Quantitative Risk Assessment for Section 12A Application for Proposed Rezoning from "Government, Institution or Community" to "Government, Institution or Community (6)" at Tuen Mun, New Territories and to Amend the Notes of the Zone Applicable to the Site for the Proposed Social Welfare Facility (Residential Care Home for the Elderly) at Section C of Lot No. 496 in D.D 132 and the adjoining Government Land, Tuen Mun, New Territories

Submitted to

Million Creation Holding Limited

Prepared By

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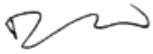
10 February 2026	0	 Michelle KWOK	 David LEE	 Claudine LEE
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ACRONYMS & ABBREVIATION

ALARP	As Low As Reasonably Practicable
BPD	Building Proximity Distance
EGIG	European Gas Pipeline Incident Data Group
EIA	Environmental Impact Assessment
EPD	Environmental Protection Department
F-N	Frequency-Fatality
G/IC	Government, Institution or Community
HKCG	Hong Kong and China Gas Company
HKPSG	Hong Kong Planning Standards and Guidelines
HKRG	Hong Kong Risk Guideline
HPTGP	High Pressure Town Gas Pipeline
IDLH	Immediate Dangerous to Life and Health
IGEM	Institution of Gas Engineers and Managers
IR	Individual Risk
LFL	Lower Flammable Limit
LRT	Light Rail Transit
MIEL	Meinhardt Infrastructure and Environment Limited
MPI	Magnetic Particle Inspection
NDT	Non-Destructive Testing
NGI	Notifiable Gas Installation
OD	Outer Diameter
OZP	Outline Zoning Plan
PHI	Potentially Hazardous Installation
PLL	Potential Loss of Life
QRA	Quantitative Risk Assessment
RCHE	Residential Care Home for the Elderly
SR	Societal Risk
TPEDM	Territorial Population and Employment Data Matrix
TPU	Tertiary Planning Unit
UFL	Upper Flammable Limit
VCE	Vapour Cloud Explosion
VPF	Value of Preventing a Fatality
WDD	Weekday Day
WDN	Weekday Night
WED	Weekend Day
WEN	Weekend Night

1 INTRODUCTION

1.1 Background

1.1.1.1 A site is proposed for Residential Care Home for the Elderly (RCHE) at Tuen Mun Tuen Fu Road (hereinafter referred as the "Proposed Development"). The Proposed Development is located at Lot 496 S.C in D.D. 132 and the Adjoining Government Land, Tuen Mun, N.T with an area of about 1,770m^2.

1.1.1.2 The Proposed Development is located to the north east of the Tuen Mun North Offtake and Pigging Station (hereinafter referred as "the Station") operated by the Hong Kong and China Gas Company (HKCG) and there is an underground 35 barg high pressure town gas pipeline (hereinafter named as the "the Pipeline") running along Tuen Fu Road and Castle Peak Road Lingnan Section near the Proposed Development. The Station and the Pipeline are classified as the Notifiable Gas Installation (NGI) under the Gas Safety Ordinance Cap. 51. The location of Proposed Development, the Station and the Pipeline are illustrated in **Figure 1**.

1.1.1.3 Meinhardt Infrastructure and Environment Limited (MIEL) was commissioned by the Million Creation Holding Limited to undertake this Quantitative Risk Assessment (QRA) to determine the risk level posed by the Station and the Pipeline to the surrounding, including the Proposed Development, and to determine the compliance with the Hong Kong Risk Guidelines (HKRG) outlined in Chapter 12 of the Hong Kong Planning Standards and Guidelines (HKPSG).

1.2 Scope of Work and Objectives

1.2.1.1 The objective of this study is to assess the potential risks associated with the Station and the Pipeline to the population in the vicinity including the construction phase in year 2028 and future operation of the Proposed Development in year 2032, and to determine whether any additional risk mitigation measures are required in the design of the Proposed Development as necessary for compliance with the Hong Kong Risk Guidelines (HKRG) outlined in Chapter 12 of the Hong Kong Planning Standards and Guidelines (HKPSG) [1].

1.2.1.2 The scope of the work of the QRA is set out as follows:

a) to determine risk levels posed to the surrounding populations with and without additional population brought by the Proposed Development; and

b) to propose mitigation measures as necessary for compliance with HKRG outlined in Chapter 12 of HKPSG [1].

1.2.1.3 The study scope of this QRA includes the Proposed Development, the Station and the 1.6km Pipeline running along Tuen Fu Road and Castle Peak Road Lingnan Section.

1.3 Risk Criteria

1.3.1 Hong Kong Planning Standards and Guidelines

1.3.1.1 Chapter 12.4 of the HKPSG [1] stipulates the risk guidelines to determine the acceptability of Potentially Hazardous Installation (PHI) in terms of individual and

societal risks. These risk guidelines are also adopted to ascertain whether the risk levels posed by the NGI are acceptable.

1.3.1.2 The individual and societal risk criteria for the risk assessment are described below:

i. **Individual Risk (IR)**: a measure of the frequency at which an individual at a specified distance from the hazardous installations is expected to sustain a specified level of harm from the realization of hazardous incident(s). The maximum level of off-site individual risk causing fatality of a person located 24 hours a day outside the facility of concern should not exceed 1×10^{-5} / year, i.e. 1 in 100,000 per year.

ii. **Societal Risk (SR)**: a measure of the relationship between the frequency of an incident and the number of fatalities that will result. It is typically expressed graphically by an F-N curve showing the cumulative frequency (F) of incidents causing N or more fatalities. The societal risk criteria are presented graphically as in **Figure 2**. There are three regions as described below:

- Acceptable: where the risk is so low that no action is necessary;
- Unacceptable: where the risk is so high that they should be reduced regardless of the cost or else the hazardous activity should not be proceeded; and
- ALARP (As Low As Reasonably Practicable)**:** where the risk associated with the hazardous activities should be reduced to a level of "As Low As Reasonably Practicable", in which the mitigation measures should be prioritized on the basis of practicality and implementation cost versus the risk reduction achieved.

1.4 Methodology

1.4.1 Overall QRA Approach

1.4.1.1 The general approach to the QRA is represented in **Figure 3**. It follows the Hong Kong Risk Guideline (HKRG) stipulated in Section 4 of Chapter 12 of the HKPSG [1], the guideline published by EMSD in 2021 – Quantitative Risk Assessment Study for High Pressure Town Gas Installation in Hong Kong [2].

1.4.2 Case to be Considered

1.4.2.1 The Proposed Development is anticipated to be under construction in 2028 and expected to fully operate as RCHE in 2032.

1.4.2.2 To determine the increase of risk levels of the NGI brought by the additional population of the Proposed Development and Additional Site, this QRA will consider the following scenarios, including:

- **Case 1 – Base Case (Year 2032):** evaluating the risk level in year 2032 without the implementation of the Proposed Development;
- **Case 2– Construction Case (Year 2028):** evaluating the risk level in Year 2028 with the construction of the Proposed Development; and

- **Case 3 – Operation Case (Year 2032):** evaluating the risk level in year 2032 with the operation of the Proposed Development in 2032.

2 HAZARDOUS INSTALLATION

2.1 Tuen Mun North Offtake and Pigging Station

2.1.1.1 The Station consists of both aboveground and underground pipework and associated equipment working at maximum 35 barg, two sets of pressure regulating units (one from 35 barg to 7 barg, another from 7 barg to 2.4 barg), and a pigging unit for 35 barg and 7 barg pressure transmission network respectively. The High Pressure (HP) network is located upstream of the station, while the Medium Pressure (MP) network is situated downstream. The technical details and layout of the Station are presented in **Appendix A**.

2.1.1.2 The Station is one of the strategic gas stations in Hong Kong which provides the largest town gas supply source for the area of Northwest New Territories. The Station consists the following pipework and critical equipment:

- One 35 barg high pressure inlet of 750 mm diameter (DN750);
- One 7 barg intermediate pressure outlet of 600 mm diameter (DN600);
- Two 2.4 barg medium pressure outlet of 400 mm diameter (DN400);
- One gas offtake unit for regulating the pressure of town gas from high pressure (35 barg) to intermediate pressure (7 barg) which consists of two streams, one in operation and the other on stand-by;
- One gas offtake unit for regulating the pressure of town gas from intermediate pressure (7 barg) to medium pressure (2.4 barg), which consists of three streams, two in operation and the other on stand-by;
- One pigging unit for the 35 barg high pressure gas transmission network; and
- One pigging unit for the 7 barg intermediate pressure gas transmission network.

2.2 Underground High Pressure Town Gas Pipeline

2.2.1.1 The Pipeline is a section of underground high pressure gas pipeline of 750mm diameter from Kung Um Road to Tong Yan San Tsuen Road along Yuen Long Highway, with a designed maximum pressure of 35 barg. The pipeline is designed in accordance with the standard of IGEM (Institution of Gas Engineers and Managers), IGEM/TD/1 [3]. It has a nominal wall thickness of 12.7 mm and is buried at a minimum depth of 1.1m.

2.2.1.2 Information of the Pipeline had been obtained from HKCG and presented in **Appendix A**. The alignment of the Pipeline as well as the location of the Station are shown in **Figure 1**.

2.3 Maintenance and Safety Management

2.3.1.1 HKCG conducts regular inspection and preventive maintenance for gas offtake stations in Hong Kong, including periodic leakage survey, equipment check and overhaul/ lubrication when necessary, pig trap maintenance and pigging operation, etc. HKCG always commits to achieve high standards of gas safety and there has

not been any incident recorded from all offtake and pigging stations since the operation started in early 80's.

2.4 Properties of Town Gas

2.4.1.1 Town gas is colourless and buoyant under ambient conditions. Odorant is added to make it smell distinctively for easy detection of gas leakage. The main components of town gas are hydrogen and methane which are flammable. It also contains carbon dioxide and a small amount of carbon monoxide which are toxic and asphyxiating. **Table 1** lists its composition and physical properties.

Table 1 Gas Composition and its Physical Properties

Component	Composition (%)	Physical Properties	Values
Hydrogen (H_2)	46.3% - 51.8%	Calorific Value (MJ/m^3)	17.27
Methane (CH_4)	28.2% - 30.7%	Specific Gravity	0.52
Carbon Dioxide (CO_2)	16.3% - 19.9%	Wobbe Index (MJ/m^3)	24
Carbon Monoxide (CO)	1.0% - 3.0%	Weaver Flame Speed	35
Nitrogen and Oxygen (N_2 & O_2)	0% - 3.3%	Lower Flammable Limit (LFL) (%)	5.5
Total	**100**		

3 PROJECT INFORMATION

3.1 Proposed Development

3.1.1.1 The Proposed Development is located at Tuen Fu Road, the opposite of Tuen Mun North Offtake and Pigging Station. The site area is approximately 1,770 m^2 with maximum 13 storeys. The layout of the Proposed Development is shown in **Appendix B**. The location of the Proposed Development is shown in **Figure 1**. It is designed for the of Residential Care Home for the Elderly with 504 beds and 236 workers. The details of Proposed Development are listed in **Table 2** and the detailed staff breakdown is listed in **Table 3**.

Table 2 Details of the Proposed Development

Development Parameter	Proposed Scheme
Site Area (Gross)	About 1,770 sq.m
Gross Floor Area	Not more than 12,000 sq.m.
Maximum Building Height (in storey)	13 storeys
Maximum Building Height (in mPD)	Not more than 52 mPD
No. of Block	1
No. of Rooms	252
No. of Beds	504
No. of Visitors	1,008

Table 3 Details of the staff in the Proposed Development

Category of staffs	No.
Kitchen	2
Register and Enrolled Nurse	46
Personal Care Worker	107
Physiotherapist	9
Officer	72
Total	**236**

Note: Assuming only personal care workers shall work shift, with about 26 of them on duty at any one time.

3.2 Study Area

3.2.1.1 The Proposed Development is subject to the risk of the Station and the highest risk 1.6km section of the Pipeline. Following EMSD's Guidance Note [2], the study zone (SZ) is taken as the area covering 200m from the Station and the Pipeline concerned according to the information provided by HKCG. The study area is illustrated in **Figure 4**.

3.3 Population Data

3.3.1 Population in the Vicinity

3.3.1.1 The surrounding populations will be directly impacted by hazardous events arising from the loss of containment of town gas in the Pipeline and the Station. According to the OZP, the land use area considered within the study area includes Residential("R"), Government, Institution or Community("G/IC"), Open Space("O") and Green Belt ("GB").

3.3.1.2 Major population groups include:

- Residents of the nearby residential buildings;
- School populations; and
- Transient population including traffic population and pedestrians.

3.3.1.3 Desktop study was conducted to collect the population information within the study area. Pending and approved Planning Applications within the study area had also been reviewed. No planned development had been identified within the study area.

3.3.1.4 Population was estimated based on the following information and assumptions:

- Assumption of average household size of 2.8 based on statistics of Town Planning Unit (TPU) 425 and 441 from 2021 Population Census [5];
- Conservative assumption of annual growth rate of 1.48% for residential population in the Tuen Mun District as observed from statistics in Projections of Population Distribution 2023 – 2031 [7];
- Conservative assumption of annual growth rate of 1.45% for industrial population in Tuen Mun district was predicted from the 2021 – based Territorial Population and Employment Data Matrix (TPEDM) [6];
- Number of students and teachers in schools obtained from school websites and school reports;
- Average class size of 25 for primary school in accordance with 2024/25 Student Enrolment Statistics established by Education Bureau; and
- Conservative assumption of annual growth at 0% for school population as predicted from the student enrolment statistics by Education Bureau in the past six years.

3.3.1.5 The population groups considered within the study area are illustrated in **Figure 4**. The detailed population data is summarised in **Table 4**.

3.3.2 Transient Population

3.3.2.1 Transient population includes traffic population of road vehicles as well as pedestrians along the road sections. Minor roads with insignificant transient population are not be explicitly considered as the population is mainly diverted from/to the major roads and are included at the major roads.

3.3.2.2 The traffic population is estimated from the traffic flow data of Annual Traffic Census 2024 [8] and the project information. The traffic population is estimated using the equations below:

$$\text{Traffic Population (ppl)} = \frac{\text{Traffic Flow } (^{\text{veh}}/_{\text{hr}}) \times {}^{\text{ppl}}/_{\text{veh}}}{\text{Speed } (^{\text{km}}/_{\text{hr}})} \times \text{Road length (km)}$$

3.3.2.3 The rail population (Light Rail Transit (LRT) and Tuen Ma Line of MTR for this study are estimated by using the equation below:

$$\text{Rail Population (ppl)} = \frac{\text{Train Capacity } (^{\text{ppl}}/_{\text{hr}}) \times \text{Loading \%}}{\text{Average Train Speed } (^{\text{km}}/_{\text{hr}})} \times \text{Rail Section Length (km)}$$

3.3.2.4 The estimated transient population is provided in **Table 4** and the detailed calculation is provided in **Appendix C.**

Table 4 Population Considered in the Study

ID	Population Name	Category	Case 1 – Base Case (Year 2032)	Case 2 – Construction Case (Year 2028)	Case 3 – Operation Case (Year 2032)	Temporal Population Change				Indoor ratio	Remarks
						WDD	WDN	WED	WEN		
01	Food Processing Factory	Industrial	6	5	6	100%	10%	40%	5%	80%	With the site area around 1291 m^2 and worker density of 700m^2/worker. Conservative rounded up to 5.
02a	Village House	Residential	1611	1519	1611	25%	100%	70%	100%	95%	Total 173 3-storey building. Assuming 1 unit per floor. Total 519 units with average household size 2.8.
02b	Village House	Residential	1182	1115	1182	25%	100%	70%	100%	95%	Total 127 3-storey house. Assuming 1 unit per floor, total 381 units with average household size 2.8.
02c	Botania Villa	Residential	2253	2124	2253	25%	100%	70%	100%	95%	Total 726 units with average household size 2.8.
02d	Future Residential Development	Residential	47	44	47	25%	100%	70%	100%	95%	Total 15 units will be provided in the Future Residential Development with A/TM-LTYY/383 in the site area.
02e	Temporary Storage	Storage	25	25	25	100%	5%	100%	5%	95%	With the site area around 16608 m^2 and worker density of 700m^2/worker. Conservative rounded up to 5.
02f	Future Residential Development	Residential	354	334	354	25%	100%	70%	100%	95%	Total 114 units will be provided in the Future Residential Development with A/TM-LTYY/249 in the site area.
02g	Temporary Storage	Storage	25	25	25	100%	5%	100%	5%	95%	With the site area around 16815 m^2 and worker density of 700m^2/worker. Conservative rounded up to 5.
03	Kai Yan Institution of Old Age Limited	Elderly Home	65	65	65	100%	100%	100%	100%	95%	Maximum capacity of 49 elderly people with 11 staffs. Conservative assumption of 65 in total.
04	Kei Tak (Nam Dai) Home For Aged Limited	Elderly Home	60	60	60	100%	100%	100%	100%	95%	Maximum capacity of 38 elderly people with 19 staffs. Conservative assumption of 60 in total.
05	Lam Tei Substation	Substation	5	5	5	100%	10%	55%	10%	100%	Conservative assumption.
06	Rosewood	Residential	56	53	56	25%	100%	70%	100%	95%	Total 9 2-storey building. Assuming 1 unit per floor. Total 18 units with average household size 2.8.
07	Pui Chak Villa	Care Centre	60	60	60	100%	100%	100%	100%	95%	Maximum capacity of 40 residential place with 12 staffs. Conservative assumption of 60 in total.
08	Warehouse	Storage	5	5	5	100%	5%	100%	5%	95%	With the site area around 2927 m2 and worker density of 700m2/worker. Conservative rounded up to 5.
09	Car Park	Car Park	5	5	5	100%	10%	50%	10%	0%	Conservative assumption.
10	Three-storey building	Residential	3	3	3	25%	100%	70%	100%	95%	A 3-storey house with 1 unit.
11	Three-storey building	Residential	28	26	28	25%	100%	70%	100%	95%	With 3 3-storey building. Assuming 1 unit per floor. Total 9 units with average household size 2.8.
12	Lam Tei Raw Water Pumping Station	Pumping Station	5	5	5	100%	0%	50%	0%	0%	Conservative assumption.
13	Diamond Jubilee Building	Vacant	0	0	0	0%	0%	0%	0%	0%	Conservative assumption.
14	Lingnan University Multi-Purpose Outdoor Sports Ground	Recreational	120	120	120	50%	5%	100%	5%	0%	Consists of an indoor student activity centre with 2 multi-purpose Function Rooms and an indoor fitness room, 1 artificial turf soccer pitch (for maximum 11 player per team), field facilities for high jump, long jump and other throwing

ID	Population Name	Category	Case 1 – Base Case (Year 2032)	Case 2 – Construction Case (Year 2028)	Case 3 – Operation Case (Year 2032)	Temporal Population Change				Indoor ratio	Remarks
						WDD	WDN	WED	WEN		
											event activities; and 2 tennis courts with floodlights; and Outdoor fitness corner. Conservative assumed 120 population in total.
15	Fu Tai Estate	Residential	18463	17409	18463	25%	100%	70%	100%	95%	According to 2021 Population Census.
16	Lingnan University	School	9542	9542	9542	100%	0%	10%	0%	90%	Total 6041 and 2392 students from Lingnan University and Lingnan Institute of Further Education with total 1109 staff.
17	South Hillcrest	Residential	962	907	962	25%	100%	70%	100%	95%	Total 310 units with average household size 2.8.
18	Beneville	Residential	2123	2001	2123	25%	100%	70%	100%	95%	Total 684 units with average household size 2.8.
19	Fu Tei Chung Tsuen Children's Playground	Recreational	10	10	10	50%	5%	100%	5%	0%	Conservative assumption.
20	Lingnan Playground	Recreational	10	10	10	50%	5%	100%	5%	0%	Conservative assumption.
21	The Yuen Yuen Institute Chan Kwok Chiu Hing Tak Primary School	School	620	620	620	100%	0%	10%	0%	90%	According to the annual report of 2024-2025, there are total 545 students, 59 teachers and 15 staff in the school. Conservative rounded up to 620 people.
22	Grove	Vacant	0	0	0	0%	0%	0%	0%	0%	Vacant site.
23	Ecclesia Theological Seminary	School	140	140	140	100%	0%	10%	0%	90%	Conservative assuming 100 students in school with 40 staff.
24	Napa Valley	Residential	304	287	304	25%	100%	70%	100%	95%	Total 98 units with average household size 2.8.
25	Tuen Fu Road Community Garden	Recreational	10	10	10	50%	5%	100%	5%	0%	Conservative assumption.
26	Siu Hong Court	Residential	12338	11634	12338	25%	100%	70%	100%	95%	According to 2021 Population Census.
27	Tuen Mun Government Primary School	School	654	654	654	100%	0%	10%	0%	90%	According to the annual report of 2024 – 2025, there are total 24 classes and 44 teaching staffs. Assumed with average class size of 25 as per info from Education Bureau and conservative assumption of 10 other staffs. Total 654 people.
28	Siu Hong Station (South) Public Transport Interchange	Bus Terminus	30	30	30	100%	10%	100%	10%	0%	Conservative assumption.
29	Castle Peak Road (San Hui) Park	Recreational	50	50	50	50%	5%	100%	5%	0%	Conservative assumption.
30	Fu Tei Fire Station	Fire Station	30	30	30	100%	100%	100%	100%	90%	Conservative assumption with reference to South Island Line (East) EIA.
31	Parkland Villas	Residential	4145	3908	4145	25%	100%	70%	100%	95%	According to 2021 Population Census.
32	Ching Leung Nunnery	Religious	60	60	60	40%	10%	100%	10%	95%	Assume 30 staffs and 30 visitors in nunnery.
33	Ching Yan Elderly Home (Inside Ching Leung Nunnery)	Elderly Home	25	25	25	100%	100%	100%	100%	95%	Maximum capacity of 10 elderly people with 9 staffs. Conservative assumption of 25 in total.

ID	Population Name	Category	Case 1 – Base Case (Year 2032)	Case 2 – Construction Case (Year 2028)	Case 3 – Operation Case (Year 2032)	Temporal Population Change				Indoor ratio	Remarks
						WDD	WDN	WED	WEN		
34	Gig Lok Monastery	Religious	60	60	60	40%	10%	100%	10%	95%	Assume 30 staffs and 30 visitors in monastery.
35	Scattered Houses	Residential	25	23	25	25%	100%	70%	100%	95%	Assuming 4 village houses including 2 with 3 floors and 2 with single floor. Total 8 units with average household size 2.8.
36	Casphalt	Religious	50	50	50	40%	10%	100%	10%	95%	Conservative assumption
37	Tuen Fu Road Disciplined Services Staff Quarters - Leisure Garden	Recreational	22	20	22	50%	5%	100%	5%	0%	Conservative assumption.
38	Tuen Fu Road Disciplined Services Staff Quarters - Residential	Residential	434	410	434	25%	100%	70%	100%	95%	Total of 140 units with average household size of 2.8.
39	Tuen Mun Treatment Works Staff Quarters (Used as Site Offices)	Industrial	33	31	33	100%	1%	50%	0%	0%	10 units are used as site offices as recorded in Government's document. Conservative assumptions of 30 people.
40	Brilliant Garden - Residential	Residential	1434	1352	1434	25%	100%	70%	100%	95%	Total 462 units with average household size of 2.8.
41	Brilliant Garden - Churches	Church	150	150	150	100%	0%	100%	0%	95%	Total 3 churches. Conservative assumption of 50 people for each church according to South Island Line EIA.
42	Brilliant Garden - Elderly Homes	Elderly Home	225	225	225	100%	100%	100%	100%	95%	Total 3 elderly homes with a total maximum capacity of 187 people. Conservative assumption of 38 staffs in total.
43	Tuen Mun Treatment Works	Industrial	33	31	33	100%	10%	40%	5%	80%	Conservative assumption.
PD_BC	Existing Proposed Development	Residential	9			25%	100%	70%	100%	95%	1 3-storey building. Assuming 1 unit on each floor. Total 3 units.
PD_CC	Proposed Development (Construction Phase)	Construction		50		100%	1%	50%	0%	0%	Based on Project Information.
PD01a_OC	Proposed Development – Main Building (Operation Phase)	Proposed Development (Elderly home)			1738	100%	33%	100%	33%	100%	Based on Project Information. There is total 1748 users. Assuming 10 users are in the outdoor area of the Proposed Development.
PD01b_OC	Proposed Development– Outdoor area (Operation Phase)	Recreational			10	100%	100%	100%	100%	0%	
R01	Lam Tei Interchange	Road	112	112	112	100%	42%	100%	42%	0%	Refer to **Appendix C**.
R02	Castle Peak Road - Lingnan	Road	337	337	337	100%	42%	100%	42%	0%	Refer to **Appendix C**.
R03	Yuen Long Highway	Road	977	885	977	100%	42%	100%	42%	0%	Refer to **Appendix C**.
R04	Tuen Kwai Road	Road	78	78	78	100%	42%	100%	42%	0%	Refer to **Appendix C**.
R05	Tuen Fu Road	Road	32	32	32	100%	42%	100%	42%	0%	Refer to **Appendix C**.

ID	Population Name	Category	Case 1 – Base Case (Year 2032)	Case 2 – Construction Case (Year 2028)	Case 3 – Operation Case (Year 2032)	Temporal Population Change				Indoor ratio	Remarks
						WDD	WDN	WED	WEN		
R06	Fu Tei Road	Road	8	8	8	100%	42%	100%	42%	0%	Refer to **Appendix C**.
R07	Tuen Mun Road	Road	406	406	406	100%	42%	100%	42%	25%	Refer to **Appendix C**.
R08	Fuk Hang Tsuen Road	Road	23	22	23	100%	42%	100%	42%	0%	Refer to **Appendix C**.
LRT01	Light Rail (Route 610 & 751)	Rail	101	101	101	100%	64%	100%	64%	0%	Refer to **Appendix C**.
LRT02	Light Rail (Route 614 & 614P)	Rail	101	101	101	100%	64%	100%	64%	0%	Refer to **Appendix C**.
TML01	Tuen Ma Line	Rail	628	628	628	100%	64%	100%	64%	0%	Refer to **Appendix C**.

3.3.3 Temporal Change in Population

3.3.3.1 To reflect the temporal changes in population within a week, the corresponding population proportion of the time periods are assumed based on observation from desktop study, the approved Environmental Impact Assessment (EIA) reports [4][9] and the project information.

3.3.3.2 Day time is defined as 07:00 to 19:00 and night time from 19:00 to 07:00 next day. The temporal changes of different population category are provided in **Table 5**. The detailed temporal changes of population for each population site considered are provided in **Table 4**.

