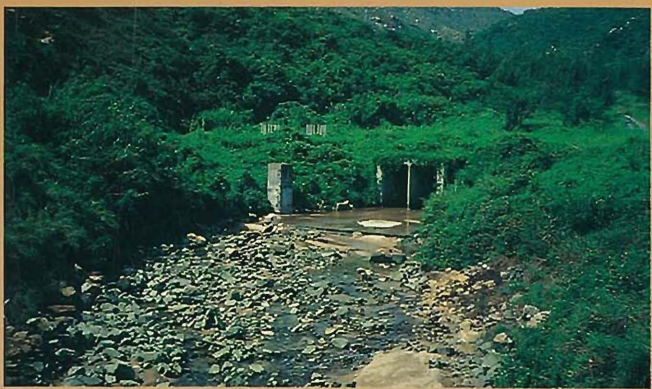
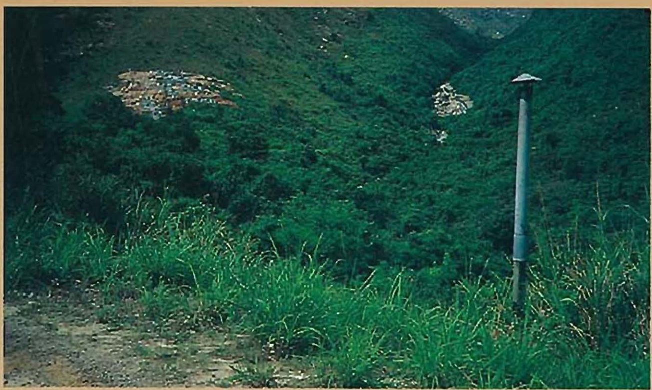
Hong Kong Government
Environmental Protection
Department



Restoration of North-West New Territories Landfills



Agreement CE 10/92

Initial Environmental Impact Assessment

Final Report

April 1995

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Agreement CE 10/92

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1. INTRODUCTION

Introduction

1.1 This Environmental Assessment (EA) was initiated in February 1994 as part of the Consultancy Study for Restoration of North-West New Territories Landfills Agreement No. CE 10/92. Details of the Brief for the EA are summarised in Chapter 2. The EA's primary objective has been to identify the key environmental issues arising out of the landfill gas management and utilisation, leachate management and restoration options proposed for the four landfill sites namely Pillar Point Valley Landfill (PPVL), Siu Lang Shui Landfill (SLSL), Ma Tso Lung Landfill (MTLL) and Ngau Tam Mei Landfill (NTML). Where appropriate, the EA process has identified the anticipated mitigation measures which will be incorporated into the restoration design of each landfill, including leachate and landfill gas control measures, and made necessary recommendations on short and long-term environmental monitoring and audit requirements. The results of this EA are addressed in the Initial Environmental Impact Assessment (IEIA) Report.

Background

1.2 PPVL and SLSL are situated near Tuen Mun whilst MTLL and NTML are located north of Yuen Long. SLSL, MTLL and NTML are closed but PPVL is still in operation.

1.3 PPVL is located in Area 46 of Tuen Mun New Town. Access to PPVL and SLSL is obtained off the Lung Mun Road which leads to Castle Peak Power Station. Prior to November 1993 when WENT Landfill started to accept waste intake, it was the only waste disposal facility for the West New Territories. The northern part of the site and the borrow area located to the west extend into the British Forces' Castle Peak Firing Range. The landfill has been in operation since August 1983, and is currently (ie in February 1994) receiving about 2,500 tonnes per day of domestic, industrial, construction and special waste. The amount of waste deposited up to August 1993 was about 6.8 Mt and the projected final volume is 13 Mt which includes the proposed extension from the original design capacity of 8 Mt. To accomplish this, it is planned to extend the landfill higher and further into the Castle Peak Firing Range with maximum height reaching approximately 225 mPD. The levels in April 1993 were about 130 mPD.

1.4 PPVL is a typical Hong Kong valley landfill in which the valley floor has been progressively lined and leachate collection pipes have been installed above the liner to direct the leachate flow to the nearby Pillar Point Sewage Treatment Works. The natural valley sides were trimmed to firm material, covered with sprayed concrete, and coated with a bituminous emulsion before waste was placed.

1.5 The other three landfills have been closed for between 10 and 20 years. The total quantity of waste deposited in the three landfills amounted to approximately 1.4 million tonnes and is largely composed of domestic and industrial wastes.

1.6 SLSL is located about 1km west of PPVL, and occupies an area of 12 ha. It has been successfully re-afforested since it was closed in 1983. From 1978 to 1983 1.2 Mt of domestic and industrial waste was deposited in the landfill. A platform to the NW of the site was also used as a disposal area for PFA from China Light & Power Castle Peak Power Station. Two overgrown filtration tanks are visible to the south-east and south-west of the site. Leachate discharges into the culverted stream and contaminated groundwater discharges onto the beach.

1.7 MTLL is located near the Chinese border closed area. The landfill site is only 2 ha and occupies the side of a valley, adjacent to a sports ground operated by Community Sports Ltd. Waste disposal of about 180,000 tonnes of domestic and industrial waste took place from 1976 to 1979. The upper two platforms on the site are poorly re-vegetated and are being used by a crude compost manufacturer at the time of the study. Some leachate seepages have been found on the north-east and south-east slopes which are covered with patches of wild shrubs and grasses. A land exchange with the Tung

Wah Group of Hospitals has been proposed and landfill gas investigations were commissioned by them in 1991.

1.8 NTML is a heavily overgrown site, located north-east of Yuen Long, and occupies a 2 ha area at the head of a narrow valley surrounded by ridgelines. Records indicate that the site was operated as an uncontrolled dump prior to 1973. After 1973 controlled landfilling took place up to 1975, and an estimated 30,000 tonnes of additional domestic and industrial waste was deposited on top of the waste already in place. The volume of waste in place based on the site area and waste depths measured in previous studies, has been estimated as 180,000 cu m. An overgrown filtration tank is clearly visible at the southern entrance to the site. At NTML no liner was installed and only rudimentary leachate collection arrangements were provided. Some residential dwellings, and a considerable number of graves lie within the adjacent areas. The site lies within a Green Belt area in the Ngau Tam Mei Development Permission Area and represents a good opportunity for a variety of sporting activities and afteruse developments.

Context of the Environmental Assessment

1.9 Restoration of the landfills has the potential to benefit the local community and improve the overall environment of the North-West New Territories area. However, the restoration of landfills also has the potential to cause, or be sensitive to, environmental impacts. Consequently, Government procedures require that an environmental assessment be conducted to determine the type and severity of the environmental impacts of the restoration proposals.

1.10 By carrying out an Environmental Assessment (EA) key environmental issues of concern can be identified at an early stage and essential information supplied to the design process. The incorporation of environmental considerations into the feasibility/planning procedure will allow for the design, construction, commissioning and afteruse stages of the development at the four landfills to be managed within the restraints of Government regulations and guidelines.

1.11 In conducting this Environmental Assessment reference has been made to relevant Ordinances and Technical Memoranda on the environment and the Hong Kong Planning Standards and Guidelines (HKPSG).

2. SCOPE OF ASSESSMENT

2.1 This chapter introduces the general process of environmental assessment and the scoping of this assessment. It also describes the approach used for selecting those issues of concern that have been examined in the later stages of study.

The Environmental Assessment Process

2.2 Environmental Assessment (EA) is a process which seeks to predict or forecast the effect that development actions will have on the natural and built environment. The general approach involves consultation and scoping followed by baseline studies of the existing environmental conditions, impact prediction, consideration of mitigation measures and the identification of monitoring and audit requirements.

2.3 Before potential impacts can be predicted, the existing environmental conditions must be defined. It is then possible to assess any changes which may occur as a result of a development. Environmental conditions may change over time and these must be evaluated as part of the EA process. In assessing the significance of any impact reference should be made to the magnitude and significance of effects, to the environmental sensitivity of nearby receptors, and to quantify thresholds and indicative criteria within government ordinances and policy guidelines. Where quantifiable criteria are not available, best expert judgement must be applied.

2.4 Where a proposal is evaluated to have a significant adverse impact on the environment, it is necessary to identify measures which will reduce or eliminate such impacts. These mitigation measures may either involve altering the design operation of the development, or may require the introduction of particular safeguards in order to ameliorate effects.

Scope of Assessment

2.5 The EA of the restoration proposals has involved a review of all available information pertaining to the existing environmental conditions within the study area. This information has been assessed in conjunction with the engineering proposals for the restored facilities.

Requirements of the Brief

2.6 In accordance with the requirements of the brief, the EA addresses the following:

- environmental impact of restoration works and land use options, during construction and operation phases, with particular reference to dust and noise producing activities;
- environmental impact of landfill gas and leachate control measures, in particular air quality impacts arising from each gas utilisation or management scheme with respect to volatile organic compounds (VOCs) and odour;
- environmental impact of leachate on adjacent water courses and their sensitive receivers at each landfill site;
- environmental and visual impacts associated with the recommended landscape proposal;
- identification of mitigation measures (including both conceptual design features and operational controls) to be used to reduce potential impacts;
- potential health and safety aspects of the high tension power lines that cross the sites;

- a review of existing environmental monitoring data (leachate, landfill gas, groundwater, surface water, marine water and sediments, air quality and ground settlement) and recommendations for baseline data collection, long-term environmental monitoring and audit requirements; and

- identification of the key environmental impacts/issues of concern which should be addressed in Final Report.

Consultation

2.7 The scoping exercise, conducted as part of the study, included early consultation with various government departments. This consultation process identified the need for:

- Restoration afteruse options for each of the landfill sites to meet the overall planning objectives and integration of the restoration proposals with associated residential, commercial and industrial developments in the adjacent planning zones;

- Leachate control measures at the landfill sites and monitoring programmes for assessment of leachate impacts on adjoining streams and underground water courses;

- Landfill gas management measures and utilisation options for local industrial/commercial use;

- Aspects of geotechnical stability, surface water drainage, existing capping design as well as waste characteristics and landfill operational details to be identified; and

- Sources of information and monitoring requirements for potential landfill gas and volatile organic compound impacts to be identified.

Review of Background Information

2.8 A review of all relevant information on the four landfills and adjacent developments within the study area has also been undertaken. The main documents reviewed include:

- Scott Wilson Kirkpatrick, March 1993, Restoration of North-West New Territories Landfills Study - Hazard Assessment. Environmental Protection Department.

- L.G. Mouchel & Partners (Asia) Ltd. (1990), North-East New Territories Landfill Leachate Disposal Study. Final Report- Volume 1. Environmental Protection Department.

- Nash J.M. (1988). A Review of Leachate Collection an Disposal Arrangements at Operating and Completed Landfills. Report No. EPD/ITP 15/88. Environmental Protection Department.

- ERL (Asia) Ltd (1989). Ma Tso Lung Landfill Gas Study. Final Report. Tung Wah Group of Hospitals.

- ERL (Asia) Ltd (1991). Ma Tso Lung Site Investigation - Landfill Gas. Simon Kwan and Associates Limited.

- Scott Wilson Kirkpatrick. Restoration of North-West New Territories Landfills Study - Technical Note TN1 Landfill Stability and Settlement, July 1993. Environmental Protection Department.

- Scott Wilson Kirkpatrick. Restoration of North-West New Territories Landfills Study - Working Paper WP1 Landfill Gas Management and Air Quality Control, August 1993. Environmental Protection Department.

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- Scott Wilson Kirkpatrick. Restoration of North-West New Territories Landfills Study - Working Paper WP5 Master Development Plans, Contract Options and Implementation Programme, November 1993. Environmental Protection Department.

- Scott Wilson Kirkpatrick. Restoration of North-West New Territories Landfills Study - Working Paper WP6 Conceptual Restoration Design, December 1993. Environmental Protection Department.

- Scott Wilson Kirkpatrick. Restoration of North-West New Territories Landfills Study - Working Paper WP7 Environmental Assessment, February 1994. Environmental Protection Department.

- Environmental Protection Department (1988). A Brief Assessment of Landfill Gas Reserves.

- Environmental Protection Department (1992). Report No. EPD/TP9/92 - Environmental Assessment of the Proposed Pillar Point Valley Landfill Extension.

- Civil Engineering Office, Engineering Development Department (1984). Data Report No. 1 on Controlled Tip Monitoring (1974 - 1984 inclusive).

- Scott Wilson Kirkpatrick (1990). Expanded Development Study for Tuen Mun Area 38 - Final Report. Territory Development Department, Tuen Mun Development Office.

- ERL (Asia Ltd) (1992). Centralised Incineration Facility for Special Wastes - Phase I, Feasibility Report. Environmental Protection Department.

- Scott Wilson Kirkpatrick (1993). Restoration of North-West New Territories Landfill Study - Pillar Point Valley Landfill Interim Environmental Measures, May 1993. Environmental Protection Department.

Issues of Concern

2.9 From the initial appraisal of information and early consultations described above it has been possible to identify those development actions likely to cause environmental effects, and those aspects of the environment most likely to be affected. The likely significant effects of the restoration proposals relate to the following key issues:

- Landfill gas;
- Air quality;
- Noise;
- Water quality;
- Landscape, landuse and visual impacts;
- Settlement; and

- High tension power lines.

2.10 Each of these issues have been addressed with respect to each of the four landfill sites in the following chapters. Specific recommendations for monitoring and audit requirements are also provided for each of the development phases (ie design, construction, operation/afteruse).

2.11 The original Brief for the study did not require an ecological assessment to be carried out. However, more recently it has been recognised that ecological impacts of the restoration works should be addressed as part of this IEIA. The consultants have therefore provided preliminary comments on the net ecological impacts of the restoration works, based on the conceptual restoration schemes.

3. ENVIRONMENTAL LEGISLATION AND GUIDELINES

3.1 This chapter provides an outline of the local environmental legislation and guidelines for landfill gas, air quality, noise and water quality. The compliance of individual environmental parameters with these requirements is covered in the following chapters of this report.

Landfill Gas

3.2 A significant piece of legislation which governs LFG utilisation is the Gas Safety Ordinance 1990 (Cap 51). It requires that LFG extraction and utilisation systems should be designed, constructed and operated by a company registered under the Ordinance.

3.3 LFG is covered by the Ordinance by being included in the definition of "synthetic natural gas". The six sets of subsidiary Regulations enacted for the Ordinance are as follows:

- Gas Quality;
- Gas Supply;
- Installation and Use;
- Miscellaneous;
- Registration of Gas Installers and Gas Contractors; and
- Registration of Gas Supply Companies.

3.4 To satisfy the Gas Quality Regulations, which are enforced by the Electrical and Mechanical Services Department (EMSD), the supply of LFG off-site should meet a minimum standard of purity. The maximum proportion of sulphur permitted must not exceed 5 milligramme (mg) of hydrogen sulphide (H_2S) per standard cubic metre of gas.

3.5 Under the Gas Supply Regulations the extraction plant and the supply of LFG are defined as a "notifiable gas installation" (NGI), and would therefore need to comply with all legal requirements for NGIs. Consequently, the site operator will need to be a Registered Gas Supply Company and the owner of the NGI will have to seek approval for the construction and use of the installation from the Gas Authority (i.e. EMSD). It is possible, however, that an LFG extraction system may be granted an exemption if only a simple gas extraction and flaring system is to be constructed and the site is not accessible to the general public.

3.6 Another specific piece of legislation influencing LFG utilisation is the Electricity Safety Ordinance 1990 which regulates the supply of electricity into the grid. This legislation is relevant where generation of electricity from LFG with subsequent supply to the grid is proposed.

Air Quality

Statutory Limits

3.7 The Air Pollution Control Ordinance (APCO) (Cap. 311) provides powers for controlling air pollutants from a variety of stationary sources, including fugitive dust emissions from construction sites. It empowers the Hong Kong Government to declare Air Control Zones (ACZs) and establish a number of stationary Air Quality Objectives (AQOs), which are listed in Table 3.1. The Fuel Restriction Regulations, which limit the sulphur fuel content in fuel oil to 0.5%, were enacted in 1990.

Table 3.1 : Hong Kong Air Quality Objectives

Pollutant	Average Time				
	1 hour	8 hour	24 hour	3 months	1 year
Sulphur dioxide	800	-	350	-	80
Total Suspended Particulates	-	-	260	-	80
*Respirable Suspended Particulates	-	-	180	-	55
Nitrogen Dioxide	300	-	150	-	80
Carbon Monoxide	30,000	10,000	-	-	-
Photochemical Oxidants (as ozone)	240	-	-	-	-
Lead	-	-	-	1.5	-

Notes:

1. *All concentrations in micrograms per cubic metre (mg m^{-3}), measured at 298°K (25°C) and 101.325 kPa (one atmosphere).*
2. *1 hour concentrations not to be exceeded more than three times per year.*
3. *8 and 24 hour concentrations not to be exceeded more than once per year.*
4. *3 month and 1 year concentrations are arithmetic means.*
5. **Respirable suspended particulates (RSP) means suspended particles in air with a nominal aerodynamic diameter of 10 microns (mm) or less.*

Guidelines

3.8 There are two guidelines which control the impact of dust and odour on the environment. An hourly average of total suspended particulates of 500 µg/m^3 has been applied as a guideline limit to construction activities in the Territory. This limit typically applies to the site boundary and/or the nearest receiver.

3.9 A limit of 2 odour units is recommended by EPD for potentially offensive installations. 2 odour units at the site boundary corresponds to a concentration of twice the odour detection threshold of known odorous chemicals.

Volatile Organic Compounds

3.10 Landfill gas contains trace concentrations of a group of substances collectively known as volatile organic compounds (VOCs). Some of these can result in odour, or are toxic or carcinogenic. Their reliable sampling and analysis is difficult and expensive. Nonetheless, concern has been expressed about VOC emissions from landfills, and their impacts have been assessed.

3.11 Table 3.2 lists all the relevant data of which the Consultants are aware from other landfills in Hong Kong. In the absence of other data, this may be used for comparative purposes.

Table 3.2 : VOC Levels Measured at Other Landfill Sites in Hong Kong ($\mu g\ m^{-3}$)

Contaminant	SENT	WENT	Shuen Wan
Vinyl Chloride	nd	nd	8.83 (6.5-11.4)
Benzene	1.4 (0.8-1.7)	0.4 - 15.2	7.38 (2.1-19.0)
1,2-Dibromoethane	nd	nd	0
1,2-Dichloroethane	7.5 (0.3-14.7)	nd	0.08 (0-0.03)
Dichloromethane	4.5 (0.6-10.8)	nd	*
Tetrachloroethylene	*	nd	6.03 (2.3-11.0)
1,1,1-Trichloroethane	2.3 (0.3-10.3)	1.8 - 8.7	3.13 (1.3-6.6)***
Trichloroethylene	0.4 (0.3-0.4)	nd	2.15 (1.7-3.0)
Trichloromethane	nd	nd	1.20 (0.1-3.2)
Tetrachloromethane	nd	nd	*

nd - *not detected*
* - *no data*
*** - *based on two readings, other values are based on four readings*
Monitoring was carried out at SENT and WENT Landfills prior to landfill operation.
At Shuen Wan Landfill the monitoring was carried out while the landfill was still in active operation.

3.12 Based on studies and guidelines from the USA, EPD has identified 10 compounds which require special consideration. These are known as Specified Air Contaminants (SACs). These 10 compounds have been selected because of their known or suspected carcinogenic effects. Table 3.3 lists typical concentration of various Specified Air Contaminants (SACs) (Ref 3.1, 3.2, 3.3).

Table 3.3 : Typical VOC Levels in Ambient Air for Specified Air Contaminants ($\mu g\ m^{-3}$)

Contaminant	Rural Area+	Urban+	Landfill++	WHO+++
Vinyl Chloride	0 (0)	0 (0)	*	
Benzene	1.5 (0.467)	5.8 (1.812)	10.5 (3.3)	3 - 160
1,2-Dibromoethane	0 (0)	0 (0)	0.15 (0.02)	
1,2-Dichloroethane	0 (0)	0.05 (0.012)	0 (0)	0 - 1.0
Dichloromethane	0.19 (0.054)	2.9 (0.840)	5.5 (1.58)	< 15
Tetrachloroethylene	0.07 (0.01)	2.5 (0.370)	*	1 - 10
1,1,1-Trichloroethane	0 (0)	0.69 (0.11)	0.13 (0.02)	
Trichloroethylene	*	*	7.1 (1.29)	
Trichloromethane	*	*	1.8 (0.34)	2 - 50
Tetrachloromethane	0 (0)	0.29 (0.06)	0.59 (0.12)	0.1 - 0.5**

* - *no data*
\+ - *daily average*
\++ - *average*
() - *ppb (parts per billion)*
\+++ *WHO reported levels*
** - *estimate*

3.13 A range of different air quality standards for SACs are used. Table 3.4 lists standards which are useful for reference, but no specific standards for VOCs have been established in Hong Kong.

Table 3.4 : Air Quality Standards (µg m^{-3})

	NYS-ALL[1]	OEL/100[2]	WHO[3]
Vinyl Chloride	0.4 (0.16)	175	*
Benzene	105.3 (33)	160	*
1,2-Dibromoethane		40	
1,2-Dichloroethane		400	700
Dichloromethane		3500	3000
Tetrachloroethylene		3350	5000
Tetrachloromethane		126	
1,1,1-Trichloroethane	38237 (7000)	19000	
Trichloroethylene	899 (167)	5350	1000
Trichloromethane		98	

nd *not detected*
() *ppb*
1 *Acceptable ambient levels of New York State (NYS-ALL) (Ref 3.4)*
2 *Occupational Exposure Levels (OEL), Health & Safety Executive, UK (Ref 3.5) (8-hour time weighted average).*
3 *World Health Organisation (WHO) Guideline (Ref 3.2) (24-hour average) (referring to non carcinogenic effects)*
* *According to WHO no safe airborne level can be recommended*

3.14 The 10 SACs and their associated cancer unit risk factors, as published by the USEPA Interpreted Risk Information System (IRIS), are listed in Table 3.5. Unit risk factors are defined as the estimated probability of a person contracting cancer as a result of constant exposure to an ambient concentration of 1 µg/m^3 over a 70 year lifetime.

Table 3.5 : Specified Air Contaminants and Associated Carcinogenic Risk Factor

Contaminant	Unit Cancer Risk $(\mu g/m^3)^{-1}$
Vinyl Chloride	8.4×10^{-5}
Dichloromethane	4.7×10^{-7}
Trichloromethane	2.3×10^{-5}
1,1,1-Trichloroethane	-
1,2-Dichloroethane	2.6×10^{-5}
Benzene	8.3×10^{-6}
Tetrachloromethane	1.5×10^{-5}
Trichloroethylene	3.7×10^{-6}
1,2-Dibromoethane	2.2×10^{-4}
Tetrachloroethylene	-

Notes

Unit Cancer Risk factors are not available for 1,1,1-Trichloroethane and Tetrachloroethylene and therefore are not included in this assessment.

Noise

3.15 The Noise Control Ordinance 1988 (NCO) (Cap. 400) was gazetted and implemented in Hong Kong in 1988 and provides a framework from which specific Regulations, Guidelines and Technical Memoranda have been produced. Of particular relevance to this study are the following documents produced by EPD:

- The Hong Kong Planning Standards and Guidelines. Environmental Guidelines for Planning in Hong Kong (Ref 3.6);
- Technical Memorandum on Noise from Construction Work other than Percussive Piling (Ref 3.7);
- Technical Memorandum on Noise from Percussive Piling (Ref 3.8); and
- Technical Memorandum for the Assessment of Noise from Places other than Domestic Premises, Public Places or Construction Sites (Ref 3.9).

3.16 Under the NCO, the acceptable noise levels (ANLs) for construction work (excluding percussive piling), are specified in the "Technical Memorandum on Noise from Construction Work other than Percussive Piling" (Ref. 3.7). For general construction work, restrictions are imposed during the evening (1900 to 2300 hrs), night-time (2300 to 0700 hrs), Sundays and public holidays. The Basic Noise Levels (BNLs) for general construction noise, as defined in this Technical Memorandum, for Area Sensitivity Ratings (ASR) A, B, C are given in Table 3.6.

Table 3.6 : Acceptable Noise Levels for Construction Works

Time Period	ANL (dB(A)) ASR		
	A	B	C
All days during the evening (1900-2300 hours), and holidays (including Sundays) during the day-time and evening (0700 - 2300 hours)	60	65	70
All days during the night-time (2300-0700 hours)	45	50	55

3.17 For construction work involving percussive piling provision is made for noise control under the NCO. Normally piling is prohibited between 1900 and 0700 hrs and on public holidays, unless special permission is granted. Between the hours of 0700 and 1900 hours, piling is allowed under permit, subject to noise level limits. In the event of work being carried out near to Noise Sensitive Receivers (NSRs), noise mitigation measures are necessary and limitations are imposed upon the permitted hours of working. The Acceptable Noise Levels (ANLs) for percussive piling are shown in Table 3.7.

Table 3.7 : Acceptable Noise Levels (ANL) for Percussive Piling

NSR Window Type or Means of Ventilation	ANL (dB(A))
a. NSR (or part of NSR) with no windows or other openings	100
b. NSR with central air conditioning system	90
c. NSR with windows or other openings but without central air conditioning system	85

3.18 Assuming that NSRs at the landfill sites are in the most sensitive category specified in the Technical Memoranda (Ref 3.8), the ANL is 85 dB(A) with the permitted hours of operation given in Table 3.8. These are based on the extent to which the Corrected Noise Level (CNL), at the NSR, exceeds the ANL.

Table 3.8 : Permitted Hours of Operation for Percussive Piling

Amount by which CNL exceeds 85 dB(A) at NSRs	Permitted hours of operating on any day not being a general holiday
More than 10 dB(A)	0800 to 0900 1230 to 1330 1700 to 1800
Between 1 dB(A) and 10 dB(A)	0800 to 0930 1200 to 1400 1630 to 1800
No exceedance	0700 to 1900

3.19 The NCO provides statutory provision for noise control from specific sources in the "Technical Memorandum for the Assessment of Noise from Places other than Domestic Premises, Public Places or Construction Sites". If the NSRs in the vicinity of landfill sites are given the highest sensitivity rating the applicable ANLs are shown in Table 3.9.

Table 3.9 : Acceptable Noise Levels for NSRs of the Highest Sensitivity Rating

Time Period	ANL (dB(A)) Area Sensitivity Rating:A
Day (0700 to 1900 hours)	60
Evening (1900 to 2300 hours)	60
Night (2300 to 0700 hours)	50

3.20 The Hong Kong Planning Standards and Guidelines (HKPSG) state that in order to plan for a better environment a new noise source should be located and designed so that the noise level at the NSR should be either at least 5 dB(A) below the ANL presented in Table 3.9, or no higher than the background noise level if the latter is not less than 5 dB(A) below the ANL. In no case should operational noise exceed 60 dB(A) during the day and 50 dB(A) at night.

Water Quality

3.21 The Water Pollution Control Ordinance (WPCO) which was enacted in 1980 and amended in 1990 (Cap. 358) is the principal legislation governing water quality in Hong Kong. The Ordinance declares Water Control Zones (WCZs) which cover the whole of Hong Kong and allows the establishment of Water Quality Objectives (WQOs) for each zone in order to promote the conservation and best use of the waters in the public interest. PPVL and SLSL lie within the North Western WCZ, while MTLL and NTML lie within the Deep Bay WCZ. These were designated in April 1992 and December 1990 respectively. The water quality objectives (WQOs) for North Western WCZ and Deep Bay WCZ are given in Tables A1.1 and A1.2 of Appendix 1 respectively.

3.22 To meet the relevant objectives, the Authority (i.e. EPD) control the quality and quantity of the effluent discharged by means of licensing. The "Technical Memorandum on Effluent Standards" (TMES) (Ref 3.10) is used as a guide by the Authority to set the quality and quantity limits for effluents discharged to foul sewers, storm water drains, inland and coastal waters. The relevant parts of the TMES, in relation to the four landfill sites, are reproduced in Tables A1.3 to A1.6 of Appendix 1. The appropriate standards from effluents discharged from the four landfill sites are identified in Table 3.10.

Table 3.10 : EPD Requirements for Effluents Discharged from the Four Landfill Sites (Ref. 3.10)

Landfill Site	Proposed Leachate Treatment Facilities	Standards for Effluents Discharge to Sewage Treatment Facilities (Ref 3.10)	Appropriate Effluent Control Categorization
PPVL	On-site leachate treatment plant (jointly with SLSL)	Effluents to foul sewers leading into Government sewage treatment plants (Table 1)**	Coastal Water Group IVa (North Western Inshore) (Table 10a)**
SLSL	On-site leachate treatment plant (jointly with PPVL)	Effluents to foul sewers leading into Government sewage treatment plants (Table 1)**	Coastal Water Group IVa (North Western Inshore) (Table 10a)**
MTLL	tanker effluent* to a leachate treatment plant elsewhere	Effluents to foul sewers leading into Government sewage treatment plants (Table 1)**	Inland Water Group C (Pond fish culture) (Table 5)**
NTML	tanker effluent* to a leachate treatment plant elsewhere	Effluents to foul sewers leading into Government sewage treatment plants (Table 1)**	Inland Water Group B (Irrigation) (Table 4)**

Note: * *leachate should be tankered for treatment and disposal at an appropriate facility at which standards for the discharge of effluents to foul sewers should be met*

** *refer to the tables given in TMES as reproduced in Appendix 1*

References

3.1 Shah J J and Heyerdahl, 1988, National Ambient Volatile Organic Compounds (VOCs) Data Base Update, EPA/600/3-88/010a.

3.2 World Health Organisation, 1987, Air Quality Guidelines for Europe, European Series 23, WHO Regional Publications.

3.3 La Regina J and Bozzelic J W, Volatile Organic Components (VOCs) at Hazardous Waste Sites and a Sanitary Landfill in New Jersey, Environmental Progress Vol 5(I).

3.4 Commission of the European Communities, 1992, Landfill Gas from Environment to Energy, Luxembourg.

3.5 Health & Safety Executive, 1993, Occupational Exposure Limits, Guidance Note EH40.

3.6 Environmental Guidelines for Planning in Hong Kong. An Extract from the Hong Kong Planning Standards & Guidelines. Hong Kong Government. April 1991.

3.7 Technical Memorandum on Noise from Construction Work other than Percussive Piling, January 1989. Environmental Protection Department.

3.8 Technical Memorandum on Noise from Percussive Piling. July 1991, Environmental Protection Department.

3.9 Technical Memorandum for the Assessment of Noise from Places other than Domestic Premises, Public Places or Construction Sites. July 1991, Environmental Protection Department.

3.10 Technical Memorandum. Standards for effluents discharged into drainage and sewerage systems, inland and coastal waters. January 1991, Environmental Protection Department.

4. PILLAR POINT VALLEY LANDFILL

Study Area

Site description

4.1 PPVL is the largest of the four landfills with an area of about 53 hectares when fully developed. The landfill is situated in a valley in a longitudinal shape, south of the British Forces' Castle Peak Firing Range and north of Lung Mun Road (Figure 4.1). It has been in operation since August 1983, and at present receives about 2,500 t/day of domestic, industrial, construction and special waste. The amount of waste deposited up to August 1993 was about 6.8 million tonnes and the projected final volume is 13 million tonnes with the proposed extension. Adjacent to the landfill to the west is a triangular-shaped borrow area with an area of about 41 hectares.

4.2 The existing landfilling activities take place largely on the western part of the site. Hydro-seeding and slope-filling works are currently taking place on the central and eastern parts of the landfill site. When landfilling work is completed, the resulting landform will include one platform of about 4 hectares located at 225 m above sea level (mPD), on the eastern side of the site. The rest of the site will have steep slopes extending outward from this platform towards the west and the south.

4.3 Adjacent to the landfill to the east is a high mountain ridge running from north to south with steep slopes. The Castle Peak mountain range extends to the north and west of the landfill. The Castle Peak Firing Range is adjacent to the landfill and covers the northern portion of the landfill site. Temporary uses extending to the south of the landfill include the Engineer's site office, Contractor's site office, the Pillar Point Vietnamese Refugee Camp and temporary open storage for containers.

4.4 The site has been developed as a containment landfill, with a leachate collection system leading to a sewer discharge, and groundwater collection beneath the basal liner. Surface seeps of leachate have developed both from perched leachate and from the toe of the landfill, together with some possible inflow of contaminated groundwater to a stream.

Environmental setting and land uses

4.5 PPVL is bounded by steep slopes on the east and the west. A stream drains southward towards the coast about 500 m away from the landfill site. The site is currently zoned as Green Belt and is located within the draft Tuen Mun Outline Zoning Plan No. S/TM/8. With the exception of Pillar Point Vietnamese Refugee Camp located at the south fringe area, there are no significant residential dwellings within the 250 m consultation zone. To the south-east of the site, a crematorium, columbarium and funeral services centre is proposed within an area of fung shui woodland planting. Two power lines cross PPVL, and also pass over SLSL nearby.

4.6 Outside the study area, there is a planned reclamation of about 125 hectares in Area 38, between the existing China Cement Plant in the west and the Pillar Point Sewage Treatment Works in the east. The plan also includes the development of a Special Industries Area (55 ha) situated to the south of SLSL, and a River Trade Terminal (56 ha) to the south of PPVL at Area 38. Subject to the implementation programme of the development, which has yet to be confirmed, the River Trade Terminal and the Special Industries Area will be in full operation in 1997 and 1999, respectively. A Centralised Incineration Facility (CIF) is proposed about 2 km to the east of PPVL, and a laundry for Queen Elizabeth Hospital at Area 40 to the south of PPVL is at the planning stage.

4.7 Regarding future on-site development at PPVL, a dual 3-lane trunk road crossing the southern part of PPVL and an LRT extension route running alongside the trunk road have been proposed to be built after 2009 and 2011 respectively. About half of the upper platform falls within the boundary of the Castle Peak Firing Range at the north end of the site.

Restoration Proposal

Introduction

4.8 A description for the preferred restoration option for PPVL is provided in this section. An outline of measures for the management of leachate and landfill gas, and ways in which landfill gas could be utilised are also described.

Restoration constraints and opportunities

4.9 An examination of land use and landscape issues has led to various restoration options being proposed for PPVL. The constraints and opportunities on the restoration development of PPVL are summarised in Table 4.1 below.

Table 4.1: Constraints and Opportunities for the Restoration of PPVL

Constraints	Opportunities
1. Transmission cable within site	1. Large site area (53 ha)
2. Port trunk road alignment cuts across southern part of site	2. Significant platform area (4.3 ha), though irregular shape
3. Pylons immediately adjacent to site	3. Southern tip is natural land offering building potential
4. Difficult terrain	4. Adjacent borrow area has building potential though topography is difficult and not within site area
5. Castle Peak Firing Range to north	5. Sea views
6. Distant from residential areas	6. Road access for bus/minibus services
7. Special Industrial Area and River Trade Terminal to south	7. Potential for spectacular, well managed landscape setting
8. Settlement problems	8. Landfilling not completed, thereby offering some scope for change in topography
9. Leachate and landfill gas emission	
10. Landfill cap needs to be protected	

4.10 Certain broad environmental quality objectives were identified and incorporated into the selection of the restoration options. These objectives were derived from the planning policy, physical constraints and opportunities of the site, and user demand and market interest. Objectives can be summarised as follows:

- optimise landscape setting of the site;
- maximise physical attributes of the site including topography, microclimate, etc;
- minimise the long-term visual impact of the landfill site;
- promote environmentally sustainable land uses; and

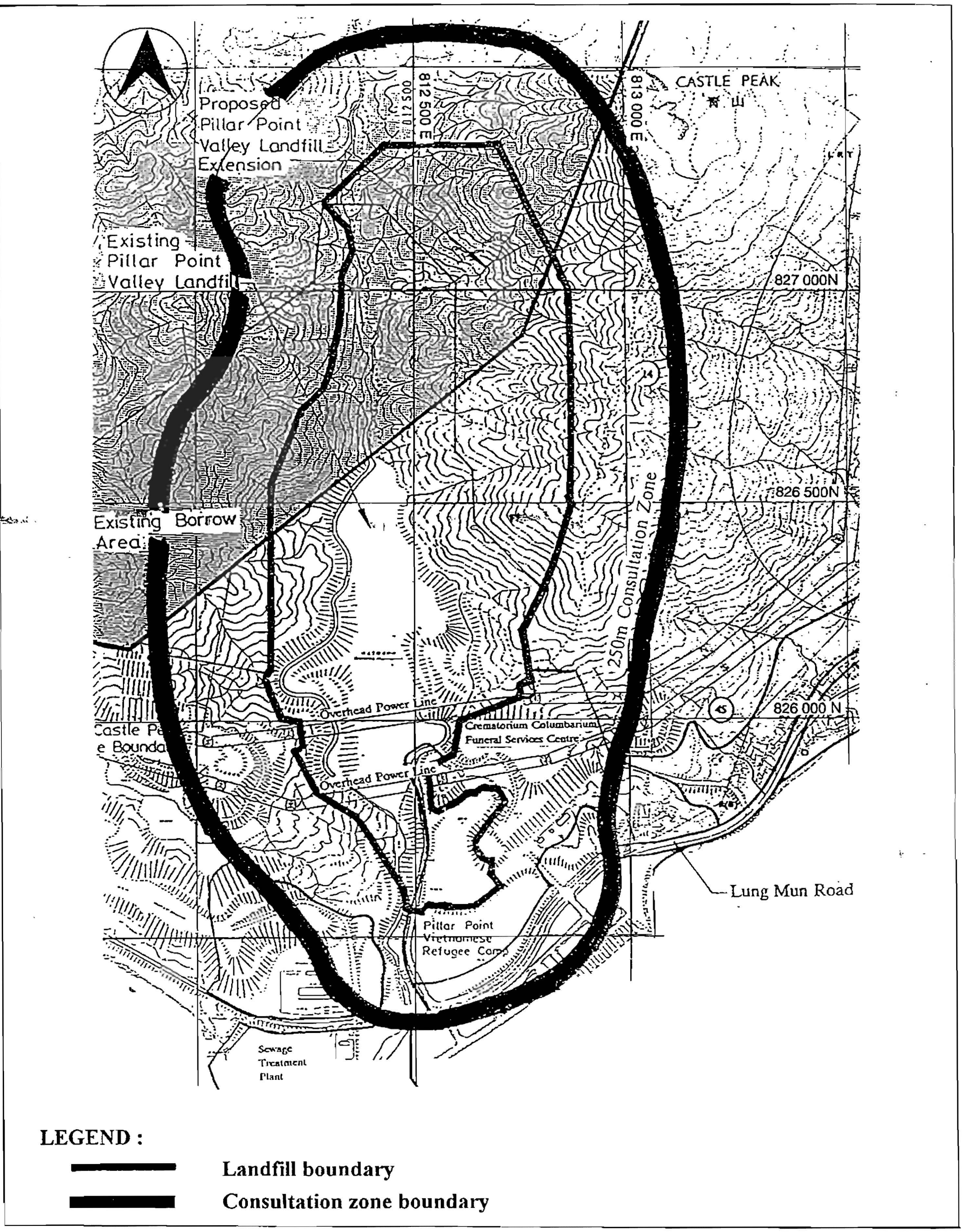


Figure 4.1

Pillar Point Valley Landfill

Landfill and Consultation Zone Boundary

- develop afteruses within the context of the draft Tuen Mun Outline Zoning Plan (OZP) No. S/TM/8;

Afteruse option

4.11 The preferred afteruse recommended for PPVL is afforestation of the slopes with associated hiking trails and viewing areas, as shown in Figure 4.2. This option focuses on outdoor recreational activities and also blends in with and enhances, the natural local topography and final contours of the landfill surface. There are four small platforms within the site and south of the landfilled area which could be suitable as a plant nursery. One platform area will be needed for siting the gas extraction plant. An area currently used for stockpiling soft material has been identified for the location of a leachate treatment plant.

- compatibility with the zoning of the site as " green belt " on the draft Tuen Mun OZP;
- a regard to the requirement that about half of the upper platform on the site will revert back to military ownership upon completion of landfilling;
- provision of a suitable mix of plant species and appropriate planting conditions to achieve effective establishment of vegetation; and
- progressive restoration of the site to minimise its long term visual impact.

Planting proposal

4.12 Figure 4.2 represents the condition of PPVL as planting progresses in accordance with the existing four-phase programme administrated by TDD/Tuen Mun. The first phase of planting started in 1993 and the last phase will be completed in 1998. The restoration of PPVL includes installation of capping layer, hydroseeding and tree planting as well as the installation of other structures for landfill gas and leachate control measures.

4.13 Capping of the landfill site forms an integral component of the restoration, in that it provides a major element in landfill gas and leachate management, by containing and enabling control of the former, and by reducing the volumes generated of the latter.

4.14 The recommended capping layer for PPVL includes the following components, and is illustrated in Figure 4.3:

- Final intermediate cover: to be placed by CED under their existing contracts. This should have a minimum thickness of 500 mm above the waste;
- Protection layer: this should be a fine grained material free from stones or other sharp particles and should be at least 150 mm thick. Alternatively a suitable protective geotextile may be used;
- Geomembrane: this should be a flexible membrane with properties compatible both with the expected magnitude of settlements and stability requirements.
- Geodrain: this material should comprise a synthetic drainage net, surrounded by suitable geotextile filters. This will then serve a combined function in both protecting the geomembrane and in providing sub-soil drainage, thus reducing the potential for a head of water to build up on the geomembrane; and
- Soil layers: soil layers should be a minimum of 1,000 mm thick comprising 850 mm cdv or cdg with the top 150 mm being an appropriate topsoil mix. In tree areas the soil layer should comprise a minimum of 1,500 mm full cdv or full cdg, where trees are planted in pits with appropriate topsoil mix. However, alternative designs for the cap may be equally acceptable, to take account of the latest developments in landfill cap design.

Settlement and slope stability

4.15 As a considerable proportion of settlement is expected to take place in the first few years following landfill completion, no heavy structures should be built directly on areas where waste has been deposited. The foundation design of roads, pathways and view point pavilions should be designed to accommodate the effects of differential settlement. Any structure should be light weight and designed to withstand typhoon conditions. To enhance the stability of the proposed cap, the layers of cdv/cdg and granular material should be compacted. To retain an adequate factor of safety, restored areas; for the purpose of this feasibility assessment, generally should have a gradient not greater than 1(V):4(H), although restricted and localized undulations in the site profile, up to a maximum of 1(V):3(H) would be acceptable.

Landfill gas management

4.16 Gas management will include gas extraction from the waste and perimeter control to prevent LFG migration off-site. As part of the restoration of the landfill, the following in relation to LFG management measures will be required:

- construction of LFG pumping wells;
- installation of gas pumping mains and condensate traps;
- provision of gas extraction pump and flare;
- installation of capping layer; and
- installation and operation of LFG utilisation plant.

4.17 Depending on the result of on-going gas monitoring, some interim venting measures may be required to ensure continued protection of existing and future buildings and structures to the south of the landfill. For example, LFG alarms within the CED offices and other site buildings should be installed, and a combination of venting trench and gas barriers, if required, should be placed.

4.18 To relieve the build-up of LFG pressure in the landfill and to prevent gas from being forced laterally off-site and also vertically, an active gas extraction system will be required at PPVL. LFG pumping wells should be drilled retrospectively and should be integrated into a LFG extraction system. Wells should be installed at an appropriate grid spacing to optimise the volume of LFG which can be collected and the system should incorporate existing wells previously constructed by CED for LFG extraction at the south of the site.

4.19 An additional active perimeter extraction system will be required if the bitumen coating which has been placed on the side walls, primarily for controlling water ingress to the site, is found to be ineffective in controlling LFG migration. Wells should be installed at appropriate intervals along the site perimeter and linked to a ring main through which gas could flow in either direction. This perimeter system should be a separate system from the main LFG collection system.

4.20 When in future years it is no longer practicable to actively extract and flare LFG because of reduced LFG production, additional passive vents should be drilled through the low LFG permeability capping layer to vent LFG to atmosphere.

Landfill gas utilisation

4.21 It is recommended that, in the least, LFG should be utilised to meet all of the power requirements of the restored landfill or alternatively, LFG should be utilised to satisfy power demands off-site which are at least equivalent to the on-site power requirements. More extensive utilisation of LFG for off-site industrial direct end use as a replacement fuel would be a more efficient option, and is also cost effective.

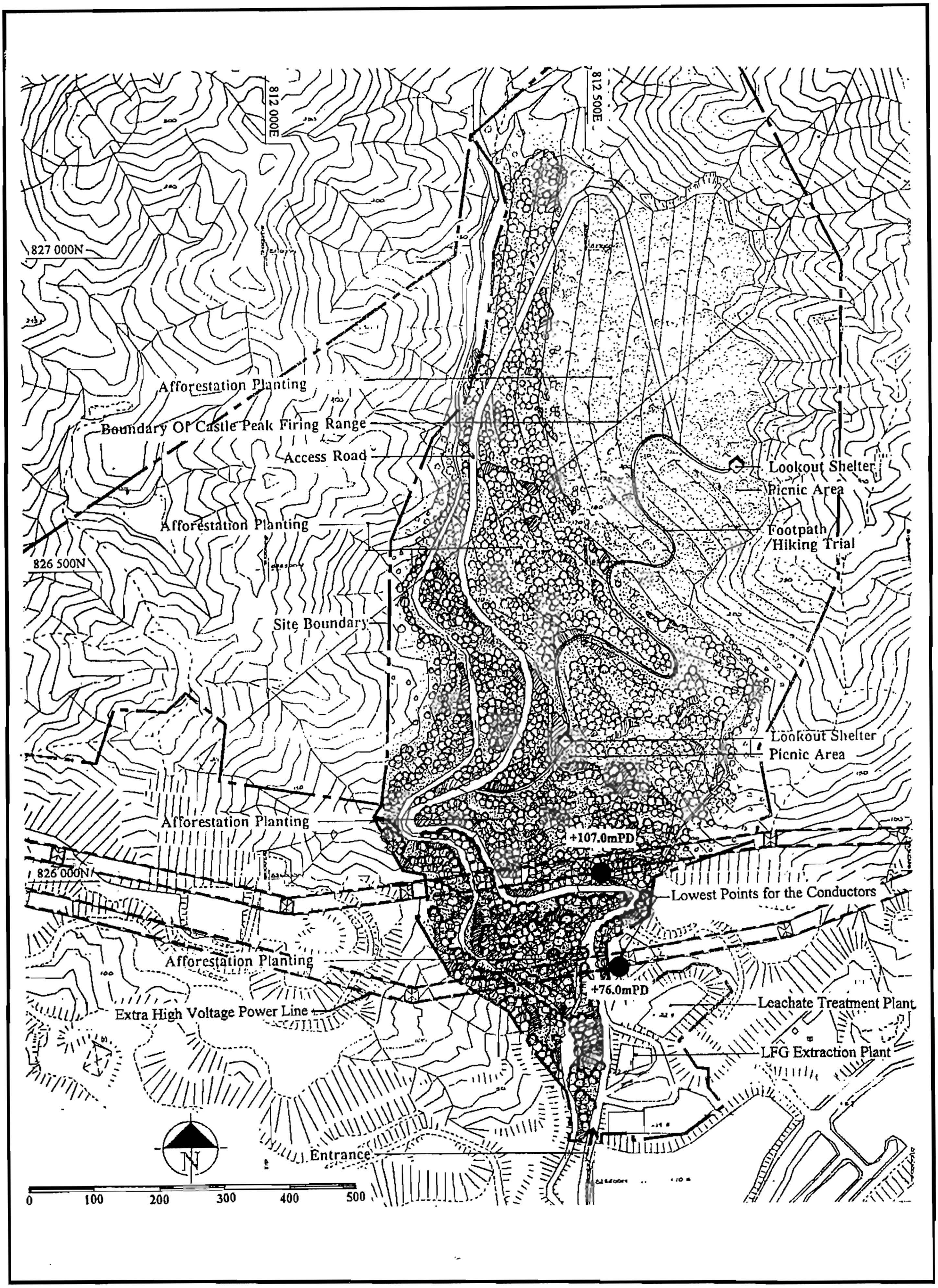
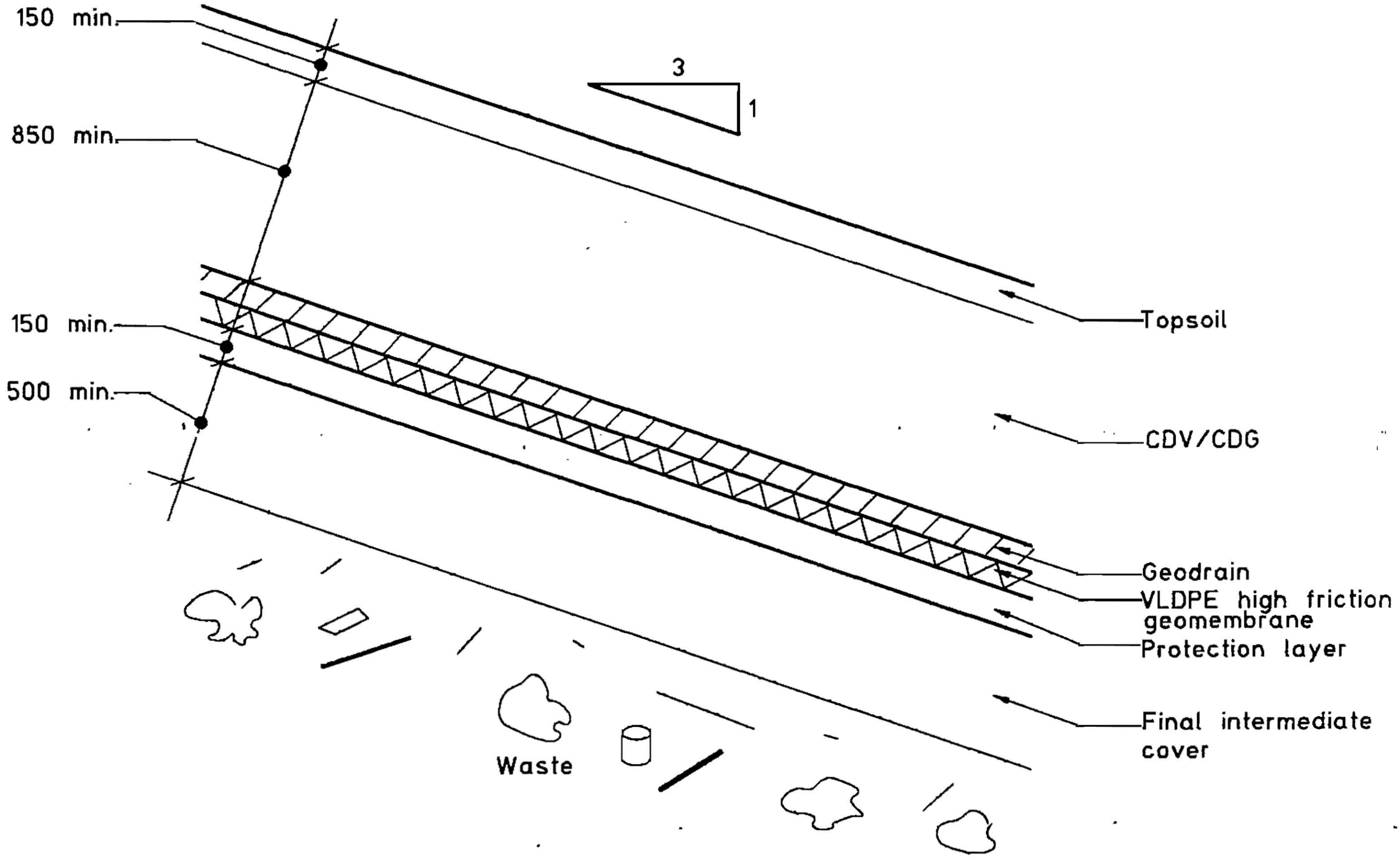


Figure 4.2
Pillar Point Valley Landfill
Master Development Plan



(All dimensions in millimetres)

Figure 4.3

Pillar Point Valley Landfill

Conceptual Design of Capping Layer

4.22 The design of a LFG utilisation scheme should be fully compatible with the proposed restoration of PPVL. The LFG extraction and utilisation plant should be placed on a level platform which is situated at the base of the site so as to collect the condensate during the extraction process. The operator of a LFG management system should primarily seek to control gas for reasons of safety and environmental protection, whilst the operator of a LFG utilisation system should seek to maximise gas extraction at a constant rate. Therefore, it is beneficial to have a single contractor responsible for both operations, with the requirements of safety and environmental protection taking priority over the needs of utilisation.

Leachate management

4.23 The leachate system for joint treatment of leachate from PPVL and SLSL must be sufficiently flexible and robust to cope with substantial fluctuations in both flow and quality of influent leachate arising from both landfills. Provision of long term monitoring data on leachate flow and quality from PPVL and SLSL will be necessary in order to allow detailed design of appropriate plant capacity and treatment facilities. The conceptual design of the leachate treatment plant is based on a combination of aerobic and anoxic biological processes for organic contaminant removal, nitrification and denitrification (Ref 4.1). This system permits subsequent "additions" of reactor tanks, should they be required, to meet the demands of increasing leachate volume following restoration of the sites. In the long term, leachate treatment will be required to meet the standards for effluent being discharged to foul sewer leading to Government sewage treatment plants as given in Table 1 of the Effluent Standards (refer to Table A1.3 of Appendix 1).

4.24 As shown in Figure 4.2, the leachate treatment plant will be placed on a single platform to the south of PPVL site. If PPVL is to remain open beyond 1997, the plant can be built in advance of the main restoration contract to meet interim demands for leachate treatment. This will enable early commissioning of the plant for use during the continuing operational phase of landfilling at PPVL. During the early period of operation it is envisaged that some waiver from the standards set in the Effluent Standards may be required, until the full size plant is fully operational.

4.25 As part of the restoration programme, a low permeability capping layer for the landfill should be constructed to reduce rainfall infiltration and hence the leachate head, and thereby reduce leachate disposal costs. Some measures should also be taken to divert leachate seepages, contaminated groundwater and some contaminated surface water to the leachate collection systems or back into the landfill, to prevent fugitive discharges off-site.

Landfill Gas

Introduction

4.26 This section describes the safety and environmental objectives of the restoration process with respect to landfill gas (LFG) and appraises the current and future potential for migration of gas off-site from the landfill. An assessment of potential impacts from the construction phase and the preferred afteruse option has been conducted, and areas for further assessment identified.

Safety and environmental objectives

4.27 The principal gaseous components of concern in LFG are:

- methane (CH_4), which is a flammable or explosive, colourless, odourless, non-toxic, asphyxiant gas which is more buoyant than air. Flammability limits are from 5 to 15% (v/v) in air.

- carbon dioxide (CO_2), which is a colourless, odourless gas which is non-flammable, and less buoyant than air. At 3% (v/v) in air, breathing becomes laboured and headaches results. At 5-6% (v/v) these symptoms become severe.

At 10% (v/v), visual disturbance, tremours and loss of consciousness may occur. CO_2 concentrations above 15% by volume may be fatal.

- hydrogen sulphide (H_2S), although not present in high concentrations is a highly toxic, flammable gas with a characteristic and offensive odour. At concentrations above 0.005% (v/v) H_2S dulls the human olfactory system such that the gas can no longer be detected.

4.28 In addition to these gases LFG contains trace constituents. The relative concentrations of these trace constituents vary, for example alcohols predominate during the early stages of decomposition, and hydrocarbons predominate during the later stages. Nitrogen (N_2) and oxygen (O_2), which are not generated within a landfill, indicate the presence of air. Issues arising from the presence of trace constituents are dealt with under Air Quality.

4.29 Odours associated with LFG result from the presence of trace constituents primarily volatile organic compounds (VOCs). LFG may also contain corrosive components such as halogenated and sulphonated hydrocarbons, which form acid mist on combination with air. Although some trace constituents are potentially harmful there is no evidence that concentrations give rise to problems at well managed sites (Ref 4.2).

4.30 It is important that strict monitoring is undertaken of LFG levels in enclosed spaces. Where personnel may be exposed it is important to avoid:

- Asphyxiation - the oxygen content in air should not fall below 18%; and

- Toxic effects and health risks - some of the minor constituents of LFG could have toxic effects although trace gases do not usually represent a health hazard following normal atmospheric dilution. Appropriate protective clothing should be worn.

4.31 The density of LFG will depend on the proportion of components present. LFG components do not normally separate when collecting in voids but layers of landfill gas may form in still air conditions as a result of density differences. The emission of warm LFG will give it buoyancy in colder air.

4.32 To ensure that site personnel are not exposed to hazardous levels of LFG, all excavations should be monitored for concentrations of flammable gases, as should O_2 at the start of the work period and throughout the work session. Work should not be allowed if O_2 levels fall below 18%.

4.33 Excavated fill material should not be left exposed on site for excessive periods in order to avoid odour generation.

Safety and environmental objects

4.34 The safety and environmental objectives of the LFG control measures proposed for all four landfill sites are defined as follows:

- the elimination as far as is practicable, or risks of explosion, combustion, toxicity, asphyxiation, odours and damage to vegetation;

- the prevention, as far as is practicable, of LFG migration off-site into adjacent areas and excluding it from buildings, services, ducts and enclosed spaces on or off the site area;

- the prevention of the unnecessary ingress of air into the landfill to minimise both the risk of underground combustion and the period of significant methane production;

- the minimization of the surface emission of LFG; and

- the protection of site workers, occupiers and users.

4.35 In order to meet these objectives and minimise the risks associated with the uncontrolled emission of LFG, it is proposed that LFG control measures be incorporated into the restoration design of all four landfills and a dedicated gas extraction and utilisation system be installed at PPVL. The general design objectives for LFG control have also been defined in earlier Working Papers WP1, WP2 and WP6 (Refs. 4.3, 4.4 and 4.1) and are briefly as follows:

- to control off-site migration of LFG into natural strata;
- to protect future restoration of the landfill;
- to be compatible with any utilisation programme;
- to be compatible with final afteruse; and
- to ensure protection of site workers, occupiers and users.

Background conditions at PPVL

4.36 PPVL is currently generating LFG from the decomposition of the landfilled wastes. Future LFG yields have been predicted for each site using a variety of methods, including mathematical models (Ref. 4.4). For PPVL, predictions of peak LFG production from the mathematical models range from 32 x 10^6 cu m LFG/year to 170 x 10^6 cu m LFG/year, with both peaks predicted to occur in 1995. The predicted mean 10 year sustainable values (1993 - 2003) range from 23 x 10^6 cu m LFG/year to 80 x 10^6 cu m LFG/year.

4.37 The current actual rates of LFG generation will vary depending on a range of environmental (e.g. moisture, temperature, atmospheric pressure) and waste (input rates, types) variables. Following peak LFG generation rates, a rapid decline in generation is predicted followed by an extended period of lower generation rates over time.

4.38 The composition of the LFG at PPVL is typical of a methanogenic landfill site and consists of approximately 50 - 60 % methane and 30 - 40 % carbon dioxide with minor constituents of nitrogen, oxygen and trace gases. LFG is under high positive pressure in the site as indicated in holes DH106, DH107 and various CED drillholes located to the south. This LFG can be expected to migrate to lower pressure areas off-site. This takes place laterally via natural (e.g. rock fissures) and man-made (e.g. pipes) high permeability pathways and vertically through the landfill surface. PPVL has a low permeability liner to contain leachate on part of the site, and this will also provide some control of LFG movement. Recommendations have been made in WP2 (Ref. 4.4) to determine the efficiency of the liner in controlling LFG migration. However, it is considered that the LFG extraction system as proposed in WP 2 for PPVL will prevent any significant off-site migration, and gas migration is not considered a problem in the longer term.

4.39 The sensitive boundary at the south of the site has a good coverage of LFG monitoring probes installed by CED, and gas monitoring data have been obtained both from CED and the consultants; data are reproduced in the Table 4.2. Whilst no, or very little, methane was detected in the monitoring points shown in Figure 4.4 at the south of the site (i.e. BH1, BH2, BH3, P1, P2 and P3), there is evidence that oxygen levels are depleted, and carbon dioxide elevated. These measurements may be precursors to more significant off-site migration of LFG in the future. There is also evidence for this in the manhole adjacent to the refugee camp, though this may be a consequence of leachate transmission through it rather than LFG migration. Results to date show no significant LFG occurrence in the vicinity of the lower platforms to the south, indicating there is no immediate hazard to the buildings. However, an interim LFG alarm system is recommended as a precautionary measure for these buildings, as suggested in WP2 (Ref. 4.4).

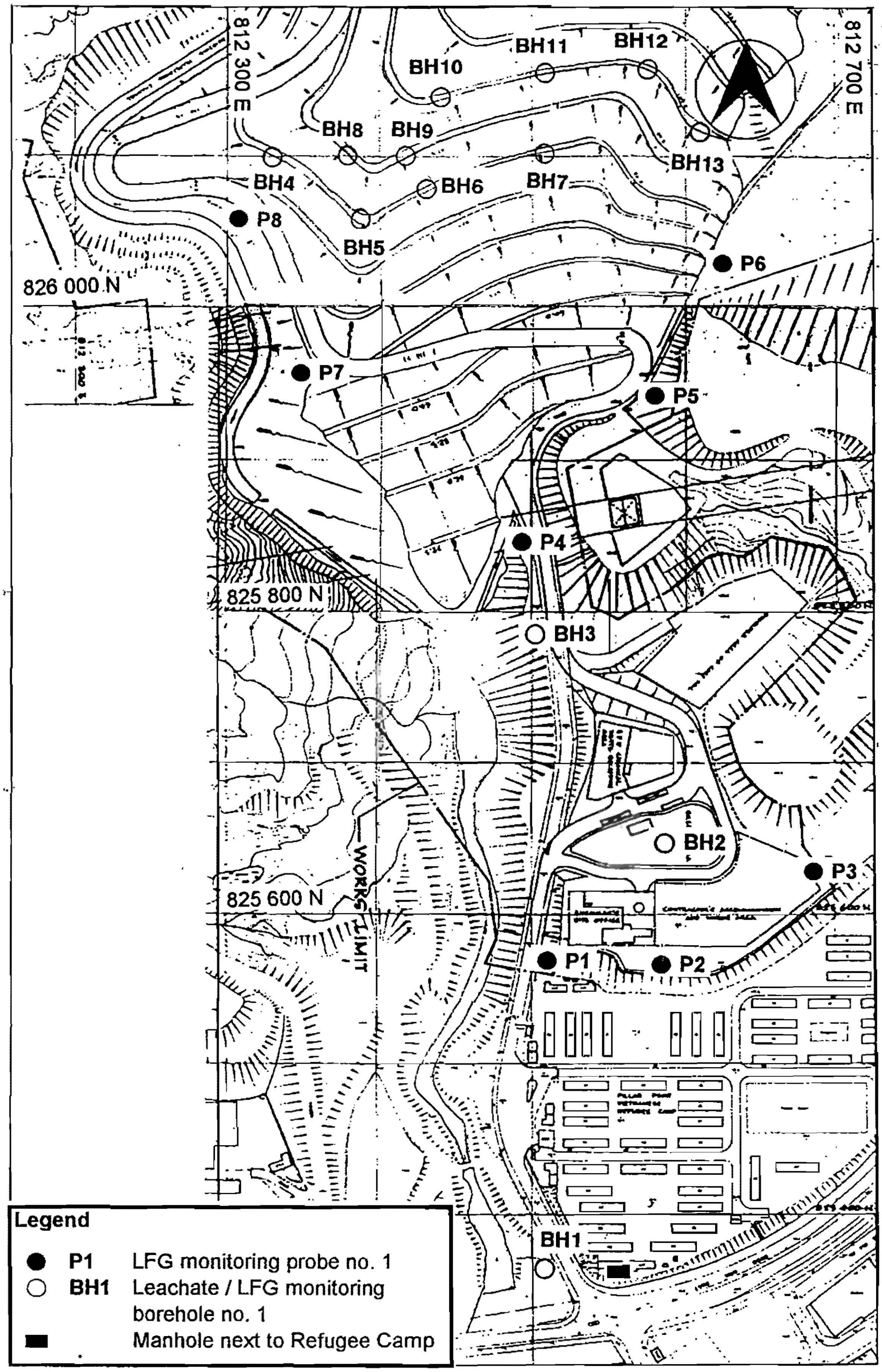
Table 4.2: PPVL - GAS MONITORING RESULTS (Sheet 1 of 2)

LOCN+	DATE	APRE	DPRE	%CH4	%LEL	%O2	%CO2	%H2	%CO	%N2	COM
DH105	2-Jul-93	1009.9	6	57.5	>100	0	36.5				
	2-Jul-93	1009.9	6	63		0.4	33	<0.05	<0.1	3.2	Lab
	20-Jul-93	1004.5		61		0.3	32	<0.05	<0.1	2.4	Lab
	28-Jul-93	1002.6	12.5	55.5	0	0	34.5				
	23-Sep-93	1009.2	34	58.3	0	0	36				
	29-Oct-93	1019.9	14	57.9	0	0.5	32.9				
	12-Nov-93	1014.7	22	57.2	0	0.5	31.7				
DH106	29-Jun-93	1007.5	191	46	1.2	<1	40				
	2-Jul-93	1009.9	-12	57.1	>100	0	41.2				
	2-Jul-93	1009.9	-12	60		0.3	38	<0.05	<0.1	1.3	Lab
	20-Jul-93	1004.5		51		0.9	40	<0.05	<0.1	3.5	Lab
	28-Jul-93	1002.6	158	52.3	0	0	38				
	23-Sep-93	1009.2	213	55.1	0	0	40				
	29-Oct-93	1019.9	312	0.04	0	20.5	0.87				
	12-Nov-93	1014.7	671	53.6	0	0.1	38				
DH107	16-Jun-93	1008.7	370	48	3.5	<1	45				
	28-Jun-93	1006.4	518	48	4.5	<1	35				
	29-Jun-93	1007.5	502	46	<1	<1	40				
	2-Jul-93	1009.9	498	55.5	>100	0	42				
	2-Jul-93	1009.9	498	56		1.2	37	<0.05	<0.1	5	Lab
	9-Jul-93	1008.4	407	46	<0.25	<0.5					
	20-Jul-93	1004.5		58		0.2	37	<0.05	<0.1	0.5	Lab
	28-Jul-93	1002.6	384	51.5	0	0	39.6				
	23-Sep-93	1009.2	1244	54.3	0	0	41.6				
	29-Oct-93	1019.9	745	54.3	0	0.3	41.6				
	12-Nov-93	1014.7	1567	53.5	0	0	40				
BH4	4-Sep-93	1009		57.1		0	35.5				
BH5	28-Jun-93	1006.4	127				42				
	9-Jul-93	1008.4	79	46	<0.25	<0.5	45				
	4-Sep-93	1009		56.6		0	38				
BH6	25-May-93	1005.6		47	3	<1					
	28-Jun-93	1006.4	144	47	3	<1	40				
	9-Jul-93	1008.4	89	47	<0.25	<0.5	40				
	4-Sep-93	1009		56.6		0	38				
BH7	25-May-93	1005.6		47	2	<1					
	28-Jun-93	1006.4	170	47	2	<1	40				
	9-Jul-93	1008.4	107	47	<0.25	<0.5	40				
	4-Sep-93	1009		57.3		0	36.8				
BH8	28-Jun-93	1006.4	161	48	2	<1	40				
	9-Jul-93	1008.4	87	48	<0.25	<0.5	35				
	4-Sep-93	1009		59.8		0	36.2				
BH9	25-May-93	1005.6		46	2	<1					
	28-Jun-93	1006.4	167	47	3.7	<1	40				
	9-Jul-93	1008.4	110.5	48	<0.25	<0.5	35				
	4-Sep-93	1009		55.2		0	38.2				

Table 4.2: PPVL - GAS MONITORING RESULTS (Sheet 2 of 2)

LOCN+	DATE	APRE	DPRE	%CH4	%LEL	%O2	%CO2	%H2	%CO	%N2	COM
BH10	25-May-93	1005.6		48	0	<1	48				
	28-Jun-93	1006.4	240	48	0	<1	40				
	9-Jul-93	1008.4	136	46	<0.25	<0.5	45				
	4-Sep-93	1009		58.3		0	38.3				
BH11	25-May-93	1005.6		48	0	1					
	28-Jun-93	1006.4	200	48	0	1	40				
	9-Jul-93	1008.4	121	48	<0.25	<0.5	40				
	4-Sep-93	1009		57.8		0	35.9				
BH12	25-May-93	1005.6		47	2	<1					
	28-Jun-93	1006.4	121	47	2	<1	40				
	9-Jul-93	1008.4	58	49	<0.25	<0.5	40				
	4-Sep-93	1009		57.6		0	36.9				
BH13	25-May-93	1005.6		48	2	<1					
	28-Jun-93	1006.4	98	48	2	<1	40				
	9-Jul-93	1008.4	58	49	<0.25	<0.5	40				
	4-Sep-93	1009		57.6		0	36.9				
P4	4-Sep-93	1009		0		14.4	3.7				
	9-Sep-93	1011.5	12	0.12	18	17.5	3.57				
P5	4-Sep-93	1009		28.3		0	22.4				
	9-Sep-93	1011.5	0	28.5	0	0.2	23.8				
P6	4-Sep-93	1009		3.5		16.3	4.3				
	9-Sep-93	1011.5	0	28.5	5	2	28.5				
P7	4-Sep-93	1009		56.1		0	36.6				
	9-Sep-93	1011.5	-12	57.9	0	0	38.4				
P8	4-Sep-93	1009		54.9		0	33.7				
	9-Sep-93	1011.5	0	56.3	0	0	35.3				
BH1*	4-Sep-93	1009		0		19.9	0				
	9-Sep-93	1011.5	-12	0.04	0	20	0.51				
BH2*	4-Sep-93	1009		0		20.1	0				
	9-Sep-93	1011.5	0	0.04	0	20.5	0.47				
BH3*	4-Sep-93	1009		0		18.5	0.5				
	9-Sep-93	1011.5	0	0.08	0	19.5	1.11				
P1*	4-Sep-93	1009		0		19.2	0.6				
	9-Sep-93	1011.5	0	0.04	0	18.8	1.46				
P2*	4-Sep-93	1009		0		11.4	5.5				
	9-Sep-93	1011.5	0	0	0	12.8	5.72				
P3*	4-Sep-93	1009		0		15.1	3.6				
	9-Sep-93	1011.5	-25	0	0	15.8	4				
Manhole*	9-Sep-93	1011.5		0.6	10	12.4	8.72				

* denote those holes located off-site
+ refer to A2.1 (Appendix 2) for abbreviations used



Note :

Consultants' investigation holes are omitted for clarity.

