Surface ppt
Sok Kwu Wan (Coral)	N*	14	14
Sok Kwu Wan (FCZ)	Average#	30.4	28.2
(SM4)	Min^	28.2	22.3
	Max^^	33.7	33.6
Kennedy Town WSD Intake	N*	20	20
(VM8)	Average#	29.6	27.6
	Min^	25.3	21.0
	Max^^	33.3	33.2

Remarks:
* : wet season water quality conditions at 5 regular EPD monitoring stations in the project area, over the years 1996-2000. The number of observations varies between 14 and 20, and consequently a period of 5 years provides a reasonable image of the variability of the water quality.
# - Average value of 5 years at EPD monitoring location
^ - Minimum value at EPD monitoring location
^^ - Maximum value at EPD monitoring location

Leaves within the Tunnel System

7.14.26 The quantity of leaves that may enter the tunnel is not quantifiable by modelling since their presence is dependent on a large number of variables that vary widely. Therefore, the present study only simply assumes that leaves will be present in the tunnel discharge.

Water Quality Modelling

7.14.27 The 1 in 2 years and the 1 in 50 year design storm event outfall hydrographs for the discharge from the Western Portal are derived using the guidelines of the Stormwater Design Manual and the hydraulic software HydroWorks. The duration of the design storm event is 4 hours and the total discharge volume is 273,345 m³ for 1 in 2 years storm event and 844,752 m³ for the 1 in 50 years storm event.

7.14.28 The Delft3D-FLOW and Delft3D-PART models have been used to simulate four scenarios for the operation phase discharges of the proposed drainage tunnel.

Scenario 1 : 1 in 50 years storm events discharge (wet season, Spring and ebb tide), which simulated the SS, *E. coli* and salinity following the implementation of proposed drainage tunnel in 2012;

Scenario 2: 1 in 50 years storm events discharge (wet season, Spring and flood tide), which simulated the SS, *E. coli* and salinity following the implementation of proposed drainage tunnel in 2012;

Scenario 3: 1 in 2 years storm events discharge (wet season, Spring and ebb tide), which simulated SS, *E. coli* and salinity following the implementation of proposed drainage tunnel in 2012;

Scenario 4: 1 in 2 years storm events discharge (wet season, Spring and flood tide), which simulated SS, *E. coli* and salinity following the implementation of proposed drainage tunnel in 2012;

7.14.29 For the pollutant concentrations in the discharge at Western Portal, Delft3D-Part simulations have been carried out for two pollutants: SS and *E. Coli*. Furthermore, the

impact of the discharge on the salinity has been calculated with Delft3D-FLOW. The pollutant concentrations in the discharge are summarized in Table 7.7. The water quality model models the absolute values only (except for Salinity that is also modelled with baseline conditions) and baseline concentrations must be added to obtain the cumulative values.

Table 7.7
Pollutant Concentrations in the Discharge at Western Portal

Scenario	Flood Volume (m^3)	*E Coli* (cfu/100 ml / total cfu)	Suspended Solids (mg/l / total kg)
1/2 years event	273,345	425 / 1.156×10^{12}	124 / 33,895
1/50 years event	844,752	140 / 1.156×10^{12}	124 / 104,750

7.14.30 Since the *E. Coli* is derived from a constant source the total amount of *E. Coli* remains the same for both the 1 in 2 years and 1 in 50 year storm events. Conversely however, the concentration will change owing to the difference in rainfall-runoff volumes. The estimated *E. coli* loading are derived in estimation of pollutant and sediment reports (Appendix G).

7.14.31 An investigation of the sediment runoff from the catchments above the intakes is discussed in Appendix G. This analysis estimates a SS concentration loading of 124 mg/L. Since the sediment is from a source with continuous supply (the earth) the concentration won't change between runoff events with different magnitudes but it will affect the total volume of sediment runoff.

7.14.32 The discharge events cause very short episodes of reduced salinity and elevated pollutant concentrations. For this reason, *maximum pollutant concentrations and minimum salinity occurring at a certain location, at any time* during the event are used to characterize the impacts of the discharge. These maximum value areas are represented as a map of iso-concentration contours which give a clear picture of the area potential affected, and the level of the potential pollution impact. These results are contained in the Appendix I of this report.

7.14.33 In general, the maximum concentration plots show a clear picture. Relatively high pollutant concentrations occur only in the direct vicinity of the Western Portal along the coast NW and SE of the outfall. As soon as the discharged storm water is entering the fast flowing and deeper waters, it is diluted and the maximum concentrations drop sharply. In the flood scenarios, the impact is strongest to the SE. While in the ebb scenarios, the NW direction is affected strongest. In the ebb scenarios, the impacted area tends to be smaller than in the flood scenarios.

7.14.34 In additional to the contour plots, the results are presented in form of maximum concentrations occurring at SRs. This provides clear indication of the potential impact on those SRs. Tables 7.8a and 7.8b show the modelling result of maximum concentrations of SS at selected SRs for the 1 in 50 year and 1 in 2 year storm events, respectively. Tables 7.9a and 7.9b show the modelling result of maximum concentrations of *E. coli* at selected SRs for the 1 in 50 year and 1 in 2 year storm events, respectively.

7.14.35 Each simulation has been run for a sufficiently long duration following the storm discharge event in order to determine the spread of the plume. The storm discharge will occur on Spring Tide Cycle.

