11 Landfill Gas Hazards Assessment

11.1 Introduction

This Section provides an evaluation of the potential landfill gas hazards arising from the construction and operation of the Project at the Tsang Tsui Ash Lagoon site. Mitigation measures have been proposed if considered necessary to minimize the identified landfill gas hazards. No adverse impact is anticipated.

The landfill gas hazard assessment has been conducted in accordance with the requirements in the Landfill Gas Hazard Assessment Guidance Note, and Clause 3.4.11 of the EIA Study Brief for the Project.

11.2 Environmental Legislation, Policies, Plans, Standards and Criteria

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 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 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 250m "Consultation Zone" around any landfill site, to ensure appropriate precautionary / protection measures would be designed and implemented to safeguard the development.

11.3 Description of the Environment

The I·PARK2 comprises an advanced thermal incineration plant with design capacity of 6,000 tonnes per day (tpd).

The southeastern corner of I·PARK2 will be located within the 250m consultation zone of the West New Territories Landfill Extension (WENTX). Therefore, a qualitative landfill gas hazard assessment addressing the landfill gas hazards arising from the WENTX and recommending the mitigation measures is

undertaken for the Project. The I·PARK2 site was an ash lagoon, which would be decommissioned by covering of at least 1m thick general fill with a formation level of about +11.5mPD by other party before construction commencement of I·PARK2. **Figure 11.1** shows the location of I·PARK2.

11.4 Potential Hazard Associated with Landfill Gas and Leachate

11.4.1 Landfill Gas

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.

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.

Typical mixtures of Landfill gas are likely to have a density close to or equal to that of air. However, different site conditions may result in a different ratio of methane to carbon dioxide. As methane is lighter than air whereas carbon dioxide is heavier than air. Different landfill gas mixtures may be lighter than air or heavier than air. As a result, landfill gas may accumulate at the bottoms of trenches/excavations or may rise up and accumulate beneath structures and foundations.

11.4.2 Leachate

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.

11.5 Landfill Gas Assessment Criteria and Methodology

11.5.1 Landfill Gas Assessment Criteria

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 LFG.

11.5.2 Source

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.

11.5.3 Pathway

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

i. Man-made pathways e.g., utility connections, stormwater channels, etc.;

ii. 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

iii. 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.

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

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.

Thus, although there may be permeable soil between the landfill site and a proposed development, say 80m from the edge of the site, if the soil layer is very shallow and thin with its upper surface exposed to the atmosphere, then it will be appropriate to consider this as a long/indirect pathway. This could of course alter if the land between the landfill site and the development was paved over or altered in some other way which reduced the potential for gas release. Similarly, if the land is flat, the surface may be prone to waterlogging which will also effectively seal it at times of heavy rain. In general, a conservative approach should be adopted, and it should be assumed that any such permeable surface soils may become less permeable in the future.

If it is known that a conduit (man-made or natural feature such as a fault plane) leads directly from the landfill to the development area, it should be regarded as a "direct/short" pathway even if it is longer than 100m.

11.5.4 Target

The different elements of the proposed Project which are sensitive to the impacts of landfill gas were identified. Such potential "target" includes 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.

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 is 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.

11.5.5 Assessment of Risk Criteria

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 11.1**. The potential implications associated with the various qualitative risk categories are summarized in **Table 11.2** below.

Table 11. 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

Source	Pathway	Target Sensitivity	Risk Category
	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 11. 2 General Categorization of Risk

Category	Level of Risk	Implication
A	Very high	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
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.

Five generic forms of protection were used in mitigating the hazards to developments. These generic forms corresponding to the five risk levels are set out in **Table 11.3** and the control terms used are defined in **Table 11.4**.

Table 11. 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 11. 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.

