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9. LANDFILL GAS HAZARD

9.1 Introduction

9.1.1.1 Section 9 of the EIA Report presents the assessment of potential landfill gas (LFG) hazard to the Project.

9.2 Environmental Legislation, Standards and Guidelines

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

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

9.2.1.2 ProPECC PN 3/96 and the Guidance Note provide an assessment framework to be followed when evaluating the risks related to developments described under Section 6.5, Chapter 9 of the Hong Kong Planning Standards and Guidelines. ProPECC PN 3/96 and Guidance Note apply to all developments proposed within a Landfill Consultation Zone, which is the area of land surrounding the landfill boundary as defined by a line running parallel to and 250 m away from the edge of the waste if this can be identified or, if not, the recognized landfill site boundary.

9.2.1.3 In accordance with aforementioned framework, the following tasks have been undertaken to assess potential LFG hazard associated with the closed and restored Ngau Tam Mei landfill (NTML) to potentially sensitive elements of the Project area situated within the NTML Consultation Zone.

- A review of background information (including landfill gas monitoring data) and studies related to the NTML including sections 14 (Landfill Gas Hazard Assessment) and Section 15 (Impacts on the Restored Ngau Tam Mei Landfill) of approved EIA, AEIAR-143/2009 for the Hong Kong Section of Guangzhou - Shenzhen - Hong Kong Express Rail Link;
- Identification of the nature and extent of the source, including the likely concentrations and / or amounts of hazardous emissions with potential to impact the Project;
- Identification of possible subsurface pathways and the nature of these pathways through which hazardous emissions must traverse if they are to reach the development;
- Identification of potentially sensitive receivers / elements of the development that maybe susceptible to landfill gas ingress/accumulation;
- Qualitative assessment of the degree of risk which the hazardous emissions may pose to aspects of the development taking account of each source-pathway-target combination; and
- A description of possible precautionary measures (if needed) during construction and operation phases assuming development constraints are surmountable, and identification of any monitoring requirements during construction and operation.

9.3 Assessment Methodology

9.3.1 Criteria

9.3.1.1 In accordance with the Landfill Gas Hazard Assessment Guidance Note, risk associated with landfill gas may be evaluated by assessment of the following three criteria:

- Source – location, nature and likely quantities/ concentrations of landfill gas with potential to affect the development;
- Pathway – the ground and groundwater conditions through which landfill gas must pass in order to reach the development; and
- Target – elements of a development that may be sensitive to the effects of landfill gas.

9.3.2 Source

9.3.2.1 The classification of the Source (i.e., Ngau Tam Mei Landfill) is undertaken 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 a 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.

9.3.2.2 The “significance” of migration is assessed by reference to the concentration, frequency and location at which gas is detected at routinely monitored locations, especially those peripheral to the area of waste deposition. Any concentration of methane or carbon dioxide > 5% v/v above background levels in any monitoring well outside the landfill boundary may indicate significant migration. Concentrations > 1% v/v methane or 1.5% v/v carbon dioxide (above background) indicate less than adequate control of the gas at source.

9.3.2.3 If monitoring data demonstrates that there is no migration of gas and little danger of gas controls failing (e.g., if these comprise solely of passive measures such as a liner) it can be assumed that the site represents a "Minor" Source. Where there is no gas migration but this may be as a result of a single, "vulnerable" control measure (e.g., an active extraction system with no warning of failure), the site should be regarded as a "Medium" or even a "Major" Source depending on the other factors (e.g., size of site and age of waste). Where the effectiveness of gas controls has not been proven by off-site monitoring, assessment always errs on the side of caution and is undertaken on the same basis as if the controls were not in place.

9.3.2.4 The reliability of the monitoring to assess the efficacy of gas control needs to take account of the design, number and locations of monitoring points and the frequency and duration over which monitoring has been undertaken. Monitoring should have been undertaken under different weather conditions including periods of low or falling atmospheric pressure.