7.14.36 The modelling results are shown in a series of contour plots and tables at selected SRs as follows:

- The maximum concentration of SS, on logarithmic concentration scales;
- The maximum deposition rate of SS;
- The maximum concentration of *E. coli*, on logarithmic concentration scales;
- The minimum surface salinity, on a scale of < 10 ppt to > 30 ppt.

7.14.37 The use of logarithmic concentration scales allows the impact assessment for different levels of pollution.

7.14.38 All plots present maximum/minimum values of vertically average concentrations, except where it is mentioned otherwise.

Table 7.8a
Modelling Results of Net Suspended Solids (Maximum Concentrations), predicted SS Concentrations with Background Values and the Respective Exceedance Duration during 1 in 50 years Storm Events

Location of sensitive receivers (Position in Water Column)	Baseline^ Concentration (mg/L)	WQO 30% increase (mg/L)	Relevant Guidelines (mg/L)	1 in 50 yrs Max SS-Flood (mg/L)	Cumulative Max SS (mg/L)	Exceedance Time^^ (Min)	1 in 50 yrs Max SS-Ebb (mg/L)	Cumulative Max SS (mg/L)	Exceedance Time^^ (Min)
Coral (Bottom)									
Green Island	8	10	-	0	8	-	0	8	-
Luk Chau Wan	7	9	-	0	7	-	0	7	-
Pak Kok	8	10	-	0	8	-	0	8	-
Sok Kwu Wan	7	9	-	0	7	-	0	7	-
Fish Culture Zones (Depth Average)									
Lo Tik Wan	8	10	50*	0	8	-	0	8	-
Sok Kwu Wan	7	9	50*	0	7	-	0	7	-
Seawater Intakes (Surface)									
Cyberport	8	10	10**	21	**29**	260	13	**21**	141
Kennedy Town	8	10	10**	7	**15**	140	1	8	-
Queen Mary Hospital	8	10	20#	27	**35**	190	57	**65**	270
Wah Fu Estate	8	10	20#	23	**31**	80	10	18	-
EPD monitoring stations (Surface)									
SM3	8	10	-	2	10	-	3	**11**	20
SM4	8	10	-	0	8	-	0	8	-
VM8	8	10	-	0	8	-	1	8	-
WM1	8	10	-	0	8	-	8	**16**	40
WM2	8	10	-	0	8	-	0	8	-

Remarks: Bold and underline: Exceedance WQO standards or relevant standard

* the water quality objectives applicable to fish culture zones are that the SS level should not exceed 50 mg/l or a 100% elevation above the maximum value recorded over the past five years whichever is the lower.

** WSD flushing water quality guidelines for seawater intake

Acceptable water quality for seawater intake

^ Baseline concentration values are taken from the report "Performance Verification of Cyberport Sewerage Outfall – Investigation, Working Paper on Effluent Plume Modelling (Final)". Refer to Paragraph 7.14.16.

^^ The duration that the Relevant Guidelines (or WQO if no relevant guidelines) is exceeded.

Table 7.8b
Modelling Results of Net Suspended Solids (Maximum Concentrations), predicted SS Concentrations with Background Values and the Respective Exceedance Duration during 1 in 2 years Storm Events

Location of sensitive receivers (Position in Water Column)	Baseline Concentration (mg/L)	WQO 30% increase (mg/L)	Relevant Guidelines (mg/L)	1 in 2 yrs Max SS-Flood (mg/L)	Cumulative Max SS (mg/L)	Exceedance Time^^ (Min)	1 in 2 yrs Max SS-Ebb (mg/L)	Cumulative Max SS (mg/L)	Exceedance Time^^ (Min)
Coral (Bottom)									
Green Island	8	10	-	0	8	-	0	8	-
Luk Chau Wan	7	9	-	0	7	-	0	7	-
Pak-Kok	8	10	-	0	8	-	0	8	-
Sok Kwu Wan	7	9	-	0	7	-	0	7	-
Fish Culture Zones (Depth Average)									
Lo Tik Wan	8	10	50*	0	8	-	0	8	-
Sok Kwu Wan	7	9	50*	0	7	-	0	7	-
Seawater Intakes (Surface)									
Cyberport	8	10	10**	12	**19**	160	4	**12**	60
Kennedy Town	8	10	10**	0	8	-	0	8	-
Queen Mary Hospital	8	10	20#	8	15	-	24	**32**	70
Wah Fu Estate	8	10	20#	13	**21**	40	4	11	-
EPD monitoring stations (Surface)									
SM3	8	10	-	0	8	-	1	9	-
SM4	8	10	-	0	8	-	0	8	-
VM8	8	10	-	0	8	-	0	8	-
WM1	8	10	-	0	8	-	4	**11**	20
WM2	8	10	-	0	8	-	0	8	-

Remarks: Bold and underline: Exceedance WQO standards or relevant standard

* the water quality objectives applicable to fish culture zones are that the SS level should not exceed 50 mg/l or a 100% elevation above the maximum value recorded over the past five years whichever is the lower.

** WSD flushing water quality guidelines for seawater intake

Acceptable water quality for seawater intake

^ Baseline concentration values are taken from the report "Performance Verification of Cyberport Sewerage Outfall – Investigation, Working Paper on Effluent Plume Modelling (Final)". Refer to Paragraph 7.14.16.

^^ The duration that the Relevant Guidelines (or WQO if no relevant guidelines) is exceeded.

