7. Landfill Gas Hazard Assessment

7.1 Introduction

This chapter presents the risk assessment of landfill gas (LFG) hazards arising from the construction, operation, restoration and aftercare phases of the Project. Appropriate protective and precautionary measures will be implemented during various phases of the Project to control the LFG hazards to a minimum and acceptable level. No adverse impact is anticipated.

The landfill gas impact assessment has been conducted in accordance with the requirements in ProPECC PN 3/96 and EPD/TR8/97, and Clause 3.4.5 of the EIA Study Brief for the Project.

7.2 Legislation, Standards and Guidelines

Relevant legislation and associated guidance notes applicable to the assessment of the LFG hazards include:

- Section 1.1(f) in Annex 7 of the Technical Memorandum on EIAO (TM-EIAO);
- Section 3.3 in Annex 19 of the TM-EIAO;
- Landfill Gas Hazard Assessment for Development Adjacent to Landfills (ProPECC PN 3/96); and
- Landfill Gas Hazard Assessment Guidance Note (1997) (EPD/TR8/97).

These guidance notes recommend that in general, assessment of LFG hazard will be required for proposed developments within the 250m consultation zone of a landfill. The WENT Landfill Extension site is located within the 250m consultation zone of the existing WENT Landfill, and the Project site itself is a potential source of landfill gas generation.

7.3 Background Information

7.3.1 Desktop Study

A comprehensive desktop review study of literature information and study reports has been undertaken to appreciate the site characteristics and determine the likelihood of potential LFG impacts on the sensitive receivers. Other sources of information include topographical and geological maps, utilities plan (gas, electricity, drainage, etc), information from previous ground investigations, engineering and operation details, gas monitoring data, visual data at existing WENT Landfill etc. The following documents have been reviewed:

- Extension of Existing Landfills and Identification of Potential Waste Disposal Sites;
  - Site Investigation Report, December 2001;
  - Ground Investigation – Final Field Work Report, October 2001;
  - Final Laboratory Testing Report, December 2001;
  - Final Strategy Environmental Assessment Report (Volume I & II), January 2003;
  - Final Site Selection Report (Volume I & II), January 2003;
  - Final Report (Volume I & II), January 2003;
- ACE-EIA Paper 9/2003 “Extensions of Existing Landfills and Identification of New Waste Disposal Sites; and
- Contract No. EP/SP/9/91 Development & Management of WENT Landfill Environmental Monitoring Monthly Report (from Year 1996 to Year 2006).

7.3.2 History and General Description of the Existing WENT Landfill

Existing WENT Landfill was commissioned in 1993 and receives waste from the North West New Territories by road as well as Island West Transfer Station, Outlying Islands Transfer Facilities, West Kowloon, North Lantau and Island East Transfer Stations by barge, with an overall capacity of 61Mm^3 occupying about 110ha area. Waste intake recorded (mainly municipal and construction waste) is about 6,580 tonnes per day in Year 2006. It has an operation life of about 25 years and an aftercare period of 30 years after the completion of operation.

The entire WENT landfill is designed in a "Confined and Contained" approach. Comprehensive landfill gas and leachate collection systems have been operating since day 1 of WENT Landfill operation to collect all the landfill gas and leachate generated from the waste body. A protective lining system is adopted to stop any migration of landfill gas and leachate which forms a barrier on the pathway to nearby development.

Monitoring exercise is regularly conducted in order to ensure that landfill gas and leachate from the entire landfill are properly collected and treated.

A landfill gas management system is also in place for daily operation. LFG generated from the deposited waste is pumped to a LFG utilisation plant, where the gas is used to generate electricity for site uses. LFG is also utilised as a heat source for the ammonia stripping processing plant used in the leachate treatment process. Surplus LFG will be completely burnt in the flaring system.

7.3.3 Geology

Figure 7.1 shows the geological map of the existing WENT Landfill, WENT Landfill Extension as well as its surrounding area. This map is based on the Hong Kong Geological Survey Map (Scale 1:20,000) Solid and Superficial Geology of Tsing Shan (Castle Peak) published by the Geotechnical Control Office (GCO, 1988), which indicates that the study area is mostly underlain by medium grained granite of the middle Jurassic to the late Cretaceous age, with megacrystic granite recorded in the south-eastern portion. This material has typically been weathered to soil within the upper 10m to 30m of the ground profile.

Several bands of ENE-WSW trending aplite dykes were recorded within the central southern portion of the site, with a notable concentration of these features in the area close to Black Point Power Station and one major dyke striking across the entire study area and even extending beyond the eastern boundary of the current WENT Landfill site. In addition, a number of ENE-WSW trending quartz vein were also recorded within southern portion of the study area.

The geological map records that superficial deposits of Pleistocene and Holocene Debris Flow Deposits (Qd) are commonly found in the valley floors and often form fans on the lower hillside slopes. Deposits of alluvium are often found down slope of the debris flow deposits.

Beach deposit are present along much of the coastline, in the areas adjacent to the alluvial deposits, and several patches of Pond Deposits (Qp) and Raised Beach Deposits (Qrb) are recorded in the flat areas at Tsang Tsui and Tsang Kok. The Tsang Tsui Lagoons are recorded as fill (PFA), which overlies marine deposits of the Hang Hau formation.

Several faults and inferred faults were recorded within the study area as shown in **Figure 7.1**. The four major faults are:

- Faults 1 & 2 : Another NNW-SSE striking fault lies along the topographic depression near the eastern boundary of the Study Area.
- Fault 3 : A NE-SW striking fault running across almost the entire Study Areas. The fault roughly follows the alignment of Nim Wan Road.

- Fault 4: A SEE-NWW striking fault lies along the topographic depression near the western boundary of the Study Area. This fault line is actually outside the 250m LFG consultation zone from the waste boundary.

The geological map also records the presence of several photolineaments.

7.3.4 Construction Programme of WENT Landfill Extension

Based on the current assumption, the extension works will be divided into 6 phases covering total tipping volume of 81Mm³ (refer to **Figure 2.6** for location of the phases). The tentative time line of the works including Nim Wan Road re-alignment is shown in **Table 7.1** as follows.

Table 7.1 Time line of extension works

Work	Construction Year	Operation Year	Nearest distance to Nim Wan Road re-alignment
Nim Wan Road re-alignment	2018	2020	N/A
Phase 1	2016	2018 to 2028	100m
Phase 2	2017	2019 to 2028	770m
Phase 3	2018	2020 to 2028	390m
Phase 4	2020	2022 to 2028	0m
Phase 5	2021	2023 to 2028	0m
Phase 6	2022	2024 to 2028	0m

Construction period of each extension phase will take about 2 years while their operation years will be immediately started afterwards. As shown in **Table 7.1**, the phase 1 work will be started in mid 2010s and the whole extension work will be completed by end 2020s.

7.3.5 Nim Wan Road Re-alignment

The existing Nim Wan Road will be re-aligned to facilitate the development of the WENT Landfill Extension. Construction of the road and the associated slope work will mainly consist of open-cut activities.

7.4 LFG Hazard Assessment

7.4.1 Approach

Qualitative assessment on the risk of LFG hazards at the receivers has been undertaken for each of the identified source-pathway-receiver combinations. Qualitative LFG hazard assessment was undertaken following the method recommended in the LFG Guidance Note. This method is based on the "Source-Pathway-Receiver" model as described below:

- Source – location, nature and likely quantities/ concentrations of LFG which has the potential to affect the WENT Landfill Extension.
- Pathway – the ground and groundwater conditions, through which LFG must pass in order to reach the WENT Landfill Extension.
- Receiver – elements of the development that are sensitive to the effects of LFG.