Figure 4.4

Pillar Point Valley Landfill

Sampling Locations for LFG Monitoring

Impacts of construction activities

4.40 LFG has the potential to be emitted during restoration construction works as a result of disturbance to existing final cover material, or by the creation of migration pathways with subsequent venting. Potential migration pathways may be inadvertently created via new drainage channels. Emplacement of the capping material will effectively prevent all vertical migration of gas via the surface, but can be expected to enhance potential lateral migration by increasing the positive pressure gradient of the gas generated. However, this is not expected to result in significant risk as the LFG extraction systems proposed in WP2 and WP6 (Refs 4.4 and 4.1) for the site will intercept gas migrating off-site.

4.41 During restoration, direct emission of LFG to atmosphere may occur for short periods through construction activities on the landfill such as exposure of the deposited waste, earth-moving of the existing cover on PPVL and installation of LFG control measures.

Mitigation Measures

4.42 By the use of suitable mitigation measures and good site practice, release of LFG during construction can be minimised. Such measures include avoiding the direct exposure of waste during earth-moving and cap restoration operations as far as is practicable, and controlling excessive vehicle movements on restored areas. The design and installation of pipework and other LFG control measures should be carried out to minimise any disturbance and to avoid potential gas migration routes.

4.43 LFG released from construction activity, in addition to that released under normal conditions from the landfill, represents potential risks both prior to and after the completion of works. Accumulation of LFG in confined structures (e.g. site offices and manholes) represents a hazard of explosion, combustion, toxicity and asphyxiation as well as odour. Measures should be taken to ensure that any confined working areas are properly ventilated and/or have adequate LFG detection equipment to avoid excessive exposure. Migration barriers (e.g. floor membranes) for construction site buildings should be provided in structures, which should also have above ground underfloor voids as additional protection. The use of any naked flames and welding equipment should be carried out in carefully designed and monitored areas. Any storage of fuel and other inflammable chemicals should take place only in specially designated areas with clear warning signs.

Impacts of LFG control measures

4.44 The potential impacts associated with the LFG control measures relate to the construction phase including:

- formation of the landfill cap;
- construction of passive vent trenches as an interim measure (if necessary);
- construction of the gas extraction system, drilling of vertical wells, and laying of pipes;
- construction of additional perimeter LFG migration control systems (if necessary);
- construction of the gas extraction plant and flare equipment; and
- drilling of the monitoring drillholes.

4.45 However none of these activities will result in emissions of LFG greater than those which are occurring during the operation of the landfill, and they will not result in any significant impacts.

Impacts of LFG extraction and utilisation measures

4.46 LFG emitted to the atmosphere, rather than being collected and flared, is damaging to the local and global environment. LFG emissions may contain harmful trace compounds, albeit at very low concentrations and represent a source of odour. Also, it is generally accepted that emission of methane causes more damage to the atmosphere than the emission of carbon dioxide.

4.47 Where a LFG extraction and utilisation system is installed, the environmental benefits of using the gas are:

- conservation of non-renewable fossil fuel resources, by using LFG as an alternative fuel; and
- slightly reduced concentrations of certain noxious emissions.

4.48 Four utilisation options have received financial analysis for PPVL (Ref 4.4). These are:

- electricity generation for on-site needs (i.e. leachate and LFG treatment plant);
- electricity generation for on-site energy requirements and off-site needs to local industry;
- electricity generation for on-site energy requirements and off-site supply to the grid; and
- direct distribution of gas to local industry.

4.49 Environmental concerns associated with the installation of utilisation equipment relate to impacts associated with construction, land required for siting equipment and operational impacts (e.g. noise and flaring activity). However, these impacts must be balanced against the overall benefits in using LFG as an alternative energy source and the positive environmental implications of safe LFG utilisation.

4.50 Higher intensity uses of LFG involving the generation of electricity for off-site as well as on-site needs entails greater environmental impacts in terms of construction, land-take and operational impacts than on-site utilisation alone. However, the greater impacts are balanced by the opportunity to use LFG more effectively and are considered worthwhile. Greater utilisation of LFG will also reduce or even avoid the requirement for gas flaring, with its associated impacts on the environment.

4.51 The option for direct distribution of gas to local industry requires the lowest intensity of resources on-site, represents the best environmental option, and provided that LFG can be extracted, supplied and utilised in an effective manner. Direct usage of LFG represents a more efficient use of energy, where conversion efficiency to electricity is estimated at only 25% to 30% (Ref 4.4).

4.52 Overall, it is considered that utilisation of LFG in any form represents significant environmental benefits, but that economic considerations will be equally important in the final selection of the most favourable LFG utilisation option.

Impact on afteruse option

4.53 The preferred afteruse recommended for PPVL is afforestation of the slopes with associated hiking trails and viewing areas. There are four small platforms situated at the south of the landfilled area; two will be used for the siting of leachate treatment facilities and landfill gas extraction plant. Although all these facilities for afteruse are situated outside the landfilled area and little LFG migration has been detected to date, there is the potential to increase LFG migration during construction and this will require the implementation of mitigation measures as described in WP2 and WP6 (Refs 4.4 and 4.1).

4.54 The landfill restoration cap (Figure 4.3) is designed to minimise uncontrolled emissions of LFG through the landfill surface, prevent unnecessary air ingress into the landfill, and allow as much LFG generated as possible to be collected. Capping of the landfill will reduce the risk of direct surface emission of LFG by several orders of magnitude, but will increase the risk of off-site lateral migration due to an increased positive gas gradient as gas continues to be generated from the deposited wastes. LFG management measures, as specified in WP2 and WP6 (Refs 4.4 and 4.1), will control gas movement and significantly reduce the risk of any off-site LFG migration. The combination of landfill capping and installation of an active control system will provide adequate protection to the proposed woodland establishment and leisure afteruse of the landfill.

4.55 The advice from EPD with regard to developments close to landfills is similar to that currently implemented in the UK and includes:

- a suggested 20 m non-building area measured off-site from the waste boundary; and
- a 250 m consultation zone for development, measured off-site from the landfill boundary.

As proposed in WP5 and WP6 (Refs 4.5 and 4.1) only low intensity afteruses on-site are proposed and no sub-structure developments are planned inside the site or within the 20m non-building area.

4.56 Any building structures on-site should be lightweight and require LFG protection measures such as gas barriers, void space for good ventilation and be fitted with gas detection alarm systems, although no buildings are currently planned. Any outdoor facilities in the picnic area and lookout shelter which involve ground disturbance would require localised thickening of the cap. Activities which may take place in the restored landfill site, including hiking and picnicking, do not represent any LFG hazard in themselves, but other unauthorised public activities may. The lighting of fires, barbecues and any activity associated with digging would need to be effectively prevented to avoid any LFG exposure risk. Camping should be prohibited to avoid the risk of LFG exposure through potential accumulation of gas in tents, although it is considered that the actual risk involved would be minimal.

Air Quality

4.57 This section details the assessment of impacts on air quality from emissions at Pillar Point Valley Landfill site. Construction activities associated with the restoration of the landfill site are considered with reference to dust and VOC emissions. A predictive assessment is made of dust impacts during construction and of impacts resulting from flaring LFG from the restoration works.

Meteorology

4.58 The typical wind regime of Hong Kong is dominated by the northeast monsoon in winter and the southwest monsoon in summer. Wind regimes are affected by topography. Surface winds may vary in speed and direction over relatively short distances. In addition to the normal variations in windspeed and direction, vertical distortion caused by surface roughness may be modified by daytime sea-breezes, and night-time land breeze effects.

4.59 A number of weather stations collecting meteorological data are positioned around Hong Kong. Because of the distances between these stations and the landfill sites, assumed data which had been agreed with EPD (see Table 4.8), was used in the predictive study.

Ambient Monitoring Analysis

VOCs

4.60 A monitoring survey of the ambient air quality with respect to SACs was carried out at positions upwind and downwind of PPVL and the other landfill sites. The specified contaminants are present in air at extremely low concentrations, and it is difficult and expensive to sample and analyse for VOCs so as to obtain reliable and accurate data. The air samples were collected using a passivated canister technique, as it is considered that this is the most appropriate method given the low concentrations expected in the ambient, rural atmosphere of the restoration sites.

4.61 The samples were sent to the USA for analysis, since no analytical facilities contacted in Hong Kong or the United Kingdom could cost-effectively achieve the detection limits specified by EPD for all compounds. Quality assurance procedures included the use of field and laboratory blanks and the spiking of canisters by the analytical laboratory prior to use in the field.

4.62 The results in Table 4.3 show that downwind levels for tetrachloromethane and dichloromethane are higher than either upwind readings taken. The difference, however, is within expected experimental variation. Measurements of other parameters showed no tendency for downwind levels to be greater than upwind levels. This suggests, based on the limited data, that uncontrolled LFG emissions from PPVL are having no significant effect on ambient VOC levels.

Table 4.3 : Monitored Ambient SAC Levels at PPVL

SAC	Method Detection Limit + (µg/m^3)	PPVL (µg/m^3)		
		uw	uwQ	dw
Vinyl Chloride	0.36	ND	ND	ND
Dichloromethane	0.73	2.0	1.7	3.2
Trichloromethane	0.73	ND	ND	ND
1.1.1-Trichloroethane	0.76	5.7	3.5	5.6
1.2-Dichloroethane	0.61	ND	ND	ND
Benzene	0.26	5.7	3.6	5.5
Tetrachloromethane	0.94	ND	0.7	1.0
Trichloroethylene	0.91	2.9	2.5	2.2
1.2-Dibromoethane	0.92	ND	ND	ND
Tetrachloroethylene	0.75	6.1	5.2	3.1

Notes

uw : *upwind*
dw : *downwind*
uwQ : *repeat upwind samples taken for quality assurance purposes*
\+ : *the method detection limit (MDL) used for the duplicate sample (µwQ) was below the MDL used for other samples*
ND : *not detected, below the method detection limit*

Methane

4.63 Table 4.4 shows the results of analysing samples taken upwind and downwind of the landfill site for methane. The downwind value is a factor of about 3 times greater than the upwind value. This indicates that PPVL may be a significant contributor to ambient levels of methane, although the detected levels of methane are of no environmental health or safety significance.

Table 4.4 : Monitored Methane Levels at PPVL

Pollutant	uw µg/m³ (ppm)	dw µg/m³ (ppm)
Methane	1765 (2.55)	4554 (6.58)

Notes

uw : upwind
dw : downwind

Dust

4.64 No particulate air quality data is available for any of the four landfill site locations. In the absence of site specific data, Table 4.5 gives data for recent monitoring of TSP and RSP levels for EPD sites in Hong Kong (Ref 4.6).

Table 4.5 : TSP and RSP Levels for EPD Monitoring Stations 1992

Site	TSP (µg/m³)	RSP (µg/m³)
Kwun Tong	105 (304)	72 (250)
Sha Tin	79 (273)	50 (171)
Tai Po	87 (285)	53 (186)
Sham Shui Po	123 (376)	71 (241)
Tsim Sha Tsui	86 (292)	54 (231)
Central Western	83* (154)	61* (142)
Junk Bay	77 (273)	44 (188)
Tsuen Wan	106 (300)	65 (201)
Kwai Chung	91 (297)	55 (186)
Hong Kong South	69 (273)	45 (105)
Mong Kok	158 (439)	71 (237)

Notes

Average values are given, with maximum daily values given in brackets
** data set incomplete*

LFG Monitoring

4.65 Samples of LFG were also taken from drillholes at each of the four landfills, and were analysed using a combined gas chromatography/mass spectrometry (GC/MS) technique. This technique allows a large number of organic compounds to be detected, which can be useful in assessing potential odour impacts. Samples were taken from the landfills by means of absorption tubes. Of the four landfills, PPVL exhibits the greatest abundance of trace gases exceeding odour limits (see Table 4.6). This is to be expected given the age and volume of wastes deposited.

4.66 Samples were obtained from CED borehole BH9 and drillholes DH107 and DH106. Duplicate samples were obtained from BH9 and DH107. Only those compounds which were detected at concentrations which exceed odour thresholds are presented in Table 4.6. Of the 25 compounds listed in Table 4.6, 18 occur at all 3 points from which samples were taken. Odorous compounds are dominated by limonene (a common trace constituent of LFG), decanes, xylenes and toluene. Esters and alcohols are indicative of LFG from relatively recently emplaced refuse, and also contribute to the gas odour.

Table 4.6 : Gases in LFG Exceeding Odour Limits at PPVL

	BH9A	BH9QA**	107A	107QA**	106B
butene (total)	3.1	8.6	0.1	0.4	4.4
pentene (isomer)	0.2	0.9	1.4	2.0	0.2
dimethyl sulphide	22	21	.08	0.2	0.1
acetone	75*	88*	0.5	0.5	12
cyclohexane	9	7.3	9.2	11	7.5
1,2 dichloroethylene	ND	ND	20.0	11	16
limonene	420*	560*	180*	85	290*
n-decane	130*	130*	96.0	43	130
butan-2-one	110*	100*	5.6	6.1	37
butan-2-ol	21	18	ND	ND	2.7
toluene	200*	260*	210*	170*	380*
n-nonane	63	58	60.0	36	70
ethyl benzene	68*	71*	90.0	52	130
xylenes	135*	157	*185.0	106	325
styrene	2.6	ND	3.8	2.0	1.5
methyl styrene	ND	ND	ND	ND	1.6
naphthalene	4.8	6.5	2.9	0.1	5.6
propan-2-ol	23	25	0.2	0.6	2.2
2-methyl propan-2-ol	4.6	4.0	1.1	1.3	2.8
heptanone	6.3	6.9	ND	ND	ND
n-propyl acetate	0.5	ND	ND	ND	ND
C_5 or C_6 ester	1.6	ND	ND	ND	1.9
n-octane	12	12	14	11	12
dimethyl disulphide	9	2	ND	ND	ND
C_5 or C_6 alcohol	2.3	2.1	ND	ND	ND

Notes

* *(all measurements in mg m^{-3}) Saturation of mass spectrometer as consequence of choice of internal standards represents underestimate*

** *Duplicate samples for QA purposes.*

ND *Not detected, below the method detection limit*

4.67 These results indicate that in an uncontrolled situation there is potential for an odour nuisance to occur. However, the proposed LFG management system will ensure that following restoration works, this potential impact will be adequately mitigated.

4.68 An olfactometry test was undertaken to the specifications of the Environmental Protection Authority (Victoria, Australia) Air Quality Branch - Technical Services

Section at each of the four landfills. Results showed that odour levels at each site were below two odour units. Therefore the odour limit value recommended by EPD is presently not exceeded at any of the landfill sites.

Assessment of Impacts on Air Quality

4.69 Dust and LFG emissions are considered the only significant potential impacts arising from restoration activities. Motor vehicle and plant emissions were not considered because significant emissions are unlikely.

4.70 The sensitive receptor identified and considered in the study of PPVL is given in Table 4.7.

Table 4.7 : Sensitive Receptor and Location

Sensitive Receptor	Grid Reference
• Pillar Point Vietnamese Refugee Camp	812600E 825450N

Dust

4.71 The major air quality issue during the preparation of site restoration will be dust emissions. It is inevitable that these activities will cause some degree of concern. Therefore dust control and mitigation measures should be adopted and enforced, through the use of statutory powers and contractual requirements.

4.72 Principal sources of dust will be:

- site preparation;
- excavations for landfill gas collection and control systems;
- wind erosion of stockpiled materials and working areas;
- material transfer activities; and
- vehicle and plant movement on unpaved roads and over the restoration site.

4.73 The quantity of dust emissions from restoration works will depend on the size of the area being worked and the level of restoration activity, specific operations and the prevailing meteorology.

4.74 Dust emissions from vehicle movements on unpaved surfaces are a function of vehicle speed, vehicle weight, number of wheels per vehicle, surface texture and moisture. Particles are lifted and dropped from rolling wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed.

4.75 Dust emissions, and hence their degree of impact, will be determined by the degree of effort placed upon dust control. Emissions, and a reduction in predicted ground level dust concentrations, can be controlled by:

- employing methods of working to minimise dust generation or impact;
- dampening down/wetting surfaces;
- providing and using water sprays, bowsers, mobile sweeping plant and vehicle wheel and body cleaning facilities;
- control of vehicle speeds and movements;
- dust control on specific operations;

- use of side enclosures and coverings where practicable for storage piles;
- covering vehicles loads with tarpaulin; and
- routing of vehicles and positioning of plant at the maximum distance from sensitive receptors.

4.76 The quantity of dust emissions generated on-site, and hence the level of dust nuisance from the restoration operations, will be governed by the size of the area being restored, the level of restoration activity, and site-specific operations at any one time. These criteria are not precisely known as yet. Dust emission values for on-site activities from the U.S. Environmental Protection Agency emission values (Ref 4.7) were used in the modelling study. Although the silt content for some of the landfill capping and site restoration materials may be high, particularly for completely decomposed volcanics (cdv) and completely decomposed granite (cdg), it is believed that these emission values are still likely to be representative, in the absence of other detailed site-specific source emission data.

4.77 The modelling parameters used in the assessment of dust impact are given in Table 4.8.

Table 4.8 : Dust Emission Modelling Parameters

a) **Emission Rates** (i) Emission from construction activity (ii) Vehicle emission on unpaved road	 0.00012 g/m^2/sec* 1870 g/v/km**
Note: *A particle size frequency distribution was based on a curve taken from CED's Geotechnical Manual for Slopes for completely decomposed granite (see Figure 4.5)* ** 1.2 tons per acre of construction per month of activity (Ref 4.7)* *** assuming the silt content was 20%, vehicle weight was 24 tons (laidened), mean vehicle speed was 8 km/hr, mean number of wheels was 6 (10 tyres)*	
b) **Model Parameters** (i) Particle size density (ii) Particle size fraction (iii) Surface roughness height	 2.5 g/cm^3 (see Figure 4.5) 5 cm
Note: *Assumed wind speeds of 1 m/s to 10 m/s for atmospheric stability classes A to F were considered. A mixing height of 500 m was considered. Variable operational areas of 0.0625 to 3 ha were considered. Predictions were made for 1-hour levels at 100 m intervals downwind of an arbitrary point on the landfill.*	

4.78 Precise construction methods have yet to be finalised and therefore dust emissions from material handling areas are difficult to evaluate and quantify. Such emissions are however, likely to be minor compared to the above identified sources.

4.79 At the request of EPD, the Fugitive Dust Model (FDM) was used to predict dust concentrations from the construction works. Previous studies in Hong Kong have used the Industrial Source Complex - Short Term (ISCST) model.

4.80 Figure 4.6 shows the maximum predicted concentrations of TSP from an arbitrary point at incremental intervals downwind of a typical construction site. The operational area sizes range from 0.0625 hectares (ha) to 3 ha. For the purpose of this study, uniform dimensions have been assumed for the operational areas. An effective watering programme (twice daily watering with complete covering) is estimated to reduce dust emissions by 50% (Ref 4.7).

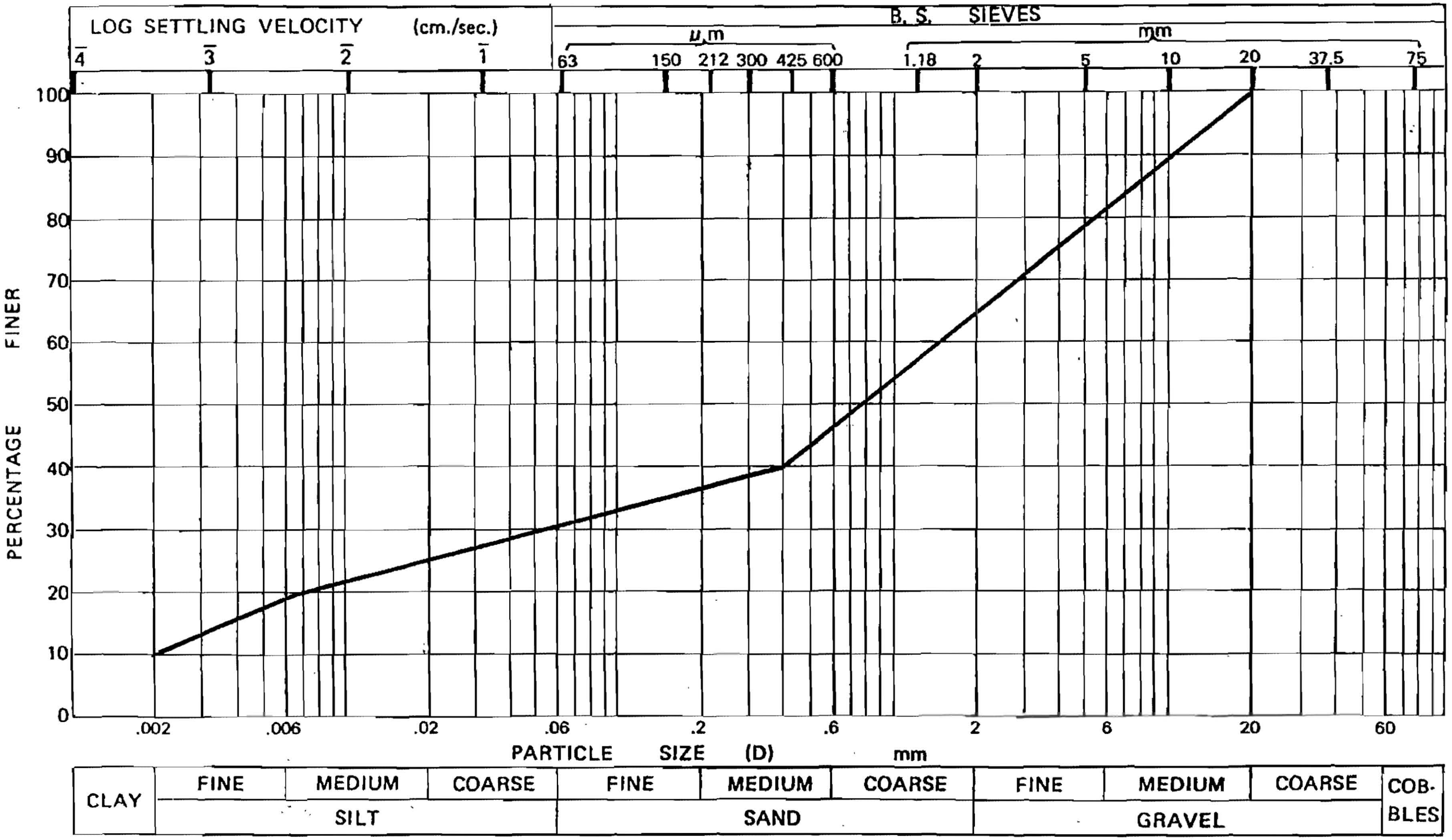


Figure 4.5
Particle Size Distribution Curve
for Completely Decomposed Granite

4.81 The CALINE-4 model was also used to predict the dust impact at the Pillar Point Vietnamese Refugee Camp (PPVRC) sensitive receptor for 5 vehicles per hour passing on an unpaved road which runs along the site boundary closest to the receptor.

4.82 The result from combining the impact of dust from a 0.0625 ha construction area situated at the site boundary and vehicles passing on unpaved roads at the site boundary, on the PPVRC sensitive receptor is:

Distance from site	= 400m
TSP concentration from vehicles	= 38 $\mu g/m^3$
TSP concentration from construction site	= 40 $\mu g/m^3$
Total predicted TSP concentration	= 78 $\mu g/m^3$

4.83 Based on the assumptions used, the modelling results predict a maximum annual 1-hour average TSP value of 78 $\mu g/m^3$.

4.84 The AQO limit that applies to TSP is that the 24-hour average should not exceed 260 $\mu g/m^3$ more than once a year. There is also a guideline limiting the 1-hour average concentrations to below 500 $\mu g/m^3$. Due to the modelling approach agreed with EPD, it is not possible to directly predict a maximum 24-hour average. Therefore it is necessary to use a conversion factor. Using a factor of 0.4 to convert the maximum 1-hour concentration to maximum 24-hour concentration (when considering a 12 hour working day), and the 50% reduction due to mitigation measures, a concentration value of 16 $\mu g/m^3$ is predicted for the maximum 24-hour concentration. This is significantly below the AQO standard of 260 $\mu g/m^3$.

Flare Gas Emissions

4.85 When the proposed restoration works have been completed and are operational, the only emissions of LFG from PPVL will be from the controlled extraction system. The proposed gas management scheme at PPVL involves active collection and ultimate burning of gases such that they will not exceed the odour threshold. Enclosed flares are considered to be the best available control technology for landfill gas and can achieve a 99% destruction efficiency of waste hydrocarbons and virtually 100% destruction of vinyl chlorides and other VOCs.

4.86 A modelling study was carried out, using the ISCST model, to predict the impact of the flare emissions on the surrounding area and the sensitive receptor. Difficulties were encountered as no data on typical LFG flare emissions are available. In Germany the TA Luft standards define the maximum concentration of various gases permitted to emit from a furnace. It is considered reasonable to require the emissions from a LFG flare to meet the same standards, and for the purpose of this modelling study, the TA Luft standards were adopted as emission values. These are listed on Table 4.9. The Oxford University Model was used to calculate the volume of landfill gas generated by the landfill. Guidelines for HCl and HF, as per the Occupational Exposure Standards (OES), are given in Table 4.10.

Table 4.9 : **Flare Emissions and Modelling Parameters**

Pollutants	Concentration* (mg/m^3)	Emission Rate (g/sec)
Particulates (TSP)	5	0.0041
Carbon monoxide (CO)	100	0.0826
Oxides of nitrogen (NO_x)	500	0.4118
Hydrogen chloride (HCl)	30	0.0250
Hydrogen fluoride (HF)	5	0.0041
Sulphur dioxide (SO_2)	500	0.4118
Total hydrocarbons (THC)	20	0.0165
Polycyclic Aromatic Hydrocarbons (PAH)	0.1	0.000083
Modelling Parameters		
Flare stack height	7 m	
Flare stack diameter	2 m	
Temperature	1150 °C	
Gas volume	5936 m^3/hr	
Flare Position	812650E 825801N	

Notes

** Concentrations based on TA Luft Standards*
Meteorological assumptions are the same as those given in Table 4.8.
USEPA Model ISCST was employed.

4.87 Table 4.11 shows the predicted pollutant concentrations from flare emissions at the sensitive receptor. Predicted maximum concentrations of flare emissions for TSP, SO_2, CO and NO_2 at the sensitive receptor are considerably below the Hong Kong AQOs. As ambient levels of TSP, SO_2, NO_2 and CO are also likely to be low in the vicinity of PPVL, the AQOs are still unlikely to be exceeded at the sensitive receptor.

4.88 On the basis of the available data, it can be concluded that the proposed management system for landfill gas at PPVL should not have a significant impact on air quality, with respect to key AQO parameters for which threshold limits apply.

4.89 Concern has been expressed on some environmental pollutants which are not specifically covered by the AQOs in Hong Kong. These pollutants include halogenated compounds such as HCl and HF, and the carcinogenic constituents of Polycylic Aromatic Hydrocarbons (PAH).

4.90 Further consideration has been given to the risk associated with emission of HCl and HF. In the absence of other air quality guidelines a safety factor of 100 can be applied to the Occupational Exposure Standards (OES) (Ref 4.8) to extend their use to the general public. A safety factor of 40 has been commonly applied, but use of a more stringent standard has been gaining favour. It was felt that the higher standard would be more appropriate for the present study due to the relatively good air quality in the immediate locality. The OES/100 guidelines for HCl and HF are given in Table 4.10. Predicted levels for HCl and HF (shown in Table 4.11) are significantly below the OES/100 guideline at the sensitive receptor.

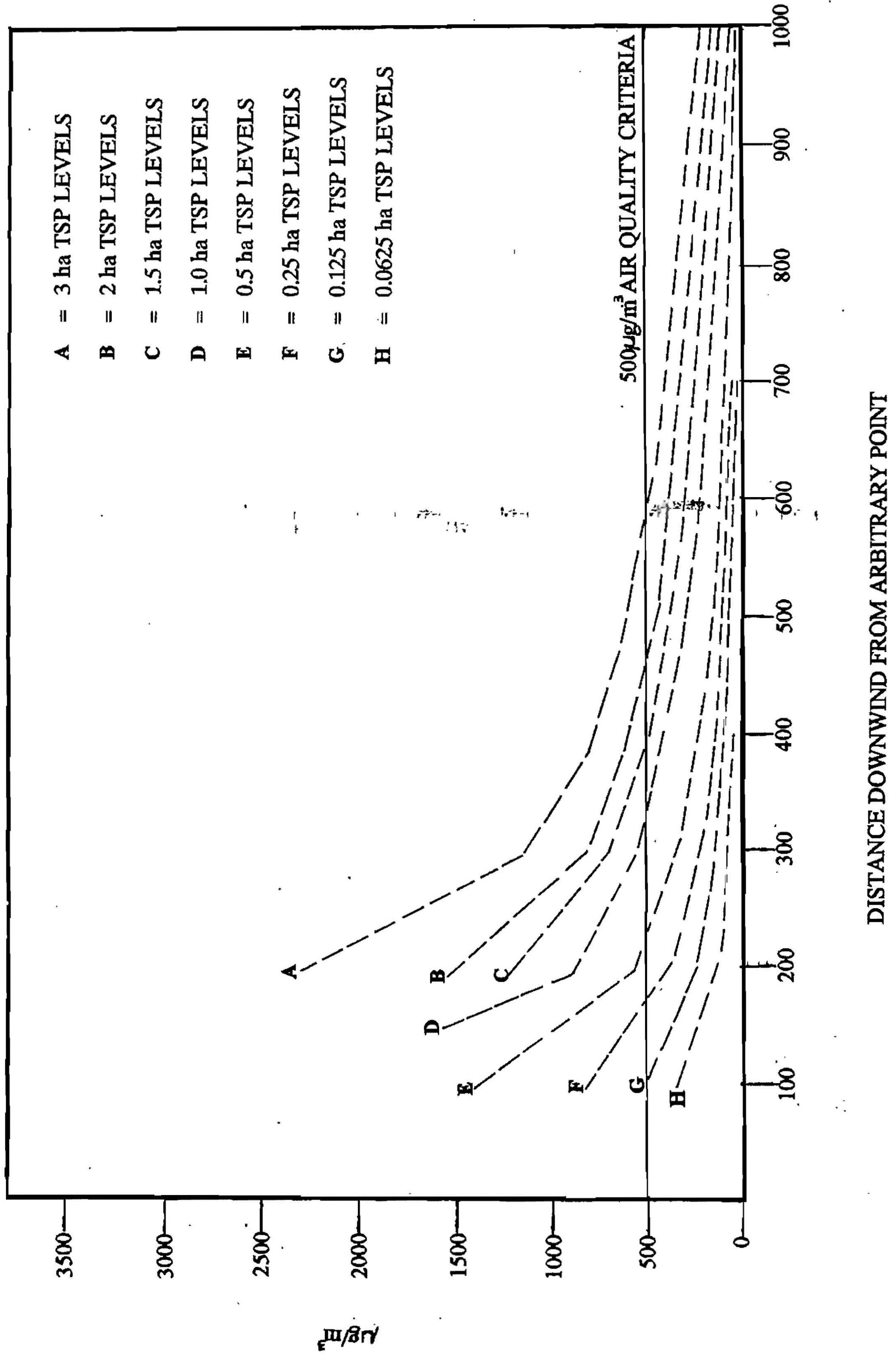


Figure 4.6

TSP Levels from Construction Site Operations

Table 4.10 : Derived OES/100 Air Quality Guideline

Pollutant*	OES ($\mu g/m^3$)**	OES/100 ($\mu g/m^3$)
HCl	7000	70
HF	2500	25

Notes

** no standards for THC*
*** short-term exposure limit (10-minute reference period)*

4.91 Confirmed or suspected carcinogens may be present as one or many compounds classified as PAHs. Although there is no direct evidence of carcinogenic compounds in PAH from the landfill gas sampling and testing carried out during this study, it is possible, though unlikely, that PAH could be present in the flare emission. A small amount of carcinogenic compounds, such as Benzo [a] Pyrene (BaP), a PAH which is confirmed to be carcinogenic, could be present in the flare emission. However, to put this issue in context, it must be emphasised that to-date there is no evidence of BaP being present in the landfill gas tested, nor is there any evidence from literature that this compound and other PAHs exist in high temperature landfill gas flares.

4.92 In the absence of actual landfill gas flaring data in respect of PAH, it is considered prudent to evaluate the probable impact of PAH carcinogens such as BaP on the sensitive receptors both on and off PPVL, should they be present in the landfill gas flare. The evaluation used BaP as an indicator of the possible carcinogens in the PAH component of the flare emission. Data from the limited air dispersion modelling carried out to evaluate the impact on the off-site sensitive receptor (the PPVRC) and at other locations on site was used. The latest Unit Risk Factor for BaP of 1.7×10^{-3} quoted from the California Air Pollution Control Offices Association was used in the assessment.

4.93 The assessment was carried out based on limited air dispersion modelling information which provided predictions of pollutant concentrations at the sensitive receptor (Table 4.11). The results suggest that the off-site sensitive receptor (PPVRC) and other on-site receptors at the higher grounds of PPVL, about 350m away from the flare, would not be exposed to BaP in excess of the risk criteria, if the flare emission contains BaP below 1.1×10^{-5} g/sec. Accordingly it would be prudent to limit the rate of BaP emission, if any, to substantially below 1.1×10^{-5} g/sec. The Contractor should be required to carry out an assessment on the possible impacts of carcinogens emitted from the flare, using a risk criteria of 10^{-6}, before his flare design is considered acceptable. Nonetheless, the Consultants consider that this level of BaP emission is unlikely and indeed achievable for flares using best available technology in respect of VOC and PAH destruction.

Table 4.11 : Predicted Concentrations at the Sensitive Receptor (PPVRC)

Pollutants	maximum 1 hour average concentration at sensitive receptor ($\mu g/m^3$)		AQO ($\mu g/m^3$)
	0(m)PD	90(m) PD	
TSP	0.04	0.22	260*
CO	0.82	4.4	30,000
NO_2 (assumed 20% of NO_x)	0.82	4.4	300
HCl	0.25	1.34	70**
HF	0.04	0.22	25**
SO_2	4.1	22.10	800
THC	0.163	0.89	***
PAH	0.0008	0.005	-

Note

* *AQO refers to 24-hour average, other AQOs refer to 1-hour average*
** *Short term exposure limit (10-minute reference period)*
*** *No standards for THC*

4.94 Locations on site close to the flare could be exposed to higher levels of BaP, if present. Table 4.12 shows the maximum concentration predicted in the vicinity of the flare for various heights above 0 mPD. The position at which maximum concentration was predicted, by the limited dispersion modelling carried out, is located about 50 m away from the proposed flare.

Table 4.12 : Maximum Predicted Concentrations in the Vicinity of PPVL

Pollutants	Height above PD(m) ($\mu g/m^3$)				AQO ($\mu g/m^3$)
	0	10	20	30	
TSP	0.81	10.1	7.1	4.0	260*
CO	16.4	203.5	143.7	80.1	30,000
NO_2 (assumed 20% of NO_x)	16.4	202.9	143.3	79.9	300
HCl	5.0	61.6	46.5	24.3	70**
HF	0.81	10.1	7.1	4.0	25**
SO_2	81.8	1014.3	716.4	399.5	800
THC	3.28	40.6	28.7	16.0	***
PAH	0.025	0.20	0.14	0.081	-

Note

* *AQO refers to 24-hour average, other AQOs refer to 1-hour average*
** *Short term exposure limit (10-minute reference period)*
*** *No standards for THC*

4.95 The only value in Table 4.12 that exceeds an AQO is SO_2 at 10m PD. However, because the expected SO_2 concentration at 0m PD level is so low (ie 82 $\mu g/m^3$), it is clear that the expected SO_2 concentration at a height where people may be breathing the air, approximately 2m from the ground, will be comfortably below the AQO level. This situation is considered acceptable with respect to air quality.

4.96 Before the absence of B(a)P emission can be demonstrated, it is considered prudent to limit public access to the vicinity of the flare. In the absence of actual landfill gas flaring data regarding B(a)P or PAHs, it may be necessary as a precaution to limit public access to an area around 50m. This restriction should be imposed until the Contractor can demonstrate that the flare operation is such that the exposure to the general public is below a carcinogenic risk of 10^{-6}. If unacceptable risk conditions are detected, the rate of emission of carcinogens must be reduced further. By way of example, the limited modelling carried out to date indicates that the emissions of B(a)P should be less than about 2.9×10^{-6} g/sec at the flare for a 50m radius restriction zone. If the emission rates can be shown to be lower then the restricted area would be correspondingly smaller. Indeed it is possible that the B(a)P emissions could be low enough such than no restriction is necessary.

Noise

Introduction

4.97 This section of the EA assesses noise impacts associated with restoration activities at the PPVL site, with particular reference to leachate and landfill gas control measures.

Background noise levels and monitoring data

4.98 Noise arising from the continuing operation of the landfill will be present in this area, until its closure. Noise arising from the container site to the east is also present, as is noise from the car testing centre.

4.99 Background noise monitoring has been undertaken at the site, measurements being made in hourly periods during the day between 07:00 hours and 19:00 hours. This monitoring was carried out by the Hong Kong Productivity Council during late November and early December 1993, and the full results are reproduced in Appendix 3. Summarised results, with a description of the monitoring locations and dominant noise sources, are given in Table 4.13. The monitoring locations and identified existing noise sensitive receivers are shown in Figure 4.7.

4.100 The results of baseline noise monitoring at PPVL-1 are dominated by vehicles at the landfill vehicle control area. This monitoring position is located on the landfill site itself, and the results therefore cannot be readily used to predict corresponding noise levels at sensitive receptors off-site.

4.101 The other monitoring position near this site is PPVL-2 which is at the boundary of the Vietnamese Refugee Camp to the south of the landfill. This refugee site is a noise sensitive receptor, and therefore the results at PPVL-2 are relevant to the study. The average L_{90} for the day of 51.3 dB(A) is moderately high, as are the L_{10} and L_{eq} figures (58.7 and 56.7 dB(A) respectively). It appears that most of this noise comes from activities at the landfill, although other sources also contribute (see Table 4.13).

Table 4.13: Summarised Baseline Noise Monitoring Results for PPVL

Monitoring Location		Major Noise Sources	Average Noise Level dB(A)		
			L_{10}	L_{90}	L_{eq}
PPVL-1	Facade of landfill site engineering office	1) Vehicle control/station opposite engineering office 2) Gusty wind in morning	60.4	52.1	58.5
PPVL-2	Boundary of Vietnamese refugee camp facing landfill site (car testing centre)	1) Dog barking 2) Container site to the east 3) Occasional noise from the refugee camp 4) Gusty wind in morning 5) Landfilling activities	58.7	51.3	56.7

Impacts of construction activities

4.102 The construction of the final contours of the restored landfill at Pillar Point Valley will involve significant earth moving activity by mobile plant working across the site. Precise details of the plant items to be employed on site will be determined by the contractor, but will include a number of items of powered mechanical equipment. It is assumed at this stage that these activities will be restricted to daytime operations only (07:00 - 19:00 hour, Mon - Sat). A construction noise permit will be required to work outside these hours, and will be necessary if percussive piling (eg for building foundations) is to be carried out on site.

4.103 The installation of the leachate and landfill gas control measures should not involve earth moving activities, and significant noise generation is not envisaged from this stage of construction activities.

Mitigation Measures

4.104 Guidance is provided in the Practical Guide for the Reduction of Noise from Construction Works (Ref 4.9), produced by EPD. Various options exist to control the noise from these activities, including the selection of quieter plant, the erection of temporary screening mounds around noisy activities, and the reduction in the numbers of items of plant in use at any one time.

4.105 Currently, receivers sensitive to noise from PPVL are few, and it should be possible to ensure that noise levels at the nearest receivers do not exceed the target level of 75 dB(A).

Impacts of leachate and landfill gas control measures

4.106 It is proposed to provide a leachate treatment plant at Pillar Point Valley Landfill. Leachate from the other landfill sites may be pumped into tankers (or via the connection pipe from SLSL) and transported by road to Pillar Point Valley. The treatment plant will be located on the eastern side of the site at its southern end, at a distance of approximately 150 metres from the nearest boundary of the Vietnamese Refugee Camp.

4.107 The primary noise source associated with leachate treatment will be aeration equipment in the lagoon. This equipment will operate 24 hours per day throughout the period when leachate is being treated. Due to the proximity to the Vietnamese Refugee Camp it may be necessary to erect semi-permanent earth bunding or other forms of screening around the southern part of the leachate treatment plant to reduce noise impacts.

4.108 There will be infrequent vehicle movements at the plant if tankers deliver leachate from the other sites, but the noise impacts resulting from these will not be significant.

4.109 Landfill gas (LFG) will be pumped from the Pillar Point Valley Landfill, and there will be some noise associated with this extraction plant. This extraction plant is to be

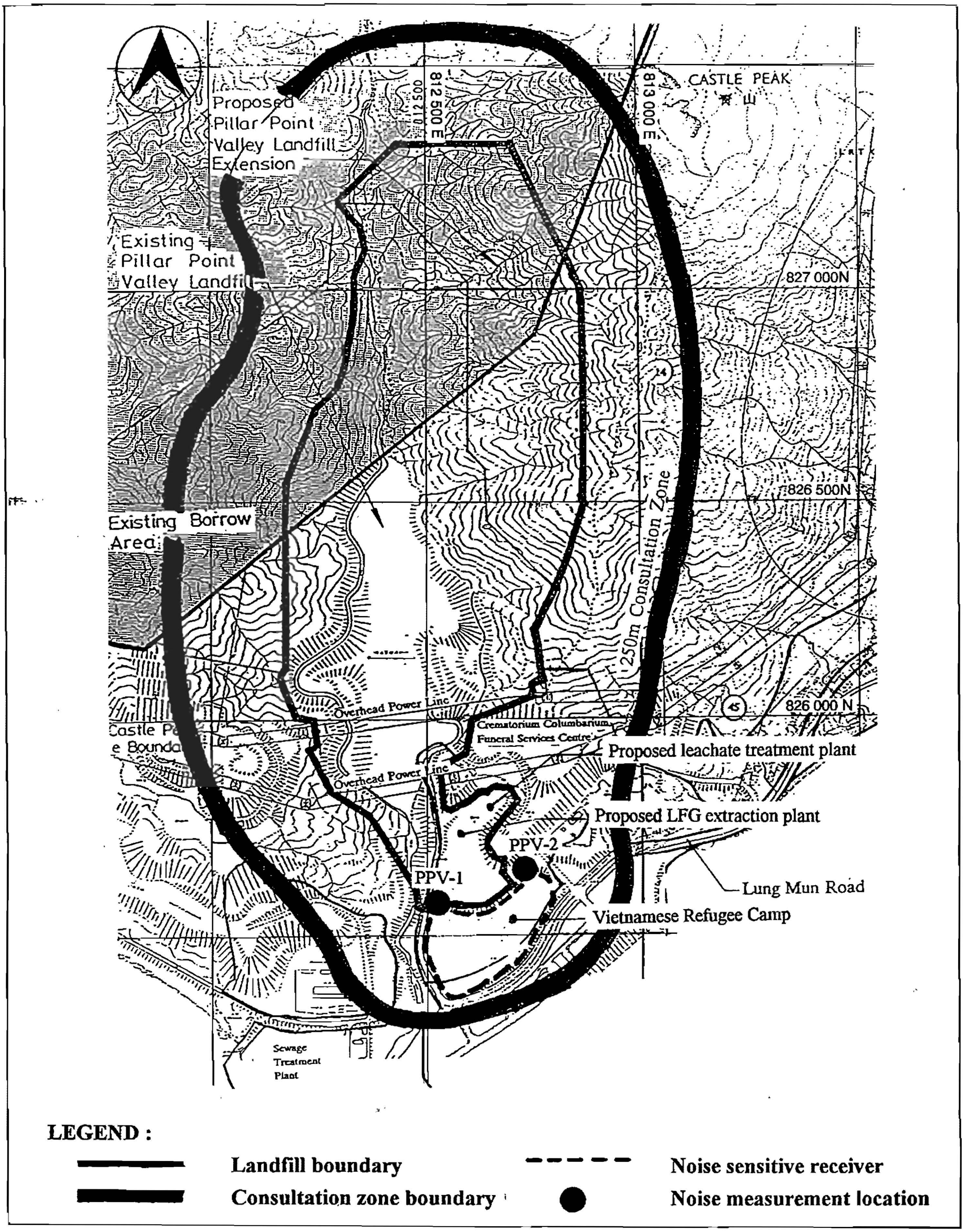


Figure 4.7
Pillar Point Valley Landfill
Sampling Locations for Noise Measurement

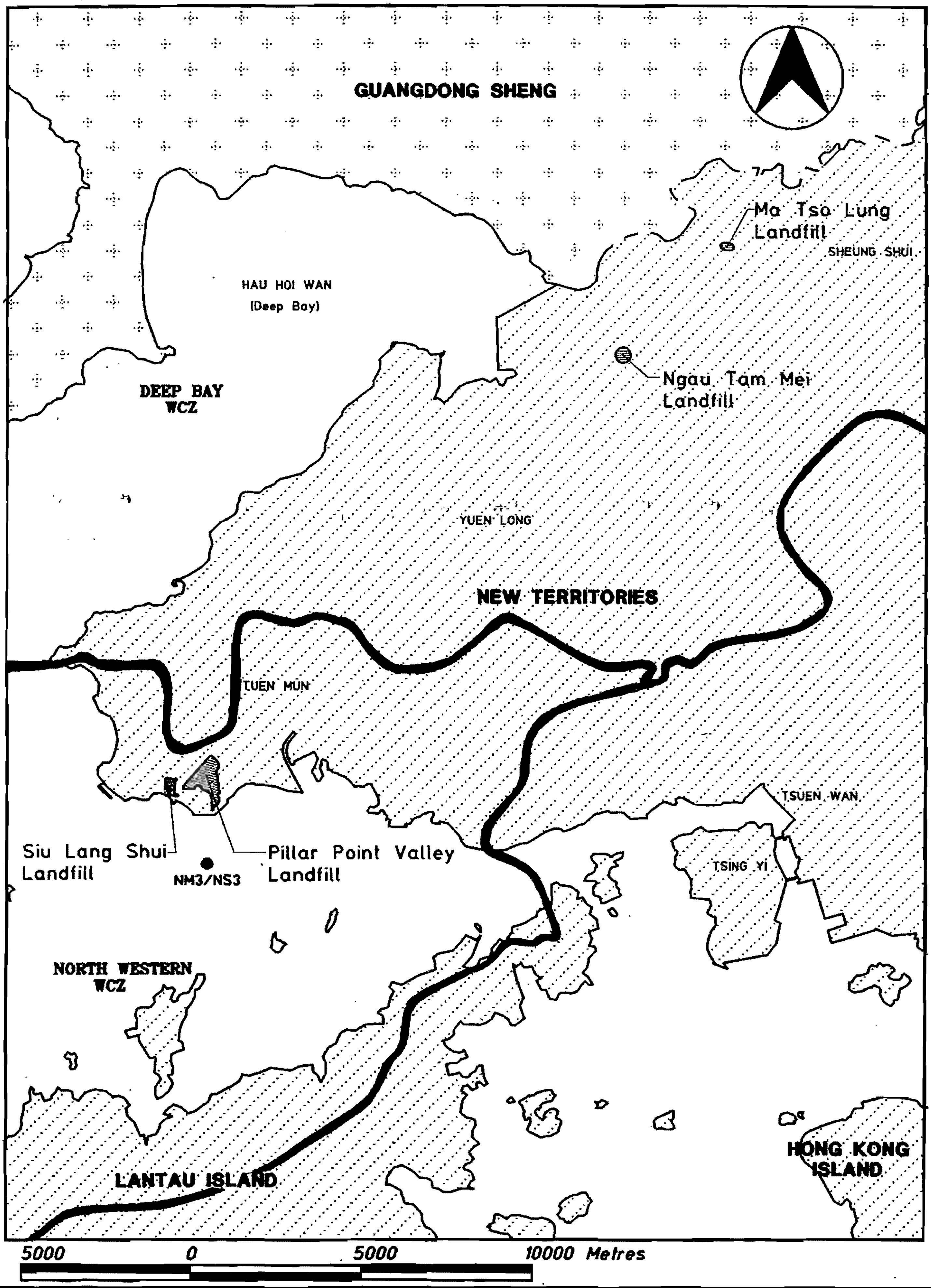


Figure 4.8

Marine Water Quality and Bottom Sediment Monitoring Station NM3/NS3 at Tuen Mun in North Western WCZ

located to the south-west of the leachate treatment plant, at a distance of approximately 110 metres from the Vietnamese Refugee Camp. It will be possible to specify pumps with a low noise output and, as necessary, to provide acoustic housings to control noise arising from this source.

4.110 In the event that the Vietnamese Refugee Camp or any other noise sensitive development are present at the post-restoration stage, a further noise impact assessment study should be carried out. In such a study attention should be paid to the landfill gas extraction plant and the leachate treatment plant.

Impacts of afteruse option

4.111 The use of the restored site as hiking and picnicking would not lead to the generation of significant levels of noise. Additionally, the provision of screening will reduce the impact of noise generated by the leachate and LFG control plant. It is not considered that any part of the afforestation afteruse would be sensitive to such noise generated on site.

4.112 A potential off-site noise sensitive receiver to the leachate treatment and gas collection plant is the existing Vietnamese Refugee Camp which is situated about 110 to 150 m south. The life span of the camp is still uncertain though it has been indicated that the camp might be closed before 1997. Given the buffer distance and noise mitigation measures outlined above, it is considered that the increase in the noise level due to the operation of the afteruse facilities would not cause excessive noise nuisance to this sensitive receiver, if it were to exist following the restoration phase.

Water Quality

Introduction

4.113 This section examines the results from the leachate, groundwater and surface water monitoring programme conducted to date for this study. The quantity of leachate flowing from the landfill is also estimated. Impacts on water quality are assessed from the construction and operation of the leachate treatment works, and consideration is given to the preferred restoration option for the landfill. The environmental quality standards and guidelines in relation to water quality are covered in Chapter 3 in which the standards for effluents discharged from PPVL and the three other landfills are given in Table 3.10.

Existing marine water quality at PPVL

4.114 PPVL lies within the North Western WCZ. Similar to other WCZs, the discharge of effluents is controlled through licensing. Marine water quality, especially the inshore waters, is influenced by local run-off and discharges from land. The marine water quality and bottom sediment quality are monitored in this region by EPD on a regular basis. The location for the monitoring stations NM3 (marine water) and NS3 (bottom sediment) which are off-shore to PPVL and SLSL is shown in Figure 4.8. The summary statistics of 1990 - 1992 marine water quality and bottom sediment quality of NM3 and NS3 adjacent to Pillar Point at Tuen Mun are given in Table 4.14 and Table 4.15 respectively. As shown in the tables, the marine water quality largely complies with the key WQOs (Table A1.1 in Appendix 1). It is, however, considered that this regional marine body contains an elevated level of nutrient, in particular inorganic nitrogen. The data shown in Table 4.15 indicate that elevated concentrations of cadmium, chromium, copper, nickel, lead and zinc at NS3 sediments compared to the Government classification of sediments as given in Table 4.16 (Ref. 4.10). These class C sediments have been seriously contaminated with different kinds of heavy metals and have potential ecotoxicological consequences for marine life and the human food chain. The sediments would require careful disposal with isolation from the marine environment. Waste water discharged to local watercourses combined with inadequate sewage treatment at Pillar Point contribute to the nitrogen enrichment of this region.

Table 4.14 : Summary Statistics of 1990 - 1992 Water Quality of North-Western Monitoring Station NM3 at Tuen Mun

Parameter	Surface	Middle	Bottom	Average
BOD5	1.15	1.04	0.83	1.01
	(0.2 - 2.17)	(0.13 - 4.02)	(0.21 - 1.56)	(0.18 - 2.41)
COND (umho/cm)	408.4	431.1	444.1	427.9
	(311.9 - 492.8)	(358.9 - 496)	(392.1 - 502.5)	(364.8 - 497.1)
DO	7.02	6.56	6.48	6.69
	(5.23 - 8.93)	(4.46 - 8.58)	(3.19 - 11.09)	(4.45 - 9.44)
DO (% Sat)	94.97	87.55	85.11	89.21
	(73.78 - 120.99)	(63.8 - 115.2)	(44.4 - 139.5)	(64.0 - 118.4)
pH (unit)	8.05	8.15	8.15	8.11
	(6.72 - 8.68)	(7.78 - 8.64)	(7.76 - 8.6)	(7.65 - 8.64)
Salinity (PPT)	27.06	28.98	30.08	28.71
	(17.56 - 32.9)	(23.54 - 32.91)	(24.34 - 32.89)	(22.17 - 32.9)
Secchi disc depth (m)	1.54	n.a.	n.a.	1.54
	(0.8 - 3.4)	n.a.	n.a.	(0.8 - 3.4)
Temp (degree C)	22.9	22.4	22.0	22.4
	(12.4 - 28.6)	(12.3 - 28.3)	(12.1 - 28.3)	(12.3 - 28.3)
TURIS (NTU)	6.45	9.04	10.54	8.68
	(2.2 - 19)	(1.9 - 40)	(1.8 - 32.0)	(2.0 - 28.3)
CHY (mg/cu m)	2.66	1.77	1.28	1.90
	(0.2 - 12.0)	(0.2 - 7.5)	(0.2 - 3.2)	(0.23 - 7.57)
FC (no./100 ml)	532.9	1327.6	1067.1	938.7
	(0.0 - 3600.0)	(30.0 - 7200.0)	(60.0 - 5200.0)	(25.0 - 3386.7)
PHAE (mg/cu m)	1.29	1.38	1.33	1.34
	(0.2 - 6.2)	(0.2 - 3.9)	(0.2 - 4.8)	(0.2 - 5.0)
SS	5.69	8.92	13.47	9.36
	(0.5 - 19.0)	(1.0 - 47.0)	(3.5 - 43.0)	(1.7 - 29.0)
E.coli (no./100 ml)	149.4	359.1	367.7	379.0
	(0.0 - 3000.0)	(20.0 - 6800.0)	(50.0 - 4700)	(15.0 - 2986.7)
TVS	1.72	3.17	2.75	2.55
	(0.5 - 11.0)	(0.5 - 37.0)	(0.5 - 15.0)	(0.5 - 21.0)
NH4-N	0.076	0.104	0.098	0.093
	(0.005 - 0.170)	(0.005 - 0.381)	(0.005 - 0.546)	(0.005 - 0.366)
NO2-N	0.033	0.03	0.029	0.031
	(0.012 - 0.076)	(0.012 - 0.067)	(0.002 - 0.086)	(0.012 - 0.069)
NO3-N	0.26	0.20	0.20	0.22
	(0.012 - 0.624)	(0.013 - 0.513)	(0.015 - 0.740)	(0.013 - 0.557)
PO4-P	0.027	0.027	0.025	0.027
	(0.002 - 0.050)	(0.002 - 0.045)	(0.002 - 0.056)	(0.002 - 0.044)
TKNS	0.41	0.432	0.403	0.417
	(0.2 - 0.64)	(0.19 - 0.82)	(0.13 - 0.66)	(0.19-0.66)
TPS	0.062	0.069	0.064	0.065
	(0.02 - 0.13)	(0.04 - 0.13)	(0.02 - 0.14)	(0.033 - 0.133)

Note:
1. Data presented are the means (geometric means E. coli)
2. Data enclosed in brackets indicate the ranges
3. Data unit presented is in mg/l except for others being specified
4. Refer to A2.2 (Appendix 2) for abbreviations used

Table 4.15 : Summary Statistics of 1990 - 1992 Bottom Sediment Quality of North-Western Monitoring Station NS3 at Tuen Mun

Parameter*	Sampling Date					
	2-Aug-90	9-Sep-91	9-Sep-91	15-Jul-92	13-Nov-92	13-Nov-92
	Type 1**	Type 1	Type 2***	Type 2	Type 1	Type 2
NH3	2.30	18.10	5.41	-	4.20	4.40
TKN	520.00	1200.00	1500.00	-	450.00	450.00
TP	1200.00	470.00	460.00	-	230.00	230.00
COD	18000.00	11000.00	19000.00	-	16000.00	14000.00
TVS (%)	8.50	8.50	10.00	-	10.00	11.00
TS (%)	62.00	41.00	97.00	-	44.00	35.00
CN	< 0.01	< 0.01	< 0.01	-	-	-
TOC (%)	0.97	0.30	1.40	-	0.70	0.50
pH (pH units)	8.23	7.70	7.60	-	-	-
S.G. (unit)	2.4840	1.5380	2.4360	-	2.5925	2.5567
Al	12000.00	25000.00	25000.00	28000.00	27000.00	28000.00
As	11.00	25.00	18.00	17.00	12.00	13.00
B	43.00	49.00	46.00	34.00	22.00	20.00
Cd	2.90	10.00	11.00	< 0.5	< 0.5	< 0.5
Cr	29.00	49.00	51.00	53.00	58.00	55.00
Cu	39.00	79.00	86.00	100.00	84.00	91.00
Fe	25000.00	32000.00	34000.00	39000.00	37000.00	42000.00
Hg	0.29	< 0.05	< 0.05	0.33	0.08	0.06
Mn	490.00	670.00	700.00	540.00	650.00	740.00
Ni	14.00	25.00	25.00	37.00	28.00	31.00
Pb	39.00	71.00	79.00	[illegible]3.00	46.00	54.00
Zn	64.00	120.00	120.00	130.00	130.00	150.00
PCBs (µg/kg)	25.00	-	-	-	6.00	-
PAHs (µg/kg)	57.00	-	-	-	69.00	-
Eh (mV)	-432.00	-118.00	-118.00	-	-122.00	-122.00

Note: * All units in mg/kg dry solids except where noted

** Bulk sample

*** Sample with particle sizes < 63 µm

(shaded) indicates the levels of metal exceed Government standards for contaminated sediments (Class B or Class C (Ref 4.10)).

Refer to A2.3 (Appendix 2) for abbreviations used

Table 4.16: Classification of Sediments by Metal Content (Ref 4.10)

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

** All units in mg/kg dry solid*

Class A - uncontaminated material
Class B - moderately contaminated material
Class C - seriously contaminated material

4.115 The Pillar Point Sewage Treatment Works (PPSTW) is situated in Area 47 which is close to PPVL. PPSTW is providing preliminary treatment facilities (screening and grit removal) to serve a domestic population of 520,000 and an industrial area of 60 ha at Tuen Mun Town. The peak flow capacity of PPSTW is about 500,000 cu m/day and its dry weather flow is about 183,000 cu m/day. The existing 1500 mm diameter submarine outfall from the PPSTW extends about 900 m south-west of the works. Leachate arising from PPVL is currently discharged directly into PPSTW.

Existing groundwater and surface water quality

4.116 Site investigations and subsequent monitoring carried out for this study have provided information with respect to groundwater quality in the vicinity of PPVL. Groundwater flow is predominantly southwards, towards the sea.

4.117 The diversion of small volumes of groundwater to sewer in 1989 suggests that it was known to have become contaminated by leachate, although there are no data available to substantiate this view.

4.118 Hong Kong has no specific objectives for surface water and ground water. However the strongest guidelines adopted elsewhere have been used to compare the analytical data in order to assess the quality of groundwater and surface water close to the site. They include:

- Dutch guidelines for assessing soil and groundwater contamination (Ref 4.11 and Ref 4.12); and

- WHO drinking water standards for groundwater (Ref. 4.13)

Table 4.17 below summarises these standards as well as the results of the analysis of groundwater and surface water at PPVL. Although the analyses of groundwater downstream of the landfill in DH103 show no evidence of contamination by leachate, some of the parameters exceed the standards quoted.

4.119 As shown in Figure 4.9, surface water sampling location W102 is a short distance downstream of both the east and west catchwater channels. The results of the analyses as given in Table A4.1 of Appendix 4 show that water is contaminated compared with the upstream location W101, exhibiting elevated chloride, conductivity, organics and ammonia. The potential sources of contamination are the surface inflow of leachate to the western catchwater, discrete seepages of leachate into the stream and possible inflow of contaminated groundwater via diffuse seepage. With the exception of pumping stream water above W101 for dampening the road surface in controlling the fugitive dust emissions, there is no other use for surface water and groundwater in the vicinity of PPVL.

4.120 The eastern catchwater is believed to be contaminated by sources not identified during this study. The CED site operator is aware of this and is currently pumping water from

Table 4.17 : Analysis of Groundwater and Surface Water at PPVL

Determinand *	Standards for Groundwater ***			Water	Source ****
	ST1	ST2	ST3		
	Dutch Grade C	Dutch VPR	WHO	Surface water	Ground-water
pH (pH units)			6.5-8.5	7.3-8.0	6-6.4
EC (uS/cm)				50-1000	150-190
Cadmium	0.01	0.006	0.005	<0.02	<0.02
Chromium	0.2	0.026	0.05	<0.1	<0.1
Copper	0.2	0.035	1	<0.1	(0.1)
Lead	0.2	0.05	0.05	<0.1	(0.4)
Nickel	0.2	0.04		<0.1	<0.1
Zinc	0.8	1	5	<0.01	0.16
Manganese			0.1	(<0.1-0.2)	(1.1)
Iron			0.3	(0.2-1.2)	(16)
Sodium			200	5.5-80	30-71
Potassium				1.6-40	5.1-5.2
Hardness (as CaCO3)			500	5.5-48	28
Sulphate			400	<10-17	<10
Sulphide	0.3				<0.1
Phosphorous				<0.1-0.4	
Nitrate			10	0.28-0.61	1.34
Ammonia Nitrogen				<0.1-63	<0.1
Kjeldahl Nitrogen					<0.1-0.1
Total Organic Carbon				<1-51	2-3
Chloride			250	5.6-110	12-30
COD				<7-200	9-80
BOD				<5-67	<5-11
E. coli (no./100ml) **			0		(180)

Note:

* All units in mg/l except where noted

** The Standard for drinking water (WHO) refers to Fecal Coliform

*** The standards for groundwater and drinking water being refered to are as follows:

ST1 Dutch Criteria for Category C Clean Up Investigations (Ref 4.11)

ST2 New Dutch Second Generation VPR Criteria (Ref 4.12)

ST3 WHO Guidelines for Drinking Water (Ref 4.13)

**** Data enclosed in brackets indicate the exceedance of the standards quoted

the eastern catchwater into the sewer discharge pipeline, to avoid direct discharge to, and contamination of, the stream.