Table 7.9a
Modelling Results of Net *E.coli* (Maximum Concentrations), predicted *E. coli* Concentrations with Background Values during 1 in 50 years Storm Events

Location of sensitive Receivers (Position in Water Column)	Baseline^ Concentration (cfu/100mL)	WQO Fish Culture Zone (cfu/100mL)	WSD seawater intake for flushing (cfu/100mL)	1 in 50 yrs *E. Coli* –flood Max (cfu/100mL)	Cumulative Max *E.Coli* (cfu/100mL)	1 in 50 yrs *E. Coli* – Ebb Max (cfu/100mL)	Cumulative Max *E.Coli* (cfu/100mL)
Coral (Bottom)							
Green Island	200	-	-	0	200	0	200
Luk Chau Wan	5	-	-	0	5	0	5
Pak Kok	6	-	-	0	6	0	6
Sok Kwu Wan	10	-	-	0	10	0	10
Fish Culture Zones (Depth Average)							
Lo Tik Wan	10	610	-	0	10	0	10
Sok Kwu Wan	15	610	-	0	15	0	15
Seawater Intakes (Surface)							
Cyberport	1,100	-	20,000	21	1,121	14	1,114
Kennedy Town	500	-	-	10	510	2	502
Queen Mary Hospital	500	-	-	24	524	57	557
Wah Fu Estate	1,100	-	-	16	1,116	9	1,109
EPD monitoring stations (Surface)							
SM3	25	-	-	3	28	2	27
SM4	25	-	-	0	25	0	25
VM8	500	-	-	0	500	0	500
WM1	1,100	-	-	0	1,100	6	1,106
WM2	500	-	-	0	500	0	500

Remarks:

^ Baseline concentration values are taken from the report "Performance Verification of Cyberport Sewerage Outfall – Investigation, Working Paper on Effluent Plume Modelling (Final)". Refer to Paragraph 7.14.16.

Table 7.9b
Modelling Results of Net *E.coli* (Maximum Concentrations), predicted *E. coli* Concentrations with Background Values during 1 in 2 years Storm Events

Location of sensitive Receivers (Position in Water Column)	Baseline^ Concentration (cfu/100mL)	WQO Fish Culture Zone (cfu/100mL)	WSD seawater intake for flushing (cfu/100mL)	1 in 2 yrs *E. Coli* -flood Max (cfu/100mL)	Cumulative Max *E.Coli* (cfu/100mL)	1 in 2 yrs *E. Coli* - Ebb Max (cfu/100mL)	Cumulative Max *E.Coli* (cfu/100mL)
Coral (Bottom)							
Green Island	200	-	-	0	200	0	200
Luk Chau Wan	5	-	-	0	5	0	5
Pak Kok	6	-	-	0	6	0	6
Sok Kwu Wan	10	-	-	0	10	0	10
Fish Culture Zones (Depth Average)							
Lo Tik Wan	10	610	-	0	10	0	10
Sok Kwu Wan	15	610	-	0	15	0	15
Seawater Intakes (Surface)							
Cyberport WSD	1,100	-	20,000	36	1,136	13	1,113
Kennedy Town	500	-	-	2	502	1	501
Queen Mary Hospital	500	-	-	26	526	71	571
Wah Fu Estate	1,100	-	-	29	1,129	16	1,116
EPD monitoring stations (Surface)							
SM3	25	-	-	0	25	2	27
SM4	25	-	-	0	25	0	25
VM8	500	-	-	0	500	0	500
WM1	1,100	-	-	0	1,100	8	1,108
WM2	500	-	-	0	500	0	500

Remarks:

^ Baseline concentration values are taken from the report "Performance Verification of Cyberport Sewerage Outfall – Investigation, Working Paper on Effluent Plume Modelling (Final)". Refer to Paragraph 7.14.16.

7.15 Discussion on the Water Quality Modelling Result

Suspended Sediment

7.15.1 The SS plots show the areas most affected by the SS for the 1 in 2 year and 1 in 50 year storm events. For both the flood and ebb tide scenarios these show that the plume is generally confined to the west coast of Hong Kong Island from Green Island to Ap Lei Chai. For the flood tide scenario the concentration of SS is more concentrated in the vicinity of Ap Lei Chai while for the ebb tide scenario the concentrations of SS are higher in the vicinity of Green Island. For SS the plots show that the coral and fish culture zones near Lamma Island are not affected for either tide scenario or discharge magnitude. The maximum surface SS concentration that may be experienced above baseline levels at the Intake SRs for the 1 in 2 year and the 1 in 50 year discharge events is 32 mg/L and 65 mg/L, respectively. Both of these maximum concentrations occur at the Queen Mary Hospital intake location and during the ebb tide scenario. Tables 7.8a and 7.8b show that for all intakes, excluding the Kennedy Town WSD Intake, both the maximum absolute and cumulative concentrations exceed the recommended threshold of 20mg/L, particularly for the Queen Mary Hospital Intake. The cumulative SS loading at the Kennedy Town WSD Intake only just exceeds the relevant threshold by 5 mg/L and only during the 1 in 50 year flood-tide scenario for a period of 140 minutes. For both the 1 in 2 year and 1 in 50 year storm events the exceedence duration for the other intakes is no longer than 4 hours at most locations.