Table 5 Temporal Change of Population within a Week

Category	Time Period			
	Weekday Day (WDD)	Weekday Night (WDN)	Weekend Day (WED)	Weekend Night (WEN)
Bus Terminus (3)	100%	10%	100%	10%
Car Park (1)	100%	10%	50%	10%
Care Centre (1)	100%	10%	100%	10%
Church (1)	100%	0%	100%	0%
Construction (1)	100%	1%	50%	0%
Elderly Home (1)	100%	100%	100%	100%
Fire Station (2)	100%	100%	100%	100%
Industrial (2)	100%	10%	40%	5%
Pumping Station (1)	100%	0%	50%	0%
Rail (4)	100%	64%	100%	64%
Recreational (2)	50%	5%	100%	5%
Religious (1)	40%	10%	100%	10%
Residential (2)	25%	100%	70%	100%
Road (4)	100%	42%	100%	42%
Tuen Mun Road (4)	100%	42%	100%	42%
School (3)	100%	0%	10%	0%
Storage (1)	100%	5%	100%	5%
Substation (1)	100%	10%	55%	10%
Proposed Development (Elderly home) (5)	100%	33%	100%	33%

Note:
(1) Based on desktop study and conservative assumption
(2) Reference to HATS Stage 2A EIA [9]
(3) Reference to South Island Line EIA [4]
(4) Refer Appendix C
(5) Based on the Project Information

3.4 Indoor / Outdoor ratio

3.4.1.1 Building structures can offer some protection from fires for the occupants inside. An indoor ratio of 95% is applied to care centre, churches, elderly homes, religious venues, residential buildings and storage, and an indoor ratio of 90% is applied to the population in fire stations and schools. Considering the industrial activities includes outdoor activities, industrial population is considered as 80% indoor. The remaining portion of population in pumping station, rail, recreational and road is assumed to be outdoor, accounting for outdoor activities and walking on pathways.

3.4.1.2 For the Proposed Development, it is planned for the use of RCHE. The outdoor activities of the users are limited and restricted in the outdoor area on site. As there is no podium or outdoor area in the main building. The indoor ratio of the Proposed Development main building is 100% and that of the outdoor area is 0%.

3.4.1.3 Passengers in vehicles are considered as 100% outdoors population although vehicles may provide certain protection. The section of Tuen Mun Road considered in this study is enclosed with noise barrier, an indoor ratio of 25% is assumed for the protection of noise barrier against fire hazards from the Station.

3.4.1.4 The indoor ratio assumed for the population considered are indicated in **Table 4**.

3.5 Source of Ignition

3.5.1.1 Flammable gas cloud from an accidental release can be ignited and led to fire or explosion if there are ignition sources present in the close proximity or along the dispersion path of the cloud. If the gas cloud is diluted outside the flammable concentration range (i.e. below LFL), or in the absent of ignition sources, no fire hazards will be expected. The energy level, timing, location and ignition effectiveness of ignition sources in the vicinity of the hazardous installations affect the extent of gas cloud dispersion and its potential impacts.

3.5.1.2 Two types of ignition sources are defined in the SAFETI model:

- **Population source**: accounting for human activities such as smoking, cooking and using electrical appliances. This is assigned implicitly to all population group by DNV SAFETI.

- **Line source – transportation route segments**: accounting for the moving vehicles on roads. The ignition probabilities are calculated from the traffic density, average vehicle speed, vehicle ignition efficiency and total length of the roads. Vehicle ignition efficiency is taken as 0.4 per 60 seconds [11]. Traffic flow and average vehicle speed are included in **Appendix C**.

- **Line source – electrical line segments**: accounting for the electrical rail transmission line. Probability of ignition is taken as 0.2 per 100m [11].

3.6 Meteorological Information

3.6.1.1 Meteorological conditions affect the consequences of a gas release, in particular wind directions, speeds and stabilities which influence the direction and degree of turbulence of a gas dispersion. Meteorological data from the Tuen Mun Government Offices Weather Station (Year 2024) was collected from the Hong Kong Observatory and adopted in the consequence modelling to compute the effects of various gas

dispersions, fires and explosions. The data are rationalized into a set of weather classes in accordance with the Netherlands Organisation for Applied Scientific Research (TNO) Purple Book [11]. The meteorological data can be expressed in the combinations of wind speeds and Pasquill stability classes. Pasquill classes (A to F) represent the atmospheric turbulence, in which class A being the most turbulent class while class F being the least turbulent class.

3.6.1.2 The six most dominant sets of wind speed-stability class combination for both day-time and night-time are listed in **Table 6** and **Table 7** respectively. The average ambient temperature adopted in the analysis is 23°C and relative humidity is 80% [10].

Table 6 Day Time Wind Direction Frequency at Tuen Mun Government Offices Weather Station (Year 2024)

Direction	Weather Class						Total
	3.0B	1.5D	4.0D	7.0D	3.0E	1.5F	
0 – 30	8.80	2.30	1.10	0.00	0.83	2.03	15.07
30 – 60	6.91	1.52	4.51	0.12	1.30	1.64	16.00
60 – 90	0.12	0.07	0.00	0.00	0.02	0.05	0.27
90 – 120	0.54	0.10	0.15	0.00	0.20	0.12	1.10
120 – 150	3.38	0.69	1.40	0.22	0.32	0.61	6.62
150 – 180	19.83	1.37	6.10	0.76	1.67	1.05	30.78
180 – 210	7.87	0.98	1.00	0.00	0.59	0.59	11.03
210 – 240	4.71	0.83	0.49	0.00	0.29	0.37	6.69
240 – 270	1.47	0.32	0.10	0.00	0.07	0.17	2.13
270 – 300	1.23	0.32	0.05	0.00	0.10	0.49	2.18
300 – 330	2.62	0.47	0.34	0.00	0.10	0.56	4.09
330 – 360	2.18	0.44	0.15	0.00	0.27	0.98	4.02
All	**59.66**	**9.41**	**15.39**	**1.10**	**5.76**	**8.68**	**100.00**

Table 7 Night Time Wind Direction Frequency at Tuen Mun Government Offices Weather Station (Year 2024)

Direction	Weather Class						Total
	3.0B	1.5D	4.0D	7.0D	3.0E	1.5F	
0 – 30	0.00	0.35	0.90	0.00	2.23	8.49	11.97
30 – 60	0.00	0.68	8.04	0.25	6.56	9.82	25.34
60 – 90	0.00	0.00	0.03	0.00	0.15	0.70	0.88
90 – 120	0.00	0.03	0.83	0.08	0.60	1.65	3.18
120 – 150	0.00	0.18	2.93	0.23	1.83	3.41	8.56
150 – 180	0.00	0.10	10.22	0.18	8.34	6.41	25.24
180 – 210	0.00	0.10	1.13	0.00	2.83	3.61	7.66
210 – 240	0.00	0.00	0.38	0.00	0.73	2.48	3.58
240 – 270	0.00	0.03	0.20	0.00	0.25	2.30	2.78
270 – 300	0.00	0.03	0.00	0.00	0.08	3.33	3.43
300 – 330	0.00	0.05	0.13	0.00	0.28	2.53	2.98
330 – 360	0.00	0.15	0.15	0.00	0.35	3.73	4.38
All	**0.00**	**1.68**	**24.92**	**0.73**	**24.22**	**48.46**	**100.00**

4 HAZARD IDENTIFICAITON

4.1 General

4.1.1.1 Hazards arising from the Station and pipeline is mainly associated with the loss of containment events due to failure of equipment and pipelines, which could lead to a release of significant amount of hazardous materials.

4.1.1.2 The possible causes that lead to equipment and pipeline failure in the Station are discussed in the following sections for consideration in the risk assessment.

4.2 Hazardous Scenarios Identified

4.2.1 External Causes

4.2.1.1 Natural Hazards

Nature hazards such as earthquake, storm, typhoon, subsidence and tsunami may cause potential damage to the town gas installations. This section will discuss the credibility of these natural hazards to loss of containment incident with respect to Hong Kong's geographical location.

Earthquake – Hong Kong is not located within the seismic belt. According to the Hong Kong Observatory, earthquakes occurring in the circum-Pacific seismic belt which passes through Taiwan and Philippines are too far away to affect Hong Kong significantly. Although there has not been any reported case of destructive earthquake tremor in Hong Kong, loss of containment incident due to earthquake is still considered credible to cause rupture of aboveground pipeline.

Subsidence / Landslides – Excessive subsidence may lead to failure of the structure and ultimately loss of containment scenario. Subsidence is usually slow in movement and such movement can be observed and remedial action can be taken in time.

The soil conditions of the Station are considered rather stable and there is no hilly region nearby. The probability of town gas leakage in the Station due to subsidence or landslides is deemed remote. Moreover, there is no reported case of leak of town gas in all offtake and pigging station since it started operation by HKCG in early 70's.

Considering that pipeline failures due to landslide have been reported by the European Gas Pipeline Incident Data Group (EGIG), it is reviewed in frequency assessment of the underground high pressure pipeline within the Station and the Pipeline (refer **Section 5.2.1)**.

Lightning – Lightning sparks could ignite the combustible gas in air. The Station is equipped with lightning rod that can effectively protect the equipment from lightning, hence lightning strike causing a release of town gas is deemed remote. In regards of the underground high pressure pipeline, lightning is considered by EGIG and thus, is studied (refer **Section 5.2.1)**.

Other Severe Environmental Events – For super typhoons observed in recent years, no major loss of containment incident had been reported in all offtake and pigging stations in Hong Kong. The Station is designed to comply with the Code of Practice on Wind Effect in Hong Kong to withstand wind load of typhoon. Also, the

Station is not near the coastal area. Therefore, loss of containment due to severe environmental event such as typhoon and storm surge or tsunami is considered unlikely.

4.2.1.2 External Fires

External fire means the occurrence of a fire event which leads to the failure of the equipment inside the Station. The Station will be bounded by metal fence wall and the equipment inside is distanced from the site boundary. External fire is unlikely to damage the equipment in the Station.

In addition, external fire from aboveground is considered not possible to damage underground gas pipelines. Hence, external fire causing loss of containment is not further assessed.

4.2.1.3 Vehicle Crash

There are vehicle access and speed restrictions imposed at the Station. Warning signage is also implemented within the Station. In addition, the Station is fenced off from Tuen Fu Road by metal fence and road balustrade. The chance of vehicle crashing into the Station and causing damage to the pipework / equipment is considered unlikely and thus not further considered.

4.2.1.4 Dropped Objects

Dropped objects such as cigarette stubs, balls etc. impacting on the facilities of the Station could be a concern. The nearest existing population to the Station is Tuen Fu Road Disciplined Services Staff Quarters.

The nearest high rise building, Tuen Fu Road Disciplined Services Staff Quarters, has been separated over 20m away from the boundary of the Station. The podium leisure garden of Tuen Fu Road Disciplined Services Staff Quarters is fenced. The possibility of a falling object directly hitting the equipment at the Station is deemed a remote scenario and is not considered in this study.

4.2.1.5 Major Leakages of Underground Water Mains

Major leakage of underground water mains could be another concern to underground pipeline. In case if the water ejects towards the gas main, it carries the surrounding soil and sand and impacts on the surface of the pipes, resulting in damage on pipe wall and loss of containment.

4.2.1.6 Operational Errors

Historical data revealed that human error is a significant contributor to equipment failure. Even though operators at the Station are well-trained to minimise the chance of human error, human error leading to leakage or loss of containment is still considered credible.

4.2.1.7 Third Party Damage

Third party damage on gas pipeline includes the damage to pipes due to drilling, hammering, excavation works, etc. In fact, the potential of third party damage to the gas piping party damage depends on the surrounding environment. Pipe wall

thickness, buried depth, concrete cover and design factor have influence on whether third party damage would result in pipe damage.

In Hong Kong, excavation/ trenching works are well controlled. As per Gas Safety Ordinance, utility mapping must be conducted to identify any underground utility within the site before any construction work commences. This could minimize the risk of damaging any existing underground utility. In addition, HKCG has issued a "Requirements for Construction Works Adjacent to Existing Gas Offtake Station and in the Vicinity of Gas Main", which the Contractor should strictly follow. Clearance distances from offtake and pigging stations and the underground high pressure town gas pipelines, as well as safety precautions during the construction works are indicated in the requirements.

Nevertheless, generic loss of containment incident due to third party damage is still a credible scenario and is considered in this study

4.2.2 Internal Causes

4.2.2.1 Corrosion

Corrosion is one of the main contributors for pipeline failure. External corrosion of a buried pipe could occur due to the contact of stray DC electric earth current or contaminated ground or coating damage. Internal corrosion occurs due to the presence of moisture and contaminants in the gas. The pipeline carries dry town gas which is not expected to have any moisture and it is coated with epoxy internally to avoid corrosion. Nevertheless, loss of containment incident due to corrosion is still a credible scenario and was considered in this assessment.

4.2.2.2 Material Defect

Material defect of pipeline including welding failure and mechanical strength failure, etc., could occur for various reasons. HKCG adopted non-destructive testing (NDT) by X-ray for each butt weld and magnetic particle inspection (MPI)/ ultrasonic test for fillet welds of the underground pipeline according to IGEM/TD/1[3]. Historical data showed that material failure leading to loss of containment is credible and such scenario is included in this assessment.

5 FREQUENCY ASSESSMENT

5.1 General

5.1.1.1 Frequency analysis involves estimation of failure frequencies resulting in a release of hazardous materials. This section examines the failure frequencies of the pipeline and the station that result in loss of containment. The analysis is based on the EMSD's Guidance Note [2] and international database, with modifications to reflect the local factors, such as good safety practice, anchorage protection, pipeline integrity, etc.

5.2 Underground High Pressure Pipeline

5.2.1 EGIG Historical Failure Data

5.2.1.1 EGIG is an industry group of 15 major gas transmission system operators in Europe, which owns an extensive database of pipeline incident data since 1970. The failure frequency over the reporting period of 1970 – 2022 is 2.78×10^{-4} per km year [12]. A steady reduction of the failure frequency over the last two decades is observed, showing improved safety performance. The recent failure frequency during 2013 – 2022 is significantly lower with only 1.19×10^{-4} per km year [12].

5.2.1.2 The breakdown of the accident frequencies by causes for all types of pipelines is shown in **Table 8**. External interference remains the dominant cause for gas leakage.

Table 8 Incident Causes for Onshore Pipeline Gas Leakage

Causes	Distribution of Incidents [12]	
	Period 1970 – 2022	Period 2013 – 2022
External Interference	45.0%	22.7%
Corrosion (Internal and External)	17.6%	25.2%
Construction Defect / Material Failure	16.5%	17.6%
Ground Movement	9.0%	19.3%
Hot Tap Made By Error	4.3%	0.8%
Other and Unknown	7.6%	14.3%
Total	100%	100%

5.2.2 Analysis of Modification Factors

5.2.2.1 <u>External Interference</u>

The major contributor of external interference in Hong Kong is third party damage, such as the inadvertent damages during excavation. The degree of damage depends on surrounding environment, wall thickness, buried depth and protection from concrete cover.

The Pipeline concerned is of size 750 mm (O.D. 30 inch) and the nominal wall thickness is 12.7mm. The pipes are buried at a minimum depth of 1.1m with concrete cover, giving significant protection to the pipeline against external interference.

In addition, the following practices are required while carrying out underground works to reduce the probability of third party damage to high pressure town gas pipeline:

- Contractor should carry out utility survey and trial trench inspection for any underground works before construction work commences.

- Much of the gas pipeline is laid under carriageway in which excavation is under stringent control. The HKCG's "Requirements for Construction Works in the Vicinity of Gas Main" and the EMSD's Code of Practice on "Avoidance of Damage to Gas Pipes, 2nd Edition" should be strictly followed for any underground excavation works to be done nearby the HKCG's gas pipeline.

According to IGEM/TD/2 [13], a reduction factor of 0.03 is suggested to take account of the design factor, wall thickness and buried depth of the Pipeline. Nevertheless, a reduction factor of 0.05 is conservatively adopted to the failure frequencies of underground gas pipeline due to external interference to account for the pipeline design and the safe practices.

5.2.2.2 Corrosion (Internal and External)

There is a decreasing trend in incidents due to corrosion against year of construction. No leak case due to corrosion has been reported for pipeline which was constructed after 1994. In addition, internal corrosion is very unlikely since town gas is dry and free from corrosive gases. External corrosion of the pipeline is prevented by cathodic protection. Hence, a reduction factor of 0.5 is adopted for all pipelines with nominal wall thickness of 12.7mm.

5.2.2.3 Construction Defect / Material Failure

There is a decreasing trend in incidents due to welding, mechanical strength and material failure against year of construction. Majority of incidents were caused by pipelines that were built before 1973. As per IGEM/TD/2 [13], the failure frequency due to material and construction defects reduces as the wall thickness increase. Moreover, the HKCG has adopted a NDT by X-ray for each butt weld and magnetic particle inspection / ultrasonic test for fillet welds of the underground pipeline in accordance to IGEM/TD/1 [3] to prevent material and construction defects. Therefore, a reduction factor of 0.1 is adopted.

5.2.2.4 Ground Movement

Ground movement can be caused by a number of causes, e.g. subsidence, landslides or flooding. Pipes of smaller diameter are more susceptible to ground movement. The major cause of the ground movement failures was due to landslide. Considering the pipeline is not constructed in a hilly region, landslides are unlikely. The pipeline is buried with a cover of at least 1.1m deep and with safety measure as described in **Section 5.2.2.1 External Interference**. A reduction factor of 0.1 is assumed to reflect the actual situation.

5.2.2.5 Hot Tap Made by Error

"Hot tap made by error" means that a connection has been made by error to a live gas transmission pipeline. Hot tap is not used by the HKCG for gas transmission pipeline and this is irrelevant to this study. A 100% reduction is adopted.

5.2.2.6 Other and Unknown

Others and unknown include failure caused by design error, lightning and maintenance error. The HKCG has extensive experience in designing and operating the underground gas pipes. It also applies stringent in-house procedures to monitor operation and maintenance of the gas pipes. The high pressure town gas pipeline is buried under the ground with a minimum concrete cover of 1.1m, lightning striking the pipeline is unlikely. A reduction factor of 0.1 is therefore assumed.

5.2.3 Adopted Failure Frequencies of the Pipeline

5.2.3.1 A direct application of the EGIG database is not appropriate to Hong Kong's situation. Reduction factors have been adopted to modify the failure rate to reflect the actual condition in Hong Kong. The breakdown of failure rates with reduction factors are listed in **Table 9**. The modified failure rates from the EGIG database for pipeline of size 750 mm are 9.49×10^{-6} per km-year.

Table 9 Breakdown of EGIG Incidents with Reduction Factors

Causes	Failure Rate (1) (per km year)	Reduction Factor	Modified Failure Rate (per km year)
External Event for Pipe Diameter (29-35")	1.80×10^{-5}	0.1	1.80×10^{-6}
Corrosion (Thickness 10-15mm)	1.40×10^{-6}	0.5	7.00×10^{-7}
Construction Defect / Material Failure (Year of construction 1984-2023)	5.65×10^{-5}	0.1	5.65×10^{-6}
Ground Movement (29-35")	6.60×10^{-6}	0.1	6.60×10^{-7}
Hot Tap Made by Error (29-35")	0	0	0
Other and Unknown	6.80×10^{-6}	0.1	6.80×10^{-7}
		Total	9.49×10^{-6}

Note: (1) Based on 12th EGIG Report [12]

5.2.3.2 The failure rate of underground pipe is conservatively taken as 1.0×10^{-5} per km-year (i.e. 1.0×10^{-8} per m-year) as recommended in EMSD's Guidance Note [2].

5.3 Tuen Mun North Offtake and Pigging Station

5.3.1 Process Equipment

5.3.1.1 The failure rates of pipes and process equipment are estimated by 'Parts Count' method with reference to the failure frequencies recommended in the EMSD's Guidance Note [2] and internationally recognized historical failure databases, as tabulated in **Table 10.**

Table 10 Failure Rates of the Process Equipment in Station

Process Equipment		**Failure Rate (per equipment year)**	**Quantity/ Pipe Length (m)**	**Failure Rate (per year)**
High Pressure (35 barg)	Valve [2]	1.10×10^{-3}	36	3.96×10^{-2}
	Flange [2]	1.00×10^{-3}	62	6.20×10^{-2}
	Connection [2]	5.70×10^{-4}	23	1.31×10^{-2}
	Aboveground Pipe [2]	2.67×10^{-7} (per m per year)	104	2.78×10^{-5}
	Underground Pipe [2]	1.00×10^{-5} (per km per year)	60	6.00×10^{-7}
	Pig Trap [18]	1.03×10^{-8}	1	1.03×10^{-8}
			Total	**1.15×10^{-1}**
Intermediate Pressure (7 barg)	Valve [2]	1.10×10^{-3}	34	3.74×10^{-2}
	Flange [2]	1.00×10^{-3}	54	5.40×10^{-2}
	Connection [2]	5.70×10^{-4}	31	1.77×10^{-2}
	Aboveground Pipe [2]	2.67×10^{-7} (per m per year)	109	2.91×10^{-5}
	Underground Pipe[2]	1.00×10^{-5} (per km per year)	120	1.20×10^{-6}
	Pig Trap [18]	1.03×10^{-8}	1	1.03×10^{-8}
			Total	**1.09×10^{-1}**

5.3.2 Operation Failure of Pig Trap

5.3.2.1 During normal operation, pig traps are isolated from the active pipework so the risk associated with it should be limited. Release of town gas from pig trap is considered possible only when it is filled with town gas during pigging operation.

5.3.2.2 HKCG conducts pigging operation once in every ten years. To ensure correct and safe sequence of pigging operations and to minimize of the risk of operation error, HKCG adopts a high standard and stringent control procedure to each pigging operation on transmission system. Mechanical interlocks will also be used on the pig

trap to prevent the door being opened before the pig trap has been free from pressurized gas. Nevertheless, pigging operation is considered additional risk to pig trap failure when the pig trap is filled with town gas and damaged by the pipe inspection gauge (PIG) manoeuvring inside. Hence, the chance of pig trap failure due to pigging operation is deemed significant only at the time when launching or receiving the PIG. In consideration of the length of the pig trap and the speed of the PIG, the critical period for the PIG moving inside the pig trap can be only a few seconds. As a conservative approach, it is taken as 15 minutes.

5.3.2.3 The diameters of the pig trap are 600mm and 750 mm, i.e., 24 and 30 inches. The failure rate of pig trap is conservatively taken as 3.60×10^{-3} per pig trap-year [18]. Taking account of the frequency of pigging operation and the critical period for PIG manoeuvring inside the pig traps, the likelihood of pig trap failure due to pigging operation is calculated as 1.03×10^{-8} per year per pig trap. Such failure is assumed resulting in rupture of the pig trap.

5.3.3 Underground Pipe

5.3.3.1 Historical database of pipeline incident published by EGIG has been reviewed in **Section 5.2** . The modified failure rates from the EGIG database for pipeline of size 750 mm are 9.49×10^{-6} per km-year. Therefore, the underground pipe in the Station is conservatively taken as 1.0×10^{-5} per km-year (i.e. 1.0×10^{-8} per m-year) as recommended in EMSD's Guidance Note [2].

5.4 Hole Size Distribution

5.4.1.1 The failure of pipes and equipment may be resulted in gas leakage from various hole sizes. According to EMSD's Guidance Note [2], the hole size distributions of process equipment, aboveground and underground pipework is taken as listed in **Table 11** and **Table 12.**

Table 11 Hole Size Distribution of Process Equipment

Hole Size Category	Hole Size	Percentage (%)
Valve	10mm	100
Flange	50mm	1
	25mm	9
	10mm	90
Instrument Connection	25mm	11.5
	10mm	88.5

Table 12 Hole Size Distribution of Pipes

Hole Size	Aboveground Pipe (1)	Underground Pipe
	Percentage (%)	
Full Bore	2.02	1

Hole Size	Aboveground Pipe (1)	Underground Pipe
	Percentage (%)	
100mm	12.12	19
50mm	25.25	30
25mm	30.30	30
10mm	30.30	20

Note: (1) Percentage distribution of various hole size is normalised to 100%.

5.5 Summary of Hazardous Failure Frequencies

5.5.1.1 The failure scenarios considered in this study and the corresponding failure frequencies are tabulated in **Table 13**.

Table 13 Failure Frequency Adopted for Each Failure Mode

Scenario Name	Description	Size of Release	Frequency (per year)	
Tuen Mun North Offtake and Pigging Station				
Process Equipment and Aboveground Pipes			**High Pressure (35 barg)**	**Intermediate Pressure (7 barg)**
OPS_10mm	Aboveground pipes, valves, flanges and instrument connection failure	10mm	1.07×10^{-1}	1.02×10^{-1}
OPS_25mm		25mm	7.10×10^{-3}	6.90×10^{-3}
OPS_50mm	Aboveground pipes and flanges failure	50mm	6.27×10^{-4}	5.47×10^{-4}
OPS_100mm	Aboveground pipes failure	100mm	3.37×10^{-6}	3.53×10^{-6}
OPS_Rup		Full Bore	5.72×10^{-7}	5.99×10^{-7}
		Sub-total	**1.15×10^{-1}**	**1.09×10^{-1}**
Underground Pipes			**High Pressure (35 barg)**	**Intermediate Pressure (7 barg)**
OPS_UG_10mm	Underground pipes failure	10mm	1.20×10^{-7}	2.40×10^{-7}
OPS_UG_25mm		25mm	1.80×10^{-7}	3.60×10^{-7}
OPS_UG_50mm		50mm	1.80×10^{-7}	3.60×10^{-7}
OPS_UG_100mm		100mm	1.14×10^{-7}	2.28×10^{-7}

Scenario Name	Description	Size of Release	Frequency (per year)	
OPS_UG_Rup		Full Bore	6.00×10^{-9}	1.20×10^{-8}
		Sub-total	**6.00×10^{-7}**	**1.20×10^{-6}**
Underground High Pressure Pipeline			**High Pressure (35 barg)**	
UG_10mm	Underground pipes failure	10mm	2.00×10^{-6}	
UG_25mm		25mm	3.00×10^{-6}	
UG_50mm		50mm	3.00×10^{-6}	
UG_100mm		100mm	1.90×10^{-6}	
UG_Rup		Full Bore	1.00×10^{-7}	
		Sub-total	1.00×10^{-5}	

5.6 Event Outcome Frequencies

5.6.1 Orientation of Release

5.6.1.1 Consequence of a pipeline failure varies by the orientation of the release. Failure can occur at top, bottom, or side of the pipe. Pressured gas releasing at the top of a pipe will result in an unobstructed vertical jet release; whereas releasing at bottom of the pipe will be a diffused jet due to loss of gas momentum by impinging with the surrounding. Releasing from side of the pipeline will result in an inclined or horizontal release.

5.6.1.2 According to EMSD's Guidance Note [2], the recommended release orientation is taken as listed in **Table 14**.

Table 14 Probability of Release Orientation

Gas Installation	Vertical	Horizontal	Inclined (45°)
Aboveground Pipe, Valves, Flanges, Instrument Connections	0.5	0.25	0.25
Underground Pipe	0.5	-	0.5

5.6.1.3 Catastrophic rupture of both aboveground and underground pipes is assumed to be top release only to account for completely unobstructed jet release.

5.6.2 Ignition Probability

5.6.2.1 Pressurized town gas release from pipeline disperses and may subsequently be ignited if the gas concentration is within the flammability limits. Immediate ignition probabilities are adopted from EMSD's Guidance Note [2]. Probability of delayed ignition is estimated as 40% of immediate unignited probability.

5.6.2.2 Vapour cloud explosion (VCE) may occur if gas cloud is ignited at confined or congested area. In view of possible congestion between buildings / villages houses, VCE is conservatively considered in massive town gas release. The probabilities of explosion, adopted from Cox, Lees and Ang [14], are 0.12 and 0.30 for large leaks (100mm) and full bore rupture respectively.