Leachate quantity and quality

4.121 Leachate generation occurs when the rate of water entering a landfill exceeds the absorptive capacity of the wastes. At PPVL, there are at least two main routes whereby water can enter the wastes - direct rainfall infiltration and groundwater entry.

4.122 Based on waste input data, rainfall records, and estimates with respect to absorptive capacity of the waste, groundwater input, and effectiveness of landfill capping (intermediate or final), the volume of leachate likely to be generated during different stages of development of the landfill, and after it is restored, can be estimated. These issues have been addressed in WP3 (Ref 4.14).

4.123 Historic leachate flows were consistent with ingress of rainfall equivalent to 120 mm/a over 40 ha in 1989. This in turn is consistent with the expectation for infiltration for a largely uncovered compacted cdg/cdv layer at the steep gradients (15 - 30%) typically created at PPVL. Since 1989, a proportion of groundwater flow has been diverted to sewer, leading to approximately a threefold dilution in the strength of the leachate discharge. It is assumed that the flow rate has increased accordingly. Given the increase in the size of the landfill to 50 ha and the diversion of groundwater to the sewer, the present leachate discharge flows could be of the following magnitudes:

peak:	686 - 977 cu m/day
average:	343 - 489 cu m/day

4.124 The details of the water quality of leachate drillholes and the leachate discharge manhole are reproduced in Table A4.1 of Appendix 4, and the summary of the analyses of leachate at PPVL is given in Table 4.18. It appears that a leachate head of several metres exists over much of the site base and exceeds 10 m in places, thereby creating a significant driving head for basal liner leakage. Table 4.18 shows that the levels of COD, iron and total nitrogen exceed the standards for effluents discharged into foul sewer (Table A1.3), indicating that discharged of leachate into the PPVSTW nearby does not always comply with the requirements of the Technical Memorandum on effluent standards for discharges to foul sewers (Ref. 4.15). The situation is unlikely to improve unless leachate pre-treatment facilities are put in place prior to sewer discharge.

4.125 Perched leachate zones may also exist. A significant surface flow of leachate was emerging at the landfill surface approximately 100m up the valley from DH106 during the time of study. Remedial works to prevent surface flows of perched leachate going to stream should be undertaken as soon as possible.

Impacts of construction activities

4.126 Construction on the landfill has the potential to allow increased infiltration of rainwater to the wastes. Earthworks may result in disturbance to existing cover material and allow a larger proportion of incident rainfall to enter the wastes. Similarly, any piling or construction of foundations may provide pathways for rainwater into the wastes.

4.127 Earthmoving, for instance in the formation of a final restoration capping, may result in high sediment loads in runoff from the site. Whilst the overall water quality may be satisfactory, the suspended solids discharging to drainage channels or the sea should be minimised. This applies also, in the event that a low permeability membrane is placed over the wastes. Increased runoff from such a surface should be controlled so that no surface erosion occurs in areas affected by this runoff. Therefore, it is recommended that the cap be hydroseeded and the slopes be regraded at the earliest opportunity following the completion of landfilling in order to reduce the extent of soil erosion. Furthermore, surface runoff channels should be progressively built to control water run-off and erosion.

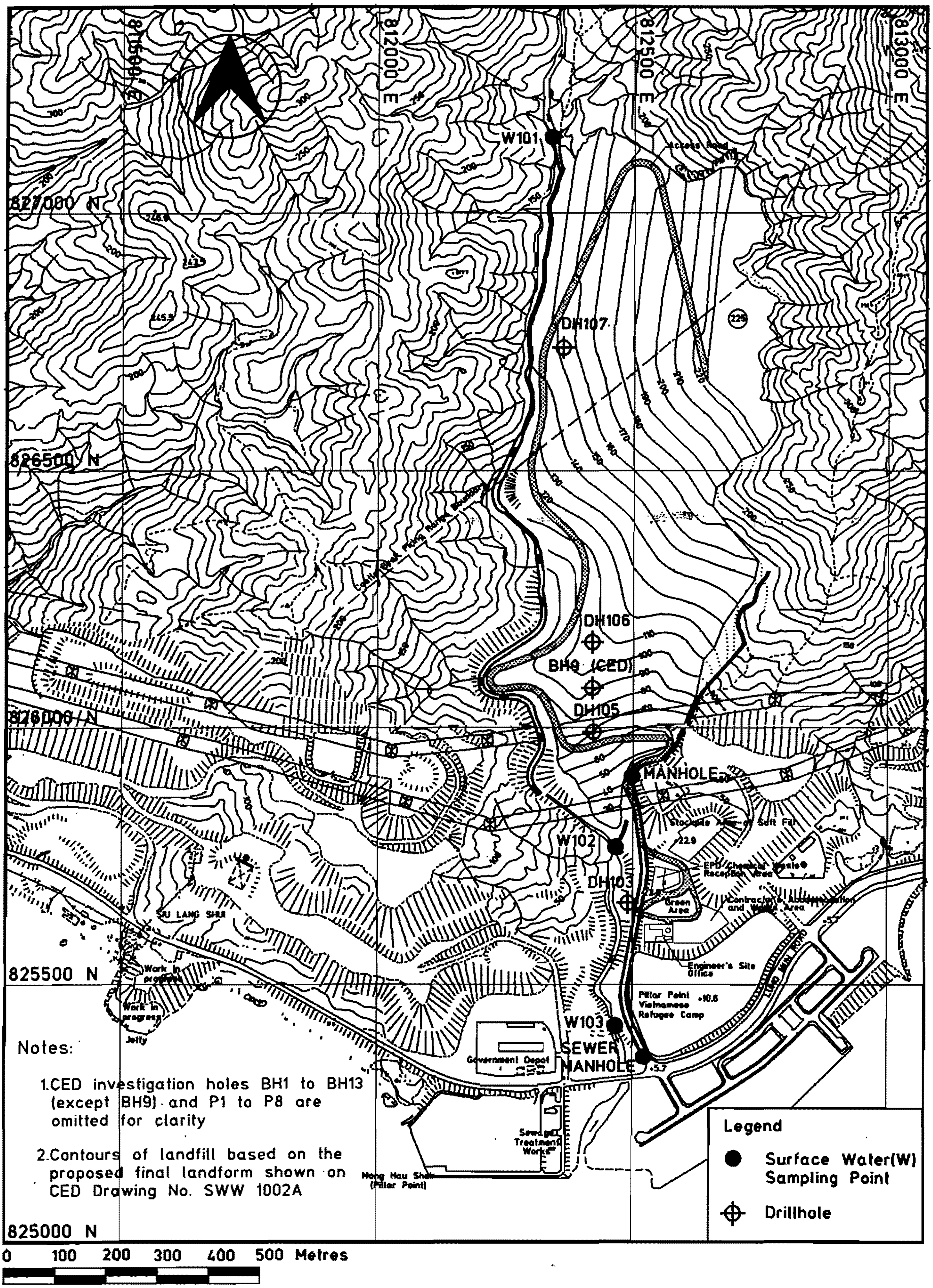


Figure 4.9

Pillar Point Valley Landfill

Sampling Locations for Leachate, Groundwater and Surface Water Monitoring

Table 4.18 : Analysis of Leachate from PPVL

Determinand*	TM on Effluent Standards ** >800 and <=1000	Landfill Site *** PPVL
pH (pH units)	6-10	6.7-7.7
Temperature (°C)	43	27.1-48.1
Suspended solids	800	
Settleable solids	100	
BOD	800	<5-410
COD	2000	(9-3500)
Oil & Grease	30	
Iron	10	(9-130)
Boron	2.4	
Barium	2.4	
Mercury	0.001	
Cadmium	0.001	<0.02
Copper	1	0.1-0.2
Nickel	1	<0.1-0.2
Chromium	0.6	<0.1-0.5
Zinc	1	0.16-0.55
Silver	1	
Cyanide	0.4	
Phenols	0.4	
Sulphide	4	<0.1-2
Sulphate	1000	<10-20
Total nitrogen	200	(<0.1-2200)
Total phosphorus	50	
Surfactants (total)	25	

Note:
* All units in mg/l except where noted
** Standards for flow rates (cu m/day) expressed as upper limits (Ref 4.15)
*** Data enclosed in brackets indicate the exceedance of standards

Impact of leachate control measures

4.128 Impacts associated with construction of leachate control measures will primarily relate to the initial installation. Works may include the following:

- construction of the landfill cap and associated drainage to minimise infiltration;
- intercepting the leachate seepages at the landfill surface;
- drilling of monitoring drillholes; and
- construction of leachate treatment plant at lower platform, together with associated pipework to transmit leachate from SLSL to the leachate treatment plant, and thence to the sewage treatment works at Pillar Point.

4.129 Impacts related to cap construction are primarily associated with short term management of incident rainfall and the associated runoff. Measures to intercept the sediment loads and perched leachate should be in place during the construction of the leachate control measures as mentioned above.

4.130 Overall, measures to control leachate at PPVL, once constructed, will have very few long-term impacts, other than the benefits associated with reducing the volumes and the strength of leachate generated at the site, and providing treatment to produce an improved quality for effluent discharged to the PPSTW, and thence to the sea.

Impacts of LFG utilisation measures

4.131 The extraction of LFG will remove large amounts of water from the wastes, which will form LFG condensate. It has been recommended in WP2 and WP6 (Refs 4.4 & 4.1) that condensate is collected in gravity pipework flowing to a central sump, from where it is pumped to the leachate treatment plant. No significant increase in surface water discharges or impacts on water quality are envisaged from LFG condensate.

4.132 No significant waste water arisings are envisaged from the LFG utilisation options identified in WP2. Small volume arisings may be expected from routine maintenance and cleansing operations of the equipment and drainage provisions should be made to collect and divert these arisings to the treatment plant.

Impacts of afteruse option

4.133 The option proposed for PPVL involves low intensity land use, with the majority of the area devoted to afforestation and recreation space. Extensive afforestation will reduce effective rainfall (ie infiltration and runoff) over the site by enhancing evapotranspiration. In all cases, site profiling may require incorporation of some appropriate intercepting drainage and surface drainage measures to collect sewage and contaminated surface water, shed rainfall and reduce rainfall infiltration.

4.134 Measures to prevent infiltration during construction works, and to minimise any damage to the capping profile, should be implemented. Areas of tree planting should take account of the likely depth of root penetration. Deep rooted species should not be planted over the cap.

Landscape, Afteruse and Visual Impacts

4.135 Upon completion, PPVL would consist of mostly uniform slopes extending from about 30mPD to 225mPD. The lower slopes up to about 120mPD would have a southerly orientation, while a large part of the upper slopes would face north-west. The new landform will contrast sharply with the steep and undulating topography of the surrounding hills. The platforms at the south end will remain the same upon completion of the landfill.

4.136 The landfill slopes will be afforested in accordance with a four-phase planting programme administered by TDD/Tuen Mun. As the tree seedlings grow to a mature size, the different phases of planting would not be distinguishable. There would be a dense woodland over most of the new slopes, with a large grassed area on the top platform. The new environment would be amenable to human use such as hiking, viewing and picnicking. The platforms south of the landfill could be easily adapted to accommodate a leachate treatment plant and gas control installations.

4.137 Selective grouping of buildings and planting could help to create orderliness and functional unity for the separate platforms. Careful positioning of the proposed leachate treatment and gas control facilities on the platform at 22.8mPD, behind existing slopes, would help to screen a large part of these plants from direct view.

4.138 There would be little adverse visual effect caused by the proposed restoration and development of afteruses on this site. Upon restoration of this landfill, the site would stand out from the surrounding areas due to its vegetation cover. Because of the dense tree cover, the uniformity of the engineered slopes would not be readily noticeable. It is considered that the visual quality of the site would be greatly improved.

Settlement

Introduction

4.139 Consolidation of waste within a landfill site is an inevitable process and cannot be effectively prevented. Settlement of landfills takes place due to the complex interplay of physical, biological and chemical processes. Initial settlement occurs predominantly due to the physical rearrangement of constituent elements of the refuse in an way analogous to the primary consolidation of cohesive soils. Later settlement mainly results from the biochemical degradation of the waste which leads to further physical settlement occurring as the internal "fabric" of the landfill no longer has sufficient strength to sustain the weight of the material above it. Normally this kind of settlement follows an exponential decay with a half-life of 5 years or less, resulting in the completion of 97% settlement within 25 years.

4.140 As the later settlement due to the biochemical degradation of the waste takes a relatively longer time prior to the stable stage, the degree of settlement has more implications for the restoration design. The amount of settlement is dependent on waste composition, the age of wastes and type of compaction, etc. For domestic waste a total settlement of 20% +/- 5% of the fill thickness is anticipated.

Existing conditions

4.141 PPVL has received wastes since 1983 and will continue receiving wastes until shortly prior to a final restoration. Consequently, initial settlement is likely to be greater than on older sites. During the time of survey, the southern flanks of PPVL have already been capped and restored by hydroseeding. Although this area was capped with an intermediate capping layer of 2 metres thick, it is expected to be tipped over as part of the proposal to extend the site up to its ultimate capacity of 13 Mt. The major problem with the cap has been localised scour which has resulted in the development of several erosion gullies down the slope.

4.142 Apart from some settlement-related features such as cracking that was observed at the junction between down-slope and across-slope drainage channel, there were no significant settlement features discovered on the restored area of the landfill during the preceding site visits. In addition, no features were observed during the walkover survey to suggest instability of the slopes. In the absence of adequate data for the settlement, it is predicted that future average settlements at the PPVL site will be in the range 7.5% to 12.5% of the total waste thickness over the next 40 years.

Impacts of construction activities

4.143 Construction activities over PPVL must take account of likely settlement even though the construction activities themselves will have little impact on the settlement of the wastes. Piling for foundations would influence only a small proportion of the wastes. Settlement would result in piled structures becoming elevated above the final level of the landfill. Piles would be subject to significant down drag forces as the surrounding waste settles. Construction of lightweight flexible structures which can tolerate the magnitude of total settlement and differential settlement anticipated on landfill sites are therefore likely to be more appropriate. Loadings imposed at the surface, unless they are very large and cover wide areas, will have little effect on the rate of settlement of the landfill sites as a whole.

4.144 Construction of LFG management control measures will consist of many drillholes with headworks and interconnecting pipe runs which must take account of on-going waste settlement. LFG control compounds must be constructed on level ground so that they are not affected by settlement or differential settlement.

4.145 Leachate management will require construction of a leachate pre-treatment plant on the platform at the south. Measures must be incorporated for the protection of the aeration lagoons from settlement if they are likely to be sited on wastes. Drainage channels should be constructed so that they do not crack and allow surface water drainage to infiltrate into the landfill and possibly damage the landfill cap, soil and sub-soil profile.

Impacts of Afteruse

4.146 The preferred afteruse for PPVL is afforestation of the slopes and upper platform. The proposed afteruse option focuses on low intensity land use with a low proportion of the site area anticipated to accommodate buildings. Although the average total settlement at PPVL could be in the range 7.5 to 12.5% of the total waste thickness over the next 40 years, it is considered that the anticipated settlement will not be critical to the activities proposed.

4.147 Correct use of flexible surface drainage channels over the landfills will enable surface water runoff to be effectively removed from the sites and will minimise disruption to proposed afteruses. Maintenance of surface water channels will also be required, including removal of any debris and repair defects.

High Tension Power Line

Potential health effects of electromagnetic fields

4.148 Electromagnetic fields (EMFs) exist wherever electricity flows and are directly in proportion to the flow of electric currents. Power lines are considered to be a major source of EMFs which have an ability to penetrate most substances and are associated with health problems. Health risks associated with strong EMFs include depression, headaches, sleeplessness, cancer and possibly even death. Children are regarded as being more at risk than adults. The potential effects on human health will depend on a variety of factors including strength of field, proximity to source, potential shielding and period of exposure.

4.149 The health effects of EMFs have been the subject of a wide ranging literature review. Some of the major studies conducted to date were unable to establish a clear causal link between EMFs and cancer (Ref 4.16), there is however consensus amongst many authors of a strong correlation between the two and need for further research into the area.

Safety clearances for the power line

4.150 To enable effective electricity transmission, most of the power cables in Hong Kong are hung onto outdoor pylons and the voltages are upgraded to several hundred thousands volts. There is always a risk to have a structure or moving object close to the high tension power lines. Therefore, a minimum clearance is required at the lowest conductor of the power lines so as to allow an adequate safety and buffer zone for the adjacent landuses.

4.151 China Light & Power Company (CLP) have a standard guideline for the minimum clearance of power cables across the regions of the New Territories, Kowloon Peninsula and Outlying Islands in Hong Kong. With the exception of NTML, 400 kV extra-high tension power lines either bisect or lie adjacent to all of the landfill sites. A minimum clearance of 5.3 metres must be maintained between the nearest conductors and any obstacles, such as an object on which a person can stand, at all times. Similarly, a minimum clearance of 7.6 metres must also be maintained between the lowest conductors and the ground (or 8.1 metres over road surface) at all times. Occasionally, clearance for building reserve is given to a particular power line adjacent to which permanent buildings and structures have been established.

Planning for afteruse option

4.152 Various forms of human activity already occur or will take place around the restored sites. As such, risk and safety aspects of short term exposure to EMFs and electricity shock from these power lines should be taken into account. In terms of the planning and design of the settings for each afteruse option, the consultants took the effects of EMFs and safety aspects into consideration, giving adequate buffer distances between power lines and the major future sensitive uses.

Impacts of high tension power line and EMF

4.153 As shown in Figure 4.2, there are two extra-high voltage tension power lines (400 kV) which cross the PPVL site in the east to west direction, parallel to one another at heights ranging from 76.0 mPD to 157 mPD within the boundary of PPVL. The lowest points of the conductors for the southern and northern power lines are 76.0 mPD and 107 mPD respectively. The approximate distances between the lowest and nearest conductor of the power lines and the sensitive receptors on the site are given in the Table 4.19.

Table 4.19: Distance to the Lowest and Nearest Conductor

Sensitive Receptor	Approximate Distance to the Lowest and Nearest Conductor
Picnic Area/ Lookout Shelter	410 m
Vietnamese Refugee Camp	810 m

4.154 The possibility of risk to human health from EMFs at these receptor sites is considered to be insignificant because they are situated at some distance from the source of EMFs, and also the length of exposure time will be relatively short within the boundaries of the restored landfill. At the picnic area and look out shelter, visitors will not stay for long enough to be at risk due to prolonged exposure. For the refugee camp, which is situated at the south-east corner outside the site boundary, the effects of EMFs to human health will be significantly dissipated because of the long separation distance to the source as indicated in Table 4.19.

4.155 There will be no major object or structure built near to the power lines for the preferred afteruse option, and the condition for the minimum clearance required by CLP will not be infringed. Furthermore, the present landfilling activity taking place at PPVL does not involve any building structure or operation which is close enough to the power lines to result in a breach of the guidance for the minimum clearance.

Conclusions and Recommendations

4.156 The recommended afteruse for PPVL is afforestation of the slopes with associated hiking trails and viewing areas. This option is considered to be compatible with the Tuen Mun OZP. It is considered that the existing topography of the site provides suitable opportunities for the siting of the LFG extraction plant and leachate treatment facility without the need for extensive earthworks.

4.157 The restoration of PPVL involves the emplacement of a capping layer, planting and installation of structures associated with leachate treatment and LFG control. It is recommended that the capping layer for PPVL should contain final intermediate cover, protection layer, geomembrane, geodrain and soil layers of which a minimum of 1,000 mm cdv or cdg should be placed on top of the cap for planting purposes.

4.158 It is recommended that no heavy structure be built directly on areas where waste has been deposited, and foundation designs of throughways and light structures should be able to accommodate differential settlement rates. Stability should be enhanced by the compaction of the cdv or cdg material, and slope gradients should be generally not greater than 1(V):4(H) to ensure an adequate factor of safety. Correct use of flexible surface drainage over the landfills will enable surface runoff to be effectively removed and will minimise disruption of the proposed afteruse.

4.159 Predictions of LFG yield at PPVL for a 10 year period (1993-2003) range from 23 $\times 10^6$ cu m to 80 $\times 10^6$ cu m LFG/year. The composition of LFG is typical of a methanogenic landfill and the gas is under positive pressure with some evidence of off-site migration. LFG management at PPVL should encompass LFG extraction and perimeter migration control, and this will require the emplacement of suitable plant and protection measures. It is recommended that off-site buildings to the south of the landfill should be protected against the possibility of LFG migration by the installation of suitable gas detection alarms.

4.160 It is concluded that, by the use of suitable mitigation measures, release of LFG during construction can be minimized. During operation, LFG would be released from passive vent trenches, if used as interim control measures, but with sufficient monitoring and displacement from sensitive receivers migration risks are considered minimal.

4.161 The LFG extraction system should be active, with LFG extraction wells being drilled retrospectively at an appropriate grid spacing to optimize LFG yield. A separate perimeter system will be required, should the bitumen coating on the sides of the landfill be inappropriate at preventing LFG migration, with extraction wells installed at an appropriate distance. With the emplacement of the capping layer and installation of the LFG extraction system, there will be no significant impacts of LFG on the proposed afteruse of the site. However, it is recommended that on-site buildings should have adequate protection measures and that public activities on-site associated with ground disturbance or fire should be prohibited.

4.162 It is recommended that LFG should be utilised to provide, in the least, on-site energy requirements, with possible direct off-site use of LFG for industrial purposes representing the most energy efficient option if more extensive utilisation is adopted. The utilisation of LFG is also recognised of being of considerable environmental benefit when compared to its release to atmosphere. It is recommended that the LFG extraction and utilisation schemes be managed by a single contractor and that facilities are located at the base of the site to ensure appropriate collection of LFG condensate.

4.163 It is recommended that the leachate treatment facility be shared with SLSL. The conceptual design is based on a combination of aerobic and anoxic biological processes. The system should permit expansion to accommodate possible future increases in flow of leachate from the landfill sites. If PPVL is to remain open beyond 1997, it is recommended that construction of the plant should proceed in advance of the main restoration contract to meet interim operational demands for leachate treatment. It is concluded that the emplacement of a low permeability capping layer will reduce the overall leachate treatment costs by lowering rainwater ingress and hence leachate generation.

4.164 An assessment of current air quality and potential impacts associated with the afteruse development of the landfill was undertaken. With respect to the construction phase, it is recommended that, to ensure TSP criteria are not exceeded dust mitigation measures be strictly applied to ensure the air quality criteria are complied with at nearby sensitive receivers. Predicted emissions from flaring activity associated with the LFG extraction plant at PPVL are low, and AQOs for TSP, SO_2, NO_2 and CO are not likely to be exceeded at sensitive receivers nearby. The predicted levels of HCl and HF are significantly below the OES/100 guideline at the sensitive receiver. It is recommended that the restoration contractor be required to carry out an assessment on the possible impact of carcinogens emitted from the flare, before their flare design be accepted.

4.165 An assessment of current noise levels and potential impacts associated with the afteruse development of the landfill was undertaken. It is concluded that, with the implementation of suitable mitigation measures, the restoration phase and installation of LFG and leachate control measures should not result in the target level of 75 dB (A) at sensitive receivers being exceeded. However, during the afteruse phase when the LFG and leachate control installations are operational, additional mitigation measures, such as the use of screening or quiet plant, will be necessary to ensure compliance with relevant noise criteria. It is not considered that any part of the afteruse site would be sensitive to noise arising from such installations.

4.166 Marine water quality in the vicinity of PPVL largely complies with the WQOs for the North Western WCZ, although elevated nutrient levels occur. Elevated concentrations of heavy metals are present in marine sediments and are such that if any dredging works were required in the area special disposal methods would be required. There is limited evidence for groundwater contamination with leachate, although surface water is believed to be affected by leachate seepage.

4.167 Peak leachate discharge rates have been estimated at between 686 and 977 cu m/day, with an average of between 343 and 489 cu m/day. The quality of leachate entering the PPSTW is of an unacceptable quality according to Technical Memorandum Standards. It is recommended that remedial works to prevent surface flows of perched leachate within the wastes be undertaken as soon as possible.

4.168 During the construction phase it is recommended that increased surface runoff should be controlled to prevent surface erosion. This could be effectively achieved by hydroseeding, slope regrading and installation of surface water drains as restoration proceeds. The leachate control measures and treatment plant will result in a significant overall benefit in terms of reducing the overall volume of leachate generated and achieving a suitable quality standard. The afteruse option and associated tree planting will have no significant water quality impacts, as long as suitable drainage and shallow rooting tree species are provided.

4.169 It is concluded that there would be little adverse visual effect caused by the proposed restoration of PPVL, and because of the density of tree cover proposed the engineered slopes would not be readily visible. Overall the visual quality of the site would be greatly improved.

4.170 It is concluded that high tension powerlines will not represent any significant risk at PPVL as no major structure will be built in the vicinity of overhead lines and clearance requirements will not be infringed.

4.171 Details are provided in Chapter 9 and Appendix 5 on recommended monitoring with respect to the key environmental parameters of concern. This monitoring programme will provide the basis for the establishment of baseline conditions prior to restoration and provide the necessary data to ensure suitable mitigation measures are implemented in the event of unacceptable impacts being detected.

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5. SIU LANG SHUI LANDFILL

Study Area

Site description

5.1 The Siu Lang Shui Landfill is located south of the Castle Peak Firing Range, off the Lung Mun Road, occupying an area of about 12 ha (Figure 5.1). The landfill is rectangular in shape and set in a valley. It was filled between November 1978 and December 1983 during which about 1.2 Mt of domestic and industrial waste was deposited. In addition, a small amount of PFA from China Light Power Castle Peak Power Station was placed on a platform to the NW of the site.

5.2 The landfill base was prepared on the coastal flood-plain of a small valley, and infilling abutted the steep sides of the valley, originally on both sides of a stream which ran through the valley. The stream was eventually enclosed in a concrete box-culvert and landfilling was continued over the top of it. The site has been successfully re-afforested and largely capped with cdg, varying from 3 - 6 m in thickness.

5.3 The topography comprises a series of slopes on which are three main platforms located on the eastern, north-west and central portions that are linked by an access road connecting with Lung Mun Road to the south. The area to the north had been designated as a borrow area to the Provisional Airport Authority (PAA) and Container Terminal 9 (CT9) contractors for reclamation at Chek Lap Kok Airport and Container Terminal 9 respectively, but the proposal has been suspended. In contrast, a proposed trunk road and Light Rapid Transit (LRT) extension are also planned to cross the landfill.

5.4 The site was engineered as a lined containment landfill, with leachate collection systems in two separate areas at the east and the west where the filtration tanks and soakaway pits are located. Contaminated groundwater was however found at a 750 mm pipe which has been constructed to direct groundwater discharge onto the beach at the south of the site. Some seepages of leachate were occurring along the bank of the stream at the south.

Environmental setting and land uses

5.5 To the north, east and west of the landfill are steep slopes covered with natural shrubs and grasses. Tree seedlings were planted in 1987, about 4 years after placement of the final cap. The trees are now well established and largely cover most of the slopes within the site boundary. Although there have been no sensitive receivers identified inside the landfill site and within the 250 m consultation zone during the time of study, some fishermen's graves are entrenched to the north of the site boundary in the proximity of a waterfall. Occasionally the site is being used as a base for military training. At present, the area has a quiet environment with scenic views overlooking the sea to the south and hills to the north and east. Existing vehicular access to the landfill is from Tuen Mun via Lung Mun Road.

5.6 As described in Chapter 4 for PPVL, the Special Industries Area (SIA) is proposed to the south of SLSL adjoining the proposed River Trade Terminal (RTT) at Area 38. The development of the proposed SIA will be carried out in parallel with the reclamation and the anticipated completion of ultimate development will be 1999. The proposed dual 3-lane trunk road and LRT extension will also cross over the SLSL site.

5.7 The preferred afteruse for SLSL is a go-kart circuit with support facilities. A race circuit of length 900 m is proposed in the central area and some small buildings will be located along the access road (for example office, go-kart storage/rental, visitor's centre and control room/club house). Spectators seating will be built on landfill slopes at the north-west and the picnic areas will be placed on the east and west platforms.

Restoration Proposal

Introduction

5.8 The proposed restoration options for SLSL have been discussed in a previous Working Paper WP5 on Master Development Plans (Ref. 5.1), and this section describes the preferred restoration option for the site which is regarded as environmentally acceptable and safe. To accomplish the long-term management of landfill gas and leachate, there are appropriate measures to control and minimise their impacts. An outline of measures for the management of leachate and landfill gas is given in the following paragraphs.

Restoration constraints and opportunities

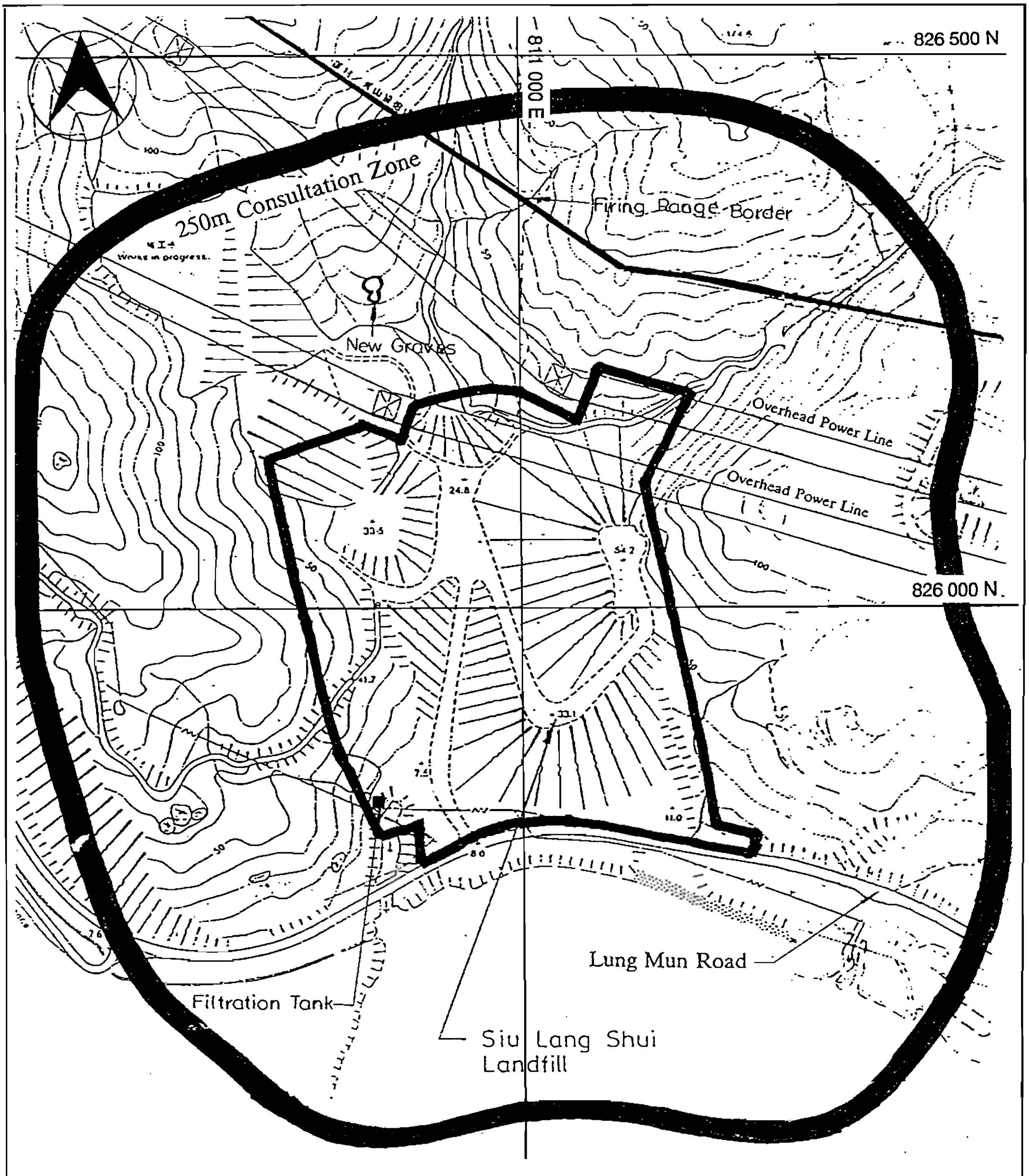
5.9 An examination of land use and landscape issues has led to restoration options being proposed for SLSL as detailed in Working Paper WP4 on Land Use Options and Planting (Ref. 5.2). The constraints and opportunities on the restoration development of SLSL are summarised in Table 5.1 below.

Table 5.1: Constraints and Opportunities for the Restoration of SLSL

Constraints	Opportunities
1. Port trunk road within site	1. Moderately sized site (12 ha)
2. LRT reserve within site	2. 5 flat areas (0.2 to 0.4 ha each)
3. Access to borrow area cuts through site	3. Attractive long distance views, and wooded areas
4. Transmission cable within site	4. Close to worker population
5. Pylons immediately adjacent to site	5. Public transport will be available in area
6. Difficult topography	6. Good location for port backup
7. Distant from residential areas	7. Established vegetation provides seclusion and slope stability
8. Special Industrial Area and River Trade Terminal to south	
9. Designated CCA restricting development potential	
10. Undesirable to disturb established vegetation	
11. Settlement problems	
12. Leachate and landfill gas emission	
13. Landfill cap to be protected	

Afteruse option

5.10 The preferred afteruse recommended for SLSL is a go-kart circuit with support facilities whilst retaining as much as possible of the existing vegetation and causing minimal disturbance to the existing land form as shown in Figure 5.2. A race circuit of length 900 m is proposed in the central area and a number of small buildings for the



LEGEND :

Landfill boundary

Consultation zone boundary

Figure 5.1

Siu Lang Shui Landfill

Landfill and Consultation Zone Boundary

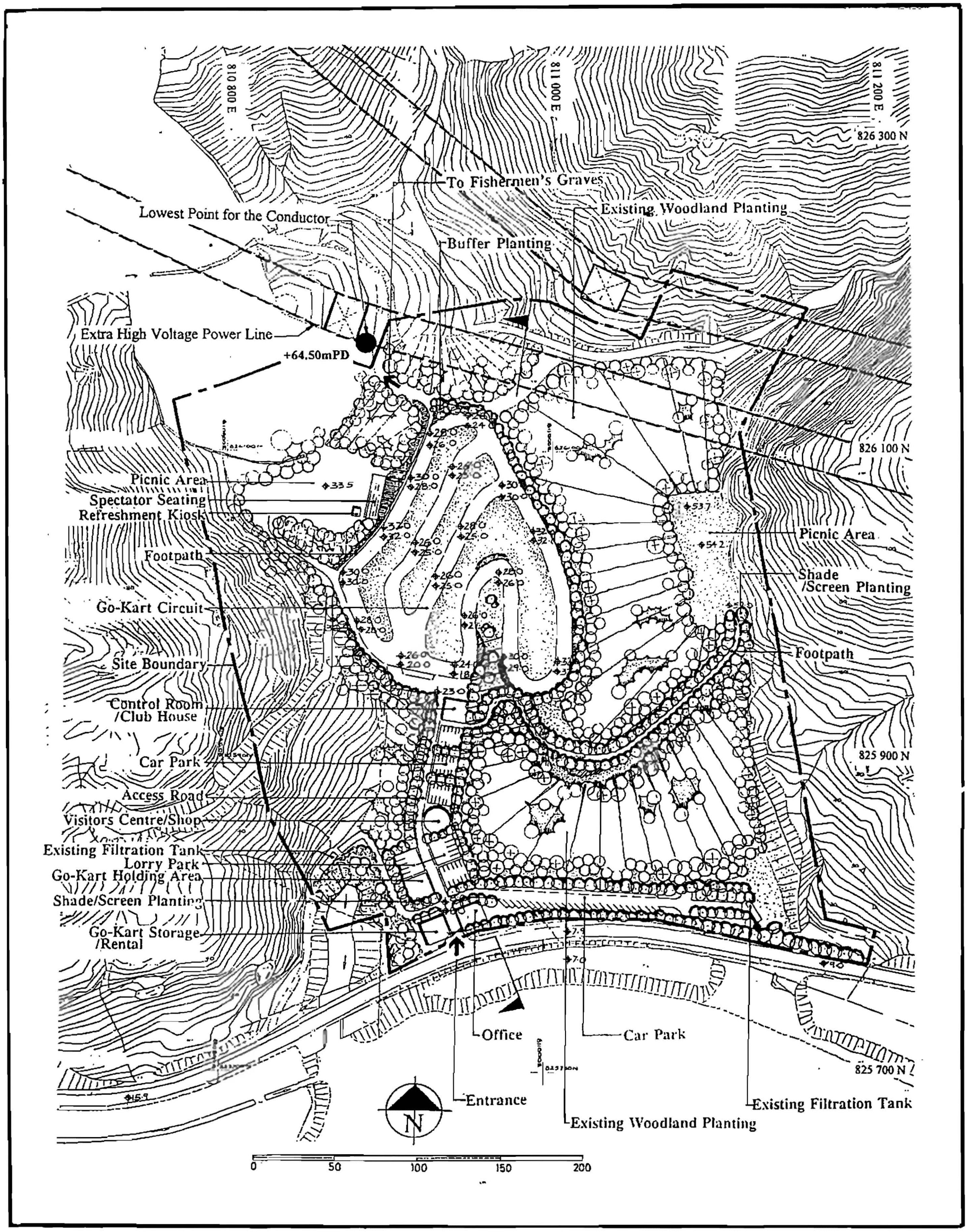


Figure 5.2
Siu Lang Shui Landfill
Master Development Plan

support facilities are located along the access road. The two small platforms on the north-west and north-east will be used as picnic areas. No barbecue facilities are proposed. No leachate treatment facility nor landfill gas extraction plant are proposed at SLSL. The broad landscape design objectives for SLSL should be:

- as far as is practicable, retain the existing site features;
- retain the existing LFG control system;
- have regard to claims by local people that much of established vegetation is "fung shui" trees;
- have regard to existing zoning of the site as "green belt" on the Draft Tuen Mun OZP.

Planting proposal

5.11 Restoration planting at SLSL has been very successful since 1987. To retain the existing trees as a structural framework to define activity areas, proposed new facilities are concentrated around the bottom of existing fill slopes and over areas where disturbance to existing trees is kept to a minimum. Replanting due to afteruse development can be grouped broadly into two categories as follows:

- reinstatement due to the removal of existing trees; and
- new planting to the defined afteruses.

Settlement and slope stability

5.12 The site has been closed for about 10 years and only a small degree of future settlement is predicted to take place. No heavy structures are planned to be located directly on top of the areas where wastes has been deposited, and therefore settlement issues are not considered to be of major significance. The foundation design of roads and pathways should be able to accommodate the effects of differential settlement. A similar design of the capping layer as defined in the Working Paper WP6 on Conceptual Restoration Design (Ref. 5.3) for MTLL should be placed near the southern end of the eastern landfill boundary where shear features occur. In tree areas over the replacement cap the soil layer should comprise a minimum of 1500 mm cdv or cdg, where trees are planted in pits with appropriate top soil mix. No deep rooted species should be selected for tree planting.

5.13 Design for slope stability at SLSL should be similar to that presented for PPVL (Ref 5.4). No features have been observed which suggest instability of slopes at SLSL. Any regrading which occurs should have slopes no greater than 1(V) to 4(H), to ensure a suitable factor of safety.

Landfill gas management

5.14 Gas management will include reinstatement of existing passive venting pipes and perimeter control to prevent LFG migration off site. In particular, management measures to control gas migration from the southern boundary will be implemented by installing a venting trench and membrane barrier, with vent pipes installed at appropriate intervals to transmit venting gas to atmosphere. The specific requirements for LFG control at SLSL are as follows:

- reinstate existing gas vent pipes after a detailed inspection is undertaken;
- design and install control systems to prevent gas migration from the southern boundary which is accomplished by installing a venting trench and membrane barrier;

- if necessary, design and install additional perimeter gas migration control which can be accomplished by extending the venting trench around the boundary of the site;

- placement of a new capping gravel layer at the southern end of the eastern landfill boundary, designed to link in with perimeter gas control measures;

- gas wells should be constructed at appropriate intervals through the trench into underlying natural strata and linked in with the venting trench;

- install LFG protection measures to buildings and other structures on site.

Leachate management

5.15 A joint leachate treatment facility for SLSL and PPVL will be more cost effective than a dedicated plant at SLSL. It must be sufficiently flexible and robust to cope with substantial fluctuations in both flow and quality of influent leachate arising from both sites. The conceptual design of the leachate treatment facility has been specified in WP6, and as proposed in Chapter 4 of this report. To overcome the problem of leachate contamination of the stream and beach, a new route for leachate disposal is needed. The long term leachate collection and management objectives at SLSL require:

- clearing of leachate collection tanks;

- routing of leachate discharging from the tanks to a single leachate holding facility;

- diversion of flow of contaminated groundwater from the beach discharge to the holding facility;

- if needed, interception of contaminated groundwater underlying the site and diversion to the leachate facility;

- design of works to pump leachate from SLSL to the proposed treatment works at PPVL;

- routine monitoring of flow and quality of influent and effluent to and from the leachate holding facility.

Landfill Gas

Background conditions

5.16 Active LFG generation is occurring at SLSL. Drillholes within the fill as indicated in Figure 5.3 monitor positive gas pressures generally between 40 and 150 Pa, which are substantially lower than those monitored at PPVL. LFG composition within wastes is similar to that for PPVL as indicated in WP1 (Ref. 5.5). Mathematical modelling of LFG generation (Ref. 5.6) predicted that peak production would have occurred in 1983. Analysis of waste samples shows some inhibition of waste breakdown (Refs. 5.6 and 5.7). Such inhibition would result in the actual rate of LFG generation being less than that predicted.

5.17 A LFG control system is currently in place at SLSL. This comprises passive gas vents linked to gravel areas within the fill. The landfill has been successfully restored with tree planting, and there is no evidence for vegetation damage or stress as a result of LFG occurrence in the root zone. Off-site LFG monitoring probes are present along the sensitive southern boundary. Monitoring results to date (see Table 5.2) show no evidence of significant off-site LFG migration in this area. These observations and findings imply that the existing LFG management system is providing effective control of LFG migrations.

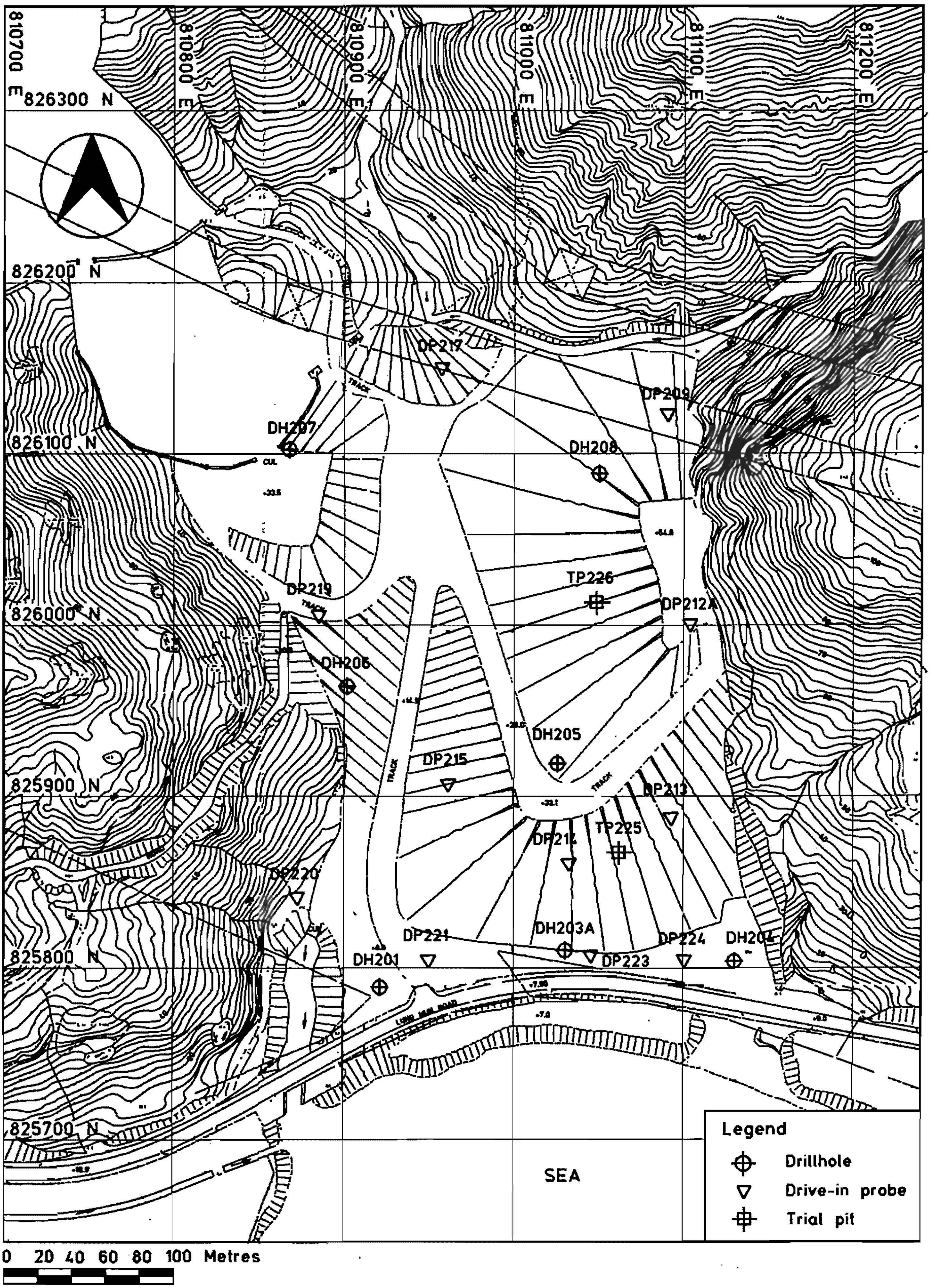


Figure 5.3

Siu Lang Shui Landfill

Sampling Locations for Landfill Gas Monitoring

Table 5.2: SLSL - GAS MONITORING RESULTS (Sheet 1 of 2)

LOCN+	DATE	APRE	DPRE	%CH4	%LEL	%O2	%CO2	%H2	%CO	%N2	COM
DH205	25-Jun-93	1004.8	7.2	47	1.4	<1	27				
	2-Jul-93	1009.8	12	54.3	>100	0	32.5				
	2-Jul-93	1009.8	12	59		0.3	29	<0.05	<0.1	11	Lab
	16-Jul-93	1007.9		46	2	<0.5					
	20-Jul-93	1004.5		60		0.2	31	<0.05	<0.1	8	Lab
	28-Jul-93	1002.6	15.2	51.5	0	0	31.3				
	23-Sep-93	1009.2	180	53.1	0	0	32.1				
	29-Oct-93	1019.9	-76	53.1	1	1	31.3				
	12-Nov-93	1014.7	149	54.7	0	0.4	31.7				
DH207	16-Jul-93	1007.9		46	1.5	<0.5					Le H.
DH208	25-Jun-93	1004.8	26.3	48	1.6	<1	40				
	2-Jul-93	1009.9	19	47	1.2	<1					
	2-Jul-93	1009.9	19	51.5	>100	0	38.8				
	2-Jul-93	1009.9	19	61		0.3	35	<0.05	<0.1	1.9	Lab
	16-Jul-93	1007.9		46	1.5	<0.5					
	20-Jul-93	1004.5		62		0.2	34	<0.05	<0.1	0.8	
	28-Jul-93	1002.6	30.5	53.9	0	0	36.1				
	23-Sep-93	1009.2	150	57.9	0	0	36.9				
	29-Oct-93	1019.9	-111	55.5	0	0.6	34.5				
	12-Nov-93	1014.7	-79	53.9	0	0.4	34.8				
DP209	25-Jun-93	1004.8	2.2	38	1	<1	30				
	2-Jul-93	1009.9	0	51.9	>100	0.01	32.1				
	28-Jul-93	1002.6	1.4	45.1	5	0	30.5				
	23-Sep-93	1009.2	214	45.6	7	0	31.3				
	29-Oct-93	1019.9	3	47.9	9	1	27.3				
	12-Nov-93	1014.7	-3	44.4	1	0.6	24.9				
DP212A	25-Jun-93	1004.8	3.4	37	<1	<1	27				
	2-Jul-93	1009.9	6	26.5	>100	0	28.5				
	28-Jul-93	1002.6	-6.5	44.8	35	0	28.5				
	23-Sep-93	1009.2	104	40.8	35	0	30.1				
	29-Oct-93	1019.9	30	45.6	7	0.5	28.1				
	12-Nov-93	1014.7	102	41.6	0	0.5	26.9				
DP213	25-Jun-93	1004.8	0.6	18	2	<1	25				
	2-Jul-93	1009.9	-6	15.5	>100	11.4	11.4				
	28-Jul-93	1002.6	0.3	18.6	65	0.3	20.6				
	23-Sep-93	1009.2	24	2.5	45	3.7	15.4				
	29-Oct-93	1019.9	2	0.04	4	15.6	7.3				
	12-Nov-93	1014.7	-26	0	4	10.4	8.84				
DP214	2-Jul-93	1009.9	-12	13.9	>100	0	18.2				
	28-Jul-93	1002.6	-44.4	0.76	0	2.1	12.6				
	23-Sep-93	1009.2	-165	1.59	2	0	15.4				
	29-Oct-93	1019.9	-178	0.04	6	8.6	8.64				
	12-Nov-93	1014.7	-86	0.28	8	0.8	13.4				

Table 5.2: SLSL - GAS MONITORING RESULTS (Sheet 2 of 2)

LOCN+	DATE	APRE	DPRE	%CH4	%LEL	%O2	%CO2	%H2	%CO	%N2	COM
DP215	25-Jun-93	1004.8	0.4	<1	8	3	8				
	2-Jul-93	1009.9	-6	1.95	39	7.3	8.22				
	2-Jul-93	1009.9	-6	2.5		4.6	11	<0.05	<0.1	81	Lab
	20-Jul-93	1004.5		1.8		3.5	10	<0.05	<0.1	81	Lab
	28-Jul-93	1002.6	-37.7	3.84	9	0	15				
	23-Sep-93	1009.2	27	1.67	35	3.3	13				
	29-Oct-93	1019.9	200	0	7	6.6	8.68				
	12-Nov-93	1014.7	280	0.08	9	4.6	8.64				
DP217	25-Jun-93	1004.8	140?	43	0.5	<1	35				
	2-Jul-93	1009.9	0	36.1	>100	4.2	26.9				
	28-Jul-93	1002.6	26.4	52.7	25	0	38				
	23-Sep-93	1009.2	213	46.8	42	1.6	32.9				
	29-Oct-93	1019.9	118	41.2	5	4.9	25.3				
	12-Nov-93	1014.7	144	43.2	26	3.4	26.9				
DP219	2-Jul-93	1009.9	6	15.5	>100	0	21				
	2-Jul-93	1009.9	6	18		0.3	21	<0.05	<0.1	62	Lab
	20-Jul-93	1004.5		11		0.4	20	<0.05	<0.1	81	Lab
	28-Jul-93	1002.6	-0.6	5.47	0	0	16.6				
	23-Sep-93	1009.2	61	3.84	5	0	16.2				
	29-Oct-93	1019.9	66	12	100	8	11.1				
	12-Nov-93	1014.7	80	22.3	5	0.4	17.4				
DP220*	2-Jul-93	1009.9	6	0.2	4	20.7	0.08				
	28-Jul-93	1002.6	-3	0	0	7.3	8.65				
	23-Sep-93	1009.2	20	0.05	2	0.7	9.9				
	29-Oct-93	1019.9	3	0	5	13.8	3.9				
	12-Nov-93	1014.7	22	0.05	9	20.6	0.04				
DP221*	2-Jul-93	1009.9	0	0.24	5	2.1	11.5				
	28-Jul-93	1002.6	-0.9	0	0	13.1	5.95				
	23-Sep-93	1009.2	0	0.05	3	14.2	4.99				
	29-Oct-93	1019.9	-5	0.05	7	18.4	1.6				
	12-Nov-93	1014.7	17	0	10	15.8	1.54				
DP223*	2-Jul-93	1009.9	0	0.2	4	11.5	5.99				
	2-Jul-93	1009.9	0	<0.1		9.9	6	<0.05	<0.1	83	Lab
	20-Jul-93	1004.5		0.8		4.2	11	<0.05	<0.1	85	Lab
	28-Jul-93	1002.6	0.3	0.64	0	0.2	12.6				
	23-Sep-93	1009.2	-69	0.04	4	1	11.1				
	29-Oct-93	1019.9	2	0	6	19.8	0.83				
	12-Nov-93	1014.7	0	0	9	14.8	2.77				
DP224*	2-Jul-93	1009.9	0	0.28	6	10.4	3.88				
	28-Jul-93	1002.6	0.4	1.84	0	0.1	11.9				
	23-Sep-93	1009.2	-25	0	2	4	9.9				
	29-Oct-93	1019.9	9	0	6	11.9	5.15				
	12-Nov-93	1014.7	-44	0	9.5	13.3	3.8				

* denote those holes located off-site
\+ refer to A2.1 (Appendix 2) for abbreviations used

5.18 Requirements for additional LFG control were presented in WP1 and WP6 (Ref. 5.5 and 5.3), and have been designed to complement the existing gas control regime. Recommended requirements are:

- to undertake a detailed inspection of existing gas vent pipes - make good or replace any which are damaged or blocked;
- to establish the effectiveness of existing membrane liners and rock face coatings in controlling off-site gas migration; information from a similar exercise proposed for PPVL should be assessed and applied to SLSL;
- if necessary, design and install additional perimeter gas migration control measures;
- to design and install control systems to prevent gas migration from the southern boundary (irrespective of findings from assessment of bitumen side-wall coating);
- to install LFG protection measures to buildings and other structures on site.

Impact of construction activities

5.19 LFG has the potential to be emitted during restoration and redevelopment as a result of disturbance to existing material, or by creation of migration pathways with subsequent venting. Only limited redevelopment is proposed at SLSL as described in WP5 and WP6 (Refs 5.1 and 5.3), with the preferred afteruse being a go-kart circuit, whilst retaining as much as possible of the existing vegetation. In the area proposed for the go-kart track, vegetation clearance and limited re-profiling and re-capping will be required. This is likely to lead to a , minor, temporary increase in surface emissions of LFG in this area. Following completion of restoration, any damaged or lost gas vents will be replaced, and any such vent pipes would link in with the granular layer below the new capping layer.

5.20 Direct emission of LFG to atmosphere may result from activities such as exposure of waste, foundation work for buildings and installations of underground utilities. Where practicable, buildings will be constructed on inert fill and areas where waste deposits are thin.

5.21 The bulk of the site will remain unaffected by construction activity, and LFG emissions in these areas will remain unaffected by construction activities.

Mitigation measures

5.22 By the use of suitable mitigation measures and good site practice, release of LFG during site development can be minimised. Such measures include minimising the exposure of wastes during re-profiling and cap restoration, and during the installation of utilities.

5.23 LFG released during construction activities, in addition to that released from the landfill under normal conditions, is a source of potential risk. Potential hazards have been defined for PPVL (Chapter 4) and recommended mitigation measures are similar.

Impact of LFG control measures

5.24 The impacts associated with LFG control measures relate to the construction phase including:

- the formation of replacement capping in the area of the go-kart track;
- the construction of vent trench and barrier along southern boundary;
- the construction of buildings, seating and infrastructures;
- the replacement of existing passive gas vents (if required);

- the construction of venting trench around remainder of site (if required); and
- the drilling of monitoring drillholes.

5.25 LFG will be released from passive gas vent within the landfill and the perimeter venting trench. Vent stacks have been proposed at a height of 3 metres above ground level, to minimise access to the top of the vent pipe and encourage venting and dissipation of gas. Wherever practicable, vent stacks will be sited away from areas of major activity, and will be assimilated into the landscape planting. Where vent stacks are unavoidably located in areas of the site which will be subjected to heavy use, they should be fitted with flame arrestors at the top of the pipe to prevent the possibility of methane ignition causing a flare back within the pipe.

5.26 No vent pipe should be enclosed in any way, and long-term monitoring should be conducted to assess the performance and condition of the gas venting systems. Long term maintenance of all venting trenches and vent pipes will be required to ensure they continue to function adequately.

5.27 All buildings will be subject to specific gas protection measures, based on a multi-barrier approach for LFG control. As a minimum requirement, all buildings should be provided with a free venting layer beneath the floor slab, incorporation of gas-proof membrane within the floor slab, special detailing of services and provision of LFG alarm systems. These measures will be additional to the general control measures for the whole of the landfill, and as such are any increased levels of gas around the buildings are considered unlikely.

Impact on afteruse option

5.28 Only a portion of the site will be reprofiled and developed. The bulk of the site will not be disturbed, where the tree establishment is unaffected by LFG. Where required, replacement capping will be to the same specification as for MTLL as proposed in WP6 (Ref 5.3). The proposed system of LFG control (as specified in WP1 and WP6) will control gas movement and direct LFG emissions to vent stacks, thus providing protection to the go-kart circuit, spectator seating areas, other development and public access areas. Additional control measures will be applied to buildings (Section 5.27).

5.29 Activities which may take place on the landfill are go-kart racing, and spectating, hiking and picnicking. There will be a requirement for car parking. All areas of the site which may take go-karts, and cars and coaches will be protected from uncontrolled gas emissions by the measures previously described (Sections 5.25 - 5.27). Vehicle and go-kart parking areas will be well ventilated to prevent the accumulation of pollutants. Other activities do not represent any LFG hazard in themselves, although other unauthorised public activities may. No barbecue area is proposed within the restored landfill site.

5.30 The advice with regard to development close to landfills is presented in Chapter 4. The area to the south of SLSL is proposed for development of a new trunk road and industrial area. The road will lie within 20 m of the waste boundary, but currently it is not known whether any buildings are planned within this zone. Buildings will almost certainly be constructed within 250 m of the landfill boundary. Proposed LFG migration control measures focus particularly on preventing migration from this sensitive southern boundary, and therefore no significant risk is envisaged.

Air Quality

Introduction

5.31 This section details the assessment of impacts on air quality from emissions at Siu Lang Shui Landfill site. Construction activities associated with the restoration of the landfill site are considered with reference to dust and VOC emissions. A predictive assessment is made of the impacts from venting of LFG on the site.

Ambient Monitoring

VOCs

5.32 Background ambient air quality measurements made upwind and downwind of the landfill were analysed for the presence of SACs. The results are given in Table 5.3. They indicate that ambient levels downwind of the landfill are higher than levels upwind for the compounds 1.1.1-trichoroethane, tetrachloroethylene and trichloroethylene. A similar but less marked difference is noticed for benzene. This would indicate there is a possibility that these gases are being emitted from the landfill. Other compounds did not show an increase level downwind.

Table 5.3 : Monitored Ambient VOC Levels at SLSL

SAC	Method Detection Limit ($\mu g/m^3$)	SLSL ($\mu g/m^3$)	
		uw	**dw**
Vinyl Chloride	0.36	ND	ND
Dichloromethane	0.73	5.6	5.6
Trichloromethane	0.73	6.9	ND
1,1,1-Trichloroethane	0.76	3.8	18.1
1,2-Dichloroethane	0.61	2.9	2.1
Benzene	0.26	6.6	8.8
Tetrachloromethane	0.94	2.4	ND
Trichloroethylene	0.91	3.6	17.0
1,2-Dibromoethane	0.92	ND	ND
Tetrachloroethylene	0.75	ND	2.9

Notes

uw : upwind
dw : downwind
ND : Not detected, below the method detection limit

Methane

5.33 Table 5.4 shows the results of analysing samples taken upwind and downwind of the landfill site for methane. The results indicate methane levels downwind of the landfill is approximately 10% higher than measurements taken upwind. This is well within the range of expected variation and it would be difficult to draw any conclusions from the measurements.

Table 5.4 : Monitored Methane Levels at SLSL

Pollutant	uw (µg/m³ (ppm))	dw (µg/m³ (ppm))
Methane	1966 (2.34)	2166 (3.13)

Notes

uw : upwind
dw : downwind

Assessment of Impacts from Dust Emissions

5.34 Only one sensitive receptor for SLSL has been identified and considered in the study, this is given in Table 5.5.

Table 5.5 : Sensitive Receptor and Location

Landfill Site	Sensitive Receptor	Grid Reference
Siu Lang Shui	Proposed Industrial Development	811036E 825782N

5.35 Chapter 4 details the modelling approach undertaken in the dust assessment study. The impact from combining the dust generated from a 0.0625 ha construction area situated on the site boundary with vehicles passing on unpaved roads at the site boundary at the sensitive receptor is:

Distance from site	= 18m
TSP concentration from vehicles	= 264 µg/m³
TSP concentration from construction site	= 640 µg/m³
Total predicted TSP concentration	= 904 µg/m³

5.36 It can be seen that the 500 µg/m³ air quality guideline is exceeded. Therefore, mitigation measures are necessary. This mitigation may include dampening down the surfaces of the unpaved road and construction site. An effective watering programme (twice daily watering over the entire site) is estimated to be able to reduce emissions by up to 50% from ground surfaces. This should be able to reduce the total TSP concentration to about 450 µg/m³ which is below the relevant air quality guideline level.

5.37 Covers and wind shields may be used at places where high emissions of dust are expected. On days where the wind direction is such that dust is blown towards the sensitive receptor and mitigating action is unable to reduce dust levels to a satisfactory level, it is possible that traffic may take a diversion and use a route further from the sensitive receptors. At times of particularly high levels it may be necessary to suspend construction activity.

5.38 The AQO that applies to TSP in Hong Kong restricts 24-hour average concentrations to below 260 µg/m³. Using a factor of 0.4 to convert the 1-hour concentration to 24-hour concentration (when considering a 12 hour working day) and a 50% reduction due to the implementation of mitigation measures listed above, a predicted TSP concentration of 180 µg/m³ is obtained which is below the relevant air quality guideline level.

5.39 Several assumptions have had to be used due to a lack of relevant site specific data and accordingly the modelling approach could only provide a broad indication of the possible dust impacts. Despite the high values predicted, the Consultants are confident that subject to sensible mitigation measures, no significant dust impacts will occur.

Assessment of Impact from VOC Emissions

5.40 Landfill gas samples were obtained from drillholes DH205 and DH208 for GC/MS analysis. Benzene was the only SAC detected in the LFG samples. The average measured concentration of benzene is given in Table 5.6.

Table 5.6 : SAC Concentrations in LFG at SLSL

Pollutant	Concentration in LFG(mg/m^3)
Benzene	3.10

5.41 VOC emissions were determined from the following:

- Oxford University Model was used to calculate the volume of landfill gas generated by the landfill;
- Concentrations of VOCs in landfill gas were derived from samples taken from two drillholes; and
- Gas venting from a total of 79 vents of which 23 were old and 56 were new installations. To take account of the position of the new vents relative to the old, it is assumed of the total emission 70% is emitted via the old vents and the other 30% via the new vents.

5.42 Table 5.7 details the emission and modelling parameters used for predictive modelling of VOCs.

Table 5.7 : VOC Emission Levels and Modelling Parameters for SLSL

Parameter	Input
Passive vent height	3 m
Gas temperature	40 °C (313 °K)
Assumed air temperature	25 °C (298 °K)
Gas volume	285 m^3/hr
	(70% via old vents and 30% via new vents)
Number of vents	79 (23 existing and 56 new)
Vent diameter	10 cm
Contaminant emission rates*	
Benzene (old vents)	0.0075 mg/sec *
Benzene (new vents)	0.0013 mg/sec *

Notes

Other Specified Air Contaminants were not detected in the landfill gas.
Meteorological assumptions are the same as those given in Table 4.8(b)
USEPA Model ISCST was employed.
VOC emission rates were derived from measured concentrations of landfill gas from a drillhole.
** the emission rates are per vent.*

5.43 The results from modelling SACs at SLSL are presented in Table 5.8. The predicted concentration at the sensitive receptor and the maximum predicted concentration values, for benzene which was the only SAC present in the LFG at SLSL, are an order of magnitude less than monitored background levels and the calculated risk is less than 1 x 10^{-6}. A conservative conversion factor of 0.3 was used to convert maximum annual 1-hour average concentrations to annual average concentrations in light of the limited data and the assumptions made in the modelling.

Table 5.8 : Predicted Concentration and Associated Risk from SACs at SLSL

Receptor	Pollutant	Maximum Annual 1-Hour Concentration ($\mu g/m^3$)	Annual Risk
Max Value 811100E 826110N	Benzene	0.4	9.96 x 10^{-7}
Sensitive Receptor 811036E 825782N	Benzene	0.2	4.98 x 10^{-7}

5.44 These results indicate that the restored SLSL site will not be a significant contributor to ambient levels of VOCs. Nonetheless it is considered prudent to include requirements in the contract documents for the Contractor to carry out detailed environmental impact assessments. The contract Specification should include environmental standards which could include risk-based guidelines on which the Contractor will have to achieve and verify in his design.

5.45 If high VOCs are detected it would be possible to install filters of activated carbon within the vent pipes to give an absorbent media for VOCs. However, this could reduce venting efficiency and hence efficiency of the landfill gas control, and extra venting arrangements may be necessary to improve the efficiency of the overall landfill gas control system so that lateral gas migration would not occur. It is considered that filtered passive vents, coupled with a regular sampling, testing and maintenance programme, could be used to effectively reduce the VOC's to acceptable levels.

5.46 Because the proposed LFG restoration works at SLSL rely on passive venting with no flaring of gas, particular attention has been given to the assessment of odour. Samples of LFG from 23 holes drilled into waste at SLSL were analysed for a comprehensive suite of odorous compounds. Table 5.9 lists the concentration of those compounds detected above their odour threshold.

