Appendix VIII

Quantitative Risk Assessment for Dangerous Goods Godown

Prepared by

Ramboll Hong Kong Limited

S16 PLANNING APPLICATION OF PROPOSED COMPREHENSIVE DEVELOPMENT AT 8 LAM CHAK STREET, KOWLOON – N.K.I.L. 6215

QUANTITATIVE RISK ASSESSMENT FOR DANGEROUS GOODS GODOWN

Date	**March 2026**
Prepared by	**Amy Ho *et. al***
	Senior Engineer
Signed	
Approved by	**Calvin Chiu**
	Senior Manager
Signed	
Project Reference	**CHPHBSHQEI00**
Document No.	**R9966_v1.1 draft**

Ramboll Hong Kong Limited

21/F, BEA Harbour View Centre
56 Gloucester Road, Wan Chai, Hong Kong

Tel: (852) 3465 2888
Fax: (852) 3465 2899
Email: hkinfo@ramboll.com

Q:\Projects\CHPHBSHQEI00\04 Deliverables\06 DG QRA Report\R9966_v1.1 draft.docx

Table of Content

List of Tables

List of Figures

List of Annex

1.0 Introduction

1.1 Project Background

A site at 8 Lam Chak Street, Kowloon – N.K.I.L. 6215 is proposed for redevelopment as comprehensive use involving 2 residential towers on a podium of commercial use (hereafter referred as the "Proposed Development"). The Site covers an area of about 6,541m^{2}, which is currently zoned as "Commercial". The location of the Site is shown in **Figure 1** .

A Dangerous Goods (DG) Godown operated by Kerry Logistics Network Limited (hereafter referred as the "DG Godown") is located at 7 Kai Hing Road, Kai Tak and in vicinity of the Proposed Development. According to the hazard to life assessments in A Rooftop Helipad at New Acute Hospital (NAH) at Kai Tak Development Area Environmental Impact Assessment (hereafter referred as the "NAH EIA") [4] and Kai Tak Development EIA [5], the risk impact of the DG Godown may influence the Proposed Development. This Quantitative Risk Assessment (QRA) is to review and demonstrate that the potential risk impact posed by the DG Godown on the population in the vicinity, including the future population brought by the Proposed Development, are in compliance with Hong Kong Risk Guidelines.

1.2 Scope of Work

The objective of this study is to assess the potential risks to the public in the vicinity of the DG Godown in year 2033, with operation of the Proposed Development.

The scope of the study is limited by the following criteria:

1. To identify all credible hazards associated with the DG Godown and its operation activities to the off-site population;

2. The transportation of DGs by DG vehicles and marine transports outside the DG Godown is outside the scope of work of this QRA Study.

It is noted that the QRA Study for the DG Godown is performed on a high-level basis due to the absence of details for the warehouse such as chemicals inventories, unit quantities, manning data etc. Various assumptions were being made based on engineering judgement. Further details are presented in following sections.

1.2.1 Hong Kong Risk Guidelines (HKRG)

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 DG Godown are acceptable.

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: 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** 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 prioritised on the basis of practicality and implementation cost versus the risk reduction achieved.

1.3 Methodology

1.3.1 Overall QRA Approach

The methodology of this study follows the previously approved EIA with hazard-to-life assessment of the DG Godown [4][5].

The major phases in QRA include:

i. Hazard Identification: The main hazards associated with the DG Godown were identified from a review of flammable and toxic materials (such as LPG, chlorine, etc.) being stored, processed and transported through the DG Godown and a literature review of accident database for incidents that have happened world-wide in similar facilities. The outcome of the hazard identification exercise is a list of hazardous scenarios with the potential to affect off-site surrounding population, which is then to be included in detailed analysis of QRA.

ii. Frequency Assessment: A frequency assessment involves analysis of likelihood of initiating events of the scenarios identified in (i) above and event tree analysis to model development of each event to their corresponding final outcomes, taking into account severity of the release event and surrounding environment.

iii. Consequence Assessment: Consequence analysis involves modelling of the physical effects using SAFETI 8.9. Consequence models were used to determine the levels of impact at varying distances from the identified hazard outcomes.

iv. Risk Summation and Assessment: Risk summation combines the likelihood and consequence of hazardous event, as well as meteorological data and population in the hazard effect zones, to give a numerical measure of the identified hazard outcomes. The risk analysis is conducted by the simulation software – SAFETI 8.9 developed by DNV and the outcome results are presented in terms of IR contours and Societal Risk (as F-N curves). The risks will be compared with the criteria outlined in HKRG to determine their acceptability.

v. Identification of Mitigation Measures: Identify and assess practicable and cost-effective risk mitigation measures if necessary to demonstrate that the risks are controlled within a level of As Low As Reasonably Practicable (ALARP). The risks of mitigated cases will then be reassessed to determine the level of risk reduction.

1.3.2 Case to be Considered

The Proposed Development is anticipated to commence operation in year 2033. This study will consider the following scenarios to demonstrate the increase in the risk levels of the DG Godown due to the construction and operation of the Proposed Development. The cases to be considered include:

- ***Case 1 – Base Case in Year 2033***: evaluating the risk level in year 2033 without redevelopment of the Proposed Development (i.e. as existing commercial building);
- ***Case 2 – Construction Case in Year 2032***: evaluating the risk level in year 2032 with the construction of the Proposed Development.
- ***Case 3 – Operation Case in Year 2033***: evaluating the risk level in year 2033 with the redevelopment of the Proposed Development.

2.0 Hazardous Storage and Operation

2.1 DG Godown

The DG Godown, located in vicinity of Proposed Development at 7 Kai Hing Road, Kai Tak, is indicated in **Figure 1**. The DG Godown was first established in 1980's. The DG Godown consists of 6 storeys with ceiling height of approximately 7'7" each floor. The DG Godown was licenced for storage of Category 2, 3, 4, 5, 6, 7, 8, 9 and 10 DGs prior to the amendment of Dangerous Goods (Application and Exemption) Regulation 2012 (Cap. 295E) effective from 2022. According to Fire Services Department(FSD)'s record in 2025, the DG Godown is licenced for storage of Class 2, 3, 3A, 4, 5, 6.1, 8 and 9 DGs [6].

The operator of the DG Godown, Kerry, were consulted in October 2025, however, no reply had been received. Assumptions had been made based on the best available information and previous approved EIA studies [4][5]. As per Kerry's website information, the DG Godown is designed and provided with:

- Separate sunken-type DG store design for safe storage and handling of dangerous goods. According to DGs Ordinance Cap. 295, DG store compartment walls shall have a fire resistance rating of no less than two hours carried from floor to ceiling;
- Explosion-proof cargo lifts and equipment in DG stores, including explosion-proof hydraulic cargo lifting platforms, explosion-proof electric forklift trucks and explosion-proof fluorescent lamps;
- Bromotrifluoromethane (BTM) fire fighting system in all DG stores:
    - According to DGs Ordinance Cap. 295, the openings of the DG premises shall be automatically closed and the mechanical ventilating system shall be automatically switched off upon actuation of total flooding gaseous system (i.e. BTM fire fighting system);
    - As per Kai Tak Development EIA [5], the BTM system is set to manual by the operators on entry to a store and remains in manual setting while the store is occupied. The switch is turned to automatic when personnel leave the store;
- Automatic sprinkler system on all floors (including loading platform and corridor);
- Fire alarm system linked to nearby fire station;
- Smoke / heat detecting system – As per Kai Tak Development EIA [5], an alarm would be raised in the DG store when thermal or smoke detectors are activated. The alarm in the store indicates that BTM fire fighting system will be activated shortly, if it were set to automatic. During this period, any personnel present in the DG store would evacuate out of the DG store;
- Gas detection system – As per Kai Tak Development EIA [5], flammable gas detectors are installed in 2 of the DG stores that are commonly used for flammable gases storge on the ground floor.
- Air ventilation system in each DG store – According to DGs Ordinance Cap. 295, the ventilation rate shall be at least 5L per seconds per square metre of the DG premises

floor area. As per Kai Tak Development EIA [5], in the event of activation of gas detectors:

- If no toxic gas was stored, ventilation would continue;
- If toxic gas was stored, fans would be shut down and gas would be confined within the store until the arrival of fire service.

As described in Kai Tak Development EIA [5], an external loading bay is used to receive/dispatch goods which are loaded/unloaded for forklift on the platform to/from trucks within the DG Godown. DG Classes of goods are not specifically segregated in the loading bay area. Goods may be temporarily stored at the unloading/loading area for a short period (several hours in some cases) and the parking bays adjacent to the loading platform, before transferring to the stores or dispatch by truck. Deliveries and dispatches are controlled by manifest sheets and risk assessment performed before goods are allowed to be stored. Highly toxic inventories, such as chlorine, had not been stored.

3.0 Project Information and Assumption

3.1 Study Area

A study area of 350 m radius from the DG Godown is adopted with reference to the NAH EIA [4], as shown in Figure 1.

3.2 Population

The population considered includes surrounding population of the DG Godown that may be impacted by the hazardous outcomes of the DG Godown. The majority of the population is contributed from the nearby planned residential developments, commercial buildings and a New Acute Hospital.

3.2.1 Population in the Vicinity

Population information was collected from desktop research. Planned developments in the vicinity were identified. The planned residential developments are considered fully operating in year 2033 for conservative purpose.

The New Acute Hospital is also considered under full operation in year 2033 as the construction works is anticipated to be completed in 2026 tentatively.

Future population within the study area is estimated based on:

- Average residential household size of 2.5 in Kwun Tong Central District Council Constituency Area as per 2021 Population Census [7];
- Maximum plot ratio of 9.5 for commercial/industrial buildings according to the OZP No. S/K22/8; and
- Conservative assumption of worker density of 25m2/worker for business use, 25m2/worker for industrial use and 700m^2/worker for warehouse.

The population groups considered within the study area are illustrated in **Figure 3**. The population data are summarised in **Table 2**.

3.2.2 Transient Population

Transient population includes traffic population as well as pedestrians along the road sections within the impacted area. Traffic population can be calculated using the equation below:

$$\text{Traffic Population (ppl)} = \frac{\frac{\text{No. of ppl}}{\text{vehicle}} \times \frac{\text{No. of vehicle}}{\text{hr}}}{\text{Traffic Speed } (\text{km}/\text{hr})} \times \text{Road Section Length (km)}$$

The transient population adopted for this study is summarised in **Table 2** with the detailed calculations provided in **Annex B**.

3.2.3 Temporal Change in Population

To reflect the temporal changes in population within a week, the corresponding population proportion of the time periods are assumed based on observation from site survey dated on 16 July 2025 and with reference to the approved Environmental Impact Assessment (EIA) reports [3][8].

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 1**.

Table 1 Temporal Change of Population within A Week

Category	Population Variation in Time Period			
	Weekday Day (WDD)	Weekday Night (WDN)	Weekend Day (WED)	Weekend Night (WEN)
Car Park (1)	100%	10%	100%	10%
Club House (1)	50%	20%	100%	20%
Commercial (2)	100%	10%	40%	5%
Construction (1)	100%	1%	50%	1%
Fire Station (1)	100%	100%	100%	100%
Hospital (3)	100%	80%	85%	80%
Industrial (2)	100%	10%	40%	5%
Open Storage (1)	100%	5%	100%	5%
Residential (2)	25%	100%	70%	100%
Retail (3)	50%	25%	100%	25%
Road (4)	100%	63%	100%	63%
Warehouse (1)	100%	0%	50%	0%

Note:

(1) Conservative assumption based on survey and judgement.
(2) Reference to HATS Stage 2A EIA [8]
(3) Reference to South Island Line EIA [3]
(4) Estimated from Annual Traffic Census 2023. Refer ***Annex B****.*

3.2.4 Indoor and Outdoor Ratio

Building structures can offer some protection from fires for the occupants inside. An indoor ratio of 95% is applied to the population in residential development, industrial buildings and commercial buildings while the remaining 5% of population is assumed to be outdoor, accounting for outdoor activities and walking pathways.

Patients and employee in hospital are mostly indoor, an outdoor ratio of 3% is conservatively assumed to account for population in potential landscape area and rehabilitation gardens.

Passengers in vehicles are considered as 100% outdoors population although vehicles may provide certain protection.