9.3.3 Pathway

9.3.3.1 The broad classification is as follows:

Very short / direct	Path length <50m for unsaturated permeable strata and fissured rock or < 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

9.3.3.2 Factors affecting the extent of gas migration such as soil permeability or spacing and direction of the fissures/joints, vadose zone thickness and the topography and nature of ground over the potential pathway need to be considered. If a preferential pathway from the landfill to the development area exists the pathway is classified as "direct/short" even if it is longer than 100m.

9.3.4 Target

9.3.4.1 Target sensitivities are classified as follows:

High sensitivity	Buildings or 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	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 or deep excavations.
Low sensitivity	Buildings/structures which are less prone to gas ingress by virtue of their foundation design (such as those with a raised floor slab). Shallow excavations and developments which involve essentially outdoor activities but where evolution of gas could pose potential problems.

9.3.5 Risk Categorization

9.3.5.1 Having determined the categories of source, pathway and target, qualitative assessment of overall risk is made by reference to **Table 9.1**. The potential implications associated with the various qualitative risk categories are summarized in **Table 9.2**.

Table 9.1 Classification of Risk Category

Source	Pathway	Target Sensitivity	Risk Category
Major	Very short / direct	High	Very High
		Medium	High
		Low	Medium
	Moderately short / direct	High	High
		Medium	Medium
		Low	Low
	Long / indirect	High	High
		Medium	Medium
		Low	Low
Medium	Very short / direct	High	High
		Medium	Medium
		Low	Low
	Moderately short / direct	High	High
		Medium	Medium
		Low	Low
	Long / indirect	High	Medium
		Medium	Low
		Low	Very Low
Minor	Very short / direct	High	High
		Medium	Medium
		Low	Low
	Moderately short / direct	High	Medium
		Medium	Low
		Low	Very Low
	Long / indirect	High	Medium
		Medium	Low
		Low	Very Low

Table 9.2 Summary of General Categorization of Risk

Category	Level of Risk	Implication
A	Very High	A less sensitive form of development should be considered otherwise 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	No precautionary measures are required.

9.3.5.2 Five generic forms of protection are used for mitigation of hazards to a development. These correspond to the risk levels set out in **Table 9.3** with the terms used defined in **Table 9.4**.

Table 9.3 Generic Protection Measures for Planning Stage Categorization

Category	Generic Protection Measures
A	Active control of gas, barriers and detection systems
B	Active control of gas, including barriers and detection systems (1)
C	Semi active controls. Detection systems in some situations
D	Passive Control
E	No precautionary measures required.

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

Table 9.4 Definition of Control Terms

Terms	Definition
Active	Control of gas by mechanical means e.g. ventilation to dilute gas, or extraction of gas from the development site using fans or blowers.
Semi active	Use of wind driven cowls and other devices which assist in the ventilation of gas but do not rely on electrically powered fans.
Passive	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 gravel in trenches or a clear void/permeable layer below structures.
Detection	Electronic systems which can detect low concentrations of gas in the atmosphere and can be linked to alarms and/or telemetry systems.

9.4 Description of Environment

9.4.1.1 The closed and restored Ngau Tam Mei Landfill is located to the southwest of The Project (**Figure 9.1**) with a small portion of the planned development node lying within Ngau Tam Mei Landfill Consultation Zone. In general, if a proposed development is to be located within the Consultation Zone of a landfill, the Project Proponent is required to undertake a landfill gas hazard assessment and submit a report to the Environmental Protection Department (EPD) for vetting.

9.4.1.2 Where a proposed development or elements of a development are of higher sensitivity, Landfill Gas Hazard Assessment (LFGHA) is required to provide preliminary technical input for formulating and evaluating development options by ascertaining the risk acceptability for development within or in close proximity to a landfill site.

9.4.1.3 Whilst development details are not finalized, the Recommended Outline Development Plan indicates the affected area is planned for development of an electricity substation with no public access.