7.15.2 Four coral sites in Lamma and Hong Kong Island (i.e. Pak Kok, Luk Chau Wan, Sok Kwu Wan and Green Island) were selected as ecological sensitive receivers (SR) for water quality assessment due to their relatively closer distances to the outfall location and the higher sensitivity of corals. The distances are ranged from 2.5km to 5.5km. The two closest FCZs (Lo Tik Wan & Sok Kwu Wan FCZs, 4km and 5.5 km respectively) were also taken as sensitive receivers for water quality. For both the Coral and FCZ SRs the absolute and cumulative maximum concentrations of SS presented in Tables 7.8a and 7.8b show that they are not affected by the plume. For all flood and tide scenarios, no net increase of the maximum and cumulative SS concentrations are predicted from the model and therefore, all predicted results are well within the Marine WQOs. All the recognised sites of marine conservation importance and the remaining FCZs inside the assessment area are further away from the outfall, ranging from 10km to 22km and from 12km to 17 km respectively, than those SRs (Please refer to Chapter 11 & 12 for details). As these ecological and FCZ SRs are not affected by the SS, all other recognised sites of marine conservation importance and the remaining FCZs which are much farther away are also not affected.

Sediment Deposition

7.15.3 Table 7.10 presents the modelled deposited sediment per m^2 for the coral SRs and shows that the maximum deposition, regardless of modelled flood and tide scenario, is extremely small (all less than $3g/m^2/d$), well below the coral sedimentation rate limit of $0.1kg/m^2/day$. Therefore, no adverse impacts to the corals are expected to occur because of the proposed tunnel scheme. As the ecological SRs are not affected by the deposited sediment, all other recognised sites of marine conservation importance which are much farther away are also not affected.

Table 7.10
Maximum Sediment Deposition Rates at Ecological Sensitive Receivers

Site	Maximum Deposition Rate ($g/m^2/day$)			
	1 in 2 year Flood	1 in 2 year Ebb	1 in 50 year Flood	1 in 50 year Ebb
Green Island	0.2	0.6	0.9	2.1
Luk Chau Wan	0.0	0.0	0.2	0.1
Pak Kok	0.1	0.1	0.5	0.2
Sok Kwu Wan	0.0	0.0	0.1	0.1

E. Coli

7.15.4 Maximum relative concentrations of higher than 100 cfu/100ml are limited to the immediate vicinity of the discharge point. *E. coli* concentrations up to 95 cfu/100ml are limited to a narrow strip along the west coast of Hong Kong Island, however, for all modelled flood and tide scenarios no exceedance in terms of maximum cumulative concentrations will occur at any of the SRs (Tables 7.9a and 7.9b). The impact is considered insignificant. As the ecological and FCZ SRs are not affected by *E. coli*, all other recognised sites of marine conservation importance and the remaining FCZs which are much farther away are also not affected.

Salinity

7.15.5 The minimum salinity plots again show the areas affected by the storm water discharge. These areas are limited to a narrow strip along the west coast of Hong Kong Island. The most affected areas are located immediately adjacent to the Western Portal where in the 1 in 2 years and the 1 in 50 year flood scenarios the minimum surface salinity is about 20 ppt and 10 ppt, respectively. Salinity will be higher in the middle and bottom layers of the water column owing to the density gradient. In the flood scenarios, the impact is stronger to the SE, while in the ebb scenarios the NW direction is affected the most. It should be noted that the background salinity shows a spatial gradient, due to the presence of the Pearl River plume.

7.15.6 The change in salinity at the ecological SRs (namely coral sites) are assessed with the results shown in Tables 11a and 11b for the 2-year and 50-year storm events, respectively. The tables show the maximum difference between the modelled baseline condition and the modelled implementation scenario (which is the accumulation of the baseline and the proposed tunnel's discharge plume). The WQO requires that "human activity should not cause the natural ambient salinity to change by more than 10%".

Table 7.11a
Change in Salinity at Ecological Sensitive Receivers for 2-year Storm Events

Site	Baseline Salinity (ppt)		Implementation Salinity (ppt)		% Change in Salinity	
	Ebb	Flood	Ebb	Flood	Ebb	Flood
Green Island	35.00	35.14	34.90	35.04	0.28	0.29
Lo Tik Wan	35.72	36.03	35.65	35.80	0.22	0.28
Pak Kok	34.51	34.51	34.18	34.21	0.94	0.87
Sok Kwu Wan	35.99	35.36	35.91	35.27	0.22	0.23

Table 7.11b
Change in Salinity at Ecological Sensitive Receivers for 50-year Storm Events

Site	Baseline Salinity (ppt)		Implementation Salinity (ppt)		% Change in Salinity	
	Ebb	Flood	Ebb	Flood	Ebb	Flood
Green Island	35.33	34.27	35.21	34.27	0.33	0.00
Lo Tik Wan	36.00	35.89	35.90	35.84	0.25	0.17
Pak Kok	34.51	32.25	34.18	32.10	0.94	0.47
Sok Kwu Wan	35.99	35.99	35.90	35.91	0.24	0.22

7.15.7 For both magnitude storm events and tide scenarios the change in salinity is less than 1% and therefore meets the WQOs. Furthermore, the change in salinity resulting from the freshwater plume discharged from the Western Portal is significantly less than the natural daily fluctuations in salinity at the SRs. As the ecological SRs are not affected by the salinity, all other recognised sites of marine conservation importance and the remaining FCZs which are much farther away are also not affected.