5.6.2.3 The ignition probabilities adopted in this study are summarized in **Table 15** below.

Table 15 Ignition Probabilities Adopted in this Study

Leak Size		Leak Size (kg/s)	Ignition Probability		Explosion Probability after Ignition
			Immediate	Delayed	
High Pressure (35 barg)	Very Small Leak (10mm)	0.4	0.01	0.40	-
	Small Leak (25mm)	2.6	0.07	0.40	-
	Medium Leak (50mm)	10.3	0.07	0.40	-
	Large Leak (100mm)	41.2	0.07	0.40	0.12
	Full Bore Rupture (750mm)	7829.3	0.30	0.40	0.30
Intermediate Pressure (7 barg)	Very Small Leak (10mm)	0.1	0.01	0.40	-
	Small Leak (25mm)	0.6	0.01	0.40	-
	Medium Leak (50mm)	2.2	0.07	0.40	-
	Large Leak (100mm)	8.9	0.07	0.40	-
	Full Bore Rupture (600mm)	1112.6	0.3	0.40	0.30

5.6.3 Event Tree Analysis

5.6.3.1 Event tree model is used to estimate the frequency of various gas leak outcomes which includes jet fire, flash fire, fireball, VCE and no ignition. It also shows different consequences of vertical and horizontal leak scenarios of the cases of immediate ignition and delayed ignition. The detailed event tree analysis is included in **Appendix E.**

6 CONSEQUENCE ASSESSMENT

6.1 General

6.1.1.1 The consequence assessment is conducted in two steps:

(1) Source term modelling to determine the release rate, release duration and released quantity;

(2) Physical effects modelling to determine the effect zones of gas dispersions, fires and explosions, based on the outputs of source term modelling. The impacts of the hazardous outcomes on the surrounding population will be analysed.

6.2 Source Term Modelling

6.2.1.1 Town gas is modelled as a mixture of hydrogen, methane, carbon dioxide and carbon monoxide. For pipelines connecting to a gas distribution network, release duration is determined by response time for isolation.

6.2.2 Gas Dispersion

6.2.2.1 Discharge rates are calculated from leak hole sizes and operating conditions of the Pipeline, which are assumed to be fixed for smaller leaks as the amount of gas leaked per unit time is small comparing to the overall amount available for release.

6.2.2.2 The releases are modelled by assuming a section of 1.1 km of high pressure town gas pipeline of diameter 750 mm, which can be isolated by manual isolation valves. A section of 3.6km intermediate pressure pipeline of diameter 600mm, which can also be isolated by manual isolation valves, is assumed and modelled for the Station as well. The closing time of the isolation valves are approximate 120 minutes.

6.2.2.3 The discharge rate is estimated based on the normal operation conditions a flow velocity of 20 m/s with the release inventory calculated from the length of pipeline and the amount release before the time of isolation.

6.2.2.4 Transient nature of release is assumed for the case of full bore rupture. The release rate is expected to be very high in the first few seconds, followed by a rapid drop to a constant level. The initial release rate and quantity which is discharged to the release point in an event of fireball following the rupture of high pressure town gas pipeline and intermediate pressure town gas pipeline are estimated from the empirical correlations developed by Bell and modified by Wilson [15][16]:

$$Q_0 = C_d A_p \psi \sqrt{\rho_0 P_0 \gamma \left(\frac{2}{\gamma+1}\right)^{\left(\frac{\gamma+1}{\gamma-1}\right)}}$$

$$Q_t = \frac{Q_0}{1+\alpha}\left(e^{\frac{-t}{\alpha^2\beta}} + \alpha e^{\frac{-t}{\beta}}\right.$$

$$\alpha = \frac{W}{\beta Q_0}$$

$$\beta \approx \frac{L\sqrt{K_\gamma}}{C\sqrt{K_A}}$$

$\beta \approx \frac{2L}{3C\sqrt{K_F}}$ for large holes where $\frac{K_A^2}{K_F K_\gamma} > 30$

Where

$$K_F = \frac{D_p}{\gamma f L_p}$$

$$K_A = \frac{A_h}{A_p}$$

$$K_\gamma = \left(\frac{\gamma+1}{2}\right)^{\frac{\gamma+1}{\gamma-1}}$$

Where Q_0 is initial mass discharge rate (kg/s)

Q_t is time dependent mass flow rate (kg/s)

W is inventory in the pipeline (kg)

C_d is discharge coefficient, assume 0.8

A_p is the cross-sectional area of the pipeline (m^2)

ψ is outflow coefficient, assume 1 for critical flow

ρ_0 is initial gas density (kg/m^3)

P_0 is initial gas pressure (N/m^3)

γ is gas specific heat ratio, 1.344 for town gas

t is the time in seconds

α is the non-dimensional mass conservation factor

β is the time constant for release rate in seconds

D_p is diameter of pipeline (m)

f is pipeline friction factor given by $f = \left[\frac{1}{-2\log\left(\frac{\epsilon}{3.715 D_p}\right)}\right]^2$

ϵ is wall roughness of pipeline (m) taken as 45μm as per TNO [11]

6.2.2.5 In modelling fires following a rupture, the transient nature of the release should be estimated. The equation is used to estimate the mass inventory which is discharged to the release point in an event of fireball following the rupture of a high pressure pipeline and an intermediate pressure pipeline as descripted in **Section 6.3.4.**

6.3 Effect and Vulnerability Modelling

6.3.1.1 Consequence model of the SAFETI v8.9 by DNV is used for calculation of hazardous area under various consequences. The following section briefly describes

mathematical models applied to various fire and gas dispersion in the consequence model.

6.3.2 Gas Dispersion

6.3.2.1 The DNV GL's proprietary UDM model is used for the dispersion calculation of town gas for non-immediate ignition scenarios. UDM has been extensively verified and has been validated against a large number of field experiments. These include continuous, elevated two phases and vapour releases. The model takes into account various transition phases, from dense cloud dispersion to buoyant passive gas dispersion, in both instantaneous and continuous releases.

6.3.2.2 Fire scenarios of different kinds may be developed in the presence of ignition source in the proximity of gas release. If no ignition source exists, the gas cloud may disperse downwind and be diluted to the concentration below its LFL. In this case, no harmful effect is anticipated since the gas would become too lean to be ignited.

6.3.3 Jet Fire

6.3.3.1 A jet fire is developed when a jet of high velocity gas is ignited. The direction and orientation of fire depend on the release orientation, release velocity and wind direction. The majority concern regarding jet fire is the heat radiation effect generated from the fire. The thermal effect to adjacent population is quantified in the consequence model.

6.3.4 Fireball

6.3.4.1 Fireball is more likely for immediate ignition of instantaneous release and heat is evolved by radiation. The principal hazard of a fireball arises from its thermal radiations. As suggested in IGEM/TD/2 [13], the fireball resulted from an immediate ignition of a rupture case has a transient nature and can typically last for 30 seconds.

6.3.4.2 Due to its intensity, its effects are not significantly influenced by weather, wind direction or source of ignition. The size, height, shape, duration, heat flux and radiation of a fireball will be determined in the consequence analysis. A 100% fatality is assumed for anyone within the fireball radius.

6.3.4.3 The following equations from CCPS[15] are used for estimation of the fireball diameter (D) and duration (t).

$$D = 5.8M^{\frac{1}{3}}$$

$$t = 0.45M^{\frac{1}{3}}$$

Where D is final diameter of fireball (m); t is fireball duration (s); M is mass of fuel (kg)

6.3.4.4 The mass of fuel is determined by calculating the quantity of fuel at each time step that can be consumed in a fireball with the same burning time as the time since the start of the release. By equating the two equations, the sizes of fireball are determined as approximately 11 tonnes for high pressure town gas pipeline of diameter 750mm and 0.9 tonnes for intermediate pressure town gas pipeline of diameter 600mm.

6.3.5 Flash Fire

6.3.5.1 A flash fire is the consequence of combustion of gas cloud resulting from delayed ignition. The flammable gas cloud can be ignited at its edge and cause a flash fire of the cloud within the LFL and Upper Flammable Limit (UFL) boundaries. Major hazards from a flash fire are thermal radiation and direct flame contact. Since the flash combustion of a gas cloud normally lasts for a short duration, the thermal radiation effect on people near a flash fire is limited. Humans who are encompassed outdoors by the flash fire will be fatally injured. A fatality rate of unity is assumed.

6.3.5.2 Since town gas is buoyant, this reduces the flash fire effects at ground level. However, the town gas plumes may be within the LFL which could have potential impact to the adjacent high rise buildings.

6.3.6 Thermal Radiation

6.3.6.1 Town gas contains methane and it is flammable gas upon ignition. The LFL for hydrogen, methane and CO is given below:

- Hydrogen: 4.0%;
- Methane: 5.0%; and
- CO: 12.5%

6.3.6.2 Carbon dioxide does not contribute to flammability. The LFL of town gas is estimated as 5.5%.

6.3.6.3 The fatality rate due to heat radiation is co-related by the thermal Probit Equation [11]:

$$\Pr = -36.38 + 2.56\, In\, Q^{\frac{4}{3}}t$$

Where Q is the thermal radiation intensity in W/m^2 and t is the exposure time in seconds.

6.3.7 Vapour Cloud Explosion

6.3.7.1 When flammable gas mixture burns, a vast gas cloud expansion occurs due to the high temperature of the combustion products formed. If this process happens within a congested / confined space, the presence of the confining barriers prevents the free expansion of the combustion products and results in the generation of overpressure, thus forming a VCE.

Table 16 Fatality Probability of Vapour Cloud Explosion

Overpressure (barg)	Indoor Fatality Probability	Outdoor Fatality Probability
0.3	1	1
0.1	0.025	0

6.3.8 Toxic Effect

6.3.8.1 Town gas contains carbon dioxide and a small amount of carbon monoxide. Carbon dioxide can be considered as toxic due to the asphyxiating properties. The Immediate Dangerous to Life and Health (IDLH) value for carbon dioxide is 40,000 ppm. However, it is believed that people can find means of escape within 30 minutes without irreversible health effects.

6.3.8.2 The Probit Equation of toxic gas dispersion for carbon monoxide is adopted.

$$\Pr = -37.98 + 3.7\ In\ (C * t)\ for\ CO,$$

Where C is concentration in ppm and t is exposure time in minutes.

6.3.8.3 Since town gas only contains low concentration of carbon monoxide (1.0 – 3.1%), the toxic release has very small impact and is negligible when comparing to the flammable effect. Thus, the impact of toxic release of town gas is not further assessed in this study.

6.3.9 Indoor Protection Factor

6.3.9.1 Buildings are assumed to offer protection to occupants against fire. The protection factor is assumed to be 90% for population with flash fire envelop [2]. A 100% exposure is assumed for open space.

6.3.9.2 In case of fireball event, a protection factor of 50% is assumed for indoor population within fireball radius [17]. Fatality rate of 10% is assumed for indoor population within impact distance of thermal radiation from jet fire and fireball.

6.3.10 Shielding Factor

6.3.10.1 Shielding factors are assumed to account for protection by the front part of the building or by other buildings from fire effects [17]. A shielding factor of 0.5 is assigned to those buildings within the fireball radius, i.e. 64.5 m, and partly inside the fireball radius. Buildings that are outside the fireball are considered being protected by the buildings in the front. The shielding factor to the following populations:

Table 17 Population with Fireball Shielding Factor

Site ID	Description	Shielding Factor
35	Scattered Houses	0.5
38	Tuen Fu Road Disciplined Services Staff Quarters - Residential	0.5

6.3.11 Height Protection

6.3.11.1 People above the cloud height is not exposed to flash fire events. In another term, these populations are protected. Height protection factor may be considered when impacted areas of jet fire and flash fire are limited and do not cover the entire high rise building, as recommended in EMSD's Guidance Note [2]. Since town gas is lighter than air, gas cloud release tends to lift off at height and may cover the village

houses and even high rise buildings. Therefore, height protection factor is not applicable in this study. Full height of the population was considered.

6.4 Consequence Result

6.4.1.1 The worst-case consequence results of fireball, jet fire, flash fire and vapour cloud explosion for the Station and the Pipeline from a release source are tabulated in **Table 18** to **Table 22** below.

Table 18 Consequence Results of Fireball

Leak Size	Fireball Radius (m)	Fireball Duration (s)
Full bore rupture (750mm)	64.5	9.2

Table 19 Consequence Results of Jet Fire

Leak Size	Effect Distance at Thermal Radiation of 12.5 kW/m^2 (m)		
	Vertical Release	Inclined Release	Horizontal Release
10mm	3.5	6.6	8.2
25mm	5.7	13.0	19.5
50mm	7.9	22.2	38.8
100mm	10.9	39.3	74.3

Table 20 Consequence Results of Flash Fire

Leak Size	Flash Fire Envelop, Distance at LFL (m)		
	Vertical Release	Inclined Release	Horizontal Release
10mm	0.3	1.7	3.9
25mm	0.8	4.3	9.7
50mm	1.6	8.8	22.4
100mm	3.5	17.4	56.8
Full bore rupture (750mm) (1)	34.5	N/A	N/A

Note:
(1) Flash fire scenario under full bore rupture is considered for vertical release only.

Table 21 Consequence Results of Vapour Cloud Explosion

Leak Size	Distance at 0.3 barg		
	Vertical Release	Inclined Release	Horizontal Release
100mm	Not Reached	18.0	62.6
Full bore rupture (750mm) (1)	60.0	N/A	N/A

Note:
(1) Vapour cloud explosion scenario under full bore rupture is considered for vertical release only.

Table 22 Consequence Results of Toxic Effect

Leak Size	Maximum Distance at 1% Lethality (1) (m)		
	Vertical Release	Inclined Release	Horizontal Release
10mm	0.1	0.8	1.2
25mm	0.1	1.2	2.5
50mm	0.3	2.2	4.9
100mm	0.6	4.6	10.2
Full bore rupture (750mm) (2)	2.7	N/A	N/A

Note:
(1) Based on an average exposure time of 10 minutes [11]
(2) Toxic release under full bore rupture is considered as vertical release only.

7 RISK ASSESSMENT

7.1 Risk Summation

7.1.1.1 Risk summation combines the estimation of likelihood and consequences of hazardous events, as well as the meteorological data, population data and other parameter in the hazard effect zones, to provide a numerical measure of the risk posed by the hazardous fatalities. DNV SAFETI v8.9 is used for modelling and risk summation.

7.1.1.2 The outcome of risk level is expressed in terms of Individual Risk (as Individual Risk (IR) Contour Plots) and Societal Risk (as F-N Curves or PLL) and compared with the risk criteria set out in the HKPSG.

7.2 Results of Individual Risk

7.2.1.1 Recalling from **Section 1.3.1**, individual risk is a measure of the frequency at which an individual at a specified distance from the hazardous installations is expected to sustain a specified level of harm from the realization of hazardous incident(s). The individual risks of the gas installation are governed by the nature of the gas facilities.

7.2.1.2 The IR contours of the Station is presented in **Figure 5**, the IR contours of the Pipeline is presented in **Figure 6** and that of both the Station and the Pipeline is presented in **Figure 7**. The IR contours corresponding to 1×10^{-5} per year is confined within the site boundary. Thus, the maximum off-site individual risk is below 1×10^{-5} per year. For the IR contours of the Pipeline, the maximum individual risk for the Pipeline is below 1×10^{-7} per year. The individual risk level decreases as the distance increases from the Pipeline. The individual risk posed by the Pipeline at the Proposed Development is less than 1×10^{-8} per year and satisfies with the individual criteria of the HKPSG.

7.3 Results of Societal Risk

7.3.1.1 The societal risk of the Station is presented in **Figure 8**. Recapturing from **Section 1.4.2**, this QRA studied the three cases for the Base Case, Construction Case and Operation Case, namely:

- **Case 1 – Base Case (Year 2032):** evaluating the risk level in year 2032 without the implementation of the Proposed Development;
- **Case 2 – Construction Case (Year 2028):** evaluating the risk level in Year 2028 with the construction of the Proposed Development; and
- **Case 3 – Operation Case (Year 2032):** evaluating the risk level in year 2032 with the operation of the Proposed Development in 2032.

7.3.1.2 The F-N data are tabulated in **Appendix F**. The societal risk of the Station and Pipeline for all the cases are lied within the “ALARP” region of the HKPSG.

7.3.1.3 Societal risk can also be represented in the form of PLL. It expresses the risk to the population as a whole and for each scenario and its location. The PLL is an integrated measure of societal risk obtained by summing the product of each F-N pair:

$$PLL = f_1N_1 + f_2N_2 + \cdots + f_nN_n$$

7.3.1.4 The total potential loss of life (PLL) of the Station and the Pipeline for Base Case in 2032 without Proposed Development is 1.88×10^{-5} fatalities per year. The PLL of the Station is 1.27×10^{-5} and that of the Pipeline is 6.06×10^{-6}.

7.3.1.5 Compared with the Base Case in 2032, the population considered in the Construction Case is lower; therefore, the PLL of the Construction Case is also lower than that of the Base Case. The total potential loss of life (PLL) of the Station and the Pipeline for Construction Case in 2028 when Proposed Development in construction is 1.85×10^{-5} fatalities per year. The PLL of the Station is 1.26×10^{-5} and that of the Pipeline is 5.85×10^{-6}.

7.3.1.6 With comparison to Base Case, the PLL of Operation Case has increased by 5.10%. The total potential loss of life (PLL) of the Station and the Pipeline for Operation Case is 1.97×10^{-5} fatalities per year. The PLL of the Station is 1.28×10^{-5} and that of the Pipeline is 6.90×10^{-6}.

7.3.1.7 The PLL is tabulated in **Table 23** and detailed PLL of the Station and Pipeline are tabulated in **Appendix G**. The major contributor to the PLL results is fireball from Full Bore Rupture of High Pressure Aboveground Pipework (DN750) which contributes around 60% of PLL in all cases.

Table 23 PLL Breakdown of the station and the pipeline for Base Case, Construction Case and Operation Case

Scenario	Hazardous outcome	Base Case		Construction Case		Operation Case	
		PLL	%	PLL	%	PLL	%
Full Bore Rupture of Aboveground Pipework (DN750) in the Station	Fireball	1.16E-05	61.73%	1.15E-05	62.43%	1.17E-05	59.24%
Full Bore Rupture of Underground Pipe (DN750)	Fireball	5.62E-06	29.95%	5.42E-06	29.36%	6.45E-06	32.68%
50mm Leak from Aboveground Pipework (DN750) in the Station	Jet Fire	3.35E-07	1.78%	3.10E-07	1.68%	3.35E-07	1.70%
100mm Leak from Aboveground Pipework (DN750) in the Station	Jet Fire	3.05E-07	1.63%	2.95E-07	1.60%	3.05E-07	1.55%
Full Bore Rupture of Underground Pipe (DN750)	Flash Fire	2.98E-07	1.59%	2.93E-07	1.59%	3.09E-07	1.56%
Other		6.24E-07	3.32%	6.18E-07	3.35%	6.42E-07	3.26%
Total		**1.88E-05**	**100.00%**	**1.85E-05**	**100.00%**	**1.97E-05**	**100.00%**

8 ALARP ASSESSMENT

8.1 Overview

8.1.1.1 As mentioned in **Section 7.3**, the F-N curve of all of the cases falls within the "ALARP" region. Therefore, risk reduction measure has been identified to reduce the increase of risk level as low as reasonably practicable.

8.1.1.2 The ALARP assessment approach involves identifying potential justifiable mitigation measures, assessing their practicability, and evaluating their costs in comparison with the safety benefits achievable through implementation. Combinations of mitigation measures may also be considered.

8.1.1.3 The safety benefits are evaluated as follows:

Safety Benefits = Value of Preventing a Fatality (VPF) × Aversion Factor× Reduction in PLL value × Design life of mitigation measure

8.1.1.4 VPF reflects the tolerability of risk by the society and represents the monetary value that the public is willing to invest to prevent a fatality. Depending on the level of risk, the VPF may be adjusted to account for public aversion to higher risks or scenarios involving multiple potential fatalities. In this study, the VPF is taken as HK$33M per person.

8.1.1.5 As refers to the Aversion Factor developed by EPD (Environmental Protection Department [19], it is calculated on a sliding scale from 1 (risks at the lower boundary of the ALARP region of the Risk Guidelines) up to a maximum of 20 (risks at the upper boundary of the ALARP region). For this study, an Aversion Factor of 5 is assumed, as the risk level is higher than the lower boundary but not approaching the upper boundary of the ALARP region. The adjusted VPF, therefore, is HK$165 million based on an Aversion Factor of 5.

8.1.1.6 With the PLL calculated for operation case which is 1.97×10^{-5} fatalities per year and assuming the design life of risk reduction measure is 40 years based on the measure would be last in the operation of the Proposed Development, the Maximum Justifiable Expenditure is $0.13 million. The cost of potential justifiable risk reduction measure for this study should be less than $0.13 million.

8.1.2 Risk Reduction measure: Provision of firewall at the site boundary along Tuen Fu Road

8.1.2.1 From the PLL analysis, it was found that the risks arising from the fireball scenario from full bore rupture of the high pressure aboveground pipework at the Station are much more significant than the others from the PLL which contributes at over 60% of the total PLL. Therefore, the risk reduction measure is proposed to reduce the risk related to the fireball scenario from full bore rupture of the high pressure aboveground pipework.

8.1.2.2 Based on the result of consequence analysis as mentioned in **Section 6.4**, the fireball with 64.5m radius result from the full bore rupture of high pressure aboveground pipeline would impact the outdoor population from Proposed Development.

8.1.2.3 With the proposed layout of the Proposed Development in **Appendix B**, the preliminary design of the Proposed Development has no physical barrier between the

Station and the site. Moreover, the population closer to the Station would expose to higher risk posed. As mentioned in **Section 3.1**, there would be limited outdoor activities assumed at site. Therefore, it is proposed that to have a two 2.5m height with 12m long firewall at the west south site boundary along Tuen Fu Road, the outdoor portion of the users and staff could be protected as shown in **Figure 11.**

8.2 Effectiveness of Risk Reduction Measure

8.2.1.1 The overall risk level of the Station and Pipeline is re-assessed in consideration with the implementation of firewall at the site boundary facing to the Station (i.e. Mitigation Case). The societal risk result, in form of F-N curve, is presented in **Figure 12** with detailed F-N data presented in **Appendix F**. In comparison to the Operation Case, the F-N curve has been decreased slightly.

8.2.1.2 For the PLL of the Station and the Pipeline for the Mitigation Case is 1.96×10^{-5} per year, contributing to 0.71% reduction to that of the Operation Case. For the PLL of the Pipeline, it is reduced from 6.90×10^{-6} to 6.87×10^{-6} with 0.45% reduction. For the PLL of the Station, it is reduced from 1.28×10^{-5} to 1.27×10^{-5} representing a reduction of 0.85%. The comparison of the PLL in Operation Case and Mitigation Case is shown in **Table 24**. The detailed PLL breakdown is presented in **Appendix G**.

Table 24 PLL Breakdown of the station and the pipeline for Operation Case and Mitigation Case

Scenario	Hazardous outcome	Operation Case		Mitigation Case	
		PLL	%	PLL	%
Full Bore Rupture of Aboveground Pipework (DN750) in the Station	Fireball	1.17E-05	59.24%	1.16E-05	59.11%
Full Bore Rupture of Underground Pipe (DN750)	Fireball	6.45E-06	32.70%	6.42E-06	32.77%
50mm Leak from Aboveground Pipework (DN750) in the Station	Jet Fire	3.35E-07	1.70%	3.35E-07	1.71%
100mm Leak from Aboveground Pipework (DN750) in the Station	Jet Fire	3.05E-07	1.55%	3.05E-07	1.56%
Full Bore Rupture of Underground Pipe (DN750)	Flash Fire	3.09E-07	1.56%	3.09E-07	1.58%
Other		6.42E-07	3.26%	6.41E-07	3.27%
Total		**1.97E-05**	**100.00%**	**1.96E-05**	**100.00%**

8.2.1.3 With reference to the quotation for the construction cost of the wall for the Proposed Development, the proposed risk reduction measure, which costs $0.74 million and exceeds the Maximum Justifiable Expenditure of $0.13 million calculated in the previous section, is considered not practicable for implementation.

8.3 Good Practices

8.3.1.1 Apart from the above measure studied, the following management practices are also recommended as good practices:

- Establish a communication channel with Hong Kong and China Gas Company Limited especially the department operating the Tuen Mun North Offtake and Pigging Station, so that the property management of the Proposed Development can be notified immediately for any major loss of containment incident in the Station, and initiate evacuation if necessary.

- Develop an emergency evacuation plan in liaison with Tuen Mun North Offtake and Pigging Station for the major fire events in the Station.

- Mandatory safety induction to new staff and resident regarding the evacuation and emergency response

- Carry out regular safety drill annually to increase safety awareness of the users.

9 REVIEW OF ZONING REQUIREMENTS FOR UNDERGROUND HIGH PRESSURE PIPELINE (IGEM/TD/1)

9.1.1 Identification of area type of the Proposed Development

9.1.1.1 With reference to **Section 6.7** of IGEM/TD/1 [3], the location adjacent to a pipeline should be categorized according to population density and/or the immediate surrounding area. The area classifications are defined as follows:

- **Type R**: Rural areas with a population density not exceeding 2.5 persons per hectare
- **Type S**: Areas which have been developed with residential properties, shops, schools, etc. where the population density is greater than 2.5 persons per hectare and less than 30 persons per hectare.
- **Type H**: Areas where there is a high population density which is greater than 30 persons per hectare and is not a Type T Area. These areas are associated with creeping development near Type S Area locations for example where a shopping centre, or an entertainment centre, or a sporting stadium, or a hospital, or a multi -storey building has been constructed near a pipeline, or an Industrial or commercial building has been repurposed for residential use.
- **Type T**: Central areas of town or cities, with a high population density resulting from for example a combination of multi-storey buildings, hospitals, major transport hubs, public meeting places etc.

9.1.1.2 According to the Project Information as listed in **Table 2** and **Table 3**, the Proposed Development has site area of 1,770 m² (i.e. 0.177 hectares) and an estimated total population of 1,748 persons. This corresponds to a population density of approximately 9,881 persons per hectare (exceeding 30 persons per hectare). The Proposed Development does not fall within Type R or Type S classifications.

9.1.1.3 Furthermore, considering the land uses and scale of the Proposed Development and the nearby area, the area is not central area of town or cities. Accordingly, the Proposed Development is considered as a Type H area.

9.1.2 Review of Minimum Building Proximity Distance (BPD)

9.1.2.1 The Proposed Development, a Residential Care Home for the Elderly, qualifies as a sensitive area per Appendix 10 of IGEM/TD/1 [3], is advised that a minimum multiplier of 4 for Building Proximity Distance (BPD) determination across all population density case.

9.1.2.2 As IGEM/TD/1 [3] does not specify BPD criteria for Type H areas, BPD recommendation for type S have been adopted as the reference basis. According to Figure 6 of IGEM/TD/1 [3] as attached in **Appendix H**, the minimum BPD for Type S areas is 3 m. Applying the Sensitive Area multiplier of 4 yields a minimum BPD of 12 m for the Proposed Development from the pipeline centreline.

9.1.2.3 The shortest separation distance between the building façade of Proposed Development and the underground high pressure pipeline along Tuen Fu Road is more than 12m measuring from the pipeline centreline as indicated in **Figure 1**.