Table 2 Population Data in the Vicinity

ID	Population Name	Population Category	Population			Indoor Ratio	Base Level (mPD)	Building Height (mPD)	Remarks
			Base Case (Yr 2033)	Construction Case (Yr 2032)	Operation Case (Yr 2033)				
01	Kai Tai Fire Station	Fire Station	50	50	50	80%	4.4	36.7	FSD had an establishment of 10,690 uniformed staffs in 2024. Assume evenly distributed to fire stations, ambulance depots, fireboat stations and other bases, average 78 staffs per fire station. Assume 2 working shifts per day, 39 uniform staffs are estimated in fire station. Rounded up to nearest 50.
02	New Acute Hospital (Acute Block)	Hospital	11843	11843	11843	97%	4.7	132.8	Reference to NAH Rooftop Helipad EIA (EIA-266/2020).
03	Planned Residential Development	Residential	4820	4820	4820	95%	4.4	115.0	1928 flats as per Planning Application No. A/K22/43. Assume average household size of 2.5.
04	Planned Residential Development	Residential	3625	3625	3625	95%	4.3	100.0	1450 flats as per Planning Application No. A/K22/31-2. Assume Domestic Household Size of 2.5.
05	Hong Kong Children's Hospital	Hospital	4188	4188	4188	97%	4.5	62.8	Reference to NAH Rooftop Helipad EIA (EIA-266/2020).
06a	Pacific Trade Centre (G/F – 3/F)	Industrial	184	184	184	95%	4.2	17.8	15-storey industrial buildings with site area of 5,343m². Assume usable floor area as 80% of total floor area. Assume 60% of area as warehouse use and 40% of area as industrial use as observed in site survey. Estimated by worker density of 25m²/worker for industrial and 700m²/worker for warehouse.
06b	Pacific Trade Centre (5/F – 17/F)	Industrial	506	506	506	95%	17.8	51.1	
07a	The Quayside (Upper)	Commercial	2370	2370	2370	95%	16.0	76.3	Total office area of 74,000m² as advised by the Planning Department. Assume usable floor area as 80% of total floor area and worker density of 25m²/worker for business.
07b	The Quayside (Lower)	Retail	300	300	300	95%	4.3	16.0	Conservative assumption from site survey.
08	Planned Commercial Development (Office)	Commercial	4180	4180	4180	0%	30.0	135.0	Reference to MPC Paper No. 10/21, total office area of 130,510m². Assume usable floor area as 80% of total floor area and worker density of 25 m²/worker for business.
09	Planned Commercial Development (Retail)	Retail	1800	1800	1800	90%	5.4	25.0	Conservative assumption based on the proportion of site area to that of Site ID07b.
10	Planned Commercial Development (Hotel)	Hotel	800	800	800	90%	96.0	120.0	Conservative assumption of 400 rooms and 2 guests per room, with reference to the Dorsett Kai Tak Hotel in nearby area with similar floor area.
11a	Harbourside (Lower)	Car Park	20	-	-	90%	4.3	22.3	Conservative assumption from site survey.
11b	Harbourside (Upper)	Commercial	2020	-	-	95%	22.3	136.5	GFA of approx. 678,990 ft². Assume usable floor area as 80% of total floor area and worker density of 25m²/worker for business.
12	One Bay East	Commercial	1501	1501	1501	95%	4.1	96.0	Reference to NAH Rooftop Helipad EIA (EIA-266/2020).
13	Kwun Tong Promenade	Recreational	20	20	20	0%	4.4	-	17 people was observed during site survey. Conservative assumption of 20 is hence adopted.
14	LPG Filling Station	Filling Station	23	23	23	0%	4.6	-	Reference to NAH Rooftop Helipad EIA (EIA-266/2020).

ID	Population Name	Population Category	Population			Indoor Ratio	Base Level (mPD)	Building Height (mPD)	Remarks
			Base Case (Yr 2033)	Construction Case (Yr 2032)	Operation Case (Yr 2033)				
15	Kai Tak Promenade	Recreational	10	10	10	0%	4.3	-	9 people was observed during site survey. Conservative assumption of 10 is hence adopted.
PD	Proposed Development:								Project information
	▪ Residential	Residential	-	-	3000	95%	23.0	136.5	
	▪ Clubhouse	Club House	-	-	70	95%	14.5	19.4	
	▪ Retail	Retail	-	-	150	95%	4.5	14.5	
	▪ Construction	Construction	-	100	-	0%			Conservative assumption
RD01	Cheung Yip Street	Road	44	44	44	0%	3.9	-	Refer to **Annex B**
RD02	Lam Chak Street	Road	11	11	11	0%	4.1	-	Refer to **Annex B**
RD03	Kai Hing Road	Road	22	22	22	0%	4.3	-	Refer to **Annex B**
RD04	Hoi Bun Road	Road	42	42	42	0%	4.0	-	Refer to **Annex B**
RD05	Wai Yip Street	Road	45	45	45	0%	4.2	-	Refer to **Annex B**
RD06	Kwun Tong Bypass	Road	133	142	144	0%	14.0	-	Refer to **Annex B**
RD07	Shing Cheong Road	Road	58	57	58	0%	12.0	-	Refer to **Annex B**

3.3 Source of Ignition

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 Lower Flammable Limit), 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.

Two types of ignition sources are defined in the model, including:

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

- *Line source – transportation route segments:* account 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 [9]. Traffic flow and average vehicle speed are included in **Annex B**.

3.4 Meteorological Information

Meteorological conditions affect the consequences of gas release, in particular wind direction, speed and stability which influences the direction and degree of turbulence of gas dispersion. Meteorological data from Kai Tak Weather Station (Year 2024) was collected from the Hong Kong Observatory and adopted in the consequence model to determine the various gas dispersion, fire and explosion effects. The data are rationalised into a set of weather classes in accordance with TNO Purple Book [9]. The meteorological data can be expressed in combination of wind speed and Pasquill stability classes. Pasquill classes (A to F) represent the atmospheric turbulence with class A being the most turbulent class while class F being the least turbulent class.

The six most dominant sets of wind speed-stability class combination for both day-time and night-time are listed in **Table 3** and **Table 4** below respectively. The average ambient temperature adopted in the analysis is 23.5°C and relative humidity is 78% [10].

Table 3 Day Time Wind Direction Frequency of Kai Tak Weather Station

Direction	Weather Class						Total
	3.5B	2.0D	4.0D	7.5D	3.0E	2.0F	
0 – 30	1.49	0.33	0.44	0.00	0.09	0.51	2.87
30 – 60	1.78	0.42	0.75	0.00	0.63	0.42	3.99
60 – 90	1.92	0.33	0.61	0.00	0.54	0.58	3.97
90 – 120	3.90	0.19	1.14	0.42	0.28	0.33	6.26
120 – 150	13.81	0.72	7.66	0.68	1.45	0.58	24.90

Direction	Weather Class						Total
	3.5B	2.0D	4.0D	7.5D	3.0E	2.0F	
150 – 180	16.54	2.17	3.36	0.12	1.14	2.06	25.39
180 – 210	2.45	0.63	0.09	0.00	0.19	0.70	4.06
210 – 240	2.03	0.54	0.07	0.00	0.16	0.28	3.08
240 – 270	5.40	0.79	0.54	0.00	0.23	0.58	7.54
270 – 300	4.39	0.68	0.77	0.02	0.28	0.68	6.82
300 – 330	2.34	0.63	0.56	0.00	0.49	0.79	4.81
330 – 360	3.39	0.28	1.45	0.14	0.56	0.47	6.28
All	59.43	7.71	17.45	1.38	6.05	7.99	100.00

Table 4 Night Time Wind Direction Frequency of Kai Tak Weather Station

Direction	Weather Class						Total
	3.5B	2.0D	4.0D	7.5D	3.0E	2.0F	
0 – 30	0.00	0.05	0.95	0.00	0.71	2.71	4.42
30 – 60	0.00	0.12	0.62	0.00	2.05	2.85	5.64
60 – 90	0.00	0.07	0.36	0.00	1.31	1.71	3.45
90 – 120	0.00	0.05	2.59	0.50	1.36	1.40	5.90
120 – 150	0.00	0.12	13.70	1.05	8.92	4.80	28.59
150 – 180	0.00	0.38	3.31	0.00	6.28	11.61	21.57
180 – 210	0.00	0.12	0.05	0.00	0.45	4.38	4.99
210 – 240	0.00	0.02	0.14	0.00	0.43	2.57	3.16
240 – 270	0.00	0.05	0.21	0.00	0.69	2.57	3.52
270 – 300	0.00	0.00	0.76	0.12	1.33	3.59	5.80
300 – 330	0.00	0.14	1.36	0.02	1.38	3.54	6.44
330 – 360	0.00	0.02	2.26	0.02	1.76	2.45	6.52
All	0.00	1.14	26.30	1.71	26.66	44.19	100.00

4.0 Hazard Identification

4.1 Overview

Hazards associated with the Kerry DG Godown were identified based on previously approved EIA Study [5], a detailed review of known incidents records worldwide and experience gained from operations of similar facilities. The major hazards arising from the Kerry DG Godown are mainly related to the loss of containment of flammable/ toxic materials leading to fire, toxic events.

This section includes the following subsections:

- Review of On-site Hazardous Materials;
- Development of Hazardous Scenarios;
- Event Leading to Hazardous Material Release;
- Review of Industry Incidents Relevant to Similar Facilities; and
- Outcome of Hazardous Material Release.

4.2 Review of On-site Hazardous Materials

The DG Godown is licensed (DG license issued by FSD) to take Class 2 to 9 DG inventories, which was previously classified as Category 2 to 10 before the amendment of Dangerous Goods (Application and Exemption) Regulation 2012 (Cap. 295E) effective from 2022.

A review on the DG categories in the repealed legislation and the DG classes in the amended legislation is tabulated in **Table 5** below.

Table 5 DG Classification

Repealed Legislation		Amended Legislation Effective from 2022		
Cat.	**Description**	**Class**	**Sub-division**	**Description**
Cat. 2	Compressed Gases	2	2.1	Flammable gases
			2.2	Non-flammable and non-toxic gases
			2.3	Toxic gases
Cat. 5	Substances giving off inflammable vapours	3		Flammable liquids
		3A		Diesel, Fuel Oil and furnace oil, having flashpoints exceeding 60°C (closed-cup test)

Repealed Legislation		Amended Legislation Effective from 2022		
Cat.	**Description**	**Class**	**Sub-division**	**Description**
Cat. 8	Readily combustible substances	4	4.1	Flammable solids, self-reactive substances, solid desensitized explosives and polymerizing substances
Cat. 9	Substances liable to spontaneous combustion		4.2	Substances liable to spontaneous combustion
Cat. 6	Substances which become dangerous by interaction with water		4.3	Substances which in contact with water emit flammable gases
Cat. 7	Strong supporters of combustion	5	5.1	Oxidizing substances
			5.2	Organic peroxides
Cat. 4	Poisonous substances	6.1		Toxic substances
Cat. 3	Corrosive substances	8		Corrosive substances
Cat. 9A	Combustible goods exempted from Sections 6 to 11 of the Ordinance	9		Miscellaneous dangerous substances or materials
Cat. 10	Other dangerous substances			

The DG stores and maximum storage quantity allowed, as listed in Table 11.4.1 and Table 11.4.2 in Kai Tak Development EIA [5] were reviewed in accordance with the amended Cap. 295E. The maximum storage quantities allowed for different type of DGs at the DG Godown are assumed remained the same after the amendment of Cap. 295E. The license allows only one (1) class of DGs to be stored in any store at one time. According to Cap. 295, incompatible DGs must not be stored in same store. It should be noted that:

- Class 2 DG is incompatible with any other classes of DG;
- Flammable gases, oxidizing gases and toxic gases are incompatible with each other; and
- Class 3 DG is incompatible with any other classes of DG except Class 3A DG or paint materials that are Class 3 or 8 DG.

Table 6 and **Table 7** presents the classes and their associated DGs allowed at the DG Godown. Noted that, due to the space occupied by packaging and reserved for forklift manoeuvring, the stores cannot store goods at a level of storage capacity as stated in the DG licence.

Table 6 DG and the Maximum Storage Quantity Allowed

Class of DG being Stored	No. of Store	Maximum Quantity to be Stored
3 or 3A	2	471,000L / 559,000L
2 or 3 or 3A or 4 or 5 or 8 or 9	1	593,500kg
3 or 3A or 4 or 5 or 8 or 9	12	504,000L / 575,000L / 640,000L / 750,000L / 664,000L / 520,000L / 720,000L / 745,000L / 702,000kg/L / 554,000kg/L / 720,000L / 690,000L
3 or 3A or 4 or 5 or 6.1 or 8 or 9	2	740,000kg/L / 715,000kg/L
4 or 5 or 6.1 or 8 or 9	1	417,000kg
2 or 4 or 5 or 6.1 or 8 or 9	4	750,000kg / 745,000kg / 460,000kg / 745,000kg

Table 7 Maximum Allowable Quantity by DG Class

DG Classes	No. of Stores allowed for storage of the mentioned DG Category	Maximum Allowable Quantity (tonne)
2	5	3293.5
3 or 3A	17	10862.5
4	20	12949.5
5	20	12949.5
6.1	7	4572.0
8	20	12949.5
9	20	12949.5
Total	**22**	**13979.5**

An external loading bay is used to receive or dispatch goods, and such action is aided by forklift to load or unload to / from trucks. Classes of goods are not specified in the loading bay area as the goods are only temporarily stored at this area (several hours) before transferring to the stores or loaded on to the truck. Deliveries and dispatches are strictly controlled by manifest sheet and risk assessment performed prior the goods are allowed to be stored.

Gas leakage detectors are installed in 2 of the DG stores (Class 2) to detect gas leakage. It is understood that there is no system of containment for any vapour release, either toxic or flammable.