7.15.8 In summary, the water quality modelling simulated the 1 in 2 years and the 1 in 50 year rain storm events are chosen for simulation to represent the reasonable frequent and typical worst case scenarios that may happen in Hong Kong respectively. Suspended solid, E. coli, and salinity were simulated. The water quality assessment result indicated that the discharge plume at Western Portal during operation phase from the proposed drainage tunnel would only be confined to the landward coastal waters on the west coast of Hong Kong Island from Green Island to Ap Lei Chai. The most affected waters are the surface layer in areas located immediately adjacent to the Western Portal.

7.15.9 The predicted water quality results show that no significant impact of the SS, E. coli and Salinity is expected on the four coral SRs and the two FCZ SRs during the operation phase, all other recognised sites of ecological importance and the remaining FCZs inside the assessment area which are much further away should not be affected.

7.16 Mitigation Measures

Maintaining Baseflow in Downstream Watercourses

7.16.1 To maintain a baseflow in the watercourses downstream of the proposed intakes, their preliminary design includes a bypass system which is elaborated as follows and is shown in Figures 7.7 & 7.8.

- Purpose of the by-pass device is to maintain the base-flow of the affected stream course.
- The by-pass system comprises an approach link and a trapezoidal channel.
- The approach link is section with inclined profiled surface at a gradient of 1 in 100. It is used to direct the base flow to the by-pass trapezoidal channel at its down stream end during the normal days.
- The trapezoidal channel is sized such that it could handle the base flow in the affected stream course which is estimated to be about 20 l/s.
- Whenever the flow in the stream course exceeding the base flow rate, the excessive flow will overflow into the intake structure via the bottom rack structure. The bottom rack structure has bar screen on the top and inclined channel at the bottom. The top level of the bar screen is level with the by-pass channel with an aim to receive the overflow from the by-pass channel.
- The by-pass channel is designed requiring minimum maintenance. However, it is recommended that the maintenance authority carry out regular maintenance inspection prior to onset of seasons and after significant rainstorm event to prevent blockage of the by-pass and bottom rack structure.

7.16.2 The base flow will be maintained in all existing affected streams due to the installation of the intake structures. Only the excess flow is diverted into the drainage tunnel during rain storm events. Therefore, it is anticipated that the water quality impacts on the downstream watercourses during the operation phase of the proposed drainage tunnel is insignificant.

7.17 Residual Impacts

Marine Water Quality

7.17.1 Based on the results of the maximum concentrations for all selected SRs, there are only three SRs (seawater intakes) that are significantly affected by SS and these are located along the SW coast of HK Island. They are Queen Mary Hospital (predominantly in the ebb scenarios), as well as Cyberport and Wah Fu Estate (predominantly in flood scenarios). The impact at Kennedy Town is also noticeable (no exceedance of SS was predicted by the water quality model to this intake standard during the 1 in 2 year event) but considered reasonably insignificant.

7.17.2 WSD have been consulted with the results of the present study and informed that the SS concentrations in the vicinity of their intake sites (Kennedy Town and Cyberport) will exceed their WQOs during storm events. For the Kennedy Town site WSD have indicated that they accept the exceedences since the exceedences are minor and are likely to occur only very infrequently. For the future Cyberport site, which is currently being designed, WSD would consider to incorporate SS sensors/turbidity meters or other appropriate equipment at the intake and increase the seawater storage capacity to cater for the situation when the pumps are shut down with exceedance of SS.

7.17.3 Both the Housing Authority and Queen Mary Hospital have been advised of the elevated SS concentrations in the vicinity of their intake sites owing to the operation of the tunnel

scheme during storm events. Having considered the distance separation, the level of exceedance, the frequency of occurrence and the mitigation measures taken at the sources, both the Housing Authority and Queen Mary Hospital have no adverse comment to the occasional slightly elevated SS concentrations at their intake sites.

7.17.4 From the contour plots, it is concluded that the area that is affected by the SS, *E. coli* and Salinity is a narrow strip along the SW coast of the Hong Kong Island, reaching to the western tip of the Island in the NW and to the waters around Ap Lei Chau in the SW.

7.17.5 Higher impacts are only expected in the direct vicinity of the outfall, directly on the coast. It should be noted the numbers mentioned are maximum values occurring for only a short period of time.

7.17.6 Based on the WQO guidelines there is no adverse water quality impacts from pollutants in the storm water (salinity, suspended solids and *E. coli*), to all the identified coral sites and fish culture zones. Insignificant residual impact of suspended solids is expected only during 1 in 2 years and 1 in 50 years rainstorm event to four identified seawater intakes. But, it should be noted that the numbers mentioned here are **maximum values, characterising a very short episode that occurs very infrequently**. It should be furthermore noted that the impact is significantly less than for the 1 in 2 year event.

7.17.7 Vegetation (including leaves) and other materials will be washed into the stream flow above the intake sites and may be conveyed to the intakes. To maximise the benefits of the tunnel system providing flood alleviation to the lower catchments of Northern Hong Kong Island, the intakes have been designed to operate under extreme hydraulic conditions in order to divert high energy flow into the tunnel system while minimising adverse affects to the surrounding intake sites. Therefore the bar sizing, shape and spacing of the intakes are designed to maximise their hydraulic effectiveness but also to prevent large stones and debris (including larger wooden branches and trunks) from entering the tunnel system. Intake structures that currently operate in Hong Kong generally do not provide upstream facilities for trapping and removing large stones, debris and other material. Conversely, for the present project a design has been proposed that will maximise hydraulic efficiency while trapping stones and debris, and that will aid self-cleansing by allowing material to wash downstream of the intakes without entering the tunnel system thereby preventing blockage. In addition to the bar racks at the entrance of the intake structure, sand trap is provided at the bottom of the intake shaft to collect debris, boulders and coarse sand. The sand trap will be operating at its maximum efficiency during the low flow condition. During storm flows material will be washed over the intake to be deposited immediately downstream in a collection area ready for removal by maintenance staff. A typical plan and long-section of the intake sites showing the collection area is shown in Figure 7.9.