The LFG sources, pathways and receivers are categorised for the hazard assessment. In accordance with the LFG Guidance Note, an assessment of the overall risk is made based on the risk category as summarised in **Table 7.2**, following determination of which category of source, pathway and receiver, the combination of existing WENT Landfill and its extension fall into during the construction, operation, restoration and aftercare stages.

For the purpose of categorising the WENT Landfill Extension, the category is based upon the highest level of risk determined for any of the potential impacts identified in **Table 7.2**, in which the general implications fall into different overall risk categories as shown in **Table 7.3**.

Table 7.2 Classification of Risk Category

Source	Pathway	Receiver Sensitivity	Risk Category
Major	Very Short/ Direct	High	Very high
		Medium	High
		Low	Medium
	Moderately Short/ Direct	High	High
		Medium	Medium
		Low	Low
	Long/ Indirect	High	High
		Medium	Medium
		Low	Low
Medium	Very Short/ Direct	High	High
		Medium	Medium
		Low	Low
	Moderately Short/ Direct	High	High
		Medium	Medium
		Low	Low
	Long/ Indirect	High	Medium
		Medium	Low
		Low	Very low
Minor	Very Short/ Direct	High	High
		Medium	Medium
		Low	Low
	Moderately Short/ Direct	High	Medium
		Medium	Low
		Low	Very low
	Long/ Indirect	High	Medium
		Medium	Low
		Low	Very Low

Table 7.3 Summary of General Categorisations of Risk

Category	Level of Risk	Implication
A	Very high (undesirable)	The type of development being proposed is very undesirable and a less sensitive form of development should be considered. At the very least, extensive engineering measures, alarm systems and emergency action plans are likely to be required.
B	High	Significant engineering measures will be required to protect the planned development.
C	Medium	Engineering measures will be required to protect the proposed development.
D	Low	Some precautionary measures will be required to ensure that the planned development is safe.
E	Very low (insignificant)	The risk is so low that no precautionary measures are required.

There may be five generic forms of protection to be used corresponding to the five risk levels as set out in **Tables 7.4** and **7.5**.

Table 7.4 Generic Protection Measures for Planning Stage Categorisation

Category	Generic Protection Measures
A	For the planned development active control of gas, supported by barriers and detection systems. Another, less sensitive form of development should also be considered.
B	Active control of gas, including barriers and detection systems [1] .
C	Use of 'semi active' or enhanced passive gas controls. Detection systems in some situations
D	Passive control of gas only.
E	No precautionary measures required.

Note: [1] The gas protection measures required to allow the safe development of a Category A risk development will need to be more extensive than those for a Category B risk development.

Table 7.5 Definition of Control Terms

Term	Definition
Active control	Control of gas by mechanical means eg. Ventilation of spaces with air to dilute gas, or extraction of gas from the development site using fans or blowers.
'Semi active' control	Use of wind driven cowls and other devices which assist in the ventilation of gas but do not rely on electricity powered fans.
Passive control	Provision of barriers to the movement of gas eg. Membranes in floors or walls, or in trenches, coupled with high permeability vents such as no-fines gravel in trenches or voids/permeable layers below structures.
Detection systems	Electronic systems based upon, for example, catalytic oxidation or infra-red measurement principles, which can detect low concentrations of gas in the atmosphere and can be linked to alarms and/or telemetry systems.

7.4.2 Sources

7.4.2.1 Existing WENT Landfill

LFG Generation

According to the EP/SP/9/91 Development and Management of WENT Landfill Monthly Reports in the year of 2002 to 2006, the LFG statistics in terms of utilisation for power generation and leachate treatment as well as flaring processes are tabulated in **Table 7.6**, indicating a significant quantity of LFG generation.

Table 7.6 Recent LFG Statistics of Existing WENT Landfill

Use	LFG Volume (m^3/hr)				
	2002	2003	2004	2005	2006
Utilized for power generation	600	750	750	750	750
Utilized for leachate treatment	4,100	4,500	4,500	4,500	4,500
Flared	5,000	5,050	4,250	4,196	2,991
Total	**9,700**	**10,300**	**9,500**	**9,446**	**8,241**

The existing WENT Landfill has been incorporated with an efficient and effective LFG management system, in which a coordinated approach to LFG monitoring, collection, extraction, flaring and utilisation is being implemented to achieve the following requirements:

- To eliminate the risk of explosion or combustion due to the presence of LFG within, below, above and inside the landfill site;
- To eliminate the hazards to flora or fauna due to toxicity or asphyxiation effect of LFG presence external to the landfill site;
- To minimise the effect of odours from LFG causing nuisance in the vicinity of the landfill site;
- To minimise the uncontrolled egress of LFG from the landfill site;
- To eliminate migration of LFG to service ducts or enclosed/confined spaces of any on-site buildings;
- To protect any temporary or permanent structures or chambers on the landfill site;
- To prevent unnecessary air ingress into the landfill;
- To prevent unnecessary build-up of LFG pressure within the landfill;
- To relieve positive pressures of LFG at the landfill boundary and near the surface;
- To facilitate the controlled extraction of LFG from the landfill;
- To facilitate the ultimate flaring and utilisation of LFG; and
- To provide signs designating hazards and precautions to avoid on-site accidents.

The contractor of the existing WENT Landfill is required to carry out LFG monitoring during landfill operation from drillholes, boreholes, gas probes and piezometers around the perimeter of the Site for methane (CH_4) and carbon dioxide (CO_2) as specified in their contract. Independent Checker will also be involved to countercheck the monitoring data. Improvement measures or justification will be provided, in case there is any major discrepancy in the monitoring results.

Based on the monitoring data at the off-site monitoring points (**Figure 7.2**) provided by the contractor, methane was all the time measured of less than 0.1% and carbon dioxide was majority measured of less than 0.5% with some occasional with peak of 9.3% in the year

from 2002 to 2006 (details refer to **Appendix 7.1**). Based on the explanations described in the monitoring reports, there is no exceedance of trigger level. It can therefore be concluded that no methane and no abnormal levels of carbon dioxide were detected in all off-site monitoring points.

With reference to the LFG Guidance Note, the source of the LFG at the existing landfill is therefore categorised as **Medium**, considering the following reasons:

- Active gas extraction system has been adopted as an essential element of LFG protection measure at the existing WENT Landfill; and
- Gas control system (details refer to the following sub-sections) has been installed and proven to be effective by comprehensive monitoring which has demonstrated that there is no migration of gas beyond the landfill boundary.

LFG barrier

The existing WENT Landfill was designed and constructed as a secure containment facility incorporating multi-layer composite liner systems covering the entire surface area of the site. The liner system and future final cap at the existing WENT Landfill form effective barriers against LFG migration. A final cap will be installed during the restoration stage to minimise uncontrolled egress of LFG from the landfill site, control of LFG arising from the landfill site, minimise uncontrolled ingress of air into the existing WENT Landfill, and avoid any impact on the quality of potentially exploitable LFG. **Figure 7.3** shows the landfill liner and final capping details.

LFG collection system

The LFG collection system at the existing WENT Landfill comprises vertical collection wells progressively constructed within the buried waste in conjunction with landfilling activities. The wells have radiant horizontal collection trenches throughout the depth of waste connecting with the extraction wells at regular intervals. The system also includes facilities to fulfil the performance requirements for the overall LFG management system, e.g. components to allow the coordination of LFG collection and extraction systems, prevent unnecessary build-up of LFG pressure within the landfill, relieve positive pressures of LFG at the landfill boundary and near surface, and control migration of LFG off-site.