As per Kai Tak Development EIA [5], if non-toxic gas is leaked and the release is detected, the gas will vent out from the DG store, otherwise the gas is confined within the store until the arrival of fire service.

4.3 Development of Hazardous Scenarios

Due to the relatively unrestricted nature of storage within the licensing limits of the DG warehouse to Class 2 to 9, substances and associated inventories have therefore been selected to generically represent the warehouse inventories. These have been chosen to represent a realistic worst case estimate of potential consequence during a warehouse fire or major toxic release. Hazardous scenarios from the previously approved EIA study [4][5] were summarised in **Table 8** and adopted in this QRA Study.

4.3.1 Warehouse Generic DG Substances

As a worst case fire/ toxic evaluation to human life, it is assumed that the maximum Class 2 inventory allowable in the license (3,293.5 tonne) is stored and that the remaining inventory is nominally Class 3 or 3A as worse case flammable hazard. Class 6.1 substances were also considered but discounted and discussed as follows.

Following the previously approved EIA study [4][5], the bounding Class 2 flammable substance is taken to be liquefied petroleum gas (LPG), which is classified as Class 2.1 flammable gas. Taking into account the possible change of operation mode of LPG cylinders suppliers to use of Kerry DG Godown for LPG cylinders store in the future, the maximum storage quantity of 40 tonne as stipulated in the Code of Practice for Hong Kong LPG Industry published by the EMSD Gas Authority [15] is applied to estimate the limiting value for a conservative assumption.

As discussed in the Kai Tak Development EIA [4], the DG Godown did not intend to store any very toxic gas inventory (e.g. chlorine). A reasonable worst case estimate for a toxic release of Class 2.3 DGs has therefore been taken as chlorine, up to the PHI threshold limit of 10 tonne, and liquefied ammonia, equivalent to the threshold limit for a generic toxic substance [13] of 100 tonne. The residual Class 2 inventory is assumed to be neither toxic nor flammable, i.e. Class 2.2, and is therefore not specifically considered.

The remaining warehouse inventory (Class 3 and above) is calculated to be 13,979.5–3,293.5=10,686 tonne in weight. This figure is within the allowable quantity for Class 3 DG. Having taken into account unused space and space occupied for operation, 75% of the remaining inventory (10,686×75%=8,015 tonne) has been assumed and modelled as ‘pentane’.

Class 6.1 inventories have also been considered for the evaluation, following the previously approved EIA study [4][5]. The representative Class 6.1 substances are assumed to be those such as Methyl Diphenyl Diisocyanate (MDI) in liquid form, which would not be expected to form a hazard to populations outside of the warehouse, other than in combustion products which may be highly toxic. The UK SRAG for Chemical Warehouses [14], indicates that very toxic/toxic substances such as phosgene, ammonia, chlorine, hydrogen chloride and hydrogen cyanide may evolve from warehouse fires (for example, phosgene could be produced from some fires involving chlorinated solvents though in a small fraction). The substance and concentration would depend on the substance combusted, which in this case is generic.

A coarse estimate is necessary to provide an assessment of the potential for toxic components evolving in a fire. In accordance with Kai Tak Development EIA [5], the following approach has therefore been applied to estimate possible toxic components in a large fire:

- Class 6.1 and Class 8 products are assumed based on which toxic combustion products can be formed in warehouse fire. Total quantity of this type of materials is taken to be 2,144 m^3;
- In which, 1,062 m^3 will be considered as MDI, with atomic composition C_{15}-H_{10}-N_2-O_2. The rest is treated as a mixture of phosphoric acid, hydrochloric acid and hydrofluoric acid. This quantity of inventory is fed into the warehouse fire model in PHAST.
- The release rate of toxic combustion products is then treated as source term in the dispersion model in SAFETI.

4.4 Event Leading to Hazardous Material Release

4.4.1 Review of Industry Incidents Relevant to Similar Facilities

A review of major international failure/ accident databases was undertaken to identify past incidents for similar facilities. The following databases were reviewed for this QRA Study. A review of incidents involving gasholder and other hazardous facilities within the Kerry DG Godown is summarised in **Annex F**.

- Institution of Chemical Engineers (IChemE);
- MHIDAS database (MHIDAS is a Major Hazard Incident Data Service developed by the Safety and Reliability Directorate of the UK Atomic Energy Authority. MHIDAS contains incidents from over 95 countries particularly the UK, U.S., Canada, Germany, France and India. The database allows access to many other important sources of accident data, such as the Loss Prevention Bulletin [16].

4.4.2 Hazardous material release from DG Godown Operation

Based on a review of the process data and literature review, the main hazardous scenarios associated with the facilities during operation in the DG Godown are summarised as follows:

- Malfunctioning forklift truck;
- Overloaded cable;
- Arson;
- Lorry fire during unloading;
- Cutting/ grinding welding;

- Spillage of grinding, welding operations;
- Spillage of non-compatible chemicals

4.4.3 Hazardous material release from External events

Release of DGs may occur due to external events and the consequence could be catastrophic failure or leak. The related external events are listed as follows:

- Earthquake;
- Aircraft crash;
- Helicopter crash;
- Typhoons (Storm Surge and Flooding)
- Landslide;
- Subsidence;
- Lightning Strike; and
- External fire.

Table 8 Identified Hazardous Sections Associated with the DG Godown

Scenario	Summary	Description	Contributing Factors	Inventory	Phase	Release / Event Duration
D-WF	Major Warehouse fire & escalating toxic release	Loss of warehouse or multiple compartments with release of toxic combustion products in a fire lasting for hours	• Generic fire – unknown source • Internal escalating fire (Hotwork, electrical cabling fault / short circuit, Incompatible materials, forklift malfunction, impact / dropped load) • External escalating fire (fire from adjacent works, vehicle, loading bay / office, heating systems, electrical failure) • Arson / sabotage • Human error / negligence	Max. store inventory: Combustion products (HCl, SO_2, NO_2) from burning of Methyl Diphenyl Diisocyanate and cleaning compound (2,144 m^3)	Liquid, Vapour and Solid	Extended Duration Indoor release –loss of building integrity (breakdown of containment system) Multiple failures of inventories as fire progresses
D-WF-EX	Major Warehouse fire & escalating toxic release	Loss of warehouse with release of toxic combustion products in a fire caused by an extreme external event	• Aircraft / helicopter crash • Seismic • Extreme environmental conditions (lightning strike, heavy rain / flooding) • Design of warehouse (subsidence / landslip)	Max. store inventory: Combustion products (HCl, SO_2, NO_2) from burning of Methyl Diphenyl Diisocyanate and cleaning compound (2,144 m^3)	Liquid, Vapour and Solid	Multiple failures of inventories as fire progresses Outdoor release – loss of building integrity (building collapsed)

Scenario	Summary	Description	Contributing Factors	Inventory	Phase	Release / Event Duration
D-SF	Fire in Single Store & escalating toxic release	Loss of a store in fire with release of toxic combustion products	• Generic fire – unknown source • Internal escalating fire (Hotwork, electrical cabling fault / short circuit, Incompatible materials, forklift malfunction, impact / dropped load) • External escalating fire (fire from adjacent works, vehicle, loading bay / office, heating systems, electrical failure) • Arson / sabotage • Human error / negligence	Max. store inventory: Combustion products (HCl, SO_2, NO_2) from burning of Methyl Diphenyl Diisocyanate and cleaning compound (643 m^3)	Liquid, Vapour and Solid	Indoor release
D-LF-AI	LPG release – loss of area (internal)	Damage of Single Class 2 inventory with thermal or explosion effects. No escalation to nearby inventories No offsite impact	• Generic/spontaneous failure (corrosion, erosion, poor management, maintenance / handling error etc.) • Forklift malfunction: Impact / dropped / shed load (truck, forklift, sharp object, heavy load) • Human error	LPG Loss of area: 10 x 50 kg cylinders (~ 1 pallet)	Liquid	Indoor instantaneous release. Detected and suppressed
D-LF-CI	LPG release – loss of containment (internal)	Damage of Single Class 2 inventory with thermal or explosion effects. No escalation to nearby inventories No offsite impact	• Generic/spontaneous failure (corrosion, erosion, poor management, maintenance / handling error etc.) • Forklift malfunction: Impact / dropped / shed load (truck, forklift, sharp object, heavy load) • Human error	LPG Loss of containment: single 50 kg cylinder	Liquid	Indoor instantaneous release Detected and suppressed

Scenario	Summary	Description	Contributing Factors	Inventory	Phase	Release / Event Duration
D-LF-EX	LPG release – loss of warehouse	Damage of Class 2 inventory with thermal or explosion effects caused by an extreme external event	• Aircraft /helicopter crash • Seismic • Extreme environmental conditions (lightning strike, heavy rain / flooding) • Design of warehouse (subsidence / landslip)	LPG Loss of area: 10 x 50 kg cylinders (~ 1 pallet)	Liquid	Outdoor instantaneous release Loss of building integrity (building collapsed)
D-LF-AE	LPG release – loss of area (external)	Damage of Class 2 inventory with external thermal or explosion effects at loading bay	• Generic/spontaneous failure (corrosion, erosion, poor management, maintenance / handling error etc.) • Forklift malfunction: Impact / dropped / shed load (truck, forklift, sharp object, heavy load) • Human error • Vehicle fire / battery recharging	LPG Loss of area: 3 x 50 kg cylinders (Punctured by forks of a forklift truck at the same time for the worst case scenario)	Liquid	Outdoor instantaneous release
D-LF-CE	LPG release — loss of containment (external)	Damage of Class 2 inventory with external thermal or explosion effects at loading bay	• Generic/spontaneous failure (corrosion, erosion, poor management, maintenance / handling error etc.) • Forklift malfunction: Impact / dropped / shed load (truck, forklift, sharp object, heavy load) • Human error • Vehicle fire / battery recharging	LPG Loss of containment: single 50 kg cylinder	Liquid	Outdoor instantaneous release.

Scenario	Summary	Description	Contributing Factors	Inventory	Phase	Release / Event Duration
D-PF-AI	Pentane fire – loss of area (internal)	Damage of Class 3 inventory with thermal or explosion effects.	• Generic/spontaneous failure (corrosion, erosion, poor management, maintenance / handling error etc.) • Forklift malfunction: Impact / dropped / shed load (truck, forklift, sharp object, heavy load) • Human error	Pentane Loss of area: multiple 50 kg drums (750 m^3)	Liquid	Indoor fire Detected and suppressed
D-PF-CI	Pentane fire – loss of containment (internal)	Damage of Class 3 inventory with thermal or explosion effects.	• Generic/spontaneous failure (corrosion, erosion, poor management, maintenance / handling error etc.) • Forklift malfunction: Impact / dropped / shed load (truck, forklift, sharp object, heavy load) • Human error	Pentane Loss of containment: single 50 kg drum	Liquid	Indoor fire Detected and suppressed
D-PF-EX	Pentane fire – loss of warehouse	Damage of Class 3 inventory with thermal or explosion effects caused by an extreme external event	• Aircraft /helicopter crash • Seismic • Extreme environmental conditions (lightning strike, heavy rain / flooding) • Design of warehouse (subsidence / landslip)	Pentane 8,015 tonne	Liquid	Outdoor pool fire Loss of building integrity (building collapsed)

Scenario	Summary	Description	Contributing Factors	Inventory	Phase	Release / Event Duration
D-PF-AE	Pentane fire – loss of area (external)	Damage of Class 3 inventory with external thermal or explosion effects at loading bay	• Generic/spontaneous failure (corrosion, erosion, poor management, maintenance / handling error etc.) • Forklift malfunction: Impact / dropped / shed load (truck, forklift, sharp object, heavy load) • Human error • Vehicle fire	Pentane Loss of area: 10 x 50 kg drums	Liquid	Outdoor pool fire
D-PF-CE	Pentane fire – loss containment (external)	Damage of Class 3 inventory with external thermal or explosion effects at loading bay	• Generic/spontaneous failure (corrosion, erosion, poor management, maintenance / handling error etc.) • Forklift malfunction: Impact / dropped / shed load (truck, forklift, sharp object, heavy load) • Human error • Vehicle fire	Pentane Loss of containment: single 50 kg drum	Liquid	Outdoor pool fire
DG-CT-W	Chlorine release – loss of warehouse	Damage of Class 2 Chlorine inventory caused by an extreme external event	• Aircraft /helicopter crash • Seismic • Extreme environmental conditions (lightning strike, heavy rain / flooding) • Design of warehouse (subsidence / landslip)	Chlorine 10 tonne	Liquid	Outdoor instantaneous release Loss of building integrity (building collapsed).

