Appendix 10

QUANTITATIVE RISK ASSESSMENT

AtkinsRéalis

Quantitative Risk Assessment (QRA) Report

Proposed Amendment to the Approved Lam Tei and Yick Yuen Outline Zoning Plan No. S/TM-LTYY/14 from "Comprehensive Development Area", "Green Belt" and "Residential (Group B) 3" Zone to "Residential (Group B) 4" Zone at Lot Nos. 837 RP (Part), 839 S.A RP (Part), 841 (Part), 1035 RP, 1037 RP and 2527 S.F RP (Part) in D.D. 130 and Adjoining Government Land, Lam Tei, Tuen Mun

Gain Million Development Limited

16 October 2026

Notice

This document and its contents have been prepared and are intended solely as information for Gain Million Development Limited and use in relation to Quantitative Risk Assessment (QRA).

AtkinsRealis Asia Limited assumes no responsibility to any other party in respect of or arising out of or in connection with this document and/or its contents.

This document has 47 pages, including the cover.

Document history

Revision	Purpose description	Originated	Checked	Reviewed	Authorised	Date
1.0	S12A pre-submission	Ho Fai LEUNG	Ho Fai LEUNG	Atlas FUNG	Kelvin CHENG	30/07/2026
2.0	S12A submission	Ho Fai LEUNG	Ho Fai LEUNG	Atlas FUNG	Kelvin CHENG	16/10/2026

Client signoff

Client	Gain Million Development Limited
Project	Quantitative Risk Assessment (QRA) Report
Job number	5233126
Client signature/date	

Contents

1. Introduction 5

1.1 Background 5

1.2 Purpose of this Report 5

1.3 Study Tasks 5

1.4 Abbreviations 5

2. Rezoning Site and High Pressure Town Gas Pipelines 6

3. Risk Criteria 7

4. Background Information 8

4.1 High Pressure Town Gas Pipeline 8

4.2 Properties of Town Gas 9

4.3 Proposed Development 9

5. Methodology 10

5.1 Overall QRA Approach 10

5.2 Assessment Methodology 10

6. Hazard Review 11

7. Frequency Assessment 13

7.1 Generic Failure Frequency 13

7.2 Orientation 13

7.3 Hole Size Distribution 13

7.4 Ignition Probability 13

7.5 Ignition Source 14

7.6 Meteorological Data 14

7.7 Event Tree Analysis 15

8. Consequence Assessment 17

8.1 Source Term and Dispersion Modeling 17

8.2 Fireball 17

8.3 Flash Fire 17

8.4 Jet Fire 17

8.5 Vapor Cloud Explosion (VCE) 17

8.6 Thermal Radiation 18

8.7 Toxicity 18

9. Population 19

9.1 Background Population 19

9.2 Proposed Development 20

9.3 Road Population 20
9.4 Time Modes and Indoor Ratio 21
10. Risk Results 26
10.1 Individual Risk 26
10.2 Societal Risk 28
11. Review of Zoning Requirements for Underground High Pressure Pipe 34
11.1 Identification of Area Type of Proposed Development 34
11.2 Review of Minimum Building Proximity Distance (BPD) 34
11.3 Safety Evaluation and Risk Analysis 35
12. Conclusions 36
13. References 37

1. Introduction

1.1 Background

1.1.1 This Quantitative Risk Assessment (QRA) Report is prepared by AtkinsRéalis Asia Limited on behalf of the Applicant, Gain Million Development Limited, in support of the proposed amendment to the approved Lam Tei and Yick Yuen Outline Zoning Plan No. S/TM-LTYY/14 from "Comprehensive Development Area", "Green Belt" and "Residential (Group B) 3" zone to " Residential (Group B) 4" zone at Lot Nos. 837 RP (part), 839 S.A RP (part), 841 (part), 1035 RP, 1037 RP and 2527 S.F RP (part) in D.D. 130 and Adjoining Government Land at Lam Tei, Tuen Mun.

1.2 Purpose of this Report

1.2.1 The objective of this study is to conduct a QRA to assess the individual risk and societal risk level of the underground high pressure town gas pipelines (South Route and North Route), taking into account of the proposed development.

1.3 Study Tasks

1.3.1 The major tasks of this study are to:

(a) Quantify the individual risk and societal risk posed by the underground high pressure town gas pipelines (South Route and North Route) to the surrounding population, including the proposed development; and

(b) Compare the risk level with the Hong Kong Risk Guidelines

1.4 Abbreviations

1.4.1 The following abbreviations are used in this Report:

AADT	Annual Average Daily Traffic
ALARP	As Low As Reasonable Practicable
BPD	Building Proximity Distance
CDA	Comprehensive Development Area
EGIG	European Gas Pipeline Incident Data Group
EMSD	Electrical and Mechanical Services Department
GB	Green Belt
OZP	Outline Zoning Plan
QRA	Quantitative Risk Assessment
TIA	Traffic Impact Assessment
TPU	Tertiary Planning Unit
VCE	Vapor Cloud Explosion

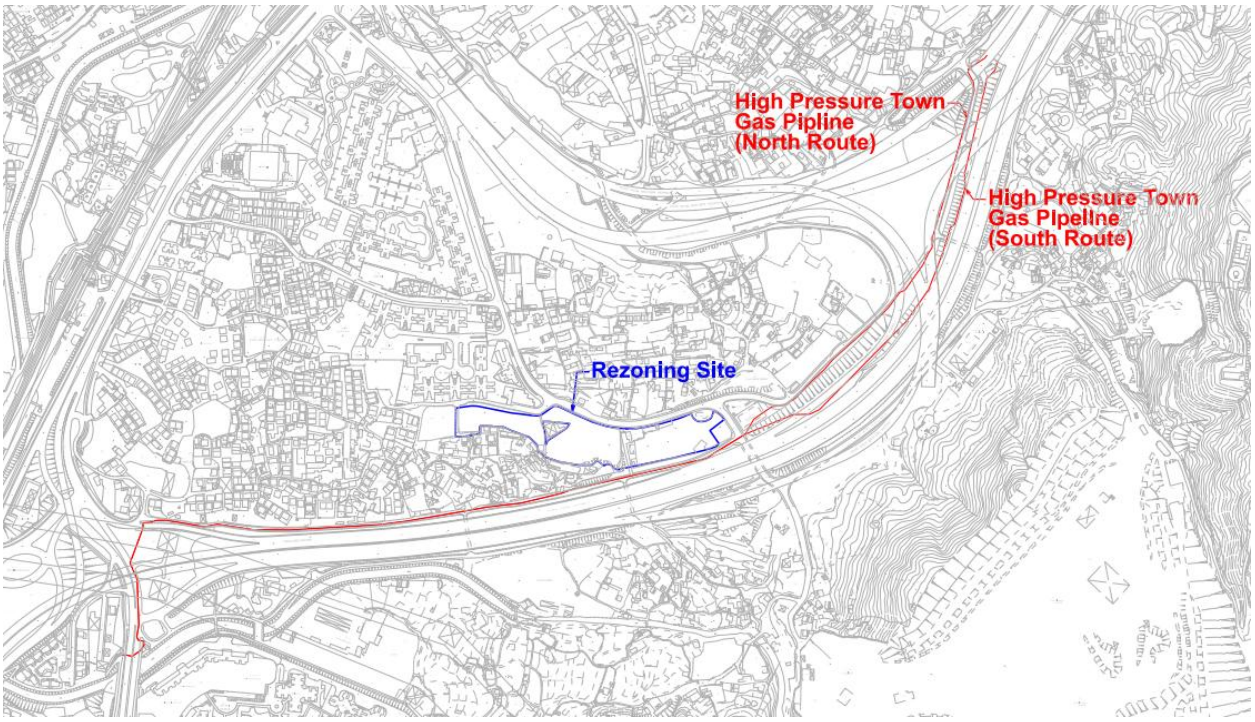
2. Rezoning Site and High Pressure Town Gas Pipelines

2.1.1 The Rezoning Site is currently zoned “Comprehensive Development Area” (“CDA”) with minor portions falling within the “Residential (Group B) 3” (“R(B)3”) and “Green Belt” (“GB”) zones under the Lam Tei and Yick Yuen Outline Zoning Plan No. S/TM-LTYY/14 (the Approved OZP).

2.1.2 The Rezoning Site has a total site area of approximately 14,036.48m^2. It is proposed to develop for a residential development with about 546 residential units. In addition, there will be a 3-storey non-domestic block that accommodates retail on G/F and social welfare facilities on 1/F and 2/F.

2.1.3 According to the information provided by the Hong Kong and China Gas Company Limited, there is an existing high pressure town gas pipeline (South Route) running along Yuen Long Highway. In addition, it has been planned to have a diversion of high pressure town gas pipeline (North Route). The two routes share a common section and then they branch off in two different sections. The two routes will not be in use simultaneously. As shown in **Figure 2-1**, the Rezoning Site is in close proximity with the gas pipelines, therefore, a QRA is required to be conducted in order to ensure the Hong Kong Risk Guidelines are still complied after taking the Proposed Development into account.

Figure 2-1 – Location of the Rezoning Site and High Pressure Town Gas Pipelines



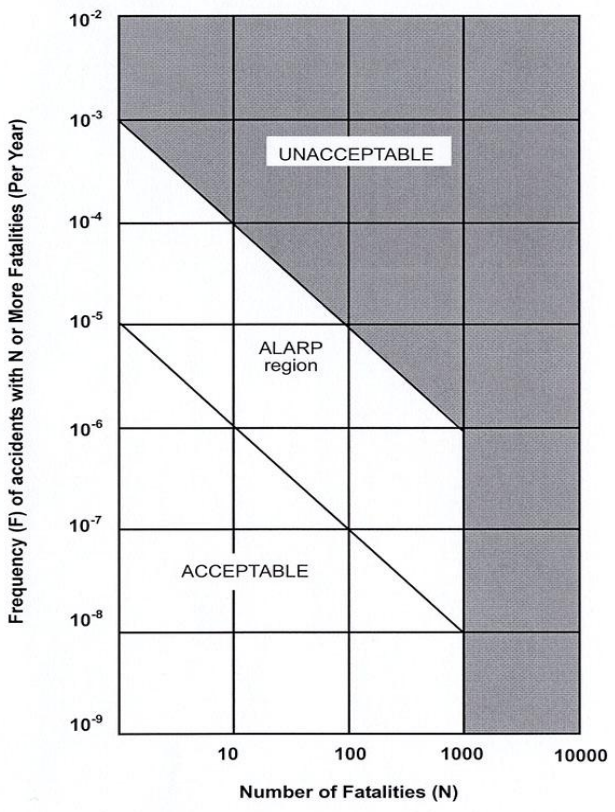
3. Risk Criteria

3.1.1 The individual and societal risk criteria specified in Chapter 12 of the Hong Kong Planning Standards and Guidelines will be applied in the current study.

3.1.2 Individual risk is the predicted increase in the chance of death per year to an individual who lives or works near a hazardous installation and it is often shown on a map of the area surrounding the hazardous installation as contours of equal risk which decrease according to distance from the hazardous installation. The estimated duration of exposure of a person to the hazardous installation should also be taken into consideration to determine the individual risk. The maximum level of off-site individual risk should not exceed 1 in 100,000 per year, i.e. 1 x 10^{-5} / year.