Table 5.9 : Trace Gases in LFG Exceeding Odour Limits for SLSL

	205B	205QB**	208A
butene (total)	4.7	1.3	2.6
pentene (isomer)	0.8	0.6	0.6
dimethyl sulphide	ND	ND	5.8
acetone	1.3	1.3	87*
propan - 2 -ol	ND	0.2	11
2-methyl propan -2-ol	0.1	0.2	0.6
cyclohexane	2	1.6	1.2
tetrahydrofuran	ND	ND	3.6
butan-2-one	2.9	2.4	72
butan-2-ol	ND	0.1	5
n-decane	46*	46*	72*
limonene	130*	110*	390*
n-octane	3.3	2.9	5.4
dimethyl disulphide	ND	ND	0.2
toluene	80*	72*	175*
C_5 or C_6 alcohol	ND	ND	1.1
n-nonane	20	17	27
ethyl benzene	33	29	59
xylenes	66	59	92
styrene	ND	0.5	1.0
methyl styrene	ND	ND	5.2
naphthalene	5.1	4.9	3.5

Notes

* *Saturation of mass spectrometer as consequence of choice of internal standards represents underestimate (all measurements in mg m^{-3})*

** *Duplicate samples for QA purposes.*

ND *Not detected; below the method detection limit*

5.47 Table 5.10 gives the results from the modelling study of the twenty two compounds that exceeded the odour threshold in the analysed landfill gas. The results are given for ground level concentrations at the sensitive receptor and at the point where the maximum concentration occurs. In every case the predicted concentrations are below the toxicity level OES/100 (the predicted risk for styrene is also below the acceptable cancer risk). The predicted concentrations of the air contaminants would not cause any odour nuisance at any present or potential sensitive receptor.

Table 5.10 : Predicted Concentrations at ASR from VOCs in the Landfill Gas

Pollutant	Maximum Concentration at point of emission (mg m^{-3})	Maximum Value 811100E 826110N Concentration (µg m^{-3})	Sensitive Receptor Concentration (µg m^{-3})	OES/100 (8hrs) (µg m^{-3})
butene (total)	4.7	0.64	0.26	
pentene (isomer)	0.8	0.11	0.044	
dimethyl sulphide	5.8	0.79	0.32	
acetone	87	12	4.8	17800
propan-2-ol	11	1.5	0.8	9800
2-methyl propan-2-ol	0.6	0.082	0.03	3000
cyclohexane	1.6	0.22	0.087	3400
tetrahydrofuran	3.6	0.49	0.2	5900
butan-2-one	72	9.9	3.9	5900
butan-2-ol	5	0.69	0.27	3000
n-decane	72	9.9	3.9	
limonene	390	54	21	
n-octane	5.4	0.74	0.30	14500
dimethyl disulphide	0.2	0.027	0.011	
toluene	175	24	9.6	1880
C_5 or C_6 alcohol	1.1	0.15	0.06	
n-nonane	27	3.7	1.5	
ethyl benzene	59	8.1	3.2	4350
xylenes	92	13	5.0	4350
styrene	1	0.13	0.055	
methyl styrene	5.2	0.71	0.28	4800
napthalene	5.1	0.70	0.28	500

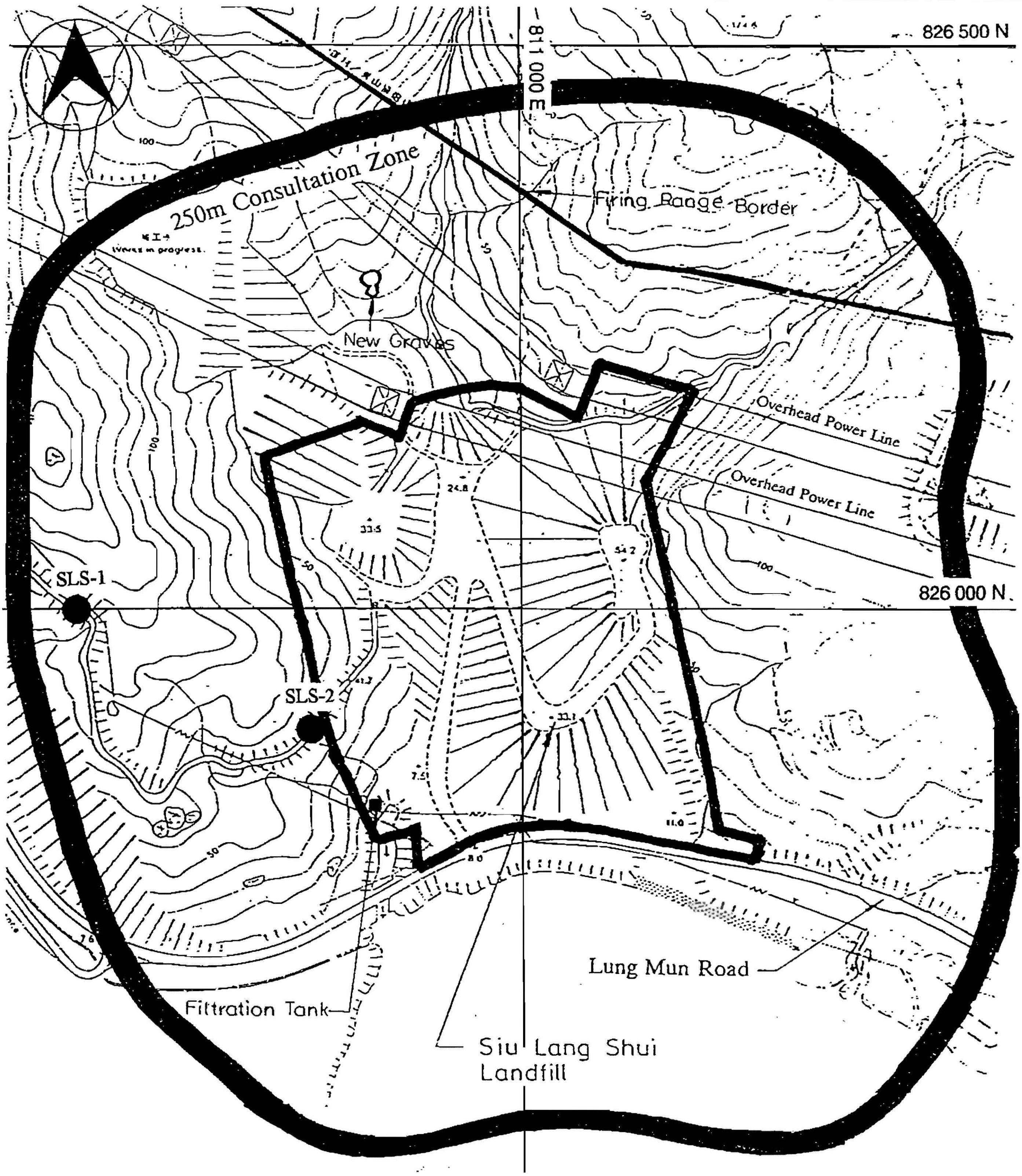
Notes

Taken from CAPCOA Air Toxics "Hot Spot" Programme Revised 1992 Risk Assessment
UCR = 5.7×10^{-7} (µg m^{-3})$^{-1}$ for Styrene
Risk at max value 7.4×10^{-8}
Risk at receptor 3.1×10^{-8}

Noise

Background Noise Levels and Monitoring Data

5.48 Similar to the case of PPVL, background noise monitoring has been carried out at SLSL, measurements being made in hourly periods during the day between 07:00 hours and 19:00 hours from 26 to 27 December 1993. Summarised results and the monitoring locations are given in Table 5.11 and Figure 5.4 respectively.



LEGEND :

———	Landfill boundary	– – – –	Noise sensitive receiver
▬▬▬	Consultation zone boundary	●	Noise measurement location

Figure 5.4
Siu Lang Shui Landfill
Sampling Locations for Noise Measurement

5.49 Existing noise sources detected at SLSL have included the power station to the west of the site, road traffic, and occasional aeroplanes.

5.50 During the day's monitoring at SLSL-1 there was a fifteen minutes period of exceptional noise from the power station, which occurred between 08:00 hours and 09:00 hours. The average noise levels at this location have therefore been calculated twice, once with the period including this exceptional noise, and once without the latter being marked with asterisks in Table 5.11.

Table 5.11: Summarised Baseline Noise Monitoring Results for SLSL

Monitoring Location		Major Noise Sources	Average Noise Level dB(A)		
			L_{10}	L_{90}	L_{eq}
SLSL-1	Boundary of EPD's 250m consultation zone	1) Power station to the west 2) Occasional aeroplanes 3) Occasional cars passing by	63.6* 65.5	62.0* 62.1	62.9 71.0
SLSL-2	Boundary of landfill	1) Occasional aeroplanes 2) Occasional cars passing by 3) Cars passing by iron bridge on Lung Mun Road	58.2	49.7	55.6

* *excluded the exceptional noise from the power station*

5.51 Examination of the full results (see Appendix 3) reveals that the L_{A10}, L_{A90} and L_{Aeq} figures for each hourly period, apart from the period including the exceptional noise from the power station, are all very similar in value. This indicates that the dominant source of noise at this location is of a steady or constant nature, and is most likely to be continuously running plant at the power station.

5.52 The other monitoring position associated with this site, SLSL-2, is located at the landfill boundary, and the results obtained here are consistent with a noise climate dominated by road traffic noise.

Impacts of Construction Activities

5.53 Construction noise impacts will depend on the scale and duration of development, the prevailing noise environment, the proximity of sensitive receptors and the type of plant used on site. Given that there will be only limited construction activities at SLSL, the increase in noise generated from the earth moving activity and other construction activities will be insignificant. Additionally, currently there are no noise sensitive receivers in the vicinity of the site, and therefore, any transient significant increase in construction noise would not cause any immediate nuisance.

Impacts of Afteruse Option

5.54 The primary source of noise associated with the preferred afteruse option would be road traffic generated by go-karts. Any buildings proposed on site could be located in less sensitive areas of the site and be screened off by substantial tree planting, in order that noise associated with their use could be mitigated. In the event that any noise sensitive developments are present at the post-restoration stage, a noise impact assessment study should be conducted.

Water Quality

Existing marine water quality at Siu Lang Shui

5.55 As at PPVL, marine waters offshore from SLSL lie within the North Western WCZ. The same monitoring stations NM3 and NS3, for monitoring of marine water quality and bottom sediment quality respectively, are the closest stations to SLSL. A stream discharge to the sea is within 100 m of the landfill. The location for the monitoring stations is shown in Figure 4.8. The summary statistics of 1990 - 1992 marine water quality and bottom sediment quality are given in Table 4.14 and Table 4.15 of Chapter 4 respectively. The comments relating to marine water quality at PPVL are also relevant to SLSL.

Existing groundwater and surface water quality

5.56 Site investigation and subsequent monitoring conducted during this study have provided information with respect to groundwater quality in the vicinity of SLSL. Groundwater flow is predominantly southwards towards the sea. Collected groundwater from under the eastern part of the landfill is currently routed under the coast road to discharge at the beach whereas groundwater collected from the western area is routed to discharge to the stream as shown in Figure 5.5.

5.57 The results of the analyses for leachate, groundwater and surface water are given in Table A4.2 of Appendix 4 and the monitoring locations are shown in Figure 5.5. The results show that groundwater contamination by leachate is evident in the three down-gradient drillholes namely DH201, DH203A and DH204 as well as the pipe discharge at the beach. Groundwater at DH201 and DH203A are contaminated with leachate passing through from the soakaway pits which are situated in between them, whereas the contamination of groundwater at DH204 is due to liner leakage. Similarly, the groundwater discharge at the beach to the south of DH201 is contaminated with leachate, possibly via liner leakage.

5.58 Table 5.12 summarises the results of the analyses of groundwater and surface water at SLSL and compares them with other groundwater standards. The analyses of groundwater at DH201, DH203A and DH204 show evidence of contamination by leachate; and the water quality would not be acceptable for drinking purposes, based on the standards quoted. However, there is no evidence of any local use of either groundwater or surface water in the vicinity of SLSL.

5.59 As shown in Table A4.2 of Appendix 4, the upstream surface water sample (W201) is unpolluted whereas some contamination has taken place at locations downstream (W203 and W204). Most of the contamination in the stream, as it enters the sea, results from the present disposal routes for leachate, rather than leakage of the culvert. Although a considerable amount of stream water helps to dilute the leachate effluent, the water quality downstream remains poor as indicated in Table 5.12.

Leachate quantity and quality

5.60 Given the uncertainties involved, and absence of direct measurement, estimates of leachate production and flow have been made in WP3 for this 12 ha landfill to be in the range 25,000 - 75,000 cu m/a (Ref 5.7). This remains too broad for satisfactory design of long term disposal options and further work as proposed in WP3 should be undertaken to refine the assessment. Notwithstanding of this, the present leachate discharge flows are estimated as follows:

peak:	137 - 411 cu m/day
average:	68.5 - 205.5 cu m/day

5.61 The details of the quality of leachate measured in drillholes, sump and filtration tanks are reproduced in Table A4.2 of Appendix 4 and the summary of the analyses of leachate at SLSL is given in Table 5.2. The data indicate that leachate quality within the site is spatially highly variable as shown by DH205 and DH207. The filtration tank leachates collected at L206 and L207 however, best represent the average conditions in the landfill and indicate that much of the landfill is methanogenic. The persistence of acetogenic conditions in DH205 may be explained by the exceptionally high NH_3-N concentration which may be attributed to a severe inhibition of anaerobic decomposition.

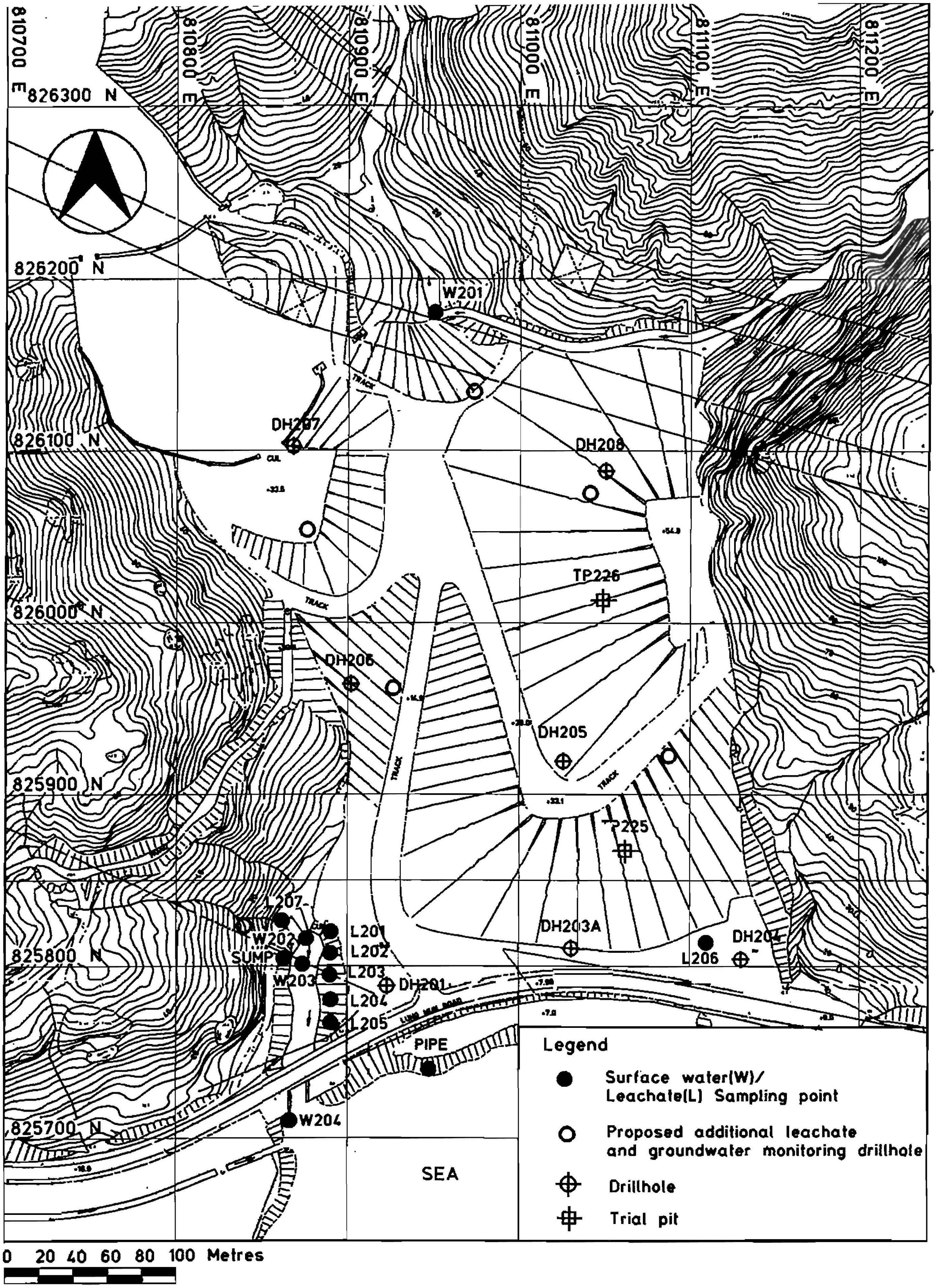


Figure 5.5

Siu Lang Shui Landfill

Sampling Locations for Leachate, Groundwater and Surface Water Monitoring

Table 5.12 : Analysis of Groundwater and Surface Water at SLSL

Determinand *	Standards for Groundwater ***			Water	Source ****
	ST1	ST2	ST3		
	Dutch Grade C	Dutch VPR	WHO	Surface water	Ground-water
pH (pH units)			6.5-8.5	6.9-8.3	(6.4-7.6)
EC (uS/cm)				67-5000	620-12000
Cadmium	0.01	0.006	0.005	<0.02	<0.02
Chromium	0.2	0.026	0.05	<0.1	(<0.1-0.2)
Copper	0.2	0.035	1	<0.1	<0.1
Lead	0.2	0.05	0.05	<0.1	(<0.1-0.3)
Nickel	0.2	0.04		<0.1	<0.1
Zinc	0.8	1	5	<0.01-0.03	0.07-0.1
Manganese			0.1	(<0.1-0.2)	(1.2-11)
Iron			0.3	(0.1-0.4)	(1.4-13)
Sodium			200	(7.5-3100)	(32-750)
Potassium				1.9-82	5.4-310
Hardness (as CaCO3)			500	14-31	(92-630)
Sulphate			400	14-50	26-340
Sulphide	0.3				<0.1-0.3
Phosphorous				0.1-0.3	<0.1
Nitrate			10	0.13-0.44	(<0.01-40.4)
Ammonia Nitrogen				<0.1-60	3.3-1100
Kjeldahl Nitrogen					4-1200
Total Organic Carbon				<1-9	7-250
Chloride			250	(7.7-3700)	(25-750)
COD				<7-56	51-1800
BOD				<5-28	6.8-120
E. coli (no./100ml) **			0		(6-890)

Note:

* All units in mg/l except where noted

** The Standard for drinking water (WHO) refers to Fecal Coliform

*** The standards for groundwater and drinking water being refered to are as follows:

ST1 Dutch Criteria for Category C Clean Up Investigations (Ref 5.9)

ST2 New Dutch Second Generation VPR Criteria (Ref 5.10)

ST3 WHO Guidelines for Drinking Water (Ref 5.11)

**** Data enclosed in brackets indicate the exceedance of the standards quoted

5.62 The leachate collection system appears to be working, but it is possible that there is some liner leakage. Drillholes indicate leachate depths of 5 and 13 m in two locations, yet do not indicate that a continuous head of leachate exists on top of the base liner. The discharge of the collected leachate is partly as it was intended, i.e. via soakaways and overflow pipes to the stream, but also partly in an unintended fashion onto the beach. Both discharge routes are unsatisfactory. Discharge to the beach is onto an area of public access, regularly used for recreation. Discharge to the stream as a result of the inflows of leachate from soakaway constructed in 1987 gives rise to a significant elevation of ammonia levels to 60 mg/l.

5.63 Table 5.13 shows that the levels of pH, BOD, COD, copper, chromium, zinc, sulphide and total nitrogen of the leachate exceed the Government standards for effluents discharge into foul sewer (Table A1.3), indicating that direct discharge of this leachate into the PPVSTW nearby should not be permissible. Similarly the direct discharge of leachate into the stream is also not acceptable. The situation is unlikely to be improved until leachate and contaminated groundwater are intercepted and directed to the proposed leachate treatment facility at PPVL for treatment prior to discharge to PPVSTW as proposed in Working Paper WP6 (Ref 5.3).

Impacts of construction activities

5.64 Given that only small amounts of earthworks are required at SLSL for the repairing of the cap and existing landfill gas venting pipe, an insignificant increase in the infiltration of rainwater to the waste and thus the leachate yield, would be anticipated. However when the regrading and widening of the existing track to form an access road as well as the construction of the go-kart circuit are undertaken, it is recommended that the measures to cope with the increase in the amount of sediment loads in runoff from the site should be adopted, similar to those also proposed at PPVL.

Impacts of leachate control measures

5.65 At present, leachate discharge via the engineered collection system is causing modest pollution of the stream and serious localised pollution of groundwater, as well as discharging in an uncontrolled manner on to the beach. In the longer term, when arrangements for collection, treatment and disposal of leachate and contaminated groundwater to a leachate treatment plant at PPVL and then to PPVSTW are in place, the problems of water pollution can be resolved. In the shorter term, when interim measures are undertaken to alleviate the beach pollution and groundwater contamination by routing all of the collected leachate directly to the stream in a controlled manner, the aesthetic condition of the beach and the groundwater quality can be partly improved. This is unlikely to significantly worsen the pollution of the stream and the inshore marine water which results from the present uncontrolled discharges, and which appears to have continued for many years.

Impacts of afteruse option

5.66 Based on proposed low intensity land use for SLSL as a go-kart circuit with support facilities, only the buildings and facilities along the main access road to the south involve a significant incidence of patronage. In all circumstances, site profiling may require incorporation of some appropriate interception drainage and surface drainage measures to collect contaminated surface water, shed rainfall and reduce rainfall infiltration.

Landscape, Afteruse and Visual Impacts

5.67 SLSL is a wooded area with trees up to 6m high over all the fill slopes. Although the new slopes are more gentle than those of the surrounding hills, they appear as a natural extension of the adjacent areas due to the dense tree cover which softens the edges between the new and existing slopes. Visually, the central area is completely enclosed by hills on three sides, while tall trees form a thick screen on the south side. The site offers a quiet and secluded environment.

Table 5.13 : Analysis of Leachate from SLSL

Determinand*	TM on Effluent Standards ** >200 and <=400	Landfill Site*** SLSL
pH (pH units)	6-10	(5.9-8.3)
Temperature (°C)	43	26.3-42.2
Suspended solids	800	
Settleable solids	100	
BOD	800	(5-12000)
COD	2000	(58-22000)
Oil & Grease	50	
Iron	25	5.3-19
Boron	5	
Barium	5	
Mercury	0.1	
Cadmium	0.1	<0.02
Copper	3	(<0.1-8.9)
Nickel	2	<0.1-0.3
Chromium	2	(<0.1-9)
Zinc	3	(0.06-36)
Silver	2	
Cyanide	1	
Phenols	1	
Sulphide	10	(<0.1-18)
Sulphate	1000	<10-72
Total nitrogen	200	(0.1-8100)
Total phosphorus	50	<0.1-18
Surfactants (total)	40	

Note:
* All units in mg/l except where noted
** Standards for flow rates (cu m/day) expressed as upper limits (Ref 5.12)
*** Data enclosed in brackets indicate the exceedance of standards

5.68 Both active and passive uses had been proposed for the site. The primarily use would be a mini go-kart circuit in the central area, with support facilities on the lower slopes and along the access road. Disturbance of existing contours and vegetation would be minimized, with construction works concentrated at the bottom of the fill slopes. Replanting has been proposed to compensate for trees that would be lost due to regrading, and to supplement planting in eroded areas. The majority of buildings would be small in size, and located away from the landfill areas. Where enclosed structures are proposed, provision should be made for gas venting. Floating foundations that could accommodate future settlement would be used where necessary, for example, at the refreshment kiosk and spectator seating, which would be located on the landfill. Passive uses such as picnic areas and nature walks would not require major modification of the platforms and slopes.

5.69 The quiet nature of the site would be changed by the introduction of a go-kart circuit. This afteruse, however, was selected in anticipation of future industrial development along the coast near this landfill site. Such development would entail major reclamation and construction of an elevated port trunk road, with an LRT reserve, across the middle of the site. It is considered, therefore, that the use of this site for a go-kart circuit would not be in conflict with such development.

5.70 To accommodate the go-kart circuit and spectator seating, there would be new filling at the toe of existing slopes, and removal of a limited number of trees. As all proposed structures are small and low in profile, they could blend readily with the surrounding. Apart from an enlargement of the central flat area, the overall visual impact of the proposed afteruse development would be of minor significance.

Settlement

Existing conditions

5.71 SLSL was filled between November 1978 and December 1983 during which about 1.2 million tonnes of domestic and industrial wastes were deposited. The future settlement has been estimated as less than 1% of the total waste thickness due to the old nature of the waste, and the current settlement rate, which would continue to exponentially decrease with time, is estimated at about 0.2% per year. The existing capping layer at SLSL is largely in good condition even though some features occur near the southern end of the eastern landfill boundary that are indicative of settlement relative to adjacent rock slopes which abut the waste at this location. With the exception of some minor cracking, often associated with settlement-related cracking in the drainage channels, most of the landfill shows no significant features indicative of waste settlement.

Impacts of construction activities

5.72 The general impacts of construction activities for settlement at SLSL are similar to those described earlier for PPVL. Specific objectives for minimizing the impacts include:

- use of flexible paving material for the surfacing of the footpaths;
- design of surface water management systems to minimise maintenance by being flexible to accommodate differential settlement; and
- use of lightweight structures where the foundation design should be able to accommodate the effects of differential settlement.

Impacts of afteruse

5.73 The preferred afteruse recommended for SLSL is a go-kart circuit with support facilities whilst retaining as much as possible of the existing vegetation and causing minimal disturbance to the existing landform. The proposed afteruse option represents a low intensity land use with a low proportion of the site area dedicated to building structures. The small anticipated settlement at SLSL is not considered significant to the activities proposed.

5.74 Correct use of flexible paving material for the surfacing of the footpaths, flexible surface drainage channels and special siting for the structures over the area where no waste is deposited are the appropriate means to minimise disruption to proposed afteruses. Subsequent works for repairing defects due to settlement would then be kept to a minimum.

High Tension Power Line

5.75 The extra-high tension power lines (400 kV) across SLSL are a continuation of the power cables situated on the west of PPVL. These two sets of power lines cross the north-east region of the site and only one of them is situated within the site boundary (Figure 5.2). The approximate distances between the lowest and nearest conductor of the power lines and potentially sensitive receptors on the site are given in the Table 5.14.

Table 5.14: Distance to the Lowest and Nearest Conductor

Sensitive Receptor	Approximate Distance to the Lowest and Nearest Conductor
Northern Boundary of the Go-kart Circuit	100 m
Picnic Area	110 m
Spectator Seating	110 m
Refreshment Kiosk	120 m
Control Room/ Club House	240 m
Visitors Centre/ Shop	310 m

5.76 Health hazards at this site might be slightly worse than for PPVL because more recreational possibilities exist for exposure to human beings, and some of these are located in closer proximity to the EMF hazard. In particular, the spectator seating adjacent to the go-kart circuit is only 110 m distance from the lowest point of the power line and length of exposure time here will be longer than for other activities on site. Also the picnic area is located at only 110 m distance. The same is also the case for the refreshment kiosk, situated 120 m away from the lowest point of the power line. However, the visitors will only stay at SLSL using the facilities for short periods of time, thus limiting their exposure to the EMF. Again, the strength of the EMF affecting human health would also be reduced with an increase in the buffer distance, as for the control room/ club house and visitors centre/ shop which are 240 m and 310 m distance respectively.

5.77 The conceptual design of the afteruse option for SLSL described earlier in this section has already taken the safety aspect of the power lines into account, thus no immediate building or structure will be installed close to the conductors of the power cables violating the minimum distance of clearance.

Conclusions and Recommendations

5.78 The recommended afteruse for SLSL is a go-kart circuit with support facilities, with the specific objective of retaining as much as possible of the existing vegetation and causing minimal disturbance to the existing landform. No leachate treatment facility or LFG extraction plant are proposed for SLSL.

5.79 It is recommended that the afteruse development is located toward the bottom of the existing landfill slopes, with replanting conducted so as to replace removal of existing trees and to enhance the remaining vegetation.

5.80 Settlement issues are not regarded as being of major significance, as future settlement is expected to be minor and no heavy structures associated with the afteruse are envisaged. A new cap should be placed near the southern end of the eastern landfill boundary where shear features occur. The capping design is similar to PPVL, but contains a granular layer to assist in the dispersion of LFG. Similarly, slope requirements are as for PPVL, where slopes in general should have a gradient of not more than 1(V) to (4 (H), to ensure an adequate factor of safety. It is recommended that flexible paving and surface water management systems be used to prevent damage due to restoration following restoration.

5.81 Peak LFG generation rates were predicted to have occurred in 1983, reaching 285 cu m/day although inhibition of waste degradation may be resulted in lower rates. The composition of LFG at SLSL is similar to that at PPVL and is indicative of a methanogenic landfill. LFG control is of particular importance at the southern boundary, where installation of a passive vent trench and membrane barrier, with appropriately spaced vent pipes is recommended. This should be extended around the periphery of the site if tests to be carried out at PPVL indicate it is necessary. In addition, appropriate LFG protection measures should be installed to on-site buildings.

5.82 Impacts of LFG during construction are expected to be minimal, as only a restricted area of earthmoving will be required over waste deposits. Following the completion of restoration, gas vents will be reinstated and integrated with the granular layer of the new capping layer. Where vent stacks are required it is recommended that they should be fitted with flame arrestors, and subject to regular inspection and maintenance. Buildings developed within the 250 m consultation zone are not considered to be subject to any significant risk from LFG migration with the installation of an appropriate LFG perimeter control system.

5.83 It is concluded that a joint leachate treatment facility for SLSL and PPVL would represent the most cost effective option. To resolve the problem of surface water contamination by leachate on-site a number of remedial measures have been recommended including improved interception and leachate holding facilities.

5.84 Operational areas during restoration are likely to be small, thereby reducing the potential incidence of significant dust impacts. The assessment of TSP impacts shows predicted levels below the AQOs if mitigation measures are strictly applied. Predictive assessment of landfill gas dispersion indicates that following restoration works, odour thresholds will not be exceeded. The results from the VOC assessment indicate that the restored site will not be significant contributor to ambient levels of VOC.

5.85 It can be concluded from noise monitoring carried out for this study that the dominant noise source in the area emanates from the power station and from road traffic. As there are no noise sensitive receivers in the vicinity of the site, transient increases in noise levels due to construction activity are unlikely to be a problem. In order to reduce noise impacts associated with the go-kart track, it is recommended that on-site buildings be located in less sensitive areas and vegetation screening be used where possible.

5.86 Marine water and sediment quality data for PPVL also apply to SLSL and the same conclusions can be drawn. Groundwater is known to be contaminated from leachate, via soakaway pits or liner leakage. Surface water quality is similarly affected. Leachate has also been found to be of an unacceptable quality for direct discharge to sewer. The situation is unlikely to improve until leachate and contaminated groundwater are intercepted and directed to the proposed leachate treatment facility at PPVL. It is recommended that measures are implemented during the construction stage to prevent excessive discharge of sediment loads, and appropriate surface drainage is installed as part of the restoration works to ensure the segregation of clean and contaminated waters

5.87 In visual impact terms it is concluded that the restoration will be of minor significance, except that the go-kart circuit would involve the enlargement of a central flat area.

Although the quiet nature of the site would be changed by the go-kart circuit, this is not out of context of the industrial development envisaged in the future.

5.88 Health hazards associated with proximity to high tension power lines at SLSL are considered to be slightly greater than for PPVL, as facilities are generally closer. However, exposure of the public will be of a transient nature, and no building or structure will be constructed within the minimum distance requirements.

5.89 Details are provided in Chapter 9 and Appendix 5 on recommended monitoring with respect to the key environmental parameters of concern. This monitoring programme will provide the basis for the establishment of baseline conditions prior to restoration and provide the necessary data to ensure suitable mitigation measures are implemented in the event of unacceptable impacts being detected.

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6. MA TSO LUNG LANDFILL

Study Area

Site description

6.1 The Ma Tso Lung Landfill is remote and located near the border closed area. The landfill site is a small site of about 2 ha where landfilling took place between July 1976 and February 1979 (Figure 6.1). Domestic and industrial wastes totalling about 180,000 tonnes were deposited.

6.2 The top of the landfill forms two platforms, at 41 mPD and 47-49 mPD. The lower platform is smaller and has a shallow gradient whilst the upper platform is larger and has a steeper gradient. These two platforms are now barren and partly occupied by a variety of unauthorized users including crude compost manufacturers. The surrounding slopes are covered with patches of wild shrubs and grasses.

6.3 The landfill has an access road to the south which connects with Castle Peak Road (Chau Tau) at Pak Shek Au (about 750 m to the south). Footpaths to the surrounding villages to the north, south and west also provide access. Parts of the site are occupied by Community Sports Ltd, a non-profit making company which proposes to share the whole landfill site with Tung Wah Group of Hospitals for building a holiday camp.

6.4 Separate groundwater and leachate collection systems were constructed as part of the lined containment landfill system. The groundwater collection system was directed north-east to a discharge point in the bed of the original valley stream at the foot of the north-east face of the landfill. The leachate collectors were routed south-east to a sump that linked to an abandoned leachate filtration tank and soakaway pits at the south-easternmost part of the landfill. Leachate seepages are causing serious pollution of surface waters both to the north-east and south-east of the site.

Environmental setting and land uses

6.5 Within the site boundary of the landfill, no distinct land sensitive users were found. However the lower platform was occupied by an illegal compost manufacturer during the time of study. Inside the 250 m consultation zone, a large orchard accompanied with some old village houses is located at the north. To the east is a football field belonging to Community Sports Ltd which, together with the landfill site, lies within a Government/Institution/Community (G/IC) area. This whole site is within the draft Kwu Tung North Outline Zoning Plan and is proposed for a future development of a holiday camp managed by Tung Wah Group of Hospitals. The outer fringes of the landfill site fall into a Green Belt area which encloses the landfill at the north-west and south-west interface. Adjacent to the football field are some small industrial buildings used mainly for timber processing.

Restoration Proposal

Introduction

6.6 The proposed restoration options for MTLL have been discussed in the previous Working Paper WP5 on Master Development Plans (Ref 6.1), and this section describes the preferred restoration option for the site which is regarded as environmentally acceptable and safe. To accomplish the long-term management of landfill gas and leachate, there are appropriate measures to control and minimise their impacts. An outline of measures for the management of leachate and landfill gas is given in the following paragraphs.

Restoration constraints and opportunities

6.7 An examination of land use and landscape issues has led to restoration options being proposed for MTLL as described in Working Paper WP4 on Land Use Options and Planting (Ref 6.2). The constraints and opportunities on the restoration development of MTLL are summarised in Table 6.1 below.

Table 6.1: Constraints and Opportunities for the Restoration of MTLL

Constraints	Opportunities
1. Small site area (2 ha)	1. Two platforms available (0.6 and 0.2 ha)
2. Distant from large population centres	2. Development proposals already formed
3. The site is already granted to Community Sports Limited	3. Road access requiring some improvement
4. Settlement problems	4. Public transport
5. Leachate and landfill gas emission	5. Adjacent to recreational facilities/land with potential for building development
6. New Landfill cap to be protected	

Afteruse option

6.8 The preferred afteruse for MTLL is a holiday camp proposed by the Tung Wah Group of Hospitals and the development plan is shown on Figure 6.2. The camp will utilise two adjacent sites, with building works concentrated on the site south of MTLL. It is intended that a wide range of outdoor sports and recreational uses will utilise the platforms and slopes of MTLL. The construction works for building the holiday camp will only commence after the restoration works for MTLL are completed in 1997, as proposed in Working Paper WP5. The broad landscape design objectives and design principles for MTLL are:

- to enhance visual aspects of the site;
- to ensure good vegetation establishment on all appropriate areas;
- to delineate areas of different afteruses;
- to regrade the landfill slopes to a gradient no steeper than 1(V) to 4(H);
- no buildings should be constructed on wastes;
- to develop after-uses within the context of the "G/IC" zone of the draft Kwu Tung North outline Zoning Plan No. S/NE-KTN/1.
- to carry out a comprehensive planting programme prior to other developments.

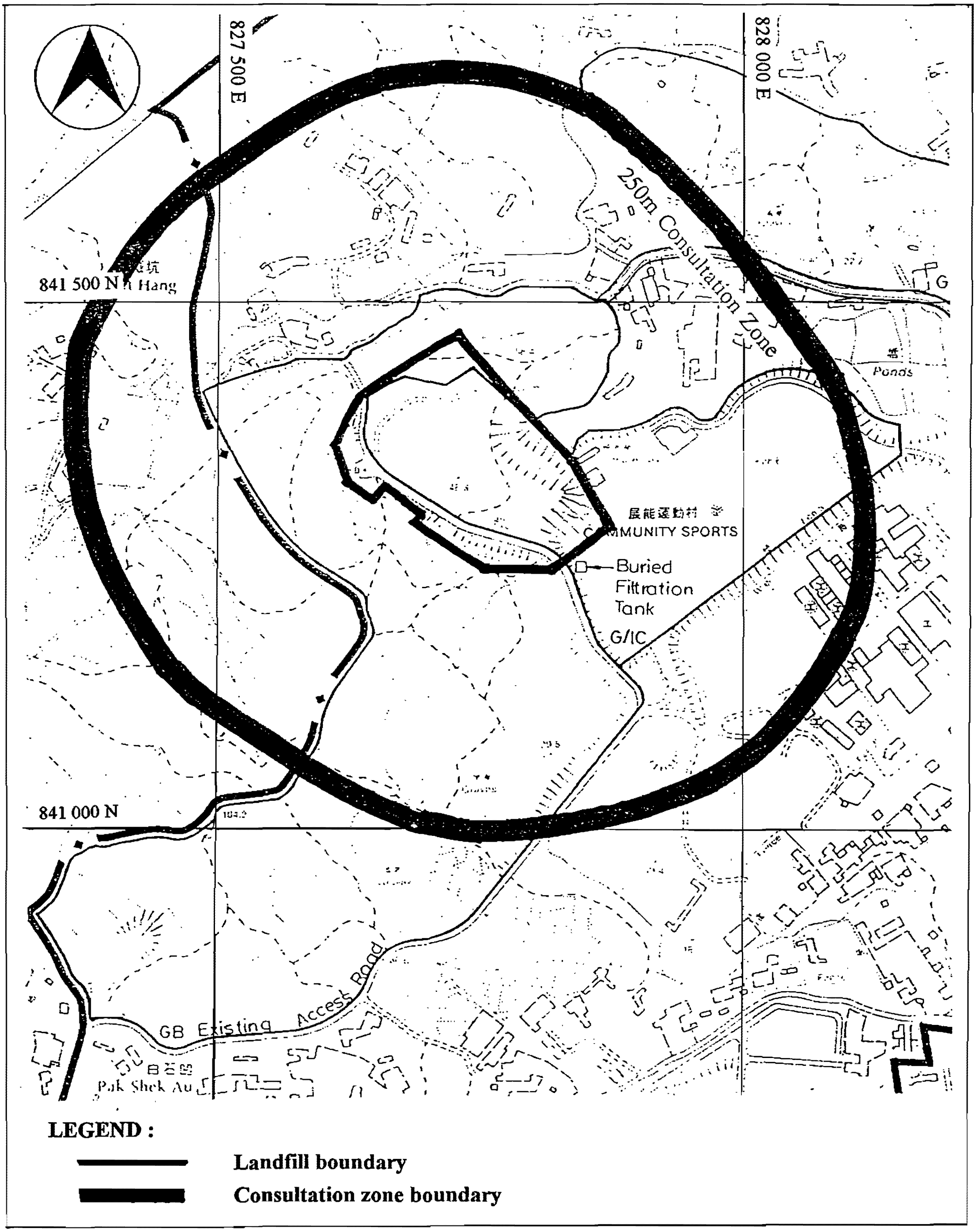


Figure 6.1
Ma Tso Lung Landfill
Landfill and Consultation Zone Boundary

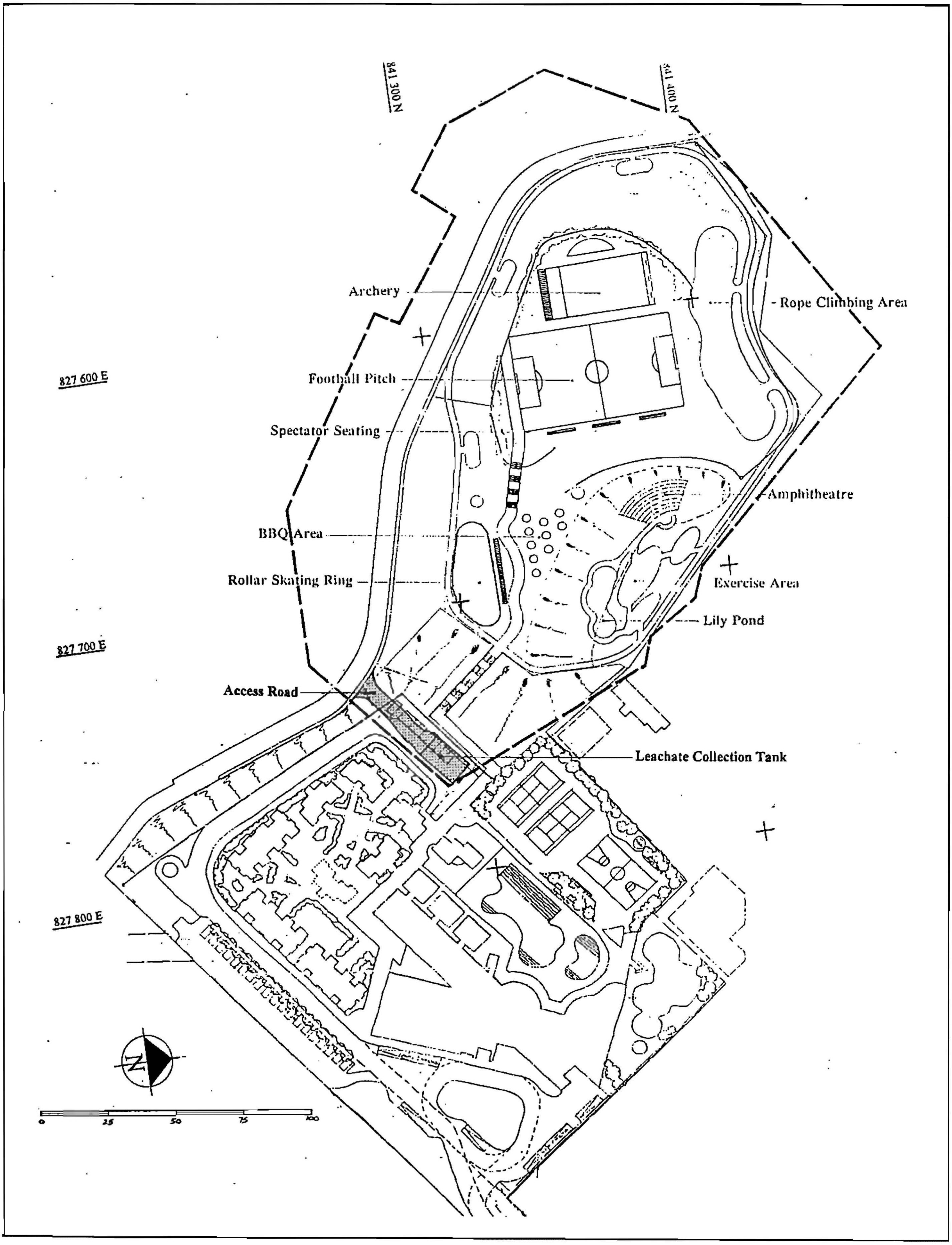


Figure 6.2
Ma Tso Lung Landfill
Development Plan

Planting proposal

6.9 It was recommended in WP4 (Ref 6.2) that stabilization of slopes with tree and shrub planting, after the initial hydroseeding, will be necessary. Trees and shrubs that are known to be successful on windy sites should be used. The planting layout should relate to the proposed afteruse and to the rural nature of the surrounding areas. Three broad categories of planting are proposed as follows:

- open grass areas with perimeter tree planting (possibly an archery area, football pitch, roller skating, barbecue area and rope climbing area);
- open grass areas with tree planting (possibly an amphitheatre, exercise area and a pond);
- informal tree and shrub mix planting (primarily on slopes).

6.10 Trees should be planted initially so as to provide a more sheltered environment for the growth of shrubs which would then be subsequently planted. During the latent period, a larger selection of shrubs could be used as in-fill planting. The landfill will require reprofiling prior to capping. The design of the capping layer for the reprofiled landfill is proposed in WP6 (Ref 6.3). In areas of the restored MTLL site requiring tree planting, the top cdv/cdg layer should be increased in thickness from 850 mm (minimum) to 1500 mm (minimum). No deep rooted species should be selected for tree planting.

Settlement and slope stability

6.11 Although most settlement has already occurred, as the site has been closed for about 13 years, there is likely to be less future settlement than predicted due to inhibition of waste degradation. No heavy structures are planned in the waste deposited areas, and the foundation design of roads and pathways should be designed to accommodate the effects of differential settlement. The conceptual design of the capping layer which has been defined in Working Paper WP6 (Ref 6.3) should accommodate future settlement.

6.12 The design criteria for slope stability at MTLL should be the same as those defined for PPVL, as described in Chapter 4.

Landfill gas management

6.13 A new LFG management system is proposed and the general design criteria for LFG control at MTLL are similar to those specified earlier for SLSL which included:

- an integrated LFG management scheme with leachate control and site capping;
- to provide protection of all buildings and other structures, both those existing and those planned for the future;
- to provide continued long term protection of afteruse, including landscape works; and
- to install venting within wastes to encourage controlled dissipation of LFG to non-sensitive areas of the site.

6.14 The LFG management system for MTLL relies on a combination of high permeability venting areas and low permeability barriers to prevent LFG from migrating towards sensitive receptors. Venting zones should be located around the boundary (perimeter vent trench), within wastes (passive venting wells), and underlying the capping layer (granular gravel blanket) which is required to join with the perimeter gas control system. The design of vent pipes should permit blending with landscape features without compromising their efficiency. No active LFG extraction facility either for flaring or utilisation is proposed for MTLL.

Leachate management

6.15 Proposed regrading and capping of the landfill will reduce leachate generation and control seepages. Leachate disposal arrangements should be in place before regrading, capping and leachate interception works are undertaken, as these are all likely to lead to temporarily increased release of leachate. To enhance collection of perched leachate, a series of "Trammel" drains should be installed at different levels on the slopes during site regrading.

6.16 The existing leachate discharge pipe at the toe of the landfill should be re-excavated, and routed to a leachate collection tank which will be located below existing ground level. Leachate should be tankered for treatment to the proposed leachate plant at PPVL or Shuen Wan Landfill or some other sites such as NENT or even WENT (Ref 6.3).

Landfill Gas

6.17 This section describes the safety and environmental objectives of the restoration process with respect to LFG. An assessment of potential impact from the construction phase and the afteruse options has been conducted, and areas have been identified for further assessment.

Safety and environmental objectives

6.18 The safety and environmental objectives proposed for MTLL are as those described in Chapter 4 for PPVL, as are the general design objectives for LFG control.

Background conditions

6.19 LFG is monitored at the locations shown in Figure 6.4.. Monitoring results are shown in Table 6.2. MTLL is currently generating LFG. Within the wastes, LFG pressure is generally positive, but lower than that at PPVL and SLSL. Generally, LFG composition is typical of that from a methanogenic landfill.

6.20 Estimated LFG yields are presented and discussed in WP2 (Ref 6.4), and summarised below:

LFG yield calculated from:

- cellulose content (1993): 136 cu m/tonne dry weight;
- calorific value (1993): 176 cu m/tonne dry weight; and
- Oxford University model (1993): 68 cu m/hour or 8 cu m/tonne dry weight.

6.21 The current actual rates of LFG generation and emission will vary depending on a range of environmental factors (eg moisture, temperature, atmospheric pressure) and waste type. The predicted maximum LFG generation occurred in 1979, with a predicted sharp decline since that date. There is some evidence of local inhibition of waste breakdown, which implies a slower rate of LFG generation than predicted, as addressed in WP3 (Ref 6.5).

6.22 Gas monitoring is undertaken around the sensitive boundary to the east and south-east (Figure 6.4). Soil gas concentrations off-site have remained generally stable during the study period, although most recent results from DH307 indicate a substantial increase in concentration of carbon dioxide which may be a precursor to a general lateral migration of LFG.

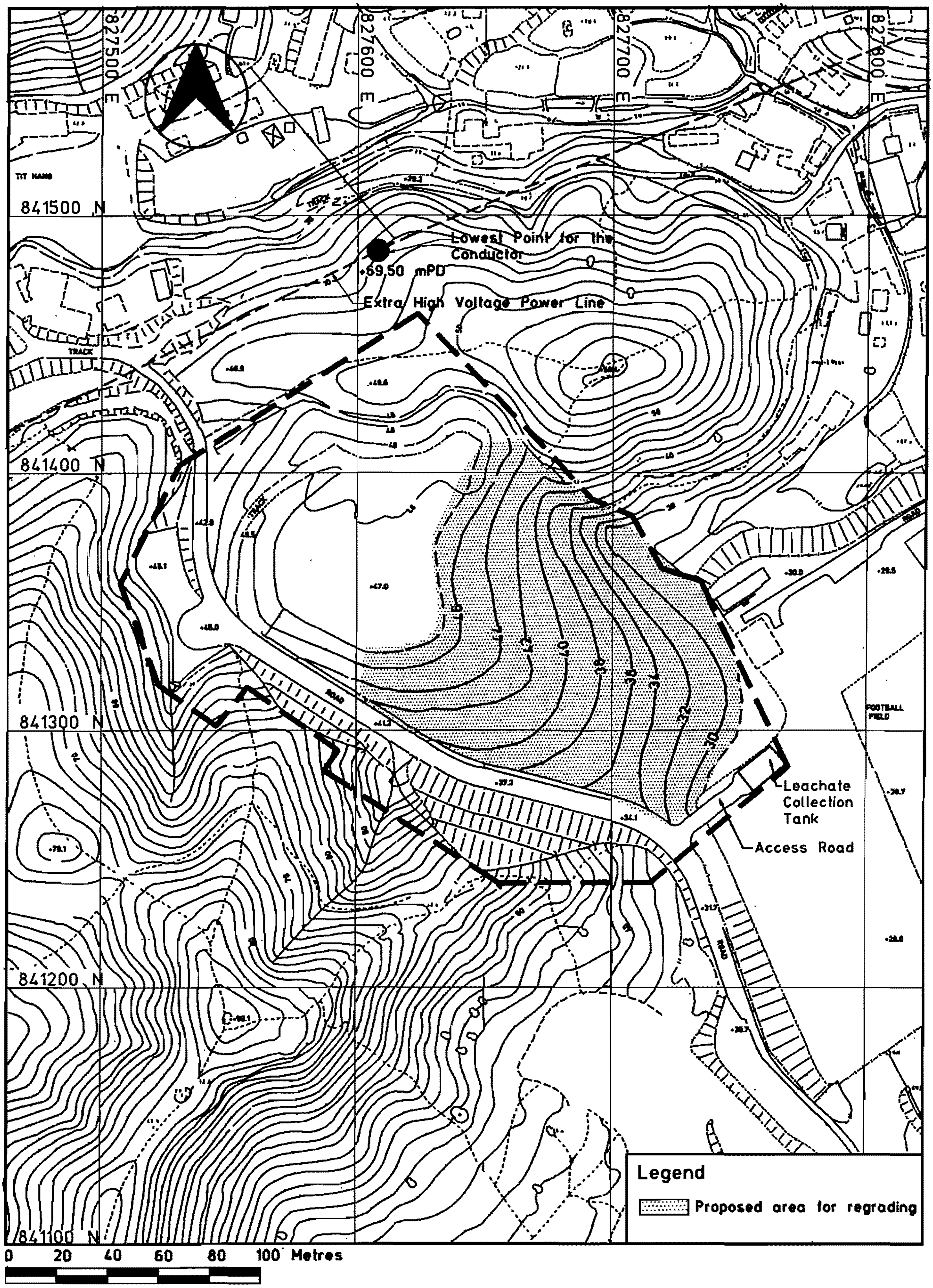


Figure 6.3
Ma Tso Lung Landfill
Conceptual Design
Regrading Profile

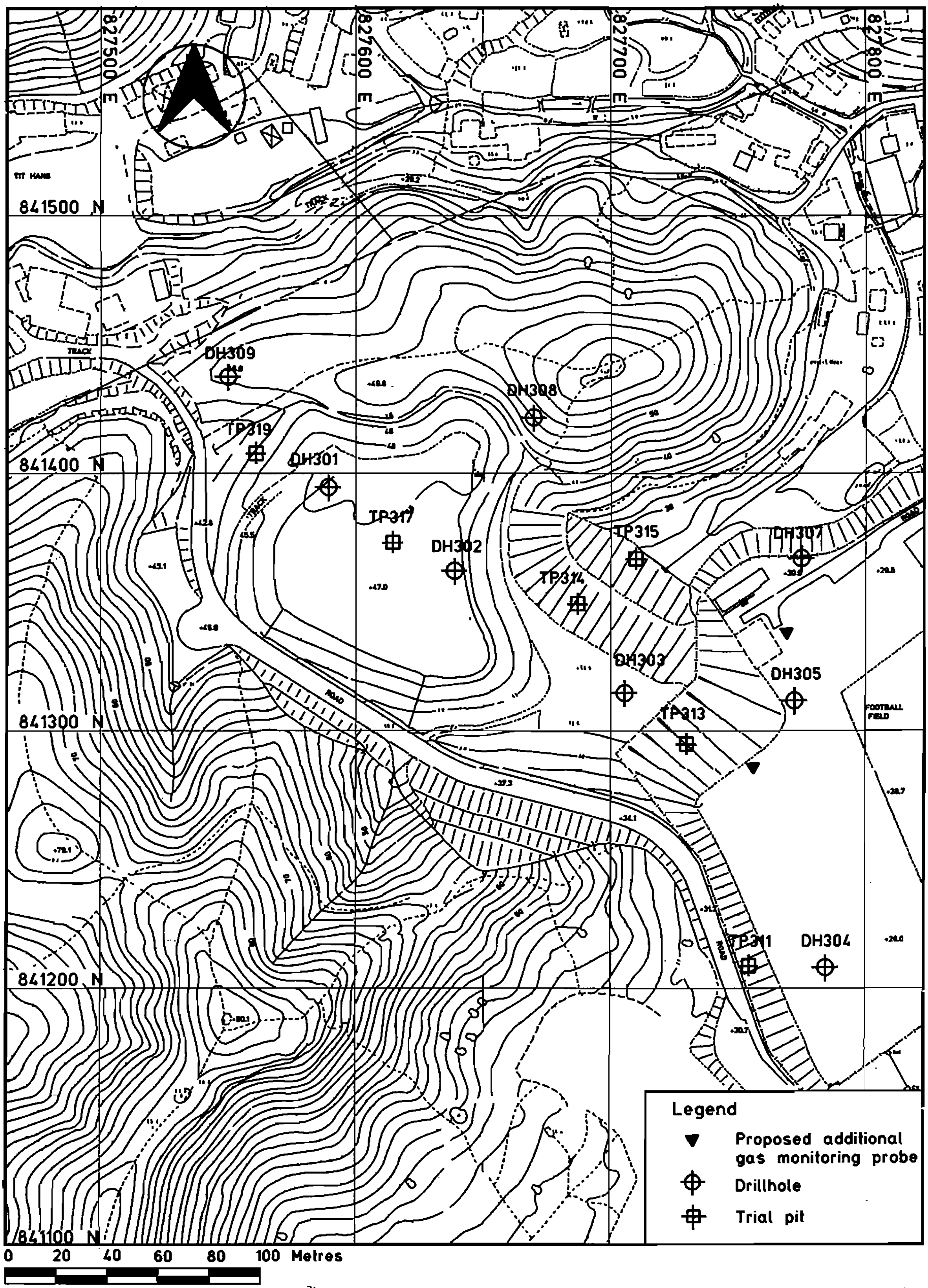


Figure 6.4

Ma Tso Lung Landfill

Sampling Locations for Landfill Gas Monitoring

Table 6.2: MTLL - GAS MONITORING RESULTS (Sheet 1 of 1)

LOCN+	DATE	APRE	DPRE	%CH4	%LEL	%O2	%CO2	%H2	%CO	%N2	COM
DH301	18-Jun-93	1008.4		58	2.5	<1	25				
	21-Jun-93	1007.2		57	2	<1	25				
	1-Jul-93	1008.6	25	65.4	>100	0	26.5				
	1-Jul-93	1008.6	25	69		0.7	25	<0.05	<0.1	3.6	Lab
	16-Jul-93	1007.9		58	2.5	<0.5					
	20-Jul-93	1004.5		63		1.1	27	<0.05	<0.1	4.5	Lab
	28-Jul-93	1002.6	14.6	62.2	0	0	26.2				
	23-Sep-93	1009.2	22	65.2	0	0	27.3				
	29-Oct-93	1019.9	31	63.8	0	0.3	25.3				
	12-Nov-93	1014.7	30	63.8	0	0.4	25.3				
DH302	1-Jul-93	1008.6	25	66.4	>100	0	25.4				
	1-Jul-93	1008.6		71		0.8	23	<0.05	<0.1	3.9	Lab
	16-Jul-93	1007.9		58.5	2	<0.5					
	20-Jul-93	1004.5		72		0.1	27	<0.05	<0.1	0.6	Lab
	28-Jul-93	1002.6	45.2	60.1	0	0	29.3				
	23-Sep-93	1009.2	662	61.5	0	0	32.9				
	29-Oct-93	1019.9	155	58.3	0	0.4	33.7				
	12-Nov-93	1014.7	138	58.7	3	0.1	34				
DH303	18-Jun-93	1008.4		61	2	<1	24				
	1-Jul-93	1008.6	25	69.3	>100	0.1	18.6				
	1-Jul-93	1008.6	25	72		0.5	18	<0.05	<0.1	6	Lab
	16-Jul-93	1007.9		54	5	0.8					
	20-Jul-93	1004.5		68		0.2	25	<0.05	<0.1	2.3	Lab
	28-Jul-93	1002.6	13.6	58.2	8	0.8	26.2				
	23-Sep-93	1009.2	60	65.4	0	0.1	26.1				
	29-Oct-93	1019.9	-82	58.7	0	0.6	32.9				
	12-Nov-93	1014.7	-47	0	6	20.3	0.27				
DH305*	18-Jun-93	1008.4		<1	32	17	5				
	1-Jul-93	1008.6	0	0.2		20.8	0.04				
	1-Jul-93	1008.6	0	0.48		18.7	0.83				
	1-Jul-93	1008.6	0	0.3		18	0.5	<0.05	<0.1	81	Lab
	16-Jul-93	1007.9		0	0	17					
	20-Jul-93	1004.5		<0.1		11	3.9	<0.05	<0.1	81	Lab
	28-Jul-93	1002.6	0.8	0	0	13.5	3.78				
	23-Sep-93	1009.2		0	0	20.1	0.91				
	29-Oct-93	1019.9	-127	0.23	0	20.7	0				
	12-Nov-93	1014.7	-47	0	6	20.3	0.27				
DH307*	18-Jun-93	1008.4		<1	1.5	13	1				
	1-Jul-93	1008.6	0	0	0.5	19.6	0.83				
	16-Jul-93	1007.9		0	0	13.5					
	28-Jul-93	1002.6	0	0	0	13.3	5.99				
	23-Sep-93	1009.2	1	0.04	0	13	7.1				
	29-Oct-93	1019.9	0	0.28	3	13.1	6.26				
	12-Nov-93	1014.7	1	0.13	7	13.7	5.59				

* denote those holes located off-site
+ refer to A2.1 (Appendix 2) for abbreviations used

Impact of construction activities

6.23 Major re-profiling and capping is proposed for MTLL prior to redevelopment. LFG has potential to be emitted during restoration construction works as a result of disturbance of existing material, exposure of waste and creation of migration pathways with subsequent venting. Potential migration pathways may be created via new drainage channels. Capping of the regraded landfill will limit surface emissions, but is likely to enhance lateral migrations. However, the proposed LFG management system as specified in WP6 (Ref 6.3) will intercept laterally migrating LFG and vent it to atmosphere in a controlled manner around the boundary of the landfill.

Mitigation measures

6.24 By the use of good site practices, release of LFG during reprofiling and capping can be minimised. Such measures include minimising surface exposure of waste (for example, temporary cover could be used to cover exposed refuse, coupled with restoring areas as quickly as possible) and locating any necessary temporary stockpiles of waste away from sensitive receptors. Once reprofiled, the site should be capped as soon as practicable. Construction of boundary venting trenches and gas vents will require excavation of waste which should be disposed of in an environmentally safe manner (either by incorporation into the reprofiling scheme or by off-site disposal to an appropriate licensed facility).

6.25 The potential risks and hazards associated with LFG accumulation in confined spaces have been discussed in Chapter 4 for PPVL. Similar mitigation measures apply to MTLL.

Impact of LFG control measures

6.26 The major impacts associated with LFG control measures relate to the construction phase, and include:

- the re-grading and capping the landfill;
- the construction of gas venting trenches and passive vents within the fill; and
- drilling of additional monitoring boreholes.

6.27 LFG will be emitted from passive gas vents in a controlled manner within the landfill and perimeter trench. Design and rationale of the location of vent stacks are similar to those for SLSL, as described in Chapter 5. Although desirable from an environmental viewpoint to collect and flare LFG, it is considered that the predicted yields from MTLL are too low for this to be a feasible option.

Impact on afteruse option

6.28 The capping specification for restoration is presented in WP6. It is proposed that the site be used for a variety of sporting and leisure activities, including a football pitch. No buildings are proposed on the restored landfill. The proposed system of LFG control comprises a perimeter venting trench and passive wells within the waste. The cap design includes a granular layer which links in with the perimeter vent trench, overlaid by a low permeability membrane to control vertical movement of LFG as suggested in WP6. Appropriate comments presented in Chapter 5 concerning potential LFG hazards for the proposed afteruse of SLSL apply equally to MTLL.

6.29 Advice with regard to development close to landfills is presented in Chapter 4. The area to the south-east and east is proposed for sports and recreational development. The final layout of buildings has not yet been finalised, but it is unlikely that buildings will be present within 20 m of the landfill boundary. However, buildings and other infra-structure will be constructed within 250 m of the landfill. All buildings within the 250 m zone will require additional gas protection measures as a precautionary measure, which should comprise as a minimum provision of a ventilated sub-floor void or gas proof membrane in the floor slab, and special detailing of services.

Air Quality

Introduction

6.30 This section details the assessment of impacts on air quality from emissions at Ma Tso Lung Landfill site. Construction activities associated with the restoration of the landfill site are considered with reference to dust and VOC emissions. A predictive assessment is made of the impacts from venting of LFG on the site.

Ambient Monitoring

VOC

6.31 Background ambient air quality measurements made upwind and downwind of the landfill were analysed for the presence of the SACs. The results are given in Table 6.3. They indicate that ambient levels downwind of the landfill are higher than levels upwind for dichloromethane. For benzene and 1,1,1-trichoroethane one of the downwind measurements is higher, but a second downwind sample did not show an increase. This would indicate there is a possibility that dichloromethane is being emitted from the landfill but the evidence is inconclusive.

Table 6.3 : Monitored Ambient VOC Levels at MTLL

SAC	Method Detection Limit (μg/m³)	MTLL (μg/m³)		
		uw	dw	dwQ
Vinyl Chloride	0.36	ND	ND	ND
Dichloromethane	0.73	1.3	4.4	3.7
Trichloromethane	0.73	ND	ND	2.3
1,1,1-Trichloroethane	0.76	4.2	12.1	2.5
1,2-Dichloroethane	0.61	ND	ND	ND
Benzene	0.26	3.5	4.5	3.5
Tetrachloromethane	0.94	ND	ND	ND
Trichloroethylene	0.91	ND	ND	ND
1,2-Dibromoethane	0.92	ND	ND	ND
Tetrachloroethylene	0.75	0.9	0.9	ND

Notes

uw : upwind
dw : downwind
dwQ : for quality assurance downwind values were retaken
ND : Not detected, below the method detection limit

Methane

6.32 Table 6.4 shows the results of analysing the samples taken upwind and downwind of the landfill site for methane. The methane measurement downwind was approximately 7% higher than that taken upwind. This is well within the range of expected variation and it would be difficult to draw any conclusions from the measurements.

Table 6.4 : Monitored Methane Levels at MTLL

Pollutant	uw (μg/m³ (ppm))	dw (μg/m³ (ppm))
Methane	1820 (2.83)	1952 (2.82)

Notes

uw : upwind
dw : downwind

Assessment of Impact from Dust Emissions

6.33 Only one sensitive receptor for MTLL has been identified and considered in the study, this is given in Table 6.5.

Table 6.5 : Sensitive Receptor and Location

Landfill Site	Sensitive Receptor	Grid reference
Ma Tso Lung	Sports Complex	827792E 841316N

6.34 Chapter 4 details the modelling approach undertaken in the dust assessment study. The impact from combining the dust generated from a 0.0625 ha construction area situated on the site boundary with vehicles passing on unpaved roads at the site boundary at the sensitive receptor is:-

Distance from site	= 24m
TSP concentration from vehicles	= 220 μg/m³
TSP concentration from construction site	= 625 μg/m³
Total predicted TSP concentration	= 845 μg/m³

6.35 It can be seen that the 500 μg/m³ air quality guideline is exceeded. Therefore, mitigation measures are necessary. This mitigation may include dampening down the surface of the unpaved road and construction site. An effective watering programme (twice daily watering over the entire site) is estimated to be able to reduce emissions by up to 50% from ground surfaces. This should be able to reduce the total TSP concentration to about 420 μg/m³ which is below the relevant air quality guideline level.

6.36 Covers and wind shields may be used at places where high emissions of dust are expected. On days when the wind direction is such that dust is blown towards the sensitive receptor and mitigating action is unable to reduce dust levels to a satisfactory level, it is possible that traffic may take a diversion and use a route further from the sensitive receptors. At times of particularly high levels it may be necessary to suspend construction activity.

6.37 The AQO that applies to TSP in Hong Kong restricts 24-hour average concentrations to below 260 μg/m³. Using a factor of 0.4 to convert the 1-hour concentration to 24-hour concentration (when considering a 12 hour working day) and a 50% reduction due to mitigation measures listed above, a predicted TSP concentration of about 170 μg/m³ is obtained, which is below the relevant air quality guideline level.

6.38 Several assumptions have had to be used due to a lack of relevant site specific data and accordingly the modelling approach could only provide a broad indication of the possible dust impacts. Despite the high values predicted, the Consultants are confident that subject to sensible mitigation measures, no significant dust impacts will occur.