7.17.8 Even though the intakes are design primarily based on hydraulic effectiveness, the size and spacing of the screen will trap a portion of the vegetation and leaves, and any other material. The trapped material will accumulate on the bars and will be washed downstream to the collection area for removal. Any vegetation and leaves that pass through the intake will be flushed through the tunnel system by the storm flow and will discharge into the sea similar to what occurs for all currently operating stormwater intakes and drainage systems. Some of this material will float on the surface of the sea but because of flow conditions within the tunnel system and site constraints at the tunnel outlet (the Western Portal) there are no formal facilities proposed to further trap leaves or other floating material. Maintenance, including the removal of leaves and other potential floating material, will be carried out on the water courses at the intakes and within the tunnel system itself before the onset of every wet season to minimise the amount of leaves and floating objects that may discharge to the sea. A refuse collecting barge will

also be employed to collect leaves and other debris floating within the discharge plume should it be necessary following large storm events. Based on the balance of maximising the effectiveness of the tunnel system preventing flooding in the lower catchments of Northern Hong Kong Island and the occasional possible discharge of leaves during extreme storm events into sea, the latter is considered a reasonable residual impact.

7.18 Interpretation of Impacts other than Modelling Parameters

7.18.1 The Water Pollution Control Ordinance (Cap. 358) provides the major statutory framework for the protection and control of water quality in Hong Kong. Under the WPCO, Hong Kong marine waters are divided into 10 Water Control Zones (WCZs). Each WCZ has a designated set of statutory Water Quality Objectives (WQOs). The proposed drainage tunnel outfall falls within the Western Buffer WCZ which has declared in June 1993. During operation, pollutant plumes generated from outfall may impact the Western Buffer WCZ as well as the adjacent Southern WCZs. The WQOs set limits for different parameters that should be achieved in order to maintain the water quality within the Western Buffer and Southern WCZs.

7.18.2 Thirteen streams were selected out of the thirty-five streams that will be intercepted by intake identified in this project, they are at the Eastern Portal, W1, W5, W10, E5(B)(P), W11(P), PRLR1(P), W3(P), TP789(P), THR2(P), W8, P5(P) and W12. The aim of the sampling is to characterize the water quality of the streams in order to make a preliminary estimation on the pollutant loading that will be discharged from the Western Portal at Pok Fu Lam. Sampling points were selected based on flow proportion of the streams entering the intakes shafts. Those sampling points represent about 65% of the likely diverted flow and include the largest catchment in the project area, the Eastern Portal with 19% of the total catchment area draining to the Western Portal.

7.18.3 Sampling of water quality at the thirteen streams for the dry and wet seasons are shown in Tables 7.12a and 7.12b, respectively. The water qualities for most of the streams are good which are contributed mainly by low BOD5, high DO, low nutrients and organic pollutants except water samples collected at W5 and W10 locations. The high quality is most likely because the stream water is flowing from the Country Parks Catchment areas upstream. For water sample collected at W5 and W10 locations, they have a relatively higher BOD5, SS, turbidity and Ammonia Nitrogen concentrations during the dry and wet seasons owing to the sites being located in built-up and residential areas. Raw sewage contamination was observed in the water sample results.

Table 7.12a
Average concentrations during March 2004 (representative for dry season)