9.4.1.4 A phased approach is adopted to qualitatively assess landfill gas hazard risk and outline a range of possible mitigation measures for consideration in the substation building design to afford an appropriate level of protection dependent upon the calculated risk.

9.5 Identification of Landfill Gas Generation, Characteristics and Hazards

9.5.1 Landfill Gas Generation

9.5.1.1 Infiltration of water into a landfill causes gases to be generated as decomposition of organic materials occurs. Once biodegradation has started the oxygen is soon exhausted and as no replenishment of the free oxygen is available, the waste mass becomes anaerobic. During anaerobic fermentation methanogens generate methane and carbon dioxide, the primary constituents of landfill gas. A typical composition of LFG is about 60% by volume of methane and 40% by volume of carbon dioxide, although these percentages can vary widely depending on the site conditions. Also present are trace quantities of hydrogen sulphide, nitrogen and gaseous hydrocarbons.

9.5.1.2 Due to the high variability in the settings of biodegradation, waste composition, and individual site characteristics, the rate of degradation and the volume of landfill gas produced per unit of waste can vary greatly. The generation of LFG is dependent on numerous environmental conditions including temperature, pH, substrate availability, moisture content and oxygen content.

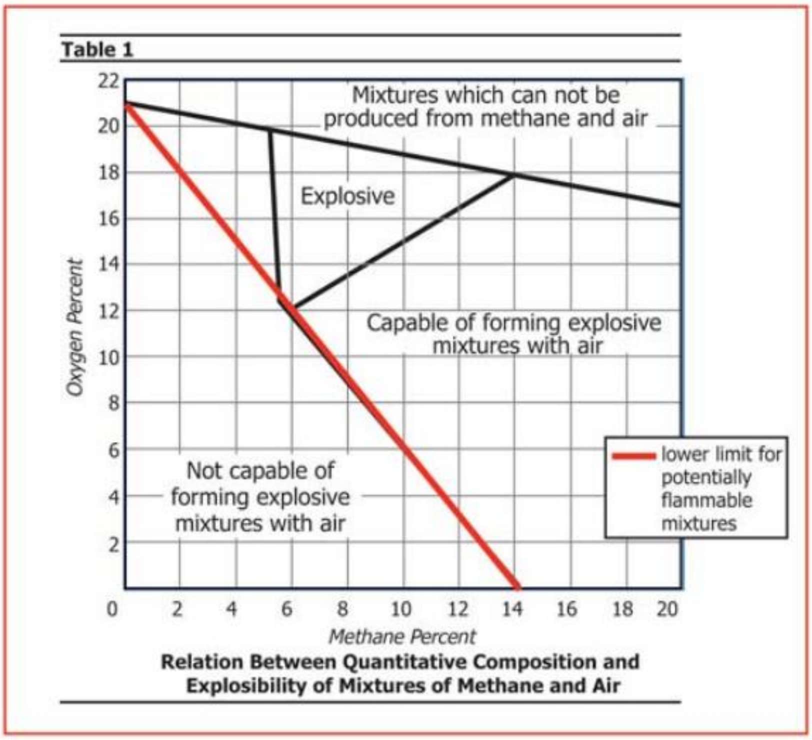
9.5.2 Landfill Gas Characteristics

9.5.2.1 Whilst methane has relatively low solubility in water, is colourless and odourless, and generally of little influence in groundwater quality, it occurs in gaseous form in the unsaturated zone. The gas, which is also an asphyxiant, is highly flammable and can be explosive when all the following conditions exist at the same time:

- Its concentration in air is between 5% of the Lower Explosive Limit (LEL) and 15% of the Upper Explosive Limit (UEL);
- the gas is in a confined space; and
- a source of ignition exists**.**

9.5.2.2 The relationship between methane and oxygen where flammable mixtures can occur is shown in **Plate 9.1** (from 30 CFR § 57.22003, MSHA Illustration 27).