Assessment of Impact from VOC Emissions

6.39 Landfill gas samples were obtained from drillholes DH301A and DH303A for GC/MS analysis. Benzene, dichloromethane and trichloroethylene were the SAC detected in the LFG samples. The average measured concentrations of these contaminants are given in Table 6.6.

Table 6.6 : SAC Concentrations in LFG at MTLL

Pollutants	Concentration in LFG(mg/m^3)
Dichloromethane	0.15
Benzene	1.20
Trichloroethylene	0.75

6.40 VOC emissions were determined from the following:

- Oxford University Model was used to calculate the volume of landfill gas generated by the landfill;
- Concentrations of VOCs in landfill gas were derived from samples taken from two drillholes, and
- Gas assumed to vent equally from each of 36 vents.

6.41 Table 6.7 details the emission and modelling parameters used for predictive modelling of VOCs.

Table 6.7 : VOC Emission Levels and Modelling Parameters for MTLL

Parameter	Input
Passive vent height	3 m
Gas temperature	30 °C (303 °K)
Assumed air temperature	25 °C (298 °K)
Gas volume	68.5 m^3/hr
Number of vents	36
Vent diameter	10 cm
Pollutants emission rates*	
- dichloromethane	0.079 µg/sec *
- benzene	0.634 µg/sec *
- trichloroethylene	0.396 µg/sec *

Notes

Other Specified Air Contaminants were not detected in the landfill gas composition.
Meteorological assumptions are the same as those given in Chapter 4.
USEPA Model ISCST was employed.
VOC emission rates were derived from measured concentrations of landfill gas from drillholes.
** the emission rates are per vent.*

6.42 The results from the modelling at MTLL are presented in Table 6.8. In Table 6.8 the predicted concentrations at the Air Sensitive Receptor (ASR) and maximum predicted concentration values of the SACs present in the landfill gas are given along with the calculated risk from cancer associated with such a concentration. A conservation conversion factor of 0.3 was used to convert maximum annual 1-hour average concentrations to annual average concentrations in light of the limited data and the assumptions made in the modelling.

Table 6.8 : Predicted concentration and Associated Risk from SACs at MTLL

Receptor	Pollutant	Maximum Annual 1-hour Concentration ($\mu g/m^3$)	Risk
Max Value	Dichloromethane	0.00523	7.2×10^{-10}
827820E 841300N	Benzene	0.041	1.0×10^{-7}
	Trichloroethylene	0.0257	2.8×10^{-8}
827792E 841316N	Dichloromethane	0.00426	6×10^{-10}
	Benzene	0.0341	8.4×10^{-8}
	Trichloroethylene	0.0213	2.4×10^{-8}

6.43 These results indicate that the restored MTLL site will not be a significant contributor to ambient levels of VOCs. Nonetheless it is considered prudent to include requirements in the contract documents for the Contractor to carry out detailed environmental impact assessments. The contract Specification should include environmental standards which could include risk-based guidelines on which the Contractor will have to achieve and verify in his design.

6.44 If high VOCs are detected it would be possible to install filters of activated carbon within the vent pipes to give an absorbent media for VOCs. However, this could reduce venting efficiency and hence efficiency of the landfill gas control, and extra venting arrangements may be necessary to improve the efficiency of the overall landfill gas control system so that lateral gas migration would not occur. It is considered that filtered passive vents, coupled with a regular sampling, testing and maintenance programme, could be used to effectively reduce the VOC's to acceptable levels.

6.45 Because the proposed LFG restoration works at MTLL rely on passive venting with no flaring of gas, particular attention has been given to the assessment of odour. Samples of LFG from 2 holes drilled into waste at MTLL were analysed for a large suite of odorous compounds. Table 6.9 lists the concentration of those compounds detected above their odour threshold.

Table 6.9 : Trace Gases in LFG Exceeding Odour Limits for MTLL

	301A	301AQ**	303A
butene (total)	0.5	0.8	1.2
pentene (isomer)	0.6	0.7	1.4
dimethyl sulphide	1.4	1.3	ND
acetone	4.9	4.7	0.2
cyclohexane	2.9	2.8	2.0
butan-2-one	22	23	ND
butan-2-ol	1.6	1.0	ND
thiophene	0.2	0.2	ND
cyclohexane	2.9	2.8	2.0
limonene	490	390	240
napthalene	4.3	4.6	0.07
n-octane	3.2	3.5	3.4
dimethyl disulphide	1.9	1.9	ND
toluene	140*	150*	210*
n-nonane	16	17	14
chlorobenzene	0.4	0.6	0.1
ethyl benzene	24	28	17
xylenes	27	30	26
styrene	0.5	0.4	ND
n-decane	33	33	24
n-undecane	21	21	8.8

Notes

* *Saturation of mass spectrometer as consequence of choice of internal standards represents underestimate (all measurements in mg m^{-3})*
** *Duplicate sample for QA purposes*
ND Not detected, below the method detection limit

6.46 Table 6.10 gives the results from the modelling study for the twenty one compounds that exceeded the odour threshold in the analysed landfill gas. The results are given for ground level concentrations at the air sensitive receptor and at the point where the maximum concentration occurs. In every case the predicted concentrations are below the toxicity level OES/100 (the predicted risk for styrene is also below the acceptable cancer risk). The predicted concentrations of the air contaminants would not cause any odour nuisance at any present or potential sensitive receptor.

Table 6.10 : Predicted Concentrations at ASR from VOCs in the Landfill Gas

Pollutant	Maximum Concentration at point of emission (mg m^{-3})	Maximum Value 827820E 841300N Concentration (µg m^{-3})	Sensitive Receptor Concentration (µg m^{-3})	OES/100 (8hrs) (µg m^{-3})
butene	1.2	0.041	0.034	
pentene	1.4	0.048	0.04	
dimehtyl sulphide	1.4	0.048	0.04	
acetone	4.9	0.16	0.14	17800
cyclohexane	2.9	0.099	0.083	3400
butan-2-one	23	0.78	0.66	5900
butan-2-ol	1.6	0.054	0.046	3000
thiophene	0.2	0.0068	0.0057	
cyclohexane	2.9	0.099	0.083	
limonene	490	17	14	
napthalene	4.6	0.16	0.13	500
n-octane	3.5	0.12	0.1	14500
dimethyl disulphide	1.9	0.064	0.054	
toluene	210	7.2	6.0	1880
n-nonane	17	0.58	0.49	
chlorobenze	0.6	0.02	0.17	2300
ethyl benzene	28	0.96	0.8	4350
xylenes	30	1.0	0.86	4350
styrene	0.5	0.017	0.014	
n-decane	33	1.1	0.94	
n-undecane	21	0.72	0.60	

Notes

Taken from CAPCOA Air Toxics "Hot Spot" Programme Revised 1992 Risk Assessment
UCR = 5.7×10^{-7} (µg $m^{-3})^{-1}$ for Styrene
Risk at max value 7.4×10^{-8}
Risk at receptor 3.1×10^{-8}

Noise

Background noise levels and monitoring data

6.47 An industrial area, including a sawmill, which lies to the south-east of the site produces significant levels of noise, and works associated with the installation of a water distribution system was also a significant source of noise of the time of the baseline monitoring exercise. Other noises of a rural nature are also present.

6.48 Background noise monitoring has been carried out at MTLL, measurements being made in hourly periods during the day between 07:00 hours and 19:00 hours from 29 November to 1 December 1993. Summarised results and the monitoring locations as well as the identified present noise sensitive receivers are given in Table 6.11 and Figure 6.5 respectively. The full results are reproduced in Appendix 3.

Table 6.11: Summarised Baseline Noise Monitoring Results for MTLL

Monitoring Location		Major Noise Sources	Average Noise Level dB(A)		
			L_{10}	L_{90}	L_{eq}
MTLL-1	Above facade on roof of nearest low-rise residential building	1) Dog barking 2) Noise from farm animals eg pigs 3) Installation of water distribution system to south	56.8	48.0	56.6
MTLL-2	Above facade on roof of Community sports centre	1) Installation of water distribution to south-east 2) Activities in playground	59.8	47.9	62.5
MTLL-3	Edge of industrial areas	1) Activities in timber factories	64.9	53.8	65.4
MTLL-4	Boundary of isolated low-rise residential building	1) Dog barking 2) Noise from farm animals eg pigs	53.9	44.0	52.5

6.49 MTLL-1 was located on the roof of the nearest low-rise residence to the Ma Tso Lung Landfill, significant noise sources being farm animals and the water distribution system installation activities. Noise from these activities was also significant at MTLL-2, which was located on the sports centre roof, as was noise from the nearby playground.

6.50 MTLL-3 was located at the edge of the industrial area where the dominant noise source was the sawmill. MTLL-4 was situated at a low-rise residential building to the west of the site where noise from animals was reported to be dominant.

6.51 Of the results obtained at the Ma Tso Lung Landfill, those at MTLL-3 were the highest, due to its proximity to the sawmill. Results obtained at the other locations were typical of noise levels in a semi-rural situation.

Impacts of construction activities

6.52 Secondary restoration at Ma Tso Lung Landfill is likely to be less extensive involving fewer items of plant. Once again, daytime only operation is assumed.

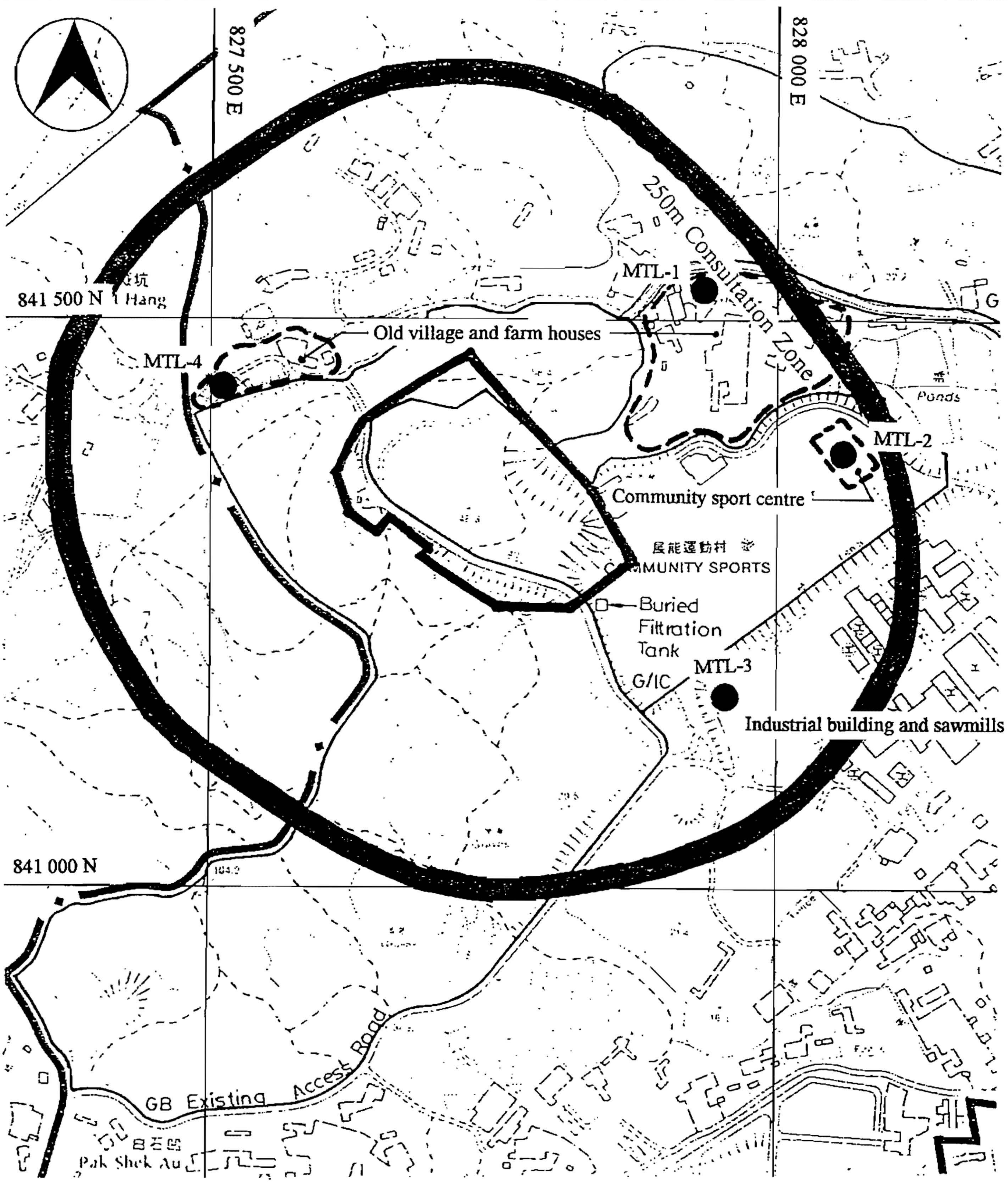
Mitigation Measures

6.53 Guidance is provided in the Practical Guide for the Reduction of Noise from Construction Works (Ref 6.6), produced by EPD. Various options exist to control the noise from these activities, including the selection of quieter plant, the erection of temporary screening mounds around noisy activities, and the reduction in the numbers of items of plant in use at any one time.

6.54 Currently, receptor sensitives to noise from MTLL are few, and it is considered that it will be possible to ensure that noise levels at the nearest receptors do not exceed the target of 75 dB(A).

Impacts of afteruse option

6.55 It is considered that there would be no significant sources of noise associated with the development of MTLL as a holiday camp. The sources of noise associated with this afteruse option can be effectively mitigated using appropriate noise attenuated measures



LEGEND :

Landfill boundary	Noise sensitive receiver
Consultation zone boundary	Noise measurement location

Figure 6.5
Ma Tso Lung Landfill
Sampling Locations for Noise Measurement

such as acoustic insulation and screening of the buildings and tree screening along the boundary of significant noise emitters.

Water Quality

Existing groundwater and surface water quality

6.56 The groundwater levels of the off-site wells (i.e. DH304, 305 and 307) indicate an apparent gradient in a southerly direction, matching that of the topography. The groundwater elevation ranges from 25.5 - 26.1 mPD at DH307 to 23.0 - 25.7 mPD at DH304. The groundwater collection system which was placed beneath the containment liner appears still to be functioning. A significant spring emerges in the bed of the stream at the north east toe of the landfill (i.e. W301) for the outflow point of the groundwater system as shown on Figure 6.6. Figure 6.6 also indicates the sampling locations for leachate, groundwater and surface water.

6.57 The results of the analyses for leachate, groundwater and surface water are given Table A4.3 of Appendix 4. As shown in this table, groundwater in drillholes immediately adjacent (DH308) and down-gradient of the site (DH304, DH305 and DH307) shows little or no evidence of contamination. Table 6.12 summarises the results of the analyses of groundwater and surface water at MTLL. Although the stream to the north-east is grossly contaminated as a result of some leachate seeps into the stream channel, there is no direct evidence that the groundwater spring makes any contribution to this contamination.

6.58 Two seepages, L301 and L302, emerging at the base of a retaining wall on the south side of the sports field, exhibit contamination which appears to be derived from leachate that has soaked into the ground. This is particularly evident in the western half of the playing field since the filtration tank was demolished in 1984.

6.59 It is unclear whether groundwater beneath the site is contaminated, but some groundwater samples taken underneath the wastes (DH301 and DH302) show little contamination as compared with the strong leachate in the landfill above. Groundwater samples are also much less contaminated than seepage at the south side of the playing fields. It is therefore unlikely that liner leakage is the source of seepage contamination.

6.60 As shown in Table A4.3 of Appendix 4, the surface water samples (W301, W302A and W302B) are contaminated with leachate seeps which emerge from the face of the fill. Comparison of quality at W302A with W302B and with leachate seeps, shows that a significant amount of nitrification, denitrification and COD removal occurs during passage from the landfill, as well as a small amount of dilution. Some leachate also seeps into the channel of the original stream bed to the north-east, where it mixes with groundwater from the outflow point of the drainage system below the landfill liner. The flows remain highly contaminated in comparison to clean surface water as indicated in Table 6.12.

Leachate quantity and quality

6.61 Major regrading of adjacent land took place during the early to mid-1980s, and almost certainly blocked the leachate drainage outlet pipe, as well as demolishing and filling in the area of the filtration tank in 1984. Since then, leachate levels have increased in the refuse. There is now a consistent line of seeps, several metres above the surrounding land on the south-east, north-east and north-west faces, which correlates well with levels in leachate monitoring drillholes installed for this study in 1993, showing 6-7m saturation in the south-east of the site and 11m saturation in the north-west. Estimated present rates of seepage are consistent with historic measurements and with estimates from water balance calculations (Ref 6.5). The present leachate discharge flows for the 2 ha site are estimated as follows:

peak:	19.2 - 30.2 cu m/day
average:	9.6 - 15.1 cu m/day

Table 6.12: Analysis of Groundwater and Surface Water at MTLL

Determinand *	Standards for Groundwater ***			Water Source ****	
	ST1	ST2	ST3		
	Dutch Grade C	Dutch VPR	WHO	Surface water	Ground-water
pH (pH units)			6.5-8.5	7.8-8.4	(5.4-8.3)
EC (uS/cm)				4100-16000	120-31000
Cadmium	0.01	0.006	0.005	(<0.02-0.2)	<0.02
Chromium	0.2	0.026	0.05	(0.2-1.8)	(0.1-1.5)
Copper	0.2	0.035	1	(0.2-0.3)	(<0.1-0.8)
Lead	0.2	0.05	0.05	(<0.1-1.3)	(<0.1-3.8)
Nickel	0.2	0.04		(<0.1-0.1)	(<0.1-0.1)
Zinc	0.8	1	5	(0.2-4.2)	0.06-0.31
Manganese			0.1	(0.6-6)	(1-3.5)
Iron			0.3	(3.6-35)	(3.7-88)
Sodium			200	(150-1000)	(5-1000)
Potassium				52-390	1.5-440
Hardness (as CaCO3)			500	(230-520)	36-140
Sulphate			400	(10-490)	<10-65
Sulphide	0.3				(<0.1-0.6)
Phosphorous				1.2-2.4	<0.1-31
Nitrate			10	(200-210)	(<0.01-12)
Ammonia Nitrogen				190-1600	<0.1-4200
Kjeldahl Nitrogen				600	<0.1-4300
Total Organic Carbon				100-600	<0.1-1100
Chloride			250	(300-1600)	(9.8-2100)
COD				350-3100	<7-2500
BOD				15-220	<5-1400
E. coli (no./100ml) **			0		(0-600)

Note:

* All units in mg/l except where noted

** The Standard for drinking water (WHO) refers to Fecal Coliform

*** The standards for groundwater and drinking water being refered to are as follows:

ST1 Dutch Criteria for Category C Clean Up Investigations (Ref 6.7)

ST2 New Dutch Second Generation VPR Criteria (Ref 6.8)

ST3 WHO Guidelines for Drinking Water (Ref 6.9)

**** Data enclosed in brackets indicate the exceedance of the standards quoted

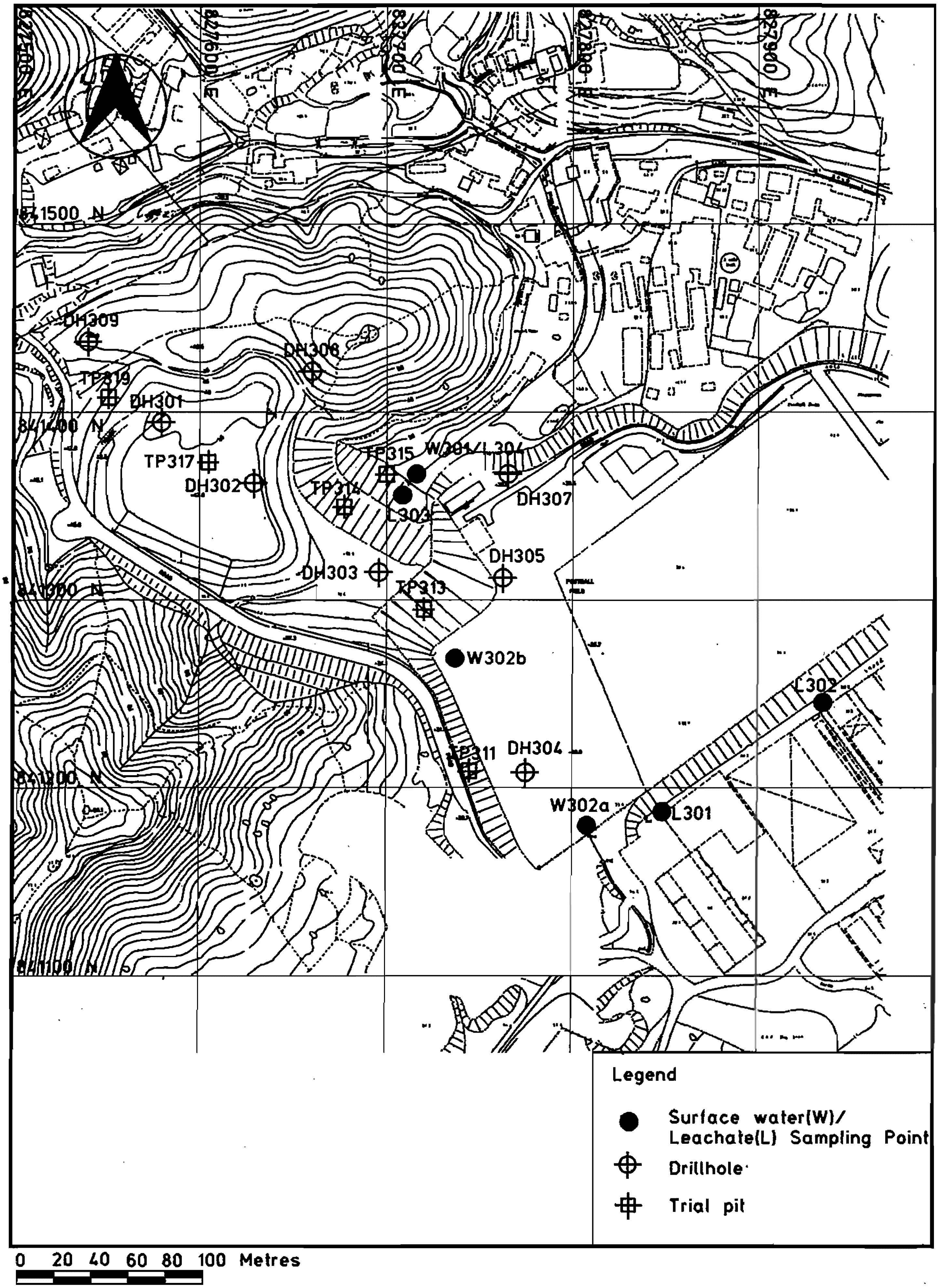


Figure 6.6

Ma Tso Lung Landfill

Sampling Locations for Leachate, Groundwater and Surface Water Monitoring

6.62 Leachate seepages are causing serious pollution of surface waters, both to the north-east and south-east of the site. Leachate draining from the site in the early 1980s was seriously contaminated, with NH_3-N concentrations exceeding 10,000 mg/l at times. The landfill still contains leachate of this strength in the north-west but the concentration becomes more dilute (down to 4,000 mgNH_3-N/l) from north-east to south-east, and escaping leachate is considerably weaker as indicated in Table A4.3 of Appendix 4. This implies that percolation of rainfall may be entering the lower platform in the south-east part of the site and diluting the leachate.

6.63 There is some evidence that waste degradation and methanogenesis may have been partly inhibited as leachate temperatures are at or below ambient external temperature. This is supported by the fact that the less diluted leachates still contain very high concentrations of BOD, COD and fatty acids even after 14 years. The possible factors responsible for the inhibition are likely to be high concentrations of NH_3-N, sulphide and heavy metals as well as low moisture content.

6.64 Table 6.13 shows that the levels of BOD, COD, iron, chromium, total nitrogen and total phosphorus of the leachate exceed the Government standards for effluent discharged into foul sewer (Table A1.3 of Appendix 1), indicating that direct discharge of leachate into the sewer leading to the sewage treatment plant nearby is not permissible. Similarly, leachate also exceeds the standards for discharge into Group C inland waters given in Table A1.5 of Appendix 1 with respect to most of the determinands.

6.65 Measures are needed to prevent uncontrolled seepage of the leachate into surface waters. Engineering works should be undertaken to regrade and recap the landfill to reduce leachate generation, to intercept and collect leachate seeps along the south-east and north-east faces of the landfill and to reinstate the outflow pipe from the leachate collection system. Collected leachate should be discharged to the leachate holding tank from which it would eventually be transported to a leachate treatment plant elsewhere, probably at PPVL, WENT Landfill or Shuen Wan Landfill.

Impacts of construction activities

6.66 Leachate management arrangements to intercept seepages and re-instate the collection system, should be in place before regrading, capping and leachate interception works are undertaken, as these activities are all likely to lead to a temporarily increased rate of leachate generation. Intercepted leachate should be tankered for treatment to a leachate treatment plant prior to discharge into a sewage treatment plant. It is anticipated that a considerable amount of sediment would occur in runoff from earthworks required for regrading and capping of the landfill. Measures as given in Chapter 4 for PPVL for mitigating the increase in sediment loads in runoff from the site should be adopted.

Impacts of leachate control measures

6.67 It is likely that regrading of the landfill, needed for slope stabilization, and capping for restoration and after-use purposes, will reduce the present areas of flat or shallow gradients, and will increase the run-off of rainwater from the site, leading to a reduction in leachate volumes. In addition, the interception of surface leachate seeps and their diversion to the leachate holding tank would improve the water quality of adjacent surface waters. When leachate seeps which flow along the slopes of the landfill are intercepted, the leachate flows to the surrounding low lands will also be eliminated, resulting in a general improvement in the ground conditions of the south-east part of the playing field. It is recommended that the leachate holding tank is relocated to a lower elevation, below existing ground level, and adequately bunded to contain any leakage or spillage. No observable visual and odour impact of leachate collected in the holding tank is envisaged in this case.

Table 6.13 : Analysis of Leachate from MTLL

Determinand*	TM on Effluent Standards** >10 and <=100	Landfill Stie *** MTLL
pH (pH units)	6-10	7.7-9.2
Temperature (°C)	43	26.1-34
Suspended solids	1000	
Settleable solids	100	
BOD	1000	(43-9900)
COD	2500	(350-23000)
Oil & Grease	100	
Iron	25	(2.7-36)
Boron	7	
Barium	7	
Mercury	0.15	
Cadmium	0.15	<0.02
Copper	4	0.2-0.3
Nickel	3	0.1-0.3
Chromium	2	(0.7-20)
Zinc	5	0.3-1.5
Silver	3	
Cyanide	2	
Phenols	1	
Sulphide	10	7.2
Sulphate	1000	<10-280
Total nitrogen	200	(240-17000)
Total phosphorus	50	(10-98)
Surfactants (total)	150	

Note:

* All units in mg/l except where noted

** Standards for flow rates (cu m/day) expressed as upper limits (Ref 6.10)

*** Data enclosed in brackets indicate the exceedance of standards

Impacts of afteruse option

6.68 The proposed low intensity land use for MTLL as a holiday camp does not involve any significant impact on the adjacent water bodies. Only the buildings and facilities concentrated on the site south of MTLL involve a high number patronage, and proper sewage facilities will be provided. In all cases, site profiling may require incorporation of some appropriate drainage to intercept seepage, and surface drainage measures to collect contaminated surface water, shed rainfall and reduce rainfall infiltration.

Landscape, Afteruse and Visual Impacts

6.69 At present, the landfill consists of two terraced platforms surrounded by natural rolling hills on three sides. The most prominent feature is the lower fill slopes facing north-east and east, which rise steeply above the adjacent low lying areas. There is no vegetation on the platforms. The lower slopes facing north-east and east are badly eroded, with only patchy groundcover plants. The slopes facing west have a slightly thicker cover of herbs, grasses and low shrubs. The large expense of bare ground is incongruent with the rural setting of the surrounding.

6.70 A range of outdoor sports and recreational uses have been proposed for this landfill. Prior to development of afteruse facilities, the site has to be restored by regrading and recapping with a final soil cover. The site would be replanted in accordance with the layout for the proposed afteruse.

6.71 The visual impact of the proposed recreational uses on the platforms would be minimal, as they would be enclosed and screened by new planting. Facilities located on the slopes would have to suit the slope profiles and blend with the surrounding contours. A planting scheme would be implemented to introduce vegetation cover on the site, for immediate as well as long term benefits. There would be great improvement to the visual quality of the site upon completion of the restoration works and establishment of the new planting.

Settlement

Existing conditions

6.72 Landfilling has taken place at MTLL between July 1976 and February 1979 with about 180,000 tonnes of domestic and industrial wastes deposited at the site of about 2 ha. No significant capping layer is present on the MTLL site other than the final intermediate cap left at the completion of landfilling. The remaining settlement has been estimated as only 1.5% of the total waste thickness due to the old nature and relatively small amount of waste deposited. This estimate assumed an exponential decay rate of 0.2% per year. Although the examination of the settlement features at the platforms was obscured by the stockpiles and other activity on the site at the time of the survey, limited differential settlement was present on the landfill.

Impacts of construction activities

6.73 The general impacts of construction activities for settlement at MTLL are similar to those described earlier for PPVL and SLSL. Specific objectives for minimizing the impacts are:

- use of flexible paving material for the surfacing of the footpaths;
- design of surface water management systems should be designed to minimise maintenance by being flexible to accommodate differential settlement; and
- use of lightweight structures, where the foundation design should be able to accommodate the effects of differential settlement.

Impacts of afteruse

6.74 The preferred afteruse for MTLL is a holiday camp proposed by the Tung Wah Group of Hospitals. There is a wide range of outdoor sports and recreational uses which utilise the platforms and slopes of the landfill site. Through appropriate planning, most of the heavy establishments such as the dormitory and function hall can be located outside the landfill site, where little or no differential settlement would take place. The proposed on-site afteruse focuses on low intensity land use, where a low proportion of the site will accommodate buildings. The small anticipated settlement at MTLL is therefore considered to be of insignificance in relation to the activities proposed.

6.75 Measures such as the correct use of flexible paving material for the surfacing of the footpaths, flexible surface drainage channels and careful positioning for the structures over the area where no waste is deposited are considered appropriate for minimising disruption to proposed afteruses. The maintenance works for repairing defects due to settlement would also be substantially reduced by the implementation of these measures.

High Tension Power Line

6.76 Extra-high tension power lines (400 kV) are locate d across the north-west region about 40 m away the boundary of MTLL (Figure 6.3). The approximate distances between the lowest and nearest conductor of the power lines and the sensitive receptors on the site are given in Table 6.14 below:

Table 6.14: Distance to the Lowest and Nearest Conductor

Sensitive Receptor	Approximate Distance to the Lowest and Nearest Conductor
Spectator Seating at Football Field	150 m
Closest Dormitory on South-East	290 m

6.77 With regard to the afteruse option as a holiday camp, the spectator seating at the football field is located relatively close to the lowest point of the power line and hence exposure to EMF will be slightly higher than for other recreational activities such as visiting the refreshment kiosk which will take shorter periods of time. The dormitory, though situated relatively far from the power line at 290 m, will result in more prolonged levels of exposure than other activities. However, given the separation distance as indicated in Table 6.14 and the relatively short exposure time, the effects of EMF affecting human health are expected to be minimal.

6.78 The conceptual design of the afteruse option for MTLL has already taken the safety aspect of the power lines into account, thus no immediate building or structure will be installed close to the conductors of the power cables violating the minimum safety clearance guidelines as given in Chapter 4, and the particular clearance for building reserve of 15.6m which is specified by CL&P for MTLL.

Conclusions and Recommendations

6.79 The preferred afteruse for MTLL is a holiday camp combined with a wide range of outdoor sports and recreational uses which will use the slopes and platforms of the landfill. Planting should be carried out to compliment the rural surroundings of the site and to enhance the local landscape.

6.80 The small degree of settlement predicted at MTLL is not expected to be significant in relation to the activities and developments proposed on-site. However control measures, as described for PPVL and SLSL, are recommended including the use of flexible paving materials and surface water drainage systems. Heavy building structures, such as dormitories and the function hall, should be placed outside waste deposited areas where possible.

6.81 It is not considered that MTLL requires an active LFG extraction system. A combination of high permeability venting areas and low permeability barriers to prevent LFG migrating towards sensitive receivers, will provide adequate protection. Venting zones should be located around the boundary and should incorporate a granular layer underneath the capping layer which is connected to the peripheral system.

6.82 LFG at MTLL is typical of that of a methanogenic landfill, and is at positive pressure although not as great as PPVL and SLSL. Whilst LFG measurements in soil gas are generally stable, there is some evidence of lateral migration. With the implementation of good management practice, impacts associated with construction and the LFG control measures are not considered to be significant. During the afteruse phase, buildings on-site and those located within the 250m consultation zone should be provided with adequate gas protection and detection measures.

6.83 In order to reduce dust impacts it is advisable to minimise the operational areas during restoration. The assessment of TSP impacts shows predicted levels below the AQOs if mitigation measures are strictly applied. Predictive assessment of landfill gas dispersion indicates that following restoration works, odour thresholds will not be exceeded. The results from the VOC assessment indicates that the restored site will not be a significant contributor to ambient levels of VOC.

6.84 Background noise in the vicinity is currently dominated by a sawmill to the south-east, animals and nearby construction works, but otherwise noise levels were typical of a semi-rural location. Given the scale of construction work required and the current paucity of sensitive receivers in the vicinity, significant noise impacts are not envisaged. Similarly, during the afteruse phase noise levels associated with the holiday camp are likely to be acceptable, although some mitigation measures to protect on-site buildings may be required.

6.85 Groundwater shows limited evidence of contamination, although a stream to the north-east is seriously contaminated by leachate as a result of leachate seepage. Surface seepages at the base of a retaining wall on the south side of the sports field are probably a result of leachate that has soaked into the ground. The present peak discharge for the 2 ha site of 19.2 - 30.3 cu m/day is not considered to be of an acceptable quality for discharge to sewer. It is recommended that engineering works be undertaken to regrade and recap the landfill to minimise leachate generation, to intercept seepages and to re-instate the present leachate collection system. The collected leachate should then be transported to an appropriate treatment facility. It is recommended that the leachate holding tank be relocated to a lower elevation, below ground level, and bunded to prevent spillage or leakage. Appropriate drainage and sewerage facilities should be designed for the afteruse phase to ensure appropriate segregation and disposal of contaminated wastewaters.

6.86 It is concluded that following regrading, recapping and planting there would be a great improvement in the visual quality of the site. Facilities should be blended within the landscape in order to be unobtrusive.

6.87 Given the separation distance of facilities from the nearby high tension power lines and the relatively limited exposure time of people located on-site, no significant problems associated with exposure to electromagnetic radiation are envisaged. No building or structure proposed as part of the afteruse development will infringe upon the minimum distance requirements for high tension powerlines.

6.88 Details are provided in Chapter 9 and Appendix 5 on recommended monitoring with respect to the key environmental parameters of concern. This monitoring programme will provide the basis for the establishment of baseline conditions prior to restoration and provide the necessary data to ensure suitable mitigation measures are implemented in the event of unacceptable impacts being detected.

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7. NGAU TAM MEI LANDFILL

Study Area

Site description

7.1 The Ngau Tam Mei Landfill (NTML) is a heavily overgrown site located north-east of Yuen Long, to the east of the New Territories Circular Road, occupying an area of 2.05 ha at the head of a narrow valley surrounded by ridgelines (Figure 7.1). Uncontrolled dumping of wastes occurred prior to 1973 after which the site was operated as a sanitary landfill from December 1973 to March 1975. No data exist on the nature or quantities of the waste inputs during or before the controlled operational period. The volume of waste, mainly composed of domestic and industrial refuse, has been estimated as 180,000 cu m.

7.2 The site forms three platforms on the western side to the site. The largest one is at a level of 33 mPD while the smaller ones are at 25 and 15 mPD, which are separated by gentle slopes. Adjacent to the site at the north and east is a high mountain ridge at a height of about 80 mPD with a gentle slope covered with short grasses. Some residential dwellings are situated inside the 250 m consultation zone for the landfill site.

7.3 After the completion of infilling, the site was capped with a variable thickness (0.9 - 2m) of cdv/cdg material. The steep faces and lower terrace were left to revegetate naturally and supported a vigorous undergrowth at the time of this study. The site has not been lined and ιeachate collection was rudimentary, consisting of a single drain running down the central axis of the site leading to a filtration tank with an overflow discharge to the stream.

Environmental setting and land uses

7.4 No sensitive users have been identified within the site boundary of NTML, which is currently covered with dense vegetation. There are, however, a number of graves situated along the fringes of the landfill site. The site lies within a Green Belt in the draft Ngau Tam Mei Outline Zoning Plan (S/YL-NTM/1). Part of the Maple Garden Residential Group C development which is situated to the north-west of the site and separated to the site by a small hill lies within the 250 m consultation zone. To the south of the landfill is Wai Tsai Village with many old village houses. A flat area of land to the south-west of the southern boundary is proposed for residential development. The eastern boundary of the access road is occupied by sheds and buildings associated with a chicken farm, to the south of which is land used for light industry and storage.

Restoration Proposal

Introduction

7.5 The proposed restoration options for NTML have been discussed in the previous Working Paper WP5 on Master Development Plans (Ref 7.1), and this section describes the preferred restoration option for the site which is regarded as environmentally acceptable and safe. To accomplish the long-term management of landfill gas and leachate, there are appropriate measures to control and minimise their impacts. An outline of measures for the management of leachate and landfill gas is given in the following sections.

Restoration constraints and opportunities

7.6 An examination of land use and landscape issues has given rise to restoration options being proposed for NTML as generally discussed in Working Paper WP4 on Land Use Options and Planting (Ref 7.2). The constraints and opportunities on the restoration development of NTML are summarised in Table 7.1.

Table 7.1: Constraints and Opportunities for the Restoration of NTML

Constraints	Opportunities
1. Small site (2.05 ha)	1. Three platforms covering one third of site
2. Part of site designated as a burial ground for local village; graves on site and adjacent.	2. Most of the rest of the site is natural landform with building potential (though it is hilly)
3. Settlement problems	3. Near to villages and Fairview Park residential area
4. Leachate and landfill gas emission	4. Accessible by public transport
5. Landfill cap to be protected	5. Good view from northwest to southwest

Afteruse option

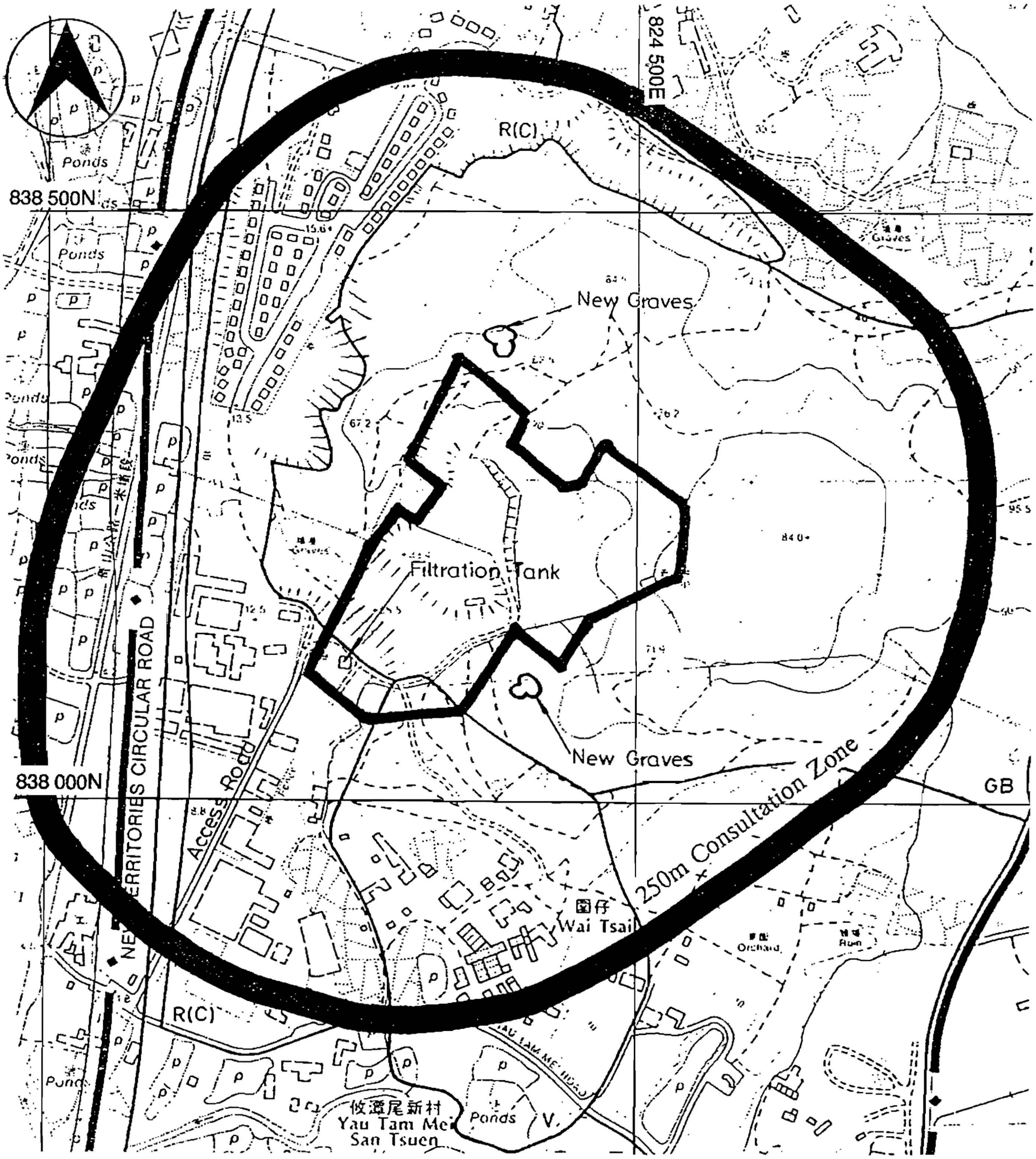
7.7 The preferred afteruse for NTML is a baseball field with associated building facilities which are mainly located near the lower end of the landfill on opposite sides of the access road, as shown on Figure 7.2. It is proposed that a baseball diamond with spectator seating is provided on the top platform, parking for cars and coaches on the middle platform, and buildings on the lower level areas, which are partly outside of the landfill area. Similar to SLSL and MTLL, the restoration work is proposed to commence in 1996, and would be completed in approximately 1 year. The broad design objectives for landscape design and afteruse are similar to those for PPVL, SLSL and MTLL. Specific criteria are as follows:

- all structures proposed for construction on the landfill should be designed to be effective against settlement and LFG accumulations;
- proposed buildings should be designed with specific gas control measures;
- development should avoid encroaching on any burial grounds as far as possible;
- visual impact of development on upper platform should be carefully considered;
- there is a need to undertake restoration planting;
- the planting mix proposed for the landfill should be in accordance with the recommended restoration option; and
- develop after-uses within the context of the Ngau Tam Mei Development Permission Area Plan (DPA/YL/YL-NTM/1) as zoned "Green Belt".

Planting Proposal

7.8 Planting of trees and shrubs at NTML should be carried out in order to accelerate vegetation establishment on site. The objectives for such planting would be to ensure long-term stability of the capping layer and to provide a spatial framework appropriate for the proposed afteruse. Planting requirements on this site can be broadly grouped into three categories as follows:

- afforestation of fill slopes;
- screen planting; and
- shade planting.



LEGEND :

Landfill boundary

Consultation zone boundary

Figure 7.1

Ngau Tam Mei Landfill

Landfill and Consultation Zone Boundary

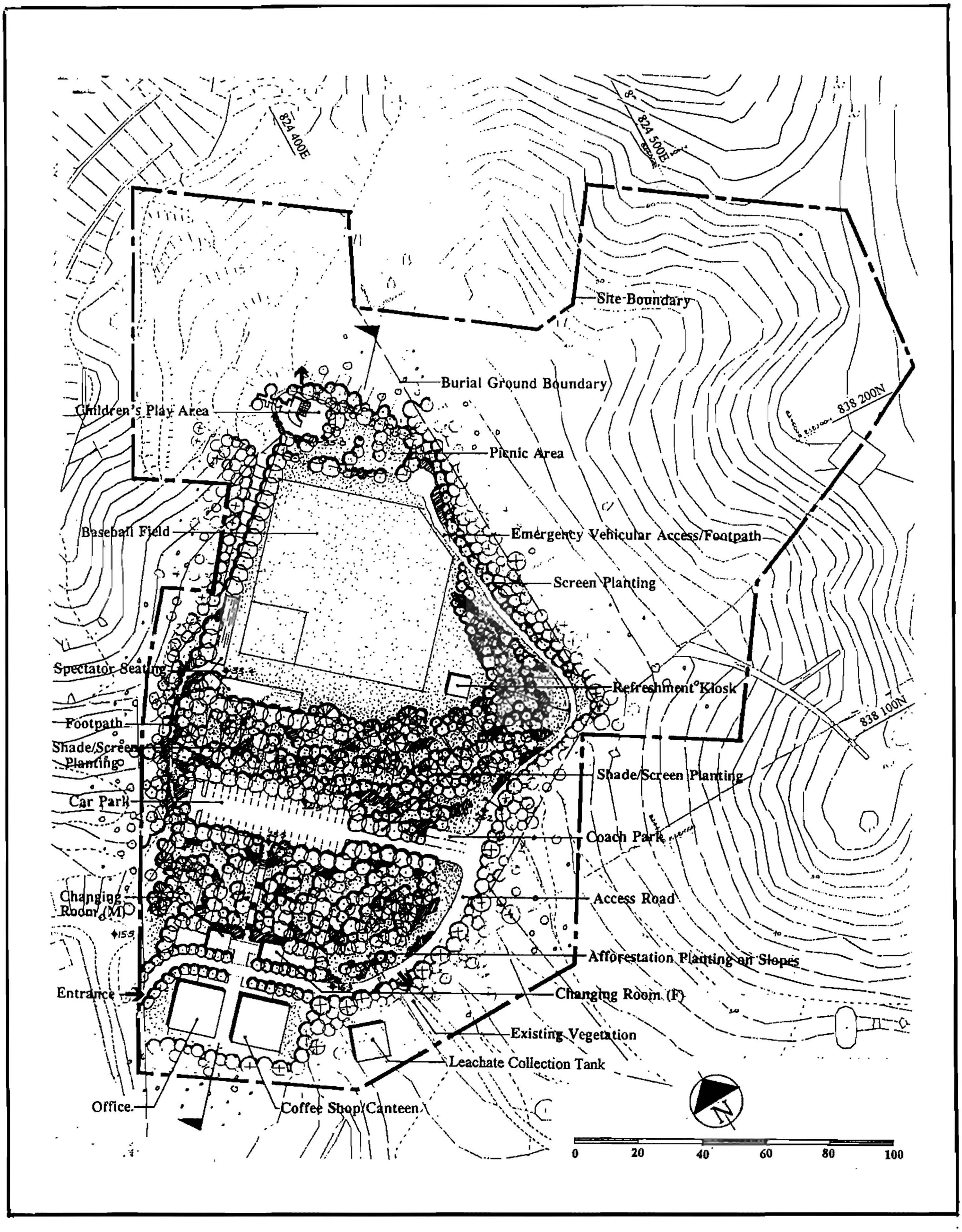


Figure 7.2
Ngau Tam Mei Landfill
Master Development Plan

Settlement and slope stability

7.9 Future settlement is predicted to be small as most settlement has already taken place. Structures proposed for the landfill should be lightweight and sufficiently flexible to compensate for the effects of limited differential settlement. Although there are no proposals to reconstruct the capping layer at NTML, for geotechnical requirements alone, some minor remedial works to repair some settlement related features may be necessary. To minimise future leachate production, enhancement of the existing capping layer as proposed for MTLL may be required. No deep rooted species of tree should be planted over the enhanced cap.

7.10 No instability features were observed during a site survey of the NTML site. The profiles of the conceptual restoration design follow in general the finished grades of NTML. Any regrading or capping enhancement should ensure that slopes have an adequate factor of safety.

Landfill gas management

7.11 The LFG management system for NTML relies on a combination of high permeability venting areas and low permeability barriers to prevent LFG from migrating towards sensitive receptors in particular to the south-western, southern and south-eastern boundaries. Venting zones should be located around the boundary (perimeter vent trench with gas vents), and within wastes (passive venting wells). The design of vent pipes should permit blending with landscape features without compromising their efficiency. No active LFG extraction facility either for flaring, or utilisation, is proposed for NTML. The capping layer (if required) should incorporate a granular layer to enhance the lateral migration of LFG toward the passive vents, thereby reducing positive gas pressure in the landfill.

7.12 Areas proposed for car parking on the middle platform should be constructed with appropriate under-venting to ensure controlled dissipation of any LFG through the capping layer. The vegetated area of the baseball diamond should be similarly protected against any vertical gas migration. The requirements for protection of buildings on the landfill will be the same as those described for PPVL and SLSL (Chapters 4 and 5).

Leachate management

7.13 A leachate interception drain should be installed around the toe of the landfill and extended along the site. The interception drain should be installed in the same area as the gas control membrane such that a dual purpose LFG and leachate barrier will be provided. This leachate collection system should collect all seepages around the toe of the landfill. Collected leachate should then be allowed to drain under gravity to a collection tank which is constructed underground and is adequately bunded. Other requirements for the tank are similar to those specified for SLSL (Chapter 5).

7.14 Leachate should be tankered for treatment and disposal at the same appropriate facilities as proposed for MTLL (Chapter 6). If a significant proportion of the leachate migrates to groundwater it will be necessary to reduce the leachate production by improving the capping layer as proposed for MTLL. The surface water leachate interception drain should still be installed.

Landfill Gas

7.15 This section describes the safety and environmental objectives of the restoration process with respect to LFG. An assessment of potential impacts from the construction phase and afteruse options has been conducted, and areas have been identified for further assessment.

Background conditions

7.16 LFG is monitored at the locations shown in Figure 7.3. Monitoring results are shown in Table 7.2. NTML is still currently generating LFG. The deep monitoring wells within the fill (DH401 and DH402) exhibit slight positive pressure, and a generally consistent gas composition. Shallow drive-in gas monitoring probes exhibit wider fluctuation in soil gas pressure and composition. Estimates of LFG yields in 1993 were as follows (Ref 7.2):

- LFG yield from cellulose content (1993): 160 cu m LFG/tonne dry weight;
- LFG yield from calorific value (1993): 150 cu m LFG/tonne dry weight; and
- LFG yield from Oxford University model (1993): 9 cu m LFG/hour (7 cu m LFG/tonne dry weight).

7.17 Predicted LFG yields are low and similar to those for MTLL. Peak LFG production was predicted to have occurred during 1975, after which an exponential decline in generation rates would have occurred.

7.18 The current actual rates of LFG generation and emission will vary depending on a range of environmental factors and waste type. As for MTLL and SLSL, there is some evidence of local inhibition of waste breakdown which implies a lower rate of LFG generation than predicted.

7.19 There is evidence for off-site occurrence of LFG, principally in the vicinity of DH408, DH411 and DP421. Oxygen depletion in other monitoring probes and drillholes may be indicative of limited LFG migration (and subsequent acidification) in these areas (DH405, DP421). Currently, it is considered that this migration does not pose a safety risk and there is no direct evidence that vegetation is being affected.

Impact of construction activities

7.20 There are no proposals to reconstruct the capping layer at NTML for geotechnical requirements alone, although minor remedial work may be required. However, enhancement of the existing capping layer to minimise future leachate production may be necessary. Such enhancement is unlikely to expose underlying refuse to any large degree. Construction of the baseball court and hardstanding would also reduce vertical gas emission and encourage lateral gas migration. The proposed LFG management system as described in WP6 (Ref 7.3) will intercept laterally migrating LFG around the sensitive SE and SW boundary, and gas vents around the remaining less sensitive boundaries will intercept much of the LFG migrating in this direction. Retro-drilling of gas vents within the fill following completion of capping will encourage on-site venting of LFG and thereby reduce the potential for off-site gas migration.

Mitigation Measures

7.21 Proposals for mitigation of environmental impact of LFG during restoration of SLSL and MTLL are equally applicable to NTML, and should be applied as appropriate to NTML.

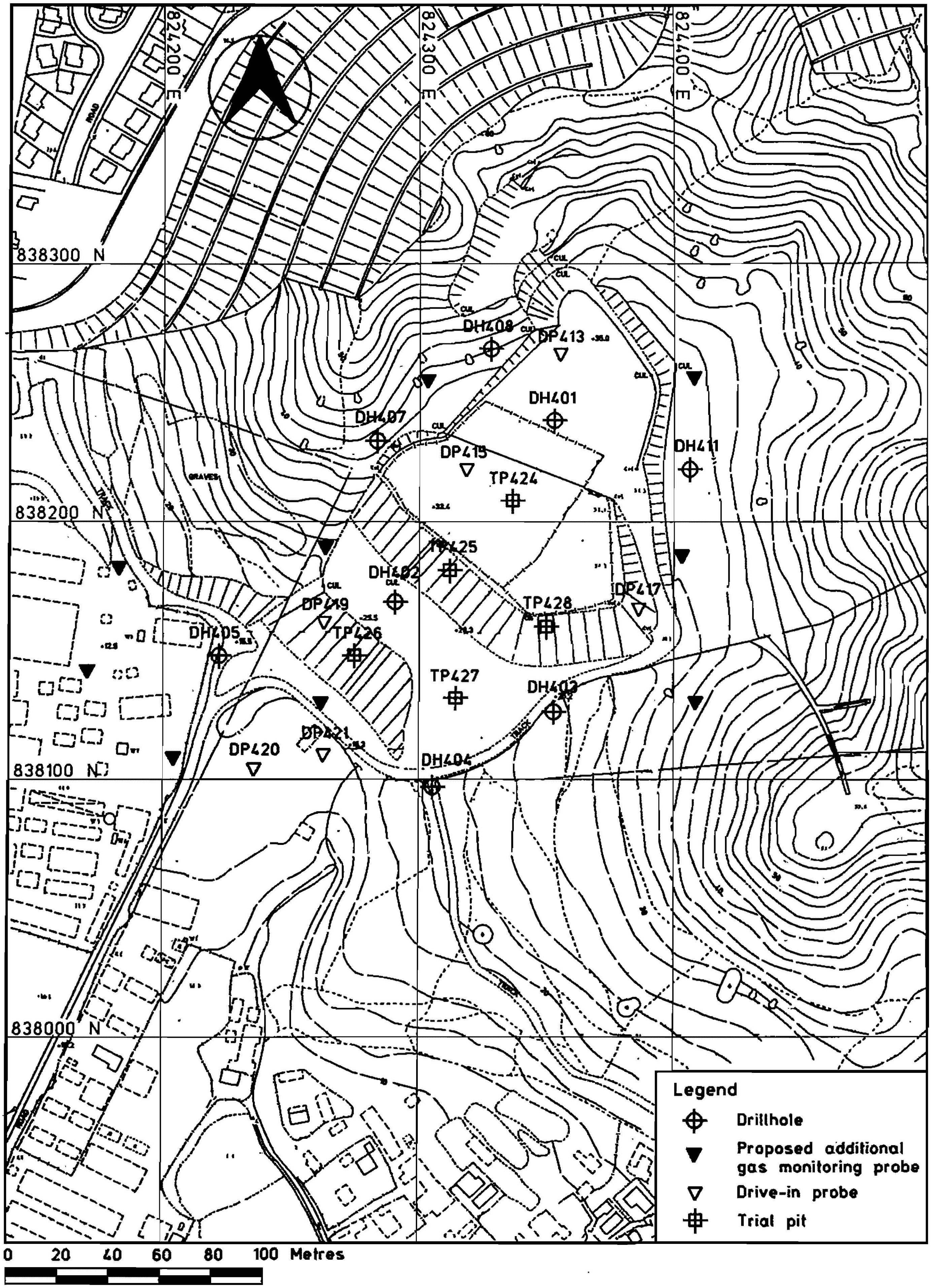


Figure 7.3

Ngau Tam Mei Landfill

Sampling Locations for landfill Gas Monitoring

Table 7.2: NTML - GAS MONITORING RESULTS (Sheet 1 of 2)

LOCN+	DATE	APRE	DPRE	%CH4	%LEL	%O2	%CO2	%H2	%CO	%N2	COM
DH401	18-Jun-93	1008.4		62	1.4	<1	20				
	23-Jun-93	1005	22	54	24	2.5	26				
	1-Jul-93	1008.6	12	67.8	>100	0	24.6				
	1-Jul-93	1008.6		54		5.4	18	<0.05	<0.1	23	Lab/A
	16-Jul-93	1007.9		51	20	2					
	20-Jul-93	1004.5		61		2.7	25	<0.05	<0.1	11	Lab
	28-Jul-93	1002.6	15.5	59.5	2.5	0.8	28.5				
	23-Sep-93	1009.2	33	68.6	0	0	26.1				
	29-Oct-93	1019.9	37	64.6	0	0.08	27.3				
	12-Nov-93	1014.7	48	62.7	0	0.6	28.1				
DH402	23-Jun-93	1005	35.5	46	1.5	<1	35				
	1-Jul-93	1008.6	25	59.9	>100	0	32.9				
	1-Jul-93	1008.6		56		3.3	20	<0.05	<0.1	16	Lab/A
	16-Jul-93	1007.9		49	2	<0.5					
	20-Jul-93	1004.5		64		1.1	29	<0.05	<0.1	5.4	Lab
	28-Jul-93	1002.6	37.5	58.3	0	0	32.9				
	23-Sep-93	1009.2	57	61.1	0	0	34.5				
	29-Oct-93	1019.9	203	59.9	0	0.06	32.9				
	12-Nov-93	1014.7	-15	59.5	2	0.9	37.1				
DP413	1-Jul-93	1008.6	0	30.5	>100	0.7	11.5				
	16-Jul-93	1007.9		37	30	2.5					
	28-Jul-93	1002.6	5.5	1.47	9	9	9.28				
	23-Sep-93	1009.2	-15	7.06	55	5	15.4				
	29-Oct-93	1019.9	3	3.18	27	5	11.9				
	12-Nov-93	1014.7	372	9.3	90	3.8	10.7				
DP415	1-Jul-93	1008.6	0	0.04	1	20.7	0.08				
	16-Jul-93	1007.9		0	1	20.5					
	28-Jul-93	1002.6	0.9	0.84	5	18.4	0.87				
	23-Sep-93	1009.2	0	38.5	22	2	17				
	29-Oct-93	1019.9	-2	0	0	13.7	6.5				
	12-Nov-93	1014.7	-150	0	7	19.4	0.71				
DP417	1-Jul-93	1008.6	-37	0.04	2	6.7	11.9				
	28-Jul-93	1002.6	0	0.04	2	11.3	9.9				
	23-Sep-93	1009.2	-54	0.13	1	5.5	12.6				
	29-Oct-93	1019.9	-87	0	0	13.7	6.5				
	12-Nov-93	1014.7	0	0	7	15.9	4.2				
DP419	1-Jul-93	1008.6	12	0.64	4.5	3.4	12.7				
	28-Jul-93	1002.6	0	12	70	1.5	16.6				
	23-Sep-93	1009.2	-1	1.83	11	1.1	16.6				
	29-Oct-93	1019.9	0	0.28	5	12.2	10.3				
	12-Nov-93	1014.7	-9	0	9	16	3.4				
DH405*	16-Jul-93	1007.9		0	0	13.5					Le H.
DH408*	16-Jul-93	1007.9		10	2	<0.5					Le H.

Table 7.2: NTML - GAS MONITORING RESULTS (Sheet 2 of 2)

LOCN+	DATE	APRE	DPRE	%CH4	%LEL	%O2	%CO2	%H2	%CO	%N2	COM
DH411*	16-Jul-93	1007.9		15	50	5					
DP420*	1-Jul-93	1008.6	25	0	1	20.4	0.08				
	28-Jul-93	1002.6	1	0	2	20	0.95				
	23-Sep-93	1009.2	-1	0	3	5.5	11.1				
	29-Oct-93	1019.9	81	0	2	18.8	0.35				
	12-Nov-93	1014.7	95	0	8	19.1	0.71				
DP421*	1-Jul-93	1008.6	0	0.32	2	20	0.39				
	28-Jul-93	1002.6	7	0.04	2	3.1	14.2				
	23-Sep-93	1009.2	26	6.64	2	2.5	10.7				
	29-Oct-93	1019.9	1114	0	0	7.4	9.4				Filled
	12-Nov-93	1014.7	12	0	6	7.3	5.63				Filled

* denote those holes located off-site
+ refer to A2.1 (Appendix 2) for abbreviations used

Impacts of LFG control measures

7.22 The impacts associated with LFG control measures relate to the construction phase include:

- the enhancement of existing capping layer (if required);
- the construction of gas venting trenches and passive gas vents within the fill;
- the drilling of additional monitoring boreholes.

7.23 LFG will be emitted from passive gas vents within the landfill and perimeter vent trench, which are of similar design to those proposed for MTLL. As for MTLL, predicted gas yields from NTML are too low for gas flaring to be a feasible option.

Impact on afteruse option

7.24 It is proposed in WP6 that the site will be used for baseball with associated spectator seating, car parking, changing rooms, office and shop, landscape planting, a picnic area and a children's play area. Areas proposed for car parking on the landfill should be constructed with appropriate under-venting to ensure controlled dissipation of any LFG which migrates through the capping layer, and should be constructed from flexible material to allow for settlement. The vegetated area of the baseball court should be similarly protected against any vertical gas migration. The requirements for buildings, other structures (such as spectator seating) and recreation areas are the same for similar structures at the other three sites.

7.25 The Housing Department has proposed residential development on adjacent land to the west of the site. Structures will certainly be located within 250 m of the landfill, and some structures may be within 20 m. The relative timings of the housing development and site restorations are not known with certainty, but it is possible that houses may be present, and occupied, during the restoration works. Measures described earlier in respect of SLSL and MTLL will assist in minimising the environmental impacts associated with redevelopment.

Air Quality

Introduction

7.26 This section details the assessment of impacts on air quality from emissions at Ngau Tam Mei Landfill site. Construction activities associated with the restoration of the landfill site are considered with reference to dust and VOC emissions. A predictive assessment is made of the impacts from venting of LFG on the site.

Ambient Monitoring

VOC Emissions

7.27 Background ambient air quality measurements made upwind and downwind of the landfill were analysed for the presence of the SACs. The results are given in Table 7.3. They indicate that ambient levels downwind of the landfill are higher than levels upwind for the compounds dichloromethane and 1,1,1-trichloroethane but not for benzene. This would indicate there is a possibility that dichloromethane and 1,1,1-trichloroethane are being emitted from the landfill. Other SACs have not been detected. However the interpretation of the monitoring results should be treated with caution as the sampling locations did not truly represent the downwind and upwind positions relative to NTML during the time of measurement.

Table 7.3 : Monitored Ambient VOC Levels at NTML

SAC	Method Detection Limit (µg/m³)	NTML (µg/m³)	
		uw**	dw**
Vinyl Chloride	0.36	ND	ND
Dichloromethane	0.73	0.8	1.3
Trichloromethane	0.73	ND	ND
1,1,1-Trichloroethane	0.76	0.8	4.0
1,2-Dichloroethane	0.61	ND	ND
Benzene	0.26	7.7	3.5
Tetrachloromethane	0.94	ND	ND
Trichloroethylene	0.91	ND	ND
1,2-Dibromoethane	0.92	ND	ND
Tetrachloroethylene	0.75	ND	ND

Notes

uw : upwind
dw : downwind
ND : Not detected, below the method detection limit
*** : uw and dw did not truly represent the downwind and upwind positions relative to NTML at the time of measurement.*

Methane

7.28 Table 7.4 shows the results of analysing the samples taken upwind and downwind of the landfill site for methane. The methane measurement downwind was approximately 4% lower than that taken upwind. This is well within the range of expected variation and it would be difficult to draw any conclusions from the measurements.

Table 7.4 : Monitored Methane at NTML

Pollutant	uw (µg/m³)	dw (µg/m³)
Methane	1758 (2.54)	1682 (2.43)

Notes

uw : upwind
dw : downwind
ug/m³ (ppm)

Assessment of Impacts of Dust Emissions

7.29 Sensitive receptors for NTML identified and considered in the study are given in Table 7.5

Table 7.5 : Sensitive Receptors and Locations

Landfill Site	Sensitive Receptor	Grid Reference
Ngau Tam Mei	• Existing Housing	824180E 838328N
	• Proposed New Housing	824216E 838140N
	• Intensive Farm	824226E 838052N

7.30 Chapter 4 details the modelling approach undertaken in the dust assessment study. The impact from combining the dust generated from a 0.0625 ha construction area situated on the boundary of the site with vehicles passing on unpaved roads at the site boundary at the closest receptor (proposed new housing ; 824216E 838140N) is:

Distance from site	= 24 m
TSP concentration from vehicles	= 220 $\mu g/m^3$
TSP concentration from construction site	= 625 $\mu g/m^3$
Total predicted TSP concentration	= 845 $\mu g/m^3$

7.31 It can be seen that the 500 $\mu g/m^3$ air quality guideline is exceeded. Therefore, mitigation measures are necessary. This mitigation may include dampening down the surface of the unpaved road and construction site. An effective watering programme (twice daily watering over the entire site) is estimated to be able to reduce emissions by up to 50% from ground surfaces. This should be able to reduce the total TSP concentration to about 420 $\mu g/m^3$ which is below the relevant air quality guideline level.

7.32 Covers and wind shields may be used at places where high emissions of dust are expected. On days when the wind direction is such that dust is blown towards the sensitive receptor and mitigating action is unable to reduce dust levels to a satisfactory level, it is possible that traffic may take a diversion and use a route further from the sensitive receptors. At times of particularly high levels it may be necessary to suspend construction activity.

7.33 The AQO that applies to TSP in Hong Kong restricts 24-hour average concentrations to below 260 $\mu g/m^3$. Using a factor of 0.4 to convert the 1-hour concentration to 24-hour concentration (when considering a 12 hour working day) and a 50% reduction due to mitigation measures listed above, a predicted TSP concentration of about 170 $\mu g/m^3$ is obtained, which is below the relevant air quality guideline level.

7.34 Several assumptions have had to be used due to a lack of relevant site specific data and accordingly the modelling approach could only provide a broad indication of the possible dust impacts. Despite the high values predicted, the Consultants are confident that subject to sensible mitigation measures, no significant dust impacts will occur.