LFG extraction system

The LFG extraction system at the existing WENT Landfill removes LFG collected from the buried waste for efficient and effective removal and conveyance to the LFG flaring and utilisation facilities. The system includes extraction wells and pipework installed within the landfill cap connecting a pumping station on-site. It also incorporates a separate collection system connected to perimeter extraction wells isolated from the main system so that it is operated independently for migration control. The system also allows LFG to be pumped in various directions to provide flexibility and security of extraction, chemical duty isolating valves suitable for flow control with status indication, gravity drainage-type condensate traps at low points on the connecting pipework, and independent pumps for the operation of gas extraction system and perimeter control system.

LFG utilisation for power generation

Two genset systems running in parallel are being operated in the existing WENT Landfill. Extracted LFG is used for combustion such that it can be efficiently and effectively consumed for power generation. The total LFG utilised by the genset systems was around 6.6 Mm^3 in 2006. The system operates to prevent generation of toxic emissions by admitting especially low fuel gas/air mixture to the combustion chamber.

LFG utilisation for ammonia stripping plant

An ammonia stripping plant has been installed and operated (24 hours per day) at upstream of the biological treatment system of the leachate treatment works for advance removal of ammonia by thermal destruction with LFG as fuel. The thermal destructor thus destroys and renders harmless the LFG and ammonia LFG is introduced into to the burners after passing through a flame arrestor. Total LFG utilisation at ammonia stripping plant was 39 Mm³ in 2006.

LFG treatment by flaring

The LFG flaring system in the existing WENT Landfill is used for combustion of the extracted LFG such that it can be efficiently and effectively consumed, which comprises a pumping station with gas flares for heat production. LFG is extracted from the landfill and conveyed by a blower through a pipeline system to create a negative pressure for low emission controlled combustion. The wet saturated LFG is dewatered in a condensate separator so that it can be burnt off in the high temperature flare. The collected condensate is discharged into the on-site leachate treatment plant. For a full time operation, the total LFG treated by the flaring system was around 26 Mm^3 in 2006.

LFG monitoring programme

The results from the routine and long-term LFG monitoring programme for the existing WENT Landfill operation indicate that the landfill has been operating satisfactorily and considered adequate with the proven LFG collection system and control plant in place to minimise any potential impact to the concerned sensitive receivers. The scope of LFG monitoring at the existing WENT Landfill covers the following:

- The quantity and quality of LFG extracted from the existing WENT Landfill site is monitored and the effectiveness of landfill liner system is regularly checked to prevent uncontrolled egress of LFG from the landfill site;
- The quantity of LFG emanating from the landfill site is automatically monitored at the LFG pumping station. The suction pressure at gas pumping station is monitored and the alarm will be activated when the pressure increased above or decreased below acceptable pre-determined levels;
- The well heads are installed with valves, connecting pipework, etc to connect with flow meters for monitoring of LFG extraction rates at individual heads;
- The quality of LFG is monitored by the facilities installed in the LFG pumping station, including CO_2, O_2 and methane concentrations, whilst the LFG composition at the well heads is monitored by gas sampling and laboratory analysis;
- The LFG flaring system is monitored for flare temperature, emissions, and differential pressure across flame arrestors;
- Routine LFG monitoring is conducted at fixed drillholes, boreholes, gas probes and piezometer locations along the existing WENT Landfill Boundary and at potential sources of concern to ensure timely implementation of emergency and contingency measures in case LFG migration or exceedance of trigger levels; and
- Implementation of “permit to work” system, monitoring to ensure safe level of LFG concentration, and implementation of sufficient mitigation measures when entering confined spaces within the landfill site.

7.4.2.2 WENT Landfill Extension

The WENT Landfill Extension itself is a source to generate LFG during the operation and aftercare phases. LFG hazards may be prone to front-line workers within the site especially where the LFG are extracted, transported and processed. With the LFG control measures in

the future WENT Landfill Extension, the source of LFG will be properly controlled within the site similar to the operation in existing WENT Landfill.

The WENT Landfill Extension will also be designed as a containment landfill incorporating multi-layer composite liner systems covering the entire surface area of the site with LFG collection and management systems to eliminate any off-site migration of LFG. By virtue of the effective control and utilisation of LFG being implemented in the existing WENT Landfill based on the past monitoring data, it is likely that the WENT Landfill Extension will be designed to adopt similar or more advanced LFG control measures so as to ensure future compliance of environmental and safety requirements. The source of LFG at the WENT Landfill Extension will be categorised as **Medium**, considering the following reasons:

- Active gas extraction systems, similar to the existing WENT Landfill, will also be installed in the WENT Landfill Extension;
- Gas control systems (**Figure 7.3 & Figure 7.6** and **Appendix 7.3**) will be installed and comprehensive monitoring (**Figure 7.7**) will be conducted to ensure that no migration of gas beyond the landfill boundary; and
- Specific control measures will be applied if necessary..

7.4.3 Pathways

The type of pathways can be broadly classified based on various geological features of the landfill extension sites such as permeability of soil; spacing, tightness and direction of fissures/joints; topography; depth and thickness of the medium through which the gas may migrate (also affected by groundwater level); nature of strata over the potential pathway; number of media involved; and depth to groundwater table and flow patterns, etc. In general, the pathway can be broadly classified as follows depending on the distance from the landfill boundary:

- **Very Short / Direct** for path length less than 50m;
- **Moderately Short / Direct** for path length of 50-100m; and
- **Long / Indirect** for path length of 100-250m.

7.4.3.1 Pathways Within WENT Landfill Extension

Natural pathways

One of the major concerns is the presence of faults (Faults 1 and 2) as shown in **Figure 7.4** crossing the existing WENT Landfill toward the eastern part of the landfill extension, which are natural pathways for preferential LFG migration. These pathways of fissured rock are less than 50m to the landfill extension and are categorised as **Very Short / Direct** according to the LFG Guidance Note.

The superficial deposits located below the formation level to the north of the landfill extension may act as natural pathways for LFG migration towards the office area of the existing WENT Landfill. These pathways of unsaturated permeable strata are less than 50m to the eastern part of the landfill extension and are categorised as **Very Short / Direct**.

Man-made pathways

There are man-made pathways in the vicinity of the site consisting of services routes leading to the existing landfill. These pathways to sensitive receivers are classified as **Very Short / Direct** towards the landfill extension, as landfill workers could be the targets during landfill operation, piping/ conduit construction, and/or drilling/boring operation.

7.4.3.2 Pathways Outside WENT Landfill Extension

Natural pathways

The separation distances between the waste boundary of WENT Landfill Extension and the Sludge Treatment Facilities (STF) and the potential site for Integrated Waste Management Facilities (IWMF) are short, less than 50m, the pathway is therefore classified as "**Very Short / Direct**" whilst the separation distance between the waste boundary of WENT Landfill Extension and the Black Point Power Station is short, less than 85m, the pathway is therefore classified as "**Moderately Short / Direct**". Mitigation measures will include installation of proper liner (**Figure 7.3**), and LFG cut-off trench barrier (**Figure 7.4 and Figure 7.6**) to prevent off-site migration.

The presence of Fault 3 (as shown in **Figure 7.4**) at the west side of the waste boundary of the WENT Landfill Extension is also identified as a potential pathway for potential LFG migration to the Black Point Power Station. The separation distance between the fault line and the power station is about 200m, so such pathway is classified as "**Long / Indirect**" pathway. Mitigation measures will include installation of proper liner (**Figure 7.3**), sealing of the fault line (**Figure 7.5**) and LFG cut-off trench barrier along the re-aligned Nim Wan Road (**Figures 7.4 and 7.6**) to prevent off-site migration.