9.1.3 Safety Evaluation and Risk Analysis

9.1.3.1 Following Clause 6.7.1.3 and 6.8 of IGEM/TD/1 [3], for an existing pipeline where a new development is planned and the population density increases such that the area would become a Type H area, the location shall be subject to detailed assessment by means of safety evaluation. Therefore, a full, quantified risk assessment of the Pipeline has been conducted. As concluded in **Section 7** and illustrated in **Figure 10**, the results fall within the Acceptable Region of the HKRG. Furthermore, the societal risk associated with the Pipeline also falls within the Negligible or Acceptable Risk Region under IGEM/TD/2 as shown in **Figure 13**.

9.1.3.2 The Proposed Development is compliant with the 12m BPD requirement derived from IGEM/TD/1 . Combine with the societal risk analysis as discussed in Section 9.1.3.1, the Proposed Development is considered to be fully compliant with the IGEM standard.

10 CONCLUSION

10.1.1.1 The Propose Development is planned to provide a Residential Care Home for the Elderly at Tuen Fu Road at the north east of Tuen Mun North Offtake and Pigging Station and the nearby underground high pressure pipeline running along Tuen Fu Road and Castle Peak Road Lingnan Section.

10.1.1.2 This QRA has studied the risk impact of the Station and the Pipeline at the Proposed Development nearby to evaluate the change of risk levels due to the increase of population brought by the Proposed Development within the consultation zone of the Station and the Pipeline. The Proposed Development is planned for carrying the construction work at 2028 and operate at 2032.

10.1.1.3 For both of the cases, the overall risk level of the Station and the Pipeline fell within “ALARP” of the HKRG. The major contributor to the increase of risk level was identified to be the fireball impact from the full-bore rupture of high pressure aboveground pipeline at the Tuen Mun North Pigging and Offtake Station to the additional population at the Proposed Development.

10.1.1.4 As the societal risk level of the Station and the Pipeline fell into the “ALARP” region in all cases, the increase of risk level should be minimised as low as reasonably practicable. Risk reduction measure with the provision of two 2.5m height with 12m long firewall at the west south site boundary along Tuen Fu Road were recommended and studied using Cost-Benefit Analysis. It was determined that the proposed risk mitigation measure was not cost-effective. Based on the Cost-Benefit Analysis, it was determined that no cost-effective mitigation measure could be identified.

10.1.1.5 A number of good practices were also recommended:

- Establish a communication channel with Tuen Mun North Offtake and Pigging Station so that the management of the Proposed Development is notified for any major loss of containment incident in the Station.
- Develop an emergency evacuation plan in liaison with Tuen Mun North Offtake and Pigging Station for the major fire events in the Station.
- Mandatory safety induction to new staff and resident regarding the evacuation and emergency response.
- Carry out regular safety drill to increase safety awareness of the users.

.

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[2] Guidance Note on Quantitative Risk Assessment Study for High Pressure Town Gas Installations in Hong Kong, Electrical and Mechanical Services Department, Hong Kong, 2021.

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[7] Planning Department, Projections of Population Distribution 2023-2031, Hong Kong, 2023

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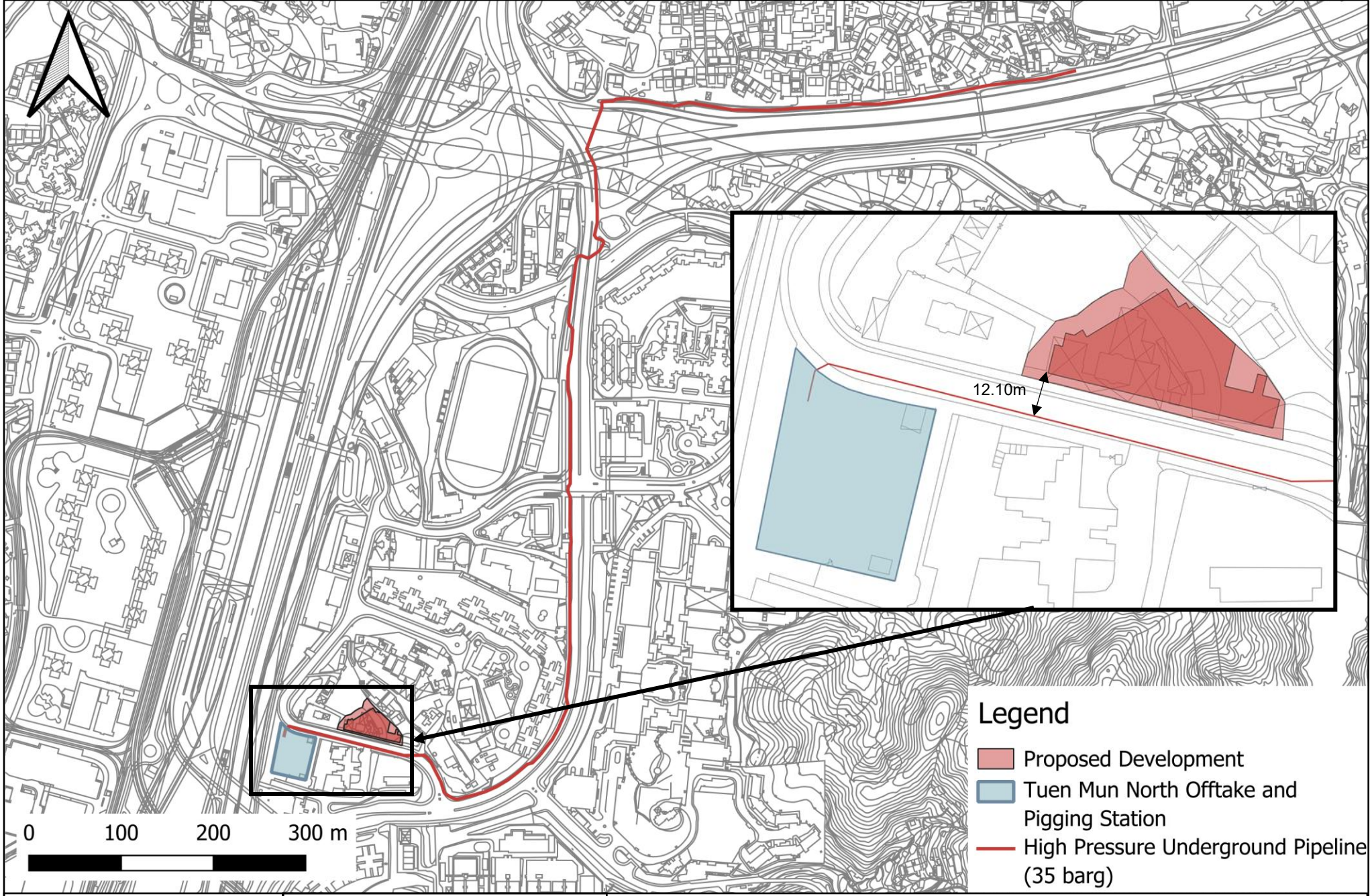
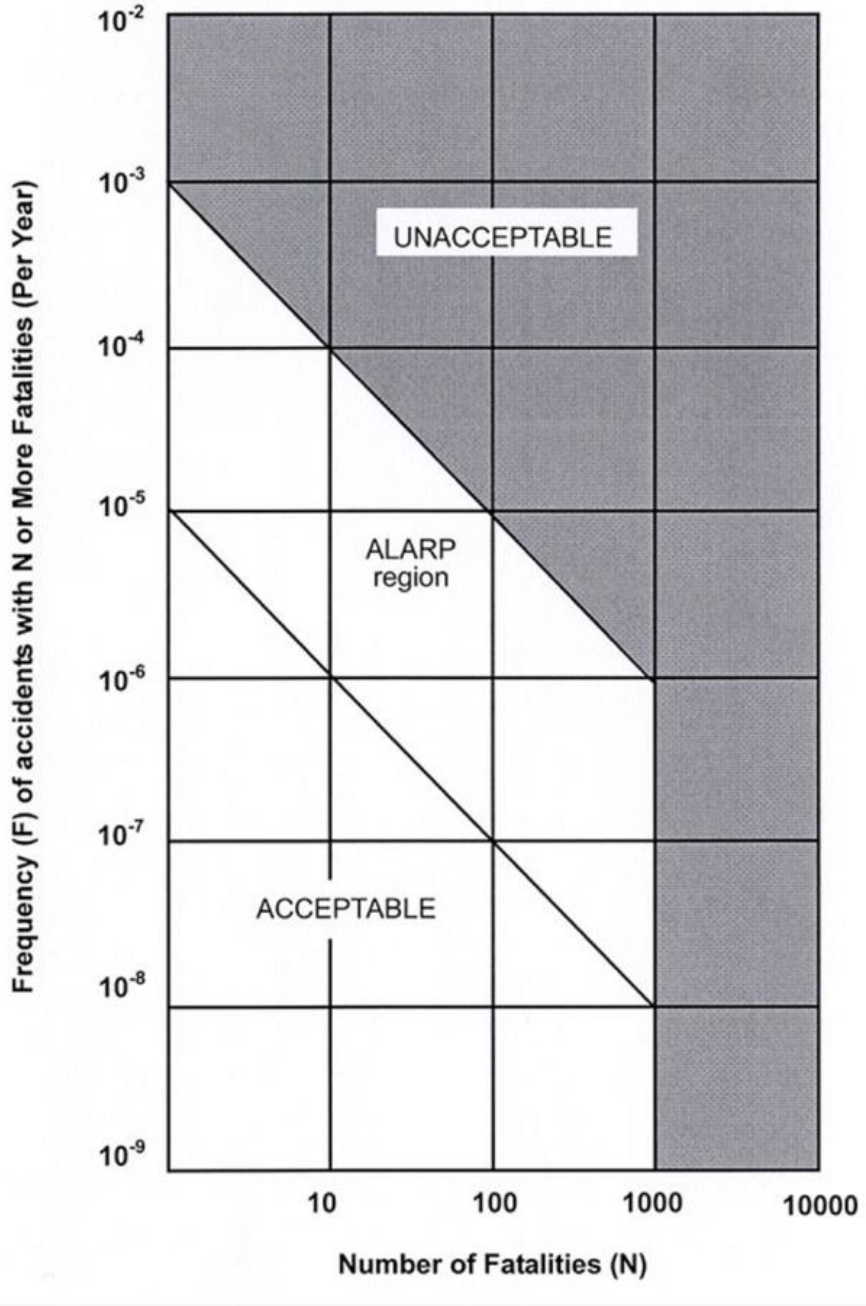
Figure



MEINHARDT

Quantitative Risk Assessment for the Residential Care Home for the Elderly (RCHE) at Tuen Mun

Figure 1 Location of the Proposed Development, Tuen Mun North Offtake and Pigging Station and the relevant underground high pressure pipeline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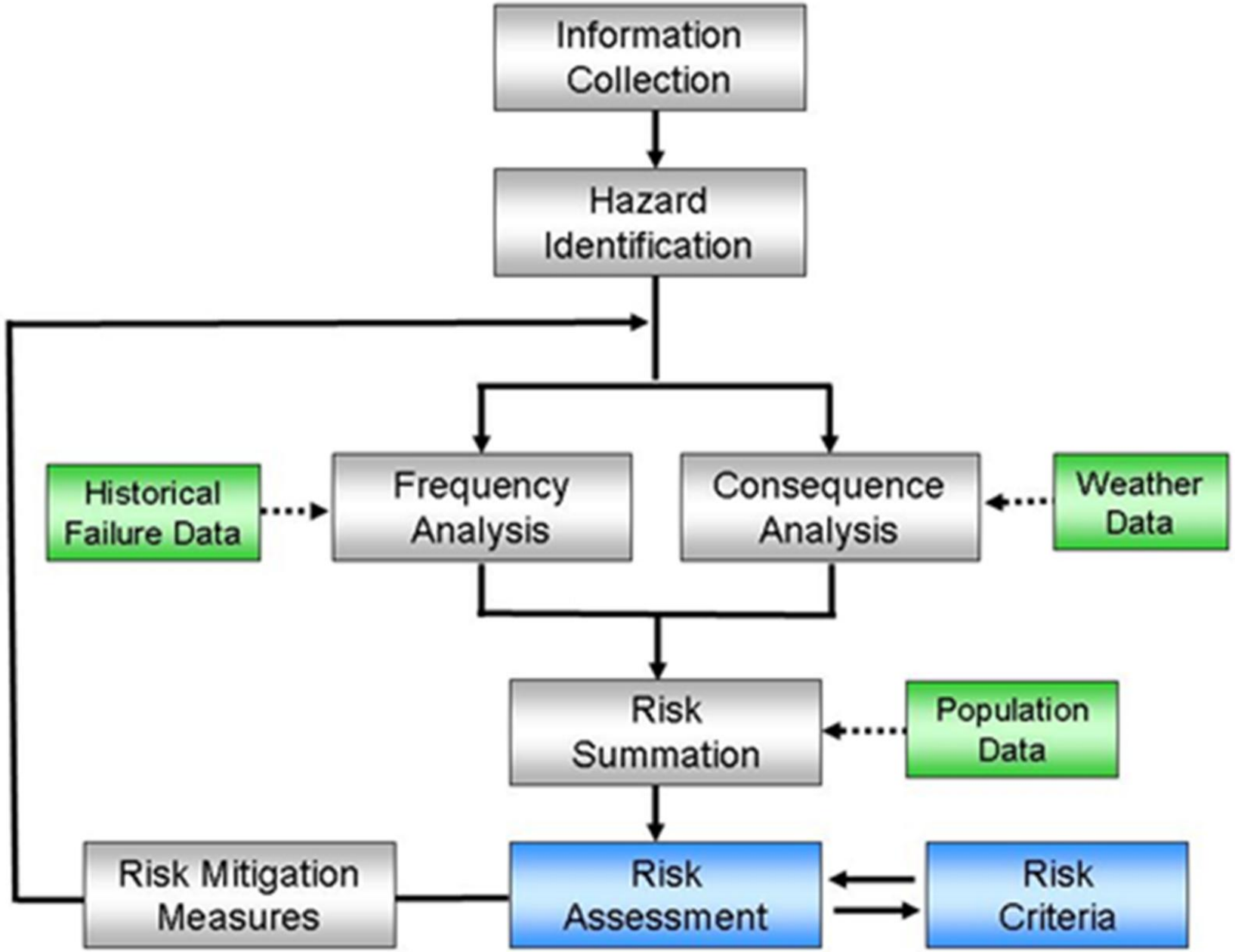
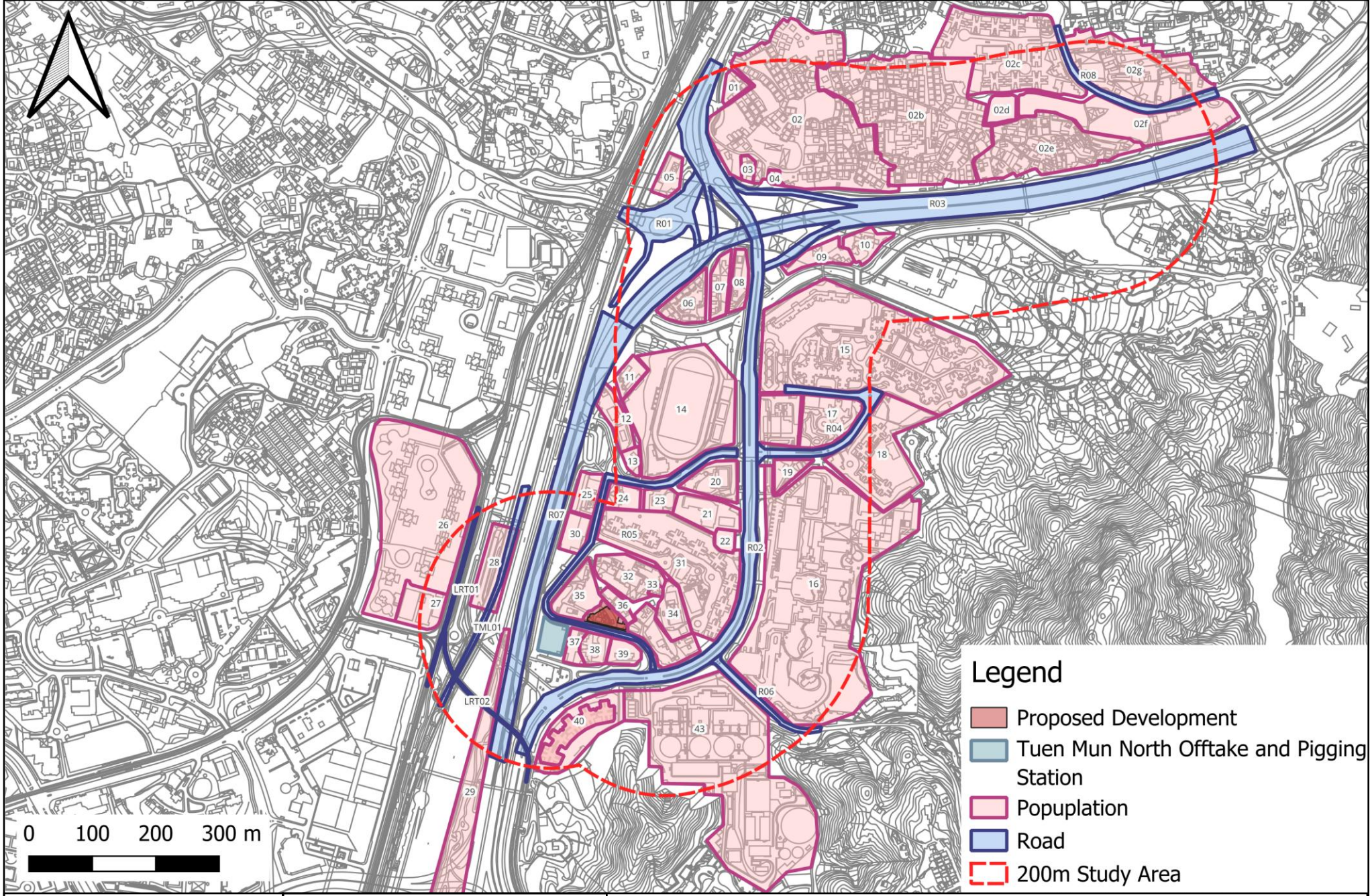
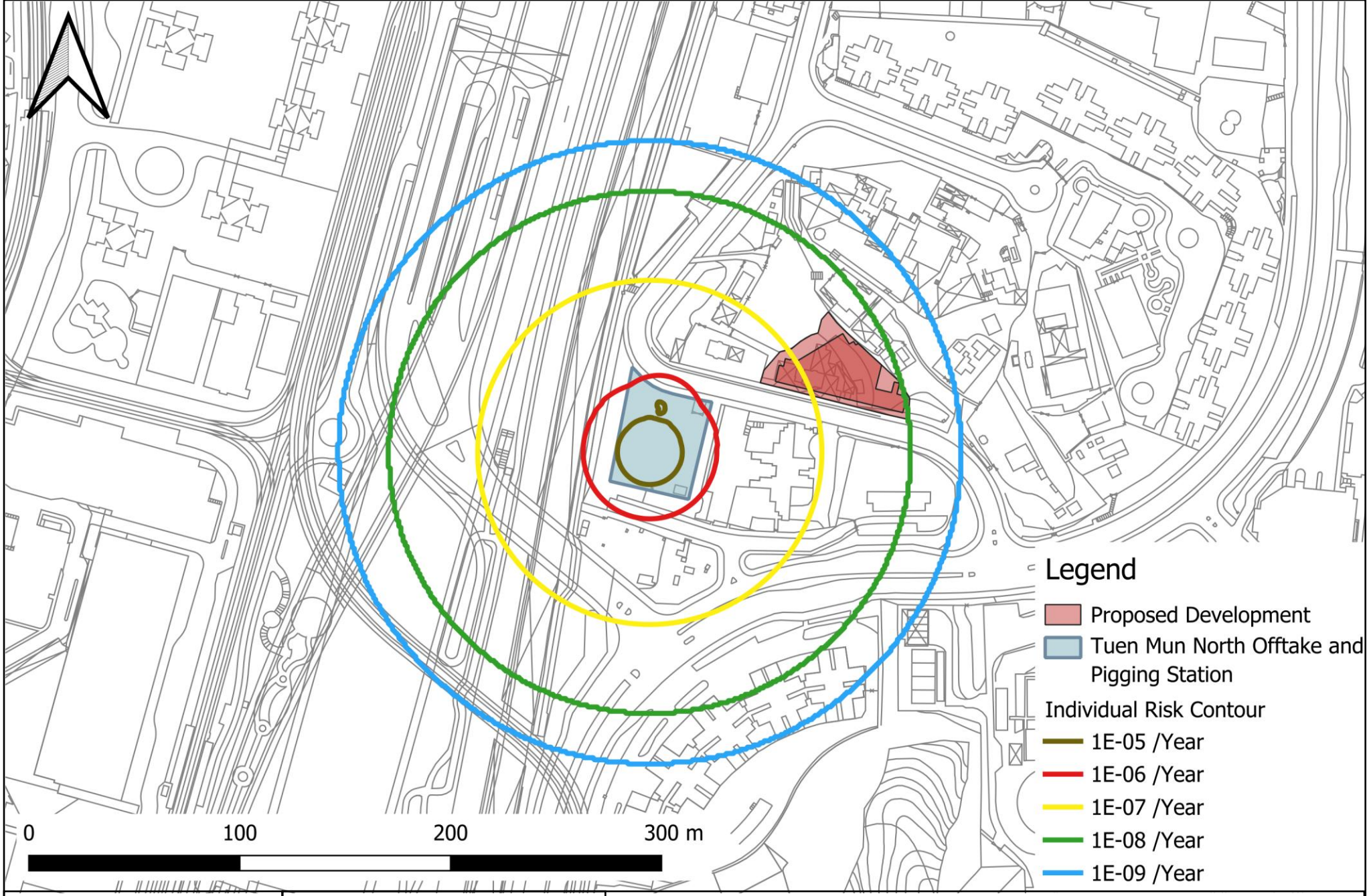
10-2
10-3
10-4
10-5
10-6
10-7
10-8
10-9
UNACCEPTABLE
ALARP region
ACCEPTABLE
10
100
1000
10000
Number of Fatalities (N)

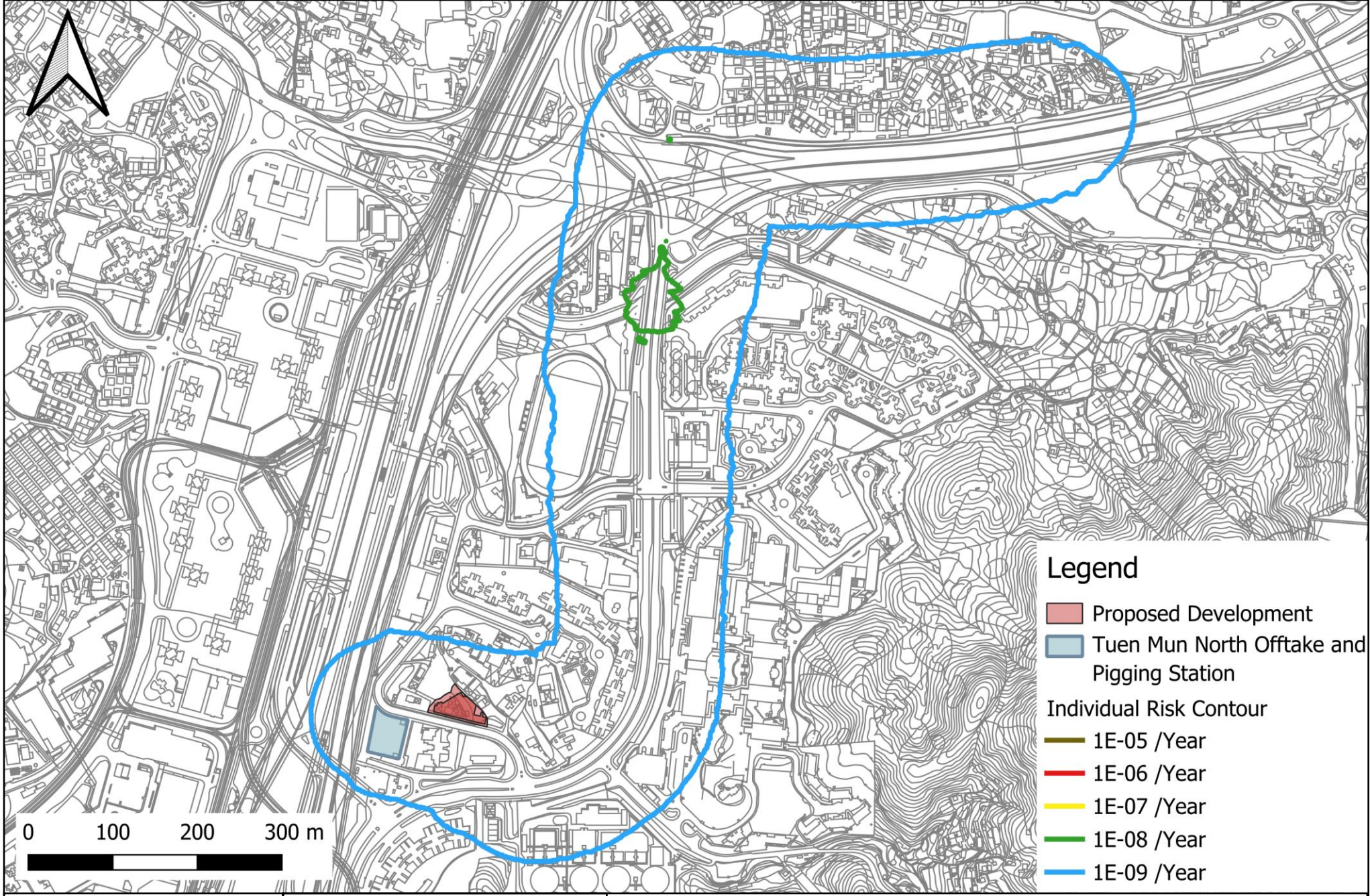

Information Collection
Hazard Identification
Historical Failure Data
Frequency Analysis
Consequence Analysis
Weather Data
Risk Summation
Population Data
Risk Mitigation Measures
Risk Assessment
Risk Criteria



MEINHARDT	Quantitative Risk Assessment for the Residential Care Home for the Elderly (RCHE) at Tuen Mun	Figure 4 Study area and population considered in the study