Test	Unit	E4(P)	W1	W5	W10	E5(B)(P)	W11(P)	PFLR1(P)	W3(P)	TP789(P)	THR2(P)	W8	P5(P)	W12
In-situ Measurement - Dry Season														
Water Depth	m	0.135	0.004	0.020	0.018	0.020	0.018	0.020	0.020	0.028	0.028	0.004	0.004	0.025
pH	at 25°C	7.41	7.75	8.15	7.94	7.96	7.98	7.65	10.33	8.15	7.82	7.87	7.67	7.61
Turbidity	NTU	3.9	7.2	26.2	19.2	8.1	12.1	8.5	25.9	4.5	17.9	32.7	3.5	13.1
Temperature	^{o}C	16.95	18.05	19.90	18.63	19.85	19.08	19.58	19.35	17.25	21.63	18.78	19.73	18.98
DO	mg/L	8.66	7.00	7.26	8.07	7.58	8.24	7.93	8.03	9.20	8.41	7.96	7.55	7.19
Salinity	ppt	0.10	0.10	0.10	0.10	0.15	0.25	0.10	0.25	0.10	0.10	0.75	0.00	0.10
Laborary analysis														
Suspended Solids	mg/L	3.8	5.2	27.8	12.8	9.5	11.1	7.7	89.2	5.1	12.2	24.0	4.6	13.7
Oil & Grease	mg/L	3.5	3.5	5.7	4.2	3.5	3.5	3.5	4.1	3.5	3.5	3.5	3.5	6.1
BOD5	mg/L	6.6	2.1	19.9	20.5	13.6	3.9	3.4	15.9	1.6	2.0	11.2	4.7	26.5
Total Organic Carbon	mg/L	1.8	1.8	9.7	8.2	3.2	2.2	2.8	5.5	1.0	1.0	10.8	1.3	9.0
TKN	mgN/L	0.5	0.5	8.8	1.4	3.0	1.3	1.1	2.5	0.4	0.6	3.7	0.8	3.1
Nitrate	mgNO_3^--N/L	0.557	3.288	0.874	0.917	2.581	0.452	0.657	1.599	1.673	0.184	3.053	0.353	0.755
Nitrite	mgNO_2^--N/L	0.525	2.043	1.016	0.492	1.141	0.297	0.382	0.710	1.100	0.127	0.464	0.225	0.286
Ammonia-N	mgNH_3^--N/L	0.037	0.052	3.320	0.217	2.189	0.075	0.083	0.070	0.052	0.025	0.344	0.060	0.450
Total Phosphorus	mgP/L	0.045	0.102	2.592	0.630	1.226	0.348	0.211	0.302	0.155	0.117	0.864	0.404	1.572
Orthophosphorus	mgP/L	0.027	0.086	1.541	0.306	0.774	0.165	0.139	0.117	0.087	0.055	0.521	0.333	0.954
E-coli	cfu/100ml	58	2,018	34,160	17,901	29,292	425	42,393	15	1,832	135	7,861	123	278,779
Chlorophyll-a	mg/m^3	3.0	7.3	5.2	4.8	5.3	4.2	6.4	22.5	5.5	3.3	1.2	1.3	8.6
Faecal coli count	cfu/100ml	228	13,416	57,480	140,000	57,480	8,899	354,119	1	1,789	739	74,034	2,000	195,959

Table 7.12b
Average concentrations during May 2004 (representative for wet season – after first flush of Rain)

Test	Unit	E4(P)	W1	W5	W10	E5(B)(P)	W11(P)	PFLR1(P)	W3(P)	TP789(P)	THR2(P)	W8	P5(P)	W12
In-situ Measurement - Wet Season														
Water Depth	m	0.180	0.030	0.020	0.030	0.030	0.020	0.050	0.020	0.020	0.020	0.050	0.020	0.020
pH	at 25°C	7.52	8.11	8.22	8.43	7.68	8.64	7.62	8.55	8.18	8.24	8.24	7.74	7.48
Turbidity	NTU	4.6	8.53	21.70	24.00	20.05	219.50	3.84	4.40	6.11	19.05	26.05	1.83	94.85
Temperature	^{o}C	21.65	21.25	22.55	21.80	21.70	22.40	22.30	22.20	20.60	21.70	22.60	21.45	22.25
DO	mg/L	7.67	8.06	6.90	7.38	6.61	7.22	6.88	8.33	8.99	8.46	7.88	9.14	6.93
Salinity	ppt	0.10	0.10	0.20	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Laborary analysis														
Suspended Solids	mg/L	4.1	8.5	25.3	8.8	14.3	90.5	3.6	5.0	3.6	11.5	14.0	3.2	80.8
Oil & Grease	mg/L	2.8	2.8	3.5	13.3	2.8	3.6	2.8	2.8	2.8	2.8	3.0	2.8	9.8
BOD5	mg/L	1.1	1.6	14.4	14.0	8.5	3.6	1.5	1.4	1.2	4.7	15.0	1.1	8.8
Total Organic Carbon	mg/L	1.0	3.5	13.8	7.2	4.8	20.3	2.0	2.0	2.0	4.0	5.8	1.0	3.0
TKN	mgN/L	0.3	0.5	8.2	0.3	1.5	1.9	0.5	0.4	0.4	0.9	0.9	2.5	1.0
Nitrate	mgNO_3^--N/L	0.500	1.800	0.290	0.470	1.425	0.483	0.465	1.825	2.375	0.690	0.588	0.528	0.618
Nitrite	mgNO_2^--N/L	0.005	0.008	0.103	5.655	0.248	0.007	0.022	0.062	0.004	0.049	0.023	0.002	0.010
Ammonia-N	mgNH_3^--N/L	0.027	0.028	4.000	2.526	0.710	0.044	0.145	0.086	0.028	0.243	0.112	0.034	0.068
Total Phosphorus	mgP/L	0.038	0.208	1.523	4.715	0.368	0.493	0.060	0.210	0.025	0.108	0.538	0.090	0.575
Orthophosphorus	mgP/L	0.028	0.143	1.043	2.110	0.273	0.135	0.039	0.161	0.021	0.065	0.170	0.068	0.295
E-coli	cfu/100ml	1,661	6,092	317,532	11	150,144	207	10,678	15,793	9,230	22,330	12,104	407	26,791
Chlorophyll-a	mg/m³	1.0	2.4	12.4	1.0	3.6	6.7	2.0	3.4	1.3	1.8	0.9	2.0	3.8
Faecal coli count	cfu/100ml	16,125	28,566	961,249	424	401,248	3,650	15,000	33,045	17,436	158,745	95,499	8,888	71,232

7.18.4 The pollutants that were sampled are SS, oil and grease, BOD_5, Total Organic Carbon, Total Kjeldahl Nitrogen, Nitrate, Ammonia-Nitrate, Total Phosphorus, Orthophosphorus, *E. coli* and Chlorophyll a. Analysis of the sampling result indicated that their dry and wet concentration loadings are low, the major reason is that about 80% of the catchments are in both Country Park and water supply catchwaters. Details of calculations are shown in Appendix G.