The presence of Fault 4 (as shown in **Figure 7.4**) at the west side of the WENT Landfill Extension is basically about 500 from the waste boundary, i.e. further 250m apart from the consultation zone. Although the fault line is underpinning to the Black Point Power Station, LFG migration from the WENT Landfill Extension to the power station upon the considerable long distance is considered not possible.

Man-made pathways

Although the Nim Wan Road re-alignment is a man-made pathway in the vicinity of the site consisting of services routes leading to the existing landfill, it is an open road and will be completed prior to the landfill extension Phase 4. Hence, it is classified as **Long / Indirect**.

7.4.4 Receivers

7.4.4.1 Receivers Within WENT Landfill Extension

Potential receivers sensitive to LFG hazards associated with the WENT Landfill Extension include the workers and staff of the WENT Landfill Extension. During the operation of the WENT Landfill Extension, drivers/operators of waste collection vehicles will have access to the waste tipping face for disposal of waste and they may not have knowledge on landfill gas hazards.

Construction Phase

- Excavation for construction of new landfill bowl;
- Deep unventilated excavations, e.g. trenches for utility installation; and
- Outbuildings, sheds and temporary structures such as construction site offices.

These receivers are categorised as **Medium Sensitivity** according to the LFG Guidance Note.

Operation, Restoration and Aftercare Phases

- Services ducts or other confined spaces at basements or ground floor levels;
- External manholes, inspection chambers, ducts or other accessible enclosed spaces under the ground;
- Waste Reception Area of the WENT Landfill Extension; and
- Aftercare facilities of the restored WENT Landfill.

These receivers are categorised as **Medium to High Sensitivity**.

7.4.4.2 Receivers Outside WENT Landfill Extension

The original consultation zone of the existing WENT Landfill is shown in **Figure 7.4**. It is overlaid with the proposed new demarcation of a 250m consultation zone corresponding to the latest footprint of WENT Landfill Extension area. The following sensitive receivers are located within the land area encroached by the new consultation zone of the landfill extension:

- Existing sensitive receiver: Black Point Power Station;
- Planned or committed sensitive receivers:
  (i) Potential site for IWMF (construction period: 2011 to 2014; operation period: 2014 onwards);
  (ii) STF (construction period: 2010 to 2012; operation period: 2012 onwards); and
  (iii) Re-aligned Nim Wan Road.

Categorisation of the receiver sensitivity is given as follows:

- Black Point Power Station: **Medium Sensitivity**. The north-eastern part of the Castle Peak Power Station would fall within the future LFG consultation zone. According to the information available from CLP's website, this part of the power station is designated for natural gas receiving station. According to the approved EIA Report for Liquefied Natural Gas (LNG) Receiving Terminal and Associated Facilities (EIA-125/2006), the power plant operator has implemented and been practicing a comprehensive and high standard Health and Safety Policy. Their statement of Safety, Health and Environmental Policy has explicitly state that they are committed to providing a safe, healthy and clean business environment for the employees, customers and the public. To achieve this, an Occupational Safety and Health management System (OSHMS) has been in place. Another Operation Integrity Management System (OIMS) is also in place to assist accomplishing the safety, health and environmental objectives.

  For personnel protection, the following measures / procedures are being practiced.

Area	**Measures / Procedures**
Inside Natural Gas Control Areas	• Smoking is totally forbidden • Use of naked light is not allowed. Where there is no alternative to using naked light such as in the event of welding, then a Hot Work Permit is required. • Use sparkproof hand tools wherever practicable and only intrinsically safe equipment. The use of portable electric equipment and tools which are capable of causing ignition are forbidden unless covered by a safety document. • Always monitor the atmosphere before commencing work and during work • Always carry a personal gas monitor to protect people
General	• Protective clothing, shoes, gloves etc should be worn as instructed • Special safety equipment such as breathing apparatus, fire retardant clothing etc should be made readily available and used as directed. • Fire extinguishers should be placed readily available where is work is being carried out.

Area	Measures / Procedures
	• Always follow the safety procedures related to natural gas. • Use only approved gas monitoring equipment

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In addition, the properties of natural gas, the safety systems of natural gas receiving terminals and the high standards adopted by the industry mean that the likelihood of any leakage occurring is very remote. If a leak occurs, natural gas vaporises but will only ignite if it mixes with air within a specific limited range (5% - 15%) and also comes into contact with an ignition source.

It should also be noted that the main constituent of both natural gas and landfill gas are methane (ref https://www.clpgroup.com/lng/lng/ng/pages/whatisnaturalgas.aspx?lang=en) and hence their combustible characteristics should be similar.

It is therefore considered that at the natural gas receiving station, CLP maintains a high level of safety standards with respect to the hazards of combustible/explosive gases and CLP staff serving the natural gas receiving stations are also believed to have good knowledge of the hazards of combustible/explosive gases. In view of this, the sensitivity of this target is classified as "Medium".

- Potential site for IWMF and STF: **Medium Sensitivity**. Access to the service voids will only allow authorised or well-trained personnel with specific safety procedures to be followed. Both of these projects are Designated Projects and hence separate approval on their respective EIAs are required. It is also anticipated their respective operators would fully address any issues on LFG and implement all necessary measures (including training course to their employees) to reduce LFG risk as apprpriate. It is therefore considered that the sensitivity of this target is classified as “Medium”.
- Re-aligned Nim Wan Road: **Low to Medium Sensitivity**. The road will be constructed by open-cut and the future operation is in an open space. Only authorised person with appropriate training can assess to manholes located along the road with specific safety procedures to be followed.

Based on the information shown in the “Statutory Planning Portal” of Planning Department (PlanD) website at http://www.ozp.tpb.gov.hk/default.aspx, there is no landuse zoning information in the vicinity of both existing WENT Landfill site and its extension. In addition, apart from STF and the potential site of IWMF, there is no other planned development within the newly proposed 250m consultation zone, see **Figure 7.7**.

If a proposed development or re-development is to be located within the future 250m consultation zone of WENT Landfill Extension, the project proponent will be required to conduct an LFG hazard assessment and submit the assessment report to the EPD for consultation and vetting in accordance with ProPECC PN 3/96 and LFG Guidance Note. The project proponent should:

- Carry out an LFG hazard assessment to evaluate the degree of risk associated with the proposed development;
- Design suitable precautionary / protection measures to render the proposed development as safe as reasonably practicable;
- Ensure that the precautionary / protection measures to be fully implemented according to the design; and
- Establish a maintenance and monitoring programme to ensure the continued performance of implemented protection measures.

The anticipated LFG mitigation and protective measures required for new developments in the extended consultation zone will be dependent on the location, distance, landuse, etc.

relative to the WENT Landfill Extension, subject to the findings and recommendations of the LFG hazard assessment on individual projects.

7.5 Qualitative Risk Assessment

With all the information regarding the sources, pathways and receivers identified in the previous sections, a qualitative risk assessment of LFG hazards is summarised in **Table 7.7** based on the criteria in stipulated in **Table 7.2**. According to the LFG Guidance Note, for the purposes of categorising the WENT Landfill Extension at the planning stage, the category is based upon the highest level of risk nominated for any of the potential impacts identified.