Plate 9.1 Flammability Levels of Methane and Oxygen



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

9.5.2.4 Gas density. 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 or heavier than air. As a result, landfill gas may accumulate in either the base or top of any voids or confined spaces.

9.5.3 Landfill Gas Hazard

9.5.3.1 Given the potentially flammability, asphyxiant properties and gaseous density of LFG, potential hazard arises in the event that LFG is able to migrate from the landfill and accumulate in confined spaces such as building basements, underground car parks, lift shafts, pumping stations, and maintenance chambers etc. For the same reasons, temporary structures such as site huts and any other unventilated enclosures erected during construction stage may also be exposed to landfill gas hazards.

9.5.4 Landfill Gas Migration

9.5.4.1 Methane will migrate along pressure gradients from areas where it is present at higher pressures to areas where it is present at lower pressures. The primary mechanism for significant methane migration in subsurface unsaturated soils is pressure-driven flow. Diffusion also occurs but at rates too low to result in unacceptable indoor air concentrations under reasonably likely scenarios.

9.5.4.2 The ability for landfill gas to migrate beyond the waste boundary varies according to the type of landfill construction details, presence of gas and leachate control measures, restoration details and permeability of the ground through which gas must travel. Factors such as changes in atmospheric pressure can also encourage gas migration.

9.5.4.3 If gas is able to intercept any buried service routes especially where the utility has been laid in an open conduit or the trench excavation has been backfilled around the utility line with coarse gravel; these may also be susceptible to potential hazards and/or they may act as preferential gas migration pathways.

9.6 Quantitative Assessment of Potential Risk

9.6.1 Source

9.6.1.1 Ngau Tam Mei Landfill occupies approximately 1.7ha and was formed in a natural stream valley generally oriented northeast to southwest. A review of information suggests that waste disposal occurred on an informal basis as early as 1963, with more formal waste placement occurring between 1973 and 1975 resulting in approximately 90,000m^3 of waste disposed of prior to landfill closure.

9.6.1.2 The landfill was configured as two platforms; an upper platform between +32mPD and +36mPD which gently slopes from northeast to southwest while the lower platform is between elevations +24mPD and +26mPD, with a slightly steeper slope towards the southwest. The toe of the landfill is approximately +16mPD.

9.6.1.3 Landfill restoration works in 1999 consisted of placement of a “high integrity” capping system over the two platforms; minor modifications to the existing leachate management system to provide for collection and transport to an off-site treatment facility; installation of a passive landfill gas (LFG) ventilation system; and on-going monitoring of groundwater, leachate levels and landfill gas. The leachate management system consists of a simple piping network installed at the base of the landfill, and a concrete chamber near the toe of the lower slope. The landfill gas management system consists of nine vertical passive vent pipes (VV-1 to VV-9) installed to depths to 3.0-9.0m across the upper platform and horizontal pipes installed in relatively shallow trenches with vertical passive vent risers aligned around the perimeter of the upper platform, along the toe of the upper slope and diagonally across and down the lower slope. The network of passive horizontal trenches and vertical risers around the perimeter of the upper platform likely have a limited depth of waste beneath.

9.6.1.4 The passive venting system acts as the primary control will minimize build-up of LFG pressure within the landfill and hence reduce the potential for sub-surface off-site migration. Under the North-west New Territories Landfills and Gin Drinkers Bay Landfill Restoration Contract No. EP/SP/30/95A LFG a monitoring programme is in place which acts as a secondary control to monitor the effectiveness of the passive venting system and provide an early warning of any off-site migration of LFG. The locations of LFG and groundwater monitoring wells are presented on **Figure 9.3**.

9.6.1.5 From the landfill gas monitoring data provided for the period July 2019-June 2021, no methane is detected in any of the monitoring wells within the waste boundary or outside the waste boundary. The majority of wells are located to the west and south of the landfill and the nearest gas monitoring wells to the Project boundary are monitoring wells A451 and DH408 located within the northern portion of the landfill. A451 is located at the top of the slope to the east of waste boundary while DH408 is located close to the toe of the slope to the west of waste boundary.

