9 Landfill Gas Hazard

9.1 Introduction

9.1.1 This Section provides an evaluation of the potential landfill gas hazards arising from the construction and operation of the proposed Project. Mitigation measures have been proposed if considered necessary to minimize the identified landfill gas hazards.

9.2 Relevant Legislation, Standards and Guidelines

9.2.1 The relevant legislation, standards and guidelines applicable to the present study for the assessment of landfill gas (LFG) hazards include:

- Section 1.1 (f) in Annex 7 and Section 3.3 in Annex 19 of Technical Memorandum on Environmental Impact Assessment Process (EIAO-TM);
- Landfill Gas Hazard Assessment Guidance Note (EPD/TR8/97) (Guidance Note)
- Practice Note for Professional Person (ProPECC) PN3/96 – Landfill Gas Hazard Assessment for Developments adjacent to Landfills

9.2.2 These legislation and guidelines recommended that in general, a qualitative assessment of the risk posed by LFG is required for a development which is proposed within a 250m "Consultation Zone" around any landfill site, to ensure appropriate precautionary measures would be designed and implemented to safeguard the development.

9.3 Potential Hazard Associated with Landfill Gas and Leachate

Landfill Gas

9.3.1 Methane, one of the major components of landfill gas, is flammable and will burn when mixed with air between approximately 5% by volume and 15% by volume (the Lower Explosive Limit (LEL) and Upper Explosive Limit (UEL) respectively). If a mixture of methane and air with a composition between the LEL and UEL is ignited in a confined space, the resulting combustion may give rise to an explosion. Methane is odourless and colourless although in landfill gas it is typically associated with numerous highly odoriferous compounds which gives some warning of its presence. However, the absence of odour should not be taken to mean that there is no methane - this can only be confirmed by using appropriately calibrated methane detectors. Methane is also an asphyxiant.

9.3.2 Carbon Dioxide, the other major component of landfill gas, is asphyxiating and causes adverse health effects at relatively low concentrations. The long-term Occupational Exposure Limit (OEL) is 0.5% by volume. Like methane, in the pure form, it is odourless and colourless and its presence (or absence) can only be confirmed by using appropriately calibrated detectors.

9.3.3 Gas Buoyancy. Methane is lighter than air whereas carbon dioxide is heavier than air. Typical mixtures of Landfill gas are likely to have a density close to or equal to that of air. However, site conditions may result in a ratio of methane to carbon dioxide which may make the gas mixture lighter than air or heavier than air. As a result, landfill gas may collect in the bottoms of trenches or excavations, or may rise up and accumulate beneath structures and foundations.

Leachate

9.3.4 The main problem associated with leachate is its potential for corrosion of steel and concrete structures and pollution of receiving waters. Leachate also presents a potential health risk to anyone who comes into contact with it. In particular, it may cause severe irritation if there is

contact with skin or eyes. Many of the compounds likely to be present in the leachate are toxic, if present at sufficiently high concentration.

9.4 Landfill Gas Assessment Criteria and Methodology

9.4.1 The risk associated with LFG has been evaluated based on the "Source – Pathway – Target" model in accordance with the Guidance Note.

Source: the location, nature and likely quantities/concentrations of LFG which have the potential to affect the Project site.

Pathway: the ground and groundwater conditions, through which the LFG must pass if they are to reach the Project site.

Target: the elements of the development which are sensitive to the effects of the hazardous materials.

Source

9.4.2 The classification of the Source (i.e. the landfill) is determined as follows:

Minor Landfill sites at which gas controls have been installed and proven to be effective by comprehensive monitoring which has demonstrated that there is no migration of gas beyond the landfill boundary (or any specific control measures) and at which control of gas does not rely solely on an active gas extraction system or any other single control measure which is vulnerable to failure; or

Old landfill sites where the maximum concentration of methane within the waste, as measured at several locations across the landfill and on at least four occasions over a period of at least 3 months (preferably longer), is less than 5 % by volume (v/v).