3.1.3 Societal risk expresses the risks to the whole population living near a hazardous installation. The societal risk criteria is presented graphically on a F-N graph as shown in **Figure** 3-1.

Figure 3-1 – Societal Risk Criterion



3.1.4 Two FN risk lines are adopted in the societal risk criteria to determine “acceptable” and “unacceptable” societal risk. Between the “acceptable” and “unacceptable” region, there is an intermediate region in which the acceptability of the societal risk is borderline and it should be reduced to a level which is “as low as reasonably practicable” (ALARP). All practicable and cost effective measures should be considered to reduce the risks. Furthermore, a vertical cut-off line at the 1000 fatality level extending down to a frequency of 1 in a billion years is adopted in the societal risk criteria in order to avoid major disasters resulting in more than 1000 deaths.

4. Background Information

4.1 High Pressure Town Gas Pipeline

4.1.1 According to the information provided by the Hong Kong and China Gas Company Limited, there is an existing high pressure town gas pipeline (South Route) running along Yuen Long Highway where the proposed development will be located. In addition, it is planned to have a diversion of high pressure town gas pipeline (North Route). The two routes share a common section and then they branch off in two different sections. The two routes will not be in use simultaneously. The pipeline is 750mm in diameter and it operates at 35 bar. It has a wall thickness of 12.7 mm and it is buried with a minimum dept of 1.1m below ground. The technical specification of the pipeline is shown in **Table 4-1**.

4.1.2 The alignment of the South Route and North Route of the high pressure town gas pipeline are shown in **Figure 2-1**.

Table 4-1 Technical Specification of the High Pressure Town Gas Pipeline

Parameter	Specification
Pipe Diameter (Nominal)	750mm
Pipe Length	North Route: 1,600m South Route: 1,600m
Pipe wall thickness	12.7mm
Design Pressure	35 barg
Maximum Operating Pressure	35 barg
Hydraulic Test Pressure	900 psi
Pipe Material	Steel
External Coating	400 micron of fusion bonded epoxy coating
Internal Coating	50 Micron Two Pack Epoxy
Year of Construction	1991-1994
Backfilling Material	Surrounded by 150mm Thick Zone 2 fresh sand
Cathodic Protection	Sacrificial Anode at about 300 m Interval
Minimum Depth	1.1m
Material Grading (Pipe/ Fitting)	API 5L X52
Jointing Method	Butt Welding
Welding Specification	Welding complied with BS4515
Non-Destructive Test of Jointing	100% X-Ray
Isolation Valves (Cameron Full Bore Ball Valve)	Upstream: Valves in Tai Tao Tsuen Downstream: Valve in Lam Tei Interchange
Valves in Tai Tao Tsuen	3.7km

4.2 Properties of Town Gas

4.2.1 Town gas is a mixture mainly consisting of hydrogen, methane, carbon dioxide and carbon monoxide. It is flammable due to the presence of hydrogen and methane. It is also toxic in nature due to the presence of carbon monoxide. Since town gas is lighter than air, it will rise and dissipate in air upon leakage. The gas composition and physical properties of town gas are shown in **Table 4-2**.

Table 4-2 Gas Composition and Physical Properties of Town Gas

Parameter	Specification
Composition	-
Hydrogen	49.0%
Methane	28.5%
Carbon Dioxide	19.5%
Carbon Monoxide	3.0%
Calorific Value	17.27 MJ m-3
Lowe Explosive Limit	5.5% volume
Wobbe Index	24
Specific Gravity	0.52
Weaver Flame Speed	35

4.3 Proposed Development

4.3.1 The Proposed Development includes five (5) residential towers above three (3) separate 3-storey podiums comprising of aboveground residential carparks, and resident's clubhouses and podium gardens, which will provide a total of 546 residential units. In addition, there will be a 3-storey non-domestic block that accommodates retail on G/F and social welfare facilities on 1/F and 2/F.

4.3.2 The construction of the Proposed Development will be completed in Year 2032 and the full population intake will be expected in the same year (i.e. 2032).

4.3.3 The location of the Proposed Development is shown in **Figure 2-1**.

5. Methodology

5.1 Overall QRA Approach

5.1.1 The elements of the QRA are consisted of the following six tasks:

i) **Data / Information Collection**: Collect and review relevant data / information associated with the underground high pressure town gas pipeline, population data etc;
ii) **Hazard Identification**: Identify hazardous scenarios associated with the operation of the underground high pressure town gas pipeline, during construction and operation phase of the Project;
iii) **Frequency Estimation**: Estimate the frequencies of each of the hazardous events leading to fatalities;
iv) **Consequence Analysis**: Analyse the consequences of each of the hazardous events;
v) **Risk Integration and Evaluation**: Evaluate the risks associated with each of the hazardous events. The evaluated risks will be compared with the Hong Kong Risk Guideline to determine their acceptability. Where necessary, risk mitigation measures will be identified and assessed to comply with the ALARP principle used in the guideline.
vi) **Identification of Mitigation Measures**: Practicable and cost-effective risk mitigation measures will be identified and assessed as necessary. Risk outcomes of the mitigated case will then be reassessed to determine the level of risk reduction.

5.2 Assessment Methodology

5.2.1 The methodology for this QRA study addresses the risk associated with the underground high pressure town gas pipeline during the construction and operation phase of the Project.

5.2.2 The QRA has been begun with reviewing the potential hazardous scenarios associated with the underground high pressure town gas pipeline and the potential causes of the identified hazardous scenarios. Site survey was also conducted to identify any external factors which might cause the hazardous scenarios.

5.2.3 The frequencies of occurrence of the hazardous scenarios haven been estimated by referring to the guidance notes published by the EMSD. Event tree analysis has also been applied to identify the sequence of development of the hazardous scenarios. For example, a release of town gas would develop into jet fire, flash fire, etc (i.e. ultimate hazardous event).

5.2.4 In consequence assessment, the software PHAST has been used to evaluate the size of each of the ultimate hazardous events. The population living or working within 200m from the underground high pressure town gas pipeline have also been identified and evaluated by desktop review and site survey.

5.2.5 The data obtained from the frequency and consequence assessment have then been input into Consultant's in-house software "Risk Tool" to produce individual risk and societal risk. The software has been used for all QRA studies conducted by the Consultant for more than a decade in Hong Kong. The QRA studies completed, with the software being used, in the past cover, for example, Potentially Hazardous Installations (e.g. LPG and Oil Terminal), High Pressure Town Gas Pipeline, LPG Filling Station, etc.

5.2.6 Finally, the estimated individual risk and societal risk have been compared with the HKRG. If necessary, mitigation measure would be recommended.

6. Hazard Review

6.1.1 The international database, 12th Gas Pipeline Incidents Report from the European Gas Pipeline Incident Data Group (EGIG), has been reviewed and the potential causes leakage are discussed below. Other potential causes that are not covered by the EGIG are also discussed below.

External Interference

6.1.2 External interference is the major cause of leakage from underground pipeline and it is contributed by third party interference. The third party interference refers to the construction activities not taken by the owner of the underground pipeline. The construction activities could be, for example, digging, piling and excavation works right above or near the underground pipeline. This hazard could be largely eliminated by detecting the presence and alignment of the underground pipeline prior of any construction works.

Corrosion

6.1.3 Corrosion is the deterioration of a metal as a result of chemical reaction between metal and surrounding environment (e.g. moisture in air). The deterioration could form pit or crack in metal. If the pit or crack happens in the high pressure town gas pipeline, gas leakage could result.

Construction Defect and Material Failure

6.1.4 Material failure could result from material manipulation and fabrication process. The inclusion of material defects and impurities could cause local hardness and result in brittle fracture. Construction defect could be due to poor welding where gas could leak through it. When material failure/construction defect happens at the town gas pipeline, gas leakage could happen.

Hot Tap Made by Error

6.1.5 Hot tapping is not adopted by the Hong Kong and China Gas Company, therefore, it is not considered relevant.

Ground Movement

6.1.6 The types of ground movement covered in the EGIG data include dike break, erosion, flood, landslide, mining, erosion of riverbed, erosion of riverbank. There is no dike/mining/riverbed/riverbank in proximity with the town gas pipeline. In addition, pipeline is buried underground, so landslide risk is not expected. Therefore, the ground movement is considered not relevant.

6.1.7 Beside the causes covered in the EGIG, other potential causes are reviewed in the following paragraphs.

Earthquake

6.1.8 Earthquake could generate ground settlement, ground movement and vibration which could potentially damage the underground town gas pipeline. According to Seismology Research Centre, pipeline would be destroyed by earthquake at intensity XI.

Subsidence/Ground Settlement

6.1.9 Since the town gas pipeline is buried underground, subsidence/ground settlement could damage it. Subsidence/ground settlement could occur due to excavation works. While excavation works is expected during the site formation for the proposed development, the site formation would be designed such that the subsidence/ ground settlement induced would not cause any damage to the underground town gas pipeline as well as other sensitive receivers.

Landslide

6.1.10 Landslide could generate a large amount of debris which could damage nearby facilities. However, the town gas pipeline is buried below ground, the debris deposition generated by landslide could not to affect the pipeline. Therefore, failure due to landslide is not considered in the study.

Breakage of Underground Water Mains

6.1.11 Fresh water and salt water are distributed to different part of Hong Kong through an extensive water mains network. Since the water pressure of water supply networks generally ranges from 60 to 80 meters (i.e. 6 to 8 bar) [4], it could damage other nearby underground utilities upon accidental release. However, the steel pipe for the high pressure town gas pipeline is designed to withstand a pressure of 35 bar which is significantly larger than the water pressure. Therefore, the accidental release of pressurized water due to water mains burst would not affect the underground pipeline.

Lightning and External Fire

6.1.12 Both lightning and external fire could not affect the town gas pipeline since the pipeline is buried below ground.

7. Frequency Assessment

7.1 Generic Failure Frequency

7.1.1 The overall failure frequency of the underground high pressure gas pipeline is 1.00E-05 as referenced from the guidance notes [3].

7.2 Orientation

7.2.1 Orientation refers to the direction of the town gas being ejected from the pipeline. For the underground high pressure pipeline, the release could happen in vertical and incline (i.e. 45º) direction. The probability for each release direction is 0.5 [3].

7.3 Hole Size Distribution

7.3.1 The hole size distribution for the underground town gas pipeline is shown in **Table** 7-1.

Table 7-1 – Hole Size Distribution [3]

Hole Size (mm)	Proportion (%)
Full bore	1
100	19
50	30
25	30
10	20

7.4 Ignition Probability

7.4.1 When flammable gas is released from the pipeline, the gas can be immediately ignited upon release. If immediate ignition does not happen, the gas will disperse in the atmosphere to form gas plume which could be ignited upon meeting an ignition source (i.e. delayed ignition). Un-ignited gas will disperse along the distance with dilution by air.

7.4.2 The ignition probability can be estimated by referring to Cox, Lees and Ang model which is summarized in **Table** 7-2.