9.6.1.6 Averaged and ranged landfill gas monitoring data for monitoring well A451 and DH408 over the 24 monitoring events between July 2019 and June 2021 is summarized in **Table 9.5**. Full monitoring data presented in **Appendix 9.1**.

Table 9.5 Summarized LFG monitoring data for A451 and DH408 July 2019- June 2021

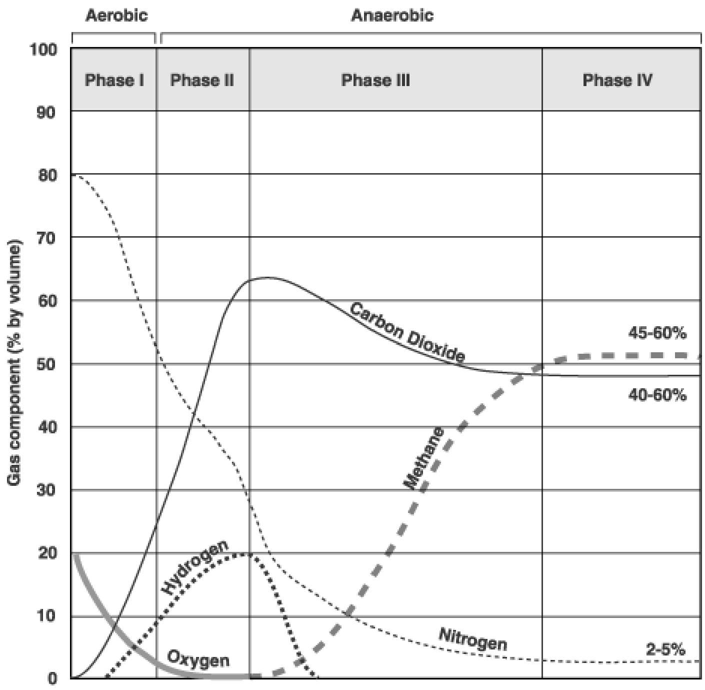
Well	Parameter	July 2019-June 2021 Average	July 2019- June 2021 Range
A451	Methane	<0.1%	-
	Carbon Dioxide	6.13%	0.8-9.9%
	Oxygen	14.48 %	8.8-20.6%
DH408	Methane	<0.1%	-
	Carbon Dioxide	2.25%	<0.1-6.1%
	Oxygen	17.80%	12.9-20.7%

9.6.1.7 As shown in the monitoring data, there is no evidence of accumulation of methane in any of the monitoring wells suggesting that methane production within the waste mass is extremely low and/or that pressure heads are insufficient to drive any lateral migration of gas beyond the waste mass. Elevated carbon dioxide concentrations are occasionally recorded an in the absence of background soil gas concentrations for reference, a conservative assumption is that the potential for off-site migration of landfill gas cannot be eliminated.

9.6.1.8 Typical landfill gas production phases are shown in Plate 9.2. The phase duration will vary according to specific landfill conditions such as composition of the waste, the restoration of the landfill, and the provision of landfill gas and leachate management systems (Crawford and Smith 1985).

9.6.1.9 Based upon the timeline of historic operations alone, gas production at Ngau Tam Mei Landfill may be in the latter stages of Phase IV or beyond with end of methane production if the majority of the organic matter has been degraded.

Plate 9.2 Production phases of typical landfill gas (USEPA 1997)



9.6.2 Classification of Source

9.6.2.1 NTML can be considered an 'old landfill' site where the maximum concentration of methane within the waste, as measured at (ongoing) monthly intervals as demonstrated by EPD data from August 2019 to July 2021 is <0.1% by volume. Whilst detections of carbon dioxide greater than 5% v/v have occasionally been measured in A451 located outside the site's eastern boundary and in DH408 located close to the toe of the slope to the west of waste boundary but within the site boundary; given the age of the landfill and likely phase of gas production, volumes of gas evolution resulting in a pressure gradient and lateral migration of gas are not anticipated to be significant especially as passive venting creates a preferential vertical gas migration pathway from the landfill.