Medium Landfill site at which some form of gas control has been installed (e.g. lined site or one where vents or barriers have been retrospectively installed) but where there are only limited monitoring data to demonstrate its efficacy to prevent migration of gas; or

Landfill site where comprehensive monitoring has demonstrated that there is no migration of gas beyond the landfill boundary but where the control of gas relies solely on an active gas extraction system or any other single control system which is vulnerable to failure.

Major Recently filled landfill site at which there is little or no control to prevent migration of gas or at which the efficacy of the gas control measures has not been assessed; or

Any landfill site at which monitoring has demonstrated that there is significant migration of gas beyond the site boundary.

Pathway

9.4.3 Generally, three types of pathways are considered for the transmission of LFG. They are:

- Man-made pathways e.g. utility connections, stormwater channels, etc.;
- Natural pathways such as rock jointing planes, fissures, and other naturally occurring phenomena which may promote or give rise to the transmission of gas over distances; and
- A combination of the previous categories. An example of the latter may be, for instance, where a specific geological feature promotes gas transmission but which stops short of directly linking the landfill and target. A man-made connection, however, may also co-exist

near the edge of the geological feature, in combination with the former, may act to link the two sites. In this instance, careful assessment of the likelihood of the mechanism acting to link the two pathways needs to be undertaken before assigning an appropriate pathway classification.

9.4.4 The broad classification of the Pathway is as follows:

Very short/direct	Path length of less than 50m for unsaturated permeable strata and fissured rock or less than 100m for man-made conduits
Moderately short/direct	Path length of 50-100m for unsaturated permeable soil or fissured rock or 100-250m for man-made conduits
Long/indirect	Path length of 100-250m for unsaturated permeable soils and fissured rock

9.4.5 In classifying the pathway, however, adjustment to the above general guidelines will often be required to take account of other factors which will affect the extent of gas migration including the following:

- a broad assessment of the specific permeability of the soil;
- spacing, tightness and direction of the fissures/ joints;
- topography;
- depth and thickness of the medium through which the gas may migrate (which may be affected by groundwater level);
- nature of the strata over the potential pathway;
- number of different media involved; and
- depth to groundwater table and groundwater flow patterns.

Target

9.4.6 The different elements of the proposed Project which will be sensitive to the impacts of landfill gas will be identified. Such potential "target" will include building basements and ground level rooms, underground carparks, service ducts and manhole, unventilated excavations and other confined spaces at or below ground level. Different levels of vulnerability or sensitivity of potential targets for landfill gas have been classified as follows:

High Sensitivity

- Buildings and structures with ground level or below ground rooms/ voids or into which services enter directly from the ground and to which members of the general public have unrestricted access or which contain sources of ignition.
- This would include any developments where there is a possibility of additional structures being erected directly on the ground on an *ad hoc* basis and thereby without due regard to the potential risks.

Medium Sensitivity

- Other buildings, structures or service voids where there is access only by authorized, well trained personnel, such as the staff of utility companies, who have been briefed on the potential hazards relating to landfill gas and the specific safety procedures to be followed.

- Deep excavations.

Low Sensitivity

- Buildings/ structures which are less prone to gas ingress by virtue of their design (such as those with a raised floor slab).
- Shallow excavations.
- Developments which involve essentially outdoor activities but where evolution of gas can pose potential problems.

9.4.7 The above examples of different categories within each criterion are to be used as a general guide only and specific aspects of a development may render it more or less sensitive than indicated. Account needs to be taken of any particular circumstances when assigning a target to one of three indicated categories.

Assessment of Risk Criteria

9.4.8 Following the determination of the categories of source, pathway and target in which the landfill, pathway and development fall, a qualitative assessment of the overall risk may be made by reference to **Table 9.1**. The potential implications associated with the various qualitative risk categories are summarized in **Table 9.2** below.