Table 7-2 – Ignition Probability from Cox, Lees and Ang Model

Leak Size	Ignition Probability (Gas Release)
Minor (< 1 kg/s)	0.01
Major (1-50 kg/s)	0.07
Massive (>50 kg/s)	0.30

7.4.3 The ignition probabilities presented by the Cox, Lees and Ang model include both immediate ignition and delayed ignition. However, in this study, it is assumed that the probabilities are all taken as immediately ignition. This approach is considered conservative, but it could minimize the chance of underestimating the risk level of the town gas pipeline, taking into account of the fact that town gas is readily flammable. The ignition probability for delayed ignition is at least 40% of immediate unignited probability [3].

$$Delayed\ Ignition\ Probability = 0.4 * (1 - immediate\ ignition\ probability)$$

7.5 Ignition Source

7.5.1 The probability of a flammable cloud being ignited (delayed ignition) as the cloud moves downwind over an ignition source could be predicted. The offsite ignition sources are identified and they are summarised in the following paragraphs.

7.5.2 Roads are defined as line source. The following assumptions are applied to estimate the presence factor of the line source and the ignition probability [3].

- Probability of ignition for a vehicle is taken as 0.4 in 60 seconds; and
- Traffic density is based on the projected peak traffic flow as adopted for population estimation

Table 7-3 – Summary of Line Ignition Source

Item	Traffic Density (veh/hr)			
	Peak Hour	Weekday Day	Weekend Day	Night
Yuen Long Highway	22,660	22,449	21,063	10,981
Castle Peak Rd – Lam Tei	4,515	4,473	4,197	2,188
Kong Sham Western Highway	2,313	2,292	2,150	1,121
Fuk Hang Tsuen Rd	770	763	716	373
Fuk Hang Tsuen Lane	115	114	107	56

7.5.3 Population area is defined as area source. The potential sources of ignition include activities such as cooking, smoking, use of heating and electrical appliance. The ignition probability, which is derived from population densities in the concerned area, is taken as 0.01 per person [3].

7.6 Meteorological Data

7.6.1 Meteorological data are required for consequence modelling and risk calculation. In the consequence modelling, both wind speed and stability class are required to determine the degree of turbulent in atmosphere which affects the dispersion of the released gas. In addition, wind-rose probabilities are required to calculate the risk level in each of the release directions from the pipeline.

7.6.2 Meteorological data have been obtained from Tuen Mun Government Office Weather Station where wind speed, stability class, weather class and wind direction are available. The data are rationalized into six combinations of wind speed and stability class [9]. The probabilities for six combinations for both day-time and night-time are shown in Table 7-4 and Table 7-5 respectively and they have been applied in the current study.

Table 7-4 – Weather Probability (Day-time)

Direction	3B	1D	4D	7D	3E	2F	Total
N	18.34	3.72	6.58	0.22	3.02	4.84	36.72
NE	1.70	0.36	0.42	0.06	0.30	0.54	3.38
E	1.28	0.2	0.48	0.08	0.16	0.32	2.52
SE	15.42	1.48	4.34	0.50	0.70	1.10	23.54
S	15.68	1.44	1.82	0.20	0.84	0.92	20.9
SW	3.92	0.56	0.28	0.00	0.10	0.42	5.28
W	2.86	0.5	0.26	0.00	0.06	0.74	4.42
NW	2.32	0.32	0.02	0.00	0.10	0.52	3.28
Total	61.52	8.58	14.2	1.06	5.28	9.40	100

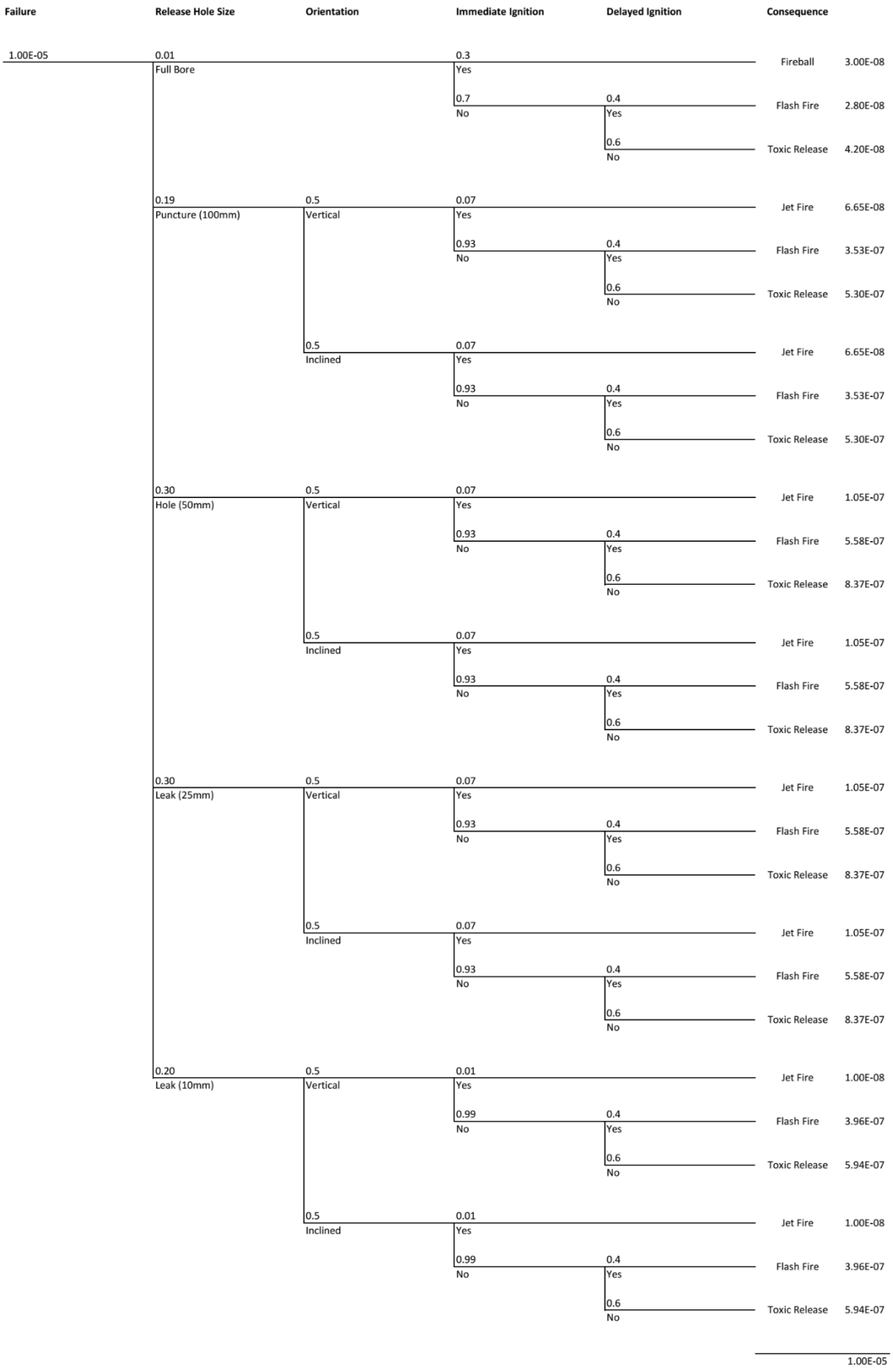
Table 7-5 – Weather Probability (Night-time)

Direction	3B	1D	4D	7D	3E	2F	Total
N	0.00	0.02	9.94	0.34	10.08	20.6	40.98
NE	0.00	0.08	0.62	0.02	1.04	3.4	5.16
E	0.00	0.00	1.12	0.14	1.60	3.86	6.72
SE	0.00	0.02	8.82	0.28	7.68	8.48	25.28
S	0.00	0.00	1.46	0.00	2.84	5.96	10.26
SW	0.00	0.00	0.10	0.00	0.48	3.20	3.78
W	0.00	0.00	0.10	0.00	0.26	5.30	5.66
NW	0.00	0.00	0.02	0.02	0.22	1.94	2.20
Total	0.00	0.12	22.18	0.80	24.2	52.74	100

7.7 Event Tree Analysis

7.7.1 Fault sequences with individual frequencies have been generated using event tree analysis. Event tree has been developed to systematically identify the sequence of development of ultimate hazardous events after an initial leakage incident. The event tree for the underground high pressure pipeline is shown in **Figure** 7-1. The possible ultimate hazardous events include fireball, jet fire, flash fire and toxic release.

Figure 7-1 Event Tree for Underground High Pressure Town Gas Pipeline



8. Consequence Assessment

8.1 Source Term and Dispersion Modeling

8.1.1 Consequence analysis includes both source term modeling and dispersion modeling.

8.1.2 Source term modeling is a model used to describe how materials are discharged from the process (e.g. pipeline). It provides a description of the discharge rate, the total quantity discharged and the state of the discharge (i.e. solid/liquid/gas).

8.1.3 Dispersion modeling is subsequently used to describe how the material is transported and dispersed downwind.

8.1.4 In the study, the software PHAST 8.0, which is coded by DNV, has been used to conduct both the source term and dispersion modeling for different physical effects. The physical effects considered in the study are discussed in the following sections.

8.2 Fireball

8.2.1 Immediate ignition following a catastrophic release of flammable town gas from the high pressure pipeline will result in a fireball and gives a massive transient dose of thermal radiation. Fireball is not significantly influenced by weather, wind direction or wind speed due to its short duration, large size and high intensity. The size of the fireball and its thermal radiation are estimated by using the software PHAST.

8.2.2 Due to the high thermal intensity inside the fireball, outdoor population staying inside the fireball (i.e. within the diameter of the fireball) is subject to 100% fatality rate [3]. A lower fatality rate of 50% is assumed for indoor population as they are partially shielded by the building [3].

8.3 Flash Fire

8.3.1 When town gas is not ignited immediately after being released, it will form a flammable gas plume which travels along the distance. If the plume comes into contact with an ignition source in an open space while it is still within its flammable limits, a flash fire will occur.

8.3.2 Due to the high thermal intensity, it is considered that there is no possibility for escape from the flash fire and a fatality rate of 100% for outdoor population inside the flammable cloud is assumed. The short duration of the flash fire means that thermal dose received by a person standing outside the flash fire is not significant and therefore, no fatality is assumed outside the flash fire envelope. A lower fatality rate of 10% is assumed for indoor population as they are partially shielded by the building [3].

8.4 Jet Fire

8.4.1 An immediate ignition of town gas released with momentum from the high pressure pipeline results in a jet fire. The thermal radiation emitted from the jet fire will affect the population in immediate vicinity.

8.5 Vapor Cloud Explosion (VCE)

8.5.1 Vapor cloud explosion could occur when a flammable vapor is ignited in a confined or partially confined space. The blast wave generated by the explosion could impose overpressure on human body and cause fatal injury.

8.5.2 The town gas pipeline is operated at a high pressure of 35 bar, the gas would be ejected with a large upward momentum upon release. In addition, town gas has a density smaller than air which makes it buoyant in nature. Because of the large release momentum and buoyant nature of the gas, the gas would be quickly dispersed upward into the atmosphere to avoid gas accumulation on the ground level from happening. Therefore, vapor cloud explosion is not further considered.