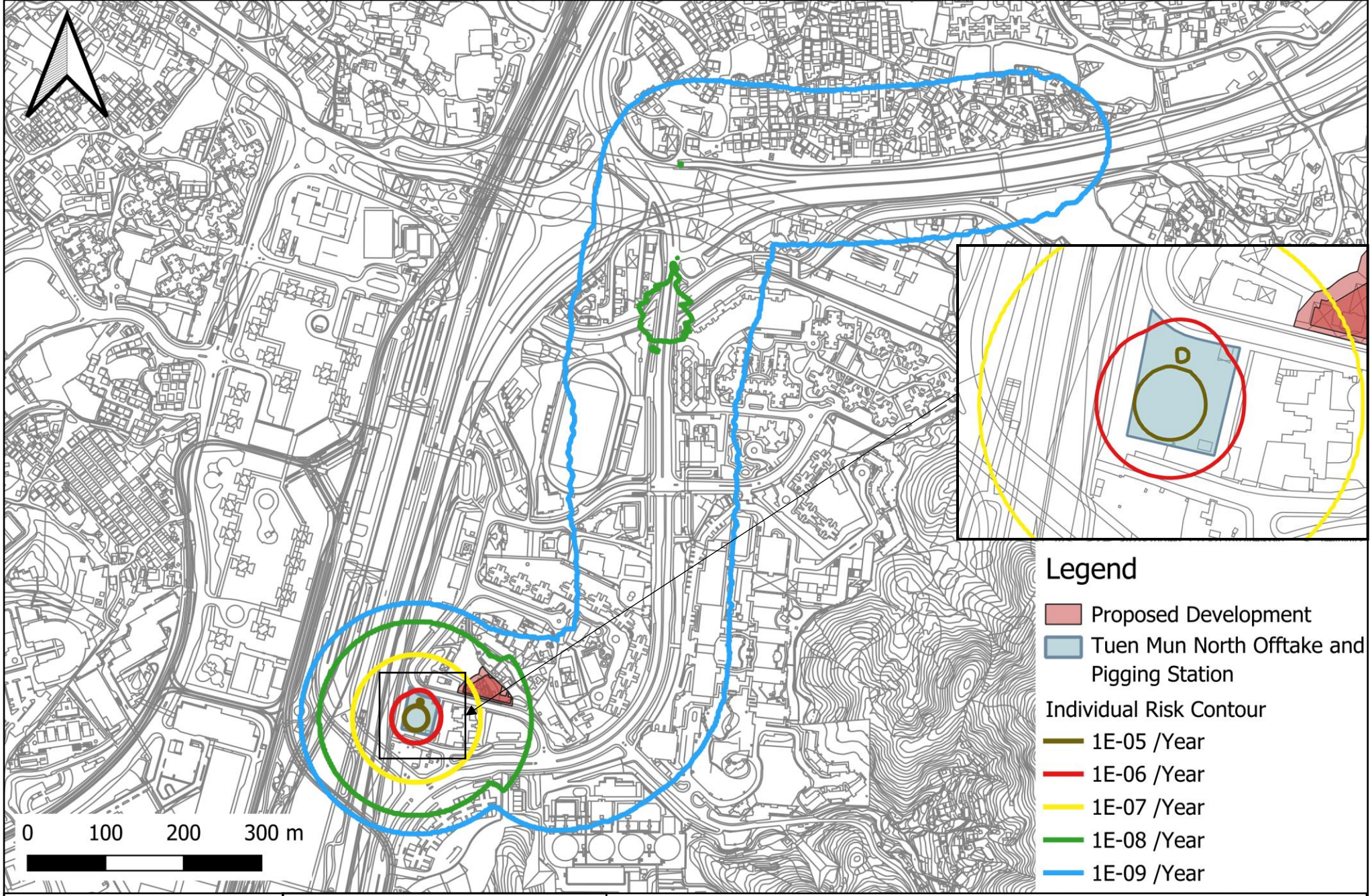
MEINHARDT	Quantitative Risk Assessment for the Residential Care Home for the Elderly (RCHE) at Tuen Mun	Figure 5 Individual Risk Contour of the Station

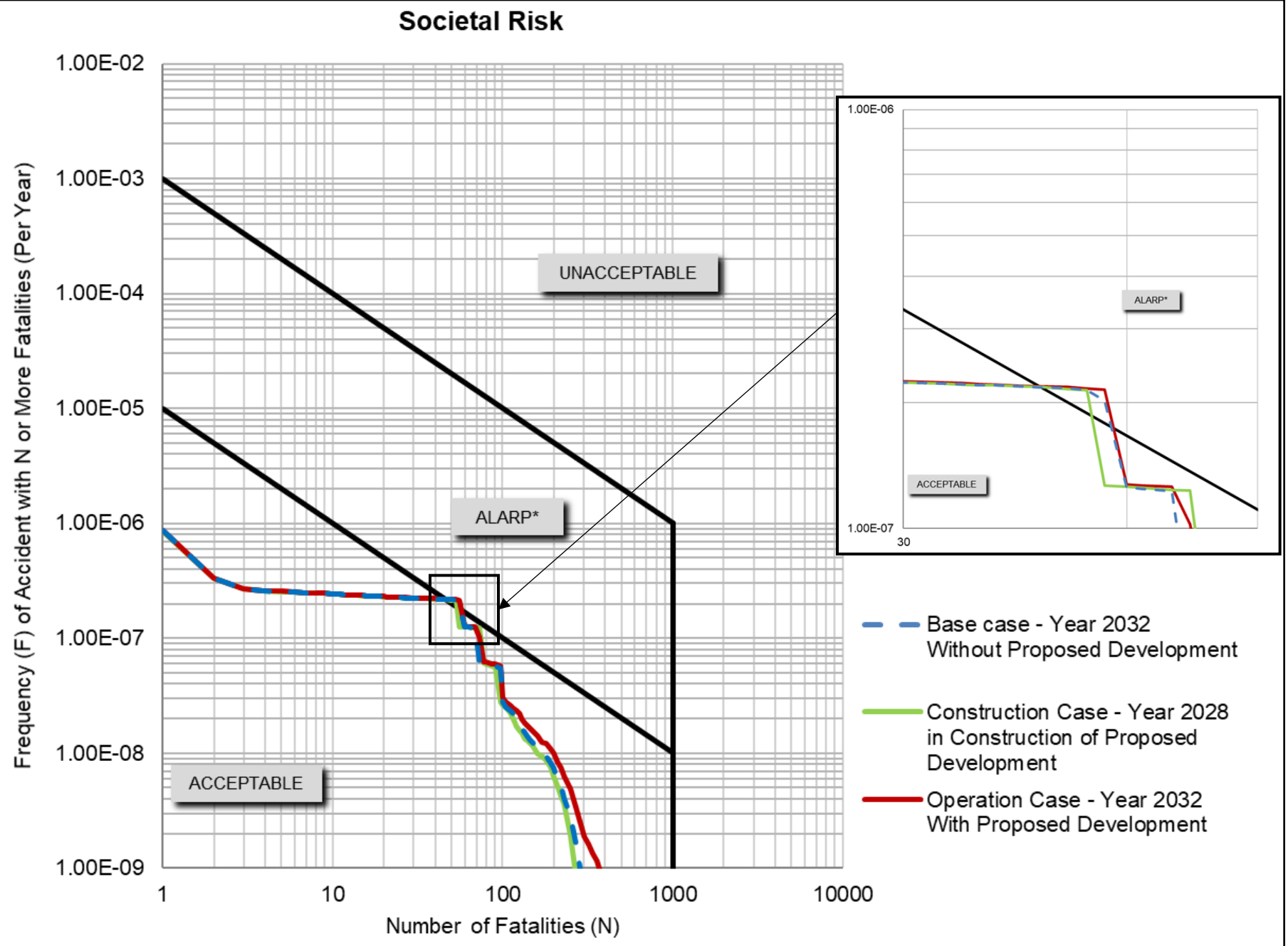


MEINHARDT

Quantitative Risk Assessment for the Residential Care Home for the Elderly (RCHE) at Tuen Mun

Figure 6 Individual Risk Contour of the Pipeline


0
100
200
300 m
Legend
Proposed Development
Tuen Mun North Offtake and Pigging Station
Individual Risk Contour
1E-05 /Year
1E-06 /Year
1E-07 /Year
1E-08 /Year
1E-09 /Year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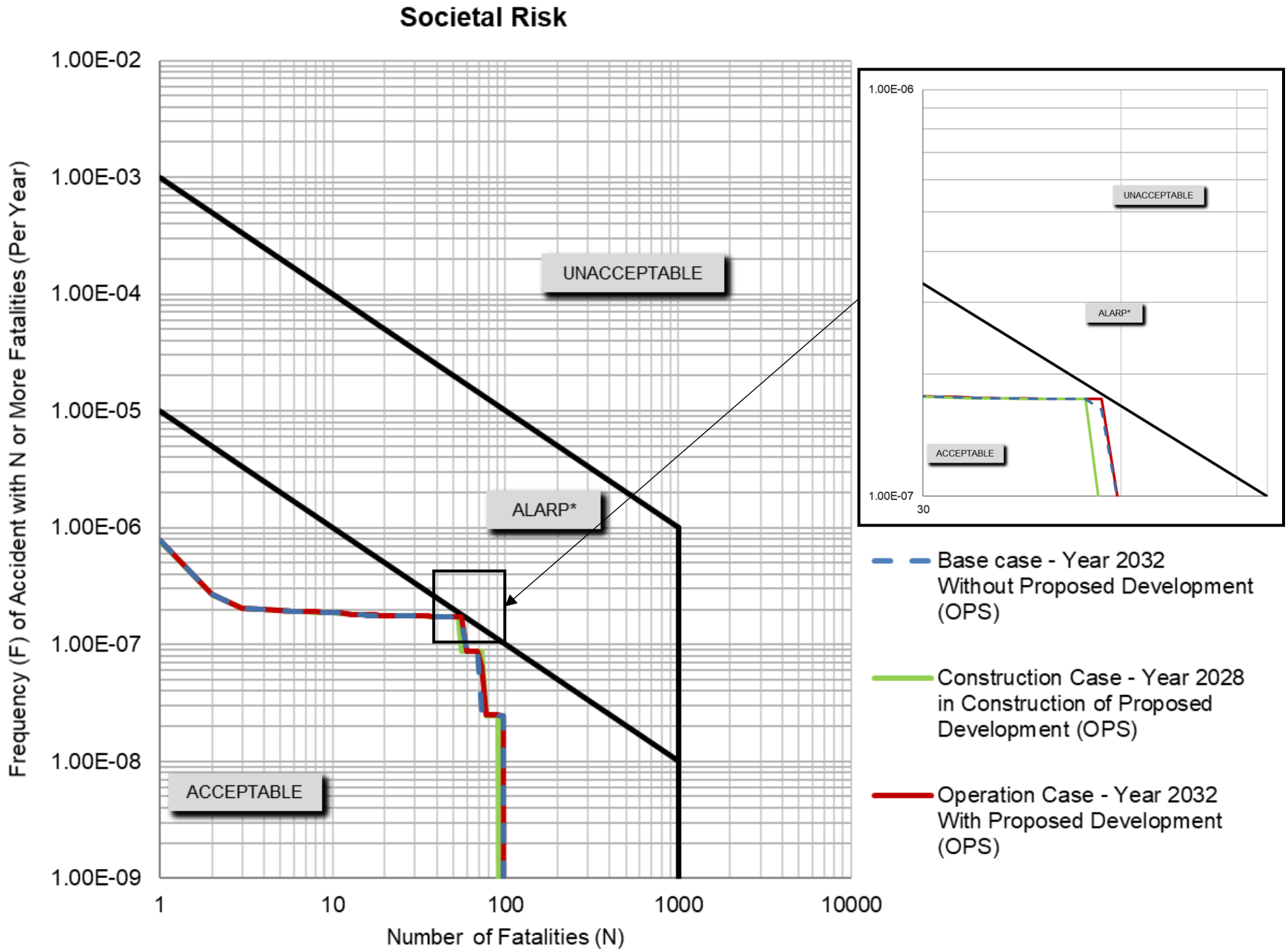
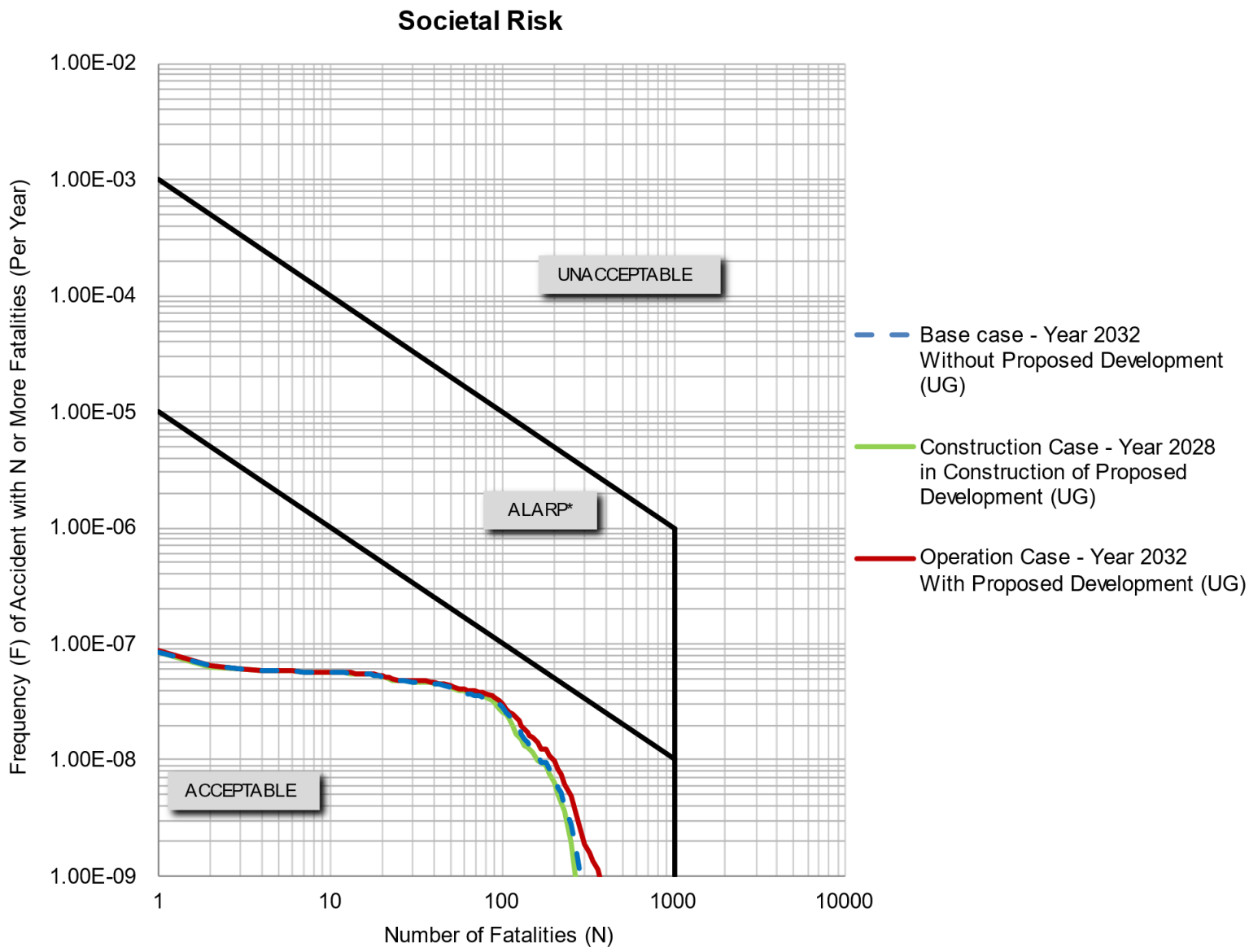
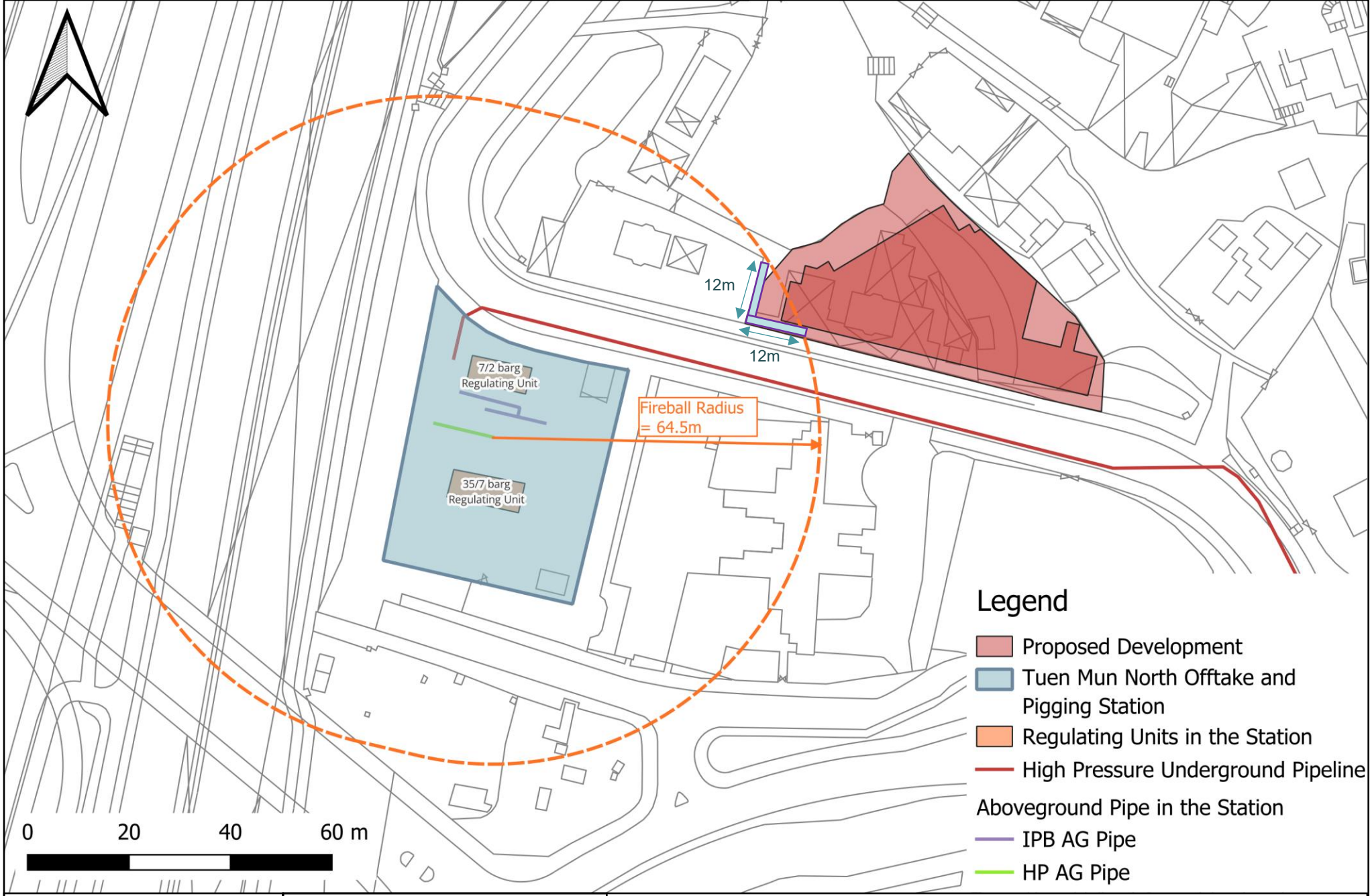
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-07
1.00E-08
1.00E-09
Frequency (F) of Accident with N or More Fatalities (Per Year)
1
10
100
1000
10000
Number of Fatalities (N)
UNACCEPTABLE
ALARP*
ACCEPTABLE
1.00E-06
1.00E-07
30
ALARP*
ACCEPTABLE
Base case - Year 2032
Without Proposed Development
Construction Case - Year 2028
in Construction of Proposed
Development
Operation Case - Year 2032
With Proposed Development


Societal Risk
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-07
1.00E-08
1.00E-09
Frequency (F) of Accident with N or More Fatalities (Per Year)
UNACCEPTABLE
ALARP*
ACCEPTABLE
1
10
100
1000
10000
Number of Fatalities (N)
1.00E-06
1.00E-07
30
Base case - Year 2032 Without Proposed Development (OPS)
Construction Case - Year 2028 in Construction of Proposed Development (OPS)
Operation Case - Year 2032 With Proposed Development (OPS)

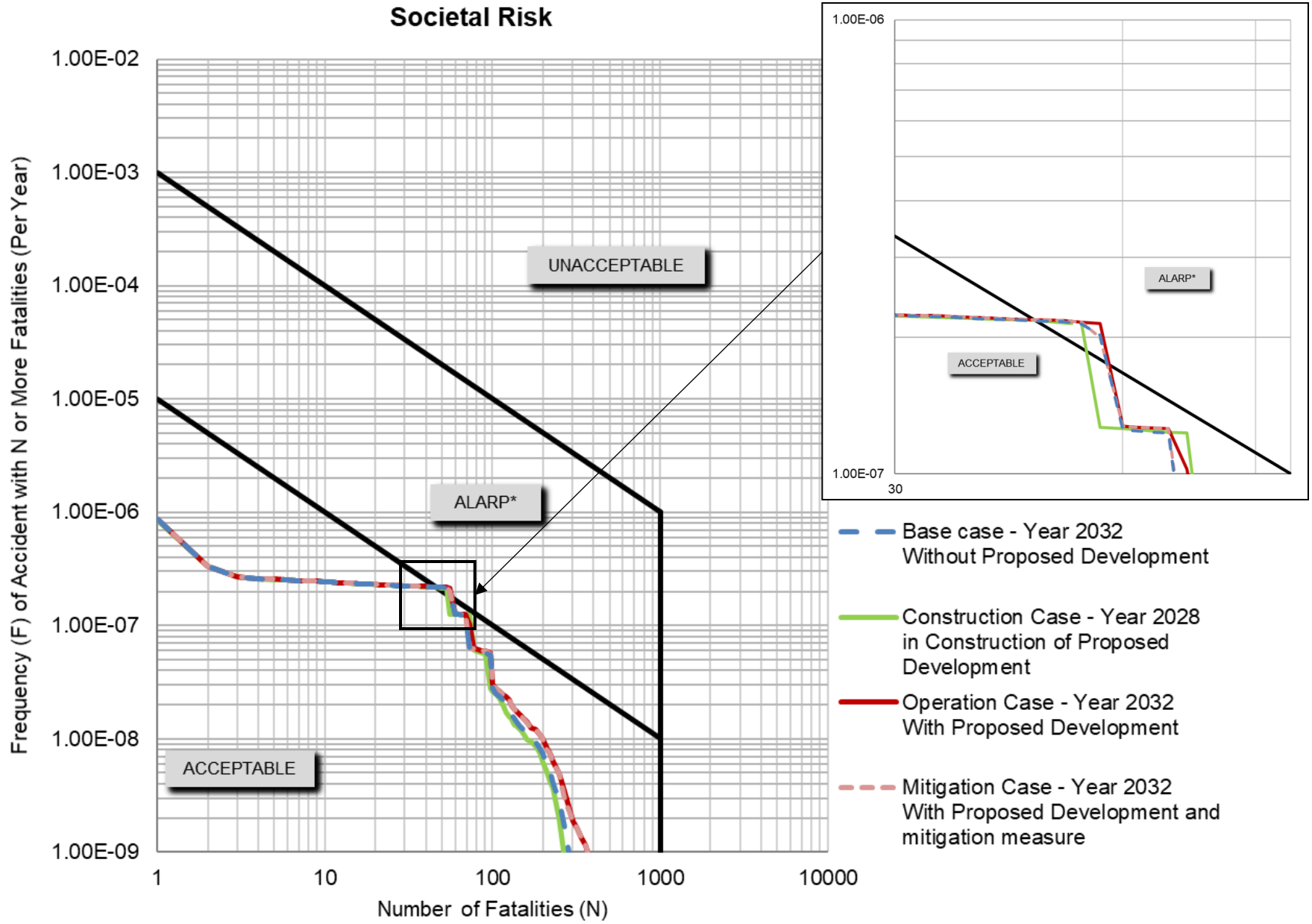

Societal Risk
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-07
1.00E-08
1.00E-09
Frequency (F) of Accident with N or More Fatalities (Per Year)
UNACCEPTABLE
ALARP*
ACCEPTABLE
1
10
100
1000
10000
Number of Fatalities (N)
Base case - Year 2032 Without Proposed Development (UG)
Construction Case - Year 2028 in Construction of Proposed Development (UG)
Operation Case - Year 2032 With Proposed Development (UG)

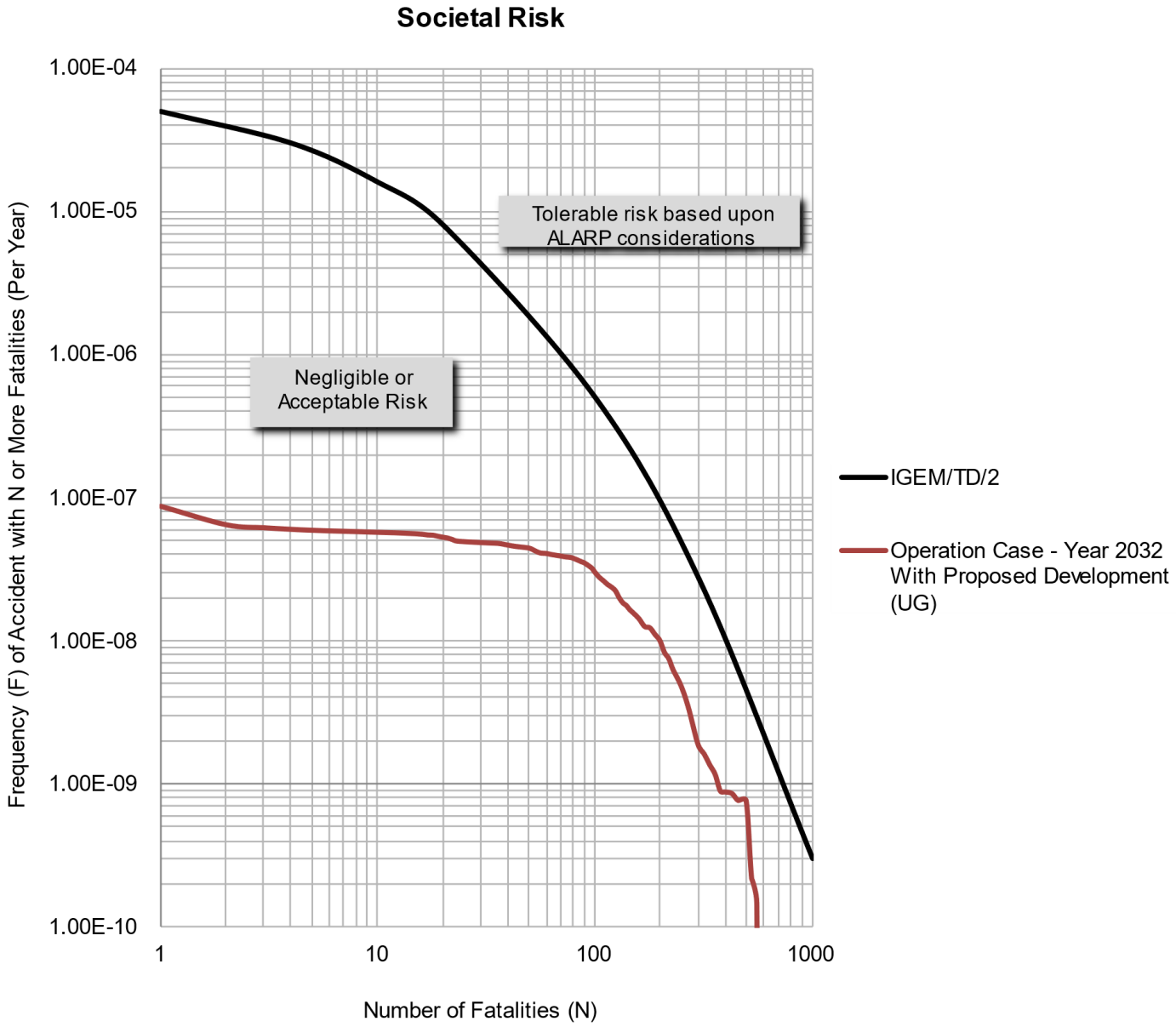


MEINHARDT

Quantitative Risk Assessment for the Residential Care Home for the Elderly (RCHE) at Tuen Mun

Figure 11 Proposed Risk Reduction Measure


Societal Risk
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-07
1.00E-08
1.00E-09
Frequency (F) of Accident with N or More Fatalities (Per Year)
UNACCEPTABLE
ALARP*
ACCEPTABLE
1
10
100
1000
10000
Number of Fatalities (N)
1.00E-06
1.00E-07
30
ALARP*
ACCEPTABLE
Base case - Year 2032
Without Proposed Development
Construction Case - Year 2028
in Construction of Proposed
Development
Operation Case - Year 2032
With Proposed Development
Mitigation Case - Year 2032
With Proposed Development and
mitigation measure


Societal Risk
1.00E-04
1.00E-05
1.00E-06
1.00E-07
1.00E-08
1.00E-09
1.00E-10
Frequency (F) of Accident with N or More Fatalities (Per Year)
Tolerable risk based upon ALARP considerations
Negligible or Acceptable Risk
IGEM/TD/2
Operation Case - Year 2032 With Proposed Development (UG)
1
10
100
1000
Number of Fatalities (N)

Appendix A
Details of Tuen Mun North Offtake and Pigging Station

香港中華煤氣有限公司
The Hong Kong and China Gas Company Limited

27 November 2025

Your Ref :
Our Ref : SM-a02-25-00115-jc

Mr David Lee
Meinhardt Infrastructure and Environment Ltd
10/F Genesis
33-35 Wong Chuk Hang Road
Hong Kong

Dear Mr Lee

RE: [PD2504001] S12a Application at Tuen Fu Road (DD132 L496C) - Request for Information for QRA

Reference is made to your email dated 26 November 2025 in relation to the captioned subject.