7.18.5 Table 7.13 present the estimate pollutants concentrations during both the 1 in 2 year and the 1 in 50 year rainstorm events that may discharge to the Western Portal for both the dry and wet seasons. The average 5 years water quality values at the WM1 EPD monitoring station are also included within these tables.

7.18.6 The estimated water quality during the 1 in 2 year and the 1 in 50 year rainstorm events at the Western Portal is very similar to the baseline of the marine water except E. coli. But this modelling of E. coli has shown that there is no impact to any SR during storm events.

7.18.7 The estimated pollutant concentrations discharged during the 1 in 2 year and the 1 in 50 year events at the Western Portal are also compared against the Western Buffer Zone WQO in Table 7.13. To be conservative, it is assumed that all of the pollutants will be diverted to the Western Portal during storm events.

7.18.8 There is a no exceedance of any pollutant concentrations when it compares against the WQO standards. Moreover, the estimated concentrations are based on 100% diversion from intakes to the proposed drainage tunnel (worse scenario). No significant impact on the marine water quality is expected at Kong Sin Wan because the estimated pollutant concentrations are extremely low. Modelling results also show that pollutant concentrations will be diluted after discharge at the outfall and the discharge pollutants plume is characterized by very short and infrequent episodes.

Table 7.13
Estimated Pollutant Concentrations Comparing with the WQO of Western Buffer Zone

Water Quality Parameters	Estimated pollutant concentrations (100% diversion) to Western Portal				Average Monitored Concentrations at WM1 1999 - 2003		WQO (Western Buffer)
	1 in 2 year Event		1 in 50 year Event				
	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	
BOD5 (mg/L)	0.035	0.032	0.011	0.010	0.64	0.65	-
Nitrate (mg/L)	0.003	0.007	0.001	0.002	0.08	0.08	-
Nitrite (mg/L)	0.002	0.001	0.001	0.000	0.02	0.02	-
Ammonia-N (mg/L)	0.002	0.004	0.001	0.001	0.07	0.04	-
TIN (mg/L)	0.007	0.012	0.002	0.004	0.17	0.15	Annual depth averaged total inorganic nitrogen - 0.4 mg/L
Total Phosphorus (mg/L)	0.002	0.003	0.001	0.001	0.04	0.04	-
Chlorophyll-a (mg/m³)	0.029	0.026	0.009	0.009	2.63	2.52	-
TKN (mg/L)	0.008	0.011	0.002	0.003	0.36	0.38	-
Orthophosphorus (mg/L)	0.001	0.002	0.000	0.001	0.02	0.02	-
Total Organic Carbon (mg/L)	0.014	0.042	0.004	0.014	-	-	-
Oil & Grease (mg/L)	0.015	0.021	0.005	0.007	-	-	-
E-coli (cfu/100ml)	54	422	17	137	318	153	610 cfu/100mL for Secondary contact recreation subzones and fish culture subzones
Suspended Solids (mg/L)	0.101	0.144	0.033	0.047	7.5	6.74	Waste discharge shall neither cause the natural ambient level to be raised by more than 30% nor give rise to accumulation of suspended solids which may adversely affect aquatic communities.

Remarks: No available EPD monitoring result.

7.19 Residual Impacts

7.19.1 The modelling results indicated the SS and *E. coli* will be diluted very rapidly after being discharged into the marine water. It will not extend to either the ecological SRs and fisheries SRs for water quality, the recognised sites of marine conservation importance, or any of identified FCZs. Minor short-term impact, of SS to seawater intakes (except at Kennedy Town) is expected only when the storm discharge event occur.

7.20 Conclusion

7.20.1 Based on the sampling, analysis and modelling work carried out for the present study, the following is concluded.

7.20.2 Though the implementation of the recommended mitigation measures and management practices, it is anticipated that the impacts upon the SRs during the construction phase will be temporary and minimal.

7.20.3 By proper adoption of mitigation measures during the construction of the temporary pier, armour rock panel and stilling basin at the Western Portal, only short term impacts on the marine water quality is expected and will be restored once the work is finished. Therefore, only insignificant disturbance to the marine bed is expected. No significant impacts to the seawater intakes, coral community and FCZs arising from the construction phase are expected.

7.20.4 During operation phase of the proposed drainage tunnel, modelling results indicate no significant impact on the seawater intakes, coral community and fish culture zones when the 1 in 2 and 1 in 50 years storm events occur. Short term impact of suspended solids on the seawater intakes is considered to be negligible. The operators of the affected seawater intakes have been consulted regarding the potential impacts to the operation of the facilities. No adverse comments are received.

7.20.5 Monitoring of water quality should be carried out during the construction phase at the Eastern and Western Portals (including the temporary berthing facility, barging point, stilling basin, and spoil transfer points related to the tunnel boring) and at specific intake sites (including monitoring of groundwater levels) identified by AFCD. During the construction and the first year of operation phase, ground water monitoring will also be carried out to confirm the steadiness of the ground water table. It was recommended that regular audits of the implementation of the specified mitigation measures be carried out during the construction phase of the Project.

7.20.6 An Environmental Monitoring and Audit (EM&A) programme in respect of water quality issues during the construction will be carried out to monitor compliance with acceptable levels of water quality indicators and to ensure that the proposed mitigation measures are implemented and are effective. No monitoring is required during the operation phase of the proposed drainage tunnel.