Scenario	Summary	Description	Contributing Factors	Inventory	Phase	Release / Event Duration
DG-AT-W	Ammonia release – loss of warehouse	Damage of Class 2 Ammonia inventory caused by an extreme external event	• Aircraft /helicopter crash • Seismic • Extreme environmental conditions (lightning strike, heavy rain / flooding) • Design of warehouse (subsidence / landslip)	Ammonia 100 tonne	Liquid	Outdoor instantaneous release Loss of building integrity (building collapsed).
DG-CT-AI	Chlorine release – loss of area (internal)	Damage of Class 2 Chlorine inventory	• Generic/spontaneous failure (corrosion, erosion, poor management, maintenance / handling error etc.) • Forklift malfunction: Impact / dropped / shed load (truck, forklift, sharp object, heavy load) • Human error / spillage • Incompatible materials	Chlorine Loss of area: multiple 50 kg cylinders (1 tonne)	Liquid	Indoor continuous release
DG-CT-CI	Chlorine release – loss of cylinder (internal)	Damage of Class 2 Chlorine inventory	• Generic/spontaneous failure (corrosion, erosion, poor management, maintenance / handling error etc.) • Forklift malfunction: Impact / dropped / shed load (truck, forklift, sharp object, heavy load) • Human error / spillage • Incompatible materials	Chorine Loss of containment: single 50 kg cylinder	Liquid	Indoor instantaneous release

Scenario	Summary	Description	Contributing Factors	Inventory	Phase	Release / Event Duration
DG-AT-AI	Ammonia release – loss of area (internal)	Damage of Class 2 Ammonia inventory	• Generic/spontaneous failure (corrosion, erosion, poor management, maintenance / handling error etc.) • Forklift malfunction: Impact / dropped / shed load (truck, forklift, sharp object, heavy load) • Human error / spillage • Incompatible materials	Ammonia Loss of area: multiple 50 kg cylinders (1 tonne)	Liquid	Indoor continuous release
DG-AT-CI	Ammonia release – loss of cylinder (internal)	Damage of Class 2 Ammonia inventory	• Generic/spontaneous failure (corrosion, erosion, poor management, maintenance / handling error etc.) • Forklift malfunction: Impact / dropped / shed load (truck, forklift, sharp object, heavy load) • Human error / spillage • Incompatible materials	Ammonia Loss of containment: single 50 kg cylinder	Liquid	Indoor instantaneous release
DG-CT-AE	Chlorine release – loss of area (external)	Damage of Class 2 Chlorine inventory at loading bay	• Generic/spontaneous failure (corrosion, erosion, poor management, maintenance / handling error etc.) • Forklift malfunction: Impact / dropped / shed load (truck, forklift, sharp object, heavy load) • Human error / spillage • Incompatible materials	Chlorine Loss of area: multiple 50 kg cylinders (1tonne)	Liquid	Outdoor continuous release

Scenario	Summary	Description	Contributing Factors	Inventory	Phase	Release / Event Duration
DG-CT-CE	Chlorine release – loss of cylinder (external)	Damage of Class 2 Chlorine inventory at loading bay	• Generic/spontaneous failure (corrosion, erosion, poor management, maintenance / handling error etc.) • Forklift malfunction: Impact / dropped / shed load (truck, forklift, sharp object, heavy load) • Human error / spillage Incompatible materials	Chorine Loss of containment: single 50 kg cylinder	Liquid	Outdoor instantaneous release
DG-AT-AE	Ammonia release – loss of area (external)	Damage of Class 2 Ammonia inventory at loading bay	• Generic/spontaneous failure (corrosion, erosion, poor management, maintenance / handling error etc.) • Forklift malfunction: Impact / dropped / shed load (truck, forklift, sharp object, heavy load) • Human error / spillage • Incompatible materials	Ammonia Loss of area: multiple 50 kg cylinders (1 tonne)	Liquid	Outdoor continuous release
DG-AT-CE	Ammonia release – loss of cylinder (external)	Damage of Class 2 Ammonia inventory at loading bay	• Generic/spontaneous failure (corrosion, erosion, poor management, maintenance / handling error etc.) • Forklift malfunction: Impact / dropped / shed load (truck, forklift, sharp object, heavy load) • Human error / spillage • Incompatible materials	Ammonia Loss of containment: single 50 kg cylinder	Liquid	Outdoor instantaneous release

4.5 Outcome of hazardous material release

Leakage or rupture scenarios of storage equipment handling flammable and toxic materials can result in a flammable/ toxic gas cloud, which may be ignited if it encounters an ignition source while its concentration lies within the flammable range. In some cases, static discharge may also cause immediate ignition of flammable gas release. For the unignited case, a toxic dispersion cloud will be formed.

Hazardous scenarios evaluated in this QRA Study include:

- Flash fire;
- Pool fire;
- Fireball; and
- Toxic Impacts.

In events of jet fire impingement, pool fire engulfment and even vehicle fires, knock-on effect of the fires is possible to cause failure of other DG cylinder / containers in form of Boiling liquid expanding vapor explosion (BLEVE) or failure of containment. The outcomes of knock-on effect of fires are considered immediately ignited. Therefore, knock-on impact of LPG fire is considered in form of BLEVE of compressed cylinders resulting in multiple fireballs of LPG cylinders. While the knock-on impact of pentane fire is considered as loss of containment releasing addition inventory into fire to form large pool fire.

5.0 Frequency Assessment

This QRA Study for the Kerry DG Godown is conducted at a high level in the absence of detail on the inventory, unit quantities, storage practices and number of movement, etc., for the Kerry DG Godown. The assumptions in **Table 9** and following sections, based on best value information and engineering judgement have therefore been applied in order to facilitate the assessment.

Table 9 DG Warehouse Assumption

Item	Quantity
Stores	22
Class 2 stores	5
Class 3 or 3A stores	16
"other" DG Class stores	1
Floors	6
Non – Class 2 inventories nominally pentane	213,720 units as 50 kg containers
Class 2.1 – nominally LPG containers	800 units as 50 kg containers
Class 2.3 – nominally Chlorine containers	200 units as 50 kg containers
Class 2.3 – nominally Ammonia containers	2,000 units as 50 kg containers

5.1 Probability of Toxic Gas Inventories and LPG Cylinders

As per the previously approved EIA studies for the Kerry DG Godown [4][5], the toxic inventories such as chlorine and ammonia had not been stored at the Kerry DG Godown, not it is the intentions that such storage would even take place. Consideration had been taken to account the local use and application of chlorine/ammonia/LPG cylinders and no past record storing such inventories [5]. The probability of this rare event is 1 / (total number of independent events) and equal to 2.74×10^{-4}, based on total number of 3,650 records over the past 10 years. The figure is applied to the study for the potential for such storage of Chlorine, Ammonia or LPG cylinder over a year.

5.2 Warehouse Fires

Warehouse fires are considered to be the most dominant major hazard associated with warehouses historically. Several of the scenarios given in **Table 8** involve this type of fire which can lead to both thermal effects and effects associated with toxic release from combustion products.

Since there are only limited information on the DG Godown and its system, the frequency assessment for warehouse fires was done without taking into account the specific features of the operations. Given the available information and based on previously approved EIA studies [4][5] the study has been made specific to the maximum extent possible.

Generic warehouse fire frequencies derived from historical warehouse fire events, as listed in **Table 10** have been applied, and proportioned these by causal factors of warehouse fires for each warehouse scenario presented in **Table 8**.

Table 10 Generic Warehouse Fire Frequencies

Reference	Description	Frequency
Hymes / Flynn [25]	General Warehouse	10^{-2} to 10^{-3}
Quest [26]	DG Warehouse	10^{-3} to 10^{-4}
Purple Book [9]	DG Warehouse	1.8×10^{-4}
UK[27]	Warehouse fire – Urban	2.5×10^{-2} to 5×10^{-3}

A frequency of 1×10^{-3} per year for generic warehouse fire is adopted for this QRA study as denoted in the previously approved EIA studies [4][5]. It is assumed that not all fires would escalate to the entire warehouse. Factors are applied to account for the probability of a warehouse fire developing into different outcomes, ranging from loss of a single store to loss of an area (within a store or out on the loading bay) [4][5]. The assumptions made and factors adopted in proportioning of warehouse fires in various scenarios (including D-WF, D-SF, D-LF-AI and D-PF-AI) are given below:

- Approximately 80% of events can be considered to start within a compartment [18]. For the purpose of the study, all other events (20%) have been assumed to lead to loss of multiple stores. A probability of 0.8 for fire initiated within a single store is therefore applied.
- An automatic fire suppression (BTM) system is in place in the store actuated on fire/smoke detection. A probability of 0.9 for successful heat and smoke detection is adopted for this QRA study [17].
- A probability of 0.8 is applied for successfully isolating the fire to the store(s) by use of the suppression system. It is assumed that where the suppression system operates successfully, the fire would be limited to a store(s) area [5].
- A probability of 0.5 is applied for the control of the fire being maintained due to physical compartmentalization. It is assumed that where the fire suppression system has failed, but the integrity of the store has been maintained, fires would be limited to loss of a single store [5].
- All other events, which either impact multiple stores simultaneously, or are not controlled to a single store / area due to failure of suppression or passive systems, are assumed to impact the entire warehouse.
- Class 2.1 DG flammable gas inventory is selected to represent hazardous scenario of LPG release, while Class 3 / Class 3A DG flammable liquid inventory is selected for hazardous scenario of pool fire. All remaining DG class inventory is considered in single store fire event.

The derivation of the warehouse fire scenarios are evaluated through event tree analysis as presented in **Annex D**.

Extreme scenarios for warehouse fire (D-WF-EX), LPG release (D-LF-EX), and pool fire (D-PF-EX) in the form of building collapse are studied. An event frequency of 1×10^{-6} per year is adopted for such events due to earthquake [5]. An event frequency of 1.91×10^{-7} per year, refer **Section 5.5.3**, as a consequence from helicopter crash is also taken into consideration as an additional event frequency contributor [4]. It is conservatively assumed that it would be a 100% building collapse in the event of earthquake or helicopter crash, and failure of entire building inventory at the same time.

The scenarios of instantaneous loss of full toxic inventory for Chlorine (DG-CT-W) and Ammonia (DG-AT-W) resulting from building collapse in the event of earthquake or helicopter crash has also been considered as per the assessment in the previously approved EIA study [4].

5.3 Warehouse Fires in Loading Bay

Fires in the loading bay area have also been considered in the analysis. The causes of such fires were shown in **Table 8** to include spontaneous/generic failure, failures due to impacting vehicles / forklifts or vehicle fires escalating to nearby inventories.

The failure of cylinders / storage inventories in the warehouse is therefore the sum of the generic failure contributions, modified by additional contribution due to the practices at the warehouse e.g. movement of inventories and external events.

The failure frequencies are derived by fault tree analysis, as presented in **Annex C**.

5.3.1 Generic Release

The likelihood of a generic/spontaneous loss of pressurized flammable inventory has been taken as the rupture frequency for a single cylinder. It is nominally assumed an average of 100 x 50 kg cylinders would be placed in the loading area awaiting storage with an overall estimated failure frequency of 6.8×10^{-4} per year for a pressurised cylinder and an overall estimated failure frequency of 5×10^{-4} for liquid container [5].

5.3.2 Impact

A spillage frequency of 1×10^{-5} per handling is adopted [9]. A modification factor of 0.1 is applied to reflect the conservatively assumed dangerous goods practices and packaging at the warehouse [5].

This QRA study is conducted based on an assumption of 10 forklifts operating throughout a 12-hour day for 6 days per week, and 15 minutes per handling, which is a total of 150,171 handlings per year [5]. The frequencies for the potential release of Class 2.1 flammable inventory, or other flammable inventories are estimated based on the proportion of each flammable inventory type, i.e. 40 tonne Class 2.1 flammable inventory and 8,015 tonne other flammable inventories, compared to the overall warehouse inventory. A fraction of 0.33 is applied for the conservative assumption of Class 2.1, or other flammable inventories handling at the loading bay area [5]. A probability of 0.01 is also applied to reflect spillage failure of multiple cylinders [19].

5.3.3 Vehicle Fires

Frequency for vehicle fires including truck / forklift is estimated as 2.9×10^{-4} per vehicle year with a conservative assumption of 10 forklifts and 5 trucks at any time [5]. Account has also been taken for the operational hours of the warehouse, assuming operation 6 days per week for 12 hours a day.

The proportion of each flammable inventory type, i.e. 40 tonne Class 2.1 inventory and 8,015 tonne other flammable inventories, compared to the overall warehouse inventory is also taken into consideration for the frequency estimation.

Knock-on effect may lead to failure of more cylinders in the event of vehicle fire, leading to potential BLEVE outcomes in form of fireball for pressurised cylinders of Class 2.1 inventory, and pool fire for flammable liquid drum of other flammable inventory. The probabilities of the BLEVE outcomes including fireball resulting from multiple BLEVE of single cylinder failure at the same time, and a single large pool fire arising from the coalescence of multiple pool fires. The impact of the single large pool fire on vehicle is confined within site and has no offsite impact. Hence it is not further considered in this QRA study.

5.4 Toxic Warehouse Releases

Toxic hazards associated with combustion products from warehouse fires are considered. Additional scenarios were identified in **Table 8**, which relate to a loss of containment from pressurized toxic inventories (nominally Chlorine and Ammonia).