A copy of technical information and drawings of the existing High Pressure 750mm along Castle Peak Road – Lingnan and Tuen Mun North Offtake and Pigging Station in the concerned area are enclosed for your action.

You are advised to provide our Company a copy of the Quantitative Risk Assessment report for review and comment.

Should you have any further enquiry, please feel free to contact Mr Jack Cheng at 9803 8817 or me at 2765 5622.

Thank you for your kind attention.

Yours sincerely

Jacqueline Hui
Senior System Maintenance Manager

JH/jc/wl

Encl

Date	3 DEC 2025		
Action	Info	Initial	Date
3/F	File		

PMF Registration
☐ Submission ☐ Client Req
☐ Des Change ☐ Doc Rec'd
Reg. done by _____ (Initial)

Recycled paper

System Maintenance Section
Transmission Operation Department
4/F, 100 Tokwawan Road, Kowloon
Tel: 2765 5622
Fax: 2392 7801
E-mail: ty.hui@towngas.com

Technical Information - High Pressure Pipeline along Castle Peak Road - Lingnan

Pipe Diameter	750mm N.B.
Operating Pressure(s) of pipeline	35 barg
Minimum Cover of the pipeline	1.1m
Pipe wall thickness	12.7mm
Year of Construction	1991 - 1994
Pipe Material Grade (Fitting)	API 5L X52
External Coating	400 micron of fusion bonded epoxy coating
Internal Coating	50 micron of Two Pack Epoxy Coating
Protection against corrosion	Cathodic Protection System - Sacrificial Anode at about 300m interval
Hydraulic Test Pressure	900 psi
Non-Destructive Test of Jointing	100% X-Ray
Welding Specification	Welding complied with BS4515
Isolation Valves	Upstream: Ball Valve at Lam Tei Interchange Downstream: Tuen Mun North Offtake and Pigging Station
Pipe Length between isolation valves	1.1km

Technical Information - TMN Offtake and Pigging Station

Equipment/ Connection Details

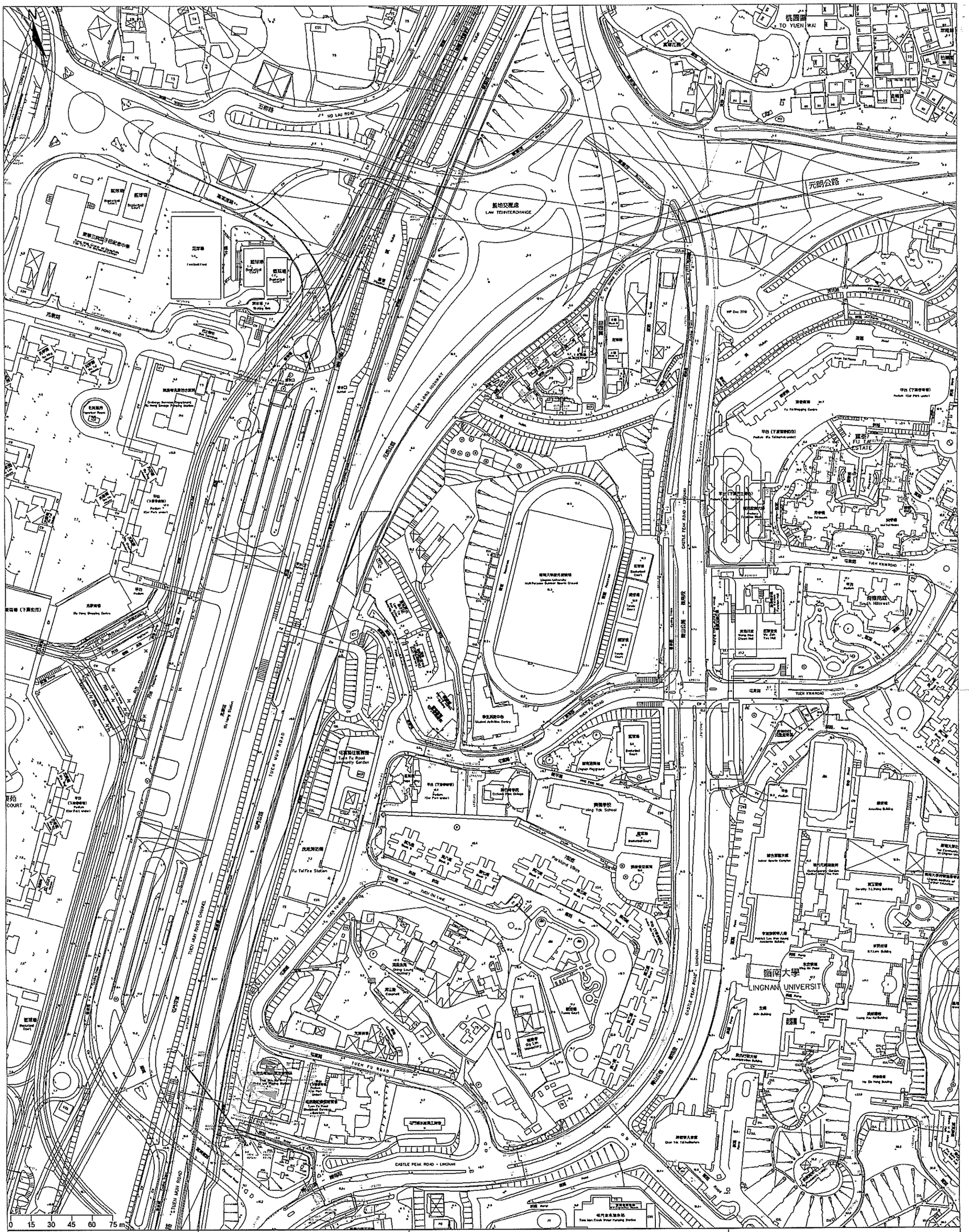
Item	Size	Quantity	Pressure
Valve	750	1	HP
	750	1	IPB
	600	2	IPB
	450	2	IPB
	400	1	HP
	400	3	IPB
	300	1	HP
	300	10	IPB
	250	11	HP
	200	8	HP
	200	3	IPB
	100	1	IPB
	50	10	HP
	50	12	IPB
	25	4	HP
Flange	750	1	HP
	600	1	IPB
	500		
	450	4	IPB
	400	12	IPB
	300	1	HP
	300	12	IPB
	250	26	HP
	200	9	HP
	100	1	IPB
	50	21	HP
	50	24	IPB
	25	4	HP
Connection	25	23	HP
	25	31	IPB
Pig Trap	750	1	HP
	600	1	IPB

Pipeline Distance within Station

HP Pipeline (Aboveground)	104.1 m
HP Pipeline (Underground)	59.91 m
IPB Pipeline (Aboveground)	109.17 m
IPB Pipeline (Underground)	120.24 m

Isolation Valve Distance

Upstream: 1.1km
Downstream: MP network



煤氣 Towngas

香港中華煤氣有限公司
The Hong Kong and China Gas Company Limited

網絡發展部

時間：14:35:57

比例：1 : 2500

圖例：

LPA	現有低壓 A 管道 (2.0 千帕以下)
LPB	現有低壓 B 管道 (2.0–7.5 千帕)
MP	現有中壓管道 (7.5–240 千帕)
IPA	現有次高壓 A 管道 (240–400 千帕)
IPB	現有次高壓 B 管道 (400–700 千帕)
HP	現有高壓管道 (700 千帕以上)
PE	設有可探索警告帶的聚乙烯管道
IPB*	現有次高壓 B 管道 (暫以較低壓力運作)
HP*	現有高壓管道 (暫以較低壓力運作)
PE*	沒有可探索警告帶的聚乙烯管道
RP / IPit	備用管道 / 保留管道檢測井
	擬建/在建管道

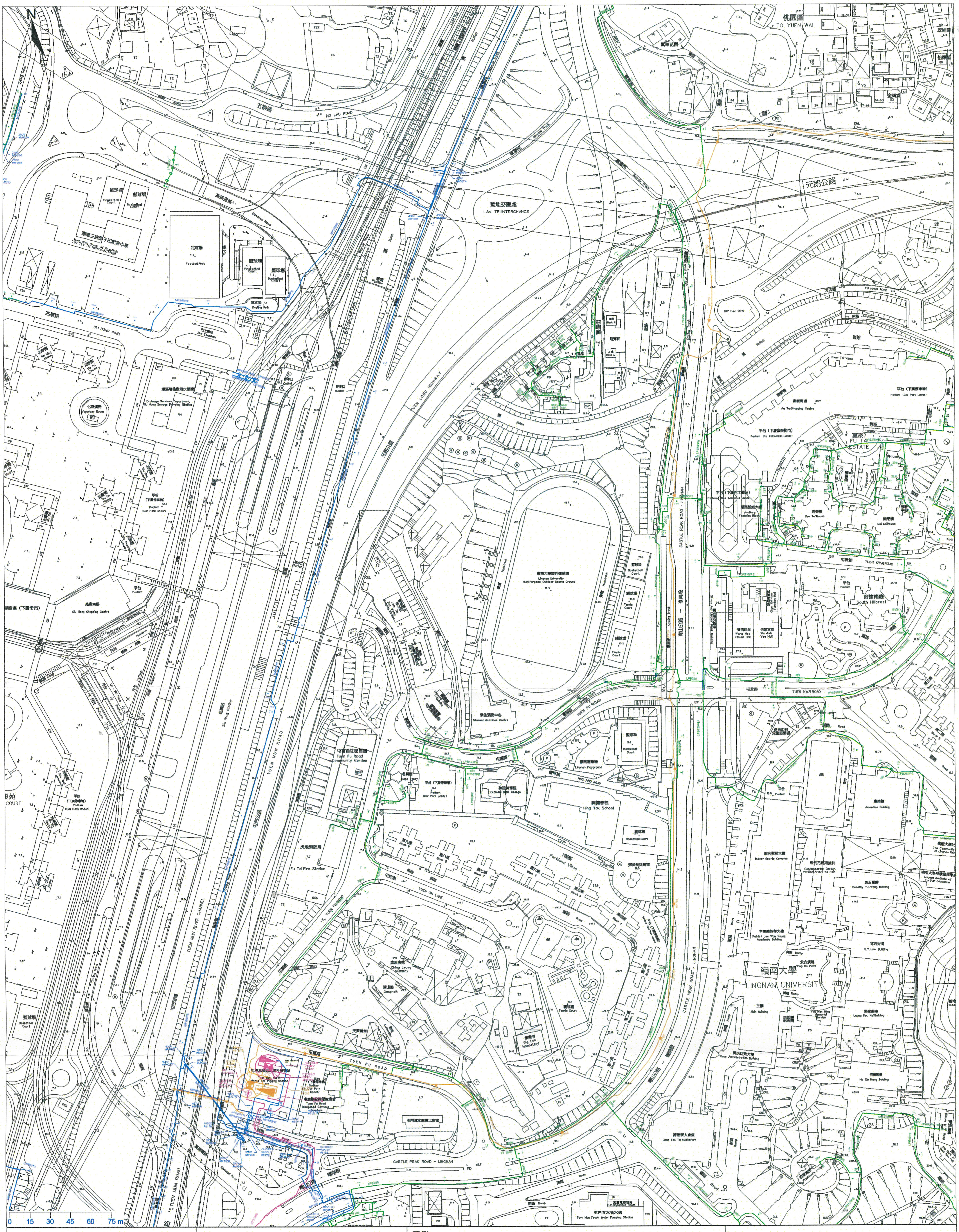
	調壓板
	冷凝液罐
	低壓管的冷凝液罐 / 放散點
	閘門
	球閥井
kip	清管井
RPIT	立管井
CP	陰極保護裝置
	大約煤深(米)
	管網通訊導管
TT BS RS WT	TT: 雙型男通 / BS: 塞氣馬鞍 RS: 雙型三通 / WT: 等土三通 [注意：雙型管件煤深，比管道深約 5 0 毫米]

圖則顯示的管道位置只作參考之用。其實際位置和深度仍須以人手開挖探孔確定。在煤氣管道設施附近施工期間，必須要加倍小心。

檢查日期： Nov 27 2025

座標 xy (816080,830354)

圖則上的地圖資料乃得到 (C)香港地政總署署長 准許翻印。
在未得到香港中華煤氣有限公司批准前，不可翻印此圖的整個或部分內容。



煤氣
Towngas
香港中華煤氣有限公司
The Hong Kong and China Gas Company Limited

網絡發展部

時間：14:35:57

比例：1：2500

圖例：

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IPA	現有次高壓 A 管道 (240-400 千帕)
IPB	現有次高壓 B 管道 (400-700 千帕)
HP	現有高壓管道 (700 千帕以上)
PE	設有可探索警告帶的聚乙烯管道
IPB*	現有次高壓 B 管道 (暫以較低壓力運作)
HP*	現有高壓管道 (暫以較低壓力運作)
PE*	沒有可探索警告帶的聚乙烯管道
RP / iPit	備用管道 / 保留管道檢測井
	擬建/在建管道
	鋼蓋板
	冷凝液罐
	無豎管的冷凝液罐 / 放散點
	閥門
	球閥井
idp	清管井
RPIT	立管井
CP	陰極保護裝置
	大約埋深(米)
	管網通訊導管
TT BS RS WT	TT:鞍型旁通 / BS:塞氣馬鞍 RS:鞍型三通 / WT:華士三通

[注意：鞍型管件埋深，比管道淺約５０毫米]

圖則顯示的管道位置只作參考之用。其實際位置和深度仍須以人手開挖探孔確定。在煤氣管道設施附近施工期間，必須要加倍小心。

檢查日期： Nov 27 2025

座標 xy (816080,830354)

圖則上的地圖資料乃得到 (C)香港地政總署署長 准許翻印。
在未得到香港中華煤氣有限公司批准前，不可翻印此圖則的全部或部份內容。

Appendix B
Proposed layout and sectional plan of the Proposed Development

- LEVEL-1 FL. PLAN

SCALE: 1:250 (A3)

B.D. REF.

F.S.D. REF.

NOTES:

1. WORK FROM FIGURED DIMENSIONS ONLY.
2. ALL DIMENSIONS SHALL BE VERIFIED ON SITE BY THE CONTRACTOR.
3. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH RELEVANT SPECIFICATIONS CONDITIONS OF CONTRACT AND ALL OTHER RELEVANT DRAWINGS. THE AUTHORIZED PERSON / REGISTERED STRUCTURAL ENGINEER SHALL BE NOTIFIED IMMEDIATELY OF ANY DISCREPANCY FOUND THEREIN.
4. THIS IS DRAWING IS NOT VALID FOR CONSTRUCTION OR OTHER PURPOSES UNLESS IT HAS BEEN SIGNED BY THE AUTHORIZED PERSON / REGISTERED STRUCTURAL ENGINEER.
5. ALL WORKS SPECIFIED ON THIS DRAWING SHALL BE CARRIED OUT STRICTLY IN ACCORDANCE WITH PROVISIONS OF THE BUILDINGS ORDINANCE AND REGULATIONS.
6. COPYRIGHT OF THIS DRAWING IS RESERVED BY THE AUTHORIZED PERSON / REGISTERED STRUCTURAL ENGINEER. NO PORTION OF THIS DRAWING MAY BE REPRODUCED WITHOUT HIS WRITTEN CONSENT.
7. DRAWINGS DEVIATED FROM THE LATEST REVISION SHOULD BE CANCELLED.

Rev.	Description	Date	Checked

Project Title :

SECTION 12A APPLICATION FOR PROPOSED REZONING FROM "GOVERNMENT, INSTITUTION OR COMMUNITY" TO "GOVERNMENT, INSTITUTION OR COMMUNITY (6)" AT TUEN MUN, NEW TERRITORIES AND TO AMEND THE NOTES OF THE ZONE APPLICABLE TO THE SITE FOR THE PROPOSED SOCIAL WELFARE FACILITY (RESIDENTIAL CARE HOME FOR THE ELDERLY) AT SECTION C OF LOT NO. 496 IN D.D. 132 AND THE ADJOINING GOVERNMENT LAND, TUEN MUN, NEW TERRITORIES

Drawing Title :

LEVEL-1 FLOOR PLAN

CLIENT

PARK NATURE

DRAWN	DATE	CHECKED	SCALE
SY	JUN 2026	EK	

JOB NO. : -

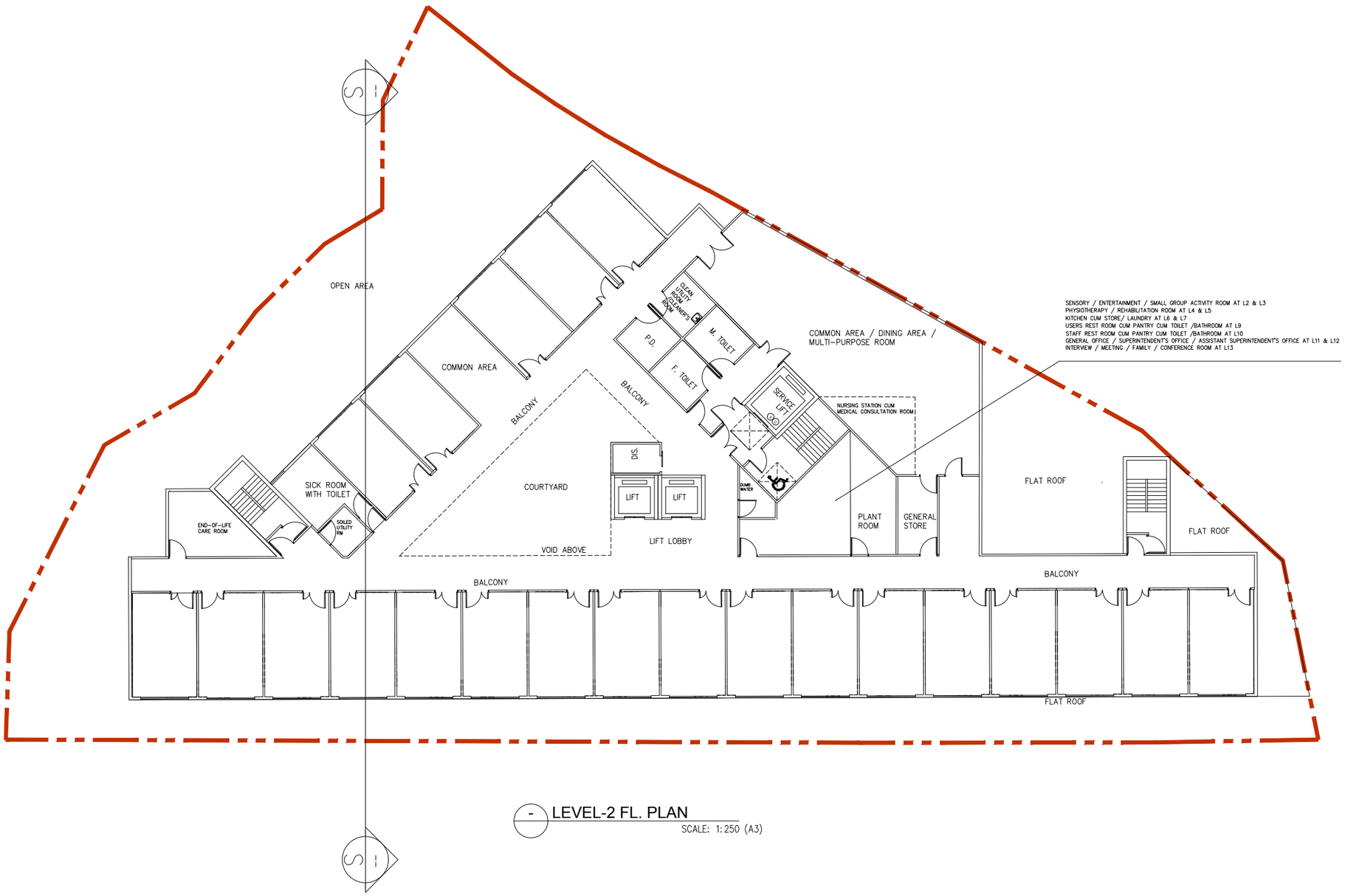
DRAWING NO. A-001

REVISION 2

AUTHORIZED PERSON :

KO B C

KO BUILDING CONSULTANCY LIMITED



- LEVEL-2 FL. PLAN

SCALE: 1:250 (A3)

B.D. REF.

F.S.D. REF.

NOTES:

1. WORK FROM FIGURED DIMENSIONS ONLY.
2. ALL DIMENSIONS SHALL BE VERIFIED ON SITE BY THE CONTRACTOR.
3. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH RELEVANT SPECIFICATIONS CONDITIONS OF CONTRACT AND ALL OTHER RELEVANT DRAWINGS. THE AUTHORIZED PERSON / REGISTERED STRUCTURAL ENGINEER SHALL BE NOTIFIED IMMEDIATELY OF ANY DISCREPANCY FOUND THEREIN.
4. THIS IS DRAWING IS NOT VALID FOR CONSTRUCTION OR OTHER PURPOSES UNLESS IT HAS BEEN SIGNED BY THE AUTHORIZED PERSON / REGISTERED STRUCTURAL ENGINEER.
5. ALL WORKS SPECIFIED ON THIS DRAWING SHALL BE CARRIED OUT STRICTLY IN ACCORDANCE WITH PROVISIONS OF THE BUILDINGS ORDINANCE AND REGULATIONS.
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Rev.	Description	Date	Checked

Project Title :

SECTION 12A APPLICATION FOR PROPOSED REZONING FROM "GOVERNMENT, INSTITUTION OR COMMUNITY" TO "GOVERNMENT, INSTITUTION OR COMMUNITY (6)" AT TUEN MUN, NEW TERRITORIES AND TO AMEND THE NOTES OF THE ZONE APPLICABLE TO THE SITE FOR THE PROPOSED SOCIAL WELFARE FACILITY (RESIDENTIAL CARE HOME FOR THE ELDERLY) AT SECTION C OF LOT NO. 496 IN D.D. 132 AND THE ADJOINING GOVERNMENT LAND, TUEN MUN, NEW TERRITORIES

Drawing Title :

LEVEL-2 FLOOR PLAN

CLIENT

PARK NATURE

DRAWN	DATE	CHECKED	SCALE
SY	JUN 2026	EK	

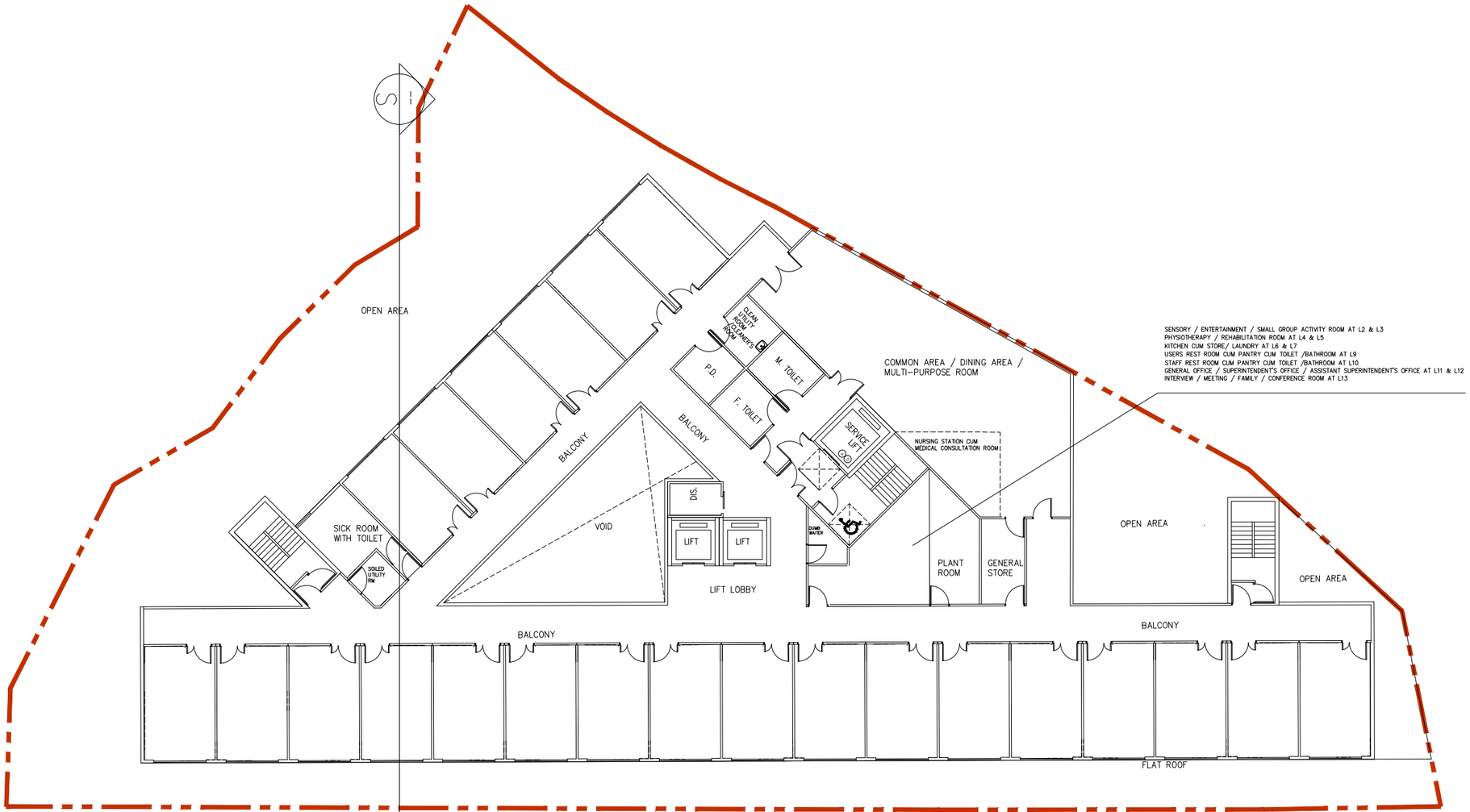
JOB NO. : -

DRAWING NO. A-002A

REVISION 1

AUTHORIZED PERSON :

KO BUILDING CONSULTANCY LIMITED



- TYP FL. PLAN

SCALE: 1:250 (A3)

BEDROOM NO. = 23 (PER FLOOR)
= 23 X 10 +22 = 252 (TOTAL)

B.D. REF.