8.6 Thermal Radiation

8.6.1 Thermal radiation emitted from a fire (e.g. jet fire) could cause harm and fatality to a person standing nearby.

8.6.2 In this study, the following probit equation, as recommended by the PHAST, will be used to assess the fatality rate due to the thermal effect with the exposure duration estimated to be 30s:

$$Probit = -36.38 + 2.56 \ln\left(I^{4/3} * t\right)$$

where, I is thermal flux (kW/m^2) and t is exposure duration (sec)

8.6.3 The fatality rates for outdoor and indoor population are assumed to be 100% and 10% respectively [3].

8.7 Toxicity

8.7.1 In case the released town gas is not ignited, it may cause toxic effect to people due to the presence of carbon monoxide.

8.7.2 In this study, the following probit equation, as recommended by the PHAST, will be used to assess the fatality rate due to the toxic effect with the exposure duration estimated to be 30 mins:

$$Probit = -7.4 + ln(C * t)$$

where, C is concentration (mg/m3) and t is exposure duration (min)

9. Population

9.1 Background Population

9.1.1 The existing population living and working within 200m from the underground high pressure town gas pipeline have been identified through desktop review and site survey.

9.1.2 According to the population projected by the Planning Department, the population for the Tertiary Planning Unit (TPU) 4.2.5 and 4.4.1 would be decreased by 7% and 13% respectively from 2021 to 2027 [7], as shown in **Table 9-1**. As shown in **Figure** 9-1**,** both TPU 4.2.5 and 4.4.1 cover the study area considered in the current study, this means that the population near the pipeline has been decreasing over the years. However, to err on conservative, the existing population (i.e. 2026) are applied for the year 2032 without reduction.

Figure 9-1 Boundary of TPU 4.2.5 and 4.4.1

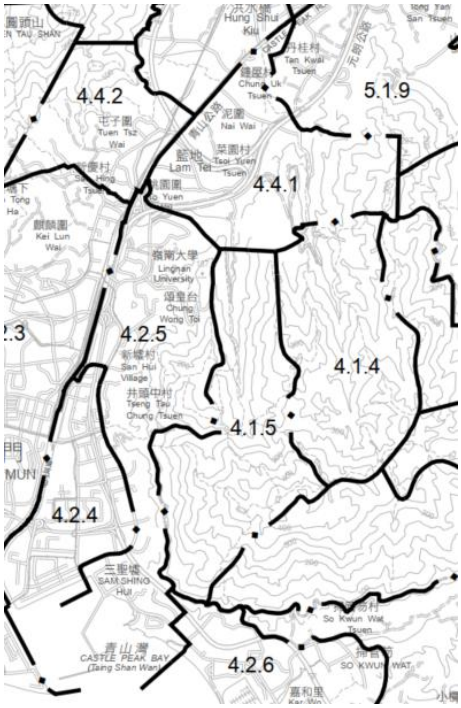


Table 9-1 - Projected Population by Tertiary Planning Unit (TPU) 2021 to 2027

TPU	Projected Population						
	2021	2022	2023	2024	2025	2026	2027
4.2.5	72,800	71,200	71,100	70,000	70,500	68,900	67,600
4.4.1	21,300	20,500	20,500	20,100	19,600	19,000	18,600

9.1.3 The average household size in Tuen Mun was 2.6 from Year 2022 to 2024 and it was reduced to 2.5 in Year 2025 [1]. To err on conservative, the average household size is taken as 2.6 in the current study.

9.1.4 The population data for the existing population for 2026 and 2032 are summarised in **Table 9-4**, **Table 9-5** and **Figure** 9-2.

9.2 Proposed Development

Construction Phase

9.2.1 Considering the scale of the proposed development, the number of construction workers is assumed to be 900 workers.

Operation Phase

9.2.2 The proposed development includes a development of 5 residential buildings which will provide a total of 546 residential units. The average household size in Tuen Mun was 2.6 from Year 2022 to 2024 and it was reduced to 2.5 in Year 2025 [1]. To be on conservative, the average household size is taken as 2.6 in the current study. Therefore, the total residential population is 1,420.

9.2.3 There will be a 3-storey non-domestic block that accommodates retail on G/F and social welfare facilities on 1/F and 2/F.

9.2.4 The total area of the shops is 370 m^2, it is assumed that the population is 100.

9.2.5 The total Gross Floor Area (GFA) of the Social Welfare Facility is 840m^2 and it is intended for the Residential Care Home for the Elderly. The facilities will provide 36 beds with 5 staff to be deployed to maintain the daily operation of the facility. Assuming there is 1 visitor per bed, the today population inside the facility is 77.

9.2.6 There are clubhouses which serve residents inside the development, the number of staff is estimated as 8.

9.2.7 Therefore, the total population of the proposed development will be 1,605.

9.3 Road Population

9.3.1 The following five roads are covered in the current study:

- Yuen Long Highway
- Castle Peak Road - Lam Tei section
- Fuk Hang Tsuen Road
- Fuk Hang Tsuen Lane
- Kong Sham Western Highway

9.3.2 The traffic flow data for the first 4 roads are obtained from the Traffic Impact Assessment (TIA) conducted for the proposed development [10]. The traffic flow data stated in the TIA are forecast to 2035, and they are conservatively applied as Year 2032 in this assessment. Since the TIA does not cover the Kong Sham Western Highway, traffic data from Annual Traffic Census (2020 to 2024) published by the Transport Department have been made referenced.

9.3.3 The 2024 Annual Traffic Census published by the Transport Department provided a detailed description of the vehicle occupancy (i.e. no of persons per vehicle) for Yuen Long Highway. The average occupancy is evaluated as 2.2.

9.3.4 The speed is referred to the posted speed limit of the road.

9.3.5 The road population is calculated by applying the following equation:

$$Person\ per\ km = \frac{No\ of\ vehicles\ per\ hour * no\ of\ persons\ per\ vehicle}{Speed}$$

9.3.6 The road population data are presented in **Table 9-5**. A summary of the analysis is given in **Appendix B**.

9.4 Time Modes and Indoor Ratio

9.4.1 The population living and working near the underground high pressure town gas pipeline varies with time and day of the year. In order to take the temporal changes into account, four time-modes have been specified in the study. The definition and weighting of these periods are summarised in **Table 9-2** and indoor/outdoor ratios for different population are shown in **Table 9-3**.

Table 9-2 – Definition of Time Modes

Time Mode	Description	Period	Hours per Week	Weighing per Year
1	Peak Hour	Monday to Saturday (7:00 to 9:00 & 18:00 to 20:00)	24	0.143
2	Weekday Day	Monday to Saturday (9:00 to 18:00)	54	0.321
3	Weekend Day	Sunday (7:00 to 19:00)	12	0.071
4	Night	Monday to Saturday (20:00 to 7:00)	79	0.470
		Sunday (19:00 to 7:00)		

Table 9-3 – Indoor / Outdoor Ratio for Different Population Categories

Population Category	Indoor / Outdoor Ratio
Residential	0.95 (0.05)
Industrial / Office	0.95 (0.05)
Playground	0.00 (1.00)
Road	0.00 (1.00)

Table 9-4 – Fixed Population Data

Item	Name	Population		Indoor Ratio	Occupancy Factor (%)				Remarks
		2026	2032		Peak Hour	Working Day	Weekend Day	Night	
1	Nai Wai Village	276	276	0.95	50	50	70	100	• 106 units, obtained from GeoInfo map and site survey • Household size is 2.6 [1]
2	Fuk Hang Tsuen Village Lower Part 1	530	530	0.95	50	50	70	100	• 204 units, obtained from GeoInfo map and site survey • Household size is 2.6 [1]
3	GreenView	83	83	0.95	50	50	70	100	• 32 units, obtained from GeoInfo map and site survey • Household size is 2.6 [1]
4	Botania Villa	842	842	0.95	50	50	70	100	• According to Centaline Property, there is a total of 9 blocks providing 726 units, in average 81 units per block. • Only block 7 to 10 fall inside the Study Area. • Household size is 2.6 [1]
5	Fuk Hang Tsuen Village Lower Part 2	185	185	0.95	50	50	70	100	• 71 units, obtained from GeoInfo map and site survey • Household size is 2.6 [1]
6	Wing Hei Garden	47	47	0.95	50	50	70	100	• 18 units, obtained from GeoInfo map and site survey • Household size is 2.6 [1]
7	Brighten Garden	273	273	0.95	50	50	70	100	• 105 units, obtained from GeoInfo map and site survey • Household size is 2.6 [1]
8	Tuen Mun San Tsuen	530	530	0.95	50	50	70	100	• 204 units, obtained from GeoInfo map and site survey • Household size is 2.6 [1]