Table 7.7 Qualitative Risk Assessment of LFG Hazards associated with WENT Landfill Extension

Source	Pathway	Receiver Sensitivity	Risk
Within WENT Landfill Extension			
LFG from existing WENT Landfill and WENT Landfill Extension : Medium	Natural (faults): Very Short / Direct Man-made (services routes): Very Short / Direct	Workers and staff during construction, operation, restoration and aftercare phases : Medium to High	Medium to High
Outside WENT Landfill Extensions			
LFG from future WENT Landfill Extensions : Medium	Potential site for IWMF and STF - Natural (separation distance): Very short / Direct Black Point Power Station - Natural (separation distance): Moderately Short / Direct Natural (faults): Long / Indirect Man-made (re-aligned Nim Wan Road): Moderately Short / Direct	Potential site for IWMF and STF operators: Medium	Medium
		Power Station operators: Medium	Medium
		Construction of Re-aligned Nim Wan Road: Low - Medium	Low to Medium

The overall risk level of LFG hazards to receivers within the landfill extension sites (i.e. the construction workforces and the future operation staff) is categorised as "**Medium to High**" (Category C and B respectively). Significant engineering measures and good site practices/precautionary measures will be required to protect the planned development and activities during the construction, operation, restoration and aftercare phases. Active gas control system supported by LFG cut-off trench barrier/sealing of fault line and monitoring systems will be required for Category B risk level.

The overall risk level of LFG hazards to the Black Point Power Station, potential site for IWMF and STF which are outside the WENT Landfill Extension but within the 250m zone from the waste boundary is categorised as "**Medium**" (Category C). Adequate engineering measures will be required to protect the Black Point Power Station, potential site for IWMF and STF. For the construction of realigned Nim Wan Road, the overall risk is "**Low to Medium**" (Category C). Some precautionary/engineering measures will be required to ensure that the workers involving in the construction of the road are protected. The use of passive gas controls will be required for Category C risk level.

"What if IWMF not proceed"

The feasibility of the potential site for IWMF is still being conducted and there is no decision on the implementation programme and site selection. In case the IWMF is not located at the middle ash lagoon, the boundary of the proposed WENT Landfill Extension would be further

expanded to include the middle lagoon. The LFG management system including LFG barrier, collection system and extraction system will also be extended to include this additional fill area, and the collected LFG would be pumped to the LFG treatment facilities for treatment. Hence, it is considered that there would not be additional impacts.

7.6 Protective and Precautionary Measures

Landfill liner, landfill gas and leachate collection & treatment system, LFG control devices, landfill capping will be designed with reference to the specifications of existing WENT Landfill. An Emergency and Contingency Plan will be devised by the future DBO Contractor for implementation of appropriate actions in case any LFG migration detected. Such measures include those currently being adopted in the existing WENT Landfill, e.g. installation of double layer liner, LFG extraction / collection / treatment / utilisation systems, gas sensors, etc.

A comprehensive review of the previous monthly reports of landfill operation for the environmental and operation monitoring data, and operation and incident records of mitigation and protective measures adopted in the existing WENT Landfill has provided the basis for the following conclusions:

- LFG liner: effective barrier to prevent LFG migration off-site;
- LFG collection and extraction system: effective to convey LFG from buried waste location to treatment and utilisation systems;
- LFG treatment by flaring: effective to convert LFG to harmless CO_2; and
- LFG utilisation for power generation: effective to convert LFG to electrical power.

Based on these review findings, the mitigation and protective measures adopted in the existing WENT Landfill are proposed for the future WENT Landfill Extension, in consideration of the following key factors:

- The WENT Landfill Extension have similar geological features to the existing WENT Landfill;
- The WENT Landfill Extension are anticipated to receive waste of similar nature to the existing WENT Landfill as a worst-case assumption;
- The WENT Landfill Extension have comparable or slightly larger capacity to the existing WENT Landfill; and
- The existing WENT Landfill operation has demonstrated the capability and success of the implemented mitigation and protective measures as precedent of the WENT Landfill Extension.

In case LFG migration is detected and confirmed, the Emergency and Contingency Plan will be triggered for implementation of the necessary action, which include but not limited to the necessary evacuation of occupants, provision of forced ventilation to the concerned sensitive receiver, investigation of potential source of LFG, increase LFG extraction rate on-site, etc. Details of the procedures will be documented in the Emergency and Contingency Plan as prepared by the future landfill operator.

7.6.1 Within WENT Landfill Extension

According to the LFG Guidance Note, significant engineering measures will be required to protect the planned development with risk category at "**High**" level (**Table 7.3)**. Recommendations for protection and precautionary measures for implementation in WENT Landfill Extension during the various Project phases are discussed as follows.

7.6.1.1 Construction Phase

General Requirements

Special precautions, in accordance with Chapter 8 of LFG Guidance Note (a copy of the Chapter is enclosed in **Appendix 7.2** for reference), should be taken in all respects of works against the possible presence of LFG due to close proximity of the existing WENT Landfill and its extension. Potential hazards of exposure to LFG, e.g. ignition, explosion, asphyxiation, toxicity, etc. should be fully aware and alerted.

The LFG risks during the construction phase should be minimised by implementing suitable precautionary measures recommended in Chapter 8 of the LFG Hazard Assessment Guidance Note (See **Appendix 7.2**). Essential measures include the following:

Prominent LFG safety warning signs should be erected on-site to alert all personnel and visitors of the hazards during excavation works. No smoking or burning should be permitted on-site in the working area, and prominent 'No smoking' and 'No Naked Flames' signs should be erected on-site where appropriate. No worker should be allowed to work alone at any time in excavated trenches or confined areas on-site.

Adequate fire fighting equipment should be provided on-site. Construction equipment should be equipped with a vertical exhaust at least 0.6m above ground installed with spark arrestors. Electrical motors and extension cords should be explosion-proof and intrinsically safe when being used on-site.

'Permit to Work' system should be implemented in accordance with the guidance on entry into confined spaces provided in 'Code of Practice on Safety and Health at Work in Confined Spaces' issued by Labour Department of HKSAR Government. Welding, flame-cutting or other hot works should be conducted only under 'Permit to Work' system following clear safety requirements, gas monitoring procedures and in the presence of qualified persons to oversee the works.

For piping assembly or conduit construction, all valves and seals should be closed immediately after installation to avoid accumulation and migration of LFG. If installation of large diameter pipes (diameter >600mm) is required, the pipe ends should be sealed on one side during installation. Forced ventilation is required prior to operation of the installed pipeline. Forced ventilation should also be required for works inside trenches deeper than 1m.

The frequency and location of LFG monitoring within the excavation area should be determined prior to commencement of works. LFG monitoring in excavations should be conducted at no more than 10mm from the exposed ground surface. For excavation works, LFG monitoring should be conducted

(1) at ground surface prior to excavation,

(2) immediately before workers entering excavations,

(3) at the beginning of each half-day work, and

(4) periodically throughout the working day when workers are in the excavation.

Any cracks on ground level encountered on-site should be monitored for LFG periodically. Appropriate action should be taken in accordance with the action plan shown in **Table 7.8**.

LFG precautionary measures involved in excavation and piping works should be provided in accordance with the LFG Guidance Note and included in the Safety Plan for the construction phase of the Project. Temporary offices or buildings should be located where free LFG has been proven or raised clear of ground at a separation distance of at least 500mm.

For large development such as WENT Landfill Extension, a Safety Officer trained in the use of gas detection equipment and landfill gas-related hazards should be present on-site throughout the groundworks phase. The Safety Officer should be provided with an intrinsically safe portable instrument appropriately calibrated and capable of measuring the following gases:

- Methane (CH4) 0-100% Lower Explosion Limit (LEL) and 0-100% v/v;
- CO_2 0-100%; and
- O_2 0-21%

Safety Measures

(a) All personnel who work on site and all visitors to the site should be made aware of the possibility of ignition of gas in the vicinity of excavations. Safety notices should be posted warning of the potential hazards.