Table 9.1 Classification of Risk Categories

Source	Pathway	Target Sensitivity	Risk Category
Major	Very short/direct	High	Very high
		Medium	High
		Low	Medium
	Moderate 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
	Moderate 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
	Moderate short/direct	High	Medium
		Medium	Low
		Low	Very low
	Long/indirect	High	Medium
		Medium	Low
		Low	Very low

Table 9.2 General Categorization of Risk

Category	Level of Risk	Implication
A	Very high	The type of development being proposed is very undesirable and 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	The risk is so low that no precautionary measures are required.

9.4.9 Five generic forms of protection will be used in mitigating the hazards to developments. These generic forms corresponding to the five risk levels are set out in **Table 9.3** and the control terms used are defined in **Table 9.4.**

Table 9.3 Generic Protection Measures for Planning Stage Categorization

Level of Risk	Generic Protection Measures
Very high	For the planned development active control of gas, supported by barriers and detection systems. Another, less sensitive form of development should also be considered.
High	Active control of gas, including barriers and detection systems.
Medium	Use of "semi-active" or enhanced passive controls. Detection systems in some situations.
Low	Passive control of gas only.
Very low	No precautionary measures required.

Table 9.4 Definition of Control Terms

Term	Definition
Active control	Control of gas by mechanical means e.g. 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 electrically powered fans.
Passive control	Provision of barriers to the movement of gas e.g. 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.

9.5 Description of the Environment

9.5.1 The proposed Project site, i.e. Tai Po Sewage Treatment Works (TPSTW), is located in Tai Po Industrial Estate (TPIE) and approximately 13.8 ha in area. It is adjacent to the western boundary of Shuen Wan Restored Landfill and fall within 250m consultation zone of the landfill as shown in **Figure 9.1**.

9.6 Qualitative Landfill Gas Assessment

Assessment Methodology

9.6.1 The potential risk of LFG from the Shuen Wan Restored Landfill to the proposed Project has been assessed in accordance with the Guidance Note and Appendix G of the EIA Study Brief

(ESB-321/2019). The assessment shall include the following:

(i) Review of background information and studies related to Shuen Wan Restored Landfill.

(ii) Identification of the nature and extent of the sources, including the likely concentrations/amounts of hazardous emissions which might have the potential for causing impacts on the Project.

(iii) Identification of possible pathways through the ground, underground cavities, utilities or groundwater and the nature of these pathways through which hazardous emissions must traverse if they were to reach the facilities within the Project site.

(iv) Identification of the potential targets associated with the Project which are sensitive to the impacts of the hazardous emissions.

(v) Qualitative assessment on the degrees of risk which the hazardous emissions may pose to the target for each of the source-pathway-target combinations.

(vi) Design of suitable level of precautionary measures and types of protection measures and contingency plan for the construction and operation of the developments proposed under the Project.

(vii) Identification of monitoring requirements for assessing the adequacy and performance of the implemented protection measures.

Desktop Study

9.6.2 The following information and documents have been reviewed for the preparation of this assessment:

- Hong Kong Geological Survey Map (HGM20 series scale 1:20,000) (Edition II – 2008);
- Approved EIA report of "Shuen Wan Golf Course" (AEIAR-221/2019);
- Approved EIA report of "Tai Po Sewage Treatment Works Stage V" (AEIAR-081/2004);
- Shuen Wan Landfill Restoration – Annual Environmental Audit Report (2016-2020)

History of Shuen Wan Restored Landfill

9.6.3 The Shuen Wan Restored Landfill was opened for the waste reception in 1973 and closed in 1995. The waste received included municipal, construction as well as industrial and commercial. The landfill site is located to the east of the of Tai Po and is approximately 55 hectares (ha) in area. The restoration works for Shuen Wan Restored Landfill commenced in December 1996 and was completed in December 1997. It has been subsequently used as a temporary golf driving range since April 1999. According to the EIA report of "Shuen Wan Golf Course" (AEIAR-221/2019), an 18-hole golf course, serving both members and the public will be constructed on the restored landfill in 2021 and operated in end 2023 tentatively.

9.6.4 Since the restoration works, monthly environmental monitoring (e.g. LFG, groundwater, leachate, surface water, etc.) and annually environmental audit have been conducted.