As mentioned in **Section 5.1**, the probability of storing toxic inventory is estimated to be 2.74×10^{-4} per year.

5.4.1 Loss of containment of single container in store (DG-CT-CI and DG-AT-CI)

The likelihood of a generic/spontaneous loss of pressurized toxic container has been taken as the rupture frequency for a single cylinder, which are taken as 6.8×10^{-6} per vessel year for Ammonia [5]. The instantaneous failure frequency of Chlorine is taken as 6.38×10^{-5} per vessel year for cylinder rupture and medium leak (7.5mm) failure [5].

200 Chlorine cylinders and 2,000 Ammonia cylinders are estimated based on the assumptions of maximum inventories of 10 tonne for Chlorine and 100 tonne for Ammonia, and nominally assuming 50 kg containers throughout.

5.4.2 Loss of containment of single container in loading bay (DG-CT-CE and DG-AT-CE)

For generic/spontaneous loss of containment of toxic pressurized cylinders in the loading bay, a similar approach to that described in **Section 5.4.1** has been applied, assuming generic failure rates of 6.8×10^{-6} per cylinder year for Ammonia and 6.38×10^{-5} per cylinder year for Chlorine. A nominal of 5 cylinders (250 kg) are assumed to be at the loading bay being handled at any one time for the chlorine and ammonia scenarios.

5.4.3 Impact in loading bay and in store (DG-CT-AE, DG-AT-AE, DG-CT-AI, DG-AT-AI)

The potential for impact has been estimated for toxic inventories applying the same approach as described in **Section 5.3.2**. The likely number of movements involving each type of nominal toxic inventory estimates have been based on the proportion of each inventory type, i.e. 10 tonne Chlorine and 100 tonne Ammonia, compared to the overall inventory of the warehouse.

A modification factor of 0.1 is applied to reflect the conservatively assumed dangerous goods practices and packaging at the warehouse [5]. A conservative assumption of 100% multiple containers failure is also adopted.

5.5 External Events

5.5.1 Earthquake

Hong Kong is not located within the seismic belt. According to 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. Moreover, buildings and infrastructures in Hong Kong are designed to withstand earthquakes up to Modified Mercalli Intensity (MMI) VII. Therefore, it is assumed that MMI VIII is of sufficient intensity to cause damage to specially designed structures. The chance of earthquake occurring at MMI VIII and higher in Hong Kong is very low in comparison with other regions [2]. Likelihood of seismic hazard is $1x10^{-5}$ per year, based on 0.4g ground acceleration, to which a 0.1 probability of roof collapse was assigned. Thus, the frequency of building collapse in an earthquake is estimated $1x10^{-6}$ per year.

5.5.2 Aircraft crash

The DG Godown is located over 28km from the Hong Kong International Airport (HKIA). The frequency of aircraft crash is estimated using the HSE methodology and the estimated number of flights predicted from air traffic statistics between year 2014 and 2024 [11]. Details refer to **Annex H**.

The final calculated rate of aircraft crash to the DG Godown is 2.48×10^{-11} per year, which is smaller than 1.0×10^{-9} per year. It is therefore not further considered in the analysis.

5.5.3 Helicopter crash

Helicopter accidents during take-off and landings are confined to a small area around the helipad, extending up to 200m only from the centre of the helipad. 93% of accidents occur within 100m of the helipad. The remaining 7% occur between 100 and 200m of the helipad [12].

A helicopter landing pad will be provided at the New Acute Hospital. According to NAH EIA [4], the DG Godown is about 265m away from the helicopter flight path. The helicopter crash rate to the DG Godown is 1.91×10^{-7} per year. It is assumed that helicopter crash may result in catastrophic failure in form of building collapse resulting in warehouse fire, LPG release, pool fire and full toxic inventory (Chlorine and Ammonia) release.

5.5.4 Typhoons (Storm Surge and Flooding)

Flotation of storage vessels is possible if equipment becomes submerged in water. Flooding from heavy rainfall is not possible due to the coastal location of the Kerry DG Godown. The primary hazard from typhoons is the storm surge and waves, which if combined with a high tide could lead to flooding of the site. Winds, and to a lesser extent pressure, cause a rise in sea level in coastal areas. In general, storm surges are limited to several meters.

5.5.5 Landslide

Risk due to landslide on the DG Godown is not considered in the analysis because the DG Godown is no located near any slopes or adjacent to a hillside.

5.5.6 Subsidence

Excessive subsidence may lead to failure of the structure and ultimately loss of containment scenario. However, subsidence is usually slow in movement. Such movement can be observed and remedial action can be taken in time. Risk from subsidence is therefore deemed remote and not further considered.

5.5.7 Lightning Strike

The Warehouse is considered to be relatively low rise compared to other buildings in the area and not therefore particularly prone to lightning strike [5]. The potential for a lightning strike to hit the facility and cause a release event is therefore deemed to be unlikely and not further assessed.

5.5.8 External fire

While there were historical records indicating some specific instances of arson and sabotage leading to major events [5], safety features are understood to be in place for the Kerry DG Godown to minimize acts of vandalism/sabotage, e.g. stores are understood to be locked, access to the facility restricted, high walls surround the warehouse to prevent road access and the facility is manned permanently. It is therefore not further assessed.

5.6 Failure Frequencies

Event frequencies used for this QRA study are summarised in **Table 11** below.

Table 11 Summary of DG Godown Frequencies Adopted by Scenario

Scenario	Description	Estimated Frequency (per year)
D-WF	Major Warehouse Fire	1.68E-04
D-SF	Fire in Single Store	3.02E-05
D-LF-AI	LPG Fire Loss of area Internal (no offsite effect)	- Note 1
D-LF-CI	LPG Fire Loss of cylinder Internal (no offsite effect)	- Note 1
D-LF-AE	LPG Fire Loss of area External	1.43E-06
D-LF-CE	LPG Fire Loss of cylinder External (no offsite effect)	- Note 1
D-PF-AI	Pentane fire Loss of Area Internal (no offsite effect)	- Note 1
D-PF-CI	Pentane fire Loss of drum Internal (no offsite effect)	- Note 1
D-PF-AE	Pentane fire Loss of Area External	2.87E-04
D-PF-AE(VF)	Pentane fire Loss of Area External – vehicle fire (no offsite effect)	1.07E-03

Scenario	Description	Estimated Frequency (per year)
D-PF-CE	Pentane fire Loss of drum External (no offsite effect)	- Note 1
DG-CT-W	Chlorine toxic release (building collapsed)	3.26E-10
DG-AT-W	Ammonia toxic release (building collapsed)	3.26E-10
DG-CT-AI	Chlorine – Loss of Area Internal	1.97E-08
DG-CT-CI	Chlorine – Loss of Cylinder Internal	3.50E-06
DG-AT-AI	Ammonia – Loss of Area Internal	1.97E-07
DG-AT-CI	Ammonia – Loss of Cylinder Internal	3.73E-06
DG-CT-AE	Chlorine – Loss of Area External	9.71E-09
DG-CT-CE	Chlorine – Loss of Cylinder External	8.74E-08
DG-AT-AE	Ammonia – Loss of Area External	9.71E-08
DG-AT-CE	Ammonia – Loss of Cylinder External	9.32E-09
D-WF-EX	Major Warehouse Fire (building collapsed)	1.19E-06
D-LF-EX	LPG Fire Loss of Area (building collapsed)	0.00E+00
D-PF-EX	Pentane fire Loss of Area (building collapsed)	1.19E-06

Note 1: Not further considered due to no offsite effect.

5.7 Ignition Probabilities

Immediate ignition is assumed a probability of 0.3 for large flammable gas releases and a probability of 0.08 for large flammable liquid release following Cox, Lees and Ang [19], as shown in **Table 12**.

Table 12 Ignition Probabilities from Cox, Lees and Ang

Release Rate	Ignition Probability Rate	
	Gas Release	Liquid Release
Minor (<1 kg/s)	0.01	0.01
Major (1-50 kg/s)	0.07	0.03
Massive (>50 kg/s)	0.3	0.08

The assumption of ignition sources and delated ignition probability for traffic vehicles are detailed in **Section 3.3**.

5.8 Event Tree Analysis

Event tree analysis is used to develop the evolution of a failure event from its initial release to the final outcome scenarios, namely, pool fire, flash fire, fireball and toxic. It depends on various factors such as release type (instantaneous or continuous), ignition sources and probabilities. The event tree analysis adopted in the study is provided in **Annex D**.

SAFETI's built-in event trees are used to calculate the frequencies of hazardous outcome scenarios.

6.0 Consequence Analysis

The simulation software SAFETI 8.9 developed by Det Norske Veritas (DNV) was employed to calculate the hazardous release and the effects zones.

6.1 Venting Out Procedures for Toxic Gas Release

Ventilation arrangement in case of toxic gas release in the warehouse was further explored. The warehouse operator has confirmed the following in the event of activation of gas detectors [5]:

- If no toxic gas was stored, ventilation would continue;
- If toxic gas was stored, fans would be shut down and gas would confined within the storeroom until arrival of fire services, FSD.

As per the previously approved EIA studies for the DG Godown [4][5], the gas detectors are installed only for flammable gas detection but not toxic gas detection. As such, the detectors may not be able to sensitively detect toxic gas leakage. There is also uncertainty in terms of future statutory regulations in terms of gas detection installation at the warehouse.

6.2 Physical Effect Modelling

6.2.1 Gas Dispersion

The built-in UDM model in SAFETI is used for modelling the dispersion in non-immediate ignition scenarios following an LPG release without rainout effect. The model takes into account various transition phases, from dense cloud dispersion to buoyant passive gas dispersion, in both instantaneous and continuous releases. Toxic effect is evaluated in the built-in UDM model when the cloud reaches population sites for release of gas without ignition.

Upon release of flammable gas, a number of possible outcomes may be occurred depended on whether the gas is ignited immediately or ignited after a period of time. The dispersion characteristics will be influenced by the meteorological conditions and the material properties, such as density, of the released gas.

Gas vaporises rapidly and forms a vapour cloud upon release. Fire scenarios of different kinds may be developed in the presence of ignition sources in the proximity of gas release. If no ignition source exists, the vapour cloud will disperse downwind and will then be diluted to a concentration below its Lower Flammable Limit (LFL). In this case, the vapour cloud will become too lean to be ignited and will have no harmful effect.

6.2.2 Fireball

Immediate ignition of an instantaneous release of massive inventory inside a pressurised vessel will result in a fireball. A fireball is characterised by its high thermal radiation intensity and short duration time. The principal hazard of fireball arises from thermal radiation, which is not significantly influenced by weather, wind direction or source of ignition.

6.2.3 Flash Fire

A flammable gas release will vaporise and form a vapour cloud. This cloud, if not ignited immediately, will move in the downwind direction, entraining air as it disperses and becomes diluted. A flash fire will occur if the vapour cloud is ignited at a concentration above its LFL.

Major hazards from flash fire are thermal radiation and direct flame contact. Because of the short duration of the flash combustion, the thermal radiation effect on persons is limited. Humans who are encompassed outdoor by the flash fire is considered be fatally injured. A fatality rate of unity is assumed for outdoor population, and 90% protection factor is assumed for indoor occupants [2].

With regard to a flash fire, the criterion chosen is that a 100% fatality is assumed for any person outdoors within the flash fire envelope.

6.2.4 Pool Fire

In case of an early ignition of a spill of flammable liquids, an early pool fire will be formed and the maximum pool diameter can be obtained by matching the burning rate with the release rate.

Under such condition, the size of the pool fire will not further increase and will be steady. In case of a delay ignition, the maximum pool radius is reached when the pool thickness at the centre of the pool reaches the maximum thickness.

6.2.5 Warehouse Fire

As per previously approved EIA studies for the DG Godown [4][5], the warehouse fire was conducted using the warehouse fire model to calculate the composition and flow rates of the combustion products released to the atmosphere. The model calculates the average chemical structure for MDI. Assuming complete combustion and NO_2, SO_2 and halides as combustion products, mass emission factor and burning rate were calculated according the building ventilation characteristics, the oxygen requirement. Outputs from the warehouse fire model were used as source terms for dispersion model for evaluation of toxic effects. Pure hydrogen chloride is assumed for the toxic effects associated with the warehouse fire for this QRA Study.

Several hours are required for developing a fire into a major warehouse fire due to containment and attenuation effects. At this extended duration, it is possible to carry out a large scale evacuation unless the fire is initiated by some extreme events and in short duration such as earthquake. The number of population being threaten for the major warehouse fire (D-WF-EX) is only a small portion. In this assessment, it is assumed 99% population can be evacuated to a safe place.

A smoke plume generated from a fire follows the tilt angle of the flame initially and rises upward due to high buoyancy caused by high temperature. Plume height (H) is calculated as L x tan(90° – tilt angle) where L is the horizontal distance from the fire site boundary. This approach is has been applied to various approved EIA studies [20][21][22] for evaluating the impact of smoke plume to elevated population. Tilt angle is taken as 60° to represent the worst scenario**. Table 13** below presents the horizontal distance from fire site boundary and its associated smoke plume height.