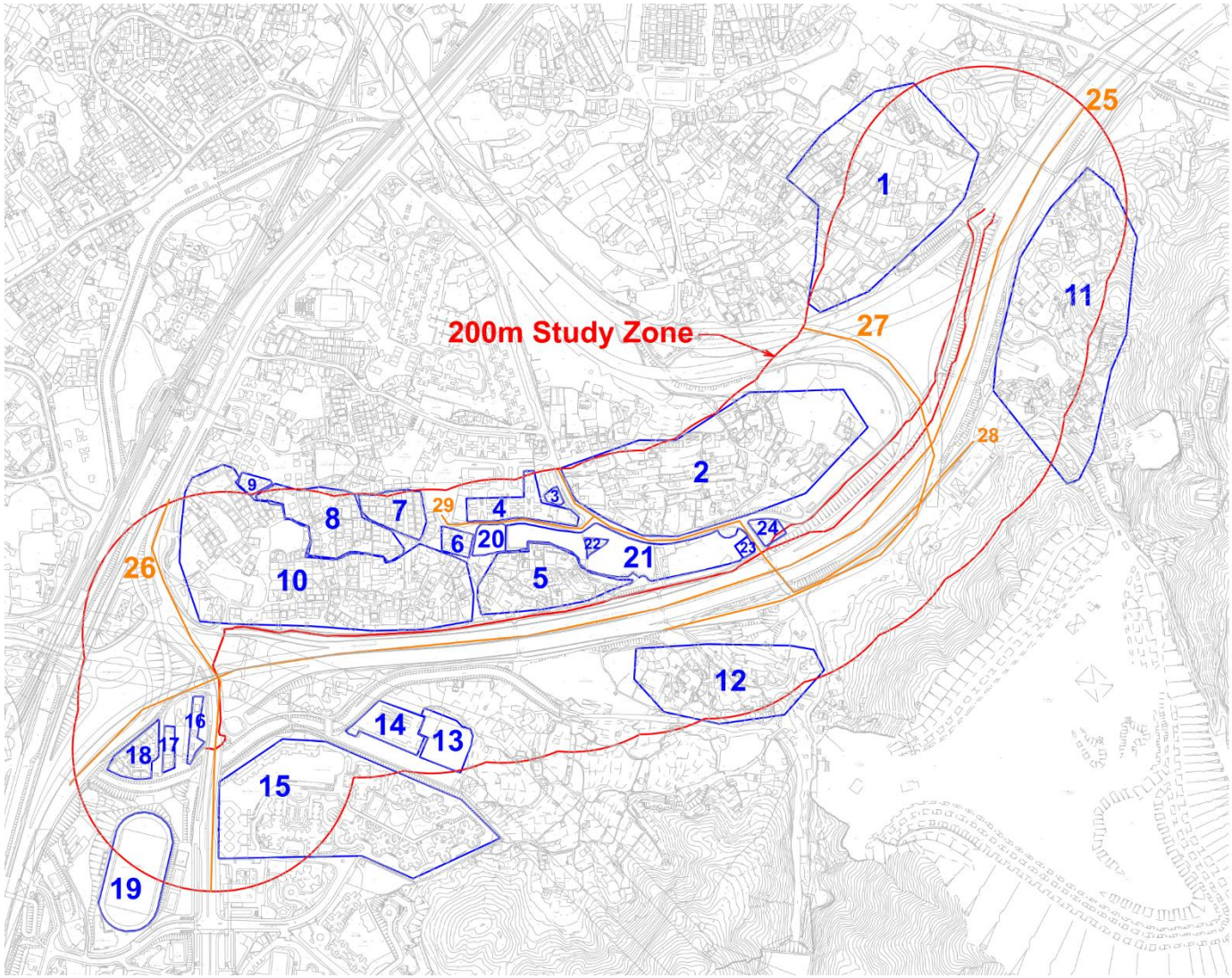
9	Chik Yuen Garden	62	62	0.95	50	50	70	100	• 24 units, obtained from GeoInfo map and site survey • Household size is 2.6 [1]
10	To Yuen Village	1,794	1,794	0.95	50	50	70	100	• 690 units, obtained from GeoInfo map and site survey • Household size is 2.6 [1]
11	Fuk Hang Tsuen Village Upper Part 2	286	286	0.95	50	50	70	100	• 110 units, obtained from GeoInfo map and site survey • Household size is 2.6 [1]
12	Fuk Hang Tsuen Village Upper Part 1	130	130	0.95	50	50	70	100	• 50 units, obtained from GeoInfo map and site survey • Household size is 2.6 [1]
13	Carpark	5	5	0	100	100	50	10	Population obtained by site survey
14	Barbecue Site	50	50	0	5	10	10	100	Population obtained by site survey
15	Fu Tai Estate	15,400	15,400	0.95	50	50	70	100	Population obtained from the Housing Authority
16	18 RoseWood	47	47	0.95	50	50	70	100	• 18 units, obtained from Centanet and site survey • Household size is 2.6 [1]
17	Village House next to 18 RoseWood	23	23	0.95	50	50	70	100	• 9 units, obtained from GeoInfo map and site survey • Household size is 2.6 [1]
18	Recycling Yard	4	4	0	50	100	10	0	• Floor area is 2900m^2; and • Population density is 700m^2/worker [6]
19	Ling Nan University Outdoor Sports Ground	10	10	0	10	100	100	0	Population obtained by site survey
20	Comprehensive Development Area at Lot 2883 in D.D. 130 Lam Tei	117	117	0.95	50	50	70	100	• 15 residential blocks, 3 storey per block [5] • Household size is 2.6 [1]

21	Proposed Development of current Project								
a	Construction Phase	-	900	0	20	100	0	0	Refer to **Section 9.2**
b	Operation Phase	-	1,605	0.95	50	50	70	100	Refer to **Section 9.2**
22	Agricultural Fa Pau Committee	-	4	0.5	20	100	0	0	Population obtained by site survey
23	Fuk Hang Tsuen Village Office	10	10	0.95	10	100	30	0	Population obtained by site survey
24	Sitting-out Area and Fuk Hang Tsuen Basketball Court	5	5	0	10	100	100	0	Population obtained by site survey

Table 9-5 – Road Population (2032)

Item	Road	Population (persons per km)			
		Peak Hour	Working Day	Weekend Day	Night
25	Yuen Long Highway	712	706	662	345
26	Castle Peak Rd - Lam Tei	199	197	185	96
27	Kong Sham Western Highway	102	101	95	49
28	Fuk Hang Tsuen Rd	34	34	32	16
29	Fuk Hang Tsuen Lane	5	5	5	3

Figure 9-2 Population Map



10. Risk Results

10.1 Individual Risk

10.1.1 The individual risk result for the high pressure underground town gas pipeline is shown in **Figure** 10-1 and **Figure** 10-2. The highest individual risk level is 1E-8 per year which is much lower than the 1E-5 per year. It is complied with the Hong Kong Risk Guideline.

Figure 10-1 Individual Risk Contour (South Route)

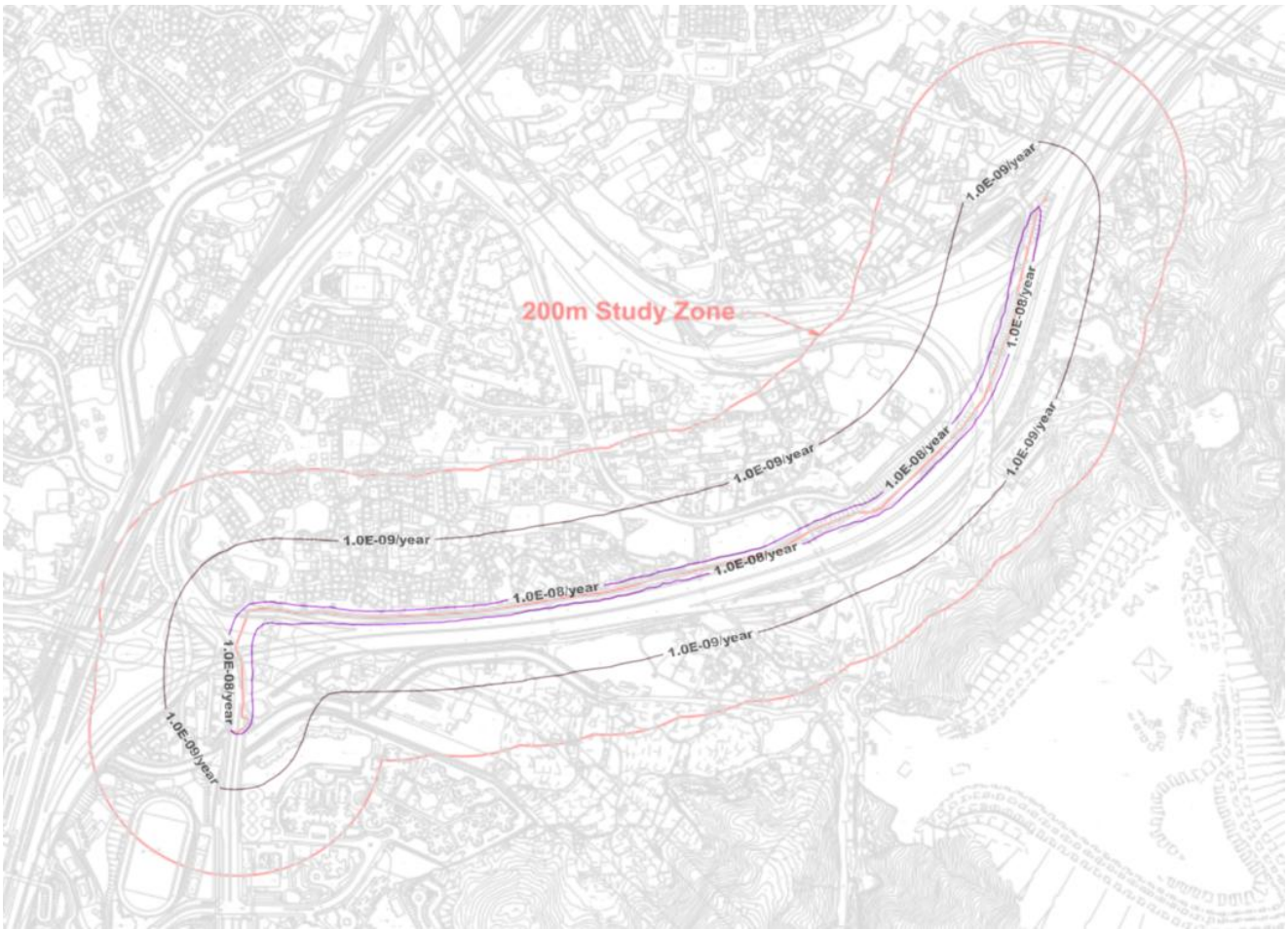
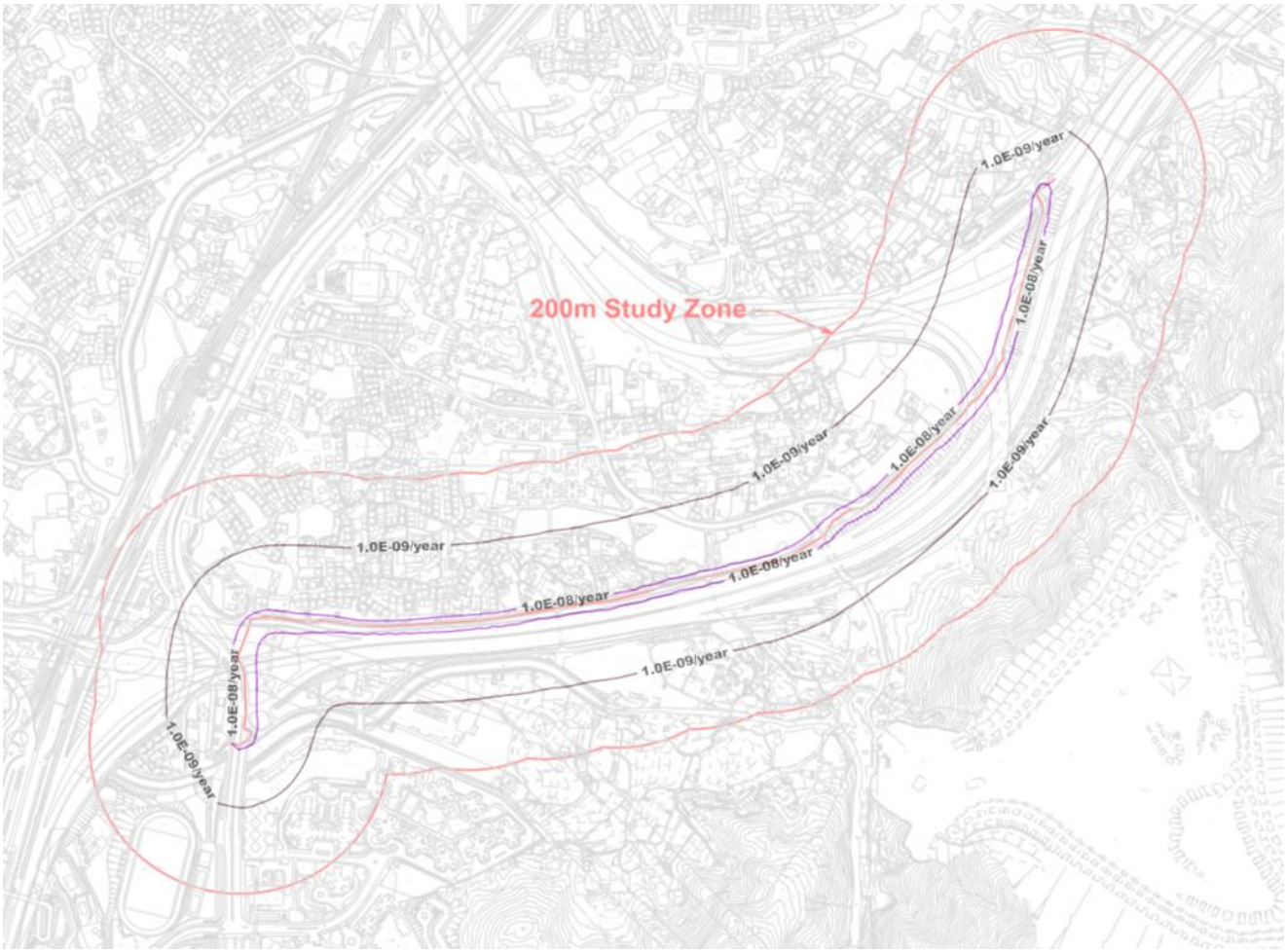


Figure 10-2 Individual Risk Contour (North Route)



10.2 Societal Risk

10.2.1 The societal risk levels of both South Route and North Route of the high pressure town gas pipeline are within “Acceptable” region of the Hong Kong Risk Guidelines for both Construction phase and Operation phase of the proposed development, as shown from **Figure** 10-3 to **Figure** 10-6.