Restoration Facilities for Shuen Wan Restored Landfill

9.6.5 The restoration facilities for Shuen Wan Restored Landfill mainly consist of landfill capping system, LFG management system and leachate management system as described below:

(I) LFG Management System

9.6.6 The LFG management system consists of active gas extraction system, LFG utilisation system, flaring system for LFG, passive vent trenches/pipes and gas monitoring probes located both on site and off site.

9.6.7 Active gas extraction from the waste is used to relieve the pressure build-up in the waste and to prevent LFG from migrating off site laterally or vertically. The extracted LFG is delivered to the Hong Kong and China Gas Company through the LFG utilisation plant for town gas production. However, when LFG utilisation plant is under maintenance, flaring system will be switched from standby mode to active mode for LFG treatment. Meanwhile, passive vent trenches and pipes use existing variations in landfill pressures and gas concentrations to vent LFG as a "fail-safe" gas migration barrier in case the gas extraction system fails. In addition, methane and carbon dioxide are monitored by the Gas Monitoring Probes (GMPs) on a monthly basis in order to ensure the effectiveness of LFG management system.

(II) Leachate Management System

9.6.8 The leachate management system consists of the active leachate extraction system, leachate pumping chambers and leachate monitoring wells.

9.6.9 The active leachate extraction system is used to pump the leachate from the platform and slopes to the leachate pumping chambers. Three leachate pumping chambers are located on the perimeter of the site. They collect the leachate intercepted by both peripheral drains beneath part of the capping layers at 30mPD, 40mPD and 38mPD platforms and side slope, followed by a series of horizontal sub-drains. The leachate collected in the chambers is pumped to the Leachate Pre-treatment Works and subsequently conveyed to the Tai Po Sewage Treatment Works for treatment.

(III) Landfill Capping Layer

9.6.10 The components of the landfill capping layer include the following (from top to bottom).

- An approximately 800mm – 850mm thick soil layer of general cover, hydroseeded to act as the growing medium;
- A geocomposite drainage layer consists of filtration geotextile, high density polyethylene (HDPE) geonet, very flexible polyethylene (VFPE) geomembrane and cushion geotextile; and
- A 500mm think final intermediate soil cover.

Geological Assessment

9.6.11 According to the geological map of Hong Kong Geological Survey, the Project site (i.e. TPSTW) and major portion of the Shuen Wan Restored Landfiill was reclaimed land (refer to **Appendix 9.1**). Site investigation records from Ginfo website of Geotechnical Engineering Office (GEO) have been studied. The upper most is a fill layer and underneath the fill is marine deposits or alluvium in the Project site. Rocks of various degrees of decomposition present below the marine deposit / alluvium layer or immediately underneath the fill layer. With reference to the approved EIA report of "Shuen Wan Golf Course" (AEIAR-221/2019), the geological formation beneath Shuen Wan Restored Landfill mainly comprises reclamation fill, underlain by Quaternary superficial deposits of fine and medium marine sands, debris flow deposits, alluvium and fill. No major fault lines or fissures have been identified across the Project Site as well as the Shuen Wan Restored Landfill for LFG migration.

Source

Landfill Gas

9.6.12 Comprehensive LFG monitoring has been conducted in monthly basis since the restoration works in December 1996. LFG monitoring in Annual Environmental Audit Reports for the Shuen Wan Restored Landfill in the past five years (2016 to 2020) has been reviewed for this assessment.

9.6.13 22 multiple level gas monitoring probes (GMPs) located at the boundary of the landfill site and 46 off-site single level gas monitoring probes (P-series) have been monitored under LFG management system. The LFG monitoring probe locations are indicated in **Appendix 9.2**. Levels of methane (CH_4) and carbon dioxide (CO_2) recorded at the monitoring probes have been summarized in **Table 9.5** and the monitoring data are tubulated in **Appendix 9.3**.