The Proposed Development is located about 40m from the Kerry Go Godown. It may fall within the smoke plume and be affected by the toxic substance in the smoke plume of warehouse fire. Details of toxic exposure will be discussed in **Section 6.2.7.**

Table 13 Smoke Plume Height against Horizontal Distance from Fire Site Boundary

Horizontal Distance from Fire Site Boundary	Smoke Plume Height (m)	Equivalent Number of Storeys*
0	0	0
35	20.2	7
70	40.4	13
105	60.6	20
140	80.8	27
175	101.0	34
210	121.2	40

Note *: Floor height is assumed to be 3 m

6.2.6 Thermal Radiation of Fires

The major hazard of a pool fire or fireball is the flame and the thermal radiation. Persons caught in the flame zone are considered be fatally injured. Persons outside the flame zone are determined by lethal probability using the following Probit equation [9]:

$Pr = -36.38 + 2.56 \ln Q^{4/3t}$

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

6.2.7 Toxic Exposure

In case the released gas is not ignited, the dispersing cloud may cause toxic effect to people. Fatality rates due to toxic exposure are determined by the probit function [5], as follows:

$$Y = -a + b \times \ln (Cn \times t)$$

Where,

Y is probit corresponding to the probability of death;

a,b,n are the constants describing the toxicity of a substance;

C is the concentration of the toxic material (ppm); and

t is duration of exposure (minutes).

Fatality due to toxic exposure depends on the exposed duration and the toxicity of the material. Similarly, toxic cloud contours correspond to 90%, 50% and 1% fatality were recorded. The exposure time was taken as 30 minutes in this QRA study. If the scenario release duration is less than 30 minutes, the actual concentrations corresponding to the certain fatality level are calculated based on the release duration instead of 30 minutes.

Persons indoors are expected to be offered some protection from the ingress of a toxic cloud in buildings, the fatality probability for indoor persons is therefore assumed to be one tenth of the outdoor fatality probability.

Chlorine

Toxicity of chlorine is reviewed and values for the constants a, b, and n is referenced from available literature of the "CCPS" [23] and "Purple Book" [9]. For this QRA Study, a is taken as -6.35, b is taken as 0.5 and n is taken as 2.75 based on Purple Book" [9].

Ammonia

Toxicity of ammonia is reviewed and values for the constants a, b, and n is referenced from available literature of the "CCPS" [23] and "Purple Book" [9]. For this QRA Study, a is taken as -15.6, b is taken as 1 and n is taken as 2 based on Purple Book" [9] .

Hydrogen Chloride

Toxicity of hydrogen chloride is reviewed and values for the constants a, b, and n is referenced from available literature of the "CCPS" [23] and "Purple Book" [9] . For this QRA Study, a is taken as -37.3, b is taken as 3.69 and n is taken as 1 based on Purple Book" [9] .

7.0 Risk Assessment

7.1 Risk Summation

Risk summation combines the likelihood and consequence of hazardous event, as well as meteorological data and population in the hazard effect zones, to give a numerical measure of risks around the DG Godown. The risk analysis is conducted by the simulation software – SAFETI 8.9 developed by DNV and the outcome results are presented in terms of IR contours and Societal Risk (as F-N curves). The risk outcomes are compared to the criteria set out in the risk guidelines, as specified in **Section 1.2.1**.

7.2 Results of Individual Risk

The IR contours for overall DG Godown and individual scenarios (LPG, Toxic, Warehouse Fire, and Pentane Fire) are presented in **Figure 4** - **Figure 8.** The individual risk contour pf 1×10^{-5} per year is out of the site boundary of the DG Godown and encroaches into public traffic road.

However, as per Hong Kong Risk Guidelines, the estimated duration of exposure of a person in the vicinity of the hazardous installation such as Kerry DG Godown should also be taken into consideration to determine the individual risk for evaluation with the Hong Kong Risk Guidelines in terms of individual risk.

Vehicles on the public traffic road in adjacent to the Kerry DG Godown are transit population and are not stationed for a fixed period of time. The speed of vehicles are assumed as 50 km/ hr while the road length is about 400 meters in vicinity of the Kerry DG Godown. As such, vehicles take about 30 seconds to move through the Kerry DG Godown. An exposure factor of 0.5 is conservatively assumed, and the IR contour of 1×10^{-5} per year is considered well confined within the site boundary of the DG Godown.

The individual risk level at the Application Site is between 1×10^{-6} to 1×10^{-8} per year.

7.3 Results of Societal Risk

The societal risk results of the overall DG Godown and individual scenarios (LPG, Toxic, Warehouse Fire, and Pentane Fire) are presented in the form of F-N curves in Error! Reference source not found. and **Figure 10** with detailed data presented in **Table 14** for comparison to the Government Risk Guidelines. Case 1 represents the risk level in year 2033 without redevelopment of the Proposed Development (i.e. as existing commercial building) while Case 2 represents the risk level in year 2032 with the construction of the Proposed Development, and Case 3 represents the risk level in year 2033 with the redevelopment of the Proposed Development.

The F-N curves of all cases fall within the "ACCEPTABLE" region and satisfy the requirement of the HKPSG. With implementation of the Proposed Development, the population brought by the Proposed Development cause slightly increase to the overall risk level of the DG Godown.

Table 14 F-N Data

No. of fatality	Frequency (per year)		
	Case 1 – Base Case in Year 2033	Case 2 - Construction Case in Year 2032	Case 3 – Operation Case in Year 2033
1	1.55E-06	1.54E-06	1.45E-06
2	1.04E-06	1.03E-06	1.01E-06
3	9.25E-07	9.15E-07	8.98E-07
4	8.31E-07	8.22E-07	8.38E-07
5	7.37E-07	7.34E-07	7.75E-07
6	6.35E-07	6.34E-07	6.84E-07
8	3.60E-07	3.60E-07	3.78E-07
10	7.81E-08	7.81E-08	7.51E-08
12	7.65E-08	7.65E-08	7.05E-08
15	7.25E-08	7.25E-08	6.81E-08
20	6.19E-08	6.19E-08	6.06E-08
25	5.09E-08	5.08E-08	5.05E-08
30	4.78E-08	4.78E-08	4.75E-08
40	4.72E-08	4.72E-08	4.70E-08
50	4.55E-08	4.55E-08	4.54E-08
60	4.44E-08	4.44E-08	4.42E-08
80	4.26E-08	4.26E-08	4.22E-08
90	4.22E-08	4.21E-08	4.16E-08
100	4.18E-08	4.16E-08	4.11E-08
120	4.06E-08	3.98E-08	3.98E-08
150	3.82E-08	3.42E-08	3.69E-08
200	3.07E-08	2.86E-08	2.88E-08
250	2.03E-08	1.82E-08	1.84E-08
300	1.82E-08	1.61E-08	1.54E-08
400	1.40E-08	1.14E-08	1.19E-08
500	1.00E-08	7.91E-09	8.29E-09
600	7.11E-09	5.54E-09	6.86E-09
800	8.07E-10	7.54E-10	5.28E-09
870	-	-	3.23E-09
900	-	-	2.76E-09
970	-	-	1.45E-09
1000	-	-	8.82E-10

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

Societal risk can also be represented in the form of Potential Loss of Life (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:

$$\mathrm{PLL} = f_1 N_1 + f_2 N_2 + \cdots + f_n N_n$$

The PLL values of the major contributors are shown in **Table 15**. With the additional population brought by the Proposed Development, the total PLL is increased by 1.2%, from 2.15×10^{-5} no. of fatality per year to 2.17×10^{-5} no. of fatality per year.

Table 15 Breakdown of PLL

Hazardous Scenario		Case 1 – Base Case		Case 2 – Construction Case		Case 3 – Operation Case	
		PLL (no. of fatality per year)	% of total PLL	PLL (no. of fatality per year)	% of total PLL	PLL (no. of fatality per year)	% of total PLL
D-PF-EX	Pentane fire Loss of Area (building collapsed)	1.51E-05	70.18%	1.39E-05	68.71%	1.53E-05	70.18%
D-PF-AE	Pentane fire Loss of Area External	4.62E-06	21.48%	4.62E-06	22.76%	4.49E-06	20.66%
D-WF-EX	Major Warehouse Fire (building collapsed)	9.87E-07	4.59%	9.55E-07	4.71%	1.21E-06	5.56%
DG-AT-W	Ammonia toxic release (building collapsed)	4.06E-07	1.89%	3.83E-07	1.89%	4.09E-07	1.88%
DG-CT-CI	Chlorine – Loss of Cylinder Internal	2.57E-07	1.20%	2.57E-07	1.27%	2.25E-07	1.03%
Others		1.43E-07	0.66%	1.36E-07	0.67%	1.49E-07	0.69%
Total		**2.15E-05**	**100%**	**2.03E-05**	**100%**	**2.17E-05**	**100%**

8.0 Conclusion

An Application Site at 8 Lam Chak Street, Kowloon – N.K.I.L. 6215 is proposed to convert from existing commercial use to comprehensive residential development. A Quantitative Risk Assessment (QRA) has studied the risk impact of a DG Godown, located at 7 Kai Hing Road, Kai Tak, posed to the surrounding populations to the surrounding population, including the additional population brought by the redevelopment of the Application Site.

The result revealed that the offsite individual risk of the DG Godown is below 1×10^{-5} per year, in which the individual risk at the Application Site is below 1×10^{-6} per year.

With the redevelopment of the Application Site, the societal risk of the DG Godown remains within "Acceptable" region of the criteria in the Hong Kong Risk Guidelines.

9.0 References

[1] *The Hong Kong Planning Standards and Guidelines (HKPSG),* Planning Department, Hong Kong SAR, 2022

[2] *Quantitative Risk Assessment Methodology for LPG Installations,* Dr. Alan B. Reeves, Francis C. Minah, Vincent H.K. Chow, Conference on Risk & Safety Management in the Gas Industry, EMSD & HKIE, Hong Kong, 1996

[3] *South Island Line (East) Environmental Impact Assessment,* MTR Corporation Limited, AEIAR- 155/2010

[4] *A Rooftop Helipad at New Acute Hospital (NAH) at Kai Tak Development Area Environmental Impact Assessment,* Hospital Authority, AEIAR- 266/2020

[5] Agreement No. CE 35/2006(CE) Kai Tak Development Engineering Study cum Design *and Construction of Advance Works– Investigation, Design and Construction Environmental Impact Assessment, Maunsell/ Aecom, AEIAR-130/2009*

[6] *Buildings with Licensed Dangerous Goods Stores (Kowllon Region)*, Fire Services Department, last accessed 07/03/2026, https://es.hkfsd.gov.hk/dg/upload/page/23/self/67ea4729a6c1e.pdf

[7] *2021 Population By-census,* Census and Statistics Department, Hong Kong

[8] *Harbour Area Treatment Scheme Stage 2A Environmental Impact Assessment,* The Drainage Services Department of HKSAR, AEIAR-121/2008

[9] *Guidelines for Quantitative Risk Assessment "Purple Book", CPR18E,* Committee for the Prevention of Disasters, 2005

[10] *Monthly Meteorological Normals for Hong Kong (1991-2020)*, Hong Kong Observatory, https://www.hko.gov.hk/en/cis/normal/1991_2020/normals.htm

[11] *Air Traffic Statistics: http://www.cad.gov.hk/english/statistics.html, Civil Aviation Department*

[12] *The Calculation of Aircraft Crash Risk in the UK,* Health and Safety Executive, United Kingdom, 1997

[13] *The Control of Major Accident Hazards Regulations 2005, United Kingdom*

[14] *UK HSE Safety Report Assessment Guide (SRAG) – Chemical Warehouses, and associated criteria, United Kingdom*

[15] *Code of Practice for Hong Kong LPG Industry, Electrical and Mechanical Services Department, Hong Kong SAR, 2023*

[16] *UK AEA, Major Hazard Incident Database (MHIDAS) Silver Platter.*

[17] *Assessment of benefits of compartmentalisation in chemical warehouses RR152 HSE, United Kingdom*

[18] *An Insight into Warehouse Fires, Willis Review*

[19] *Cox, Lees and Aug, Classification of Hazardous Locations, IChemE, 1990.*

[20] *Hazard to Life Assessment for Development of EcoPark in Tuen Mun Area 38 (EIA-104/2005)*

[21] *Hazard to Life Assessment for Tung Chung – Ngong Ping Cable Car Project (EIA-090/2003)*

[22] *Hazard to Life Assessment for Permanent Aviation Fuel Facility for Hong Kong International Airport (EIA-127/2006)*

[23] *Center for Chemical Process Safety of the American Institute of Chemical Engineer, Guidelines for Chemical Process Quantitative Risk Analysis, Second Edition, 2000.*

[24] *A Review of Large Warehouse Fires, Loss Prevention Bulletin 132*

[25] I. Hymes and J.F. Flynn, *The probability of fires in warehouses and storage premises,* AEA Technology, HSE/SRD/089/00001/90/WP1, September 1992