(b) Those staff who work in, or have responsibility for 'at risk' areas, including all excavation workers, supervisors and engineers working within the Consultation Zone, should receive appropriate training on working in areas susceptible to landfill gas, fire and explosion hazards.

(c) An excavation procedure or code of practice to minimise landfill gas related risk should be devised and carried out by the project proponent.

(d) No worker should be allowed to work alone at any time in or near to any excavation. At least one other worker should be available to assist with a rescue if needed.

(e) Smoking, naked flames and all other sources of ignition should be prohibited within 15m of any excavation or ground-level confined space. 'No smoking' and 'No naked flame' notices should be posted prominently on the construction site and, if necessary, special areas designated for smoking.

(f) Welding, flame-cutting or other hot works should be confined to open areas at least 15m from any trench or excavation.

(g) Welding, flame-cutting or other hot works may only be carried out in trenches or confined spaces when controlled by a 'permit to work' procedure, properly authorised by the Safety Officer (or, in the case of small developments, other appropriately qualified person).

(h) The permit to work procedure should set down clearly the requirements for continuous monitoring for methane, carbon dioxide and oxygen throughout the period during which the hot works are in progress. The procedure should also require the presence of an appropriately qualified person, in attendance outside the 'confined area', who shall be responsible for reviewing the gas measurements as they are made, and who shall have executive responsibility for suspending the work in the event of unacceptable or hazardous conditions. Only those workers who are appropriately trained and fully aware of the potentially hazardous conditions which may arise should be permitted to carry out hot works in confined areas.

(i) Ground level construction plant should be fitted with vertical exhausts at least 0.6m above ground level and with spark arrestors.

(j) Any electrical equipment, such as motors and extension cords, should be intrinsically safe.

(k) During piping assembly or conduit construction, all valves/seals should be closed immediately after installation. As construction progresses, all valves/seals should be closed as installed to prevent the migration of gases through the pipeline/conduit. All piping/conduiting should be capped at the end of each working day.

(l) Mobile offices, equipment stores, mess rooms etc. should be located on an area which has been proven to be gas free (by survey with portable gas detectors) and ongoing monitoring should be carried out to ensure that these areas remain gas free. The use of permanent gas detectors may be appropriate in some circumstances where there is a relatively high risk but for many developments it will be sufficient to have regular monitoring undertaken manually by the safety officer. The particular arrangements to be adopted at a specific site will need to be determined during the risk assessment/design of protection measures.

(m) Alternatively, such buildings should be raised clear of the ground. If buildings are raised clear of the ground, a minimum, clear separation distance (as measured from the highest point on the ground surface to the underside of the lowest floor joist) should be 500mm.

(n) During construction, adequate fire extinguishing equipment, fire-resistant clothing and breathing apparatus (BA) sets should be made available on site.

- At larger developments, fire drills should be organised at not less than six monthly intervals.
- The developer should formulate a health and safety policy, standards and instructions for site personnel to follow.

Monitoring

Periodically during groundworks construction, CH_4, CO_2 and O_2 should be monitored in the works area by using appropriately calibrated portable gas detection equipment.

The monitoring frequency and areas to be monitored should be set down prior to commencement of groundworks either by the Safety Officer or by an appropriately qualified person.

Routine monitoring should be carried out at all excavations, manholes and chambers and any other confined spaces that may have been created by the temporary storage of building materials on-site.

All measurements in excavations should be made with the monitoring tube located not more than 10mm from the exposed ground surface.

Monitoring of excavations should be undertaken as follows:

(a) For excavations deeper than 1m, measurements should be conducted:

- At ground surface before excavation commences;
- Immediately before any worker enters the excavation;
- At the beginning of each working day for the entire period the excavation remains open; and
- Periodically throughout the working day whilst workers are in the excavation.

(b) For excavations between 300mm and 1m, measurements should be conducted:

- Directly after the excavation has been completed; and
- Periodically whilst the excavation remains open.

(c) For excavations less than 300mm, monitoring may be omitted at the discretion of the Safety Officer or other appropriately qualified person.

Actions in the Event of Gas Being Detected

Depending on the results of the measurements, actions required will vary and should be set down by the Safety Officer or other appropriately qualified person. As a minimum these should encompass those actions specified in **Table 7.8**.

Table 7.8 Actions in the Event of Gas Being Detected in Excavations

Parameter	Monitoring Result	Action
O_2	<19%	Ventilate trench/ void to restore O_2 level to >19%
	<18%	Stop works, evacuate personnel/ prohibit entry, and increase ventilation to restore O_2 level to >19%
CH_4	>10% LEL*	Post 'No smoking' signs, prohibit hot works, and ventilate to attenuate CH_4 level to <10% LEL
	>20% LEL	Stop works, evacuate personnel/ prohibit entry, and ventilate to attenuate CH_4 level to <10% LEL
CO_2	>0.5%	Ventilate to attenuate CO_2 level to <0.5%
	>1.5%	Stop works, evacuate personnel/ prohibit entry, and ventilate to attenuate CO_2 level to <0.5%

Note: * LEL: Lower Explosion Limit

7.6.1.2 Operation, Restoration and Aftercare Phases

Where any service voids, manholes and inspection chambers within the landfill extension are entered for maintenance and LFG monitoring, all the safety requirements in accordance with the 'Code of Practice on Safety and Health at Work in Confined Spaces' issued by Labour Department of HKSAR Government should be strictly followed.

Buildings on-site should be incorporated with passive system relying on natural air movement to prevent gas build-up and active system requiring energy input to mechanically move air to protect against LFG build-up. Design measures for sub-surface building services should include generic measures such as LFG barriers, gas vents and strategic routing of any service utilities away from the potential LFG migration pathways.

Any new-built permanent building structures within the landfill extension sites, forced ventilation and gas detection system with audible alarm should be installed. No person should be allowed to enter or remain in any confined areas when CO_2 levels >1.5% v/v or O_2 levels <18% v/v is detected. Access to confined spaces in the landfill extension sites should be controlled to only authorised persons.

Specific types of gas protection measures which can be applied to building services have been provided in accordance with the LFG Guidance Note (details are appended in **Appendix 7.4**). They generally include LFG barriers, gas vents, location of service entries above ground, and service conduits passing through consultation zone.

General Protection Measures

Passive systems

The most common way of preventing gas from entering an area is to set a "LFG cut-off trench barrier" (**Figure 7.6**) into the area which is either keyed into low permeability strata or extended at least 1m below the lowest groundwater level.

The presence of a LFG cut-off trench barrier to the movement of gas may lead to a gradual build up of gas on the landfill side of the barrier if the gas migration pathway is covered by low permeability materials. To relieve the potential build up of gas, it may be necessary to

install additional measures for venting the gas such as trenches filled with no-fines, granular material, e.g. gravel, connected to venting pipes which will provide a preferential pathway for the release of gas to atmosphere.

Gas monitoring

With either passive or active systems, it is usual to install monitoring wells into the ground on the development side of the LFG cut-off trench barrier or extraction wells. These are used to measure the concentrations of CH_4 and CO_2 within the ground and hence determine the effectiveness of the measures in preventing LFG migration.