10.2.2 The overall PLL for the South Route and North Route of the high pressure town gas pipeline during construction phase are 8.47E-06 and 7.41E-06 respectively. The overall PLL for the South Route and North Route of the high pressure town gas pipeline during operation phase are 8.86E-06 and 7.86E-06 respectively. The breakdown of the PLL are given from **Table 10-1** and **Table 10-4**.

Figure 10-3 FN Curve for Construction Phase (South Route)

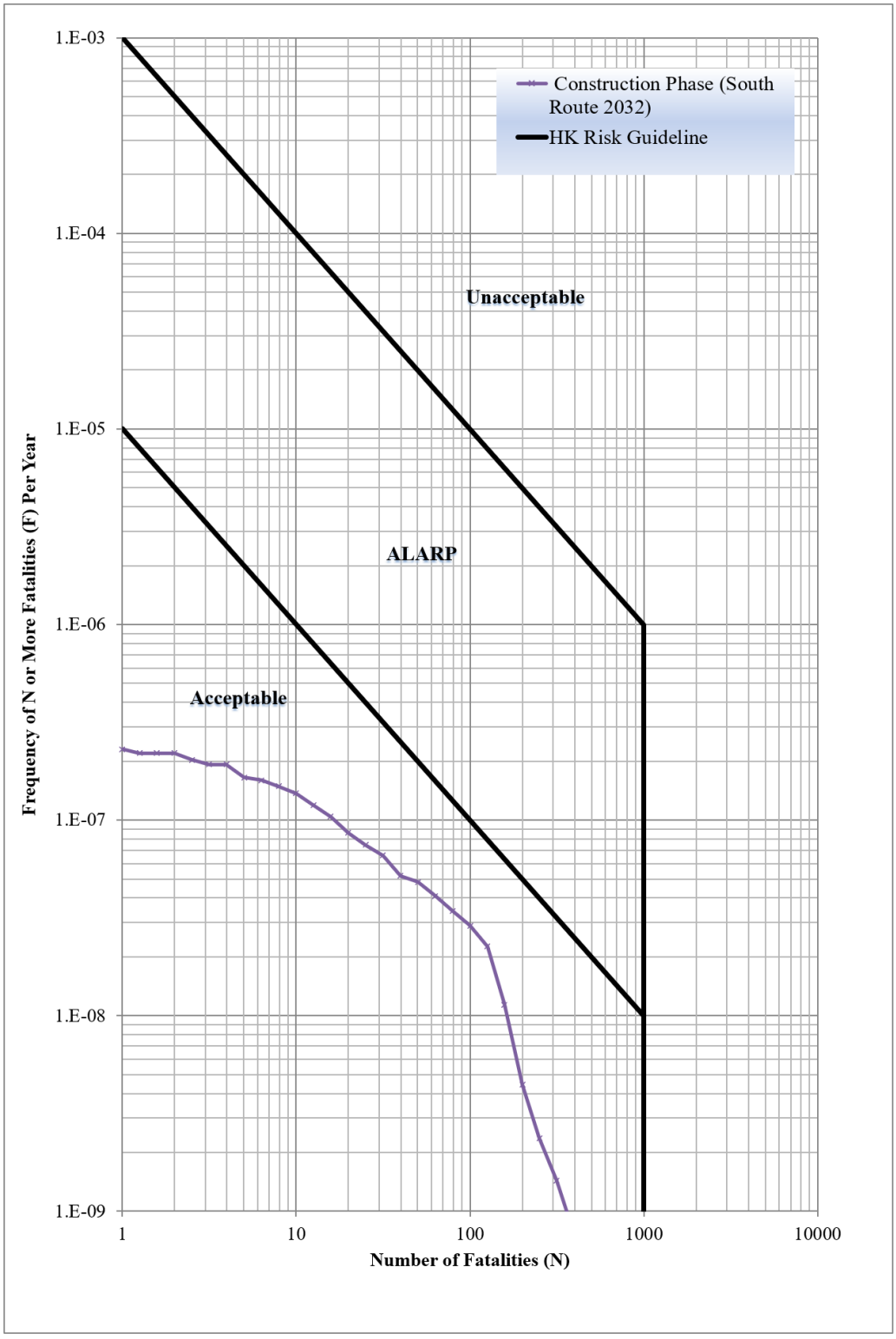


Figure 10-4 FN Curve for Construction Phase (North Route)

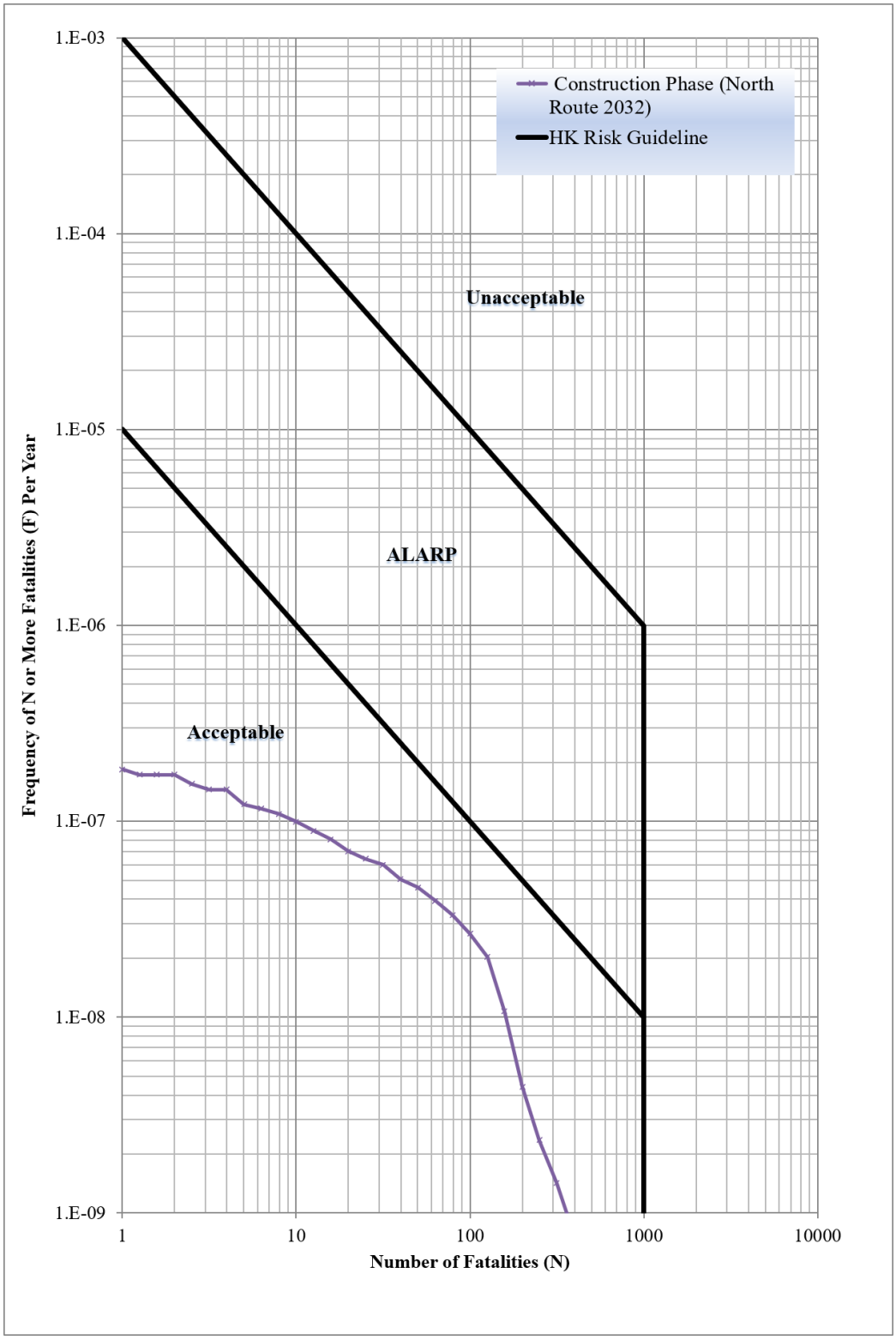


Figure 10-5 FN Curve for Operation Phase (South Route)