F.S.D. REF.

NOTES:

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7. DRAWINGS DEVIATED FROM THE LATEST REVISION SHOULD BE CANCELLED.

Rev.	Description	Date	Checked

Project Title :

SECTION 12A APPLICATION FOR PROPOSED REZONING FROM "GOVERNMENT, INSTITUTION OR COMMUNITY" TO "GOVERNMENT, INSTITUTION OR COMMUNITY (6)" AT TUEN MUN, NEW TERRITORIES AND TO AMEND THE NOTES OF THE ZONE APPLICABLE TO THE SITE FOR THE PROPOSED SOCIAL WELFARE FACILITY (RESIDENTIAL CARE HOME FOR THE ELDERLY) AT SECTION C OF LOT NO. 496 IN D.D. 132 AND THE ADJOINING GOVERNMENT LAND, TUEN MUN, NEW TERRITORIES

Drawing Title :

TYPICAL FLOOR PLAN

CLIENT

PARK NATURE

DRAWN	DATE	CHECKED	SCALE
SY	JUN 2026	EK	

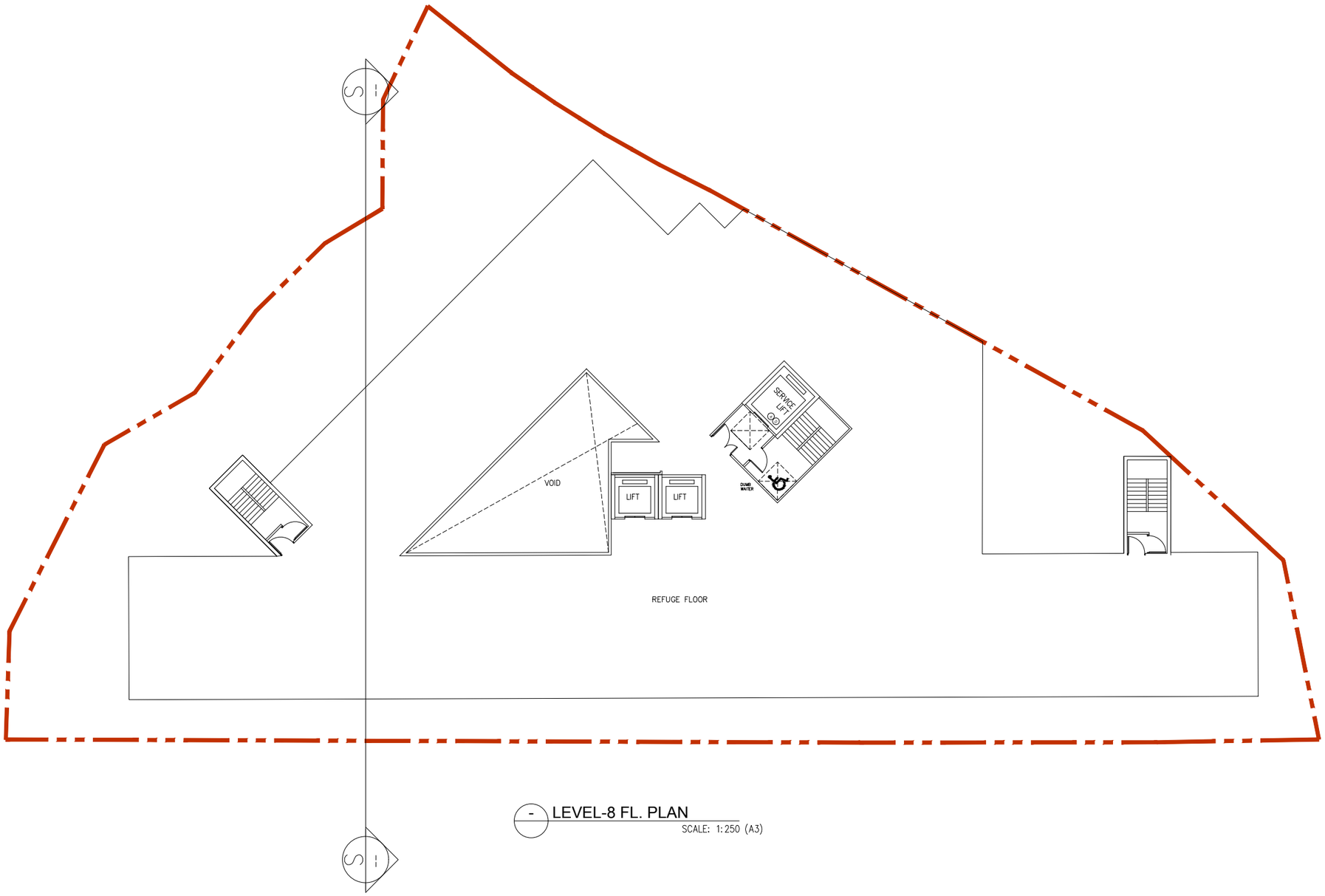
JOB NO. : -

DRAWING NO. A-002

REVISION 3

AUTHORIZED PERSON :

KO BUILDING CONSULTANCY LIMITED



- LEVEL-8 FL. PLAN

SCALE: 1:250 (A3)

B.D. REF.

F.S.D. REF.

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Rev.	Description	Date	Checked

Project Title :

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Drawing Title :

LEVEL-8 FLOOR PLAN

CLIENT

PARK NATURE

DRAWN	DATE	CHECKED	SCALE
SY	JUN 2026	EK	

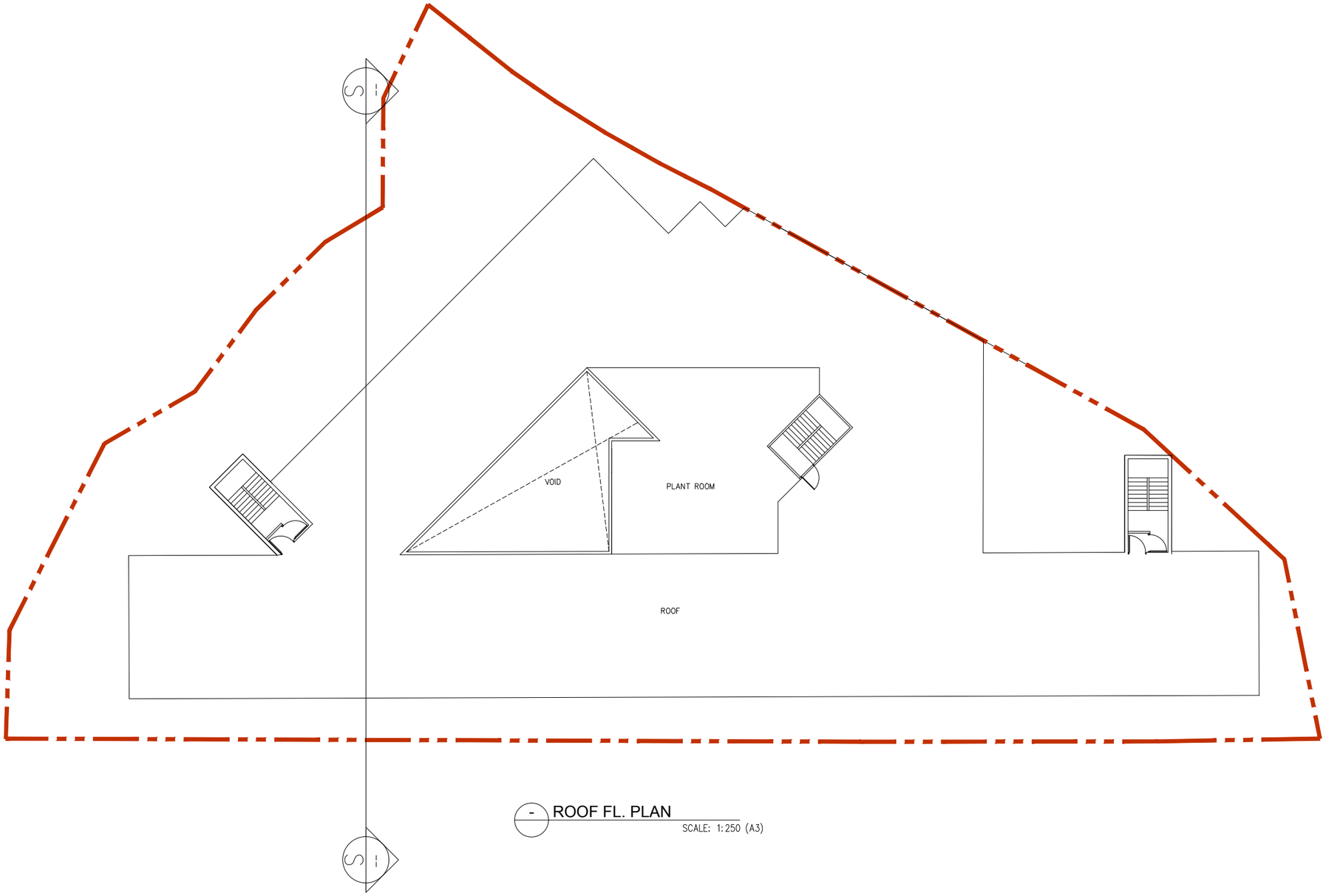
JOB NO. : -

DRAWING NO. A-003

REVISION 2

AUTHORIZED PERSON :

KO BUILDING CONSULTANCY LIMITED



- ROOF FL. PLAN
SCALE: 1:250 (A3)

B.D. REF.

F.S.D. REF.

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Rev.	Description	Date	Checked

Project Title :

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Drawing Title :

ROOF FLOOR PLAN

CLIENT

PARK NATURE

DRAWN	DATE	CHECKED	SCALE
SY	JUN 2026	EK	

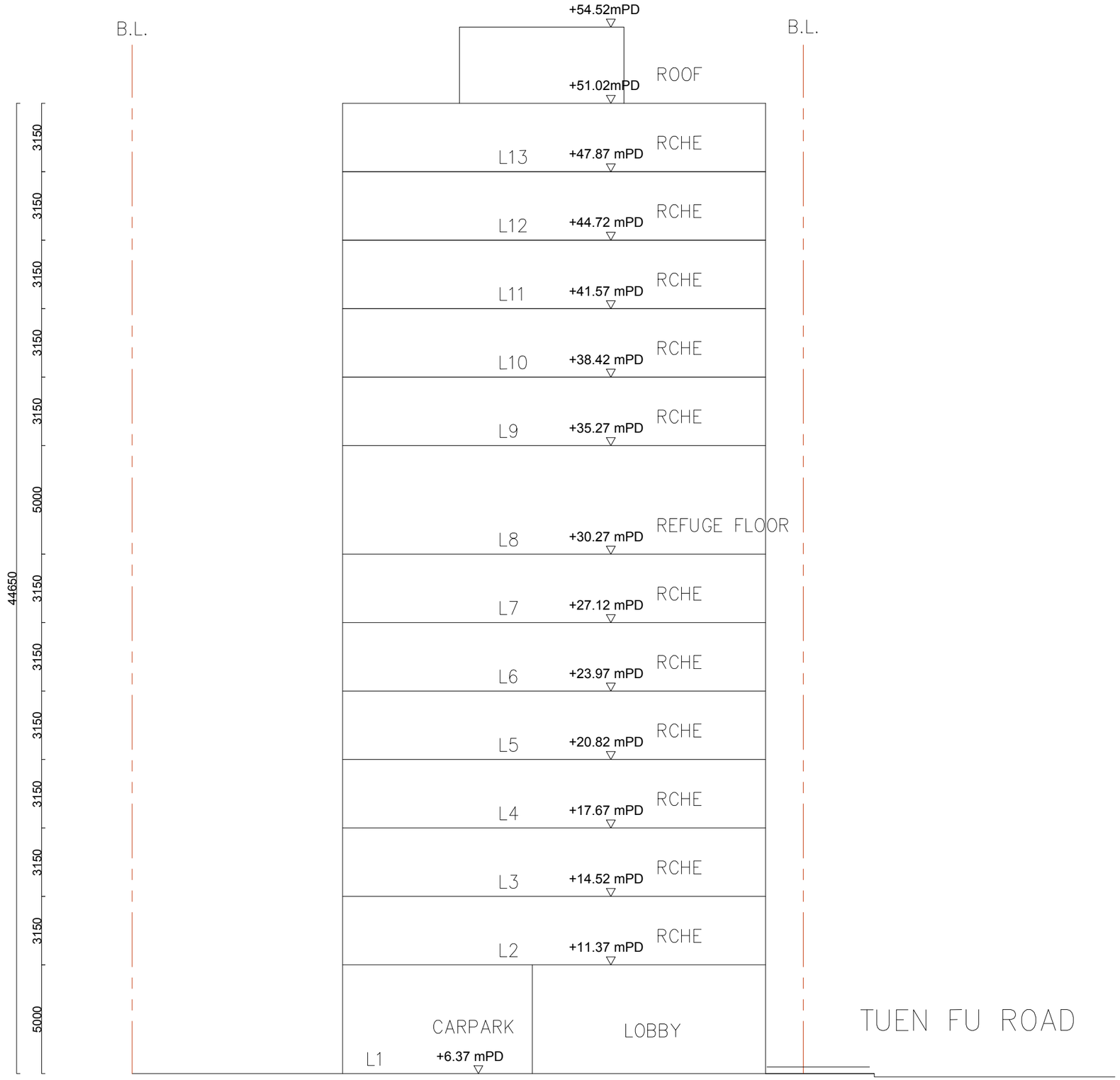
JOB NO. :
-

DRAWING NO.
A-004

REVISION
2

AUTHORIZED PERSON :

KO BUILDING CONSULTANCY LIMITED



- SECTIONAL DIAGRAM

SCALE: 1:200 (A3)

B.D. REF.

F.S.D. REF.

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Rev.	Description	Date	Checked

Project Title :

SECTION 12A APPLICATION FOR PROPOSED REZONING FROM "GOVERNMENT, INSTITUTION OR COMMUNITY" TO "GOVERNMENT, INSTITUTION OR COMMUNITY (6)" AT TUEN MUN, NEW TERRITORIES AND TO AMEND THE NOTES OF THE ZONE APPLICABLE TO THE SITE FOR THE PROPOSED SOCIAL WELFARE FACILITY (RESIDENTIAL CARE HOME FOR THE ELDERLY) AT SECTION C OF LOT NO. 496 IN D.D. 132 AND THE ADJOINING GOVERNMENT LAND, TUEN MUN, NEW TERRITORIES

Drawing Title :

SECTIONAL DIAGRAM

CLIENT

PARK NATURE

DRAWN	DATE	CHECKED	SCALE
SY	JUN 2026	EK	

JOB NO. : -

DRAWING NO. A-005

REVISION 2

AUTHORIZED PERSON :

KO BC
KO BUILDING CONSULTANCY LIMITED

Proposed Land Exchange for Social Welfare Facility and Public Carpark at Lot 496 S.C in D.D.132 and the adjoining Government Land

Development Schedule

Class of Site					A						
Zoning					GIC						
Site Area					1770	sqm					
Height Restriction (Under OZP)					3	Storey					
Mean Street Level					6.37	mPD					
Permitted Max Plot Ratio of Non-Domestic (Under BO)					11.0						
Permitted Max Site Coverage of Non-Domestic (Under BO)					69%						
Plot Ratio of Non-Domestic Provided											
GFA of Non-Domestic Provided (Level 1)					678.00	sqm					
GFA of Non-Domestic Provided (Level 2)					1081.50	sqm					
GFA of Non-Domestic Provided (Level 2 - 7, 9 - 12)	1017.80	sqm	x	10	10178.00	sqm					
GFA of Non-Domestic Provided (Refuge Floor at Level 8)					72.00	sqm					
TOTAL GFA of Non-Domestic Provided					12009.50	sqm					
Plot Ratio of Non-Domestic Provided					6.8	<	10.5				
Site Coverage of Non-Domestic Provided											
				=	1217	/	1770	x	100	%	
				=	69%			<	69%		
Building Height Provided											
No. of Storey					13	Storey					
Building Height					51.02	mPD					
					44.65	m	(5m at Level 1 and Level 8, 3.15m at RCHE Floor)				

		MPD
Level 1	5	6.37
Level 2	3.15	11.37
Level 3	3.15	14.52
Level 4	3.15	17.67
Level 5	3.15	20.82
Level 6	3.15	23.97
Level 7	3.15	27.12
Level 8	5	30.27
Level 9	3.15	35.27
Level 10	3.15	38.42
Level 11	3.15	41.57
Level 12	3.15	44.72
Level 13	3.15	47.87
R/F		51.02

Appendix C
Transient Population Calculation

C1. Estimation of Traffic Population

C1.1 Calculation of Traffic Variation within the Day

The traffic flow variation on all roads within study area is assumed to be same as that of Core Station No. 5012 on Tuen Mun Road, which is the nearest traffic station with hourly traffic and vehicle occupancy data.

Station No. / Road		Ratio of Day-time and Night-time Traffic Flow (1)		Ratio to Weekday Daytime Traffic Flow	
		Day	Night	Day	Night
S5012 / Tuen Mun Road (from Sham Tseng to Tsing Long Highway – Ting Kau Bridge)	**All-day**	70.6%	29.4%	100%	41.7%

Source: Core Station 5012, Hong Kong Annual Traffic Census 2024
Notes: (1) Derived from hourly variation of all day traffic flow

C1.2 Estimation of Average Occupancy per Vehicle

The average occupancy adopted is estimated from the vehicle occupancy data of Core Station No. 5012.

Time		Motor cycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light goods vehicle	M & H goods vehicle	Non Fr. Bus	SD Fr. bus	DD Fr. bus
16 hours	**Pro (%)**	2.7	51.0	6.4	0.4	0.4	19.8	11.8	2.4	0.1	5.1
	Ocp	1.1	1.3	2.0	3.8	9.5	1.3	1.1	15.0	1.1	41.4
Pro x Ocp		0.030	0.662	0.128	0.015	0.038	0.257	0.130	0.360	0.001	2.109

Source: Core Station 5012, Hong Kong Annual Traffic Census 2024

The estimated average occupancy = $\sum Pro \times Ocp$ = 3.7 persons per vehicle

C1.3 Estimation of Traffic Flow

The traffic flows are projected to year 2028 and 2032 from the most recent five years Annual Average Daily Traffic (AADT) data of Traffic Stations.

Station No	Road	AADT (Veh/day)					Average Annual Growth (1)	Predicted AADT (Veh/day) (2)	
		Year 2020	Year 2021	Year 2022	Year 2023	Year 2024		Year 2028	Year 2032
S5025	Yuen Long Highway Expressway	103100	113690	109410	116440	122600	2.52%	135453	149654
S6604	Lam Tei Main St Local Distributor	950	1020	1070	1150	1220	4.96%	1481	1797

Notes: (1) For the Average of annual growth of Traffic Station were observed to be negative, they are conservatively assumed to be 0%.
(2) Predicted AADT = AADT in 2024 x (1+Average Annual Growth) $^{(Future\ year\ -\ 2023)}$

ID	Road	Traffic Station	Year 2028 Traffic Flow (veh/hr)		Year 2032 Traffic Flow (veh/hr)	
			Day Time (1)	Night Time (2)	Day Time (1)	Night Time (2)
R01	Lam Tei Interchange	N/A(3)	5165	3787	5165	3787
R02	Castle Peak Road – Lingnan	N/A(3)	1485	1380	1485	1380
R03	Yuen Long Highway	S5025	7970	3318	8805	3666
R04	Tuen Kwai Road	N/A(3)	820	910	820	910
R05	Tuen Fu Road	N/A(3)	235	190	235	190
R06	Fu Tei Road	N/A(4)	149	138	149	138
R07	Tuen Mun Road	N/A(3)	10085	4199	10085	4199
R08	Fuk Hang Tsuen Road	S6604	87	36	106	44

Notes: (1) Day-time Hourly Traffic Flow = Predicted AADT x Ratio Day-time Traffic Flow / 12 hours
(2) Night-time Hourly Traffic Flow = Predicted AADT x Ratio Night-time Traffic Flow / 12 hours
(3) The traffic flow of R01, R02, R04, R05 and R07 are based on the Project Information.
(4) It is assumed that R06 is 10% of R02.

C1.4 Estimation of Traffic Flow and Transient Population

ID	Road	Average Occupancy (ppl/veh)	Speed (km/hr)	Study Distance (km)	Traffic Population (1) (ppl)		Pedestrian (ppl)		Transient Population (3)(4) (ppl)	
					Year 2028	Year 2032	Year 2028	Year 2032	Year 2028	Year 2032
R01	Lam Tei Interchange	3.7	50	0.276	107	107	5	5	112	112
R02	Castle Peak Road - Lingnan	3.7	50	1.318	147	147	190	190	337	337
R03	Yuen Long Highway	3.7	50	1.487	885	977	0	0	885	997
R04	Tuen Kwai Road	3.7	50	0.360	23	23	55	55	78	78
R05	Tuen Fu Road	3.7	50	0.667	12	12	20	20	32	32
R06	Fu Tei Road	3.7	50	0.205	3	3	5	5	8	8
R07	Tuen Mun Road	3.7	70	0.718	386	386	20	20	406	406
R08	Fuk Hang Tsuen Road	3.7	50	0.278	2	3	20	20	22	23

Notes: (1) Traffic Population = Average Occupancy × Hourly Traffic Flow × Road Length / Traffic Speed
(2) Transient Population = Traffic Population + Pedestrian

C2. Estimation of Rail-based Population
C2.1 Estimation of Passenger Flow

Parameters	LRT III		LRT IV		MTR
Line	610	751	614	614P	Tuen Ma Line
Number of cars per train[1]	2	2	2	2	8
Maximum Car Capacity (ppl / car) [1]	255	255	255	255	339
Maximum train frequency (train / hour) [1]	15	15	15	15	22
Maximum Carrying Capacity in one direction (ppl/hr) [1]	7650	7650	7650	7650	75000
Train loading rate during peak hour [2]	100%	100%	100%	100%	100%
Passenger flow during peak hour in one direction, ppl/hr	7650	7650	7650	7650	75000
Passenger flow during peak hour in two direction, ppl/hr [3]	11500	11500	11500	11500	112500
Passenger flow during non-peak hour in two directions, ppl/hr [4]	5750	5750	5750	5750	56250

Notes:
(1) MTR Business Overview,2023-2024
(2) According to LegCo Document CB(1)980/15-16(07), passenger density during peak hour was only around 4 ppsm. Assume train loading rate is 100% with population density of 4 ppsm.
(3) Assume passenger flow in the opposite direction is half of passenger flow in one direction
(4) Assume passenger flow during non-peak hour is half of that during peak hour

C2.2 Calculation of Rail Population

i. LRT III – Route 610

Time Mode	No of Service Hour (1)(2)			Passenger Flow, ppl/hr			Average Speed (3) (km/hr)	Study Distance (km)	Population	Population Ratio to Population in WDD
	Peak	Non-peak	Total	Peak	Non-peak	Weighted Average				
WDD	2	10	12	11500	5750	6708	20	0.3	101	100%
WDN	2	5	7	11500	5750	4313	20	0.3	65	64%
WED	2	10	12	11500	5750	6708	20	0.3	101	100%
WEN	2	5	7	11500	5750	4313	20	0.3	65	64%

ii. LRT III – Route 751

Time Mode	No of Service Hour (1)(2)			Passenger Flow, ppl/hr			Average Speed (3) (km/hr)	Study Distance (km)	Population	Population Ratio to Population in WDD
	Peak	Non-peak	Total	Peak	Non-peak	Weighted Average				
WDD	2	10	12	11500	5750	6708	20	0.3	101	100%
WDN	2	5	7	11500	5750	4313	20	0.3	65	64%
WED	2	10	12	11500	5750	6708	20	0.3	101	100%
WEN	2	5	7	11500	5750	4313	20	0.3	65	64%

iii. LRT IV – Route 614

Time Mode	No of Service Hour (1)(2)			Passenger Flow, ppl/hr			Average Speed (3) (km/hr)	Study Distance (km)	Population	Population Ratio to Population in WDD
	Peak	Non-peak	Total	Peak	Non-peak	Weighted Average				
WDD	2	10	12	11500	5750	6708	20	0.3	101	100%
WDN	2	5	7	11500	5750	4313	20	0.3	65	64%
WED	2	10	12	11500	5750	6708	20	0.3	101	100%
WEN	2	5	7	11500	5750	4313	20	0.3	65	64%

iv. LRT IV – Route 614P

Time Mode	No of Service Hour (1)(2)			Passenger Flow, ppl/hr			Average Speed (3) (km/hr)	Study Distance (km)	Population	Population Ratio to Population in WDD
	Peak	Non-peak	Total	Peak	Non-peak	Weighted Average				
WDD	2	10	12	11500	5750	6708	20	0.3	101	100%
WDN	2	5	7	11500	5750	4313	20	0.3	65	64%
WED	2	10	12	11500	5750	6708	20	0.3	101	100%
WEN	2	5	7	11500	5750	4313	20	0.3	65	64%

v. MTR – Tuen Ma Line

Time Mode	No of Service Hour (1)(2)			Passenger Flow, ppl/hr			Average Speed (4) (km/hr)	Study Distance (km)	Population	Population Ratio to Population in WDD
	Peak	Non-peak	Total	Peak	Non-peak	Weighted Average				
WDD	2	10	12	112500	56250	65625	45	0.43	628	100%
WDN	2	5	7	112500	56250	42188	45	0.43	404	64%
WED	2	10	12	112500	56250	65625	45	0.43	628	100%
WEN	2	5	7	112500	56250	42188	45	0.43	404	64%

Notes:
(1) Service hour of MTR is between 06:00 - 01:00 (19 hours per day)
(2) Assume peak hours are from 07:00 – 09:00 and 18:00 – 20:00
(3) Assume 20km/hr according to the total route length and travel time of the first train
(4) MTR Business Overview,2023-2024

Appendix D
Atmospheric Stability Class-Wind Speed Frequencies

Day Time Atmospheric Stability Class-Wind Speed Frequencies at Tuen Mun Government Offices Weather Station (Year 2024)

Wind Speed	STABILITY CLASS						Total
	A	B	C	D	E	F	
0-2	11.1%	5.5%	0.0%	7.0%	0.0%	9.0%	32.5%
2-4	6.0%	16.4%	9.5%	11.8%	5.3%	0.6%	49.6%
4-6	0.0%	6.0%	4.5%	5.5%	0.2%	0.0%	16.2%
6-8	0.0%	0.0%	0.5%	1.2%	0.0%	0.0%	1.6%
>8	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	17.0%	27.9%	14.6%	25.4%	5.5%	9.6%	100.0%

Night Time Atmospheric Stability Class-Wind Speed Frequencies at Tuen Mun Government Offices Weather Station (Year 2024)

Wind Speed	STABILITY CLASS						Total
	A	B	C	D	E	F	
0-2	0.0%	0.0%	0.0%	1.4%	0.0%	49.2%	50.6%
2-4	0.0%	0.0%	0.0%	13.1%	21.3%	3.0%	37.5%
4-6	0.0%	0.0%	0.0%	9.9%	1.4%	0.0%	11.2%
6-8	0.0%	0.0%	0.0%	0.7%	0.0%	0.0%	0.7%
>8	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	0.0%	0.0%	0.0%	25.1%	22.6%	52.2%	100.0%