Building Protection Design Measures

Passive systems

Passive control measures for buildings include the following:

- Gas-resistant polymeric membranes which can be incorporated into the floor or wall construction as a continuous sealed layer. Membranes should be able to demonstrate low gas permeability and resistant to possible chemical attack and may incorporate aluminium wafers to improve performance.
- Other building materials, e.g. dense well-compacted concrete or steel shuttering which provide a measure of resistance to gas permeation.
- Creation of a clear void under the structure which is ventilated by natural structure and providing preferential pathways for release of gas.
- Synthetic composite geotextile which provide a free-venting cellular structure and provide preferential pathways for release of gas.

Passive control measures may be used in low and medium risk situations where gas emissions are expected to be at relatively low rates and concentrations and venting to atmosphere is unlikely to cause a hazard or nuisance due to the low concentration or high dilution which will occur.

Active systems

Active control measures are employed where the rates of gas emission are too high to rely on passive ventilation or in particular circumstances where, for example, there is a sensitive target to protect. Active control measures include the following.

- A void under the structure like passive control, but it is continuously ventilated by a fan such that any emissions of gas from the ground are mixed and diluted in the air flow before discharge to atmosphere. The rate of ventilation is usually expressed in terms of the volume of air changes (volume of void) per hour and is designed to ensure that, based on the estimated rate at which gas will enter the void; the LFG will be diluted to safe concentrations. Discharge to atmosphere usually takes place above eaves level of the building.
- Construction of a granular layer incorporating perforated collector pipes which is continually ventilated by a fan, such that any emissions of gas from the ground are drawn towards the end of the pipes and diluted in the air flow before discharge to atmosphere above the eaves level of the building.
- Creation of a positive pressure zone below the building structure by injection of migrated LFG into the granular layer.
- Creation of positive air pressure zones within building structures to counteract possible LFG migration into the building from the ground.

Active control measures should be used in conjunction with passive barriers, e.g. membranes in floors, in order that there is no migration of air / gas flow through a floor or

wall into a structure. Gas detection systems should also be used to monitor gas in extracted air flow, and to monitor internal spaces inside buildings. Active systems are normally required for high risk sites where gas has been measured in the ground at or close to the development site, and buildings are close to the source of gas.

Gas detection system

Gas detection systems include the following:

- A series of sensors located in appropriate positions within a structure where gas has the potential to accumulate, e.g. near service entries, inside ventilation basements, cupboards or ducts. The sensors detect flammable gas by catalytic oxidation or infra-red principles, and pass data back to a control panel by electrical cabling. The control panel can be set to have two triggers activating alarms and may also be linked by wireless telemetry or internet off-site.
- A series of sampling tubes which are located in appropriate positions and run back to a single measurement station operating on infra-red measurement principles. A pump automatically draws samples of air/gas along each tube in a pre-set pattern such that measurements of flammable and/or other gases (e.g. CO_2) can be taken at regular and frequent intervals. Triggers, alarms, wireless telemetry and internet systems can be incorporated.
- Manual monitoring can be conducted using a range of portable instruments. Instruments used in areas where flammable gas may be present should be intrinsically safe.

Gas detection system should only be proposed where there is an organisation involved n the long-term use of the development which can be relied upon to maintain and calibrate the system on a regular basis. Where a detection system is used as a final defence, it must be ensured that appropriate emergency action, to be taken in the event of the trigger levels being exceeded, are specified explicitly in an Emergency and Contingency Plan.

Maintenance of control measures

Fundamental to the success of gas protection measures is the means by which they are monitored, managed and maintained, and thus all designs must be accompanied by a statement or set of procedures showing how the measures proposed can be confidently expected to operate satisfactorily for the duration of the potential gas-producing lifetime of the landfill.

Design Measures for Sub-surface Building Services

Generic Protection Measures

- LFG Barrier – As for barriers used to prevent movement of gas through the ground, use may be made of clay (or clay-rich soils), bentonite or polymeric membranes (e.g. HDPE). A LFG barrier used to prevent movement of gas through services may form part of a more extensive barrier to prevent general mitigation towards the development. In the case of water pipes and sewers which are not always fully filled, water traps e.g. U-bends, should be provided to effectively seal off the conduit and prevent gas-phase transport.
- Gas Vents – Vent pipes or gridded manhole covers may be used to avoid build-up of gas in underground utilities manholes. Venting stacks may be built into inspection chambers or connected to collection pipes within high permeability drainage layers adjacent to LFG barriers. Under all circumstances, care should be taken in accessing any manhole chambers especially those which are not fitted with vents and necessary safety procedures must be followed.

- Location of Service Entry Points Above Ground – In some cases it is possible to route service entries into a building above ground level, therby providing a discontinuity in the gas migration pathway and thus eliminating the risk of gas entry to the building interior.

Services Conduits Passing through Consultation Zone

In addition to the general guidance given above, the following recommendations apply to service conduits which pass through the Consultation Zone with connections to developments outside the Zone:

- For all service runs, the aim should be to provide a protection barrier located at the point where the trenches passes through the perimeter of the consultation zone.
- The service run through the consultation zone may remain "unprotected" since the risks will be minimised by the protection measures installed at the perimeter of the consultation zone and as the general public may not have access to such underground features.
- The service run should be designated as a "special route" and the utility companies should be informed to that effect so that they may implement precautionary measures.
- Any future works such as maintenance or extensions should be subject to the recommendations specified in the LFG Guidance Note.
- Any above ground (minor) termination features e.g. telecom cabinets should be considered to be "buildings" and should be protected by e.g. membrane barriers to minimise the possibility of gas ingress.

Guidance for Entry into Manholes and Chambers

- Any chamber, manhole or culvert which is large enough to permit access to personnel should be subject to entry safety procedures. Such work in confined spaces is controlled by the Factory and Industrial Undertakings (F&IU) (Confined Spaces) Regulations of the F&IU Ordinance.

7.6.2 Outside WENT Landfill Extension

The administrative control on development adjacent to the future WENT Landfill Extension shall be defined by the 250m consultation zone, which is a line running parallel to and 250m away from the edge of the waste boundary of the landfill extension site.

A preliminary 250m LFG consultation zone for existing WENT Landfill and its extension is proposed as depicted in **Figure 7.4**. The final demarcation of this zone should be updated for the LFG Guidance Note with respect to the final footprint of WENT Landfill Extension. This 250m consultation zone acts as a precautionary measure, within which any development or re-development projects falling in whole or in part should give attention to the procedures, requirements and guidelines so that potential hazards associated with LFG for the proposed development can be minimised or avoided at an early stage.

As illustrated in **Figure 7.4**, the extension of the consultation zone will attribute to the additional encroachment of land with appropriate area of 232ha. However, these areas are imposed with various extents of development constraints, e.g. low development potential due to steep hill slopes and terrain.

As mentioned in Section 7.4.4.2, the existing and planned/committed developments in the extended consultation zone include the following:

- Black Point Power Station (medium risk);
- Potential site for IWMF and STF (medium risk); and
- Re-aligned Nim Wan Road construction (low to medium risk).

Whilst the WENT Landfill Extension will be designed as a containment landfill incorporating multi-layer composite liner systems covering the entire surface area of the site with LFG collection and management systems to eliminate any off-site migration of LFG, in order to offer enhanced protection for these targets, it is proposed that a LFG cut-off trench barrier should be built along the site boundary of the WENT Landfill Extension, as shown in **Figure 7.4**, of preventing gas from entering an area, which is keyed into low permeability strata or extends at least 1m below the lowest groundwater level. The presence of a LFG cut-off trench barrier to the movement of gas may lead to a gradual build up of gas on the landfill side of the barrier if the gas migration pathway is covered by low permeability materials. To relieve the potential build up of gas, it may be necessary to install additional measures for venting the gas such as trenches filled with no-fines, granular material, e.g. gravel, connected to venting pipes which will provide a preferential pathway for the release of gas to atmosphere. An outline of LFG cut-off trench barrier and a more detailed typical design of it are shown in **Figure 7.6**. This LFG cut-off trench barrier will cut off any gas migration from WENT Landfill Extension to the power station, IMWF and STF which falls into the 250m LFG consultation zone of existing WENT Landfill and its extension.