11.6 Qualitative Landfill Gas Assessment

11.6.1 Assessment Methodology

The potential risk of LFG from the WENTX to the proposed Project has been assessed in accordance with the Guidance Note and Appendix J of the EIA Study Brief (ESB-365/2024). The assessment shall include the following:

(i) Review of background information and studies related to the WENTX
(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 for the construction and operation of the Project.
(vii) Identification of monitoring requirements for assessing the adequacy and performance of the implemented protection measures.

11.6.2 Desktop Study

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

- Hong Kong Geological Survey Map (HGM 20 series scale 1:20,000 map) (Edition II - 2008);

- Approved EIA report of "West New Territories Landfill Extension" (AEIAR-147/2009) and the supporting document for Variation of Environmental Permit for West New Territories Landfill Extension (VEP-617/2022);
- Approved EIA report of "Development of the Integrated Waste Management Facilities Phase 1" (AEIAR-163/2012);

11.6.2.1 Background of the West New Territories Landfill Extension

WENTX forms an integral part in the Strategic Plan as recommended in the study "Extension of Existing Landfills and Identification of Potential New Waste Disposal Sites" in maintaining the continuity of landfill capacity in the West New Territories. The project is to develop the WENTX lying between the existing West New Territories Landfill (WENT Landfill) and the Black Point Power Station at Nim Wan. It is located at the southern of the I·PARK2 site location. According to the supporting document for Variation of Environmental Permit (VEP) for WENTX issued in 2022, the waste filling area will occupy a footprint of about 100 hectares to provide a landfilling capacity of 76 Mm^3. Subject to the design by WENTX contractor, the landfill will be developed in 6 phases and the final level of WENTX will be about +270 mPD.

Similar to the WENT Landfill, WENTX will be designed as a containment landfill. Comprehensive landfill gas and leachate collection systems will be developed to collect the landfill gas and leachate generated from the waste body. A protective lining system will also be adopted to stop any migration of landfill gas and leachate which forms a barrier on the underground to nearby development. According to the WENTX Environmental Monitoring and Audit Manual (EM&A manual), regular environmental monitoring will be implemented in order to ensure that landfill gas and leachate from the landfill are properly collected and treated. The major components and layout of WENTX subject to be detailed design by WENTX contractor are shown in **Figure 11.2**.

The WENTX contract was awarded in 2023 and will commence waste intake in 2026 tentatively. The environmental monitoring of WENTX will be commenced upon the commencement of WENTX construction.

11.6.2.2 Geological Assessment

According to the Hong Kong Geological Survey Map Sheet 5 (Scale 1:20,000) as abstracted in Figure 11.3, the area of the I-PARK2 site was mid portion of a former coastal bay underlaid by superficial deposit of marine sand with some silt and by beach sand and alluvium along the original shoreline. The bay was reclaimed since early 1990 and used as the lagoons for storage of pulverized fuel ash (PFA). Records of drillholes sunk within the I-PARK2 area showed up to 15m thick PFA underneath the current formation level of +7 mPD to +10.5mPD, overlaying marine deposit and alluvial deposits. The ash lagoon would be decommissioned by covering of at least 1m thick general fill with a formation level of about +11.5mPD by the others before construction commencement of I·PARK2.

The Geological Survey Map Sheet 5 shows the land area to the south of I-PARK2 is a hillside terrain underlaid by medium grained granite. A short length of fault was mapped on the Geological Survey Map Sheet 5 running roughly parallel a section of Nim Wan Road between +55mPD to +65mPD on the overlooking hillside within WENTX area. No information of fault line in the I-PARK2 area is given on the Geological Survey Map Sheet 5. Also, the framework of known and inferred fault systems in Hong Kong

as given in the "Pre-quaternary Geology of Hong Kong" (GEO, 2000, Figure 9.7, p. 139) shows no major fault line connecting the WENTX and I-PARK2 sites.