9.6.2.2 Assessment suggests that there is no serious LFG migration problem therefore the restored NTML can be classified as a "Minor" Source.

9.6.3 Pathways

9.6.3.1 Potential pathways through which landfill gas may migrate include; transmission along natural pathways such as fissures or joints in rock; man-made pathways such as through permeable backfill in utilities trenches; or a combination of both.

9.6.3.2 Recent groundwater monitoring data indicates the thickness of the unsaturated zone of the subsurface through which gas may migrate.

Table 9.6 Depth (m) to groundwater measured from the wellhead cover

Well /Date	17-8-19	6-11-19	19-2-20	14-5-20	14-8-20	18-11-20	5-2-21	18-5-21
A458	4.33	6.99	8.57	9.18	4.02	8.09	8.94	9.45
DH403	16.12	17.04	19.12	19.94	19.52	19.31	20.22	20.71
DH404A	8.4	10.53	13.04	13.85	12.25	12.85	13.98	14.54
DH405	6.33	7.33	8.73	9.23	7.64	8.29	8.74	9.19
DH407	24.15	23.28	25.07	26.07	26.4	26.15	Dry	Dry
DH408	20.98	20.66	22.19	Dry	22.76	22.66	Dry	Dry
GW1	18.13	18.47	20.5	21.28	21.62	20.47	21.05	21.92

9.6.3.3 Whilst the gauged depths to groundwater show that a considerable unsaturated zone thickness exists, a review of the geological situation shows that the majority of NTML is underlain by coarse ash crystal tuff that is slightly metamorphosed. No faults or fissures are identified below the landfill. Gas permeability of the rock mass is negligible and will be controlled by the fracture / fissure pattern, therefore the rate of movement of gas will be slow and any build-up of gas could only occur over a long period of time.

9.6.3.4 Whilst mapped information identifies unconsolidated superficial debris flow deposits above the rock at the location where the Project area encroaches the consultation zone, although these superficial deposits are anticipated to be more gas permeable, any gas would need to pass through rock first, therefore natural migration pathways are classified as "Long and Indirect". No man-made pathways are identified. **Figure 9.2** illustrated the superficial geology in the vicinity of Ngau Tam Mei Landfill.

9.6.4 Targets

9.6.4.1 Construction Phase - Preliminary development plans within the Landfill Consultation Zone are to construct an electrical substation (G5.4). Landfill restoration facilities within NTML will remain unaffected. Whilst excavation is expected and this may create confined spaces within trenches where risk of exposure of LFG can increase, given the pathway assessment, risk is likely to be negligible. Furthermore, construction work within the consultation zone would be undertaken by trained workers with risk assessment, safety supervision and implementation of safe construction methodologies acting to mitigate identified risks. Furthermore, construction will mainly be undertaken in an outdoor environment therefore, in general the sensitivity of this group is considered "Low".

9.6.4.2 Operation Phase - To facilitate further assessment of hazards, the Guidance Note suggests consideration of the intended use and contents, provision and reliability of ventilation and frequency of use of each at risk area.

9.6.4.3 By nature, an electrical substation is a restricted access facility which the public will not have access to. Moderately sensitive elements of the proposed development may include transformer rooms / capacitors / cable rooms at ground level where access is only by authorized, well trained personnel where training can include familiarization with potential hazards associated with LFG and specific safety procedures to be followed. Low sensitivity elements of the development may include a car park and security post (if any). Based on these assumptions the target is conservatively classified as "Moderately Sensitive".

9.6.5 Source-Pathway-Target Analysis

9.6.5.1 On the basis of the source, pathways and targets identified above, a source-pathway-target analysis has been undertaken and is presented according to EPD's assessment framework in **Table 9.7**.