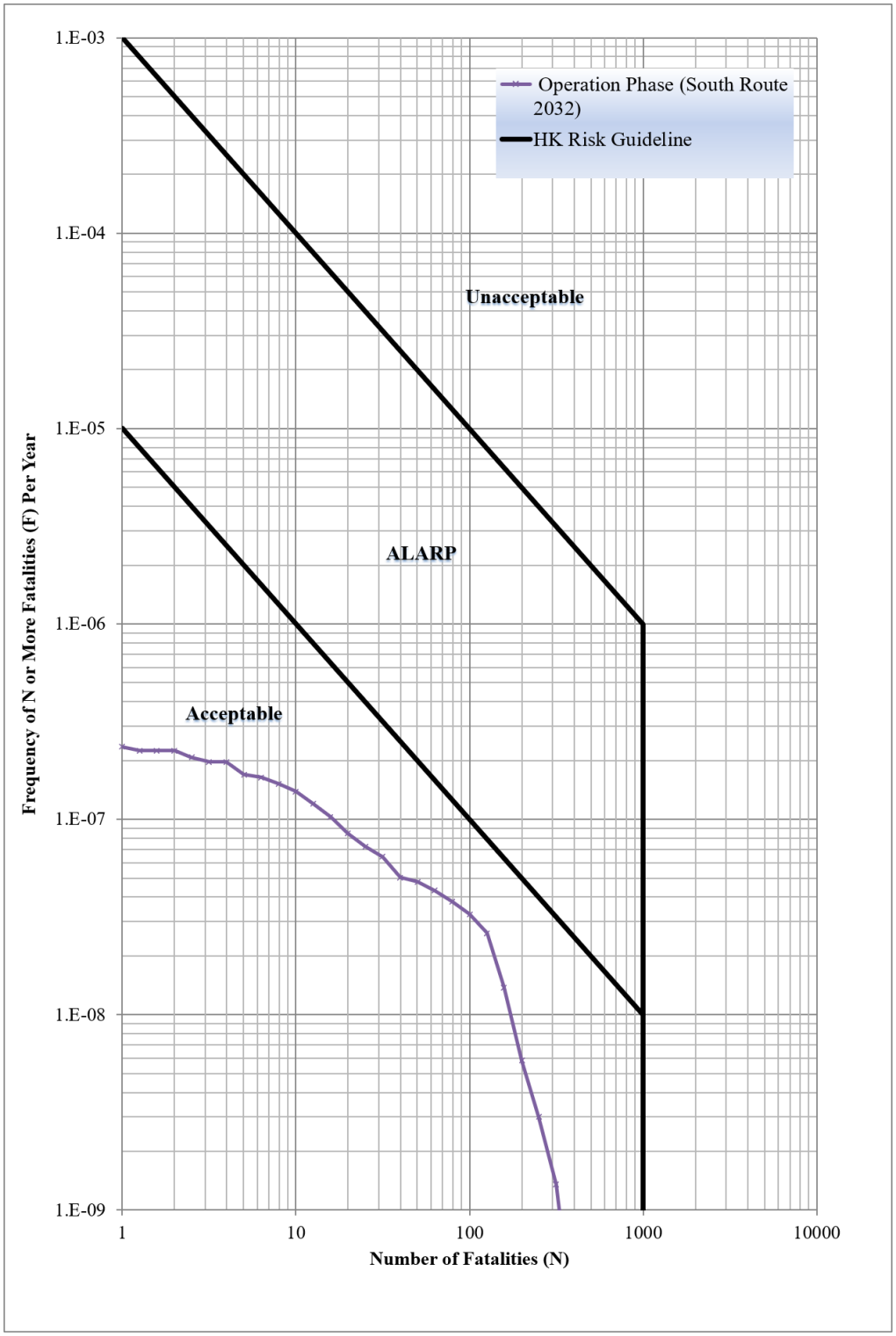


Figure 10-6 FN Curve for Operation Phase (North Route)

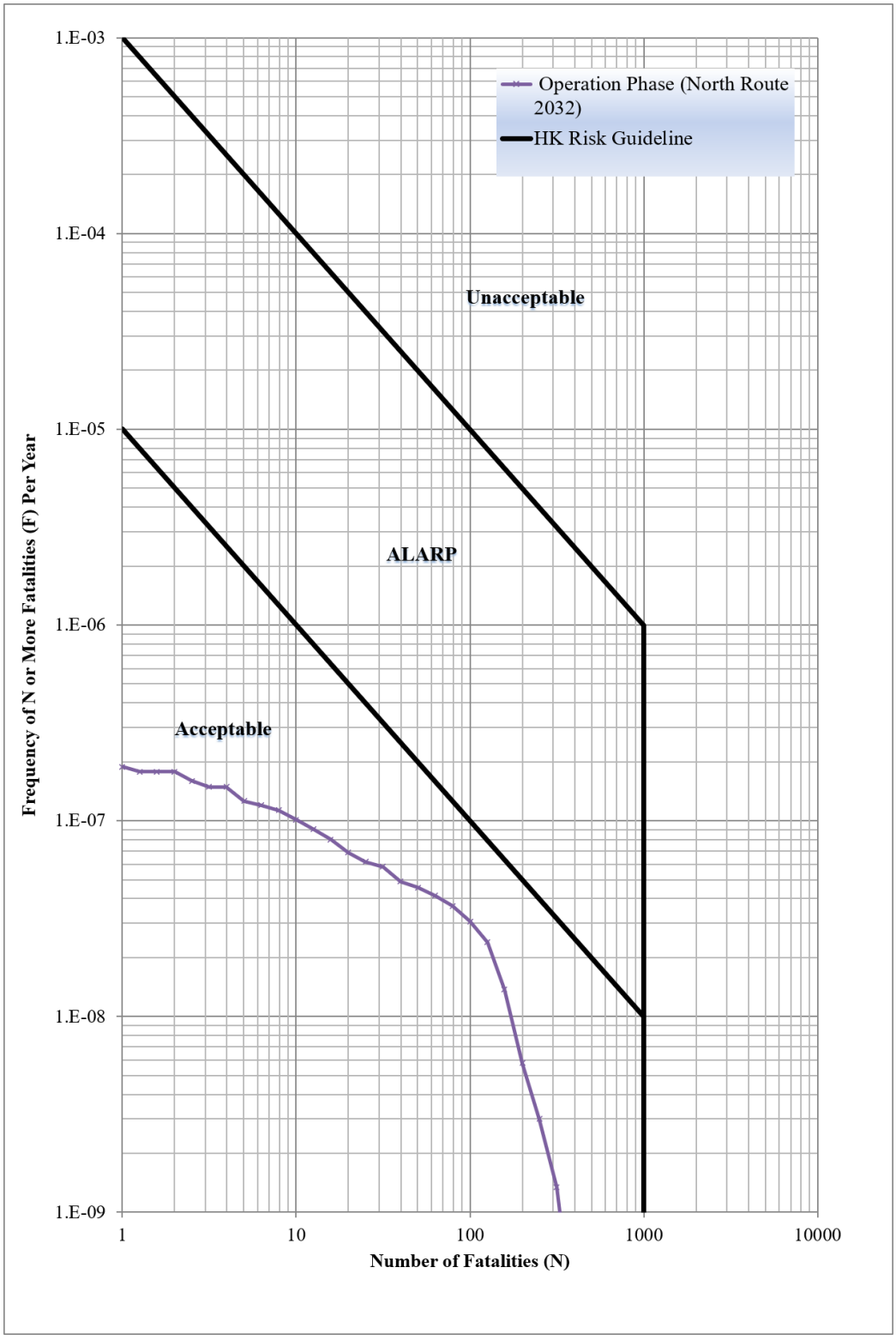


Table 10-1 – PLL Breakdown for South Route (Construction Phase)

Scenario	PLL	Percentage (%)
Rupture Fireball	6.21E-06	73.3
100mm_Inclined_Jef Fire	1.46E-06	17.3
100mm_Vertical_Jef Fire	7.60E-07	9.0
Others	4.00E-08	0.4
Total	8.47E-06	100

Table 10-2 – PLL Breakdown for North Route (Construction Phase)

Scenario	PLL	Percentage (%)
Rupture Fireball	5.96E-06	80.4
100mm_Inclined_Jef Fire	9.69E-07	13.1
100mm_Vertical_Jef Fire	4.59E-07	6.2
Others	2.20E-08	0.3
Total	7.41E-06	100

Table 10-3 – PLL Breakdown for South Route (Operation Phase)

Scenario	PLL	Percentage (%)
Rupture Fireball	6.61E-06	74.6
100mm_Inclined_Jef Fire	1.45E-06	16.4
100mm_Vertical_Jef Fire	7.59E-07	8.6
Others	4.10E-08	0.4
Total	8.86E-06	100

Table 10-4 – PLL Breakdown for North Route (Operation Phase)

Scenario	PLL	Percentage (%)
Rupture Fireball	6.42E-06	81.6
100mm_Inclined_Jef Fire	9.63E-07	12.3
100mm_Vertical_Jef Fire	4.59E-07	5.8
Others	1.80E-08	0.3
Total	7.86E-06	100

11. Review of Zoning Requirements for Underground High Pressure Pipe

11.1 Identification of Area Type of Proposed Development

11.1.1 According to IGEM/TD/1, the location adjacent to a pipeline should be categorised according to population density and/or the nature of the immediate surrounding area. The classifications are defined as follow:

- 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 with multi-storey buildings, hospitals, major transport hub, public meeting places etc

11.1.2 The total area of the Proposed Development is 14,036m^2 (i.e. 1.4036 hectares) and the estimated population is 1,640. This corresponds to a population density of 1,168 persons per hectare. (i.e. exceeding 30 persons per hectare). Therefore, the Proposed Development does not fall within Type R or Type S classification.

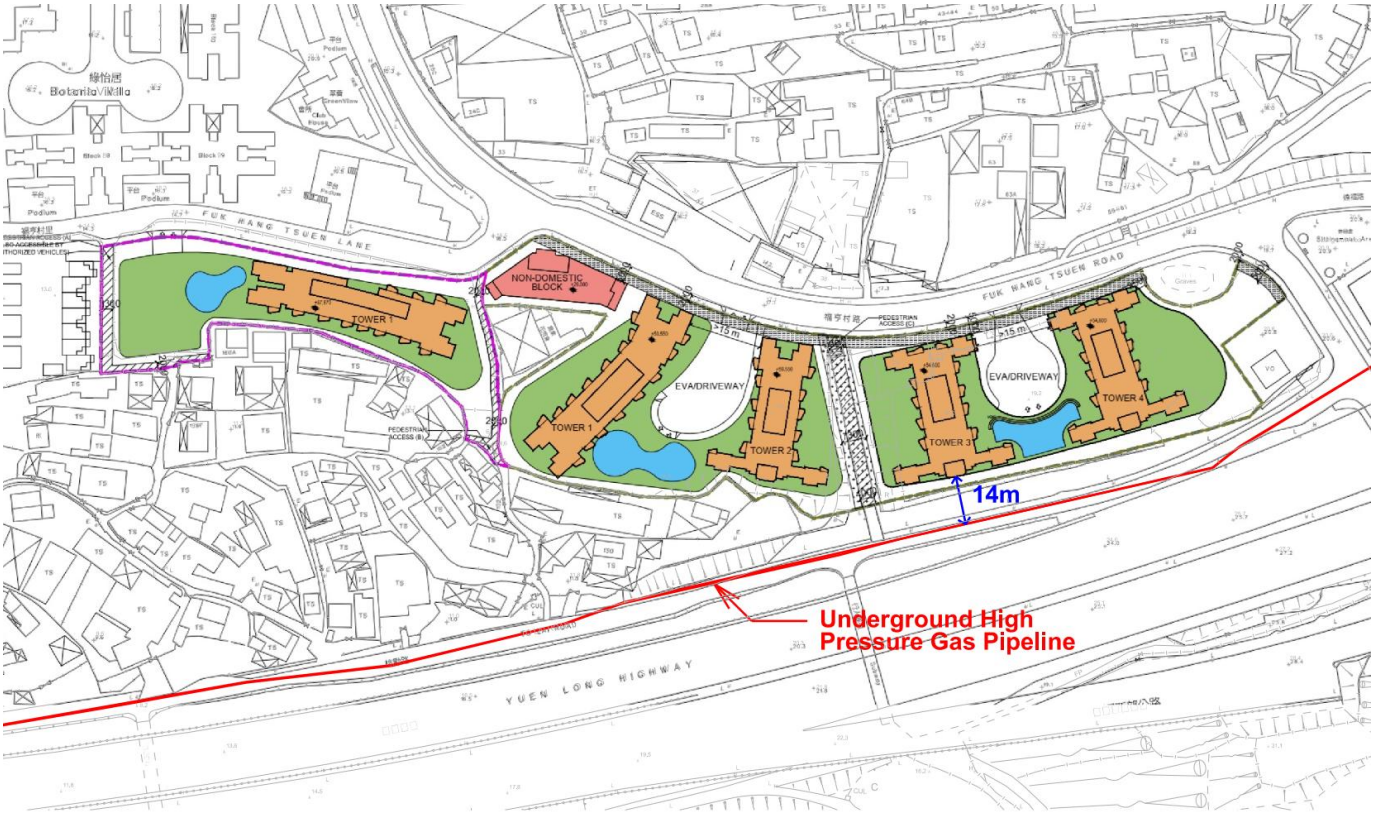
11.1.3 Considering the land uses and scale of the Proposed Development and the nearby area, the area is not central area of town or cities. Accordingly, the Proposed Development is considered as a Type H area.