Following the general discussion given in the "Quaternary Geology of Hong Kong" (GEO. 2000, Section 3, p.58) on the hydrogeology of Hong Kong, the groundwater flow is expected to follow the northward trending topography with flows through the soil mantle and in the interconnected joints of the granite layer and surface deposits. A stream along the south side of the access road leading to the Tsang Tsui Columbarium forms a topographic depression separating the WENTX landfilling area and I-PARK2 area and could restrict groundwater flow from WENTX landfilling area to the I-PARK2 area.

11.6.3Source

11.6.3.1 Landfill Gas

As mentioned in **Section 11.6.2.1**, WENTX will commence waste intake in 2026 tentatively for decades (subject to the actual waste intake rate), which will be a source to generate LFG. The size of WENTX is about 100 ha and nature of waste to be received are mainly municipal solid waste. Landfill Gas (LFG) hazards may be prone to front-line workers within the site especially where the LFG are extracted, transported and processed. With the proposed LFG control measures and utilization facilities in the WENTX, the source of LFG will be properly controlled within the site similar to the operation in existing WENT Landfill.

According to the EIA report for WENTX, the 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. Therefore, the source of LFG at the WENTX is categorised as **Medium**, considering the following reasons:

- Active gas extraction systems, similar to that adopted in the existing WENT Landfill, will be installed in the WENTX;
- Gas control systems will be installed, and comprehensive monitoring will be conducted to ensure that no migration of gas beyond the landfill boundary; and
- Specific control measures (e.g., landfill gas cut-off trench barrier) will be applied if necessary.

11.6.4 Pathway

I·PARK2 will be located more than 100m away from the waste boundary of WENTX. There are no existing man-made services and utilities connecting directly between the Project Site and WENTX. However, if there are any utility connections between the landfill and project site in future, such utility connections might act as preferential pathways for LFG migration. Nevertheless, the presence of a 12m-wide stream that is always filled with water (south of the I·PARK2 site) acts as a passive venting system to stop LFG from further migrating to the I·PARK2 site. Thus, the stream provides a form of protection to the I·PARK2 site.

According to the Hong Kong Geological Survey Map (Scale 1:20,000) on the solid and superficial geology of Tsing Shan (Castle Peak), the superficial geology of the I·PARK2 was mainly "undivided, mainly marine mud" with part of "marine sand". It is also noted that no natural feature such as a fault

plane leads directly from the WENTX to the I·PARK2 development area. The subsoil underneath the I·PARK2 would mainly be ash, which is very compact with low porosity. The ash lagoon will be decommissioned by covering of at least 1m thick general fill with a formation level of no less than +11.5mPD by other party. Consider the stream in between I·PARK2 and WENTX, the compact and low porosity subsoil, and a relatively high water table, it is anticipated that the chance for LFG migrating to the I·PARK2 site would be very remote.

However, the separation distances between the waste boundary of WENTX and the potential site for the I·PARK2 at the Tsang Tsui Ash Lagoons (TTAL) site are more than 100m, the pathway is therefore classified as **Long / indirect.**

11.6.5 Target

During construction, the site would be occupied by construction workers who are well trained and with proper and safe construction methodology to be followed. Also, the construction would be mainly carried out in an outdoor environment. Therefore, in general the group is considered as "Low**"** sensitivity except for specific targets as below.

The specific location of the site office is yet to confirm. Should the site office to be located within the WENTX consultation zone, the construction workers and supporting staff would be working in an indoor environment with potential LFG hazards. The site office will be accessed only by authorized, well trained personal, who have been briefed on the potential hazards relating to landfill gas and all relevant safety precautions and procedures to be followed. Therefore, this group is considered as "Medium" sensitivity.

Under the reference design, part of the IBA treatment facility and administrative building of I·PARK2 will fall within the WENTX consultation zone. During the operation stage of the I·PARK2, the IBA treatment facility and administrative building are generally restricted to authorized personnel, and visitors to the administrative building will be guided by the operators of the I·PARK2. The risk level for this Target Sensitivity is therefore categorized as "Medium".