Moreover, LFG monitoring wells will be installed in the ground on the development side of the barrier to measure the concentration of methane and carbon dioxide and hence to determine the effectiveness of the barrier as preventing LFG migration.

In order to prevent gas migration through the fault line in particular to the existing Black Point Power Station, sealing of fault line ends by grouting will be implemented (see **Figure 7.5**). Grouting of fault lines is a technique commonly carried out on tunnelling and excavation projects in order to prevent the ingress of water along features that have a higher hydraulic conductivity than the surrounding rock mass, such as laterally persistent geological fault lines. The sealing of conductive features is typically carried out through the injection of cement bentonite grouts, which are pumped into the ground through drillholes formed to intersect the features of concern. In the event that investigation works during the detailed design stage identify the presence of laterally persistent faults running beneath the landfill site, and leading towards sensitive receivers, the following works could be carried out in order to minimize the risk of landfill gas migration:

- Sealing of any surface exposures of the 'fault' feature exposed during the site formation works. This could be carried out through the application of a shotcrete cover prior to the placement of the landfill liner, which also acts as a barrier to landfill gas migration.
- Ground treatment at the landfill boundary, comprising pressurised injection of grout within a series of inclined drillholes formed to intersect the fault at various depths. These would effectively form an impermeable barrier against the lateral migration of landfill gas along the fault line.
- Adequate venting of landfill gases such that insufficient pressures develop to result in lateral or downward migration of gas.

Nevertheless, it is worth noting that the landfill will be a closed system – ie. the liner system itself will prevent any gas migration. All other works mentioned above are just precautionary in nature.

For the construction of re-aligned Nim Wan Road, the protection measures mentioned in the section 7.6.1 will be followed to minimise LFG risks during the construction of the road.

7.6.3 Design of LFG Protection Measures for the WENT Landfill Extension

The results from the routine and long-term LFG monitoring programme for the existing WENT Landfill operation indicate that the landfill has been operating satisfactorily and considered adequate with the proven LFG collection system and control plant in place to minimise any potential impact to the concerned sensitive receivers. It is likely that the WENT Landfill Extension will be designed to adopt similar or more advanced LFG control

measures so as to ensure future compliance of environmental and safety requirements. Landfill gas protection measures adopted in the existing WENT Landfill are appended in **Appendix 7.3**.

The design of the landfill gas protection measures to be adopted on-site, e.g. utilities, buildings, LFG cut-off trench barrier, monitoring wells and facilities related to the WENT Landfill Extension project will be performed by a landfill gas specialist consultant appointed by future DBO contractor. Moreover, the landfill gas protection measures will be checked and certified by a qualified independent consultant. The contractor shall ensure that the required protective measures are implemented and constructed in accordance with the design and shall establish a maintenance and monitoring programme for ensuring the continual performance of the implemented protection measures. The above requirements shall be included in the tender documents of WENT Landfill Extension project.

When the detailed design is available, the future contractor is required to undertake further landfill gas hazard assessment to take account of the more readily available detailed information to finalise the design of the landfill gas protection measures recommended in this report. During the future detailed design stage, a review of the preliminary qualitative LFG hazard assessment presented in the report will be carried out, a detailed qualitative LFG hazard assessment will be prepared and all the report together with the detailed design of gas protection measures will be submitted to EPD for vetting.

7.7 Monitoring Requirement

LFG monitoring should be conducted in various phases of WENT Landfill Extension with the following key objectives:

- To ensure the safety and health of workers during the construction stage of landfill extension.
- To determine the performance and effectiveness of LFG mitigation measures and control systems on preventing uncontrolled LFG migration.
- To establish a monitoring regime for buildings within the landfill site services routes and other enclosed areas as a warning system for detection of any potential build-up of hazardous LFG concentrations.
- To ascertain the characteristics of the landfill and estimate the quantity and quality of the LFG production in order to assess the potential for future utilisation.

The LFG monitoring programme of the existing WENT Landfill including the monitoring frequency and location was reviewed to suit the WENT Landfill Extension. Additional monitoring before and during realignment of Nim Wan Road is suggested at the boundary of new Nim Wan Road to ensure that there is no major change of baseline condition from existing WENT Landfill. Detailed LFG monitoring requirements will be established in the EM&A Manual for WENT Landfill Extension including the specifications of monitoring locations, parameters, equipment, procedures, frequency, reporting format, Action and Limit (A/L) Levels, Event and Action Plan (EAP), and Emergency and Contingency Plan, etc. With reference to the monitoring data of the existing landfill operation, monitoring for a suite of LFG parameters will be continued, including:

- Surface gas: CH_4, CO_2, O_2;
- Monitoring holes: Pressure, methane, carbon dioxide, oxygen, flammable gas;
- Well head: Pressure, oxygen, methane, carbon dioxide, flammable gas, volatile organic compounds (VOCs).

The LFG monitoring locations of the existing WENT Landfill site is shown in **Figure 7.7**. The proposed tentative monitoring locations for the WENT Landfill Extension including the

monitoring wells along the LFG cut off trench barrier are shown in **Figure 7.7**, which are subject to changes depending on the design, phasing and modification by the DBO Contractor.

In general, the LFG monitoring programme should include on-site and off-site monitoring for the above parameters at frequency specified in the future Landfill Monitoring Plan (LMP). Similar to that being practised in the existing WENT Landfill, on-site and off-site monitoring for LFG should be conducted including:

- Quantity and quality of extracted LFG at individual well head;
- Quantity of LFG automatically monitored at LFG pumping station;
- Fixed surface and borehole locations along the landfill site boundary and at potential sources of concern;
- Monitoring safe level of LFG concentration, and implementation of sufficient mitigation measures when entering confined spaces within the landfill site;
- Off-site monitoring for LFG at highly sensitive receivers; and
- Detailed requirements of LFG monitoring shall be defined in the EM&A Manual and LMP.

The measured LFG results will be checked for compliance against the pre-defined A/L Levels established in the EM&A Manual and in the LMP developed by the DBO Contractor. In case exceedance of compliance level is detected at any locations, the EAP will be triggered for necessary action to be taken.

If abnormally high LFG level is detected at any off-site sensitive receivers, the Emergency and Contingency Plan will be strictly followed to trigger the planned action without delay, which may include but not limited to the evacuation of occupants, provision of forced ventilation to the concerned sensitive receiver, investigation of potential source of LFG, increase LFG extraction rate on-site to minimise migration etc. Details of the procedures will be documented in the Emergency and Contingency Plan.

7.8 Conclusion

The results of this qualitative risk assessment for LFG hazards associated with the construction, operation, restoration and aftercare phases indicate that the overall risks to the receivers within the WENT Landfill Extension would be categorised as "**Medium"** to **"High**" and that to the receivers outside the WENT Landfill Extension would be "**Low"** to **"Medium**". The sensitive receivers falling within the newly proposed 250m consultation zone shall be prone to LFG potential risk and appropriate protective and precautionary measures including engineering design and monitoring programme have been proposed to reduce such risk to acceptable levels. With these measures in place, no adverse impact would be anticipated.