Table 9.5 Summary of LFG monitoring data during 2016 to 2020

Monitoring Year	CH_4 (% v/v)		CO_2 (% v/v)	
	Range	Average	Range	Average
Multiple Level Gas Monitoring Probes (GMPs)				
2016	0.0 – 0.0	0.0	0.0 – 3.1	0.23
2017	0.0 – 0.0	0.0	0.0 – 3.7	0.13
2018	0.0 – 0.0	0.0	0.0 – 2.3	0.21
2019	0.0 – 0.0	0.0	0.0 – 2.6	0.14
2020	0.0 – 0.0	0.0	0.0 –1.7	0.17
Single Level Gas Monitoring Probes (P-series)				
2016	0.0 – 0.0	0.0	0.0 – 6.9	0.22
2017	0.0 – 0.0	0.0	0.0 – 6.3	0.27
2018	0.0 – 0.0	0.0	0.0 – 10.4	0.27
2019	0.0 – 0.0	0.0	0.0 – 2.9	0.14
2020	0.0 – 0.0	0.0	0.0 –5.1	0.22
Standard Compliance Level	**1.0% v/v (i.e. 1.0% v/v above natural background)**		**8.6% v/v (i.e. 1.5% v/v above natural background)**	
Level Indicating Significant Migration	**5.0% v/v (i.e. 5.0% v/v above natural background)**		**12.1% v/v (5.0% v/v above natural background)**	

Note: According to Annual Environmental Audit Report for Shuen Wan Restored Landfill, the natural background levels for methane and carbon dioxide are 0.0% v/v and 7.1% v/v respectively.

9.6.14 The results reveal that no methane gas was detected during January 2016 to December 2020 for all gas monitoring probes. The carbon dioxide levels at the monitoring probes ranged from 0.0% to 10.4% during 2016 to 2020. Most of them were well below the standard compliance level of 8.6% v/v (i.e. 1.5% v/v above natural background of 7.1% v/v) stipulated in the Guidance Note. One exceedance of the standard compliance of carbon dioxide at single level gas monitoring probes P63bS (10.4%) was observed during June 2018.

9.6.15 Surface gas emission survey were also performed by EPD and the locations of the surface gas emission survey are indicated in **Appendix 9.2.** The survey results during 2016 to 2020 are summarized in **Table 9.6**. It is observed that no exceedance of action (1000ppm methane) and target limit (1.0% or 10,000ppm methane) for surface gas emissions was recorded during January 2016 to December 2020.

Table 9.6 Summary of Surface Gas Emissions during 2016 to 2020

Monitoring Year	CH_4 (ppm)
2016	6.4 – 9.8
2017	7.1 – 9.4
2018	7.0 – 8.6
2019	7.0 – 8.5
2020	7.0 – 9.3
Action Limit	**1,000 ppm methane**
Target Limit	**1.0% v/v or 10,000 ppm methane**

9.6.16 With reference to Section 3.10 of the Guidance Note, concentration of greater than 1% v/v methane or 1.5% v/v carbon dioxide (above background levels in each case) indicate less than adequate control of the gas at source. From the LFG monitoring results, one exceedance of 1.5% v/v above natural background (i.e. 8.6% v/v) at P63bS (10.4%) was observed during June 2018. Considering the single exceedance episode at single monitoring location, the high level of carbon dioxide measured were unlikely caused by LFG migration from the Shuen Wan Restored Landfill. However, as a conservative assessment, the source level due to Shuen Wan Restored Landfill is classified as **Medium**.

Leachate

9.6.17 Capping layer and leachate extraction system has been installed at Shuen Wan Restored Landfill since the restoration in 1997 for the control of flow direction and leachate level. The leachate collected in the chambers is pumped to the Leachate Pre-Treatment Works and eventually discharged to the Tai Po Sewage Treatment Works for treatment. Hence, the effect of leachate on the construction and operation of the proposed Project would not be expected.