9.6.5.2 This classification is intended only as preliminary guidance on the nature of protective works anticipated for the development, and a more detailed investigation and reassessment at the development stage will allow targeted and more accurate design of protective measures.

Table 9.7 Source-Pathway-Target Analysis

<table>
<tr><th>Minor Source</th><th>Long / Indirect Pathway</th><th>Target Sensitivity – Low for Construction Phase /Medium for Operation Phase</th><th>Risk Category</th></tr>
<tr><td rowspan="2">NTML can be considered an ‘old landfill’ site where the maximum concentration of methane within the waste, as measured at (ongoing) monthly intervals as demonstrated by EPD data from August 2019 to July 2021 is <0.1% by volume. Whilst detections of carbon dioxide greater than 5% v/v have occasionally been measured in A451 located outside the site’s eastern boundary and in DH408 located close to the toe of the slope to the west of waste boundary but within the site boundary; given the age of the landfill and likely phase of gas production, volumes of gas evolution resulting in a pressure gradient and lateral migration of gas are not anticipated to be significant especially as passive venting creates a preferential vertical gas migration pathway from the landfill.

Assessment suggests that there is no serious LFG migration problem therefore the restored NTML can be classified as a “Minor” Source.</td><td rowspan="2">The majority of NTML is underlain by coarse ash crystal tuff that is slightly metamorphosed. No faults or fissures are identified below the landfill. Gas permeability of the rock mass is negligible and will be controlled by the fracture / fissure pattern, therefore the rate of movement of gas will be slow and any build-up of gas could only occur over a long period of time.

Whilst mapped information identifies unconsolidated superficial debris flow deposits above the rock at the location where the Project area encroaches the consultation zone, although these superficial deposits are anticipated to be more gas permeable, any gas would need to pass through rock first, therefore natural migration pathways are classified as “Long and Indirect”. No man-made pathways are identified between the landfill and the planned development.</td><td>Construction Phase - Whilst foundation construction may entail excavation which may create confined spaces where risk of exposure of LFG can increase; given the pathway assessment, risk is likely to be negligible. Furthermore, construction work would be undertaken by trained workers with risk assessment, safety supervision and implementation of safe construction methodologies acting to mitigate identified risks. Construction Phase target are classified as “Low’ Sensitivity</td><td>Source Pathway Receptor linkages classify the overall risk during construction phase to be “Very Low”.</td></tr>
<tr><td>Operation Phase - By nature, an electrical substation is a restricted access facility which the public will not have access to. Moderately sensitive elements of the proposed development may include transformer rooms / capacitors / cable rooms at ground level. Low sensitivity elements of the development may include a car park and security post (if any).

Based on these assumptions the target sensitivity during operation is classified as “Medium”</td><td>Source Pathway Receptor linkages classify the overall risk during operation phase to be “Low”.

For a low risk development Some precautionary measures will be required to ensure that the planned development is safe. The gas protection measures may be located on the boundary of the development closest to the landfill.

Generic measures may be limited to passive gas control such as provision of barriers to the movement of gas or high permeability vents such as no-fines gravel in trenches or voids/permeable layers below structures.</td></tr>
</table>

9.7 Recommended Protection Measures

9.7.1.1 For a “Low” risk situation, some precautionary measures will be required to ensure that the planned development within the consultation zone is safe. Generic measures are presented in the following sections.

9.7.2 Protection Measures during Construction

9.7.2.1 During construction phase, the risk was classified as very low (insignificant) that no precautionary measures are required.

9.7.3 Protection Measures during Operation

9.7.3.1 During the operation phase of the development, if further groundworks or construction works are planned, the same landfill gas precautionary measures as those recommended for the construction stage should be followed.

9.7.3.2 Using the prescribed methodology and evaluation of possible migration pathways to an as yet detailed design; an overall low risk categorization is derived; therefore some passive engineering measures require consideration for incorporating into the design to ensure the development with the consultation zone remains safe during operation.