Appendix E
Event Tree Analysis

TUEN MUN NORTH OFFTAKE AND PIGGING STATION

Underground Pipeline (High Pressure 35 barg)

Underground Pipeline Failure (per km-yr)
1.00E-05

Release Frequency (/yr)	Failure Probability	Release Orientation		Immediate Ignition		Delayed Ignition		Explosion after Ignition		Outcome Frequency (/yr)	Outcome Consequence
1.00E-05	0.20	Vertical	0.5	Yes	0.01					1.00E-08	Vertical jet fire
	leak 10mm			No	0.99	Yes	0.40			3.96E-07	Flash fire
	2.00E-06 /yr					No	0.60			5.94E-07	No ignition
		Inclined	0.5	Yes	0.01					1.00E-08	Inclined jet fire
				No	0.99	Yes	0.40			3.96E-07	Flash fire
						No	0.60			5.94E-07	No ignition
	0.30	Vertical	0.5	Yes	0.07					1.05E-07	Vertical jet fire
	leak 25mm			No	0.93	Yes	0.40			5.58E-07	Flash fire
	3.00E-06 /yr					No	0.60			8.37E-07	No ignition
		Inclined	0.5	Yes	0.07					1.05E-07	Inclined jet fire
				No	0.93	Yes	0.40			5.58E-07	Flash fire
						No	0.60			8.37E-07	No ignition
	0.30	Vertical	0.5	Yes	0.07					1.05E-07	Vertical jet fire
	leak 50mm			No	0.93	Yes	0.40			5.58E-07	Flash fire
	3.00E-06 /yr					No	0.60			8.37E-07	No ignition
		Inclined	0.5	Yes	0.07					1.05E-07	Inclined jet fire
				No	0.93	Yes	0.40			5.58E-07	Flash fire
						No	0.60			8.37E-07	No ignition
	0.19	Vertical	0.5	Yes	0.07					6.65E-08	Vertical jet fire
	leak 100mm			No	0.93	Yes	0.40	Yes	0.12	4.24E-08	Flash fire followed by explosion
	1.90E-06 /yr							No	0.88	3.11E-07	Flash fire
						No	0.60			5.30E-07	No ignition
		Inclined	0.5	Yes	0.07					6.65E-08	Inclined jet fire
				No	0.93	Yes	0.40	Yes	0.12	4.24E-08	Flash fire followed by explosion
								No	0.88	3.11E-07	Flash fire
						No	0.60			5.30E-07	No ignition
	0.01	Vertical	1	Yes	0.3					3.00E-08	Fireball
	Full bore rupture			No	0.7	Yes	0.40	Yes	0.3	8.40E-09	Flash fire followed by explosion
	1.00E-07 /yr							No	0.7	1.96E-08	Flash fire
						No	0.60			4.20E-08	No ignition

TUEN MUN NORTH OFFTAKE AND PIGGING STATION

Underground Pipeline (High Pressure 35 barg)

Underground Pipeline Failure (per km-yr)	Underground pipeline length in gas station (m)
1.00E-05	60

Release Frequency (/yr)	Failure Probability	Release Orientation		Immediate Ignition		Delayed Ignition		Explosion after Ignition		Outcome Frequency (/yr)	Outcome Consequence
6.00E-07	0.20	Vertical	0.5	Yes	0.01					6.00E-10	Vertical jet fire
	leak 10mm			No	0.99	Yes	0.40			2.38E-08	Flash fire
	1.20E-07 /yr					No	0.60			3.56E-08	No ignition
		Inclined	0.5	Yes	0.01					6.00E-10	Inclined jet fire
				No	0.99	Yes	0.40			2.38E-08	Flash fire
						No	0.60			3.56E-08	No ignition
	0.30	Vertical	0.5	Yes	0.07					6.30E-09	Vertical jet fire
	leak 25mm			No	0.93	Yes	0.40			3.35E-08	Flash fire
	1.80E-07 /yr					No	0.60			5.02E-08	No ignition
		Inclined	0.5	Yes	0.07					6.30E-09	Inclined jet fire
				No	0.93	Yes	0.40			3.35E-08	Flash fire
						No	0.60			5.02E-08	No ignition
	0.30	Vertical	0.5	Yes	0.07					6.30E-09	Vertical jet fire
	leak 50mm			No	0.93	Yes	0.40			3.35E-08	Flash fire
	1.80E-07 /yr					No	0.60			5.02E-08	No ignition
		Inclined	0.5	Yes	0.07					6.30E-09	Inclined jet fire
				No	0.93	Yes	0.40			3.35E-08	Flash fire
						No	0.60			5.02E-08	No ignition
	0.19	Vertical	0.5	Yes	0.07					3.99E-09	Vertical jet fire
	leak 100mm			No	0.93	Yes	0.40	Yes	0.12	2.54E-09	Flash fire followed by explosion
	1.14E-07 /yr							No	0.88	1.87E-08	Flash fire
						No	0.60			3.18E-08	No ignition
		Inclined	0.5	Yes	0.07					3.99E-09	Inclined jet fire
				No	0.93	Yes	0.40	Yes	0.12	2.54E-09	Flash fire followed by explosion
								No	0.88	1.87E-08	Flash fire
						No	0.60			3.18E-08	No ignition
	0.01	Vertical	1	Yes	0.3					1.80E-09	Fireball
	Full bore rupture			No	0.7	Yes	0.40	Yes	0.3	5.04E-10	Flash fire followed by explosion
	6.00E-09 /yr							No	0.7	1.18E-09	Flash fire
						No	0.60			2.52E-09	No ignition

TUEN MUN NORTH OFFTAKE AND PIGGING STATION

Aboveground Pipe and Equipment (High Pressure 35 barg)

Aboveground pipeline length in gas station	
104	m
Pipe size in gas station	
750	mm

Aboveground pipeline failure in gas station	2.78E-05	per yr
Valve failure in gas station	3.96E-02	per yr
Flange failure in gas station	6.20E-02	per yr
Instrument connection failure in gas station	1.31E-02	per yr
Pig trap operation failure in gas station	1.03E-08	per yr
Total	1.15E-01	per yr

Release Frequency (/yr)	Failure Probability	Release Orientation		Immediate Ignition		Delayed Ignition		Explosion after Ignition		Outcome Frequency (/yr)	Outcome Consequence
1.15E-01	0.93	Vertical	0.50	Yes	0.01					5.35E-04	Vertical jet flame
	leak 10mm			No	0.99	Yes	0.40			2.12E-02	Flash fire
	1.07E-01 /yr					No	0.60			3.18E-02	No ignition
		Horizontal	0.25	Yes	0.01					2.68E-04	Horizontal jet flame
				No	0.99	Yes	0.40			1.06E-02	Flash fire
						No	0.60			1.59E-02	No ignition
		Inclined	0.25	Yes	0.01					2.68E-04	Inclined jet flame
				No	0.99	Yes	0.40			1.06E-02	Flash fire
						No	0.60			1.59E-02	No ignition
	0.06	Vertical	0.50	Yes	0.07					2.48E-04	Vertical jet flame
	leak 25mm			No	0.93	Yes	0.40			1.32E-03	Flash fire
	7.10E-03 /yr					No	0.60			1.98E-03	No ignition
		Horizontal	0.25	Yes	0.07					1.24E-04	Horizontal jet flame
				No	0.93	Yes	0.40			6.60E-04	Flash fire
						No	0.60			9.90E-04	No ignition
		Inclined	0.25	Yes	0.07					1.24E-04	Inclined jet flame
				No	0.93	Yes	0.40			6.60E-04	Flash fire
						No	0.60			9.90E-04	No ignition
	0.005	Vertical	0.50	Yes	0.07					2.19E-05	Vertical jet flame
	leak 50mm			No	0.93	Yes	0.40			1.17E-04	Flash fire
	6.27E-04 /yr					No	0.60			1.75E-04	No ignition
		Horizontal	0.25	Yes	0.07					1.10E-05	Horizontal jet flame
				No	0.93	Yes	0.40			5.83E-05	Flash fire
						No	0.60			8.75E-05	No ignition
		Inclined	0.25	Yes	0.07					1.10E-05	Inclined jet flame
				No	0.93	Yes	0.40			5.83E-05	Flash fire
						No	0.60			8.75E-05	No ignition
	2.94E-05	Vertical	0.50	Yes	0.07					1.18E-07	Vertical jet flame
	leak 100mm			No	0.93	Yes	0.40	Yes	0.12	7.52E-08	Flash fire followed by explosion
	3.37E-06 /yr							No	0.88	5.51E-07	Flash fire
						No	0.60			9.40E-07	No ignition
		Horizontal	0.25	Yes	0.07					5.90E-08	Horizontal jet flame
				No	0.93	Yes	0.40	Yes	0.12	3.76E-08	Flash fire followed by explosion
								No	0.88	2.76E-07	Flash fire
						No	0.60			4.70E-07	No ignition
		Inclined	0.25	Yes	0.07					5.90E-08	Inclined jet flame
				No	0.93	Yes	0.40	Yes	0.12	3.76E-08	Flash fire followed by explosion
								No	0.88	2.76E-07	Flash fire
						No	0.60			4.70E-07	No ignition
	4.98E-06	Vertical	1	Yes	0.30					1.72E-07	Fire ball
	Full bore rupture (750mm)			No	0.70	Yes	0.40	Yes	0.3	4.80E-08	Flash fire followed by explosion
	5.72E-07 /yr							No	0.7	1.12E-07	Flash fire
						No	0.60			2.40E-07	No ignition

TUEN MUN NORTH OFFTAKE AND PIGGING STATION

Underground Pipeline (Intermediate Pressure 7 barg)

Underground Pipeline Failure (per km-yr)	Underground pipeline length in gas station (m)
1.00E-05	120

Release Frequency (/yr)	Failure Probability	Release Orientation		Immediate Ignition		Delayed Ignition		Explosion after Ignition		Outcome Frequency (/yr)	Outcome Consequence
1.20E-06	0.20	Vertical	0.5	Yes	0.01					1.20E-09	Vertical jet fire
	leak 10mm			No	0.99	Yes	0.40			4.75E-08	Flash fire
	2.40E-07 /yr					No	0.60			7.13E-08	No ignition
		Inclined	0.5	Yes	0.01					1.20E-09	Inclined jet fire
				No	0.99	Yes	0.40			4.75E-08	Flash fire
						No	0.60			7.13E-08	No ignition
	0.30	Vertical	0.5	Yes	0.07					1.26E-08	Vertical jet fire
	leak 25mm			No	0.93	Yes	0.40			6.70E-08	Flash fire
	3.60E-07 /yr					No	0.60			1.00E-07	No ignition
		Inclined	0.5	Yes	0.07					1.26E-08	Inclined jet fire
				No	0.93	Yes	0.40			6.70E-08	Flash fire
						No	0.60			1.00E-07	No ignition
	0.30	Vertical	0.5	Yes	0.07					1.26E-08	Vertical jet fire
	leak 50mm			No	0.93	Yes	0.40			6.70E-08	Flash fire
	3.60E-07 /yr					No	0.60			1.00E-07	No ignition
		Inclined	0.5	Yes	0.07					1.26E-08	Inclined jet fire
				No	0.93	Yes	0.40			6.70E-08	Flash fire
						No	0.60			1.00E-07	No ignition
	0.19	Vertical	0.5	Yes	0.07					7.98E-09	Vertical jet fire
	leak 100mm			No	0.93	Yes	0.40			4.24E-08	Flash fire
	2.28E-07 /yr					No	0.60			6.36E-08	No ignition
		Inclined	0.5	Yes	0.07					7.98E-09	Inclined jet fire
				No	0.93	Yes	0.40			4.24E-08	Flash fire
						No	0.60			6.36E-08	No ignition
	0.01	Vertical	1	Yes	0.3					3.60E-09	Fireball
	Full bore rupture			No	0.7	Yes	0.40	Yes	0.3	1.01E-09	Flash fire followed by explosion
	1.20E-08 /yr							No	0.7	2.35E-09	Flash fire
						No	0.60			5.04E-09	No ignition

TUEN MUN NORTH OFFTAKE AND PIGGING STATION

Aboveground Pipe and Equipment (Intermediate Pressure 7 barg)

Aboveground pipeline length in gas station	
109	m
Pipe size in gas station	
600	mm

Aboveground pipeline failure in gas station	2.91E-05	per yr
Valve failure in gas station	3.74E-02	per yr
Flange failure in gas station	5.40E-02	per yr
Instrument connection failure in gas station	1.77E-02	per yr
Pig trap operation failure in gas station	1.03E-08	per yr
Total	1.09E-01	per yr

Release Frequency (/yr)	Failure Probability	Release Orientation		Immediate Ignition		Delayed Ignition		Explosion after Ignition		Outcome Frequency (/yr)	Outcome Consequence
1.09E-01	0.93	Vertical	0.50	Yes	0.01					5.08E-04	Vertical jet flame
	leak 10mm										
	1.02E-01 /yr			No	0.99	Yes	0.40			2.01E-02	Flash fire
						No	0.60			3.02E-02	No ignition
		Horizontal	0.25	Yes	0.01					2.54E-04	Horizontal jet flame
				No	0.99	Yes	0.40			1.01E-02	Flash fire
						No	0.60			1.51E-02	No ignition
		Inclined	0.25	Yes	0.01					2.54E-04	Inclined jet flame
				No	0.99	Yes	0.40			1.01E-02	Flash fire
						No	0.60			1.51E-02	No ignition
	0.06	Vertical	0.50	Yes	0.07					2.42E-04	Vertical jet flame
	leak 25mm										
	6.90E-03 /yr			No	0.93	Yes	0.40			1.28E-03	Flash fire
						No	0.60			1.93E-03	No ignition
		Horizontal	0.25	Yes	0.07					1.21E-04	Horizontal jet flame
				No	0.93	Yes	0.40			6.42E-04	Flash fire
						No	0.60			9.63E-04	No ignition
		Inclined	0.25	Yes	0.07					1.21E-04	Inclined jet flame
				No	0.93	Yes	0.40			6.42E-04	Flash fire
						No	0.60			9.63E-04	No ignition
	0.005	Vertical	0.50	Yes	0.07					1.92E-05	Vertical jet flame
	leak 50mm										
	5.47E-04 /yr			No	0.93	Yes	0.40			1.02E-04	Flash fire
						No	0.60			1.53E-04	No ignition
		Horizontal	0.25	Yes	0.07					9.58E-06	Horizontal jet flame
				No	0.93	Yes	0.40			5.09E-05	Flash fire
						No	0.60			7.64E-05	No ignition
		Inclined	0.25	Yes	0.07					9.58E-06	Inclined jet flame
				No	0.93	Yes	0.40			5.09E-05	Flash fire
						No	0.60			7.64E-05	No ignition
	3.24E-05	Vertical	0.50	Yes	0.07					1.24E-07	Vertical jet flame
	leak 100mm										
	3.53E-06 /yr			No	0.93	Yes	0.40			6.57E-07	Flash fire
						No	0.60			9.86E-07	No ignition
		Horizontal	0.25	Yes	0.07					6.18E-08	Horizontal jet flame
				No	0.93	Yes	0.40			3.29E-07	Flash fire
						No	0.60			4.93E-07	No ignition
		Inclined	0.25	Yes	0.07					6.18E-08	Inclined jet flame
				No	0.93	Yes	0.40			3.29E-07	Flash fire
						No	0.60			4.93E-07	No ignition
	5.49E-06	Vertical	1	Yes	0.30					1.80E-07	Fire ball
	Full bore rupture (600mm)										
	5.99E-07 /yr			No	0.70	Yes	0.40	Yes	0.3	5.03E-08	Flash fire followed by explosion
								No	0.7	1.17E-07	Flash fire
						No	0.60			2.52E-07	No ignition

Appendix F
F-N Data

No. of fatality	Frequency (per year)			
	Case 1 – Base Case (Year 2032)	Case 2– Construction Case (Year 2028)	Case 3 – Operation Case (Year 2032)	Mitigation Case 1
1	8.66E-07	8.42E-07	8.67E-07	8.67E-07
2	3.36E-07	3.35E-07	3.36E-07	3.36E-07
3	2.68E-07	2.67E-07	2.68E-07	2.68E-07
4	2.61E-07	2.60E-07	2.61E-07	2.61E-07
5	2.56E-07	2.55E-07	2.56E-07	2.56E-07
6	2.50E-07	2.50E-07	2.51E-07	2.51E-07
8	2.47E-07	2.47E-07	2.48E-07	2.48E-07
10	2.44E-07	2.44E-07	2.45E-07	2.45E-07
12	2.39E-07	1.90E+01	2.40E-07	2.40E-07
15	2.35E-07	2.34E-07	2.36E-07	2.36E-07
20	2.30E-07	2.29E-07	2.30E-07	2.30E-07
25	2.25E-07	2.25E-07	2.26E-07	2.26E-07
30	2.23E-07	2.23E-07	2.24E-07	2.24E-07
40	2.19E-07	2.19E-07	2.20E-07	2.20E-07
50	2.16E-07	2.15E-07	2.18E-07	2.18E-07
60	1.25E-07	1.26E-07	1.27E-07	1.27E-07
80	5.92E-08	5.98E-08	6.22E-08	6.19E-08
90	5.68E-08	5.58E-08	5.94E-08	5.94E-08
100	2.81E-08	2.59E-08	3.01E-08	3.01E-08
120	2.08E-08	1.69E-08	2.35E-08	2.35E-08
150	1.25E-08	1.16E-08	1.56E-08	1.56E-08
200	7.44E-09	6.31E-09	9.97E-09	9.97E-09
250	2.82E-09	1.94E-09	4.84E-09	4.84E-09
300	6.06E-10	5.99E-10	1.87E-09	1.87E-09
400			8.72E-10	8.72E-10

Note: Values less than 1E-9 per year are not shown in the figure of F-N curve

Appendix G
PLL Breakdown

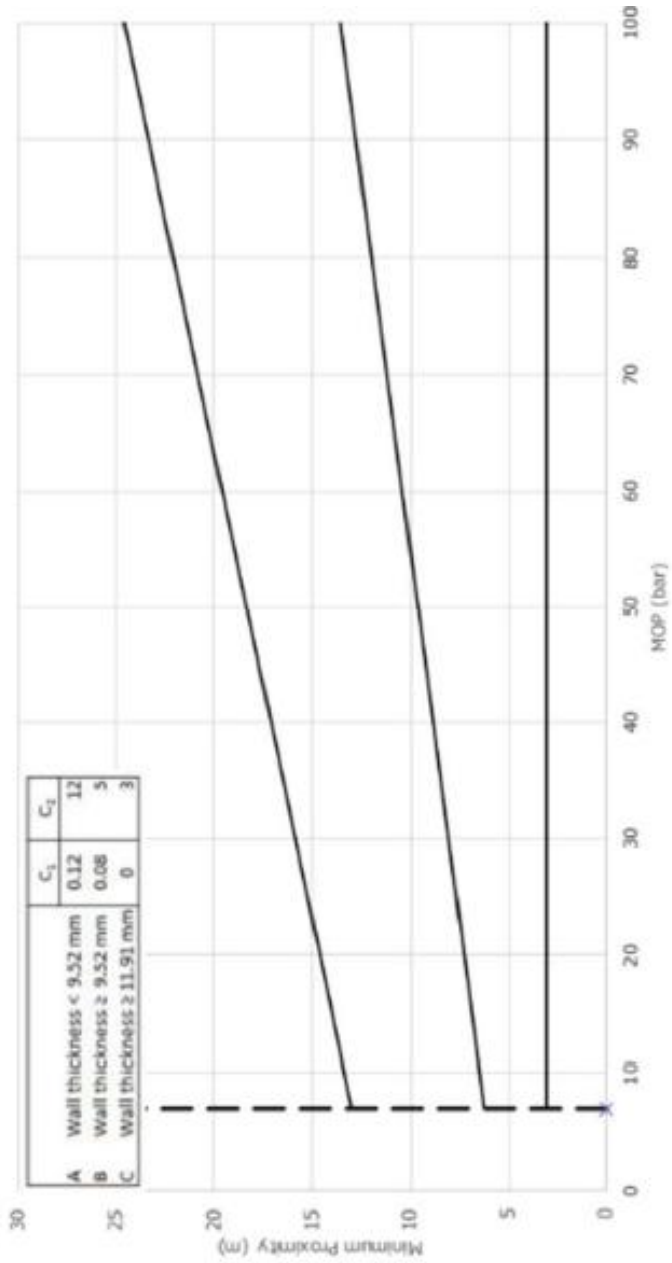
G1. Detail PLL Breakdown for the Station and Pipeline

Scenario	Hazardous Outcome	Base Case		Construction Case		Operation Case		Mitigation Case	
		PLL	%	PLL	%	PLL	%	PLL	%
Full Bore Rupture of Aboveground Pipework (DN750) in the Station	Fireball	1.16E-05	61.73%	1.15E-05	62.43%	1.17E-05	59.25%	1.16E-05	59.12%
Full Bore Rupture of Underground Pipe (DN750)	Fireball	5.62E-06	29.95%	5.42E-06	29.36%	6.45E-06	32.68%	6.41E-06	32.76%
50mm Leak from Aboveground Pipework (DN750) in the Station	Jet Fire	3.35E-07	1.78%	3.10E-07	1.68%	3.35E-07	1.70%	3.35E-07	1.71%
100mm Leak from Aboveground Pipework (DN750) in the Station	Jet Fire	3.05E-07	1.63%	2.95E-07	1.60%	3.05E-07	1.55%	3.05E-07	1.56%
Full Bore Rupture of Underground Pipe (DN750)	Flash Fire	2.98E-07	1.59%	2.93E-07	1.59%	3.09E-07	1.56%	3.09E-07	1.58%
Full Bore Rupture of Aboveground Pipework (DN600) in the Station	Fireball	2.08E-07	1.11%	2.09E-07	1.13%	2.08E-07	1.06%	2.08E-07	1.06%
Full Bore Rupture of Underground Pipe (DN750)	VCE	1.28E-07	0.68%	1.26E-07	0.68%	1.32E-07	0.67%	1.32E-07	0.68%
Full Bore Rupture of Underground Pipeline (DN750) in the Station	Fireball	1.21E-07	0.65%	1.21E-07	0.65%	1.23E-07	0.62%	1.21E-07	0.62%
Full Bore Rupture of Aboveground Pipework (DN750) in the Station	VCE	6.34E-08	0.34%	6.11E-08	0.33%	7.64E-08	0.39%	7.64E-08	0.39%
50mm Leak from Aboveground Pipework (DN600) in the Station	Jet Fire	4.05E-08	0.22%	4.05E-08	0.22%	4.05E-08	0.21%	4.05E-08	0.21%
Full Bore Rupture of Aboveground Pipework (DN750) in the Station	Flash Fire	1.47E-08	0.08%	1.44E-08	0.08%	1.47E-08	0.07%	1.47E-08	0.08%

Scenario	Hazardous Outcome	Base Case		Construction Case		Operation Case		Mitigation Case	
		PLL	%	PLL	%	PLL	%	PLL	%
100mm Leak from Aboveground Pipework (DN750) in the Station	Flash Fire	1.30E-08	0.07%	1.29E-08	0.07%	1.30E-08	0.07%	1.30E-08	0.07%
100mm Leak from Underground Pipe (DN750)	Flash Fire	1.19E-08	0.06%	1.13E-08	0.06%	1.20E-08	0.06%	1.20E-08	0.06%
100mm Leak from Aboveground Pipework (DN600) in the Station	Jet Fire	7.10E-09	0.04%	7.27E-09	0.04%	7.10E-09	0.04%	7.10E-09	0.04%
100mm Leak from Aboveground Pipework (DN750) in the Station	VCE	4.53E-09	0.02%	4.49E-09	0.02%	4.53E-09	0.02%	4.53E-09	0.02%
Full Bore Rupture of Underground Pipeline (DN600) in the Station	Fireball	4.17E-09	0.02%	4.18E-09	0.02%	4.17E-09	0.02%	4.17E-09	0.02%
50mm Leak from Underground Pipe (DN750)	Flash Fire	3.80E-09	0.02%	3.55E-09	0.02%	3.80E-09	0.02%	3.80E-09	0.02%
100mm Leak from Underground Pipe (DN750)	VCE	1.63E-09	0.01%	1.54E-09	0.01%	1.64E-09	0.01%	1.64E-09	0.01%
Full Bore Rupture of Underground Pipeline (DN750) in the Station	VCE	4.46E-10	0.00%	4.31E-10	0.00%	5.44E-10	0.00%	5.44E-10	0.00%
25mm Leak from Underground Pipe (DN750)	Flash Fire	2.86E-10	0.00%	2.67E-10	0.00%	2.86E-10	0.00%	2.86E-10	0.00%
100mm Leak from Underground Pipe (DN750)	Jet Fire	1.73E-10	0.00%	1.71E-10	0.00%	1.77E-10	0.00%	1.77E-10	0.00%
Full Bore Rupture of Underground Pipeline (DN750) in the Station	Flash Fire	9.37E-11	0.00%	9.13E-11	0.00%	9.37E-11	0.00%	9.37E-11	0.00%
50mm Leak from Underground Pipe (DN750)	Jet Fire	8.94E-11	0.00%	8.67E-11	0.00%	8.99E-11	0.00%	8.99E-11	0.00%
10mm Leak from Underground Pipe (DN750)	Jet Fire	4.46E-11	0.00%	4.39E-11	0.00%	4.46E-11	0.00%	4.46E-11	0.00%

Scenario	Hazardous Outcome	Base Case		Construction Case		Operation Case		Mitigation Case	
		PLL	%	PLL	%	PLL	%	PLL	%
25mm Leak from Underground Pipe (DN750)	Jet Fire	4.26E-11	0.00%	4.12E-11	0.00%	4.26E-11	0.00%	4.26E-11	0.00%
100mm Leak from Aboveground Pipework (DN600) in the Station	Flash Fire	3.38E-11	0.00%	3.38E-11	0.00%	3.38E-11	0.00%	3.38E-11	0.00%
10mm Leak from Underground Pipe (DN750)	Flash Fire	1.43E-11	0.00%	1.31E-11	0.00%	1.43E-11	0.00%	1.43E-11	0.00%
100mm Leak from Underground Pipeline (DN750) in the Station	Jet Fire	3.69E-13	0.00%	3.63E-13	0.00%	3.69E-13	0.00%	3.69E-13	0.00%
100mm Leak from Underground Pipeline (DN600) in the Station	Jet Fire	3.21E-13	0.00%	3.21E-13	0.00%	3.21E-13	0.00%	3.21E-13	0.00%
	Total	**1.88E-05**	**100.00%**	**1.85E-05**	**100.00%**	**1.97E-05**	**100.00%**	**1.96E-05**	**100.00%**

Appendix H
Minimum Proximity Distance to Normally-Occupied Buildings of Pipeline Design to Operate in Type S Areas from IGEM/TD/1



MINIMUM BPD = (C1 x MOP) + C2 and is calculated from the centre line of the pipe, rounded to the nearest metre.

FIGURE 6 - MINIMUM PROXIMITY DISTANCE TO NORMALLY-OCCUPIED BUILDINGS OF PIPELINES DESIGNED TO OPERATE IN TYPE S AREAS.

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