Pathway

Natural Pathways

9.6.18 For the natural pathways, the presence of natural cavities is directly related to the prevailing local geology. Any presence of fault lines may act as a preferential pathway for LFG migration. The geological formation beneath the Project Site mainly comprises of natural earth overlying marine deposits or alluvium. There are no major fault lines persisting between Shuen Wan Restored Landfill and the Project Site directly. The Project works will be undertaken at the western side of the TPSTW and no underground works would be carried out outside the proposed upgrading/expansion boundary. The shortest path length between the western waste boundary of the Shuen Wan Restored Landfill and the upgrading/expansion boundary would be approximately 11m (refer to **Figure 9.1**). As such, the natural pathways are categorized as **Very Short/Direct**.

Man-made Pathways (Utilities)

9.6.19 According to the findings of the utility survey, potential man-made pathway such as electricity cables, gas pipelines, watermain and sewage pipe are within the boundary of the TPSTW. However, there are no existing man-made services and utilities connecting directly between the Project Site and the Shuen Wan Restored Landfill. As such, the man-made pathways are categorized as **Long/Indirect**. Relevant correspondences and layout plans regarding the above man-made services and utilities are provided in **Appendix 9.4**.

Target

9.6.20 The Project mainly comprises the following works:

- Construction and operation of new treatment facilities, modification / demolition of existing treatment facilities of TPSTW;
- Providing effluent reuse facilities; and
- Providing co-digestion facilities for imported sewage sludge and organic waste / pre-treated food waste

9.6.21 In accordance with the Guidance Note, the following potential targets have been identified:

Construction of Upgrading TPSTW

9.6.22 During the construction phase, it is expected that deep excavations will be involved for the construction of some buildings/structures, and works will be undertaken below ground level. No source of ignition will occur nor be allowed in the excavation areas. According to the Guidance Note, deep excavations is considered as **Medium Sensitivity**.

Operation of Upgrading TPSTW

9.6.23 The following proposed buildings / facilities would be located within the consultation zone of the Shuen Wan Restored Landfill:

- Proposed Buildings (e.g. Administration / Maintenance Building and Electrical Room)
- Proposed Biogas Recovery and Storage Facilities
- Proposed Sewage Treatment Facilities
- Proposed Co-digestion and Sludge Related Facilities
- Proposed Reclaimed Water Plant

9.6.24 Access to these buildings/facilities is restricted to the authorized contractors, DSD staffs or other authorized persons who will be briefed on the potential LFG hazards and the specific safety procedures to be followed. This target is considered as **Medium Sensitivity**.

Assessment of Hazard

9.6.25 With reference to **Table 9.1**, source-pathway-target analyses have been undertaken and the results are presented in **Table 9.7**.

Table 9.7 Summary of Qualitative Source-Pathway-Target Analysis

Source	Pathway	Target	Risk
Shuen Wan Restored Landfill (Medium)	Natural pathways (Very Short/Direct)	Construction of upgrading TPSTW (Medium sensitivity)	Medium
		Operation of upgrading TPSTW (Medium sensitivity)	Medium
	Man-made pathways (Long/Indirect)	Construction of upgrading TPSTW (Medium sensitivity)	Low
		Operation of upgrading TPSTW (Medium sensitivity)	Low

9.6.26 The qualitative landfill gas hazard to the proposed Project would be **Low** to **Medium** for the construction and operation of the upgrading TPSTW.

9.7 Recommended Precautionary and Protection Measures

9.7.1 The overall potential hazard for the proposed Project associated with the Shuen Wan Restored Landfill would be **Low** to **Medium** for both construction and operation of TPSTW. Referring to **Table 9.2**, semi-active or enhanced passive controls as well as gas detection system are recommended.

Construction Phase

Safety Measures

9.7.2 The following safety measures shall be implemented during the construction phase:

- 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.
- A Safety Officer, trained in the use of gas detection equipment and landfill gas-related hazards, should be present on site during the groundworks trenching and construction stages.
- All staff working in the Consultation Zone should receive appropriate training on working in areas susceptible to landfill gas, fire and explosion hazards.
- An excavation procedure or code of practice to minimize landfill gas related risk should be devised and carried out.
- No worker should be allowed to work alone at any time in or near to any excavation areas within the Consultation Zone. At least one other worker should be available to assist with a rescue if needed.
- 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, especially in excavation or trenches.
- Welding, flame-cutting or other hot works should be confined to open areas at least 15m from any trench or excavation.
- 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 authorized by the Safety Officer.
- 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.
- Ground level construction plant used within in Consultation Zone should be fitted with vertical exhausts at least 0.6m above ground level and with spark arrestors.
- Any electrical equipment, such as motors and extension cords, should be intrinsically safe.