Assessment of Impact from VOC Emissions

7.35 Landfill gas samples were obtained from drillholes DH402A and DH401B for GC/MS analysis. Benzene, vinyl chloride, dichloromethane and trichloroethylene were the SACs detected in the LFG samples. The average measured concentrations of these contaminants are given in Table 7.6:

Table 7.6 : SAC Concentrations in LFG at NTML

Pollutants	Concentration in LFG(mg/m^3)
Vinyl Chloride	0.2
Dichloromethane	0.35
Benzene	1.00
Trichloroethylene	0.45

7.36 VOC emissions were determined from the following:

- Oxford University Model was used to calculate the volume of landfill gas generated by the landfill;
- Concentrations of VOCs in landfill gas were derived from samples taken from two drillholes; and
- Gas assumed to vent equally from each of 34 vents.

7.37 Table 7.7 details the emission and modelling parameters used for predictive modelling of VOCs.

Table 7.7 : VOC Emission Levels and Modelling Parameters for NTML

Parameter	Input
Passive vent height	3 m
Gas temperature	30 °C (303 °K)
Assumed air temperature	25 °C (298 °K)
Gas volume	9 m^3/hr
Number of vents	34
Vent diameter	10 cm
Pollutant emission rates*	
Vinyl chloride	0.0148 µg/sec *
Dichloromethane	0.0.0257 µg/sec *
Benzene	0.074 µg/sec *
Trichloroethylene	0.03309 µg/sec *

Notes
Other Specified Air Contaminants were not detected in the landfill gas composition.
Meteorological assumptions are the same as those given in Chapter 4.
USEPA Model ISCST was employed.
VOC emission rates were derived from measured concentrations of landfill gas from drillholes
** the emission rates are per vent.*

7.38 The results from the modelling at NTML are presented in Table 7.8. The predicted concentrations at the Air Sensitive Receptors (ASRs) and maximum predicted concentration values of the SACs present in the landfill gas are given along with the calculated cancer risk associated with such a concentration. A conservation conversion faction of 0.3 was used to convert maximum annual 1-hour average concentrations to annual average concentrations in light of the limited data and the assumptions made in the modelling.

Table 7.8 : Predicted Concentration and Associated Risk from SACs at NTML

Receptor	Pollutant	Maximum Annual 1-Hour Concentration ($\mu g/m^3$)	Annual Risk
Max Value	Vinyl Chloride	0.00083	2.1×10^{-8}
824440E	Dichloromethane	0.00146	2.1×10^{-10}
838300N	Benzene	0.00416	1.1×10^{-8}
	Trichloroethylene	0.00187	2.1×10^{-10}
Sensitive Receptors	Vinyl Chloride	0.0006	1.5×10^{-8}
824226E	Dichloromethane	0.0009	1.3×10^{-10}
838052N	Benzene	0.003	7.5×10^{-9}
	Trichloroethylene	0.001	1.1×10^{-9}
824216E	Vinyl Chloride	0.0004	1.0×10^{-8}
838140N	Dichloromethane	0.0007	9.9×10^{-11}
	Benzene	0.002	5.0×10^{-9}
	Trichlorethylene	0.0009	9.9×10^{-10}
824180E	Vinyl Chloride	0.0004	1.0×10^{-9}
838328N	Dichloromethane	0.0007	9.9×10^{-11}
	Benzene	0.002	5.0×10^{-8}
	Trichloroethylene	0.0009	9.9×10^{-9}

7.39 Table 7.8 shows that the predicted concentration of dichloromethane and benzene are well below the measured ambient levels and the predicted concentration of trichloroethylene and vinyl chloride are well below the minimum detectable limit of the measuring method used. Other SACs not detected in the landfill gas from the boreholes are detected in the ambient air. This would suggest that the landfill site is not a significant contributor to ambient levels of SACs. The maximum predicted ground level concentrations for SACs are below the acceptable risk of 10^{-6}.

7.40 These results indicate that the restored NTML site will not be a significant contributor to ambient levels of VOCs. Nonetheless it is considered prudent to include requirements in the contract documents for the Contractor to carry out detailed environmental impact assessments. The contract Specification advised include environmental standards which could include risk-based guidelines on which the Contractor will have to achieve and verify in his design.

7.41 If high VOCs are detected it would be possible to install filters of activated carbon within the vent pipes to give an absorbent media for VOCs. However, this could reduce venting efficiency and hence efficiency of the landfill gas control, and extra venting arrangements may be necessary to improve the efficiency of the overall landfill gas control system so that lateral gas migration would not occur. It is considered that filtered passive vents, coupled with a regular sampling, testing and maintenance programme, could be used to effectively reduce the VOG's to acceptable levels.

7.42 Because the proposed LFG restoration works at NTML rely on passive venting with no flaring of gas, particular attention has been given to the assessment of odour. Samples of LFG from 2 holes drilled into waste at NTML were analysed for a large suite of odorous compounds. Table 7.9 lists the construction of those compounds detected above their odour threshold.

Table 7.9 : Trace Gases in LFG Exceeding Odour Limits for NTML

	402A	402AQ*	401B
butene (total)	2.0	1.1	ND
pentene (isomer)	1.5	0.9	0.7
dimethyl sulphide	0.06	0.08	ND
butan-2-one	2.3	2.1	0.1
n-octane	3.3	2.9	3.5
dimethyl disulphide	0.4	0.6	ND
toluene	100	68	0.5
n-nonane	20	16	16
n-decane	53	35	17
n-undecane	25	17	4.0
ethyl benzene	15	10	0.6
xylenes	37	23	2.5
limonene	680	370	ND
naphalene	8.2	5.4	0.08

Notes

* *Duplicate sample for QA purposes*
ND Not detected, below method detection limit

7.43 Table 7.10 gives the results from the modelling study for the fourteen compounds that exceeded the odour threshold in the analysed landfill gas. The results are given for ground level concentrations at the ASRs and at the point where the maximum concentration occurs. In every case the predicted concentrations are below the toxicity level OES/100. The predicted concentrations of the air contaminants would not cause any odour nuisance at the ASRs.

Table 7.10 : Predicted Concentrations at ASR from VOCs in the Landfill Gas

Pollutant	Maximum Concentra -tion at point of emission (mg m^{-3})	Maximum Value 824440E 838300N Concentra -tion (μgm^{-3})	ASR 824180E 838328N Concentra -tion (μgm^{-3})	ASR 824216E 838140N Concentra -tion (μgm^{-3})	ASR 824226E 838052N Concentra -tion (μgm^{-3})	OES/100 (8hrs) (μgm^{-3})
butene	2	0.0084	0.004	0.004	0.0059	
pentene	1.5	0.0063	0.003	0.003	0.0044	
dimehtyl sulphide	0.08	0.00033	0.00016	0.00016	0.00024	
butan-2-one	2.3	0.0096	0.0046	0.0046	0.0068	5900
n-octane	3.5	0.015	0.007	0.007	0.010	14500
dimethyl disulphide	0.6	0.0025	0.0012	0.0012	0.0018	
toluene	100	0.42	0.20	0.20	0.30	1880
n-nonane	20	0.084	0.04	0.04	0.059	
n-decane	53	0.22	0.11	0.11	0.16	
n-undane	25	0.10	0.051	0.051	0.074	
ethyl benzene	15	0.063	0.03	0.03	0.044	4350
xylenes	37	0.15	0.075	0.075	0.11	4350
limonene	680	2.8	1.4	1.4	2	
naphalene	8.2	0.034	0.017	0.017	0.024	500

Noise

Background noise levels and monitoring data

7.44 This site lies to the east of New Territories Circular Road, and road traffic noise is therefore present. Also, typical rural noises are present.

7.45 Background noise monitoring has been conducted at NTML, measurements being made in hourly periods during the day between 07:00 hours and 19:00 hours from 30 November to 2 December 1993. Summarised results and the monitoring locations as well as the identified present noise sensitive receivers are given in Table 7.11 and Figure 7.4 respectively. The full results are reproduced in Appendix 3.

7.46 Three baseline noise monitoring locations were used around NTML. NTML-1 was at the centre of a vacant site designated for residential development, where noise from road traffic on the New Territories Circular Road was dominant. NTML-3, situated near residential premises to the north-west of the site, was also exposed to noise from New Territories Circular Road, although additional noise from a local source was reported here. The results at these locations are consistent with a semi-rural setting.

7.47 NTML-2 was situated to the south of the site and farther from New Territories Circular Road than the other monitoring positions. The noise levels recorded were therefore lower, the only source noted being a dog barking.

Impacts of Construction Activities

7.48 Similar to the case of SLSL, very limited earth moving activities associated with the construction of the final cap and leachate and LFG facilities will be carried out at NTML, such that construction noise would be insignificant. If however there is any construction to be taken place close to the noise sensitive receivers as indicated in Figure 7.4, the noise mitigation measures described for MTLL should equally be applied here.

Table 7.11: Summarised Baseline Noise Monitoring Results for NTML

Monitoring Location		Major Noise Sources	Average Noise Level dB(A)		
			L_{10}	L_{90}	L_{eq}
NTML-1	Centre of vacant construction site due to be developed for residential use	1) Traffic on New Territories Circular Road 2) Dog barking	63.2	55.2	60.3
NTML-2	Above facade on roof of residential building	1) Dog barking	49.1	43.9	48.0
NTML-3	Facade of residential building	1) Traffic on New Territories Circular Road 2) Activities at neighbouring house	58.1	52.2	56.3

Impacts of Afteruse Option

7.49 Currently there are few noise sensitive receptors in the vicinity of the site and transient increases in noise levels due to baseball activity are unlikely to be a problem. However, this situation should be reviewed if there are any significant changes in land use in the vicinity of the site at the time of the afteruse development. In any case it is considered prudent to adopt similar noise attenuation measures as mentioned for MTLL.

Water Quality

Existing groundwater and surface water quality

7.50 The piezometric water levels suggest a steep hydraulic gradient from north-east to south-west. At the lower end of the landfill there is an unsaturated zone of 8 m between the base of the landfill, at 15 mPD, and groundwater at 7 mPD. The unsaturated zone may be less elsewhere beneath the site. This implies that the underlying strata are relatively permeable to a significant depth.

7.51 The results of the analyses for groundwater and surface water are given in Table A4.4 of Appendix 4 and the monitoring locations are shown in Figure 7.5. They show that none of the groundwater samples from outside the site (i.e. DH403, DH404, DH405, DH407 and DH408) show any evidence of contamination by leachate. Dissolved solids levels are moderate and all the waters are acidic and contain high concentrations of dissolved iron and manganese. Table 7.12 shows that the levels of heavy metals in local groundwater mainly exceed the standards quoted.

7.52 Although groundwater in drillholes around the site perimeter shows no evidence of leachate contamination, it is possible that leachate may have moved vertically beneath the wastes and then westwards, missing the drillholes installed for this study. A groundwater sample from beneath the wastes (i.e. DH402) did show evidence of leachate contamination and also evidence of stratification of groundwater quality (Ref 7.4).

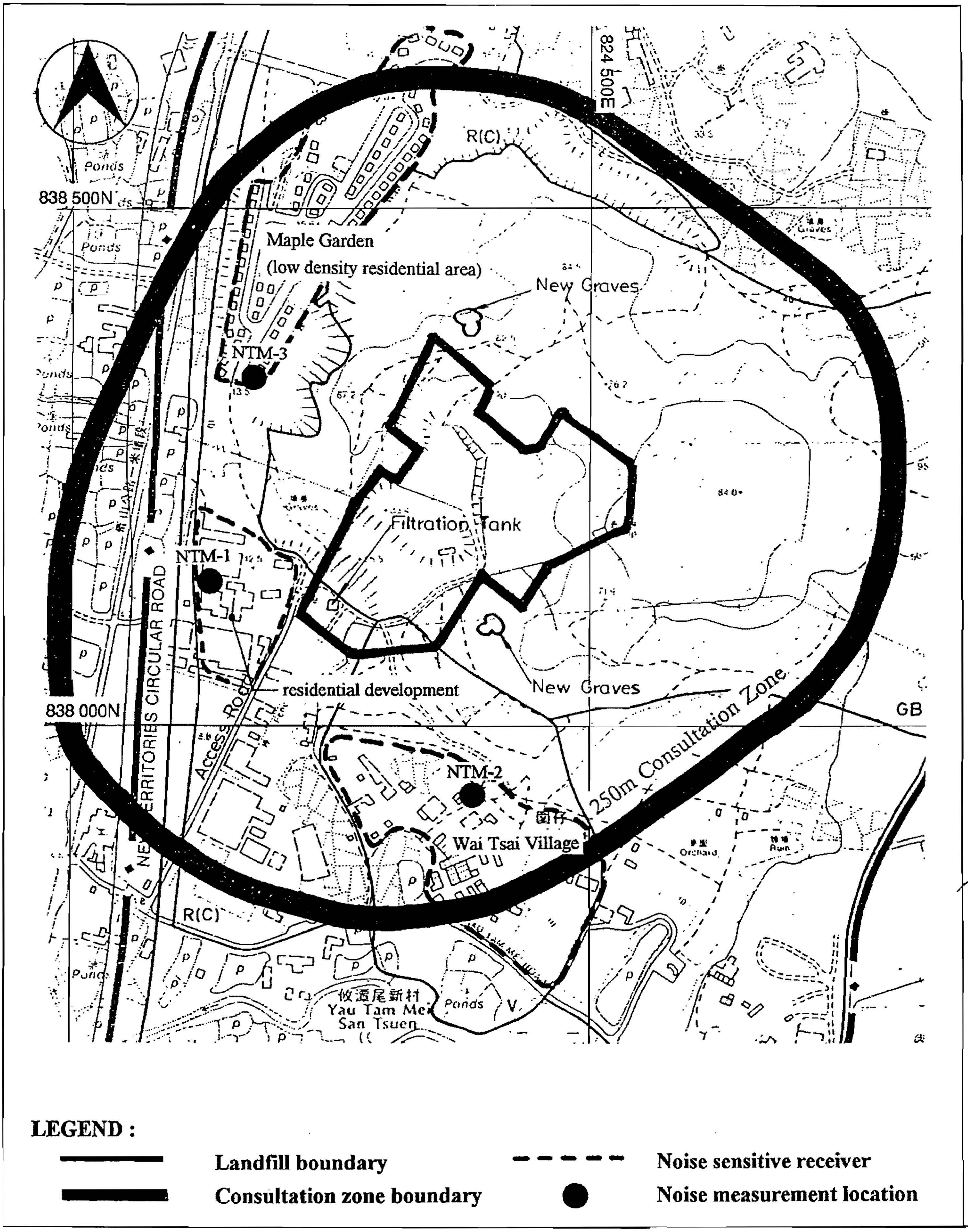


Figure 7.4

Ngau Tam Mei Landfill

Sampling Locations for Noise Measurement

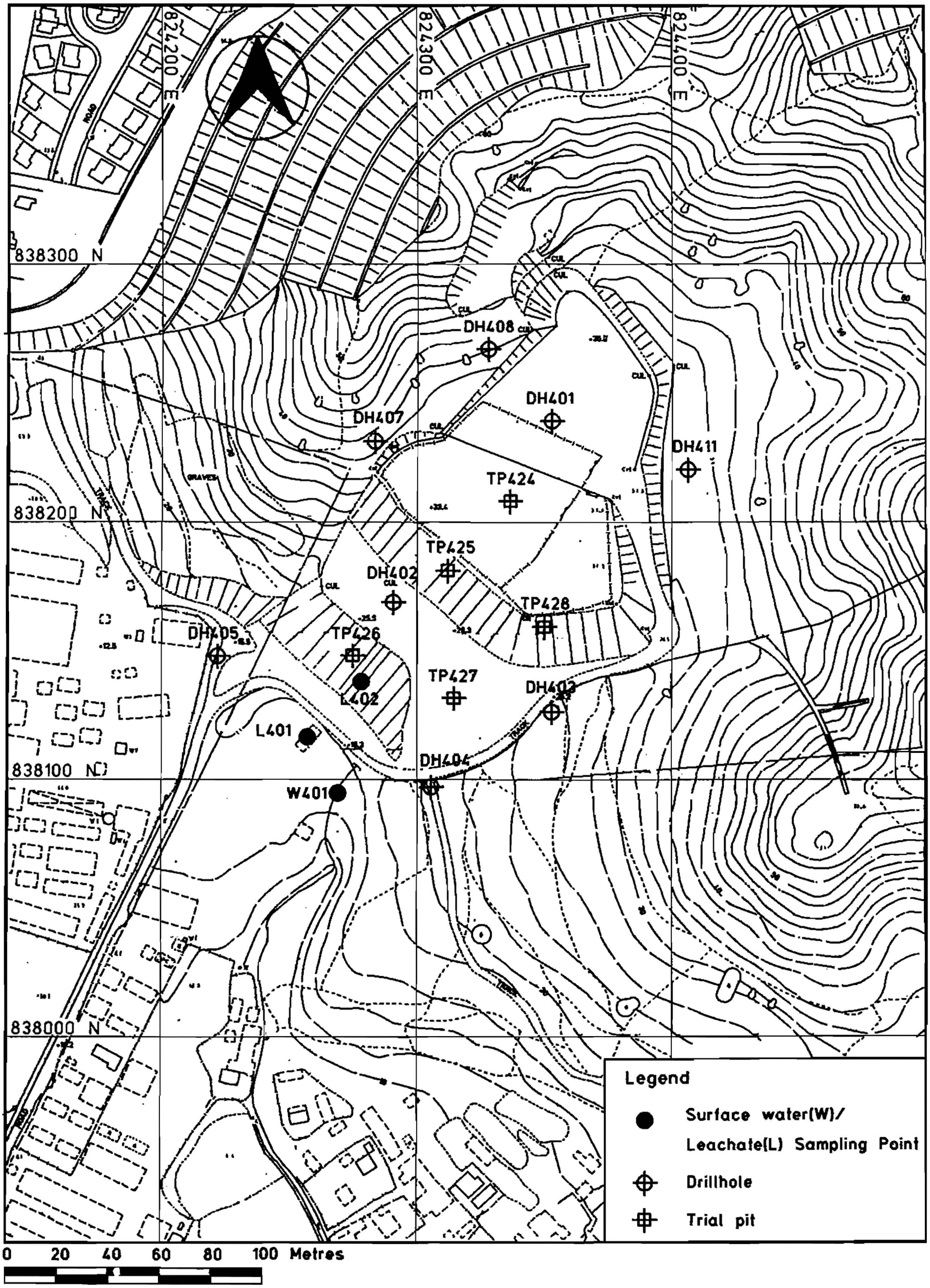


Figure 7.5

Ngau Tam Mei Landfill

Sampling Locations for Leachate, Groundwater and Surface Water Monitoring

Table 7.12 : Analysis of Groundwater and Surface Water at NTML

Determinand *	Standards for Groundwater ***			Water Source ****	
	ST1 Dutch Grade C	ST2 Dutch VPR	ST3 WHO	Surface water	Ground-water
pH (pH units)			6.5-8.5	7.4-8.5	(4.5-6.6)
EC (uS/cm)				130-21000	147-2800
Cadmium	0.01	0.006	0.005	<0.02	(<0.02-0.03)
Chromium	0.2	0.026	0.05	<0.1	(<0.1-0.1)
Copper	0.2	0.035	1	<0.1	(<0.1-0.4)
Lead	0.2	0.05	0.05	<0.1	(<0.1-1.1)
Nickel	0.2	0.04		<0.1	<0.1
Zinc	0.8	1	5	0.03	0.04-0.48
Manganese			0.1	(0.9)	(1.8-140)
Iron			0.3	(0.9)	(6-29)
Sodium			200	52	(5-550)
Potassium				32	2.6-22
Hardness (as CaCO3)			500	130	61-160
Sulphate			400	24	<10-72
Sulphide	0.3				<0.1
Phosphorous				0.4	<0.1
Nitrate			10	(18)	<0.01-1.9
Ammonia Nitrogen				77	<0.1-31
Kjeldahl Nitrogen					<0.1-32
Total Organic Carbon				16	<0.1-25
Chloride			250	75	(6.6-1100)
COD				75	<7-300
BOD				16	<5-7.8
E. coli (no./100ml) **			0		(0-50)

Note:

* All units in mg/l except where noted

** The Standard for drinking water (WHO) refers to Faecal Coliform

*** The standards for groundwater and drinking water being refered to are as follows:

ST1 Dutch Criteria for Category C Clean Up Investigations (Ref 7.5)

ST2 New Dutch Second Generation VPR Criteria (Ref 7.6)

ST3 WHO Guidelines for Drinking Water (Ref 7.7)

**** Data enclosed in brackets indicate the exceedance of the standards quoted

7.53 The details for the analyses of surface seeps and off-site leachate are shown in Table A4.4 of Appendix 4. The quality of the leachate is highly variable by the time it reaches the course of the stream draining to the south-east (i.e. W401), and is probably dependent on the amount of surface run-off available for dilution. Water sampled at W401 remains moderately contaminated in comparison to clean surface water as indicated in Table 7.12. No flow rates could be taken as the flows were too small for measurement during the periods on site. The leachate head above the lower site perimeter is about 4 m and is smaller than at other landfills in this study. Without a leachate collection system, the net flow of leachate to surface waters may be relatively small. There is no evidence that this small and periodic flow of surface water is being locally used.

7.54 L401 and L402 were sampled at the filtration tank and at a concrete drainage channel at the foot of the lower slope of the landfill. These two samples show gross contamination by leachate. L401 is approximately half the strength of the leachate within the wastes. The perched seepage (L402) showed evidence of nitrification probably as a result of passing through aerated soil or across a vegetated surface.

Leachate quantity and quality

7.55 In view of the absence of a base liner or of a proper leachate collection system, the low head of leachate (i.e. 4 - 8 m of leachate at DH402) is consistent with leakage to groundwater. Given that NTML is a small landfill (2.05 ha) which has been virtually capped and vegetated, the present leachate discharge flows have been estimated in WP3 as follows:

peak:	27.4 cu m/day
average:	13.7 cu m/day

7.56 The leachate in the drillholes (DH401 and DH402) is methanogenic, with neutral pH, low COD, low BOD/COD ratio and low NO_x-N concentrations. The leachate has significant concentrations of heavy metals, notably Pb, Cr and Zn. The NH_3-N concentration is still very high, even after 18 years since closure and this may have been the cause of inhibited degradation of wastes. A large amount of degradable matter remains, and the present rate of biological activity is thought to be small. The site still has the potential to generate additional quantities of gas and leachate.

7.57 In addition to a zone of leachate saturation, perched leachate exists within the wastes at a higher level. Some leachate leaves the site and enters a small stream, either via a leachate collection drain and filtration tank, or via uncontrolled seeps, including perched leachate which enters surface water drains. The quality of the leachate seeps to the stream and surface water drains are referred to in Sections 7.51 and 7.52.

7.58 Treatment of the leachate will be needed before it can be properly disposed of as the levels of COD, iron, chromium and total nitrogen exceed the Government standards for effluents discharged into foul sewer (Table 7.13). Similarly, leachate quantity fails to meet the standards for direct discharge to surface water of Group D (inland waters) (Table A1.6 of Appendix 1). Therefore, it is recommended that leachate should be tankered away for treatment and disposal at an appropriate facility elsewhere.

Impacts of construction activities

7.59 Similar to the case of MTLL, leachate disposal arrangements should be in place before leachate interception works the enhancement of the existing capping layer are undertaken, as these are and likely to lead to a temporarily increased release rate of leachate. Mitigation for controlling the leachate seepages and sediment loads in runoff during the construction phase should be adopted as proposed at the other landfills.

Table 7.13 : Analysis of Leachate from NTML

Determinand*	TM on Effluent Standards** TM1 >10 and <=100	Landfill Site *** NTML
pH (pH units)	6-10	7.4-8.2
Temperature (°C)	43	26.4-29.7
Suspended solids	1000	
Settleable solids	100	
BOD	1000	73-450
COD	2500	(360-3900)
Oil & Grease	100	
Iron	25	(16-140)
Boron	7	
Barium	7	
Mercury	0.15	
Cadmium	0.15	<0.02
Copper	4	0.2-0.6
Nickel	3	0.1-0.3
Chromium	2	(1.6-4.5)
Zinc	5	1-3.2
Silver	3	
Cyanide	2	
Phenols	1	
Sulphide	10	4-4.8
Sulphate	1000	<10
Total nitrogen	200	(560-4800)
Total phosphorus	50	0.9-8
Surfactants (total)	150	

Note:
* All units in mg/l except where noted
** Standards for flow rates (cu m/day) expressed as upper limits (Ref 7.8)
*** Data enclosed in brackets indicate the exceedance of standards

Impacts of leachate control measures

7.60 It is likely that the enhancement of the existing capping layer to minimise future leachate production would also reduce the risk of groundwater contamination, and thereby save on the annual costs of leachate treatment. Leachate interception and holding of leachate in the containment tank would substantially reduce the uncontrolled seepage of the leachate into surface water, thereby resulting in an improved local water quality. As the leachate tank will be underground and adequately bunded to contain any leakage or spillage, no significant visual and odour impact of leachate collected in the holding tank is anticipated.

Impacts of afteruse option

7.61 The proposed low intensity land use for NTML as a baseball field with associated facilities would not involve any significant impact in the adjacent water bodies. Only the buildings and facilities concentrated to the south-east of NTML involve a high number of patronage where proper sewage facilities would be provided. In all cases, site reprofiling may require the incorporation of appropriate interception and surface drainage measures to collect sewage and contaminated surface water, shed rainfall and reduce rainfall infiltration.

Landscape, Afteruse and Visual Impact

7.62 NTML was formed in a small valley surrounded by low hills on three sides. The site is in an early stage of natural regeneration, and is covered with small shrubs, tree seedlings, groundcovers and climbers. The surrounding hills, where there is a mix of wooded area and open grassland, contribute much to the visual quality and landscape value of the site.

7.63 A proposed baseball field would occupy the larger top platform, with most support facilities located at or near the toe of the lower slopes. The associated buildings are one-storey high and small in size. There would be provision for gas venting in all enclosed structures. Floating foundations to accommodate future settlement would be used where necessary for structures that are located on the landfill, which include a refreshment kiosk and spectator seating. Very minor filling around the base of the bottom slopes would be required to create flat areas for the buildings, as well as to improve the gradient of the access road.

7.64 Physical changes to this site due to afteruse development would not be noticeable from the outside. There would be glimpses of the low buildings clustered at the bottom of the slopes. There would be tree planting on the fill slopes and around the proposed activity areas. Grass would cover the entire top platform, interspersed with shade and screen planting of trees and shrubs.

7.65 The internal view of the site would be significantly changed from an unattended natural wasteland into a managed sports ground. All the fill slopes would have a thick cover of trees and shrubs, forming an extension of the natural area around the site.

Settlement

Existing conditions

7.66 Uncontrolled dumping of wastes occurred prior to 1973 after which the site was operated as a sanitary landfill from December 1973 to March 1975 during which period about 180,000 cu m of wastes were deposited at NTML. The remaining settlement has been estimated as 0.4% of the total waste thickness which assumed an existing exponentially decay rate of 0.1% per year. Settlement features may have been present on the site, but were not noticeable on areas where the 1-metre thick cap was inspected. Although some settlement-related cracking was observed for the drainage channels, the rigid concrete structures appeared to be in a reasonable condition.

Impacts of construction activities

7.67 The general impacts of construction activities for settlement at NTML are similar to those described earlier for PPVL, SLSL and MTLL. Specific objectives for minimizing the impacts are:

- the use of flexible paving material for the surfacing of the footpaths.
- the design of surface water management systems to minimise maintenance by being flexible to accommodate differential settlement.
- the use of lightweight structures, where the foundation design of the structure should be able to accommodate the effects of differential settlement.

7.68 Structures proposed for the landfill should be lightweight and sufficiently flexible to compensate for the effects of limited differential settlement. The maintenance works for repairing defects due to settlement would then be reduced.

Impacts of afteruse

7.69 The preferred afteruse for NTML is a baseball field with associated building facilities which are largely placed on the flat area at the base of, and beyond, the landfill area. The proposed on-site afteruse focuses on low intensity land use with a low proportion of the site area to accommodate building structures. Future settlement is predicted to be small which is therefore not considered to be of significance with respect to the activities proposed.

High Tension Power Line

7.70 There is no high tension power line located either within the landfill site or close to the site boundary.

Conclusions and Recommendations

7.71 The recommended afteruse for NTML is a baseball field with associated building facilities including spectator seating, parking area and support buildings. The broad design objectives for landscape design and afteruse are similar to those of the other landfill sites and will result in a compatible landuse with the surrounding environs.

7.72 Settlement is not envisaged to be a significant problem in the restoration of the landfill site, as most settlement has already taken place. However, all building structures should be lightweight and sufficiently flexible to cope with limited differential settlement, and paving and drainage systems should be constructed of suitably flexible materials. Existing slopes are considered to be in a stable condition and no future problems are envisaged provided slope regrading does not result in slopes in excess of 1(V): 4 (H) gradient.

7.73 LFG management should include high permeability venting areas and low permeability barriers along the southern, south-western and south-eastern boundaries towards sensitive receptors. Parking areas and the baseball diamond should be suitably protected to prevent vertical gas migration and site buildings should incorporate protection and alarm systems as for PPVL and SLSL. There is no recommendation to upgrade the capping layer as present, although this should be reviewed in the event of LFG migration or excessive leachate generation.

7.74 Predicted LFG yields are low and do not warrant any LFG extraction or utilisation. There is some evidence of off-site LFG migration, but it is considered that this does not presently represent a safety risk. As there are currently no proposals to reconstruct the capping layer, there should be no significant release of LFG as a result of earthmoving activities during the construction phase. The proposed LFG control system and protection measures will ensure that LFG migration presents no safety risk during the afteruse phase of the site. In the event of residential development to the west of the site, building protection measures are recommended.

7.75 In order to reduce dust impacts it is advisable to minimise the operational areas during restoration. The assessment of TSP impacts shows predicted levels below the AQOs if mitigation measures are strictly applied. Predictive assessment of landfill gas dispersion indicates that following restoration works, odour thresholds will not be exceeded. The results from the VOC assessment indicates that the restored site will not be a significant contributor to ambient levels of VOC.

7.76 The noise environment at NTML is typical of a semi-rural settings, with some influence from traffic on New Territories Circular Road. As no significant earthmoving activities are required for restoration, associated noise impacts should be minimal and within acceptable limits. In the event of construction in close vicinity to identified sensitive receivers, suitable mitigation measures, as for MTLL, should be implemented. With the implementation of noise control measures, noise impacts will not be of significance at NTML.

7.77 Although there is only limited evidence for groundwater contamination outside the landfill site, it is recognised that leachate flow outside the site boundary may be present due to the absence of a liner or proper leachate collection system. The quality of leachate is such that treatment is recommended prior to disposal, and leachate interception and holding is recommended prior to transportation for treatment elsewhere. No significant water quality impacts are associated with the afteruse of NTML, although suitable drainage measures should be incorporated into the design to segregate clean and contaminated waters.

7.78 It is concluded that physical changes for the restoration of the site would not be visible from the outside, although the internal view would be significantly changed from an unattended natural wasteland into a managed sports ground. However, the site could be fully integrated into the surrounding landscape by the provision of suitable vegetation on the surrounding fill slopes.

7.79 Details are provided in Chapter 9 and Appendix 5 on recommended monitoring with respect to the key environmental parameters of concern. This monitoring programme will provide the basis for the establishment of baseline conditions prior to restoration and provide the necessary data to ensure suitable mitigation measures are implemented in the event of unacceptable impacts being detected.

References

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7.3 Scott Wilson Kirkpatrick, December 1993, Restoration of North-West new Territories Landfills - Working Paper WP6 Conceptual Restoration Design. Environmental Protection Department, Hong Kong.

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7.5 Leidraed Bodemsanering af 1.4, November 1988, Dutch Criteria Index for Assessing Soil and Groundwater Contamination.

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7.7 World Health Organisation, 1984. Guideline for Drinking Water.

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8. ECOLOGY

Introduction

8.1 When the brief for the current consultancy agreement was finalised in 1992, there was no provision in the Brief to carry out an ecological impact assessment on the proposed landfill restoration works.

8.2 More recently there has been a growing concern in the community on the ecological impacts of development projects, and the Consultants have been asked to comment on the ecological impacts of the proposed restoration works. The following observations are intended simply to put the restoration proposals in an ecological context and to make a preliminary comment on the ecological significance of the restoration proposals.

Pillar Point Valley Landfill

8.3 At present, the landfill has no ecological value as it is operational, and no particular flora and fauna are established. It is therefore considered that any restoration will be ecologically beneficial.

Siu Lang Shui Landfill

8.4 Some restoration works have already been undertaken (ie tree seedlings planted in 1987 are now well established). Restoration proposals are that established vegetation should be protected as far as possible. Any disturbance will be minimal and limited to the site boundary area (except for reinstatement of existing gas vents if necessary).

8.5 The only area where significant earthworks will take place (ie disturbance to vegetation) is along the southern boundary adjacent to Lung Mun Road. Limited site clearance to enable leachate/groundwater interception and construction of a holding tank is anticipated. Although no detailed ecological survey has been carried out in this study, it is considered that in this area the vegetation cover is less well developed with common species of no particular ecological value. It is worth noting that we have observed a very large number of butterfly of a single species (thought to be *Euploea core*, Common Crow Butterfly) in the woodland at the north and north-east platforms in December 1993 and November 1994. However neither earthworks nor restoration works will take place in these areas. It is therefore considered that the proposed landfill restoration causes no undesirable ecological impact.

Ma Tso Lung Landfill

8.6 No restoration has been undertaken at this small landfill since its closure in 1979. The two platforms are now barren and partly occupied by a crude compost manufacturing facility. The surrounding slopes are covered with patches of recolonised wild shrubs and grasses that are common species of no particular ecological value. Therefore, the proposed landfill restoration causes no undesirable ecological impact and some ecological benefit would result following the completion of restoration.

Ngau Tam Mei Landfill

8.7 No planting programme has been carried out upon landfill closure, although the site itself has developed a sparse cover of self-seeded vegetation since its closure in 1976. Similar to SLSL, restoration proposals are that established vegetation should be protected as far as possible during restoration. Any disturbance will be minimal and limited to the site boundary area (ie installation of gas vents and leachate/groundwater interception drains). Therefore neither earthworks nor restoration works will cause any significant ecological impact.

Ecological Impact Assessment - Summary

8.8 In the Consultants view, the overall ecological impact due to the proposed landfill restoration works at the four landfill sites is regarded as insignificant. The construction of the restoration works is of a short-term and transitory nature and will result in minimal disturbance to the existing vegetation. However a detailed ecological impact assessment would be beneficial as part of the afteruse contract under the Dual Contracts Option. The afteruse developer/contractor would be in a better position, relative to the restoration contractor, having knowledge and direction from Government on the recreational needs of the community, to evaluate the residual impacts of the restoration works and the ecological impacts potentially caused by the afteruse development and operation. Therefore, it is recommended that a detailed ecological impact assessment be undertaken by the afteruse contractor.

9. ENVIRONMENTAL MONITORING AND AUDIT REQUIREMENTS

General Introduction

9.1 Monitoring will be required throughout the different stages of the restoration programme for each of the landfill sites in this study as follows:

Design Monitoring

- immediate additional investigations and monitoring to be carried out over the next twelve months following the monitoring undertaken for the consultancy study in order to obtain data for detailed design of LFG and leachate control measures;

Baseline Monitoring

- regular monitoring to determine the ambient environmental level of a parameter (e.g. noise) prior to development in order to assess the magnitude of predicted impacts as a result of the restoration and afteruse of the landfill sites. Baseline monitoring also permits the determination of environmental performance criteria for the restoration and afteruse of the sites;

Construction Monitoring

- additional environmental monitoring during construction to detect any unacceptable impacts according to legislative standards, appropriate guidelines and established environmental performance criteria;

Post-restoration Audit Monitoring

- Long-term monitoring during the afteruse phase of each of the landfills to determine whether the landfilled areas are continuing to comply with environmental and safety objectives established and whether any deterioration in the integrity of the restoration work is taking place in order that remedial action may be taken.

9.2 Monitoring requirements for each monitoring phase are given for each landfill in Appendix 5. All analytical suites that are referred to in the monitoring requirements can be found in Appendix 6. Monitoring protocols for the measurement of specified parameters are given in Appendix 7.

Monitoring and Audit Requirements

9.3 The contractor(s) responsible for the restoration and subsequent afteruse of each of the landfill sites should also be ultimately responsible for monitoring the environmental performance related to the construction and operation of the restored sites. Where considered necessary, the contractor(s) should also be responsible for further collection of additional baseline monitoring data. In all cases it is recommended that the monitoring work be conducted at the expense of the contractor(s) by an independent body who are subject to a periodic independent audit of monitoring and reporting procedures.

9.4 Auditing of monitoring results will be required to ensure that the restoration and operation of the sites and their related afteruses comply with environmental standards and guidelines, and performance criteria, as specified in the restoration contract. The roles of monitoring and auditing are distinct, and responsibilities should therefore be clearly established.

9.5 The environmental monitoring programme should have the following characteristics:

(i) It must provide continuity of environmental management throughout the baseline, construction and post-restoration monitoring phases of the developments.

(ii) It should provide high quality information which can be utilised via a feedback loop to assess compliance with legislative standards, appropriate guidelines and performance criteria.

(iii) It should be conducted by an independent body, such as an analytical laboratory, which is paid for, and is the responsibility of, the contractor. The contractor should ensure that sampling, analytical and reporting procedures are consistent with HOKLAS or NAMAS accreditation standards, and are appropriate in scope and detail (as approved by EPD).

9.6 In addition to the environmental monitoring role, which should be the ultimate responsibility of the site contractor, there is a need for an independent audit of the contractor's environmental performance. The key requirements of the auditing role are as follows:

(i) It should be independent of the site contractor(s) and associated monitoring body.

(ii) It should provide regular and independent reports on the standard of performance of the restoration and/or afteruse contractor(s), and forward these to the contractor as well as to EPD.

(iii) The cost of the auditing role should be met by the site contractor(s) on terms established by Government and set out in the tender document.

9.7 The tender document for the design, construction and operation of the afteruses of the sites should include a specification and programme for the environmental monitoring and audit role. It is important that the tenderer demonstrates adequate provision and time for the collection of sufficient baseline data prior to the commencement of restoration in the tender submission. Details of monitoring regimes and monitoring and audit responsibilities should be set out in a site operations manual prepared by the successful tenderer(s). Nonetheless, an addition monitoring programme is being carried out; the results of which will be made available to the tenderers.

9.8 The role of the independent auditor should be as follows:

(i) To establish the degree of compliance of each facility with legislative standards, appropriate guidelines and environmental performance criteria. To establish from the baseline monitoring the Trigger, Action and Target limits, as appropriate, for compliance monitoring.

(ii) To review changes in measured parameters to detect any deterioration in environmental conditions associated with the construction and operation of the facilities.

(iii) To review management practices critical to the environmental integrity of each site and to recommend Action plans for increased frequency of monitoring, implementation of remedial measures and control of works when Trigger, Action and Target limits are exceeded.

(iv) To recommend improvements to the management practices and specify mitigation measures to reduce adverse environmental impacts to acceptable levels.

(v) To conduct review meetings with the site contractor(s) and EPD representatives to consider environmental performance and to provide feedback into the afteruse facilities environmental performance. This should happen on a regular (e.g. fortnightly) basis during the construction with a provision for more regular meetings should a particular environmental problem arise (e.g. exceedance of dust air quality objective).

9.9 Audits should be conducted on a regular and frequent basis during site construction by an independent consultant. An initial audit should be undertaken to review the monitoring programmes for the baseline, construction and post-restoration phases to ensure that

- sampling, analytical and reporting procedures are consistent with HOKLAS or NAMAS accreditation standards, and are appropriate in scope and detail (as approved by EPD).

9.10 A further audit should be conducted at the end of the routine monitoring period to establish Trigger and Action limits for specified environmental parameters, and also Target limits where these are not governed by specified legislative standards. This audit should also result in the formulation of agreed Action Plans for the increased frequency of monitoring, implementation of remedial measures and control of works in the event of Trigger, Action and Target limits being exceeded.

9.11 Audits during the construction phase should be conducted every three months, and be supplemented by regular meetings, to ensure compliance with relevant Trigger, Target and Action limits and implementation of Action Plans, where appropriate. Further audits should be conducted after the third month following completion of restoration and normal operation of the afteruse and six monthly thereafter. Auditing frequency and scope may be reduced after fifteen months depending on the findings of the initial audits, but should not be conducted on less than an annual basis.

10. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Pillar Point Valley Landfill

10.1 The recommended afteruse for PPVL is afforestation of the slopes with associated hiking trails and viewing areas. This option is considered to be compatible with the Tuen Mun OZP. It is considered that the existing topography of the site provides suitable opportunities for the siting of the LFG extraction plant and leachate treatment facility without the need for extensive earthworks.

10.2 The restoration of PPVL involves the emplacement of a capping layer, planting and installation of structures associated with leachate treatment and LFG control. It is recommended that the capping layer for PPVL should contain final intermediate cover, protection layer, geomembrane, geodrain and soil layers of which a minimum of 1,000 mm cdv or cdg should be placed on top of the cap for planting purposes.

10.3 It is recommended that no heavy structure be built directly on areas where waste has been deposited, and foundation designs of throughways and light structures should be able to accommodate differential settlement rates. Stability should be enhanced by the compaction of the cdv or cdg material, and slope gradients should be generally not greater than 1(V):4(H) to ensure an adequate factor of safety. Correct use of flexible surface drainage over the landfills will enable surface runoff to be effectively removed and will minimise disruption of the proposed afteruse.

10.4 Predictions of LFG yield at PPVL for a 10 year period (1993-2003) range from 23 $x10^6$ cu m to 80 $x10^6$ cu m LFG/year. The composition of LFG is typical of a methanogenic landfill and the gas is under positive pressure with some evidence of off-site migration. LFG management at PPVL should encompass LFG extraction and perimeter migration control, and this will require the emplacement of suitable plant and protection measures. It is recommended that off-site buildings to the south of the landfill should be protected against the possibility of LFG migration by the installation of suitable gas detection alarms.

10.5 It is concluded that, by the use of suitable mitigation measures, release of LFG during construction can be minimized. During operation, LFG would be released from passive vent trenches, if used as interim control measures, but with sufficient monitoring and displacement from sensitive receivers migration risks are considered minimal.

10.6 The LFG extraction system should be active, with LFG extraction wells being drilled retrospectively at an appropriate grid spacing to optimize LFG yield. A separate perimeter system will be required, should the bitumen coating on the sides of the landfill be inappropriate at preventing LFG migration, with wells installed at an appropriate distance. With the emplacement of the capping layer and installation of the LFG extraction system, there will be no significant impacts of LFG on the proposed afteruse of the site. However, it is recommended that on-site buildings should have adequate protection measures and that public activities on-site associated with ground disturbance or fire should be prohibited.

10.7 It is recommended that LFG should be utilised to provide, in the least, on-site energy requirements, with possible direct off-site use of LFG for industrial purposes representing the most energy efficient option. The utilisation of LFG is also recognised of being of considerable environmental benefit when compared to its release to atmosphere. It is recommended that the LFG extraction and utilisation schemes be managed by a single contractor and that facilities are located at the base of the site to ensure appropriate collection of LFG condensate.

10.8 It is recommended that the leachate treatment facility be shared with SLSL. The conceptual design is based on a combination of aerobic and anoxic biological processes. The system should permit expansion to accommodate future increases in flow of leachate from the landfill sites. If PPVL is to remain open beyond 1997, it is recommended that construction of the plant should proceed in advance of the main restoration contract to meet interim operational demands for leachate treatment. It is concluded that the emplacement of a low permeability capping layer will reduce the overall leachate treatment costs by lowering rainwater ingress and hence leachate generation.

10.9 An assessment of current air quality and potential impacts associated with the afteruse development of the landfill was undertaken. With respect to the restoration phase, it is recommended that, to ensure TSP criteria are not exceeded dust mitigation measures be strictly applied to ensure the air quality criteria are complied with at nearby sensitive receivers. Predicted emissions from flaring activity associated with the LFG extraction plant at PPVL are low, and AQOs for TSP, SO_2, NO_2 and CO are not likely to be exceeded at sensitive receivers nearby. The predicted levels of HCl and HF are significantly below the OES/100 guideline at the sensitive receiver. It is recommended that the restoration contractor be required to carry out an assessment on the possible impact of carcinogens emitted from the flare, before their flare design be accepted.

10.10 An assessment of current noise quality and potential impacts associated with the afteruse development of the landfill was undertaken. It is concluded that, with the implementation of suitable mitigation measures, the restoration phase and installation of LFG and leachate control measures should not result in the target level of 75 dB (A) at sensitive receivers being exceeded. However, during the afteruse phase when the LFG and leachate control installations are operational additional mitigation measures, such as the use of screening or quiet plant, will be necessary to ensure compliance with relevant noise criteria. It is not considered that any part of the afteruse site would be sensitive to noise arising from such installations.

10.11 Marine water quality in the vicinity of PPVL largely complies with the WQOs for the North Western WCZ, although elevated nutrient levels occur. Elevated concentrations of heavy metals are present in marine sediments and are such that if any dredging works were required in the area special disposal methods would be required. There is limited evidence for groundwater contamination with leachate, although surface water is believed to be affected by leachate seepage.

10.12 Peak leachate discharge rates have been estimated at between 686 and 977 cu m/day, with an average of between 343 and 489 cu m/day. The quality of leachate entering the PPSTW is of an unacceptable quality according to Technical Memorandum Standards. It is recommended that remedial works to prevent surface flows of perched leachate within the wastes be undertaken as soon as possible.

10.13 During the construction phase it is recommended that increased surface runoff should be controlled to prevent surface erosion. This could be effectively achieved by hydroseeding, slope regrading and installation of surface water drains as restoration proceeds. The leachate control measures and treatment plant will result in a significant overall benefit in terms of reducing the overall volume of leachate generated and achieving a suitable quality standard. The afteruse option and associated tree planting will have no significant water quality impacts, as long as suitable drainage and shallow rooting tree species are provided.

10.14 It is concluded that there would be little adverse visual effect caused by the proposed restoration of PPVL, and because of the density of tree cover proposed the engineered slopes would not be readily visible. Overall the visual quality of the site would be greatly improved.

10.15 It is concluded that high tension powerlines will not represent any significant risk at PPVL as no major structure will be built in the vicinity of overhead lines and clearance requirements will not be infringed.

10.16 Details are provided in Chapter 9 and Appendix 5 on recommended monitoring with respect to the key environmental parameters of concern. This monitoring programme will provide the basis for the establishment of baseline conditions prior to restoration and provide the necessary data to ensure suitable mitigation measures are implemented in the event of unacceptable impacts being detected.

Siu Lang Shui Landfill

10.17 The recommended afteruse for SLSL is a go-kart circuit with support facilities, with the specific objective of retaining as much as possible of the existing vegetation and causing minimal disturbance to the existing landform. No leachate treatment facility or LFG extraction plant are proposed for SLSL.

10.18 It is recommended that the afteruse development is located toward the bottom of the existing landfill slopes, with replanting conducted so as to replace removal of existing trees and to enhance the remaining vegetation.

10.19 Settlement issues are not regarded as being of major significance, as future settlement is expected to be minor and no heavy structures associated with the afteruse are envisaged. A new cap should be placed near the southern end of the eastern landfill boundary where shear features occur. The capping design is similar to PPVL, but contains a granular layer to assist in the dispersion of LFG. Similarly, slope requirements are as for PPVL, where slopes in general should have a gradient of not more than 1(V) to (4 (H), to ensure an adequate factor of safety. It is recommended that flexible paving and surface water management systems be used to prevent damage due to restoration following restoration.

10.20 Peak LFG generation rates were predicted to have occurred in 1983, reaching 285 cu m/day although inhibition of waste degradation may be resulted in lower rates. The composition of LFG at SLSL is similar to that at PPVL and is indicative of a methanogenic landfill. LFG control is of particular importance at the southern boundary, where installation of a passive vent trench and membrane barrier, with appropriately spaced vent pipes is recommended. This should be extended around the periphery of the site if tests to be carried out at PPVL indicate it is necessary. In addition, appropriate LFG protection measures should be installed to on-site buildings.

10.21 Impacts of LFG during construction are expected to be minimal, as only a restricted area of earthmoving will be required over waste deposits. Following the completion of restoration, gas vents will be reinstated and integrated with the granular layer of the new capping layer. Where vent stacks are required it is recommended that they should be fitted with flame arrestors, and subject to regular inspection and maintenance. Buildings developed within the 250 m consultation zone are not considered to be subject to any significant risk from LFG migration with the installation of an appropriate LFG perimeter control system.

10.22 It is concluded that a joint leachate treatment facility for SLSL and PPVL would represent the most cost effective option. To resolve the problem of surface water contamination by leachate on-site a number of remedial measures have been recommended including improved interception and leachate holding facilities.

10.23 Operational areas during restoration are likely to be small, thereby reducing the potential incidence of significant dust impacts. The assessment of TSP impacts shows predicted levels below the AQOs if mitigation measures are strictly applied. Predictive assessment of landfill gas dispersion indicates that following restoration works, odour thresholds will not be exceeded. The results from the VOC assessment indicate that the restored site will not be significant contributor to ambient levels of VOC.

10.24 It can be concluded from noise monitoring carried out for this study that the dominant noise source in the area emanates from the power station and from road traffic. As there are no noise sensitive receivers in the vicinity of the site, transient increases in noise levels due to construction activity are unlikely to be a problem. In order to reduce noise impacts associated with the go-kart track, it is recommended that on-site buildings be located in less sensitive areas and vegetation screening be used where possible.

10.25 Marine water and sediment quality data for PPVL also apply to SLSL and the same conclusions can be drawn (see Section 4.122). Groundwater is known to be contaminated from leachate, via soakaway pits or liner leakage. Surface water quality is similarly affected. Leachate has also been found to be of an unacceptable quality for direct discharge to sewer. The situation is unlikely to improve until leachate and contaminated groundwater are intercepted and directed to the proposed leachate treatment facility at PPVL. It is

- recommended that measures are implemented during the construction stage to prevent excessive discharge of sediment loads, and appropriate surface drainage is installed as part of the restoration works to ensure the segregation of clean and contaminated waters

10.26 In visual impact terms it is concluded that the restoration will be of minor significance, except that the go-kart circuit would involve the enlargement of a central flat area . Although the quiet nature of the site would be changed by the go-kart circuit, this is not out of context of the industrial development envisaged in the future.

10.27 Health hazards associated with proximity to high tension power lines at SLSL are considered to be slightly greater than for PPVL, as facilities are generally closer. However, exposure of the public will be of a transient nature, and no building or structure will be constructed within the minimum distance requirements.

10.28 Details are provided in Chapter 9 and Appendix 5 on recommended monitoring with respect to the key environmental parameters of concern. This monitoring programme will provide the basis for the establishment of baseline conditions prior to restoration and provide the necessary data to ensure suitable mitigation measures are implemented in the event of unacceptable impacts being detected.

Ma Tso Lung Landfill

10.29 The preferred afteruse for MTLL is a holiday camp combined with a wide range of outdoor sports and recreational uses which will use the slopes and platforms of the landfill. Planting should be carried out to compliment the rural surroundings of the site and to enhance the local landscape.

10.30 The small degree of settlement predicted at MTLL is not expected to be significant in relation to the activities and developments proposed on-site. However control measures, as specified for PPVL and SLSL, are recommended including the use of flexible paving materials and surface water drainage systems. Heavy building structures, such as dormitories and the function hall, should be placed outside waste deposited areas where possible.

10.31 It is not considered that MTLL requires an active LFG extraction system. A combination of high permeability venting areas and low permeability barriers to prevent LFG migrating towards sensitive receivers, will provide adequate protection. Venting zones should be located around the boundary and should incorporate a granular layer underneath the capping layer which is connected to the peripheral system.

10.32 LFG at MTLL is typical of that of a methanogenic landfill, and is at positive pressure although not as great as PPVL and SLSL. Whilst LFG measurements in soil gas are generally stable, there is some evidence of lateral migration. With the implementation of good management practice, impacts associated with construction and the LFG control measures are not considered to be significant. During the afteruse phase, buildings on-site and those located within the 250m consultation zone should be provided with adequate gas protection and detection measures.

10.34 In order to reduce dust impacts it is advisable to minimise the operational areas during restoration. The assessment of TSP impacts shows predicted levels below the AQOs if mitigation measures are strictly applied. Predictive assessment of landfill gas dispersion indicates that following restoration works, odour thresholds will not be exceeded. The results from the VOC assessment indicates that the restored site will not be a significant contributor to ambient levels of VOC.

10.35 Background noise in the vicinity is currently dominated by a sawmill to the south-east, animals and nearby construction works, but otherwise noise levels were typical of a semi-rural location. Given the scale of construction work required and the current paucity of sensitive receivers in the vicinity, significant noise impacts are not envisaged. Similarly, during the afteruse phase noise levels associated with the holiday camp are likely to be acceptable, although some mitigation measures to protect on-site buildings may be required.

10.36 Groundwater shows limited evidence of contamination, although a stream to the north-east is seriously contaminated by leachate as a result of leachate seepage. Surface seepages at the base of a retaining wall on the south side of the sports field are likely a result of leachate that has soaked into the ground. The present peak discharge for the 2 ha site of 19.2 - 30.3 cu m/day is not considered to be of an acceptable quality for discharge to sewer. It is recommended that engineering works be undertaken to regrade and recap the landfill to minimise leachate generation, to intercept seepages and to re-instate the present leachate collection system. The collected leachate should then be transported to an appropriate treatment facility. It is recommended that the leachate holding tank be relocated to a lower elevation, below ground level, and bunded to prevent spillage or leakage. Appropriate drainage and sewerage facilities should be designed for the afteruse phase to ensure appropriate segregation and disposal of contaminated wastewaters.

10.37 It is concluded that following regrading, recapping and planting there would be a great improvement in the visual quality of the site, and facilities would be blended within the landscape in order to be unobtrusive.

10.38 Given the separation distance of facilities from the high tension power lines on-site and the relatively limited exposure time of people located on-site, no significant problems associated with exposure to electromagnetic radiation are envisaged. No building or structure proposed as part of the afteruse development will infringe upon the minimum distance requirements for high tension powerlines.

10.39 Details are provided in Chapter 9 and Appendix 5 on recommended monitoring with respect to the key environmental parameters of concern. This monitoring programme will provide the basis for the establishment of baseline conditions prior to restoration and provide the necessary data to ensure suitable mitigation measures are implemented in the event of unacceptable impacts being detected.

Ngau Tam Mei Landfill

10.40 The recommended afteruse for NTML is a baseball field with associated building facilities including spectator seating, parking area and support buildings. The broad design objectives for landscape design and afteruse are similar to those of the other landfill sites and will result in a compatible landuse with the surrounding environs.

10.41 Settlement is not envisaged to be a significant problem in the restoration of the landfill site, as most settlement has already taken place. However, all building structures should be lightweight and sufficiently flexible to cope with limited differential settlement, and paving and drainage systems should be constructed of suitably flexible materials. Existing slopes are considered to be in a stable condition and no future problems are envisaged provided slope regrading does not result in slopes in excess of 1(V): 4 (H) gradient.

10.42 LFG management should include high permeability venting areas and low permeability barriers along the southern, south-western and south-eastern boundaries towards sensitive receptors. Parking areas and the baseball diamond should be suitably protected to prevent vertical gas migration and site buildings should incorporate protection and alarm systems as for PPVL and SLSL. There is no recommendation to upgrade the capping layer as present, although this should be reviewed in the event of LFG migration or excessive leachate generation.

10.43 Predicted LFG yields are low and do not warrant any LFG extraction or utilisation. There is some evidence of off-site LFG migration , but it is considered that this does not presently represent a safety risk. As there are currently no proposals to reconstruct the capping layer, there should be no significant release of LFG as a result of earthmoving activities during the construction phase. The proposed LFG control system and protection measures will ensure that LFG migration presents no safety risk during the afteruse phase of the site. In the event of residential development to the west of the site, building protection measures are recommended.

10.44 In order to reduce dust impacts it is advisable to minimise the operational areas during restoration. The assessment of TSP impacts shows predicted levels below the AQOs if mitigation measures are strictly applied. Predictive assessment of landfill gas dispersion indicates that following restoration works, odour thresholds will not be exceeded. The results from the VOC assessment indicates that the restored site will not be a significant contributor to ambient levels of VOC.

10.45 The noise environment at NTML is typical of a semi-rural setting , with some influence from traffic on New Territories Circular Road. As no significant earthmoving activities are required for restoration, associated noise impacts should be minimal and within acceptable limits. In the event of construction in close vicinity to identified sensitive receivers, suitable mitigation measures, as for MTLL, should be implemented. With the implementation of noise control measures, as for MTLL, noise impacts will not be of significance at NTML.

10.46 Although there is only limited evidence for groundwater contamination outside the landfill site, it is recognised that leachate flow outside the site boundary may be present due to the absence of a liner or proper leachate collection system. The quality of leachate is such that treatment is recommended prior to disposal, and leachate interception and holding is recommended prior to transportation for treatment elsewhere. No significant water quality impacts are associated with the afteruse of NTML, although suitable drainage measures should be incorporated into the design to segregate clean and contaminated waters.

10.47 It is concluded that physical changes for the restoration of the site would not be visible from the outside, although the internal view would be significantly changed from an unattended natural wasteland into a managed sports ground. However, the site could be fully integrated in to the surrounding landscape by the provision of suitable vegetation on the surrounding fill slopes.

10.48 Details are provided in Chapter 9 and Appendix 5 on recommended monitoring with respect to the key environmental parameters of concern. This monitoring programme will provide the basis for the establishment of baseline conditions prior to restoration and provide the necessary data to ensure suitable mitigation measures are implemented in the event of unacceptable impacts being detected.