For manholes, inspection chambers, voids of services/utilities or underground structures if any within I·PARK2 and the WENTX consultation zone which will only be accessed by authorized and well-trained personnel who have been briefed on the potential hazards relating to landfill gas and the specific safety procedures to be followed, the risk level for this Target Sensitivity is categorized as "Medium" for ground level or below ground rooms/voids without sources of ignition. For ground level or below ground rooms/voids which contains sources of ignition, these targets should be categorised as "High" sensitivity.

Community facilities are planned within the administration building, but the actual use and the design of the facilities have not yet been finalized. Since the community facilities will be an indoor environment and opened to general public, on a conservative approach, the risk level for this Target Sensitivity is categorized as "High".

Some ground or below ground level construction works may be carried out at I·PARK2 during operation. As the works will be outside the boundary of the WENTX, the waste filling area, landfill gas cut-off trench barrier as well as the LFG management facilities of WENTX will not be affected. Nevertheless, as the

details of the construction works and depth of excavations cannot be confirmed, the target is therefore classified as "Medium" sensitivity.

11.7 Summary of Qualitative Source-Pathway-Target Analysis

With reference to **Table 11.1**, source-pathway-target analyses have been undertaken and the results are presented in **Table 11.5**.

Table 11. 5 Summary of Qualitative Source-Pathway-Target Analysis

Source	Pathway	Target	Risk
WENT Landfill Extension (Medium)	**During Construction**		
	More than 100m from WENTX waste boundary (Long/ Indirect Pathway)	General – Construction workers, well trained and follow specific safety procedures, mainly outdoor works (Low Sensitivity Target)	Very Low
		Site Office – Construction workers and support staff, well trained and follow specific safety procedures, indoor environment (Medium Sensitivity Target)	Low
	During Operation		
	More than 100m from WENTX waste boundary (Long/ Indirect Pathway)	IBA treatment facility and administrative building of I·PARK2 – Authorized personnel and visitors guided by the operators of the I·PARK2 (Medium Sensitivity Target)	Low
		Manholes, inspection chambers, voids of services/utilities or underground structures if any within I·PARK2 and the WENTX consultation zone (High Sensitivity Targets for ground level or below ground rooms/voids with sources of ignition and Medium Sensitivity Targets for those without sources of ignition)	Medium/Low
		Community facilities within the administrative building - indoor environment and open to general public (High Sensitivity Target)	Medium
		Ground or Below Ground Level Construction Works at I·PARK2 during operation (Medium Sensitivity Target)	Low

The overall risk levels for construction phase and for operation phase associated with the WENT Landfill Extension are **Low** and **Medium** respectively, based on the highest level of risk for the potential impacts identified.

11.8 Recommended Precautionary and Protection Measures

11.8.1 Introduction

Based on **Table 11.2**, engineering measures will be required for "Medium" level of risk during operation phase of I·PARK2 while precautionary measures will be required for "Low" level of risk during construction phase of I·PARK2. As per Table 4.2 in the EPD's Landfill Gas Hazard Assessment Guidance Note, the required generic protective measures include "Use of 'semi-active' or enhanced passive gas controls, with detection systems in some situations" for "Medium" level of risk during operation phase of I·PARK2 and "Passive control of gas only" for "Low" level of risk during construction phase of I·PARK2. The suggested preventive actions can be found in **Sections 11.8.2** and **11.8.3**.