- During piping assembly or conduiting construction within Consultation Zone, 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.
- 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 / measurement should be carried out, preferably at least at the beginning of every working day, to ensure that these areas remain gas free. 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.
- Adequate fire extinguishing equipment, fire-resistant clothing and breathing apparatus sets should be made available on site. Fire drills should be organized at not less than six monthly intervals.

LFG Monitoring

9.7.3 LFG Monitoring shall be undertaken during construction phase as described below:

- Periodically during ground-works construction, the works area should be monitored for methane, carbon dioxide and oxygen using appropriately calibrated portable gas detection equipment.
- The monitoring frequency and areas to be monitored should be set down prior to commencement of ground-works either by the Safety Officer or by an appropriately qualified person.
- Routine monitoring should be carried out in all excavations, manholes and chambers and any other confined spaces that may have been created by, for example, the temporary storage of building materials on the site surface.
- All measurements in excavations should be made with the monitoring tube located not more than 10mm from the exposed ground surface.
- For excavations deeper than 1m, measurements should be made:
  - at the 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 through the working day whilst workers are in the excavation.
- For excavations between 300mm and 1m deep, measurements should be made:
  - directly after the excavation has been completed; and
  - periodically whilst the excavation remains open.
- For excavations less than 300mm deep, monitoring may be omitted, at the discretion of the Safety Officer or other appropriately qualified person.

- 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 shall encompass those actions specified in **Table 9.8**.

Table 9.8 Actions in the Event of Gas Being Detected in Excavations

Parameter	Measurement	Action
O_2	< 19%	• ventilate trench/void to restore O_2 to >19%
	< 18%	• stop works • evacuate personnel/prohibit entry • increase ventilation to restore O_2 to >19%
CH_4	> 10% LEL	• prohibit hot works • ventilate to restore CH_4 to <10% LEL
	>20% LEL	• stop works • evacuate personnel/prohibit entry • increase ventilation to restore CH_4 to <10% LEL
CO_2	> 0.5%	• ventilate to restore CO_2 to <0.5%
	> 1.5%	• stop works • evacuate personnel/prohibit entry • increase ventilation to restore CO_2 to <0.5%

- The hazards from landfill gas during the construction phase shall be minimized by precautionary measures recommended in the Guidance Note.
- In any emergency situation, the Safety Officer or other appropriately qualified person, shall have the necessary authority and shall ensure that the confined space is evacuated and the necessary works implemented for reducing the concentrations of gas. The following organizations should also be contacted as appropriate:
  - Hong Kong Police Force (HKPF);
  - Fire Services Department (FSD); and
  - Landfill Operator

Operational Phase

Building Protection Design

9.7.4 Where below ground service entries are necessary to the buildings/facilities, the entry point should be sealed to prevent gas entry.

9.7.5 Where practicable, natural ventilation through windows and openings, coupled with wind driven cowls and other devices as required, should be provided at or below the ground floor of new permanent building structures of the Project.

9.7.6 Where natural ventilation is not feasible, the floors and walls at the ground level and the below ground rooms / voids of any proposed permanent structures should consist of gas resistant material with low gas permeability. Gas detection systems with audio alarm and forced ventilation should also be provided in such area of the Project. In addition, a clear void or a gas vent (e.g. in the form of no-fines gravel in trenches) should be created under these structures to vent and dilute any gas emitted from the ground.

9.7.7 The aforementioned gas detection systems should be calibrated and maintained at regular basis in according to the recommendation of manufacturer's instruction. The operators of the

Project should also make sure that the gas detection systems are in functions during the operational phase of the Project.