APPENDIX 1

WATER QUALITY OBJECTIVE AND EFFLUENT DISCHARGE QUALITY CRITERIA

- Table A1.1 — Selection of Water Quality Objectives for North Western Marine Waters
- Table A1.2 — Selection of Water Quality Objectives for Marine Waters Deep Bay
- Table A1.3 — Standards for Effluent Discharged into Foul Sewer Leading Into Government Sewage Treatment Plants
- Table A1.4 — Standard for Effluent Discharged into the Inshore Waters of Southern, Mins Bay, Junk Bay, North Western, Eastern Buffer and Western Buffer Water Control Zones
- Table A1.5 — Standards for Effluents Discharged into Group C Inland Waters
- Table A1.6 — Standards for Effluents Discharged into Group B Inland Waters

APPENDIX 1: Water Quality Objective and Effluent Discharge Quality Criteria

Table A1.1 Selection of Water Quality Objectives for North Western Marine Waters

Water Quality Parameters		Objective	Part(s) of zone
E coli	-	annual geometric mean not to exceed 610/100 mL	secondary contact recreation subzones
D.O. within 2 m of bottom	-	not less than 2 mg/L for 90% samples	marine waters
Depth average D.O.	-	not less than 4mg/L for 90% samples	marine waters
pH value	-	to be in the range 6.5 - 8.5, change due to waste discharge not to exceed 0.2	marine waters except bathing beach subzones
Salinity	-	change due to waste discharge not to exceed 10% of natural ambient level	whole zone
Temperature change	-	change due to waste discharge not to exceed 2°C	whole zone
Suspended solids	-	waste discharge not to rise the natural ambient level by 30% nor cause the accumulation of suspended solids which may adversely affect aquatic communities	marine waters
Toxicants	-	not to be present at levels producing significant toxic effect	whole zone
Unionized ammonia	-	annual mean not to exceed 0.021 mg/L	whole zone
Nutrients	-	not to be present in quantities that cause excessive algal growth	marine waters
	-	annual mean depth average inorganic nitrogen not to exceed 0.5 mg/L	marine waters except Castle Peak subzone

Table A1.2 Selection of Water Quality Objectives for Marine Waters Deep Bay

Water Quality Parameters		Objective	Part(s) of zone
E coli	-	annual geometric mean not to exceed 610/100 mL	secondary contact recreation subzones
D.O. within 2 m of bottom	-	not less than 2 mg/L for 90% samples	outer marine subzone except mariculture subzone
Depth average D.O.	-	not less than 4 mg/L for 90% samples	outer marine subzone except mariculture subzone
D.O. at 1 m below surface	-	not less than 4 mg/L for 90% samples	inner marine subzone except mariculture subzone
	-	not less than 5mg/L for 90% samples	mariculture subzone
pH value	-	to be in the range 6.5 - 8.5, change due to waste discharge not to exceed 0.2	whole zone except bathing beach subzone
Salinity	-	change due to waste discharge not to exceed 10% of natural ambient level	whole zone
Temperature change	-	change due to waste discharge not to exceed 2°C	whole zone
Suspended solids	-	waste discharge not to raise the natural ambient level by 30% nor cause the accumulation of suspended solids which may adversely affect aquatic communities	marine waters
Toxicants	-	not to be present at levels producing significant toxic effect	whole zone
Unionised ammonia	-	annual mean not to exceed 0.021 mg/L	whole zone
Nutrients	-	not to be present in quantities that cause excessive algal growth	marine waters
	-	annual mean depth average inorganic nitrogen not to exceed 0.7 mg/L	inner marine subzone
	-	annual mean depth average inorganic nitrogen not to exceed 0.5 mg/L	outer marine subzone

Table A1.3 Standards for effluents discharged into <u>foul sewers leading into Government sewage treatment plants</u>
(All units in mg/L unless otherwise stated; all figures are upper limits unless otherwise indicated)

Determinand / Flow rate (m^3/day)	≤10	>10 and ≤100	>100 and ≤200	>200 and ≤400	>400 and ≤600	>600 and ≤800	>800 and ≤1000	>1000 and ≤1500	>1500 and ≤2000	>2000 and ≤3000	>3000 and ≤4000	>4000 and ≤5000	>5000 and ≤6000
pH (pH units)	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10
Temperature (°C)	43	43	43	43	43	43	43	43	43	43	43	43	43
Suspended solids	1200	1000	900	800	800	800	800	800	800	800	800	800	800
Settleable solids	100	100	100	100	100	100	100	100	100	100	100	100	100
BOD	1200	1000	900	800	800	800	800	800	800	800	800	800	800
COD	3000	2500	2200	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Oil & Grease	100	100	50	50	50	40	30	20	20	20	20	20	20
Iron	30	25	25	25	15	12.5	10	7.5	5	3.5	2.5	2	1.5
Boron	8	7	6	5	4	3	2.4	1.6	1.2	0.8	0.6	0.5	0.4
Barium	8	7	6	5	4	3	2.4	1.6	1.2	0.8	0.6	0.5	0.4
Mercury	0.2	0.15	0.1	0.1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cadmium	0.2	0.15	0.1	0.1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Copper	4	4	4	3	1.5	1.5	1	1	1	1	1	1	1
Nickel	4	3	3	2	1.5	1	1	0.8	0.7	0.7	0.6	0.6	0.6
Chromium	2	2	2	2	1	0.7	0.6	0.4	0.3	0.2	0.1	0.1	0.1
Zinc	5	5	4	3	1.5	1.5	1	0.8	0.7	0.7	0.6	0.6	0.6
Silver	4	3	3	2	1.5	1.5	1	0.8	0.7	0.7	0.6	0.6	0.6
Other toxic metals individually	2.5	2.2	2	1.5	1	0.7	0.6	0.4	0.3	0.2	0.15	0.12	0.1
Total toxic metals	10	10	8	7	3	2	2	1.6	1.4	1.2	1.2	1.2	1
Cyanide	2	2	2	1	0.7	0.5	0.4	0.27	0.2	0.13	0.1	0.08	0.06
Phenols	1	1	1	1	0.7	0.5	0.4	0.27	0.2	0.13	0.1	0.1	0.1
Sulphide	10	10	10	10	5	5	4	2	2	2	1	1	1
Sulphate	1000	1000	1000	1000	1000	1000	1000	900	800	600	600	600	600
Total nitrogen	200	200	200	200	200	200	200	100	100	100	100	100	100
Total phosphorus	50	50	50	50	50	50	50	25	25	25	25	25	25
Surfactants (total)	200	150	50	40	30	25	25	25	25	25	25	25	25

Table A1.4 Standards for effluents discharged into the <u>inshore waters of Southern, Mirs Bay, Junk Bay, North Western, Eastern Buffer and Western Buffer Water Control Zones</u>
(All units in mg/L unless otherwise stated; all figures are upper limits unless otherwise indicated)

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

Table A1.5 Standards for effluents discharged into Group C inland waters

(All units in mg/L unless otherwise stated; all figures are upper limits unless otherwise indicated)

Determinand \ Flow rate (m^3/day)	≤100	>100 and ≤500	>500 and ≤1000	>1000 and ≤2000
pH (pH units)	6-9	6-9	6-9	6-9
Temperature (°C)	30	30	30	30
Colour (lovibond units) (25mm cell length)	1	1	1	1
Suspended solids	20	10	10	5
BOD	20	15	10	5
COD	80	60	40	20
Oil & Grease	1	1	1	1
Boron	10	5	4	2
Barium	1	1	1	0.5
Iron	0.5	0.4	0.3	0.2
Mercury	0.001	0.001	0.001	0.001
Cadmium	0.001	0.001	0.001	0.001
Silver	0.1	0.1	0.1	0.1
Copper	0.1	0.1	0.05	0.05
Selenium	0.1	0.1	0.05	0.05
Lead	0.2	0.2	0.2	0.1
Nickel	0.2	0.2	0.2	0.1
Other toxic metals individually	0.5	0.4	0.3	0.2
Total toxic metals	0.5	0.4	0.3	0.2
Cyanide	0.05	0.05	0.05	0.01
Phenols	0.1	0.1	0.1	0.1
Sulphide	0.2	0.2	0.2	0.1
Fluoride	10	7	5	4
Sulphate	800	600	400	200
Chloride	1000	1000	1000	1000
Total phosphorus	10	10	8	8
Ammonia nitrogen	2	2	2	1
Nitrate + nitrite nitrogen	30	30	20	20
Surfactants (total)	2	2	2	1
E. coli (count/100ml)	1000	1000	1000	1000

Table A1.6 Standards for effluents discharged into Group B inland waters

(All units in mg/L unless otherwise stated; all figures are upper limits unless otherwise indicated)

Determinand \ Flow rate (m^3/day)	≤200	>200 and ≤400	>400 and ≤600	>600 and ≤800	>800 and ≤1000	>1000 and ≤1500	>1500 and ≤2000	>2000 and ≤3000
pH (pH units)	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5
Temperature (°C)	35	30	30	30	30	30	30	30
Colour (lovibond units) (25mm cell length)	1	1	1	1	1	1	1	1
Suspended solids	30	30	30	30	30	30	30	30
BOD	20	20	20	20	20	20	20	20
COD	80	80	80	80	80	80	80	80
Oil & Grease	10	10	10	10	10	10	10	10
Iron	10	8	7	5	4	3	2	1
Boron	5	4	3	2.5	2	1.5	1	0.5
Barium	5	4	3	2.5	2	1.5	1	0.5
Mercury	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cadmium	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Selenium	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1
Other toxic metals individually	0.5	0.5	0.2	0.2	0.2	0.1	0.1	0.1
Total toxic metals	2	1.5	1	0.5	0.5	0.2	0.2	0.2
Cyanide	0.1	0.1	0.1	0.08	0.08	0.05	0.05	0.03
Phenols	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Sulphide	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Fluoride	10	10	8	8	8	5	5	3
Sulphate	800	800	600	600	600	400	400	400
Chloride	1000	1000	800	800	800	600	600	400
Total phosphorus	10	10	10	8	8	8	5	5
Ammonia nitrogen	5	5	5	5	5	5	5	5
Nitrate + nitrite nitrogen	30	30	30	20	20	20	10	10
Surfactants (total)	5	5	5	5	5	5	5	5
E. coli (count/100ml)	100	100	100	100	100	100	100	100

APPENDIX 2

KEY TO PARAMETERS CODES

- Table A2.1 Key to Parameters Codes for LFG Monitoring Results
- Table A2.2 Key to Parameters Codes for Table 4.17
- Table A2.3 Key to Parameters Codes for Table 4.18
- Table A2.4 Key to Parameters Codes for Table Analyses of Leachate, Groundwater and Surface Water

APPENDIX 2 : Key to Parameters Codes

A2.1 Key to Parameters Codes for LFG Monitoring Results

Key to parameters codes:

LOCN	Monitoring Locations for LFG
DATE	Date for Sampling
APRE	Atmospheric Pressure
DPRE	Drillhole or Drive-in-probe Differential Pressure
% CH_4	% Methane
% LEL	% Lower Explosive Limit
% O_2	% Oxygen
% CO_2	% Carbon Dioxide
% H_2	% Hydrogen
% CO	% Carbon Monoxide
% N_2	% Nitrogen
COM	Comment

Comment Abbreviation:

Lab	Laboratory analysis for confirmation test
?	Questionable data
Le H.	Leachate hole
Lab/A	Laboratory analysis for confirmation test and air contaminated sample
Filled	The hole was filled with water

A2.2 Key to Parameters Codes for Table 4.14

BOD_5	Biological Oxygen Demand (5 Days)
COND	Conductivity
DO	Dissolved Oxygen
TURB	Turbidity
CHY	Chlorophyll-a
FC	Faecal Coliform
PHAE	Phaeo-Pigment
SS	Suspended Solid
E. coli	*Escherichia coli*
TVS	Total volatile Solid
NH_4-N	Ammonia-Nitrogen
NO_2-N	Nitrite-Nigrogen
NO_3-N	Nitrate-Nitrogen
PO_4-P	Ortho-Phosphate
TKNS	Total Kjeldahl Nitrogen

A2.3 Key to Parameters Codes for Table 4.15

NH3	Ammonia-Nitrogen
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorus
COD	Chemical Oxygen Demand
TVS	Total Volatile Solids
TS	Total Solids
CN	Cyanide
TOC	Total Organic Carbon
S.G.	Specific Gravity
Al	Aluminium
As	Arsenic
B	Boron
Cd	Cadmium
Cr	Chromium
Cu	Copper
Fe	Iron
Hg	Mercury
Mn	Manganese
Ni	Nickel
Pb	Lead
Zn	Zince
PCBs	Polychlorinated Biphenyls
PAHs	Polycyclic Aromatic Hydrocarbons
EL	Electrochemical Potential

A2.4 Key to Parameters Codes for Analyses of Leachate, Groundwater and Surface Water (Appendix 4)

Flow	Flow Rate
DIP	Below Groundwater Level
Depth	Water Depth
Temp	Temperature
pH	pH Value
D.O.	Dissolved Oxygen
EC	Electrical Conductivity
Chloride	Chloride Ion
COD	Chemical Oxygen Demand
TOC	Total Organic Carbon
BOD	Biological Oxygen Demand (5 Days)
NO_3-N	Nitrate-Nitrogen
NO_2-N	Nitrite-Nigrogen
SO_4	Sulphate
Total-P	Total Phosphorus
Alkalinity	Alkalinity (as $CaCO_3$)
Hardness	Total Hardness (as $CaCO_3$)
Ca	Calcium
Mg	Magnesium
Na	Sodium
K	Potassium
Fe	Iron
Mn	Manganese
Zn	Zince
Cu	Copper
Pb	Lead
Cd	Cadmium
Cr	Chromium
VFA	Volatile Fatty Acids
S	Sulphide
E coli	*Escherichia coli*

APPENDIX 3

RESULTS OF ENVIRONMENTAL NOISE MONITORING

Table 1: Results of Environmental Noise Monitoring for PPV-1 on Pillar Point Valley Landfill

Dynamic Range of Sound Level Meter : 30.8-103.8 dB

Date	Measurement period (1 hr interval)		Noise Level dB(A)			Remarks
	Start	Finish	L10	L90	Leq	
24/11	7:00	8:00	57.5	50.0	54.8	
	8:00	9:00	62.5	53.5	59.8	
	9:00	10:00	62.5	55.0	59.9	
	10:00	11:00	62.5	55.0	60.0	
	11:00	12:00 noon	61.5	53.0	58.6	
	12:00 noon	1:00	59.5	49.5	56.3	
	1:00	2:00	65.0	55.5	62.0	
	2:00	3:00	62.5	53.0	59.8	
	3:00	4:00	60.0	51.0	57.1	
	4:00	5:00	60.5	52.5	57.9	
	5:00	6:00	59.0	50.0	55.8	
	6:00	7:00	52.0	47.0	50.2	

Table 2 : Results of Environmental Noise Monitoring for PPV-2 on Pillar Point Valley Landfill

Dynamic Range of Sound Level Meter : 28.9-101.9 dB

Date	Measurement period (1 hr interval)		Noise Level dB(A)			Remarks
	Start	Finish	L10	L90	Leq	
24/11	7:00	8:00	59.3	51.3	57.9	
	8:00	9:00	63.3	53.3	59.1	
	9:00	10:00	59.3	51.8	58.4	
	10:00	11:00	56.8	50.3	55.0	
	11:00	12:00 noon	57.3	48.8	54.9	
	12:00 noon	1:00	57.3	48.8	54.5	
	1:00	2:00	59.8	53.8	57.6	
	2:00	3:00	58.8	52.8	56.5	
	3:00	4:00	59.3	53.3	57.2	
	4:00	5:00	59.3	51.8	56.7	
	5:00	6:00	57.3	50.3	55.0	
	6:00	7:00	56.3	48.8	53.7	

Table 3: Results of Environmental Noise Monitoring for SLS-1 on Siu Lang Shui Landfill

Dynamic Range of Sound Level Meter : 30.8-103.8 dB

Date	Measurement period (1 hr interval)		Noise Level dB(A)			Remarks
	Start	Finish	L10	L90	Leq	
26/11	12:00 noon	1:00	64.0	62.0	63.1	
	1:00	2:00	63.5	62.0	62.8	
	2:00	3:00	63.5	62.0	62.8	
	3:00	4:00	63.0	61.5	62.1	
	4:00	5:00	63.0	62.0	62.5	
	5:00	6:00	63.0	62.0	62.5	
	6:00	7:00pm	63.0	61.5	62.3	
27/11	7:00am	8:00	63.5	62.0	62.9	
	8:00	9:00	86.0	63.0	81.1	*
	9:00	10:00	65.0	63.0	64.1	
	10:00	11:00	64.5	62.0	63.4	
	11:00	12:00 noon	63.5	62.0	62.7	

* Approximately 15min. noise from power station

Table 4: Results of Environmental Noise Monitoring for SLS-2 on Siu Lang Shui Landfill

Dynamic Range of Sound Level Meter : 28.9-101.9 dB

Date	Measurement period (1 hr interval)		Noise Level dB(A)			Remarks
	Start	Finish	L10	L90	Leq	
26/11	11:00	12:00 noon	56.8	45.3	53.1	
	12:00 noon	1:00	57.3	47.3	53.8	
	1:00	2:00	58.3	49.8	55.5	
	2:00	3:00	59.3	51.3	56.2	
	3:00	4:00	58.3	50.3	55.6	
	4:00	5:00	58.3	50.3	55.7	
	5:00	6:00	58.3	49.8	55.6	
	6:00	7:00pm	56.3	48.3	53.0	
27/11	7:00am	8:00	57.8	46.3	54.2	
	8:00	9:00	59.3	52.3	56.9	
	9:00	10:00	59.8	53.3	58.3	
	10:00	11:00	58.8	51.8	56.2	

Table 5 : Results of Environmental Noise Monitoring for MTL−1 on Ma Tso Lung Landfill

Dynamic Range of Sound Level Meter : 30.8−103.8 dB

Date	Measurement period (1 hr interval)		Noise Level dB(A)			Remarks
	Start	Finish	L10	L90	Leq	
30/11	2:00	3:00	54.4	47.4	53.3	
	3:00	4:00	56.4	47.9	55.4	
	4:00	5:00	63.9	50.9	60.6	
	5:00	6:00	54.4	45.9	56.3	
	6:00	7:00pm	55.9	45.9	54.2	
1/12	7:00am	8:00	51.9	43.9	49.8	
	8:00	9:00	62.9	47.9	58.7	
	9:00	10:00	56.9	48.4	55.7	
	10:00	11:00	52.9	48.9	51.9	
	11:00	12:00 noon	54.9	48.9	53.5	
	12:00 noon	1:00	57.9	49.4	57.3	
	1:00	2:00	58.9	50.4	60.1	

* Normal domestic activities

Table 6 : Results of Environmental Noise Monitoring for MTL−2 on Ma Tso Lung Landfill

Dynamic Range of Sound Level Meter : 28.9−101.9 dB

Date	Measurement period (1 hr interval)		Noise Level dB(A)			Remarks
	Start	Finish	L10	L90	Leq	
30/11	12:00 noon	1:00	51.9	40.9	48.2	
	1:00	2:00	52.9	42.9	50.6	
	2:00	3:00	65.9	51.4	60.8	*
	3:00	4:00	66.4	48.9	61.9	*
	4:00	5:00	63.4	50.9	60.1	*
	5:00	6:00	55.9	48.9	54.3	
	6:00	7:00	53.9	42.4	51.2	
1/12	7:00am	8:00	46.9	40.4	44.5	
	8:00	9:00	62.4	43.9	57.8	
	9:00	10:00	54.4	50.9	53.2	
	10:00	11:00	67.9	51.4	63.3	
	11:00	12:00 noon	74.4	66.9	71.5	*

* Activities from the playground

Table 7 : Results of Environmental Noise Monitoring for MTL-3 on Ma Tso Lung Landfill

Dynamic Range of Sound Level Meter : 30.8-103.8 dB

Date	Measurement period (1 hr interval)		Noise Level dB(A)			Remarks
	Start	Finish	L10	L90	Leq	
29/11	12:00 noon	1:00	63.8	40.3	55.6	
	1:00	2:00	66.3	64.8	65.5	*
	2:00	3:00	66.8	65.3	66.2	*
	3:00	4:00	64.8	46.8	60.0	*
	4:00	5:00	69.3	63.8	66.5	*
	5:00	6:00	65.3	42.8	61.1	
	6:00	7:00pm	54.8	46.3	52.5	
30/11	7:00am	8:00	50.3	35.3	49.0	
	8:00	9:00	68.8	45.3	65.9	*
	9:00	10:00	70.8	65.8	69.9	*
	10:00	11:00	69.3	65.3	67.6	*
	11:00	12:00 noon	68.3	64.3	68.5	*

* Activities from timber factories

Table 8 : Results of Environmental Noise Monitoring for MTL-4 on Ma Tso Lung Landfill

Dynamic Range of Sound Level Meter : 28.9-101.9 dB

Date	Measurement period (1 hr interval)		Noise Level dB(A)			Remarks
	Start	Finish	L10	L90	Leq	
29/11	1:00pm	2:00	53.0	41.5	50.2	
	2:00	3:00	54.5	41.5	53.9	
	3:00	4:00	52.0	39.5	49.8	
	4:00	5:00	53.5	49.5	52.2	
	5:00	6:00	55.5	49.5	53.2	
	6:00	7:00pm	57.5	48.0	54.9	
30/11	7:00am	8:00	44.5	41.0	44.2	
	8:00	9:00	56.0	41.0	52.8	
	9:00	10:00	56.5	49.5	54.0	
	10:00	11:00	55.0	47.5	52.4	
	11:00	12:00 noon	55.5	44.0	53.5	
	12:00 noon	1:00	53.5	40.0	51.5	

Table 9 : Results of Environmental Noise Monitoring for NTM-1 on Ngau Tam Mei Landfill

Dynamic Range of Sound Level Meter : 30.8-103.8 dB

Date	Measurement period (1 hr interval)		Noise Level dB(A)			Remarks
	Start	Finish	L10	L90	Leq	
30/11	2:00	3:00	63.3	55.3	60.5	
	3:00	4:00	63.3	55.3	60.5	
	4:00	5:00	63.3	55.8	60.6	
	5:00	6:00	62.8	55.8	60.3	
	6:00	7:00pm	62.3	55.3	59.5	
1/12	7:00am	8:00	61.3	52.3	58.2	
	8:00	9:00	62.8	55.3	59.8	
	9:00	10:00	63.8	55.8	60.8	
	10:00	11:00	64.3	56.8	61.3	
	11:00	12:00 noon	63.8	56.3	60.8	
	12:00 noon	1:00	63.3	54.3	60.0	
	1:00	2:00	63.8	54.3	60.5	

Table 10 : Results of Environmental Noise Monitoring for NTM-2 on Ngau Tam Mei Landfill

Dynamic Range of Sound Level Meter : 30.8-103.8 dB

Date	Measurement period (1 hr interval)		Noise Level dB(A)			Remarks
	Start	Finish	L10	L90	Leq	
30/11	2:00	3:00	53.5	48.5	52.4	
	3:00	4:00	52.5	47.5	50.8	
	4:00	5:00	49.0	43.0	47.0	
	5:00	6:00	48.0	44.5	46.7	
	6:00	7:00pm	48.0	43.0	46.4	
1/12	7:00am	8:00	49.0	40.0	45.9	
	8:00	9:00	49.0	42.5	47.2	
	9:00	10:00	48.5	43.5	46.3	
	10:00	11:00	48.5	43.5	46.5	
	11:00	12:00 noon	48.0	44.5	46.6	
	12:00 noon	1:00	49.0	43.5	47.0	
	1:00	2:00	46.5	43.0	46.4	

Table 11: Results of Environmental Noise Monitoring for NTM-3 on Ngau Tam Mei Landfill

Dynamic Range of Sound Level Meter : 30.8-103.8 dB

Date	Measurement period (1 hr interval)		Noise Level dB(A)			Remarks
	Start	Finish	L10	L90	Leq	
1/12	3:00	4:00	59.4	54.4	57.3	
	4:00	5:00	59.9	53.9	57.3	
	5:00	6:00	59.4	54.4	57.5	
	6:00	7:00pm	59.9	54.9	57.7	
2/12	7:00am	8:00	57.4	49.9	55.2	
	8:00	9:00	59.4	52.9	57.8	
	9:00	10:00	57.9	51.9	56.4	
	10:00	11:00	57.9	50.9	56.4	
	11:00	12:00 noon	56.4	50.9	54.5	
	12:00 noon	1:00	55.4	49.9	53.3	
	1:00	2:00	55.9	49.9	53.6	
	2:00	3:00	57.9	51.9	56.2	

ANALYSES OF LEACHATE, GROUNDWATER AND SURFACE WATER

Table A4.1 (Appendix 4)
Pillar Point Valley Landfill
Analyses of leahcate, groundwater and surface water (concentrations in mg/L) (Sheet 1 of 3)

Parameter+	Surface water								
	W101	W101	W101	W102	W102	W102	W103	W103	W103
	6/5/93	16/8/93	20/10/93	6/5/93	16/8/93	20/10/93	6/5/93	16/8/93	20/10/93
Flow (cu m/s)					0.13	0.07			
DIP (mbg)									
Depth (m)									
Temp. (°C)	28.1	29.3	26.3	29.4	30.5	27.7	31.1	29.6	26.9
pH	7.46	7.3	7.4	7.52	7.4	7.9	8.02	7.9	7.9
D.O.	7.7	7.4	7.1	6.9	7.3	6.2	7.4	6.2	2.1
EC (uS/cm)	60	130	50	1000	230	840	630	430	660
Chloride	5.6	32	7.2	73	78	110	48	81	93
COD	<7	<7	<7	44	26	150	24	200	180
TOC	<1	1	4	51	10	40	26	50	40
BOD	<5	<5	<5	6	11	38	<5	67	30
NH3-N	1.4	<0.1	<0.1	2.2	22	63	30	23	48
TON									
TKN									
NO3-N	0.28			0.35			0.61		
NO2-N	0			0.08			0.7		
SO4	<10			11			17		
Total - P	<0.1			0.6			0.4		
Alkalinity									
Hardness	5.5			42			48		
Ca	1.3			13			16		
Mg	0.4			2.6			2.1		
Na	6	20	5.5	81	75	95	44	69	80
K	1.6	2.1	1.8	26	15	40	16	30	32
Fe	0.2			1.2			0.6		
Mn	<0.1			0.2			0.1		
Zn	<0.01			<0.01			<0.01		
Cu	<0.1			<0.1			<0.1		
Ni	<0.1			<0.1			<0.1		
Cr	<0.1			<0.1			<0.1		
Pb	<0.1			<0.1			<0.1		
Cd	<0.02			<0.02			<0.02		
VFA									
S									
E. coli									

\+ refer to A2.4 (Appendix 2) for abbreviations used

Appendix 4.1 (Appendix 4)
Pillar Point Valley Landfill
Analyses of leachate, groundwater and surface water (concentrations in mg/L) (Sheet 2 of 3)

Parameter+	Leachate Quality								
	DH105	DH105	DH105	DH106	DH106	DH106	DH107	DH107	DH107
	18/6/93	16/8/93	20/10/93	18/6/93	16/8/93	20/10/93	30/7/93	16/8/93	20/10/93
Flow (cu m/s)									
DIP (mbg)	15.8	16.5	16.4	32	32.2	no water	18.6	11	10.7
Depth (m)	2.2	1.5	1.6	17	16.8		1.85	9.45	9.75
Temp. (°C)	31.1	31.8	31.8	48.1	46.9			40.8	38.9
pH	6.73	7.4	6.7	7.77	7.7		7.57	7.6	7.5
D.O.									
EC (uS/cm)	2000	4100	5500	25000	21000		24000	16000	20000
Chloride	560	730	690	2400	2300		2000	2000	1700
COD	540	510	310	3500	2500		2400	2600	1900
TOC	80	150	60	600	1000			800	450
BOD	170	29	15	410	250		320	210	190
NH3-N	240	360	320	2200	2000		1900	1900	1500
TON									
TKN	240	370	340	2200	2100		1900	2000	1800
NO3-N	0.07			0			0.04		
NO2-N	0			0					
SO4	20			<10			<10		
Total - P									
Alkalinity							3700		
Hardness	220								
Ca	41			12			54		
Mg	24			30			56		
Na	430	610	580	2800	2100		1700	1400	1000
K	76	140	160	1000	980		870	930	880
Fe	130			9					
Mn	7			0.2					
Zn	0.27			0.55					
Cu	0.1			0.2					
Ni	<0.1			0.2					
Cr	0.1			0.5					
Pb	2			0.2					
Cd	<0.02			<0.02					
VFA	44			410					
S	<0.1			2					
E. coli	3			40					

note: no water was found at DH106 on 20.10.93
+ refer to A2.4 (Appendix 2) for abbreviations used

Table A4.1 (Appendix 4)
Pillar Point Valley Landfill
Analyses of leahcate, groundwater and surface water (concentrations in mg/L) (Sheet 3 of 3)

Parameter+	Groundwater Quality			Leachate Discharge Manhole
	DH103	DH103	DH103	Manhole
	18/6/93	16/8/93	20/10/93	5/7/93
Flow (cu m/s)				
DIP (mbg)	7.9	8.2	8.3	n.a.
Depth (m)	3.1	2.8	2.7	n.a.
Temp. (°C)	27.2	27.1	29.5	
pH	6.35	6	6.3	7.2
D.O.				
EC (uS/cm)	160	150	190	8600
Chloride	12	22	30	870
COD	80	10	9	860
TOC	3	2	3	350
BOD	11	<5	<5	190
NH3-N	<0.1	<0.1	<0.1	720
TON				
TKN	0.1	0.1	<0.1	
NO3-N	1.34			<0.01
NO2-N	0.02			<0.01
SO4	<10			<10
Total - P				
Alkalinity				4000
Hardness	28			
Ca	8.2			68
Mg	1.5			45
Na	71	30	30	820
K	5.1	5.1	5.2	390
Fe	16			
Mn	1.1			
Zn	0.16			
Cu	0.1			
Ni	<0.1			
Cr	<0.1			0.2
Pb	0.4			
Cd	<0.02			
VFA	11			
S	<0.1			
E. coli	180			

\+ refer to A2.4 (Appendix 2) for abbreviations used

Table A4.2 (Appendix 4)
Siu Lang Shui Landfill
Analyses of leahcate, groundwater and surface water (concentrations in mg/L) (Sheet 1 of 3)

Parameter+	Surface water											
	W201	W201	W201	W202	W202	W202	W203	W203	W203	W204	W204	W204
	5/5/93	17/8/93	21/10/93	5/5/93	17/8/93	21/10/93	5/5/93	17/8/93	21/10/93	16/7/93	17/8/93	21/10/93
Flow (cu m/s)											0.1	0.05
DIP (mbg)												
Depth (m)												
Temp. (°C)	24.1	29.6	25.4	23.9	28.7	24.6	24.2	29.1	24.4		30	25.2
pH	7.6	7.9	8.3	7	7	8.3	6.9	7.2	8	7.6	6.9	8
D.O.	8.7	8.1	8.6	7.9	7.5	6.5	8	8.2	7.6		6.2	6.9
EC (uS/cm)	89	83	67	120	81	240	270	150	140	1400	5000	2000
Chloride	8.6	7.7	9.1	10	8.8	19	50	54	27	340	3700	400
COD	<7	<7	8	<7	<7	24	9	<7	<7	14	56	44
TOC	<1	1	3	<1	2	4	<1	2	4	2	9	7
BOD	<5	<5	<5	<5	<5	28	<5	<5	6.2	10	<5	8.9
NH3-N	<0.1	<0.1	<0.1	1.3	1.1	13	2.1	1.1	3.8	11	16	60
TON												
TKN												
NO3-N	0.13			0.42			0.44					
NO2-N	<0.01			0.08			0.08					
SO4	18			14			50					
Total - P	0.1			0.1			0.3					
Alkalinity												
Hardness	14			18			31					
Ca	4			5			6.5					
Mg	0.9			1.2			3.8					
Na	9	8.2	7.5	10	9.5	22	35	32	14		3100	250
K	2.5	1.9	2.3	2.9	2.4	5.7	3.8	3.6	3.3		82	24
Fe	0.1			0.3			0.4					
Mn	<0.1			0.1			0.2					
Zn	0.03			<0.01			<0.01					
Cu	<0.1			<0.1			<0.1					
Ni	<0.1			<0.1			<0.1					
Cr	<0.1			<0.1			<0.1					
Pb	<0.1			<0.1			<0.1					
Cd	<0.02			<0.02			<0.02					
VFA												
S												
E. coli												

+ refer to A2.4 (Appendix 2) for abbreviations used

Table 4.2 (Appendix 4)
Siu Lang Shui Landfill
Analyses of leahcate, groundwater and surface water (concentrations in mg/L) (Sheet 2 of 3)

Parameter	Leachate Quality											
	DH205	DH205	DH205	DH207	DH207	DH207	L201	L202	L203	L204	L205	Pipe
	4/6/93	17/8/93	21/10/93	4/6/93	17/8/93	21/10/93	16/7/93	16/7/93	16/7/93	16/7/93	16/7/93	5/7/93
Flow (cu m/s)												
DIP (mbg)	21	18.3	27.1	15	14.9	14.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Depth (m)	19	21.7	12.9	4.2	4.3	4.3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Temp. (°C)	38.7	40.7	42.2	26.3	26.9	26.7						
pH	7.88	7.9	8.3	6.33	6.1	5.9	8.1	8.2	8	7.8	8.2	7.4
D.O.												
EC (uS/cm)	78000	53000	56000	2000	120	220	10200	9000	10300	6700	6400	8440
Chloride	4800	4900	4900	20	16	22	670	640	670	340	330	470
COD	22000	22000	17000	58	190	82	980	890	860	440	660	970
TOC	7500	7600	8000	8	100	15	250	250	200	120	100	300
BOD	12000	11000	8400	5.5	5	8.9	59	120	65	70	190	370
NH3-N	8300	7900	8700	<0.1	<0.1	0.7	1100	880	1100	570	530	850
TON												
TKN	8000	8100	8100	0.1	0.2	1						
NO3-N	<0.01			0.01								
NO2-N	0.03			<0.01								
SO4	72			<10								<10
Total - P	18			<0.1								
Alkalinity												3800
Hardness	58			180								
Ca	11			50								30
Mg	7.5			13								10
Na	4000	5000	4200	26	20	16						420
K	1300	1400	1400	16	9.7	6.4						170
Fe	19			9								5.3
Mn	0.3			7								
Zn	36			0.06								
Cu	8.9			<0.1								
Ni	0.3			<0.1								
Cr	9			<0.1								
Pb	0.7			0.1								
Cd	<0.02			<0.02								
VFA	5000			21								
S	18			<0.1								
E. coli	0			12								
B				0.4								
Se				<5								
Al				5								

Note: no water was found at DH208 on 17.8.93 and 21.10.93
+ refer to A2.4 (Appendix 2) for abbreviations used

Table A4.2 (Appendix 4)
Siu Lang Shui Landfill
Analyses of leahcate, groundwater and surface water (concentrations in mg/L) (Sheet 3 of 3)

Parameter+	Groundwater Quality									Leachate Quality		
	DH201	DH201	DH201	DH203	DH203	DH204	DH204	DH204	DH208	L206	L207	Sump
	4/6/93	17/8/93	21/10/93	4/6/93	17/8/93	4/6/93	17/8/93	21/10/93	28/5/93	16/7/93	16/7/93	5/7/93
Flow (cu m/s)					21/10/93							
DIP (mbg)	6.7	7	1	4.9		2.2	2.7	2.7	n.a.	3.8	4.2	1.3
Depth (m)	5.3	5	11	7.1	0	10.1	9.6	9.6	n.a.	n.a.	n.a.	n.a.
Temp. (°C)	25.3	28.3	27.7	26.4		24.9	28.2	28.2	34.3			
pH	7.34	7.5	7.6	6.42		7.08	7.6	7.6	6.88	7.54	7.49	7.6
D.O.					no							
EC (uS/cm)	5400	5200	12000	3300	water	2200	4100	12000	620	4000	14000	1700
Chloride	370	460	750	170		25	210	480	38	290	1000	110
COD	290	690	1800	94		51	490	620	84	940	1200	85
TOC	120	200	250	24		9	150	140	7	100	750	30
BOD	26	41	76	12		22	66	120	6.8	63	160	34
NH3-N	420	640	1100	69		29	460	760	3.3	320	1400	99
TON										0.01	1.6	12
TKN		670	1200	62		30	490	850	4	320	1500	
NO3-N	7.55			40.4		2.47			<0.01			
NO2-N	0.44			0.12		0.24			<0.01			
SO4	51			340		26			260	120	<10	24
Total - P	<0.1			<0.1		<0.1			<0.1			
Alkalinity										640	2700	610
Hardness	200			630		92			230			
Ca	27			140		33			54	64	54	51
Mg	19			24		3.2			12	18	27	6.2
Na	480	430	750	140		26	210	450	32	270	1100	100
K	110	160	310	27		14	86	210	5.4	110	360	54
Fe	13			5		6			1.4			
Mn	1.2			6		1.2			11			
Zn	0.07			0.1		0.06			0.07			
Cu	<0.1			<0.1		<0.1			<0.1			
Ni	<0.1			<0.1		<0.1			<0.1			
Cr	0.2			<0.1		<0.1			<0.1			0.1
Pb	0.3			<0.1		<0.1			<0.1			
Cd				<0.02		<0.02			<0.02			
VFA	47			62		10			6.3			
S	0.3			<0.1		<0.1			<0.1			
E. coli	14			130		890			6			
B												
Se												
Al												

Note: no water was found at DH203 on 17.8.93 and 21.10.93
under fill groundwater was sampled at DH208 on 28.5.93, and thereafter no water was found
+ refer to A2.4 (Appendix 2) for abbreviations used

Table A4.3 (Appendix 4)
Ma Tso Lung Landfill
Analyses of leahcate, groundwater and surface water (concentrations in mg/L) (Sheet 1 of 3)

Parameter+	Surface water								Leachate seeps		
	W301	W301*	W301	W301	W302A	W302A	W302A	W302B	L301	L302	L303
	6/5/93	16/7/93	13/8/93	12/10/93	6/5/93	13/8/93	12/10/93	6/5/93	16/7/93	16/7/93	16/7/93
Flow (cu m/s)		18	18	9.6							0.93
DIP (mbg)											
Depth (m)											
Temp. (°C)	31		27.9	27.9	32.7	30.8	30	34			
pH	8.38	7.99	7.9	8.1	7.84	8.2	8.4	9.23	8.43	8.04	8.34
D.O.	4.3		0.5	0.72	7.4	0.9	0.66	0.21			
EC (uS/cm)	9200	5000	5600	4100	5900	13000	16000	11000	16000	2400	16700
Chloride	870	350	410	300	610	1600	1300	930	1400	240	1400
COD	940	430	350	3100	390	2100	1000	720	520	350	1200
TOC	120	100	120	250	230	600	550	180	420	60	250
BOD	15	200	110	27	49	220	210	43	460	54	44
NH3-N	430	530	670		190	1200	1600	500	2100	140	2200
TON		<0.01							0.02	0.01	86
TKN		600							2200	240	2400
NO3-N	210				200			110			
NO2-N	50				5.9			24			
SO4	490	10			290			280	66	20	33
Total - P	1.2				2.4			10			
Alkalinity		2000							8000	680	8500
Hardness	230				520			200			
Ca	42	4.8			160			44	12	41	24
Mg	10	7.8			23			20	4.2	10	12
Na	550	150	330	190	400	1000	700	600	780	140	730
K	200	65	73	52	180	390	390	240	250	52	300
Fe	35				3.6			2.7			
Mn	6				0.6			0.4			
Zn	4.2				0.2			0.3			
Cu	0.3				0.2			0.3			
Ni	0.1				<0.1			0.1			
Cr	1.8				0.2			0.7			
Pb	1.3				<0.1			<0.1			
Cd	0.02				<0.02			<0.02			
VFA											
S											
E coli											
B											
Se											
Al											

Note: * W301 and L304 were the same location for the sampling of surface water
+ refer to A2.4 (Appendix 2) for abbreviations used

Table A4.3 (Appendix 4)

Ma Tso Lung Landfill

Analyses of leahcate, groundwater and surface water (concentrations in mg/L) (Sheet 2 of 3)

Parameter+	Leachate Quality									Groundwater Quality	
	DH301	DH301	DH301	DH302	DH302	DH302	DH303	DH303	DH303	DH308	DH309
	17/6/93	13/8/93	12/10/93	17/6/93	13/8/93	12/10/93	17/6/93	13/8/93	12/10/93	12/10/93	
Flow (cu m/s)											no
DIP (mbg)	9.8	8.9	8.2	9.2	8.5	8.5	10.4	9.8	9.1	17.7	water
Depth (m)	6.7	7.6	8.3	11.3	12	12	6.6	7.2	7.9	2.5	0
Temp. (°C)	27.2	27.1	27.5	29.1	28.9	30.8	26.5	26.1	27.9	26.2	
pH	8.01	8.1	8.1	7.96	7.7	7.7	7.73	7.7	7.7	6.2	
D.O.											
EC (uS/cm)	75000	112000	64000	61000	40000	28000	27000	46000	28000	120	
Chloride	8000	6300	5000	4500	2300	2000	1400	2000	1200	9.8	
COD	20000	22000	12000	23000	3500	2800	3800	5300	2500	7	
TOC	6200	7700	9500	7500	1900	1300	900	1800	800	10	
BOD	9900	9800	5200	14000	1400	790	1400	2000	480	5	
NH3-N	13400	13000	9400	9800	4100	3300	3600	5100	3900	1.8	
TON											
TKN	14000	13000	9700	9400	4300	3400	17000	5300	3800	2	
NO3-N	<0.01			<0.01			<0.01				
NO2-N	<0.01			<0.01			<0.01				
SO4	180			220			<10				
Total - P	98			14			18				
Alkalinity											
Hardness	11			30			100				
Ca	0.2			3.4			4500				
Mg	2.5			5.2			12				
Na	4100	4000	3100	2600	1400	1300	4500	1200	750	5	
K	1400	1300	1000	840	570	510	710	480	160	2.9	
Fe	36			33			28				
Mn	0.5			0.3			0.8				
Zn	1.2			1.5			0.58				
Cu	0.2			0.3			0.2				
Ni	0.3			0.2			0.1				
Cr	20			15			3.5				
Pb	0.3			0.3			0.2				
Cd	<0.02			<0.02			<0.02				
VFA	5200			8400			990				
S	16			16			7.2				
E. coli	0			0			4000				
B											
Se											
Al											

Note: no water was found at DH308 on 17.6.93 and 13.8.93 whilst no water has been found at DH309

+ refer to A2.4 (Appendix 2) for abbreviations used

Table A4.3 (Appendix 4)
Ma Tso Lung Landfill
Analyses of leahcate, groundwater and surface water (concentrations in mg/L) (Sheet 3 of 3)

Parameter+	Groundwater Quality											
	DH301	DH302	DH303	DH304	DH304	DH304	DH305	DH305	DH305	DH307	DH307	DH307
	31/5/93	4/6/93	7/6/93	4/6/93	13/8/93	12/10/93	3/6/93	13/8/93	12/10/93	3/6/93	13/8/93	12/10/93
Flow (cu m/s)												
DIP (mbg)	12	15	13	5.1	3.5	2.4	3.7	4.3	3.7	4.3	4.9	4.9
Depth (m)	n.a.	n.a.	n.a.	15.3	16.9	18	10.8	10.2	10.8	10.1	9.5	9.5
Temp. (°C)	27.8	29.4	28.1	24.6	25.1	26.2	25	26	25.9	25.3	24.9	26.4
pH	6.17	7.14	8.26	5.86	5.4	5.5	6.04	6	5.9	6.1	5.7	5.5
D.O.												
EC (uS/cm)	340	3600	31000	440	760	280	420	710	210	380	790	240
Chloride	72	340	2100	36	39	35	48	44	47	37	87	54
COD	92	2500	1800	12	<7	80	<7	<7	<7	28	8	11
TOC	1	680	1100	<1	3	8	1	2	6	7	5	20
BOD	8.3	1400	780	<5	<5	<5	<5	<5	<5	12	<5	<5
NH3-N	6.1	360	4200	0.3	0.3	0.9	<0.1	<0.1	0.9	<0.1	<0.1	<0.1
TON												
TKN	6.6	370	4300	0.5	0.4	1.5	0.4	0.1	1.2	<0.1	0.2	0.1
NO3-N	1.4	0.11	<0.01	12			11			<0.01		
NO2-N	0.01	0.03	0.04	0.24			0.06			0.01		
SO4	18	65	<10	<10			<10			13		
Total - P	<0.1	<0.1	31	<0.1			<0.1			<0.1		
Alkalinity												
Hardness	81	110	36	55			110			140		
Ca	8.5	11	10	19			30			48		
Mg	15	20	2.8	2			8.9			3.2		
Na	16	130	1000	41	75	45	34	15	18	28	62	35
K	3.3	59	440	2.4	1.6	3.6	2.1	1.5	1.9	4.4	1.6	0.8
Fe	6.5	88	18	8			3.7			15		
Mn	1.5	1.2	1	1.3			2			3.5		
Zn	0.01	0.16	0.31	0.26			0.06			0.14		
Cu	<0.1	0.8	0.1	<0.1			<0.1			<0.1		
Ni	<0.1	<0.1	0.1	<0.1			<0.1			<0.1		
Cr	<0.1	0.3	1.5	<0.1			<0.1			<0.1		
Pb	<0.1	3.8	<0.1	<0.1			0.1			0.3		
Cd	<0.02	<0.02	<0.02	<0.02			<0.02			<0.02		
VFA	13	1200	620	21			<5			<5		
S	<0.1	0.6	<0.1	<0.1			<0.1			<0.1		
E. coli	100	600	0	4			16			32		
B												
Se												
Al												

note: under fill groundwater has been sampled at DH301, DH302 and DH303 during the site investigation
+ refer to A2.4 (Appendix 2) for abbreviations used

Table A4.4 (Appendix 4)

Ngau Tam Mei Landfill

Analyses of leahcate, groundwater and surface water (concentrations in mg/L) (Sheet 1 of 3)

Parameter+	Leachate Quality								Surface Water		
	DH401	DH401	DH401	DH402	DH402	DH402	L401	L402	W401	W401	W401
	3/6/93	11/8/93	11/10/93	17/6/93	11/8/93	11/10/93	16/7/93	16/7/93	3/6/93	11/8/93	11/10/93
Flow (cu m/s)										0	0
DIP (mbg)	14.3	14	14	6.4	5.6	3	n.a.	n.a.	n.a.	n.a.	n.a.
Depth (m)	>1.15	>1.45	>1.45	4.6	5.2	8	n.a.	n.a.	n.a.	n.a.	n.a.
Temp. (°C)	27.1	29.7	27.3	27.2	26.4	27.4			25.2	28.2	23.7
pH	7.72	7.4	7.7	7.62	7.6	7.8	8.06	8.17	7.43	8.5	7.8
D.O.									6	2.6	3.2
EC (uS/cm)	23000	26000	22000	27000	41000	34000	10000	4500	130	21000	9400
Chloride	1300	1200	1300	1800	2600	2200	720	370	75	1400	700
COD	3900	1800	3000	2200	2100	2400	650	360	75	890	550
TOC	600	900	600	500	1400	1500	150	80	16	380	220
BOD	210	450	73	340	260	210	130	88	17	15	240
NH3-N	2000	2400	2600	3200	4500	4400	1200	400	77	1900	1100
TON							0.02	78			
TKN	2100	2600	2700	3300	4800	4400	1400	560			
NO3-N	2.91			<0.01					18		
NO2-N	0.03			<0.01					7.1		
SO4	<10			<10			<10	20	24		
Total - P	0.9			8					0.4		
Alkalinity							5100	1800			
Hardness	180			84					130		
Ca	20			14			70	70	45		
Mg	32			12			22	18	6		
Na	920	1000	830	1200	1600	7500	420	260	52	800	880
K	500	420	450	480	660	650	230	180	32	360	260
Fe	140			16					0.9		
Mn	9			1.5					0.9		
Zn	3.2			1					0.03		
Cu	0.6			0.2					<0.1		
Ni	0.3			0.1					<0.1		
Cr	4.5			1.6					<0.1		
Pb	8.2			1.3					<0.1		
Cd	<0.02			<0.02					<0.02		
VFA	630			120							
S	4			4.8							
E. coli	120			4000							
B											
Se											
Al											

Note: + refer to A2.4 (appendix 2) for abbreviations used

Table A4.4 (Appendix 4)
Ngau Tam Mei Landfill
Analyses of leahcate, groundwater and surface water (concentrations in mg/L) (Sheet 2 of 3)

Parameter+	Groundwater Quality									
	DH402	DH403	DH403	DH403	DH404	DH404	DH404	DH405	DH405	DH405
	9/6/93	3/6/93	11/8/93	11/10/93	3/6/93	11/8/93	11/10/93	3/6/93	11/8/93	11/10/93
Flow (cu m/s)										
DIP (mbg)	26	19.8	19.2	16.4	14	13.1	9.4	9.7	9.5	7.3
Depth (m)	n.a.	8.2	8.8	11.6	7.5	8.4	12.1	47	47.2	49.4
Temp. (°C)	28.5	25.9	25.9	26	24.6	24.5	25.9	24.5	24.6	25.4
pH	4.47	6.4	5.8	5.9	6.6	5.7	5.7	6.21	6.1	5.6
D.O.										
EC (uS/cm)	2800	320	510	147	280	520	145	220	590	240
Chloride	1100	43	83	6.6	19	26	14	19	67	28
COD	300	<7	<7	8	<7	<7	24	<7	<7	<7
TOC	25	<1	2	8	1	1	16	<1	3	8
BOD	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
NH3-N	31	<0.1	<0.1	<0.1	<0.1	<0.1	2.9	0.2	<0.1	<0.1
TON										
TKN	32	0.2	0.4	0.3	0.2	0.2	3.5	0.1	0.5	0.1
NO3-N	1.4	0.75			0.14			1.9		
NO2-N	0.04	0.01			0.02			0.02		
SO4	72	10			16			<10		
Total - P	<0.1	<0.1			<0.1			<0.1		
Alkalinity										
Hardness	160	87			94			61		
Ca	24	24			28			20		
Mg	24	6.5			5.5			2.5		
Na	550	24	56	5	14	20	7	10	40	26
K	22	7.4	7.3	4.8	5.2	2.6	3.3	6.4	6.9	6.6
Fe	26	6			14			24		
Mn	140	1.8			2.5			2.1		
Zn	0.48	0.1			0.25			0.14		
Cu	0.1	<0.1			<0.1			<0.1		
Ni	<0.1	<0.1			<0.1			<0.1		
Cr	<0.1	<0.1			<0.1			<0.1		
Pb	1.1	<0.1			0.1			0.1		
Cd	0.03	<0.02			<0.02			<0.02		
VFA	21	16			21			21		
S	<0.1	<0.1			<0.1			<0.1		
E. coli	28	10			50			14		
B										
Se										
Al										

Note: under fill groundwater was sampled at DH402 on 9.6.93
+ refer to A2.4 (appendix 2) for abbreviations used

Table A4.4 (Appendix 4)

Ngau Tam Mei Landfill

Analyses of leahcate, groundwater and surface water (concentrations in mg/L) (Sheet 3 of 3)

Parameter+	Groundwater Quality						
	DH407	DH407	DH407	DH408	DH408	DH408	DH411
	9/6/93	11/8/93	11/10/93	3/6/93	11/8/93	11/10/93	
Flow (cu m/s)							no
DIP (mbg)	26.3	26.8	24.4	24	22.7	27.1	water
Depth (m)	3.7	3.2	5.6	4.5	5.8	1.4	0
Temp. (°C)	27	28.3	27.3	26.1	28	27	
pH	5.91	5.9	6.1	5.87	5.9	5.9	
D.O.							
EC (uS/cm)	260	380	240	210	910	100	
Chloride	22	42	13	16	35	9.3	
COD	14	<7	61	16	<7	18	
TOC	<1	5	5	1	6	5	
BOD	<5	<5	7.8	<5	<5	<5	
NH3-N	<0.1	1	0.4	<0.1	<0.1	0.1	
TON							
TKN	0.1	1.5	0.8	1.5	0.2	0.4	
NO3-N	<0.01			0.43			
NO2-N	0.01			0.02			
SO4	10			21			
Total - P	<0.1			<0.1			
Alkalinity							
Hardness	79			70			
Ca	20			18			
Mg	2.8			5			
Na	16	30	11	8.5	25	5	
K	6.6	7.6	7.1	4	5.6	4.1	
Fe	10			29			
Mn	7			4			
Zn	0.04			0.19			
Cu	<0.1			0.4			
Ni	<0.1			<0.1			
Cr	0.1			<0.1			
Pb	0.1			0.4			
Cd	<0.02			<0.02			
VFA	<5			<5			
S	<0.1			<0.1			
E. coli	2			0			
B							
Se							
Al							

Note: no water has never been found at DH411

+ refer to A2.4 (appendix 2) for abbreviations used

APPENDIX 5

ENVIRONMENTAL MONITORING REQUIREMENTS

- Appendix A5.1 Environmental Monitoring Requirements for PPVL
- Appendix A5.2 Environmental Monitoring Requirements for SLSL
- Appendix A5.3 Environmental Monitoring Requirements for MTLL
- Appendix A5.4 Environmental Monitoring Requirements for NTML

Appendix 5.1: Environmental Monitoring Requirements for PPVL

Design Monitoring

Leachate, groundwater and surface water

1. In addition to the existing drillholes, more samples should be taken from CED drillholes (i.e. 4 holes) for future monitoring of leachate and groundwater levels and quality. In addition, DH105 should be grouted up and redrilled to a shallower depth whilst a replacement DH107 should be drilled for routine monitoring. All drillholes containing leachate and groundwater should be dipped monthly for 6 months; after which a review of the most appropriate drillholes for further monitoring should be conducted. Pumped samples should be taken from the drillholes every 6 months for a year and analysed for full analysis (Suite A). Fixed levels on all drillholes to be re-surveyed annually.

2. Existing monitoring points for surface water (i.e. W101 and W103) should be sampled every three months for a year and analysed for full analysis (Suite B).

3. Non-routine monitoring of leachate level should be undertaken at DH106 for a 2 - 4 week period to assess the response of leachate levels to barometric pressure changes, a similar exercise on additional drillholes may be needed, subject to the results obtained at DH106.

4. Detailed monitoring should be initiated to define the flow and quality of the leachate and contaminated groundwater in accordance with the interim note given in Appendix 3 of Working Paper WP3 at least for a year, after which the monitoring frequency should be reviewed. In summary, monitoring should include:

   - continuous monitoring of combined flow at existing V-notch weir inside the manhole next to the refugee camp;

   - continuous monitoring of groundwater low-flows in pipeline diverted to join the 600 mm leachate pipe;

   - routine monitoring of the quality of combined discharge at existing V-notch weir inside the manhole next to the refugee camp, as follows:

     - daily for 6 weeks for reduced analysis (Suite C)
     - weekly for 1 year for reduced analysis (Suite C)
     - monthly for 1 year for full analysis (Suite A)
     - quarterly for 1 year for full analysis (Suite B);

   - routine monitoring of the quality of groundwater low flows at the existing sump adjacent to eastern catchwater cascade channel, as follows:

     - weekly for 6 weeks for reduced analysis (Suite C)
     - monthly for 1 year for full analysis (Suite A)
     - quarterly for 1 year for full analysis (Suite B); and

   - groundwater overflows to eastern cascade

     - daily sample when flowing for reduced analysis (Suite D); continue for 6 months or until 20 samples have been collected, after which the frequency should be reviewed.

5. The infiltration cells installed in 1989 should be reinstated for further monitoring at least for a year.

6. A regular walk-over inspection of the site should be undertaken to identify any leachate seepages entering surface waters.

Landfill gas

7. In addition to the existing drillholes including those holes converted from observation wells for monitoring leachate and groundwater, CED drillholes BH1 - BH13 and P1 to P8, as well as the manhole next to the refugee camp, should be monitored on a regular basis. Monitoring requirements are:

- monthly on-site monitoring of LFG for a year for soil gas pressure, % methane, % oxygen, % carbon dioxide and % LEL; and
- 24 bulk gas samples should be collected for laboratory confirmatory analysis.

8. Flammable gas alarms should be installed within the premises of CED and the landfill operation contractor for detection of any LFG ingress.

9. To further assess the effectiveness of bitumen coating in controlling LFG migration, 5 drillholes should be installed in each of the three periphery areas as given in Figure 2.4 of Working Paper WP6 for LFG monitoring at least one year as follows:

- monthly on-site monitoring of LFG for soil gas pressure, % methane (CH_4), % oxygen (O_2), % carbon dioxide (CO_2) and % LEL; and
- 12 bulk gas samples should be collected for laboratory confirmatory analysis.

10. To provide further information on the quality of extracted LFG, pumping for a continuous period of up to 6 months should be undertaken from a selected hole. Results will enable refinement of long term yields, and provide greater confidence to potential users that gas yields can be maintained.

Air

11. No additional air quality monitoring to that undertaken for this study is recommended.

Noise

12. No additional noise monitoring to that undertaken for this study is recommended.

Baseline Monitoring

Leachate, groundwater and surface water

13. Drillholes should be selected for baseline monitoring following 6 months of design monitoring. These drillholes should continue to be monitored for the baseline period as follows:

- Leachate and groundwater levels. Dip all drillholes monthly. Obtain bulk samples of leachate/groundwater every sixth month for full suite analysis (Suite A) .
- Leachate at V-notch weir in manhole in road. Continue flow monitoring and monitoring of quality once every month for full analysis (Suite A).
- Groundwater low flows, sampled from existing sump adjacent to eastern catchwater cascades channel. Continuous flow monitoring and monitoring of quality once per month for full analysis (Suite A).
- Groundwater overflow to eastern cascade. Install equipment for recording intermittent volumes of discharge. Aim to take 4 samples/year for full analysis (Suite A).

14. Existing surface water monitoring locations should be monitored as follows:

- Monitor monthly for Reduced Suite D*
- Monitor 3-monthly for Full Suite A*

* Add "suspended solids" to both of these suites.

Landfill gas

15. Off-site LFG probes and drillholes monitor monthly for % LEL, % CH_4, % CO_2, % O_2 using portable instruments, and take bulk samples once per year for bulk compositional analysis using gas chromatography. If developments occur within 50 m of any landfill, monitoring frequency should be increased to once per week, until landfill restoration has been completed. On-site building structures should be monitored continuously.

16. Gas concentrations should not exceed the following compliance objectives:

- CH_4 : 1% by volume or 20% LEL
- CO_2 : 1.5% by volume as upper limit
- O_2 : 18% by volume as lower limit

Air

17. Monitoring is recommended for TSP and RSP at two locations on the site boundary and at the Vietnamese Refugee Camp. Measurements should be made over a continuous 2 week period with 24 hour measurements and 3 x 1-hour measurements per day.

18. No additional odour or VOC monitoring to that undertaken for this study is recommended.

Noise

19. Baseline noise monitoring will be required at two locations near the northern boundary of the Vietnamese Refugee Camp and away from local noise sources so that the representative ambient noise level is recorded. If the restoration activities and afteruse at each landfill site give rise to noise during the period 07:00 hours to 19:00 hours only, it will only be necessary to make baseline measurements during this period. However, if noise from any site is anticipated between 19:00 hours and 23:00 hours, or between 23:00 hours and 07:00 hours, it will also be necessary to make baseline measurements during the other relevant period(s).

20. It will be necessary to repeat all measurements on a total of three occasions (three different days), at different times during the specified hours each for a 30 minute period.

Construction Monitoring

Leachate, groundwater and surface water

21. It is recommended that monitoring is conducted as for baseline monitoring, but at the following frequencies, i.e.:

- Leachate and groundwater levels. Dip all drillholes weekly. Obtain bulk samples of leachate/groundwater every two months for full suite analysis (Suite A) .
- Leachate at V-notch weir in manhole in road. Continue flow monitoring and monitoring of quality twice per month for full analysis (Suite A).
- Groundwater low flows, sampled from existing sump adjacent to eastern catchwater cascades channel. Continuous flow monitoring and monitoring of quality twice per month for full analysis (Suite A).

- Groundwater overflow to eastern cascade. Install equipment for recording intermittent volumes of discharge. Take samples twice monthly for full analysis (Suite A).

22. Existing surface water monitoring locations should be monitored as follows:

- Monitor twice monthly for Reduced Suite D*; and

- Monitor monthly for Full Suite A*.

  * Add "suspended solids" to both of these suites.

Target Limits should conform to the upstream water quality (W101) if it is unpolluted. In the absence of standards limits should be at 50 % above baseline recorded levels with Trigger and Action Limits set at 20 % and 30% above baseline levels respectively.

Landfill gas

23. All excavations, confined spaces and vent trenches, including any trenches required for interim control at PPVL, monitor continuously for the following compliance objectives:

- CH_4 : not to exceed 1% by volume or 20% LEL
- CO_2 : not to exceed 1.5% by volume
- O_2 : not to fall below 18% by volume

24. Monitoring during construction should aim to determine whether or not the restoration process is enhancing off-site gas migration with respect to baseline conditions, prior to any restoration work taking place. Monitoring should be conducted for each off-site and on-site gas monitoring probes and drillholes once per week. Compliance objective for each off-site probe and drillholes should be as follows:

25. Gas concentrations not to exceed the following:

- CH_4 : 1% by volume or 20% LEL above baseline level
- CO_2 : 1.5% by volume above baseline level
- O_2 : not to fall more than 3% by volume below baseline level

Air

26. Monitoring is recommended for TSP and RSP at two locations on the site boundary and at the Vietnamese Refugee Camp. Boundary locations should be selected to be at the nearest point to the restoration works. Measurements should be made continuously with 3 x 1-hour measurements per day and 24-hour measurements. The compliance objectives for dust monitoring are as follows:

- Hourly average TSP concentration at boundary not to exceed 500 $\mu g/m^3$; and

- 24-hour concentrations at sensitive receptors should not to exceed 260 $\mu g/m^3$ for TSP and 180 $\mu g/m^3$ for RSP.

27. These objectives should be treated as Target limits, where Trigger and Action limits should be determined from the baseline data taking into account natural variability of measured parameters. In any event, the 1-hour Trigger and Action limits for TSP at the site boundary should be no higher than 300 and 400 $\mu g/m^3$ respectively, and the 24-hour Trigger and Action limits at sensitive receptors should be 150 and 200 $\mu g/m^3$ respectively. For RSP levels the 24-hour Trigger and Action limits at sensitive receptors should no greater than 80 and 130 $\mu g/m^3$ respectively.

28. Odour monitoring should be carried out daily at the site boundary. Sampling for olfactometry testing to determine compliance with 2 odour limit is considered impractical to apply, and detection of odour at the boundary by non-construction

personnel is considered reasonable. In the event of odour detection, samples should then be taken for olfactometry testing to determine compliance with the objective.

29. VOC monitoring during the construction period should depend on the extent and duration of the restoration. The detailed requirements and frequency of monitoring should be established as part of the Detailed EIA to be carried out by the Restoration Contractor.

Noise

30. Locations for construction noise monitoring will generally be the same as those used for the baseline noise study.

31. Noise from general construction noise is covered by the Technical Memorandum as Noise from Construction Work Other than Percussive Piling. Although there are no controls for construction noise (other than piling) between 0700 hours and 1900 hours (Monday to Saturday, but excluding general holidays including Sundays) a Target Limit of 75 dB (A) should be applied, with Trigger and Action limits set according to baseline noise levels, accounting for natural variation. Where possible, construction noise should be no more than 10 dB (A) above baseline levels.

32. If construction takes place during the evening (1900 to 2300 hours) or night-time (2300 to 0700) hours the respective noise criteria of 60 dB (A) and 45 dB (A) (Area Sensitivity Rating A) at noise sensitive receptors should be applied.

33. Monitoring should be conducted in accordance with the Technical Memorandum Standard on Noise from Construction Work other than Percussive Piling on a continuous sound pressure level (Leq) over a 5 minute period. Noise measurements should be repeated over a representative 1-hour period during day, evening and night-time as appropriate every third day. The frequency of monitoring should be increased in the event of complaint.

34. Noise from percussive piling is dealt with in the Technical Memorandum on Noise from Percussive Piling. Although the need for percussive piling at construction sites is not envisaged, noise monitoring should be undertaken at each affected NSR in accordance with the Memorandum if percussive piling is carried out on a site. This will enable typical noise impacts at affected NSRs to be established at an early stage, and compliance with the relevant Technical Memorandum confirmed or denied. If compliance is not demonstrated, mitigation in terms of the hours of operation and/or numbers of items of plant operating concurrently, or in the form of acoustic screening will be required. In such cases, further monitoring will be required to establish compliance or otherwise with the Technical Memorandum.

Post-restoration Audit Monitoring

Leachate, groundwater and surface water

35. It is recommended that monitoring is conducted as for routine monitoring i.e.:

- Leachate and groundwater levels. Dip all drillholes monthly. Obtain bulk samples of leachate/groundwater every sixth month for full suite analysis (Suite A) .
- Leachate at V-notch weir in manhole in road. Continuous flow monitoring and monitoring of quality once per month for full analysis (Suite A).
- Groundwater low flows, sampled from existing sump adjacent to eastern catchwater cascades channel. Continuous flow monitoring and monitoring of quality once per month for full analysis (Suite A).
- Groundwater overflow to eastern cascade. Install equipment for recording intermittent volumes of discharge. Aim to take 4 samples/year for full analysis (Suite A).

36. Existing surface water monitoring locations should be monitored as follows:

- Monitor monthly for Reduced Suite D*; and
- Monitor 3-monthly for Full Suite A*.

* Add "suspended solids" to both of these suites.

37. Restoration works are expected to result in an overall decrease in surface and groundwater impacts. However, Target Limits should conform to the upstream water quality (W101) if it is unpolluted. In the absence of standards limits should be at 50 % above baseline recorded levels with Trigger and Action limits set at 20 % and 30% above baseline levels respectively.

38. It is recommended that the above monitoring frequencies be upheld for the first two years following completion of restoration and be reduced accordingly in the event of compliance with relevant standards and environmental performance criteria.

Landfill gas

39. Monitoring should continue at the same frequency as specified for routine monitoring prior to restoration. Gas composition, temperature, pressure extraction rate should be monitored weekly at the gas extraction pump. The well field, pipework and condensate disposal should be inspected in detail once every 3 months to check for deterioration and maintenance requirements.

Air

40. No significant air impacts are envisaged following site restoration and afteruse. It is not considered necessary that long term dust monitoring is continued during the post-restoration phase is required, but should be limited to quarterly measurements for 24-hour and 3 x 1-hour per day measurements over a six day period for the initial year following completion of restoration only. This should however be continued if dust levels are significantly above baseline levels for any reason.

41. Odour assessment along the site boundary is recommended on a quarterly basis. In the event of odour detection further samples should be taken for olfactometry tests for testing compliance with the 2 odour unit criteria.

42. VOC monitoring should be carried out, as a minimum, for compounds specified in Table 4.3, to ensure that concentrations are within acceptable limits. It is recommended that monitoring be undertaken, as a minimum, quarterly for three years at four locations at the landfill boundary and at two selected on-site or off-site locations.

43. The flare stack should be monitored annually to ensure compliance with standards specified in Table 4.13.

Noise

44. Noise will be generated by fixed noise sources including the landfill gas extraction plant, and by the leachate treatment plant. This equipment is located at the southern end of the site, relatively close to the only sensitive receptor, the Vietnamese Refugee Camp and will represent a steady and continuous noise source. In addition, sensitive receptors exposed to noise from the fixed leachate and landfill gas plant may exist within the restored site, and these too should be monitored.

45. Relevant standards for operational noise are provided in the Technical Memorandum for the Assessment of Noise from places other than Domestic Premises , Public Places or Construction Sites. Acceptable noise levels for the day/evening (0700 to 2300 hours) and the night-time (2300 to 0700 hours) periods are 60 dB (A) and 50 dB (A) respectively. Furthermore, Hong Kong Planning Guidelines recommend that noise levels should be 5 dB (A) below these specified levels, and that in the case of

background levels being 5 dB (A) lower than the specified levels the acceptable noise level should not be higher than background levels. On the basis of routine monitoring results, these background noise levels should be the defined Target Limit for operational noise.

46. It will be necessary to monitor noise at the chosen monitoring locations for a 30 minute period during the day/evening and night-time periods with all plant operating at full capacity, with care taken to ensure that extraneous noise sources do not affect measurements made. Wind direction should be noted, and noise levels should be measured on at least one occasion when the wind direction is from noise source to sensitive receptors.

47. It is considered that further noise monitoring will not be necessary unless particular items of plant are changed in the future, if the operating conditions alter significantly. If the relevant guidelines are exceeded, it will be necessary to reduce noise impacts by screening, or by modifications to the plant itself or its housings. Further noise monitoring will then be required to confirm compliance.

Settlement and slope stability

48. A general site survey should be undertaken at six monthly intervals to detect signs of slope failure or stress. Similarly, such surveys should be undertaken on a monthly basis to detect any settlement beyond anticipated rates presented in this report.

Appendix 5.2: Environmental Monitoring Requirements for SLSL

Design Monitoring

Leachate, groundwater and surface water

1. More information is needed on leachate flow rates and on leachate levels and quality within the landfill. In order to allow better assessment of the risks of basal leakage and to further monitor the quality of the leachate flowing to the filtration tanks, one additional drillhole by the western filtration tank is required, as well as two and three additional drillholes in the western and eastern areas respectively as shown in Figure 5.5 (Chapter 5). In addition to these new drillholes, all existing monitoring points (including a replacement hole for DH203A) for leachate and groundwater should be monitored as follows:

   - monthly for at least one year for level and quality for full analysis (Suite A); and
   - quarterly for at least one year for level and quality for full analysis (Suite B).

2. To further determine the design criteria for leachate treatment, locations L206 and L207 as shown in Figure 5.5 (the eastern and western filtration tanks respectively), should be analysed monthly for at least one year for full analysis (Suite B).

3. To quantify the flows for leachate treatment and disposal in wet and dry seasons, flow into each filtration tank (locations L206 and L207) should be measured and recorded continuously for at least one year.

4. Monitoring of the surface water quality should be continued for at least a year. The flow rate should be taken whilst water samples are being taken at the existing monitoring points for surface water (i.e. W201 and W204) as follows:

   - monthly for at least one year for the water flow and quality for full analysis (Suite A); and
   - quarterly for at least one year for the water flow and quality for full analysis (Suite B).

Landfill gas

5. In order to further assess the effectiveness of LFG control measures and the LFG migration, all existing monitoring points for LFG monitoring and those holes converted for LFG monitoring along the south boundary of the site (i.e. DH203A, DH204 and DH201) should be monitored on a monthly basis and supplemented with an occasional laboratory confirmatory test for landfill gas in composition.

Air

6. No additional air quality monitoring to that undertaken for this study is recommended.

Noise

7. No additional noise monitoring to that undertaken for this study is recommended.

Others

8. Permeability testing on the cap should also be done to allow a more accurate assessment of the leachate production rates. A structural assessment of the box culvert should be carried out to assess the physical condition and long-term integrity of the culvert. Settlement markers should also be monitored so as to verify whether settlement rates are greater than those recorded and predicted.

Baseline Monitoring

Leachate, groundwater and surface water

9. It is recommended that baseline monitoring at the site should be carried out as follows:

- monitoring of all drillholes for level readings at monthly intervals and sampling at six monthly intervals for full analysis (Suite A); and

- monitoring of surface waters at locations W201, W202, W203, and W204 with samples taken monthly for reduced analysis (Suite D) and every three months for full analysis (Suite A).

Landfill gas

10. Off-site LFG probes and drillholes monitor monthly for % LEL, % CH_4, % CO_2, % O_2 using portable instruments, and take bulk samples once per year for bulk compositional laboratory analysis. On-site building structures should be monitored continuously.

11. Gas concentrations should not exceed the following compliance objectives:

- CH_4 : 1% by volume or 20% LEL;

- CO_2 : 1.5% by volume as upper limit; and

- O_2 : 18% by volume as lower limit

12. If developments occur within 50 m of the landfill, monitoring frequency should be increased to once per week, until landfill restoration has been completed.

Air

13. Monitoring is recommended for TSP and RSP at two locations on the site boundary. Measurements should be made over a continuous 2 week period with 24 hour measurements and 3 x 1-hour measurements per day.

14. VOC monitoring during the construction period should depend on the extent and duration of the restoration. The detailed requirements and frequency of monitoring should be established as part of the Detailed EIA to be carried out by the Restoration Contractor.

Noise

15. As no sensitive receptors were identified within 250m of the landfill, no further baseline monitoring is recommended. However, if sensitive receptors are present at the time of restoration suitable monitoring, as described for PPVL should be undertaken to establish ambient noise levels.

Construction Monitoring

Leachate, groundwater and surfacewater

16. Construction monitoring should be undertaken as for baseline monitoring, with the following alterations:

- monitoring of drillholes DH201, DH203A, and DH204 should be increased with samples of groundwater taken monthly for reduced analysis (Suite D). All drillholes should be dipped on a monthly basis.

- monitoring of surface water at locations W201, W202, W203, and W204 with samples taken weekly for reduced analysis (Suite D*).

* Add "suspended solids" to this suites.

17. Target limits should conform to the upstream water quality (W201) if it is unpolluted. In the absence of standards limits should be at 50 % above baseline recorded levels with Trigger and Action limits set at 20 % and 30% above baseline levels respectively.

Landfill gas

18. All excavations, confined spaces and vent trenches should be monitored continuously for the following compliance objectives:

- CH_4 : not to exceed 1% by volume or 20% LEL;
- CO_2 : not to exceed 1.5% by volume; and
- O_2 : not to fall below 18% by volume

19. At each site where restoration is taking place, each off-site and on-site gas monitoring probe and drillhole should be monitored once per week. It should be recognised that there is already evidence of off-site gas migration in some drillholes and gas monitoring probes. Therefore, it is inappropriate to apply blanket compliance criteria to each monitoring location. Monitoring during construction should aim to determine whether or not the restoration process is enhancing off-site gas migration with respect to baseline conditions, prior to any restoration work taking place. Therefore, the following compliance objectives should apply during construction:

Gas concentrations not to exceed the following:

- CH_4 : 1% by volume or 20% LEL above baseline level;
- CO_2 : 1.5% by volume above baseline level; and
- O_2 : not to fall more than 3% by volume below baseline level

Air

20. Monitoring is recommended for TSP and RSP at two locations on the site boundary. Boundary locations should be selected to be at a suitable point close to the restoration works. Measurements should be made continuously with 3 x 1-hour measurements per day and 24-hour measurements. The compliance objectives for dust monitoring are as follows:

- Hourly average TSP concentration at boundary not to exceed 500 $\mu g/m^3$; and
- 24-hour concentrations at sensitive receptor not to exceed 260 $\mu g/m^3$ for TSP and 180 $\mu g/m^3$ for RSP.