11.8.2 Construction Phase

11.8.2.1 Safety / Precautionary Measures

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

- For staff who work in, or have responsibility for "at risk" area, such as all excavation workers, supervisors and engineers working within the WENTX consultation zone, should receive appropriate training on working in areas susceptible to landfill gas, fire and explosion hazards.
- Safety Officer shall register under the Factories and Industrial Undertakings Ordinance and relevant associated regulations, trained in the use of gas detection equipment and landfill gas-related hazards (or other appropriately qualified person), and should be present on site throughout the groundworks phase. The Safety Officer (or other appropriately qualified person) should be provided with an intrinsically safe portable instrument.
- 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.
- 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 WENTX 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.
- Where there are any temporary site offices, or any other buildings located within the WENTX consultation zone which have enclosed spaces with the capacity to accumulate LFG, then they should either be located in an area which has been proven to be free of landfill gas (by survey using portable gas detectors); or be raised clear of the ground by a minimum of 500mm. This aims to create a clear void under the structure which is ventilated by natural air movement such that emission of gas from the ground are mixed and diluted by air.
- Ground level construction plant used within the WENTX 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 the WETNX 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.
- The contractor should formulate a health and safety policy, standards and instructions for site personnel to follow.
- The contractor shall adopt the precautionary measures in Section 8 of the Guidance Note for the period of construction of infrastructure within the WENTX consultation zone.
- Adequate fire extinguishing equipment, fire-resistant clothing and breathing apparatus (BA) sets should be made available on site. Fire drills should be organized at not less than six monthly intervals.
- Service runs within the WENTX consultation zone should be designated as “special routes”; utilities companies should be informed of this and precautionary measures should be implemented. Precautionary measures should include ensuring that staff members are aware of the potential hazards of working in confined spaces such as manholes and service chambers, and that appropriate monitoring procedures are in place to prevent hazards due to asphyxiating atmospheres in confined spaces. Detailed guidance on entry into confined spaces is given in Code of Practice on Safety and Health at Work in Confined Spaces (Labour Department, Hong Kong).

- The precautionary and protection measures recommendations in Section 8 of the Guidance Note relating to the drilling of boreholes under site investigation / ground investigation works shall be adopted if such works will be carried out within the WENTX consultation zone.

11.8.2.2 LFG Monitoring

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

- Periodically during ground-works construction within the WENTX consultation zone, the works area should be monitored for methane, carbon dioxide and oxygen using appropriately calibrated portable gas detection equipment, which is appropriately calibrated and capable of measuring the following gases in the ranges indicated below:
  - ∇ Methane: 0-100% LEL and 0-100% v/v
  - ∇ Carbon dioxide: 0-100%
  - ∇ Oxygen: 0-21%
- 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.
- The monitoring frequency and areas to be monitored should be determined prior to commencement of groundworks either by the Safety Officer or by an appropriately qualified person.
- 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 11.6**.

Table 11. 6 Actions in the Event of Gas Being Detected

Parameter	Measurement	Action
Oxygen (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%
Methane (CH_4)	>10% LEL (i.e. >0.5% by volume)	• prohibit hot works • ventilate to restore CH_4 to <10% LEL
	>20% LEL (i.e. >1% by volume)	• stop works • evacuate personnel/prohibit entry • increase ventilation to restore CH_4 to <10% LEL
Carbon Dioxide (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 within the WENTX consultation zone shall be minimized by precautionary measures recommended in the Landfill Gas Hazard Assessment 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);
  - Environmental Protection Department (EPD); and
  - Landfill Operator

11.8.3 Operational Phase

During detailed design stage, the future I·PARK2 contractor shall prepare a detailed qualitative risk assessment and detailed design of landfill gas protection measures and submit to EPD for vetting. The submission shall include maintenance and monitoring programmes to ensure the continued performance of the proposed control measures, an event and action plan as well as an emergency and contingency plan. The types of protection measures which can be adopted are described below in relation to the generic terms set out in **Table 11.3**.

11.8.3.1 Gas Barrier

The most common way of preventing gas from entering an area of ground is to set a "gas barrier" into the ground which is either keyed into low permeability strata or extends at least 1m below the lowest groundwater level.

The presence of a gas 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.