9.7.8 Forced ventilation should be used if methane of more than 0.5 % (by volume) in the internal atmosphere (e.g. in voids or rooms as mentioned above) is detected.

9.7.9 No person should enter or remain in any confined spaces (e.g. in voids or rooms as mentioned above) where the carbon dioxide concentration exceeds 1.5 % (by volume).

9.7.10 Oxygen concentration should be monitored and no person shall enter or remain in any confined spaces (e.g. in voids or rooms as mentioned above) where the oxygen content of air has fallen below 18 % by volume.

9.7.11 All the access to these confined spaces (e.g. in rooms or voids as mentioned above) should be restricted only to authorised personnel who should be aware of the LFG hazard. No member of general public should be permitted or allowed to access these confined spaces, manholes or inspection chambers.

Guidance for Entry into Manholes and Chambers

9.7.12 When service voids, manholes or inspection chambers within the proposed site are entered for maintenance, monitoring and a checklist system of safety requirements should be performed before entry in accordance with Code of Practice on Safety and Health at Work in Confined Spaces published by Labour Department.

9.7.13 All the access to the confined spaces would be restricted only to authorized personnel who should be aware of the LFG hazard. No member of general public should be permitted or allowed to access these confined spaces, manholes or inspection chambers.

9.8 Evaluation of Residual Impacts

9.8.1 Provided that all the recommended mitigation measures and monitoring programme are properly implemented, no unacceptable residual landfill gas hazard is expected from the Project.

9.9 Environmental Monitoring and Audit (EM&A) Requirements

9.9.1 During the whole construction phase and the first 2 years of operational phase, the ongoing monitoring and implementation performance on the recommended precautionary and protection measures would be provided and reviewed in the monthly EM&A report. The need of further reporting the ongoing monitoring and implementation performance on the recommended precautionary and protection measures could be reviewed at the end of the second year of operation.

9.10 Contingency Plan for Construction and Operational Phases

9.10.1 Detection of LFG at the Project site could be the consequence of accidents or emergency situations such as failures of the LFG management system of Shuen Wan Restored Landfill or failures of the recommended precautionary and protection measures of the Project. All construction, operation and maintenance personnel working on-site should be made aware of the hazards of LFG and the proposed precautionary and protection measures.

9.10.2 To provide a mechanism to minimise the impact of such emergency situations and the subsequent management and rectification of the situations, a contingency plan should be formulated prior to the construction and commissioning of the Project. The construction contractor under the construction contract and the plant operators of the Project should carry

out necessary actions according to the procedures of the contingency plan. An outline of the contingency plan is given below:

- Descriptions of the proposed LFG hazard precautionary and protection measures of the Project.
- Guidelines for regular inspection of the proposed LFG hazard precautionary and protection measures and routine integrity checking and maintenance of the proposed building protection measures / devices / facilities.
- Emergency responses such as evacuation procedures and rectification procedures to reduce LFG concentration (e.g. by increasing ventilation rate) and, if required, restore normal operation of the LFG hazard precautionary and protection measures / facilities or liaison with the restored landfill operator.
- Roles and responsibilities for implementing the proposed LFG precautionary and protection measures and contingency plan.
- The contacts of Government Departments (HKPF and FSD) to be notified and stakeholders (i.e. suitable personnel of contractor/DSD for implementing the contingency plan and landfill operator) in case of emergency situations.

9.11 Conclusion

9.11.1 The results of this qualitative risk assessment for LFG hazards posed by the Shuen Wan Restored Landfill to the Project site would be **Low** to **Medium** during both construction and operational phases. With proper implementation of the recommended precautionary and protection measures, the safety of all personnel presence at the Project site would be safeguarded during the construction and operational phases. Thus, there would be no adverse impact anticipated on the feasibility of the Project.

9.11.2 During the whole construction phase and the first 2 years of operational phase, the ongoing monitoring and implementation performance on the recommended precautionary and protection measures would be provided and reviewed in the monthly EM&A report. The need of further reporting the ongoing monitoring and implementation performance on the recommended precautionary and protection measures could be reviewed at the end of the second year of operation.