[26] *Qest Intermodal Logistics at Enfield EIS,* PHA, Rev2 2005

[27] T. Maddison & G. Atkinson*, The ass essment of individual risks from fires in warehouses containing toxic materials,* Loss Prevention Bulletin, No. 132, pp. 29- 34, December 1996

[28] *Reassessment of Chlorine Hazard for Eight Existing Water Treatment Works,* ERM, 2001

Figures

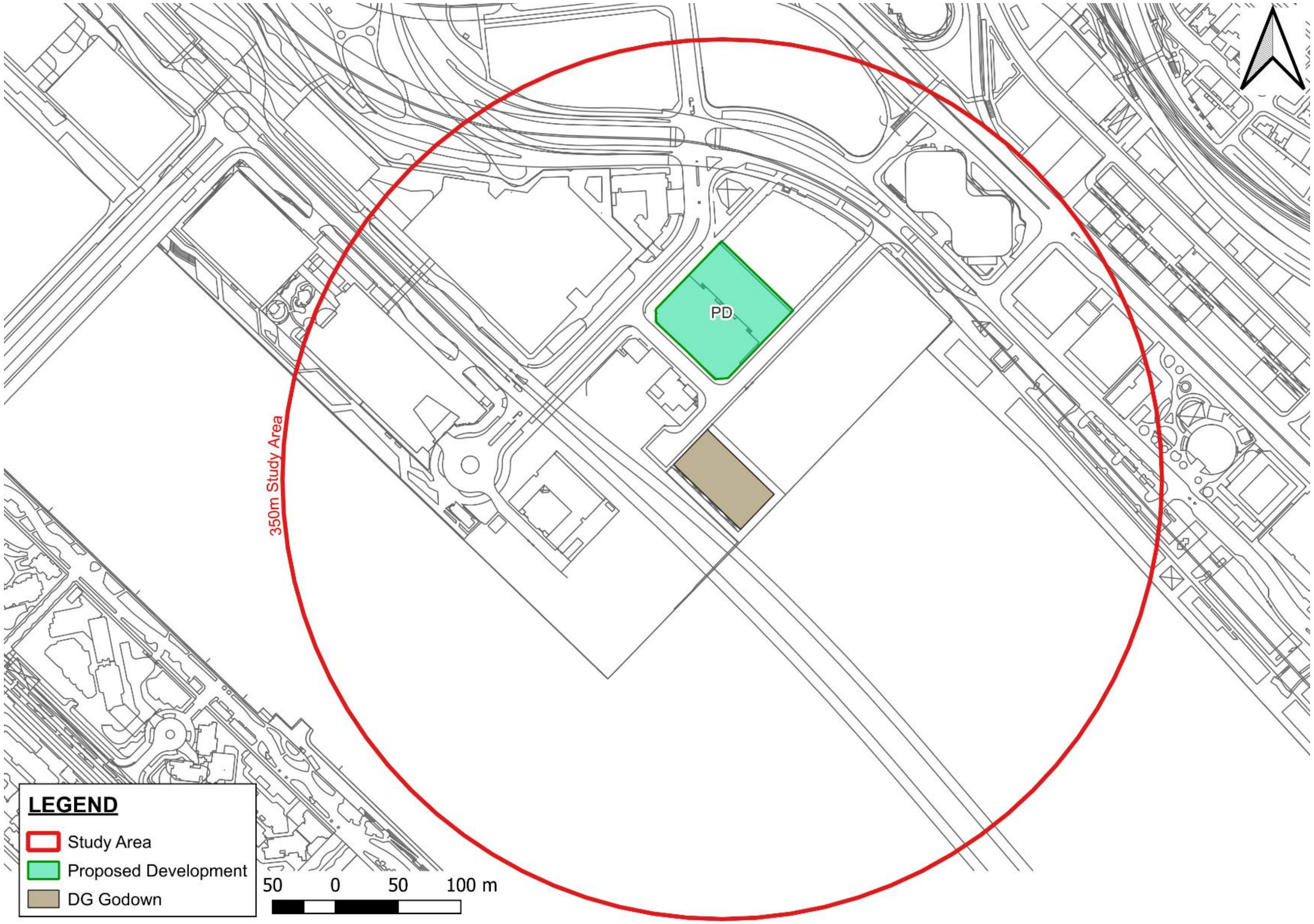


Figure 1 Location of the Site and Study Area

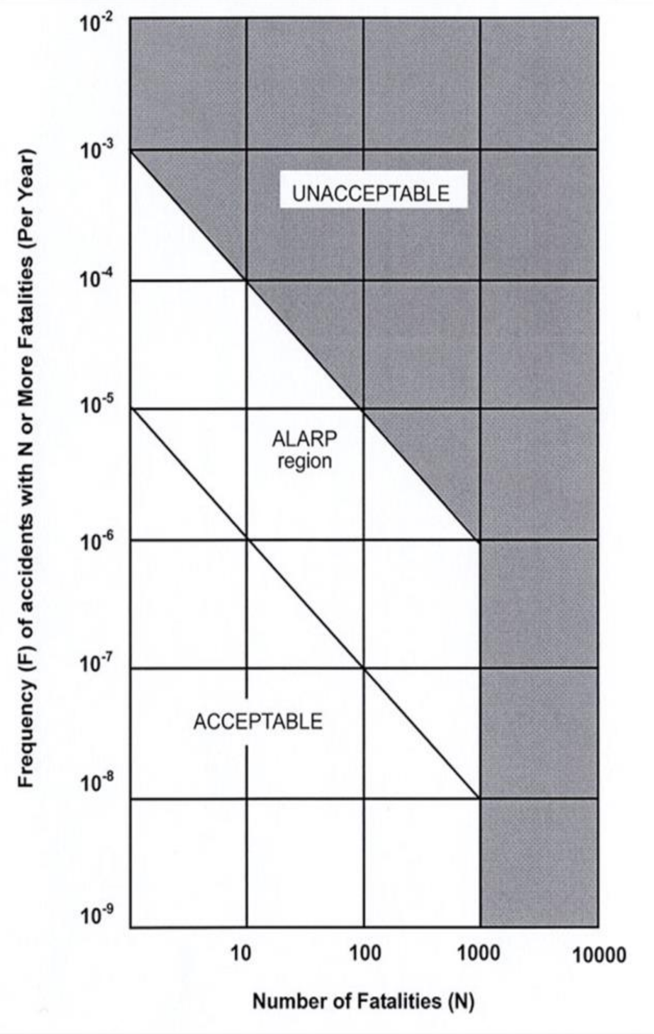


Figure 2 Societal Risk Guideline

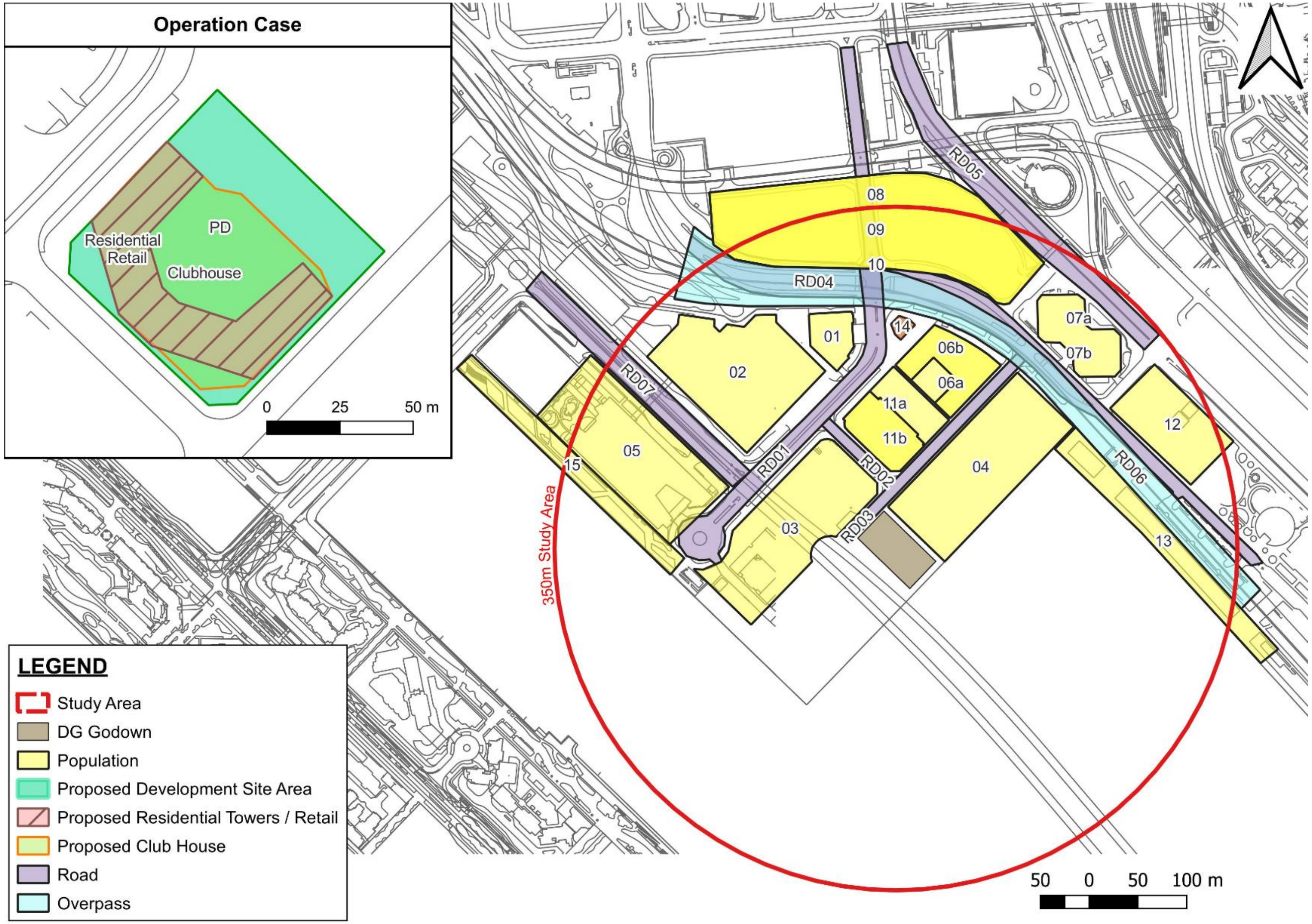


Figure 3 Population Considered in this Study

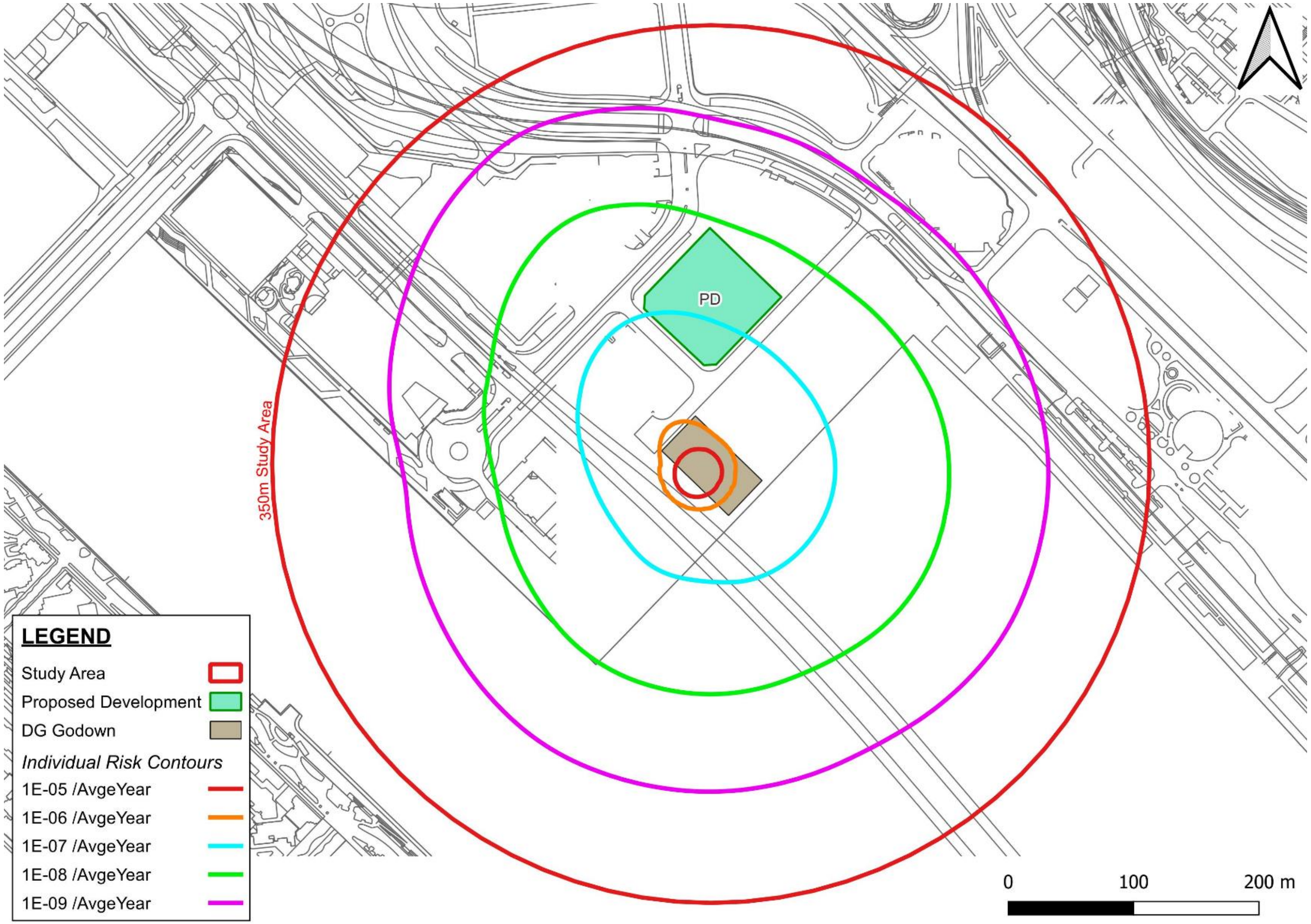


Figure 4 Individual Risk of the DG Godown (Overall)