According to the supporting document for Variation of Environmental Permit (VEP) for WENTX issued in 2022, the proposed landfill gas cut-off trench barrier has been adjusted with the revised boundary of WENTX site. It should be built along the boundary between WENTX landfill, I·PARK2 and T·PARK. This will cut off any gas migration to the I·PARK2 from the WENTX and the barrier should be installed under the WENTX project.

It is also recommended that several landfill gas monitoring wells be installed into the ground on the development side of the gas barrier by the I·PARK2 contractor. These are used to measure the concentrations of methane and carbon dioxide within the ground and hence determine the effectiveness of the measures in preventing LFG migration. The I·PARK2 contractor shall ensure that appropriate action (e.g. to notify the EPD and the WENTX landfill operator for inspection of the landfill gas cut-off trench barrier, to inspect sealing of joints and identify the cause, to rectify defects and seal the cracks if any, etc.), to be taken in the event of the trigger levels being exceeded, are specified in the detailed qualitative risk assessment as mentioned above.

If ground or below ground level construction works will be carried out, the recommended precautionary and protection measures in **Section 11.8.2.1** should be adopted, where applicable.

11.8.3.2 Building Protection Design

11.8.3.2.1 Passive Control

Passive control measures for building structures with ground level or below ground rooms / voids including the following could be considered in the detailed design if necessary:

- 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 air movements such that any emissions of gas from the ground are mixed and diluted by air;
- Synthetic composite geotextile which provides 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; and
- 'Semi active' control such as the use of wind driven cowls and other devices which assist in the ventilation of gas but do not rely on electrically powered fans.

11.8.3.2.2 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.

The future I·PARK2 contractor shall maintain and calibrate the gas detection system if any on a regular basis and ensure that appropriate emergency action, to be taken in the event of the trigger levels being exceeded, are specified in the detailed qualitative risk assessment as mentioned above. These should include procedures for evacuation if necessary.

11.8.3.2.3 Maintenance of Control Measures

Fundamental to the success of landfill 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.

11.8.3.3 Design Measures for Sub-Surface Building Services

Generic protection measures for the sub-surface building services including the following are recommended:

- A gas barrier used to prevent movement of gas through services may form part of a more extensive barrier to prevent general mitigation towards the Project development. The gas barrier may be made of clay (or clay-rich soils), bentonite or polymeric membranes (e.g. HDPE). 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; and
- 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 in high permeability drainage layers adjacent to gas barriers. Under all circumstances, care should be taken when accessing any manhole chambers especially those which are not fitted with vents and necessary safety procedures must be followed.

11.8.3.4 Guidance for Entry into Manholes and Chambers

During the operation phase, any service voids, manholes, chambers or culvert within the proposed site, which is large enough to permit access to personnel should be subject to entry safety procedures. Works in confined spaces are controlled by the Factories and Industrial Undertakings (Confined Spaces)

Regulation of the Factories and Industrial Undertakings Ordinance and the Safety Guide to Working in Confined Spaces should be followed to ensure compliance with the above regulations.

In general, when work is being undertaken in confined spaces, sufficient approved resuscitation equipment, breathing apparatus and safety torches should be made available. Persons involved in or supervising such work should be trained and practiced in the use of such equipment. A permit-to-work system for entry into confined spaces should be developed by an appropriately qualified person and the system should be consistently employed. The safety measures recommended in Chapter 7 of the Landfill Gas Hazard Assessment Guidance Note should also be strictly followed.

All the access to confined spaces should be restricted only to authorized personnel who are aware of the landfill gas hazard. No general public should be permitted or allowed to access the service voids, manholes, chambers or wells.

11.8.3.5 Landfill Gas Monitoring

Regular monitoring of landfill gas should be done at the monitoring wells (as mentioned in the second last paragraph of **Section 11.8.3.1**) as well as at the underground service voids and manholes by the I·PARK2 contractor. The maintenance and monitoring programmes shall be included in the detailed qualitative risk assessment as mentioned above to ensure the continued performance of the proposed control measures.