21. These objectives should be treated as Target limits, where Trigger and Action limits should be determined from the baseline data taking into account natural variability of measured parameters. In any event, the 1-hour Trigger and Action limits for TSP at the site boundary should be no higher than 300 and 400 $\mu g/m^3$ respectively, and the 24-hour Trigger and Target limits should be 150 and 200 $\mu g/m^3$ respectively. For RSP levels 24-hour Trigger and Action limits should be no greater than 80 and 130 $\mu g/m^3$ respectively.

22. Odour monitoring should be carried out daily at the site boundary. Sampling for olfactometry testing to determine compliance with 2 odour limit is considered impractical to apply, and detection of odour at the boundary by non-construction personnel is considered reasonable. In the event of odour detection, samples should then be taken for olfactometry testing to determine compliance with the objective.

23. VOC monitoring during the construction period is not recommended. It is considered that adherence to the safety standards for LFG are more appropriate.

Noise

24. As no sensitive receptors were identified within a 250 m radius of the site, no construction monitoring is considered necessary. in the event that a sensitive receptor is present at the time of restoration suitable monitoring should be conducted as for PPVL.

Post-restoration and Audit Monitoring

Leachate, groundwater and surface water

25. It is recommended that monitoring be conducted as for baseline monitoring, but should also include continuous volume records of leachate removal, and monitoring of leachate quality for full analysis (Suite A) once every month.

26. Restoration works are expected to result in an overall decrease in surface and groundwater impacts. However, Target limits for surface water should conform to the upstream water quality (W201) if it is unpolluted. In the absence of standards limits should be at 50 % above baseline recorded levels with Trigger and Action limits set at 20 % and 30% above baseline levels respectively.

27. It is recommended that the above monitoring frequencies be upheld for the first two years following completion of restoration and be reduced accordingly in the event of compliance with relevant standards and environmental performance criteria.

Landfill gas

28. Following restoration and installation of LFG control system, further off-site migration of LFG will be prevented. Monitoring should continue at the same frequency as specified for routine monitoring. In some off-site locations, soil gas concentrations may already breach the above compliance standards following restoration, and allowance should therefore be made for the possibility that it may take many months, or possibly years, to dissipate by natural process such that uncontaminated natural background soil gas compositions are achieved, against which standards for compliance could be compared.

29. On-site passive gas vents and gas vents in perimeter venting trenches should be monitored monthly for % LEL, % CH_4, % CO_2 and % O_2 plus soil gas pressure to assess performance of gas control measures. In addition, annual bulk samples should be obtained for confirmatory laboratory analysis of gas composition. Sufficient bulk samples should be taken to represent about 10% of sampling points. It is inappropriate to assign compliance objectives to these monitoring points, but a routine annual audit of monitoring results should be undertaken to ensure gas control systems are functioning, and to identify any areas requiring maintenance/replacement.

Air

30. No significant air impacts are envisaged following site restoration and afteruse. It is not considered necessary that long term dust monitoring is continued during the post-restoration phase is required, but should be limited to quarterly measurements for 24-hour and 3 x 1-hour per day measurements over a six day period for the initial year following completion of restoration only at one selected sensitive receptor on-site. This should however be continued if dust levels are significantly above baseline levels for any reason.

31. Odour assessment along the site boundary is recommended on a quarterly basis. In the event of odour detection further samples should be taken for olfactometry tests for testing compliance with the 2 odour unit criteria.

32. VOC monitoring should be carried out, as a minimum, for compounds specified in Table 4.3 to ensure that concentrations are within acceptable limits. It is recommended

that monitoring be undertaken, as a minimum, quarterly for three years at four locations at the landfill boundary and at two selected on-site or off-site locations.

Noise

33. As landfill gas control will be by passive venting, and leachate will be removed from the site by tanker for treatment elsewhere there will be no on-site fixed noise sources. However, the go-kart circuit has the potential to generate significant noise and monitoring should therefore be conducted to ensure compliance with suitable noise standards at any identified sensitive receptor following restoration.

34. It is considered that noise standards provided in the Technical Memorandum for the Assessment of Noise from places other than Domestic Premises, Public Places or Construction Sites, should be applied rather than the less stringent traffic noise criteria given in the Hong Kong Environmental Planning Guidelines. Acceptable noise levels for the day/evening (0700 to 2300 hours) and the night-time (2300 to 0700 hours) periods are 60 dB (A) and 50 dB (A) respectively. These background noise levels should be the defined Target Limit for operational noise. The operation of the go-kart circuit should be suitably controlled so as not to contravene these noise limits at sensitive diurnal periods.

35. It will be necessary to monitor noise at the chosen monitoring locations for a 30 minute period during the day/evening periods with the go-kart circuit at full capacity, with care taken to ensure that extraneous noise sources do not affect measurements made. Wind direction should be noted, and noise levels should be measured on at least one occasion when the wind direction is from noise source to sensitive receptors.

36. It is considered that further noise monitoring will not be necessary unless the operating conditions alter significantly. If the relevant guidelines are exceeded, it will be necessary to reduce noise impacts by screening, or by the provision of secondary mitigation measures (e.g. double glazing). Further noise monitoring will then be required to confirm compliance.

Settlement and slope stability

37. A general site survey should be undertaken at six monthly intervals to detect signs of slope failure or stress. Similarly, such surveys should be undertaken on a quarterly basis to detect any settlement beyond anticipated rates presented in this report.

Appendix 5.3: Environmental Monitoring Requirements for MTLL

Design Monitoring

Leachate, groundwater and surface water

1. Further investigations to confirm the extent, source and significance of groundwater contamination under the sports field should be undertaken. It is considered that an additional four holes should be installed for the monitoring of groundwater quality and levels for at least one year. Water samples should be taken every month for full analysis (Suite A).

2. To refine the design of leachate treatment, existing monitoring drillholes including a replacement hole for DH309, should be routinely monitored for a period of at least one year for both groundwater quality and levels as follows:

   - monthly for at least one year for the water levels and quality for full analysis (Suite A); and

   - quarterly for at least one year for the water levels and quality for full analysis (Suite B).

3. To further assess the quantity of leachate intercepted through the existing leachate collection system, it is considered necessary to uncover, inspect and unblock the original 450mm pipe draining leachate from the landfill to the filtration tank and then connect it to a temporary holding tank at which the leachate flow and quality (monthly sampled for full suite B analysis) should be monitored for at least one year.

4. Monitoring of the surface water quality should be continued for at least a year. The flow rate should be taken whilst water samples are being taken at the existing monitoring points for surface water (i.e. W301 and W302a) as follows:

   - monthly for at least one year for the water flow and quality for full analysis (Suite A); and

   - quarterly for at least one year for the water flow and quality for full analysis (Suite B).

Landfill gas

6. In order to further assess the LFG migration, all existing monitoring points for LFG monitoring and two additional LFG monitoring drillholes along south-east boundary of the site as shown in Figure 6.4 (i.e. one between DH307 and DH305, one between DH305 and water sampling location W302b) should be monitored on a monthly basis and supplemented with an occasional laboratory confirmatory test for landfill gas composition.

7. Similarly, the groundwater monitoring wells DH309 and DH308 should be monitored for gas composition at depths of 5m, 10m and 15m below ground level on a monthly basis and supplemented with an occasional laboratory confirmatory test.

Air

8. No additional air quality monitoring is proposed beyond that undertaken for this study.

Noise

9. No additional noise monitoring is proposed beyond that undertaken for this study.

Baseline Monitoring

Leachate, groundwater and surface water

10. It is recommended that baseline monitoring at the site should be carried out as follows:

- monitoring of drillholes DH309, DH308, DH301, DH302, DH303, DH307, DH305, and DH304 should be dipped monthly, with six monthly samples taken for full analysis (Suite A); and

- monitoring of surface waters at locations W301, W302b, W302a, L301, and L302. Where flow is occurring, monitor monthly for reduced analysis (Suite D) and every 3 months for full analysis (Suite A).

Landfill gas

11. Off-site LFG probes and drillholes monitor should be monitored monthly for % LEL, % CH_4, % CO_2, % O_2 using portable instruments, bulk samples should be taken once per year for bulk compositional analysis using laboratory gas chromatography. On-site building structures should be monitored continuously.

12. Compliance objective for the above gas concentration not to exceed the following:

- CH_4 : 1% by volume or 20% LEL;

- CO_2 : 1.5% by volume as upper limit; and

- O_2 : 18% by volume as lower limit

13. If developments occur within 50 m of the landfill, monitoring frequency should be increased to once per week, until landfill restoration has been completed.

Air

14. Monitoring is recommended for TSP and RSP at two locations on the site boundary and at a residential sensitive receptor to the north-east or north-west of the site. Measurements should be made over a continuous 2 week period with 24 hour measurements and 3 x 1-hour measurements per day.

15. No additional odour or VOC monitoring to that undertaken for this study is recommended.

Noise

16. A number of noise-sensitive receptors exist within 250 metres of the designated consultancy zone boundary. These are identified as:

- community sports centre; and

- small-holdings to the north-east and north-west of the site.

17. Baseline noise monitoring will be required at these sensitive receptors, and away from local noise sources (e.g. local sawmill) so that the representative ambient noise level is recorded. If the restoration activities and afteruse at each landfill site give rise to noise during the period 07:00 hours to 19:00 hours only, it will only be necessary to make baseline measurements during this period. However, if noise from any site is anticipated between 19:00 hours and 23:00 hours, or between 23:00 hours and 07:00 hours, it will also be necessary to make baseline measurements during the other relevant period(s).

18. It will be necessary to repeat all measurements on a total of three occasions (three different days), at different times during the specified hours each for a 30 minute period.

Construction Monitoring

Leachate, groundwater *and surface water*

19. Construction monitoring should be carried out as follows:

- monitoring of drillholes as for baseline monitoring, except increase collection frequency of samples of groundwater (DH309, DH308, DH307, DH305, DH304) to monthly for reduced analysis (Suite D). Dipping of drillholes should be carried out on a monthly basis.

- monitoring of surface water, where flow is occurring, for all points for reduced analysis (Suite D)* on a weekly basis.

* Add "suspended solids" to this suite.

20. Target limits should conform to relevant standards and guidelines specified in the Technical Memorandum on Effluent Standards (see Appendix A1.5) where relevant. In the absence of standards limits should be at 50 % above baseline recorded levels with Trigger and Action limits set at 20 % and 30% above baseline levels respectively.

Landfill gas

21. All excavations, confined spaces and vent trenches should be monitored continuously for the following compliance objectives:

- CH_4 : not to exceed 1% by volume or 20% LEL
- CO_2 : not to exceed 1.5% by volume
- O_2 : not to fall below 18% by volume

22. Off-site gas monitoring probes and drillholes. There is already evidence of off-site gas migration in some drillholes and gas monitoring probes. Therefore, it is inappropriate to apply blanket compliance criteria to each monitoring location at each site. Monitoring during construction should aim to determine whether or not the restoration process is enhancing off-site gas migration with respect to baseline conditions, prior to any restoration work taking place. Therefore, the following compliance objectives should apply during construction.

23. At each site where restoration is taking place, monitor each off-site and on-site gas monitoring probes and drillholes once per week. Compliance objective for each off-site probe and drillhole as follows:

24. Gas concentrations not to exceed the following:

- CH_4 : 1% by volume or 20% LEL above baseline level
- CO_2 : 1.5% by volume above baseline level
- O_2 : not to fall more than 3% by volume below baseline level

Air

25. Monitoring is recommended for TSP and RSP at two locations on the site boundary and at two sensitive receivers off-site. Boundary locations should be selected to be at the nearest point to the restoration works. Measurements should be made continuously with 3 x 1-hour measurements per day and 24-hour measurements. The compliance objectives for dust monitoring are as follows:

- Hourly average TSP concentration at boundary not to exceed 500 $\mu g/m^3$; and

- 24-hour concentrations at sensitive receptor not to exceed 260 $\mu g/m^3$ for TSP and 180 $\mu g/m^3$ for RSP.

26. These objectives should be treated as Target limits, where Trigger and Action limits should be determined from the baseline data taking into account natural variability of measured parameters. In any event, the 1-hour Trigger and Action limits for TSP at the site boundary should be no higher than 300 and 400 $\mu g/m^3$ respectively, and 24-hour Trigger and Action limits at the sensitive receptors should be 150 and 200 $\mu g/m^3$ respectively. For RSP levels at the sensitive receptors 24-hour Trigger and Action limits should be no greater than 80 and 130 $\mu g/m^3$ respectively.

27. Odour monitoring should be carried out daily at the site boundary. Sampling for olfactometry testing to determine compliance with 2 odour limit is considered impractical to apply, and detection of odour at the boundary by non-construction personnel is considered reasonable. In the event of odour detection, samples should then be taken for olfactometry testing to determine compliance with the objective.

28. VOC monitoring during the construction period should depend on the extent and duration of the restoration. The detailed requirements and frequency of monitoring should be established as part of the Detailed EIA to be carried out by the Restoration Contractor.

Noise

29. Locations for construction noise monitoring will generally be the same as those used for the baseline noise study.

30. Noise from general construction noise is covered by the Technical Memorandum as Noise from Construction Work Other than Percussive Piling. Although there are no controls for construction noise (other than piling) between 0700 hours and 1900 hours (Monday to Saturday, but excluding general holidays including Sundays) a Target limit of 75 dB (A) should be applied, with Trigger and Action limits set according to baseline noise levels, accounting for natural variation. Where possible, construction noise should be no more than 10 dB (A) above baseline levels.

31. If construction takes place during the evening (1900 to 2300 hours) or night-time (2300 to 0700 hours) the respective noise criteria of 60 dB (A) and 45 dB (A) (Area Sensitivity Rating A) at noise sensitive receptors should be applied.

32. Monitoring should be conducted in accordance with the Technical Memorandum Standard on Noise from Construction Work other than Percussive Piling on a continuous sound pressure level (Leq) over a 5 minute period. Noise measurements should be repeated over a representative 1-hour period during day, evening and night-time as appropriate every third day. The frequency of monitoring should be increased in the event of complaint.

33. Noise from percussive piling is dealt with in the Technical Memorandum on Noise from Percussive Piling. Although the need for percussive piling at construction sites is not envisaged, noise monitoring should undertaken at each affected NSR in accordance with the Memorandum if percussive piling is carried out on a site. This will enable typical noise impacts at affected NSRs to be established at an early stage, and compliance with the relevant Technical Memorandum confirmed or denied. If compliance is not demonstrated, mitigation terms of the hours of operation and/or numbers of items of plant operating concurrently, or in the form of acoustic screening will be required. In such cases, further monitoring will be required to establish compliance or otherwise with the Technical Memorandum.

Post-restoration and Audit Monitoring

Leachate, groundwater and surface water

34. It is recommended that monitoring be conducted as for baseline monitoring, but should also include continuous volume records of leachate removal, and monitoring of leachate quality for full analysis (Suite A) once every month.

35. Restoration works are expected to result in an overall decrease in surface and groundwater impacts. However, Target limits for surface water should conform to the Technical Memorandum on Effluent Standards (see Appendix A1.5) where relevant. In the absence of standards limits should be at 50 % above baseline recorded levels with Trigger and Action Limits set at 20 % and 30% above baseline levels respectively.

36. It is recommended that the above monitoring frequencies be upheld for the first two years following completion of restoration and be reduced accordingly in the event of compliance with relevant standards and environmental performance criteria.

Landfill gas

37. Following restoration and installation of LFG control system, further off-site migration of LFG will be prevented. Monitoring should continue at the same frequency as specified for routine monitoring. In some off-site locations, soil gas concentrations may already breach the above compliance standards following restoration, and allowance should therefore be made for the possibility that it may take many months, or possibly years, to dissipate by natural process such that uncontaminated natural background soil gas compositions are achieved, against which standards for compliance could be compared.

38. On-site passive gas vents and gas vents in perimeter venting trenches should be monitored monthly for % LEL, % CH_4, % CO_2 and % O_2 plus soil gas pressure to assess performance of gas control measures. In addition, annual bulk samples should be obtained for confirmatory laboratory analysis of gas composition. Sufficient bulk samples should be taken to represent about 10% of sampling points. It is inappropriate to assign compliance objectives to these monitoring points, but a routine annual audit of monitoring results should be undertaken to ensure gas control systems are functioning, and to identify any areas requiring maintenance/replacement.

Air

39. No significant air impacts are envisaged following site restoration and afteruse. It is not considered necessary that long term dust monitoring is continued during the post-restoration phase is required, but should be limited to quarterly measurements for 24-hour and 3 x 1-hour per day measurements over a six day period for the initial year following completion of restoration only. This should, however, be continued if dust levels are significantly above baseline levels for any reason.

40. Odour assessment along the site boundary is recommended on a quarterly basis. In the event of odour detection further samples should be taken for olfactometry tests for testing compliance with the 2 odour unit criteria.

41. VOC monitoring should be carried out, as a minimum, for compounds specified in Table 4.3, to ensure that concentrations are within acceptable limits. It is recommended that monitoring be undertaken, as a minimum, quarterly for three years at four locations at the landfill boundary and at two selected on-site or off-site locations.

Noise

42. As landfill gas control will be by passive venting, and leachate will be removed from the site by tanker for treatment elsewhere there will be no on-site fixed noise sources. However, the on-site uses associated with the holiday camp have the potential to act as sensitive noise receptors to off-site noise sources and monitoring should be conducted to determine whether noise levels are within acceptable limits.

43. Relevant standards for operational noise are provided in the Technical Memorandum for the Assessment of Noise from places other than Domestic Premises , Public Places or Construction Sites. Acceptable noise levels for the day/evening (0700 to 2300 hours) and the night-time (2300 to 0700 hours) periods are 60 dB (A) and 50 dB (A) respectively. Furthermore, Hong Kong Planning Guidelines recommend that noise levels should be 5 dB (A) below these specified levels, and that in the case of

background levels being 5 dB (A) lower than the specified levels the acceptable noise level should not be higher than background levels. On the basis of routine monitoring results, these background noise levels should be the defined Target limit for on-site noise impacts.

44. It will be necessary to monitor noise at the chosen on-site monitoring locations for a 30 minute period during the day/evening and night-time periods during the presence of the dominant off-site noise source. Wind direction should be noted, and noise levels should be measured on at least one occasion when the wind direction is from noise source to sensitive receptors.

45. It is considered that further noise monitoring will not be necessary unless the off-site noise source conditions alter significantly. If the relevant guidelines are exceeded, it will be necessary to reduce noise impacts by screening, or by the provision of secondary mitigation measures (e.g. double glazing) to on-site receptors. Further noise monitoring will then be required to confirm compliance.

Settlement and slope stability

46. A general site survey should be undertaken at six monthly intervals to detect signs of slope failure or stress. Similarly, such surveys should be undertaken on a quarterly basis to detect any settlement beyond anticipated rates presented in this report.

Appendix 5.4: Environmental Monitoring Requirements for NTML

Design Monitoring

Leachate, groundwater and surface water

1. Further investigations and monitoring are needed in order to refine the design of the leachate management system. The flow and quality of leachate should be monitored at the outlet pipe from the filtration tank for a period of one year. Leachate sample should be taken on a monthly basis for the full analysis (Suite B).

2. Regular monitoring of the flow and water quality at existing monitoring point W401 and its downstream sampling point (Figure 7.5, Chapter 7) should be carried out for one year as follows:

   - monthly for the water flow and quality for full analysis (Suite A); and
   - quarterly for the water flow and quality for full analysis (Suite B).

3. Existing drillholes should be routinely monitored for one year. Water levels should be measured monthly, with samples obtained for quality analysis as follows:

   - monthly for 1 year for full analysis (Suite A); and
   - quarterly for 1 year for full analysis (Suite B).

4. Additional groundwater drillholes should be installed at the north-west and beneath the site in order to further assess the groundwater quality at different depth intervals during drilling. Water levels should be measured monthly, with samples obtained for full analysis (Suite A) for one year.

Landfill gas

5. Monitoring results to date indicate off-site occurrence of LFG at some locations, although not in the area of the sensitive western boundary. The extent of LFG migration has not been established. Therefore, it is recommended that additional gas monitoring probes be installed at locations shown in Figure 7.3, Chapter 7. Additional probes are included in the sensitive area proposed for housing. Monitoring of gas pressure and composition are required at least for a year on a monthly basis and should be supplemented with an occasional laboratory confirmatory test.

6. To further monitor the LFG migration, existing gas monitoring points and those leachate and groundwater holes converted for LFG monitoring should be monitored monthly for at least a year for gas pressure and composition and supplemented with an occasional laboratory confirmatory test.

Air

7. No additional air quality monitoring to that undertaken for this study is recommended.

Noise

8. No additional noise monitoring to that undertaken for this study is recommended.

Others

9. Permeability tests and chemical tests for action exchange capacity, clay mineral content, loss on ignition and carbonate content should be undertaken on core samples of the turf underlying the landfill.

Baseline Monitoring

Leachate, groundwater and surface water

10. Baseline monitoring should be undertaken as follows:

- monitoring should be undertaken for all drillholes with monthly level measurements and six monthly samples for full analysis (Suite A).
- monitoring of surface waters at location W401 (if flowing) monthly for reduced analysis (Suite D), and every three months for full analysis (Suite A).

Landfill Gas

11. Off-site LFG probes and drillholes monitor monthly for % LEL, % CH_4, % CO_2, % O_2 using portable instruments, and take bulk samples once per year for bulk compositional analysis using laboratory gas chromatography. On-site building structures should be monitored continuously.

12. Compliance objectives for the above gas concentration not to exceed the following:

- CH_4 : 1% by volume or 20% LEL;
- CO_2 : 1.5% by volume as upper limit; and
- O_2 : 18% oy volume as lower limit

13. If developments occur within 50 m of the landfill, monitoring frequency should be increased to once per week, until landfill restoration has been completed.

Air

14. Monitoring is recommended for TSP and RSP at two locations on the site boundary and at the closest residential sensitive receptor to the site. Measurements should be made over a continuous 2 week period with 24 hour measurements and 3 x 1-hour measurements per day.

15. No additional odour or VOC monitoring to that undertaken for this study is recommended.

Noise

16. Noise sensitive receptors (NSRs) in the vicinity of NTML has been identified as follows:

- residential properties to the north- west of the site;
- residential properties to the south- west of the site; and
- residential properties to the south of the site.

17. Baseline noise monitoring will be required at these sensitive receptors, and away from local noise sources so that the representative ambient noise level is recorded. If the restoration activities and afteruse at each landfill site give rise to noise during the period 07:00 hours to 19:00 hours only, it will only be necessary to make baseline measurements during this period. However, if noise from any site is anticipated between 19:00 hours and 23:00 hours, or between 23:00 hours and 07:00 hours, it will also be necessary to make baseline measurements during the other relevant period(s).

18. It will be necessary to repeat all measurements on a total of three occasions (three different days), at different times during the specified hours each for a 30 minute period.

Construction Monitoring

Leachate, groundwater and surface water

19. Construction monitoring should be undertaken as for baseline monitoring, with the following alterations:

- monitoring of drillholes (DH405, DH407, DH408, DH411, DH403, DH404) for groundwater monthly for reduced analyses (Suite D). All drillholes should be dipped on a monthly basis
- monitoring of surface water at location W401 (if flowing) weekly for reduced analysis (Suite D*)

* Add "suspended solids" to this suite.

20. Target limits should conform to relevant standards and guidelines specified in the Technical Memorandum on Effluent Standards (see Appendix A1.6) where relevant. In the absence of standards limits should be at 50 % above baseline recorded levels with Trigger and Action limits set at 20 % and 30% above baseline levels respectively.

Landfill gas

21. All excavations, confined spaces and vent trenches should be monitored continuously for the following compliance objectives:

- CH_4 : not to exceed 1% by volume or 20% LEL;
- CO_2 : not to exceed 1.5% by volume; and
- O_2 : not to fall below 18% by volume

22. There is already evidence of off-site gas migration in some drillholes and gas monitoring probes. Therefore, it is inappropriate to apply blanket compliance criteria to each monitoring location. Monitoring during construction should aim to determine whether or not the restoration process is enhancing off-site gas migration with respect to baseline conditions, prior to any restoration work taking place. Therefore, the following compliance objectives should apply during construction:

23. Gas concentrations should not exceed the following:

- CH_4 : 1% by volume or 20% LEL above baseline level;
- CO_2 : 1.5% by volume above baseline level; and
- O_2 : not to fall more than 3% by volume below baseline level

Air

24. Monitoring is recommended for TSP and RSP at two locations on the site boundary and at the nearest sensitive receptor. Boundary locations should be selected to be at the nearest point to the restoration works. Measurements should be made continuously with 3 x 1-hour measurements per day and 24-hour measurements. The compliance objectives for dust monitoring are as follows:

- Hourly average TSP concentration at boundary not to exceed 500 $\mu g/m^3$; and
- 24-hour concentrations at sensitive receptor not to exceed 260 $\mu g/m^3$ for TSP and 180 $\mu g/m^3$ for RSP.

25. These objectives should be treated as Target limits, where Trigger and Action limits should be determined from the baseline data taking into account natural variability of measured parameters. In any event, the 1-hour Trigger and Action limits for TSP at the site boundary should be no higher than 300 and 400 $\mu g/m^3$ respectively, and the 24-hour Trigger and Action limits at the sensitive receptors should be 150 and 200 $\mu g/m^3$ respectively. For RSP levels at the sensitive receptors Trigger and Action limits should be no greater than 80 and 130 $\mu g/m^3$ respectively.

26. Odour monitoring should be carried out daily at the site boundary. Sampling for olfactometry testing to determine compliance with 2 odour limit is considered impracticai to apply, and detection of odour at the boundary by non-construction personnel is considered reasonable. In the event of odour detection, samples should then be taken for olfactometry testing to determine compliance with the objective.

27. VOC monitoring during the construction period should depend on the extent and duration of the restoration. The detailed requirements and frequency of monitoring should be established as part of the Detailed EIA to be carried out by the Restoration Contractor.

Noise

28. Locations for construction noise monitoring will generally be the same as those used for the baseline noise study.

29. Noise from general construction noise is covered by the Technical Memorandum as Noise from Construction Work other than Percussive Piling. Although there are no controls for construction noise (other than piling) between 0700 hours and 1900 hours (Monday to Saturday, but excluding general holidays including Sundays) a Target limit of 75 dB (A) should be applied, with Trigger and Action limits set according to baseline noise levels, accounting for natural variation. Where possible, construction noise should be no more than 10 dB (A) above baseline levels.

30. If construction takes place during the evening (1900 to 2300 hours) or night-time (2300 to 0700 hours) the respective noise criteria of 60 dB (A) and 45 dB (A) (Area Sensitivity Rating A) at noise sensitive receptors should be applied.

31. Monitoring should be conducted in accordance with the Technical Memorandum Standard on Noise from Construction Work other than Percussive Piling on a continuous sound pressure level (Leq) over a 5 minute period. Noise measurements should be repeated over a representative 1-hour period during day, evening and nigh-time as appropriate every third day. The frequency of monitoring should be increased in the event of complaint.

32. Noise from percussive piling is dealt with in the Technical Memorandum on Noise from Percussive Piling. Although the need for percussive piling at construction sites is not envisaged, noise monitoring should be undertaken at each affected NSR in accordance with the Memorandum if percussive piling is carried out on a site. This will enable typical noise impacts at affected NSRs to be established at an early stage, and compliance with the relevant Technical Memorandum confirmed or denied. If compliance is not demonstrated, mitigation terms of the hours of operation and/or numbers of items of plant operating concurrently, or in the form of acoustic screening will be required. In such cases, further monitoring will be required to establish compliance or otherwise with the Technical Memorandum.

Post-restoration and Audit Monitoring

Leachate, groundwater and surfacewater

33. It is recommended that monitoring be conducted as for baseline monitoring, but should also include continuous volume records of leachate removal, and monitoring of leachate quality for full analysis (Suite A) once every month.

34. Restoration works are expected to result in an overall decrease in surface and groundwater impacts. However, Target limits should conform to relevant standards and guidelines specified in the Technical Memorandum on Effluent Standards (see Appendix A1.6) where relevant. In the absence of standards limits should be at 50 % above baseline recorded levels with Trigger and Action Limits set at 20 % and 30% above baseline levels respectively.

35. It is recommended that the above monitoring frequencies be upheld for the first two years following completion of restoration and be reduced accordingly in the event of compliance with relevant standards and environmental performance criteria.

Landfill gas

36. Monitoring should continue at the same frequency as specified for routine monitoring. In some off-site locations, soil gas concentrations may already breach the above compliance standards following restoration. Following restoration and installation of LFG control system, further off-site migration of LFG will be prevented. However, existing LFG in off-site probes and drillholes may take many months or possibly years to dissipate by natural process such that uncontaminated natural background soil gas compositions are achieved, against which standards for compliance could be compared.

37. On-site passive gas vents and gas vents in perimeter venting trenches should be monitored monthly for % LEL, % CH4, % CO2 and % O2 plus soil gas pressure to assess performance of gas control measures. In addition, annual bulk samples should be obtained for confirmatory laboratory gas chromatography analysis. Sufficient bulk samples should be taken to represent about 10% of sampling points. It is inappropriate to assign compliance objectives to these monitoring points, but a routine annual audit of monitoring results should be undertaken to ensure gas control systems are functioning, and to identify any areas requiring maintenance/replacement.

Landfill gas

38. Following restoration and installation of LFG control system, further off-site migration of LFG will be prevented. Monitoring should continue at the same frequency as specified for routine monitoring. In some off-site locations, soil gas concentrations may already breach the above compliance standards following restoration, and allowance should therefore be made for the possibility that it may take many months, or possibly years, to dissipate by natural process such that uncontaminated natural background soil gas compositions are achieved, against which standards for compliance could be compared.

39. On-site passive gas vents and gas vents in perimeter venting trenches should be monitored monthly for % LEL, % CH_4, % CO_2 and % O_2 plus soil gas pressure to assess performance of gas control measures. In addition, annual bulk samples should be obtained for confirmatory laboratory analysis of gas composition. Sufficient bulk samples should be taken to represent about 10% of sampling points. It is inappropriate to assign compliance objectives to these monitoring points, but a routine annual audit of monitoring results should be undertaken to ensure gas control systems are functioning, and to identify any areas requiring maintenance/replacement.

Air

40. No significant air impacts are envisaged following site restoration and afteruse. It is not considered necessary that long term dust monitoring is continued during the post-restoration phase is required, but should be limited to quarterly measurements for 24-hour and 3 x 1-hour per day measurements over a six day period for the initial year following completion of restoration only. This should however, be continued if dust levels are significantly above baseline levels for any reason.

41. Odour assessment along the site boundary is recommended on a quarterly basis. In the event of odour detection further samples should be taken for olfactometry tests for testing compliance with the 2 odour unit criteria.

42. VOC monitoring should be carried out, as a minimum, for compounds specified in Table 4.3, to ensure that concentrations are within acceptable limits. It is recommended that monitoring be undertaken, as a minimum, quarterly for three years at four locations at the landfill boundary and at two selected on-site or off-site locations.

Noise

43. As landfill gas control will be by passive venting, and leachate will be removed from the site by tanker for treatment elsewhere there will be no on-site fixed noise sources. The afteruse option of a baseball field and associated facilities is not envisaged to arise in significant noise emissions and afteruse noise monitoring is not considered necessary at the site. However, in the event of noise complaint noise monitoring should be conducted as for SLSL.

Settlement and slope stability

44. A general site survey should be undertaken at six monthly intervals to detect signs of slope failure or stress. Similarly, such surveys should be undertaken on a quarterly basis to detect any settlement beyond anticipated rates presented in this report.

APPENDIX 6

ANALYSIS SUITES FOR LEACHATE, GROUNDWATER AND SURFACE WATER

Appendix 6: Analysis Suites for Leachate, Groundwater and Surface Water

Analysis Suite	Determinands
1. Suite A Full Analysis	Sanitary Parameters: pH, TOC, COD, BOD, NH_3-N, TKN, NO_x-N, orthophosphate, temperature Major ions: Na, K, Ca, Mg, Cl, SO_4, alkalinity (as $CaCO_3$) Metals: Fe, Mn, Zn, Cu, Ni, Cr, Pb, Cd
2. Suite B Full Analysis	Sanitary Parameters: pH, TOC, COD, BOD, NH_3-N, TKN, NO_x-N, orthophosphate, temperature Major ions: Na, K, Ca, Mg, Cl, SO_4, alkalinity (as $CaCO_3$) Metals: Fe, Mn, Zn, Cu, Ni, Cr, Pb, Cd Additional Parameters: suspended solids, settleable solids, oil & grease, B, Ba, Hg, Ag, CN^-, phenol, S, surfactants (total), E.coli
3. Suite C Reduced Analysis	NH_3-N, Cl, COD, EC, alkalinity (as $CaCO_3$)
4. Suite D Reduced Analysis Suite	Sanitary Parameters: pH, TOC, COD, BOD, NH_3-N, TKN, NO_x-N, orthophosphate, temperature Major ions: Na, K, Ca, Mg, Cl, SO_4, alkalinity (as $CaCO_3$)

APPENDIX 7

MONITORING PROTOCOLS

Appendix 7: MONITORING PROTOCOLS

Monitoring Protocol - Dust

1. Air quality monitoring should be undertaken prior to and during restoration of the landfills to ensure that the 500 $\mu g/m^3$ (hourly average) TSP air quality guideline and Hong Kong AQO's for total suspended particulates and respirable suspended particulates (TSP and RSP) are not exceeded.

2. Monitoring of dust should be carried out prior to the commencement of the Initial Works until the last Certificate of Completion to determine dust levels at sensitive receptors. and include a suitable sampling period for the determination of baseline TSP and RSP levels according to Appendix 5.

3. TSP and RSP should be collected using a high volume sampler whose performance specification complies with that required by USA Standard Title 40, Code of Federal Regulations Chapter 1 (Part 50). The RSP fraction shall be collected by the use of an appropriate assembly attached to the sampler.

4. The Contractor should ensure that the flow rate of the high volume sampler is set in accordance with the manufacturer's instructions prior to commencing the sampling to within the range recommended in USA Standard Title 40, Code of Federal Regulations Chapter 1 (Part 50). The flow rate should also be checked after the monitoring period and any change from the original setting noted.

5. A direct reading dust meter capable of achieving a comparable result as that of a high volume sampler may be used for 1-hour sampling.

6. Monitoring of dust should be carried out in accordance with the following documents:

   - *Code of Federal Regulations Chapter 1 (Part 50) Appendix B and J, USA Standard Title 40.*

   - *Air Quality Objectives (AQOs), Hong Kong Government.*

   - *Environmental Monitoring and Audit: Guidelines for Dust Monitoring, Hong Kong Government*

7. Two air sampling locations shall be sited at the site boundary. Locations shall depend upon:

   - meteorological conditions (particularly the prevailing wind characteristics) at the time of sampling;
   - the location of dust generating activities on the site (construction phase only); and
   - the location of the nearest sensitive receptors likely to be affected.

   For each sampling location, two samplers (one for TSP and one for RSP) should be placed at least 2 metres apart. A minimum of 2 metres of separation from walls, parapets, and penthouses is required for rooftop samplers. Likewise a minimum of 2 metres of separation from any supporting structure measured horizontally shall be observed such that an unrestricted airflow is maintained around the samplers.

8. Monitoring at each locations shall comprise the collection of a continuous 24 hours duration over a continuous 2 week and 3 x 1-hour measurement per day for the routine monitoring. During the period of construction, measurements should be made continuously with 3 x 1-hour measurements per day and 24-hour measurements. If it is required, 3 x 1-hour per day of dust measurement with a frequency of once in every six days and 24-hour measurement once every three months for the initial year following completion of restoration. For the 1-hour monitoring, three times for every day at the highest dust impact occasion should be observed.

Reporting

9. In recording the results, the following information relating to the monitoring shall be presented:

- Site name;
- Details of the assessment point, including its location, distance from the landfill activity being monitored, description of intervening topography, height above ground level and distance from any buildings or other influencing structures;
- Weather conditions, including wind speed and direction, and (in the case of long-term monitoring) rain, mist and fog;
- The location and/or source under investigation;
- Details of equipment used, including the manufacturer, model/type, serial number and date of last full calibration by an accredited laboratory;
- Flow rate before and after measurements;
- The date and time period over which the monitoring was undertaken;
- The laboratory report which is to include details of all weightings and the methodology used;
- The measured TSP and RSP levels to be expressed in terms of $\mu g/m^3$;
- Any other information likely to be appropriate (eg presence of other dust sources during the monitoring period, activities at the site not representative); and
- The name(s) of the monitoring personnel.

Monitoring Protocol - Noise

10. Noise monitoring will be required for determining ambient noise levels prior to the commencement of restoration and during the restoration and afteruse phases of the development. By conducting regular monitoring, it can be determined as to whether the landfilled areas are continuing to comply with environmental and safety objectives established and whether any deterioration in the integrity of the restoration work is taking place in order that remedial action may be taken.

11. Monitoring during baseline period should be conducted at two locations close to the site boundary and the nearest noise sensitive receptors (NSRs) for each restoration site according to Appendix 5, with LAeq (30 min) noise measurements taken over the day/evening (0700 to 1900 hours) and night period (2300 to 0700 hours) at different times during the specified hours on three separate days.

12. Monitoring requirements during construction monitoring should be, minimally, the noise measurement of daytime LAeq (5 min) should be carried out over a representative 1-hour period during day, evening and night-time as appropriate every third day at affected NSR in accordance with the Technical Memorandum.

13. Monitoring during the operational phase of the restoration should ensure that noise emissions from adjacent land uses are not causing excessive problems on the site and that noise generating activities on site do not constitute a nuisance to site users or those off-site. It is recommended that noise monitoring (LA_{eq} (30 mins)) takes place at the sensitive on-site uses of each of the sites, in the direction of the dominant noise source and at sensitive receivers at each landfill site. The monitoring period should be included the time period during the day/evening and night-time periods with all plant operating at full capacity. Monitoring should be undertaken, minimally on a quarterly basis.

14. Sound level meters used by the Contractor shall comply with Type 1 specifications given in International Electrical Commission (IEC) publications 651:1979 and 804:1985. Calibration equipment to be used on Site shall meet IEC 942, Type 1 specifications.

15. Other measuring and analysis instrumentation used shall be of a comparable professional quality. Only microphones giving a free-field response shall be used for noise monitoring. Wherever necessary, the equipment shall be protected against moisture. For long-term monitoring, the equipment shall be kept in a weather-proof case and an appropriate outdoor microphone unit shall be used. Equipment shall be used in accordance with manufacturer's instructions and, in all instances, shall be treated with care.

16. The Contractor shall ensure that noise monitoring equipment used is calibrated at least annually by an accredited calibration laboratory for compliance with the appropriate parts of IEC publications 651 and 804 (and any other relevant national standard). On-Site calibration equipment shall similarly be tested for compliance with IEC 942.

17. Immediately prior to, and following each noise measurement, the accuracy of the sound level meter shall be checked using an acoustic calibrator generating a known sound pressure level at a known frequency. In carrying out this procedure, the necessary barometric pressure corrections shall be applied. In cases of long-term monitoring, the accuracy of the noise monitoring system shall be similarly checked on at least a daily basis. Measurements may be accepted as valid only if the calibration levels before and after the noise measurement agree to within 1.0 dB.

18. Noise measurement equipment and necessary accessories (such as windshields and tripods) shall be carefully looked after and properly maintained. Prior to noise measurements being undertaken, appropriate checks shall be made to ensure that all such equipment and the necessary power supply are in good working order.

19. Monitoring of noise shall be carried out with reference to the following documents:

Technical Memorandum on the Assessment of Noise from Construction Work other than Percussive Piling, Hong Kong Government.

How to Apply for a Construction Noise Permit, Hong Kong Government.

Technical Memorandum for the Assessment of Noise from Places other than Domestic Premises, Public Places or Construction Sites, Hong Kong Government.

20. Where a measurement is carried out at a building, the assessment point shall be at a position 1 m from the exterior of the building facade at a height of at least 1.2 m above ground level. Where a measurement is to be made of noise being received at a place other than a building, the assessment point shall be at least 1.2 m above ground level, at an appropriate point. In choosing the appropriate point, the measurement position shall be at least 3.5 m from any reflecting surface other than the ground and shall be chosen to give as unobstructed view as possible of the landfill Site. In such cases of free-field measurement, a negative correction of 3dB(A) shall be applied to the performance criteria quoted in Appendix 5.

21. The microphone of the sound level meter shall be so oriented that it is pointing at the source of noise being monitored such that the microphone diaphragm is perpendicular to the plane of the incident sound waves. It shall be protected using an appropriate windshield. To avoid reflections from the operator's body, the microphone shall be mounted on a tripod, whether attached to the sound level meter or not.

22. The time of day and period of the monitoring shall be appropriate for the exercise and all reasonable steps shall be taken to ensure that the restoration or afteruse phase being measured are truly representative of the activities at the facility.

23. Any noise measurement shall be made in terms of the A-weighted equivalent continuous sound pressure level (L_{Aeq}). Noise measurements shall be carried out with an integrating sound level meter using the "fast" response mode. Noise measurements shall be taken over a 30-minute period, as defined in the "Technical Memorandum for the Assessment of Noise from Places other than Domestic Premises, Public Places or Construction Sites" or 5-minute period as defined in the "Technical Memorandum on Noise from Construction Work other than Percussive Piling".

24. Noise measurements shall be rounded to the nearest whole dB, with values of 0.5 dB or more being rounded upwards.

25. Noise measurements shall not be made in the presence of mist, fog or rain or with wind at a steady speed exceeding 5 m/s, or gusts exceeding 10 m/s.

26. Measurements shall not be made during temperatures outside the range recommended by the equipment manufacturers.

27. Noise measurements shall not be made when other intrusive noise sources (other than Influencing Factors) are apparent at the assessment point. If this cannot be practically avoided, due account shall be made of such sources in the assessment procedure.

Reporting

28. In recording the results, the following information relating to the monitoring shall be presented:

- Site name;
- The area of the Site and/or source and/or activity under investigation;
- The date and time period over which the monitoring was undertaken;
- Details of the assessment point, including its location, distance from the landfill activity being monitored, description of intervening topography, height above ground level and distance from any reflecting surface;
- Weather conditions, including wind speed and direction, rain, mist and fog;
- Details of equipment used, including the manufacturer, model/type, serial number and date of last full calibration by an accredited laboratory;
- Equipment settings;
- Calibration levels before and after measurements;
- Battery voltage before and after measurements;
- Presence of Influencing Factors;
- The name of the sampling technician; and
- Any other information likely to be appropriate (eg presence of other noise sources during the monitoring period, activities at the site not representative).

29. In presenting the results, the Contractor shall demonstrate that the noise levels obtained are reasonable having regard to the activity being monitored. This may be done by (a) comparison with previous studies at the assessment point of the same activity or (b) by

predicting the likely noise level using the information and procedures detailed in the "Technical Memorandum for the assessment of Noise from Places other than Domestic Premises, Public Places or Construction Sites."

Monitoring Protocol - Landfill Gas

30. Additional monitoring was recommended in previous Working Papers. Specific monitoring will be required to assess the effectiveness of the gas management and utilisation systems installed at the PPVL Appropriately spaced drillholes will need to be regularly sampled to allow for the early detection of any LFG migration which may constitute a safety/environmental risk to nearby developments or to uses on the restored sites.

31. Before and during the restoration phase, continuous monitoring for landfill gas will be required in the existing LFG monitoring points and in the vicinity of gas-venting trenches (if any), to check compliance with performance criteria given in Appendix 5. Regular sampling should also be conducted on a weekly basis of peripheral drillholes and on-site probes following the emplacement of the landfill cap during the restoration phase.

32. During the operational phase routine monitoring of LFG should continue at the same frequency as specified for routine monitoring prior to restoration. In addition, routine monitoring of ambient LFG over the cap is considered necessary to detect any vertical migration of gas. Walkover surveys on a six monthly basis were recommended over the general cap area with three monthly walk-overs adjacent to passive gas venting trenches. Peripheral drillholes should be monitored on a monthly basis during the afteruse phase, where bulk gas samples are taken on a yearly basis for verification purposes. Quarterly monitoring of internal building structures was recommended for the detection of LFG accumulation, in addition to the installation of LFG detection systems where necessary. Provisions for monitoring of underground structures (e.g. manholes, drainage systems), upon the commencement of any maintenance work were also made to detect LFG accumulation. Any underground structures or manholes would be routinely inspected on a monthly basis, and again before any underground work commences to check for the presence of LFG. If necessary areas should be fully ventilated prior to work commencing and workers should receive appropriate breathing apparatus. In the event of excessive concentrations of LFG being detected, then investigation should be initiated to trace the source of the gas.

33. Equipment used under field conditions should be of a robust and weatherproof design and such that readings do not change significantly if the instrument is tilted. Where flammable gas concentrations could be encountered, the Contractor should ensure that the equipment is intrinsically safe.

34. The Contractor should ensure that the equipment used is designed in such a way as to reduce the effect of humidity and temperature changes to 2% of full scale deflection.

35. Where methane levels below the Lower Explosive Limit of methane in air (LEL) are expected the detectors used for monitoring should operate on the principle of catalytic combustion. For higher methane concentrations, the detectors used should operate on the principle of thermal conductivity.

36. For methane and oxygen measurement, monitors used for gas detection should be the Gas Measurement Instruments (GMI) Oxygen Gascoseeker or Gas Surveyor or similar approved by the Employer. For pressure measurements the Air Neotronics Micromanometer or similar approved should be used.

37. For carbon dioxide measurement, monitors used for gas detection should operate on the principle of Infra Red. A detector such as the LFG10 manufactured by Analytical Development Company or similar approved by the Employer should be used for this purpose.

38. As an alternative to the above, the Contractor may monitor gas composition with the permanent monitoring holes and piezometers using an automated sampling/gas detection system certified by the Independent Consultants and subject to the Employer's consent.

39. The Contractor should measure surface emissions of landfill gas at the ground surface, on-site in enclosed spaces and manholes and off-site at ground level as part of the assessment of vegetation stress. A Flame Ionisation Detector such as Gastec manufactured by Research Engineers Limited or similar acceptable system should be used for this purpose.

40. The Contractor should monitor buildings for the presence of landfill gas within the Site where daily or continuous measurements are required using a permanent gas detection system. The Contractor should ensure that the following Design criteria are met by the detection system:

- Detector heads should be located within all Site buildings. The locations should be concentrated close to service entry points or other areas where gas ingress or gas accumulation may occur. The detectors should have two preset alarm levels and should be fitted with audible alarms.

- There should be a main control box which houses the individual control cards for each detector head. These should indicate the concentrations of methane being detected at each detector head which require to be manually reset following triggering.

- A central control panel which should alert Site personnel, visually and with an audible alarm, when the gas concentration at any detector reaches one of the threshold levels, should be located in the office of the agent responsible for Operation or another Site building which is continually occupied.

- The system should include an auto dial-out facility to enable appropriate personnel to be alerted if detectors are triggered outside the hours of Operation.

- The alarm system should have a sensitivity of detecting methane of a concentration not higher than 1% by volume.

41. Stainless steel gas cylinders, glass gas bombs or 10 litre Tedlar bags should be used to obtain landfill gas samples for Gas Chromatography analysis, with appropriate analytical detector. For bulk gas component analysis, flame ionisation detectors would be an acceptable method, except for carbon dioxide analysis where a thermal conductivity detector should be used.

42. The Contractor should follow the manufacturer's recommendations for calibration and maintenance. Notwithstanding this requirement, instruments should be calibrated and maintained by the manufacturer at least once every 6 months. In addition, gas detection equipment should be checked with calibration gas before and after use and any deviation of the readings from within the stated accuracy for the appropriate range should be noted with the results and the instrument calibration corrected.

43. For gas detectors installed within buildings, a six monthly calibration by the manufacturer should be undertaken.

44. Monitoring of landfill gas should be carried out in accordance with the following documents:

Waste Management Paper 27 : The Control of Landfill Gas; HMIP 1989

Measurement of Gas Emissions from Contaminated Land, UK Building Research Establishment Report 1987

Health and Safety Executive (HSE) EH 40/93 Occupational Exposure Limits

45. The Contractor should undertake landfill gas monitoring using suitably competent and trained staff.

Surveys of surface gas emissions

46. The Contractor should undertake the gas survey concentrating on areas identified as being particularly at risk from occurrence of gas emissions. A walkover survey should be undertaken at a slow pace with the inlet tube of the meter probe a few centimetres only above ground level. Measurements should be taken in areas off-site where there is visible vegetation stress or die back which may be caused by depletion of soil oxygen and accumulation of toxic gases or vapours in the root zone, together with on-site in cracks or areas of settlement, surface drains, subsurface service entries to buildings and any other enclosed spaces. The Contractor should note that flame ionisation detectors are not intrinsically safe and should not be used in areas where naked flames are prohibited. They should not be used in confined areas or buildings without first checking for the presence of flammable gases using intrinsically safe instruments.

Monitoring of monitoring hole and piezometer installations

47. Monitoring of the efficiency of the gas control system both within and beyond the Permitted Waste boundary should be achieved by monitoring holes and piezometers along the boundaries.

48. The Contractor should monitor pressure at any installation where methane was present on the previous monitoring occasion. Monitoring of pressure should be followed by methane, oxygen, and carbon dioxide for the purpose of accuracy and safety.

49. Zero checks should be carried out on 10% LEL and any other scales at the bottom of the range which can be adjusted on the instrument itself. Oxygen should be checked on arrival on site and on every occasion when readings less than 20% oxygen are obtained. These checks should be carried out in fresh air, away from any possible gas emissions. Where gas is detected, the instrument should be completely pumped through with fresh air between readings.

50. Portable instruments are particularly susceptible to water ingress. Where there is any possibility of the presence of water within the sampling point the instrument should be held well above the monitoring point to reduce the chance of water reaching the inlet port. Where the instrument is hand pumped and where the bulb will not inflate, the inlet tube should be immediately disconnected to prevent water being drawn up the sample tubing.

Surveys of Site Buildings and other confined spaces

51. Procedures should be set up for investigating gas ingress into site buildings, manholes, trenches, below ground utilities and ductings or other confined spaces where the lower gas threshold of 10% LEL is reached and for evacuation where the upper gas threshold of 20% LEL is reached.

Analysis Suites

52. The Contractor should monitor the following parameters relating to surface gas emissions:

- Methane
- Flammable Gas

53. The Contractor should monitor the following parameters in monitoring holes and piezometer installations using portable equipment:

- Pressure (within installations, relative to atmospheric pressure)
- Methane

- LEL
- Carbon dioxide
- Oxygen

54. The Contractor should collect and submit bulk gas samples from monitoring holes for confirmatory laboratory analysis by gas chromatography for the following parameters:

- Methane
- Carbon dioxide
- Oxygen
- Nitrogen
- Hydrogen
- Flammable gas
- Carbon monoxide

Frequency of Sampling

55. The frequency of monitoring should be according to Appendix 5 and should be increased during any of the following situations:

- Increase in gas pressure or quality found during routine monitoring;
- Control systems being amended by the Contractor;
- Capping of part or all of the Site;
- Pumping of leachate ceases or starts, or leachate levels rise within the Permitted Waste;
- Extremities of climate (eg barometric pressure dropping rapidly). This can significantly affect gas migration; and
- Building development taking place on or adjacent to the Site. Additional monitoring points should probably be required if this occurs.

Reporting

Surface Emissions

56. The Contractor should monitor the background concentrations of parameters in the ambient air on and in the vicinity of the site. As flame ionisation detectors are not specific to methane, the Contractor should take care with the interpretation of the results and notes should be made of all possible sources of flammable hydrocarbons wherever positive readings are obtained. Where fluctuating readings are obtained, for instance where air movement cannot be eliminated, the results should be noted as a range, or specified as maximum peak readings. For the quarterly surveys of vegetation stress beyond the site boundary, measurements of surface emissions obtained should be noted together with a description of the location, type of vegetation and stress observed.

Permanent gas detection system

57. The Contractor should record any events which involve triggering of any detector head. These should be downloaded from the gas detection system software into the environmental monitoring data-base.

Monitoring holes and piezometers

58. The Contractor should record all results, stating the manufacturer's stated accuracy for each scale. Readings at the bottom of the scale should be recorded not as 0 but as <1% or <0.5%

LEL, as appropriate, according to the accuracy of that scale. Results should be recorded as peak, steady, rising or falling. As a number of parameters should be monitored on each occasion from each installation, the parameter and appropriate scale (ie. LEL or % methane by volume) should be clearly recorded in separate columns. Units should be stated clearly on tables used for recording the results and these should be consistent throughout the monitoring period. The type, model and serial number of instruments used for monitoring should be recorded with each set of results. In addition, the results obtained when calibrating each instrument following use should be recorded. Although on site, it may be more practical to record the monitoring results on paper, these should be transferred regularly to the Contractor's Site computer system containing the environmental database.

Monitoring Protocol - Landfill Gas Flare Stack

59. It should be specified that three ports are inserted into the side of the flare at various levels. A stainless steel and neoprene sampling line should be used to ensure no reactions with flare gas exhaust emissions. The sample should be taken using a pump and analysis by:

- a portable hand held equipment - bulk gases
- flame ionisation (portable on-site equipment)
- mass-spectrometer/gas chromatography.

Monitoring should ensure compliance, as a minimum but not limited to, the recommended flare emission standards used as the basis for the Initial Environmental Impact Assessment. The detailed monitoring requirements could be established by the Restoration Contractor as part of the Detailed Environmental Impact Assessment. Compliance monitoring should be carried out on a weekly basis for the first 2 months of operation, and thereafter at 3-month intervals.

Reporting

60. In recording the results, the following information relating to the monitoring shall be presented:

- Site name;
- Weather conditions;
- The location and/or source under investigation;
- Details of equipment used, including the manufacturer, model/type, serial number and date of last full calibration by an accredited laboratory;
- Instrument calibration details;
- The date and time period over which the monitoring was undertaken;
- The laboratory report and the methodology used;
- The measured pollutant levels to be expressed in terms of mg/m^3 at 3 vol% O_2 (dry;
- Any other information likely to be appropriate (eg flare performance); and
- The name(s) of the monitoring personnel.

Monitoring Protocol - Odour

61. The principal problem of odour monitoring is the characterisation and perception of odour and the wide range of individual sensitivities that are experienced in smelling them. In the case of refuse odours, these can arise from a combination of chemicals which can have additive, synergistic or suppressant effects. Instrumental methods for low level odour detection may also be less sensitive than the human nose. The identification of the precise refuse related malodorous compound is therefore difficult and costly.

62. The environmental performance criteria (see Appendix 5) stipulates that a level of 2 odour units shall not be exceeded at the site boundary during the operational and afteruse phase, superimposed on any prevailing ambient odour. Odour monitoring should be conducted on a weekly basis during the restoration phase and quarterly during the afteruse phase, or more frequently upon receipt of any odour complaints.

63. The contractor should employ an independent consultant to undertake regular patrols and sensing of the site boundary followed by recording and reporting of the results and their likely source. Any necessary remedial actions can then be implemented. Odour patrols by operating personnel should be avoided as their perception of the odour would be masked by odour fatigue from their frequent work exposure.

64. Compliance monitoring of persistent odour incidents should be conducted using EPD's odour panel monitoring approach.

Monitoring Protocol - VOC For Ambient Air

65. Monitoring for ambient concentrations of volatile organic compounds (VOCs) which originate from Permitted Waste deposited in the landfill shall be carried out with reference to the following documents:

Brookes B I and Young P J, The Development of Sampling and Gas Chromatography and Mass Spectrometry Analytical Procedures to identify and Determine the Minor Organic Components of Landfill Gas, Talanta, Vol 30, No 9, pp 665 - 676.

Young P J and Parker A, Vapours, Odours and Toxic Gases from Landfills, Proceedings of ASTM International Symposium of Industrial and Hazardous Waste, March 1983.

Scott P E, The Characterisation and Identification of Potentially Toxic and Odorous Trace Components in Landfill Gas, Waste Research Unit, Environmental Safety Centre, AEA Technology Harwell, March 1990.

Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air, Environmental Monitoring Systems Laboratory, 1989, USEPA.

Testing Guidelines for Active Solid Waste Disposal Sites, 1986, Air Resource Board, State of California.

66. On each monitoring occasion, as a minimum requirement, four sample locations including upwind and downwind ambient air sampling sites at the landfill boundary and the likely affected air sensitive receivers (ASRs) shall be selected. In addition, ambient air shall be collected, as a minimum requirement, at 2 facilities/locations opened to the public within the restored landfills having maximum predicted air toxic levels and high utilization rates. Representative sample of LFG shall also be collected from gas collection system or in-site boreholes for analysis of VOCs and methane. The monitoring locations chosen shall depend upon the following factors (to be logged on each sampling occasions).

- The location and sources of VOC emissions from the site.
- The proximity of vehicular traffic whose exhaust emissions would interfere with the monitoring results.
- The location of the nearest sensitive receivers likely to be affected.
- Weather conditions, particularly the prevailing wind direction, at the time of sampling. No sampling is allowed during rain.

67. The monitoring locations shall be located as close as possible to the breathing zone, be adequately secured and free from interference likely to affect the collection efficiency of the VOCs.

68. The measurement technique for VOCs shall be adsorption tubes containing a solid/charcoal trapping medium. For ethanethiol and butanethiol the equipment specified in the National

Institute for Occupational Safety and Health (NIOSH) Method 2525 shall be used. For methanethiol the equipment specified in the Occupation Safety and Health Administration (OSHA) Method 26 shall be used. Methane shall be trapped using a low flow-rate pump to capture ambient air in a Tedlar bag for direct analysis on a gas chromatography.

69. The sampling methodology for the VOCs shall be based on established and validated procedures related to the type and quantity of adsorption material used and the required detection limits. The sampling volume and flow rate shall be related to the type and quantity of adsorption material used. The air flow rate, as indicated by a rotameter connected in series between the pump and the adsorption tubes, shall be recorded as a standard both before and after sampling. In event of any significant difference between initial and final sampling flow rates, the sampling shall be repeated. Some procedure shall be taken to ensure that the sampling volume does not exceed the retention volume with an adequate safety margin to prevent break through. Two adsorption tubes linked in series shall be employed for each sample, the second tube acting as a back-up to trap any VOCs not retained in the first duplicate. Duplicate samples shall also be simultaneously collected at each location for duplicate analysis preferably collected at different flow rates. Travel blanks and spiked samples shall be employed to check for contamination of the samples during transit, and to check recovery of the trapped VOCs respectively. Methane sample bags shall be sealed immediately following collection.

70. The air pumps and rotameters shall be regularly serviced and calibrated in accordance with the manufacturer's instructions. The calibration of rotameters, pumps and any other sampling equipment used shall be checked prior to, and after each monitoring period and any difference noted. The power supply for pumps shall be checked prior to monitoring to ensure that the equipment can function for the required operating period. In all instances, sampling equipment shall be treated and maintained with care.

71. Samples shall be properly stored and marked together with prompt discharge and analysis of samples.

72. Analysis of samples shall be performed by a laboratory equipped with a capillary gas chromatography linked to a mass spectrometer. Analytical instruments shall be properly calibrated with authentic VOC standards. Laboratory shall also be capable of achieving the required detection limit.

73. Any addition to the list of VOCs below will necessitate a review of the sampling and analytical techniques.

Trichloroethylene
Vinyl chloride
Methylene chloride
Chloroform
1,2-dichloroethane
1,1,1-trichloroethane
Carbon tetrachloride
Tetrachloroethylene
1,2-dibromoethane
Benzene
Methane (300)

The required detection limits for the above compounds should be 0.2 ppb, except for methane which shall be 300 ppb (in brackets).

74. This suite of analysis shall be subject to annual review between the Employer and the Contractor. Equipment and methods shall vary depending on the compounds to be determined and therefore may be subject to amendment.

75. Monitoring of the sampling locations shall be performed on a quarterly basis during the after-care period for three consecutive years and thereafter subject for a review for longer period of monitoring. The frequency of monitoring should be increased in the event of complaint.

76. In recording the results, the following information relating to the monitoring shall be presented:

- Site name.
- The sampling location for each adsorption tube.
- Details of all the equipment used, including manufacturer, model/type, and date of last full calibration.
- Any difference in calibration checks performed before and after monitoring.
- The date and times at which sampling was undertaken.
- Weather conditions during sampling, including wind speed, direction, rain, mist, temperature, etc.
- Flow rates at the start and finish of each sampling period, the duration of sampling, the average flow rate, and the volumes of air sampled.
- The laboratory report which is to specify the weight of each VOC determined on each adsorption tube, the analytical detection limit for each VOC, and the percentage recovery of spikes.
- The concentration of each VOC at each sampling location, adjusted for any loss during analysis or any contamination during transit.
- Any other relevant information (eg the presence of nearby vehicular movements).

Monitoring Protocol - Water Quality

77. Monitoring of leachate, groundwater and surface water shall be carried out prior to the commencement of the restoration phase to provide further baseline monitoring data, and both during the restoration and afteruse phases of the development. The purpose of water quality monitoring will be to:

- To give a profile of groundwater and surface water quality at each monitoring point such that any pollution can be accurately defined with respect to baseline data; and.
- To provide data to assess the impact on the nearby water bodies quality of leachate migration or liner failure.

78. Sampling should be carried out at a frequency and extent as indicated in Appendix 5.

79. The on-site sampling method for surface water should follow the British Standard BS6068: Part 6: Section 6.1: 1981. Each water sample is collected by immersing into the sub-surface water with (i.e. within 500 mm below water surface) an beaker or open-mouth PE bottle with its opening pointing upstream. Each sample bottle should be fully filled and sealed.

80. Each sample for groundwater and leachate should as far as possible be truly representative at the point from which it is taken, without dilution or contamination by water from other sources or by other material. Subject to the availability of water inside the holes, at least 3 times the liquid volume of the drillhole should be pumped out for purging purpose prior to taking the groundwater and leachate samples. The water samples (about one litre) should be kept in a clean and suitable gas-tight and watertight container. The bottle and stopper should be rinsed three times with the groundwater or leachate before filling with the samples. The containers should be well capped to prevent any loss of sample and be completely filled with the sample.

81. Once collected and labelled the water samples should be kept in cool boxes or other suitable containers for onward delivery to laboratory. It is necessary to take a separate sub-sample for each determinand which requires a different preservation method. Sample preservation

details should be clearly recorded on the sample label and in the accompanying documentation. The sample shall be transferred to the container with minimum agitation to minimize loss of dissolved gases.

82. Before taking a groundwater or leachate sample, the water level should be measured using a dip meter. Attention should be paid to record any false signal due to the moist LFG escaping from the hole.

83. After collecting a surface water, groundwater and leachate sample, some on-site measurements should be carried out (i.e. pH, temperature, dissolved oxygen and electrical conductivity). All the on-site measuring equipment should be calibrated with standard solutions before and after taking to the field. Moreover, on-site calibration should also be carried out if necessary.

84. Those parameters to be test as specified in Appendix 6 should be determined as quickly as possible in the laboratory using standard or acceptable methods (e.g. American Society for Testing and Materials (ASTM) or American Public Health Association (APHA) - American Water Works Association (AWWA) - Water Pollution Control Federation (WPCF) standards, etc).

85. Sample containers shall be clearly marked to show the following:

- Site name;
- Unique sampling location reference (including depth); and
- Date and time of sample collection.

Reporting

86. An on-Site sampling report shall include:

- Site name;
- Any sample preservation;
- Unique sampling location reference;
- The sampling device used;
- Time and date of sampling;
- The name of the sampling technician;
- Tidal activity (only apply to the location close to the sea);
- The appearance, condition and temperature of the water body;
- Weather conditions and air temperature; and
- Any storage requirements.

Monitoring Protocol - Slope Stability

87. Slope monitoring should be conducted according to the frequency and extent given in Appendix 5 for the restoration and afteruse phases of the landfills.

88. Slopes should be inspected by suitably experienced and qualified persons on a regular basis during the restoration and afteruse phase. Where actual ground conditions encountered differ adversely from the assumptions on which the design was based, the restoration design should be reassessed. Where slopes exhibit signs of failure or stress, emergency remedial works should be immediately carried out to restore stability, and the design of the slope should be reassessed. Where ground conditions, slope failure or slope distress necessitate reassessment of the design, a submission should be made to the Geotechnical Engineering Office of the Hong Kong Government (GEO) in accordance with the procedures in Lands and Works Branch Technical Circular 3/88 (or subsequent circular updating these requirements).

89. In addition, consideration should be given to the installation of instruments (e.g. piezometers, inclinometers etc) which may give warning of an imminent slope failure and allow remedial measures to be undertaken before such a failure occurs.

90. Design of all slopes should be undertaken in accordance with the following documents:

Geotechnical manual for Slopes, prepared by Geotechnical Engineering Office, Civil Engineering Department, Hong Kong Government.

British Standard BS 6031:1982, Code of Practice for Earthworks.

Geotechnics of Waste Slopes, ASTM 1990.

Model Specification for Reinforced Fill Structures, prepared by Geotechnical Engineering Office, Civil Engineering Department, Hong Kong Government.

Geoguide 1: Guide to Retaining Wall Design, prepared by Geotechnical Engineering Office, Civil Engineering Department, Hong Kong Government.

Works Branch Technical Circular No 19/91: Permanent Reinforced Fill Structures, November 1991, Works Branch Hong Kong Government.

and any other standards as may be set from time to time by the Geotechnical Engineering Office (GEO) of the Civil Engineering Department or Works Branch of the Hong Kong Government.

91. A review of slopes constructed on the site should be undertaken on an annual basis. The review should demonstrate that the design standards are being met and should include a review of the slope performance including the effects of measured fluid levels and measured movements. A copy of this review should be submitted to GEO.

Monitoring Protocol - Settlement

92. Settlement monitoring should be conducted according to the frequency and extent specified in Appendix 5 for the landfill afteruse phases.

93. Settlement/movement markers should be constructed on the surface of the restored landfill. The markers should be constructed at a maximum spacing of 100 m and should be constructed immediately following completion of restoration in any specified area. The levels of the markers should be determined to the nearest millimetre. Co-ordinants should be measured to the nearest centimetre in order to monitor for lateral movement. Fixed level markers constructed in form stable ground level should be used as fixed points for the purpose of these measurements.

94. The levels and locations of the settlements markers should be determined on a monthly basis following their installation, with the following information being recorded:

- date;

- level in mPD to the nearest millimetre;
- co-ordinates to the nearest centimetre;
- difference from previous reading;
- difference from initial reading;
- depth of waste below marker;
- age profile of waste below marker; and
- percentage settlement since initial reading.

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