11.2 Review of Minimum Building Proximity Distance (BPD)

11.2.1 As IGEM/TD/1 does not specify BPD criteria for Type H area, BPD recommendation for Type S have been adopted as the reference basis. The minimum BPD for Type S area is 3m.

11.2.2 The minimum separation distance between the underground high pressure town gas pipeline and nearest building inside the Proposed Development is 14m, as shown in **Figure** 11-1, which is larger than the requirement of 3m as specified in the IGEM/TD/1.

Figure 11-1 Minimum Separation Distance between Normally Occupied Building inside Proposed Development and Town Gas Pipeline



11.3 Safety Evaluation and Risk Analysis

11.3.1 The Proposed Development is classified as Type H Area. With reference to IGEM/TD/1, the Proposed Development shall be subjected to detailed assessment by means of safety evaluation. Therefore, a QRA study has been conducted which concludes that both individual risk and societal risk are complied with the Hong Kong Risk Guidelines.

12. Conclusions

12.1.1 A review has been conducted to assess the risk associated with the operation of the existing and to-be-diverted underground high pressure town gas pipeline during the construction and operation phase of the Project.

12.1.2 The review concluded that the individual risk level of the gas pipeline is below 1E-05 per year, which is complied with the Hong Kong Risk Guidelines, for both construction phase and operation phase of the Project. The societal risk of the gas pipeline falls within “Acceptable” region for both construction phase and operation phase of the Project.

12.1.3 As a matter of good practices, the following recommendations are recommended:

- Conduct a utility survey and trial pit inspection for any underground works before the commencement of construction works to reduce the probability of inadvertently damaging the underground town gas pipelines;
- Liaise with Hong Kong and China Gas Company Limited on any additional construction requirements specific to the Development Site; and
- Establish a proper communication channel between the Project Proponent and the Hong Kong and China Company Limited.

13. References

1. Census and Statistics Department (2022 – 2025), Population and Household Statistics Analysed by District Council District.
2. EGIG (2023), Gas Pipeline Incidents, 12th Report of the European Gas Pipeline Incident Data Group (period 1970 – 2022).
3. EMSD (2021), Guidance Note on Quantitative Risk Assessment Study for High Pressure Town Gas Installations in Hong Kong.
4. HKSAR (2017), Press Release, LCQ7: Incidents of Water Mains Burst.
5. I Architects Limited (2022), Broad Development Parameters of the Applied Use/Development in respect to Application No. A/TM-LTYY/383.
6. Planning Department of the HKSAR (2025), Hong Kong Planning Standards and Guidelines.
7. Planning Department of the HKSAR (2025), Projections of Population Distribution 2023 – 2031.
8. Transport Department of the HKSAR (2020 to 2024), Annual Traffic Census.
9. TNO (2005), Guidelines for Quantitative Risk Assessment “Purple Book”.
10. AtkinsRéalis (2026), Traffic Impact Assessment for the proposed amendment to the approved Lam Tei and Yick Yuen Outline Zoning Plan No. S/TM-LTYY/14 from “Comprehensive Development Area”, “Green Belt” and “Residential (Group B) 3” zone to “ Residential (Group B) 4” zone at Lot Nos. 837 RP (part), 839 S.A RP (part), 841 (part), 1035 RP, 1037 RP and 2527 S.F RP (part) in D.D. 130 and Adjoining Government Land at Lam Tei, Tuen Mun.

APPENDICES

Appendix A.

Correspondence from HKCG

From: Hui Jacqueline T.Y. [mailto:ty.hui@towngas.com]
Sent: Monday, July 06, 2026 5:12 PM
To: IP Wai Yi, Alison <alison.ip@hld.com>
Cc: YIU Chi Wai, Albert <albert.yiu@hld.com>; YUE Lit Fung, Owen <owen.yue@hld.com>; Lai Kam To <kt.lai@towngas.com>; Ng Brian H.W. <brian.ng@towngas.com>; Chan Remus Y.C. <remus.chan@towngas.com>; Cheng Jack W. <cheng.jack@towngas.com>
Subject: Re: Lam Tei Rezoning - QRA - RFI / Towngas

Dear Alison

Please find the concerned existing 750mm high pressure pipeline technical information in the following table and the drawing as attached.
Should Atkins require further information, please feel free to contact me at 29631132 or Mr. Jack Cheng at 98038817.

Thanks & regards
Jacqueline Hui

Technical Specification for the existing and proposed 750mm HPTGP

Parameter	Specification
Pipe Diameter (Nominal)	750mm
Pipe wall thickness	12.7mm
Design Pressure	35 barg
Maximum Operating Pressure	35 barg
Hydraulic Test Pressure	900 psi
Pipe Material	Steel
External Coating	400 micron of fusion bonded epoxy coating
Internal Coating	50 Micron Two Pack Epoxy
Year of Construction	1991-1994
Backfilling Material	Surrounded by 150mm Thick Zone 2 fresh sand
Cathodic Protection	Sacrificial Anode at about 300 m Interval
Minimum Depth	1.1m
Material Grading (Pipe/ Fitting)	API 5L X52
Jointing Method	Butt Welding
Welding Specification	Welding complied with BS4515
Non-Destructive Test of Jointing	100% X-Ray
Isolation Valves (Cameron Full Bore Ball Valve)	Upstream: Valves in Tai Tao Tsuen Downstream: Valve in Lam Tei Interchange
Pipe Length between isolation valves	3.7km

Appendix B.

Traffic Flow Analysis

Yuen Long Highway

Table 1: Peak Hour Traffic Flow for Construction Phase and Operation Phase

Year	Description	Peak Hour Traffic Flow (veh/hr)	Remarks
2032	Construction Phase and Operation Phase	22,660	• The traffic flow is referenced from the Traffic Impact Assessment conducted for the proposed development

Table 2: Estimated Traffic Flow

Item	Peak Hour	Weekday Day	Weekend Day	Night_Weekday *	Night_Weekend *
Traffic flow contribution	23.6	52.5	65.7	23.9	34.3
No of hours	4	9	12	11	12
Hourly traffic flow	22,660	22,449	21,063	8,349	10,981
No of persons per km	712	706	662	263	345

Remark: [*]: The largest value (i.e. 345) will conservatively be applied for the night time traffic flow for both weekday and weekend.

Castle Peak Road – Lam Tei

Table 1: Peak Hour Traffic Flow for Construction Phase and Operation Phase

Year	Description	Peak Hour Traffic Flow (veh/hr)	Remarks
2032	Construction Phase and Operation Phase	4515	• The traffic flow is referenced from the Traffic Impact Assessment conducted for the proposed development

Table 2: Estimated Traffic Flow

Item	Peak Hour	Weekday Day	Weekend Day	Night_Weekday *	Night_Weekend *
Traffic flow contribution	23.6	52.5	65.7	23.9	34.3
No of hours	4	9	12	11	12
Hourly traffic flow	4,515	4,473	4,197	1,664	2,188
No of persons per km	199	197	185	73	96

Remark: [*]: The largest value (i.e. 96) will conservatively be applied for the night time traffic flow for both weekday and weekend.

Kong Sham Western Highway

Core Station No. 5516

Table 1: AADT for Kong Sham Western Highway from 2020 to 2024 [8]

Year	AADT *
2020	16,430
2021	17,230
2022	16,460
2023	17,500
2024	22,880

Remark: [*] The data are obtained from 2020 – 2024 Annual Traffic Census published by the Traffic Department.

Table 2: AADT for Construction Phase and Operation Phase

Year	Description	Estimated AADT (veh/hr)	Remarks
2032	Construction Phase and Operation Phase	39,254	• Based on Table 1, the yearly growth rate is estimated as 6.8% • The traffic flow is assumed to be further increased by 1% due to construction vehicle during construction phase; or due to population intake during operation phase.

Table 3: Estimated Traffic Flow

Item	Peak Hour	Weekday Day	Weekend Day	Night_Weekday *	Night_Weekend *
Traffic flow contribution	23.6	52.5	65.7	23.9	34.3
No of hours	4	9	12	11	12
Hourly traffic flow	2,313	2,292	2,150	852	1,121
No of persons per km	102	101	95	38	49

Remark: [*]: The largest value (i.e. 49) will conservatively be applied for the night time traffic flow for both weekday and weekend.

Fuk Hang Tsuen Road

Table 1: Peak Hour Traffic Flow for Construction Phase and Operation Phase

Year	Description	Peak Hour Traffic Flow (veh/hr)	Remarks
2032	Construction Phase and Operation Phase	770	• The traffic flow is referenced from the Traffic Impact Assessment conducted for the proposed development

Table 2: Estimated Traffic Flow

Item	Peak Hour	Weekday Day	Weekend Day	Night_Weekday *	Night_Weekend *
Traffic flow contribution	23.6	52.5	65.7	23.9	34.3
No of hours	4	9	12	11	12
Hourly traffic flow	770	763	716	284	373
No of persons per km	34	34	32	13	16

Remark: [*]: The largest value (i.e. 16) will conservatively be applied for the night time traffic flow for both weekday and weekend.

Table 1: Peak Hour Traffic Flow for Construction Phase and Operation Phase

Year	Description	Estimated AADT (veh/hr)	Remarks
2032	Construction Phase and Operation Phase	115	• The traffic flow is referenced from the Traffic Impact Assessment conducted for the proposed development

Table 2: Estimated Traffic Flow

Item	Peak Hour	Weekday Day	Weekend Day	Night_Weekday *	Night_Weekend *
Traffic flow contribution	23.6	52.5	65.7	23.9	34.3
No of hours	4	9	12	11	12
Hourly traffic flow	115	114	107	42	56
No of persons per km	5	5	5	2	3

Remark: [*]: The largest value (i.e. 3) will conservatively be applied for the night time traffic flow for both weekday and weekend.

AtkinsRéalis

AtkinsRealis Asia Limited
13/F Wharf T&T Centre
Harbour City
Tsim Sha Tsui
Kowloon
Hong Kong

info.hk@atkinsrealis.com

© AtkinsRealis Asia Limited except where stated otherwise