11.8.3.6 Protection Measures for Community Facilities

At I·PARK2, community facilities are currently under planning, and while the actual utilization and design of these facilities remain pending, the following safety measures will be enforced during the operational phase of the community facilities if necessary:

- All personnel who work on site and visitors will be made aware of the potential hazards relating to landfill gas. Safety notices in both Chinese and English shall be prominently displayed around the site to warn individuals of potential hazards.
- Smoking and open fires will be strictly prohibited.
- Regular monitoring of landfill gas and maintenance protocols will be conducted at the community facilities to ensure safety.
- Specific precautions will be implemented for all rooms, including the use of air conditioning with natural and mechanical ventilation, application of gas-proofing coatings on ground floor slabs, installation of gas alarms, and restriction of access to invited or registered guests/visitors.

11.8.3.7 Design of LFG Protection Measures

As this Project is at the Preliminary Design Stage, a detailed design is not available yet and the above qualitative landfill gas hazard assessment is just a preliminary one based on limited available information. When the detailed design of the I·PARK2 is available, the future I·PARK2 contractor is required to undertake further landfill gas hazard assessment to take account of the more readily available detailed information to finalize the design of the landfill gas protection measures recommended in this report. During the detailed design stage, a review of this preliminary qualitative risk assessment should be carried out and a detailed qualitative landfill gas risk assessment as described

in Section 1.15 and Chapter 6 of the Landfill Gas Hazard Assessment Guidance Note should be prepared. The detailed qualitative landfill gas risk assessment together with the detailed design of landfill gas protection measures and a landfill gas monitoring programme should be submitted to EPD for vetting.

The design of the landfill gas protection measures to be adopted on-site should be performed by a competent professional person who has knowledge on LFG protection measures appointed by the contractor of the I·PARK2. The detailed design of the landfill gas protection measures shall form part of the detailed qualitative risk assessment as stated above, which shall be certified by the Environmental Team Leader and verified by the Independent Environmental Checker before submission to EPD for vetting. The contractor should ensure that the required protection measures are implemented and constructed in accordance with the design and a maintenance and monitoring programme should be established to ensure the continued performance of the implemented protection measures. The above requirements should be included in the tender documents of the I·PARK2.

11.9 Evaluation of Residual Impacts

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

11.10 Environmental Monitoring and Audit (EM&A) Requirements

During construction, a Safety Officer should be appointed to carry out the monitoring works as presented in **Section 11.8.2** of this report.

During operation, regular monitoring of landfill gas at the monitoring wells, underground service voids and manholes should be conducted by a Safety Officer or an appropriately qualified person appointed by the I·PARK2 contractor in accordance with the monitoring programmes in the detailed qualitative risk assessment to be submitted during detailed design stage.

11.11 Conclusion

The results of this qualitative risk assessment for LFG hazards posed by the WENT Landfill Extension to the Project site would be "Low" during construction phase and "Medium" during operation phase. With proper implementation of the recommended precautionary and protection measures, the safety of all personnel and general public (i.e., visitors) presence at the Project site would be safeguarded. In particular, it is noted that landfill gas cut-off trench barrier will be built along the boundary between the I·PARK2 and WENTX under the WENTX project to cut off any landfill gas migration. Monitoring wells are recommended to be installed into the ground on the development side of the gas barrier by the I·PARK2 contractor for verifying the effectiveness of the above measures. Should the monitoring reveal the presence of landfill gas, the seal of the joints shall be inspected, and consideration shall be given to seal the cracks. Moreover, necessary landfill gas protection measures such as passive and/or semi-active

control measures and detection systems will be incorporated in the buildings in the project and the measures will be designed by a competent professional person during the detailed design stage.

Provided that all the recommended precautionary and protection measures are implemented properly, the safety of all personnel and general public (i.e. visitors) presence at the proposed Project site would be safeguarded and there would be no unacceptable risk of landfill gas on I·PARK2 during construction and operation of the Project.