9.7.3.3 For this situation (development of an electricity substation), generic passive precautionary measures may include utility protection measures for services passing through the consultation zone, creation of a subsurface preferential gas venting pathway or construction of a subsurface gas barrier and venting of manholes and above ground terminations. In ground venting or gas barrier protection measures may be located on the boundary of the development closest to the landfill. Dependent upon the orientation of the development and detailed design, utilities penetrating a ground floor slab on grade may require sealing.

9.7.3.4 Implementation of a combination of these generic measures should effectively mitigate landfill gas hazard.

9.7.3.5 Utility Protection Design Measures - For all service runs, the aim should be to provide a protective barrier at the point where the trenches pass through the perimeter of the consultation zone such that trench excavations do not form a route for gas migration. The void around any service ducts, pipes or cables within conduits at the point where the trench passes through the perimeter of the consultation zone should be filled with gas resistant mastic. Service runs within the consultation zone may remain “unprotected” since risk will be minimized by the protection measures installed at the perimeter of the consultation zone and as the general public may not have access to such underground features.

9.7.3.6 All ducts, manholes and chambers to utility services should be sealed from the surrounding ground to prevent gas entry and provided with vented covers to allow any gas that enters to dissipate to atmosphere.

9.7.3.7 The service run should be designated as a “special route” and utility companies should be informed to that effect so that they may implement precautionary measures. 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).

9.7.3.8 Structure Protection Design Measures - Passive control measures may be used in low risk situations for low gas concentrations at relatively low emissions rates and where venting to atmosphere is unlikely to cause a hazard or nuisance due to dilution in ambient air.

9.7.3.9 Passive control measures for structures with ground level or below ground rooms or other voids should be considered in the detailed design:

- For sub-surface building services/utilities, generic protection measures should include U-bends fitted to water pipes and sewers which are not always fully filled to effectively seal off the conduit and prevent gas-phase transport.
- For building services penetrating the ground floor slab, collar seals should be installed to prevent gas ingress via the penetration.
- Vent pipes or gridded manhole covers may be used to avoid build-up of gas in underground utility manholes.

9.7.4 Guidance for Entry into Service Rooms / Voids, Manholes and Chambers

9.7.4.1 Any service voids, manholes or chambers which are 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 Regulation.

9.7.4.2 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 8 of the Landfill Gas Hazard Assessment Guidance Note should also be strictly followed.

9.8 Environmental Monitoring and Audit

9.8.1.1 No monitoring is required during the construction phase of the Project.

9.8.1.2 Monitoring for landfill gases shall be conducted during the operation phases of the Project. It is recommended that pre-entry monitoring should be undertaken, where applicable, in accordance with the requirements of the Factories and Industrial Undertaking (Confined Spaces) Regulation. For excavations of 1m depth or more, landfill gas should be monitored before entry and periodically during the works. If drilling is required, the procedures for safety management and working procedures described in the EPD's Landfill Gas Hazard Assessment Guidance Note should be adopted.

9.8.1.3 The monitoring programme and detailed actions should be submitted to EPD for approval in the detailed design stage. The proposed parameters, locations and frequency of landfill gas monitoring for various phases of Project are detailed in the EM&A Manual.

9.9 Conclusion

9.9.1.1 A small portion of the Project lying within Ngau Tam Mei Landfill Consultation Zone. Quantitative landfill gas hazard is conservatively assessed as "Very Low" for the construction phase and "Low" for the operation phase. Some precautionary measures will be required to ensure that the planned development is safe.

9.9.1.2 Generic measures may be limited to passive gas control such as provision of barriers to the movement of gas or high permeability vents such as no-fines gravel in trenches between the landfill and development,

9.9.1.3 The designer of the building works should undertake detailed design of the mitigation measures during the detailed design stage. Provided that the construction and operation phase protection measures are appropriately designed and properly implemented, safety will be safeguarded and landfill gas impacts will be mitigated.