Figure 5 Individual Risk of the DG Godown (LPG)

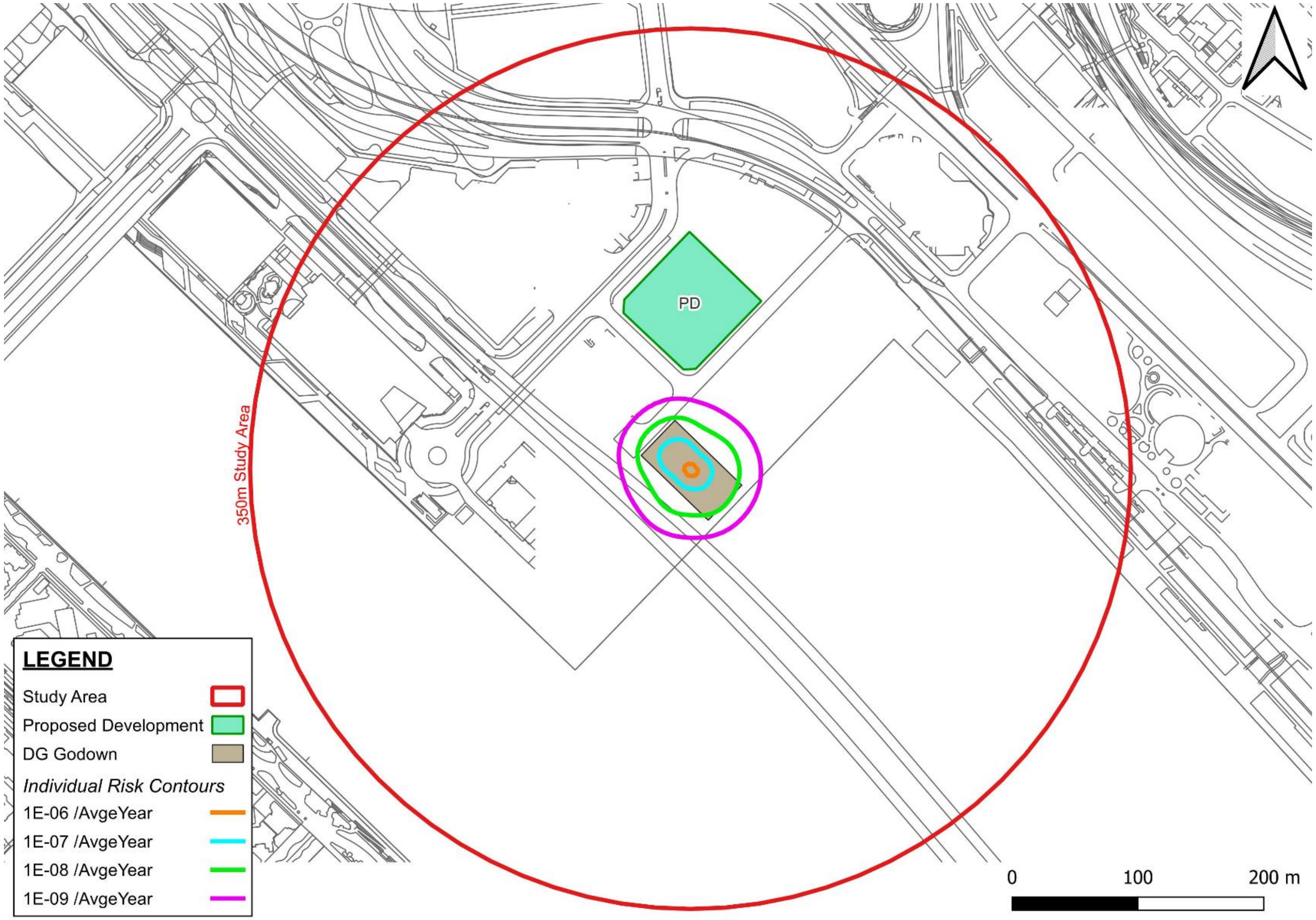


Figure 6 Individual Risk of the DG Godown (Toxic)

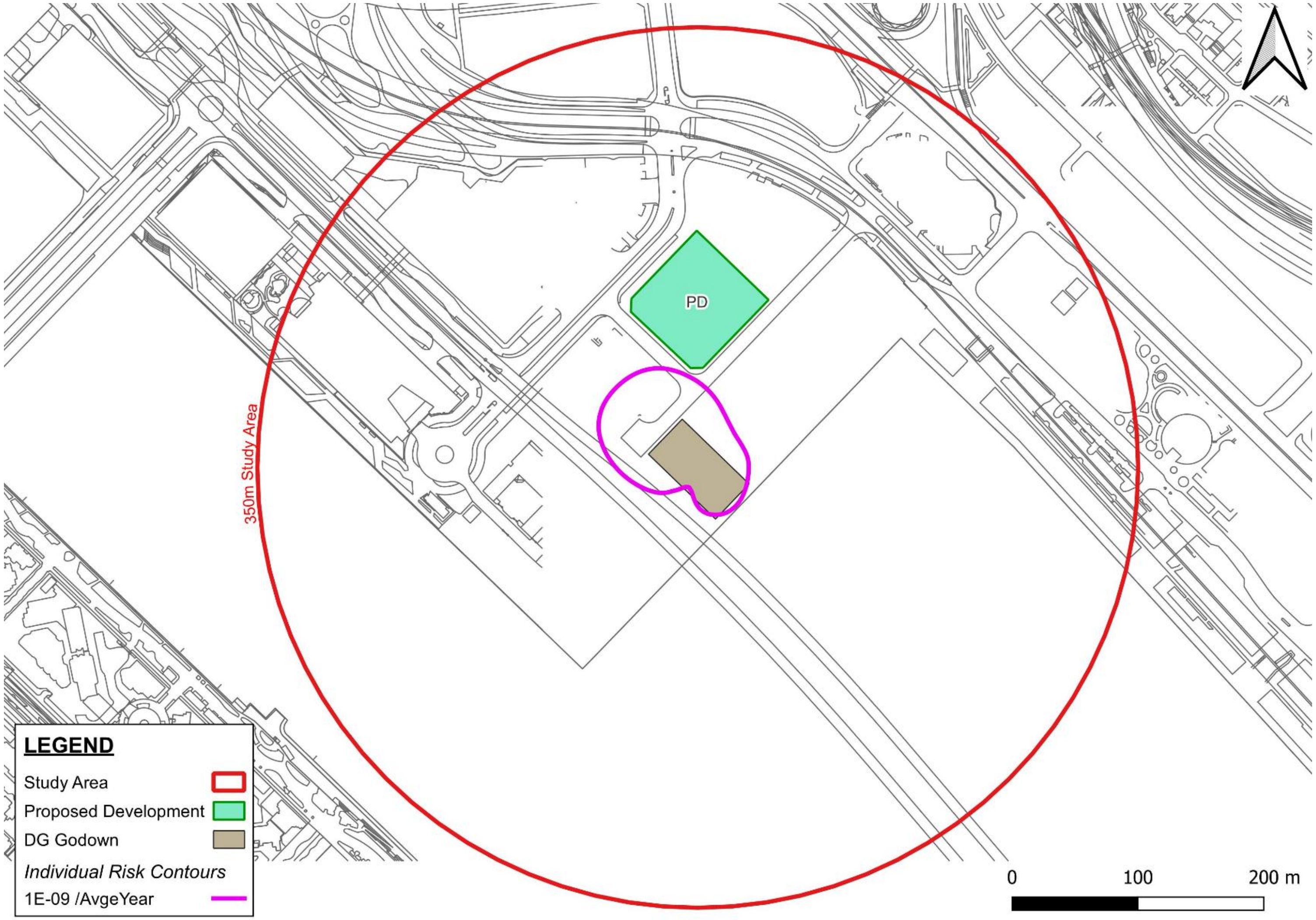


Figure 7 Individual Risk of the DG Godown (Warehouse Fire)

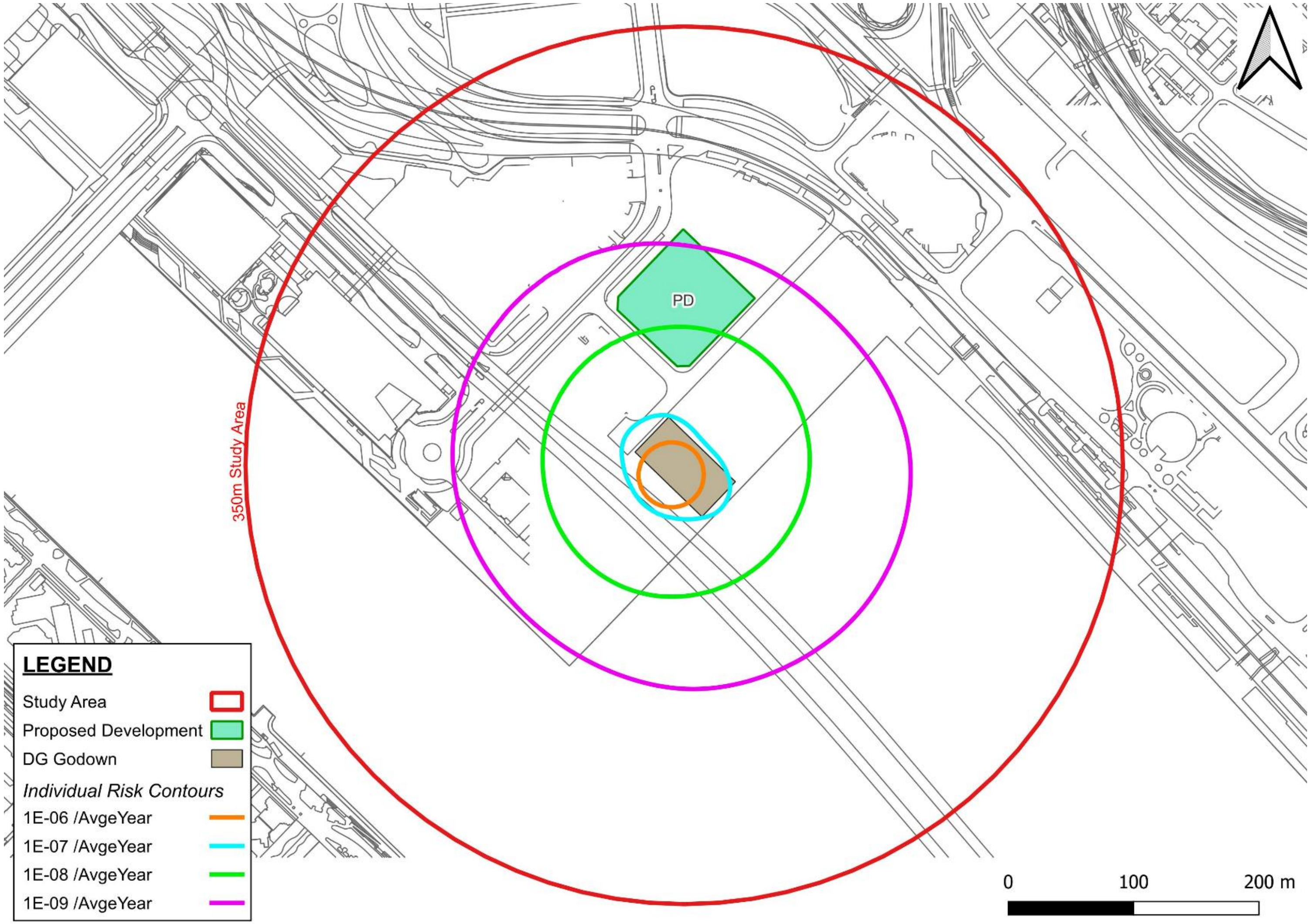


Figure 8 Individual Risk of the DG Godown (Pentane Fire)

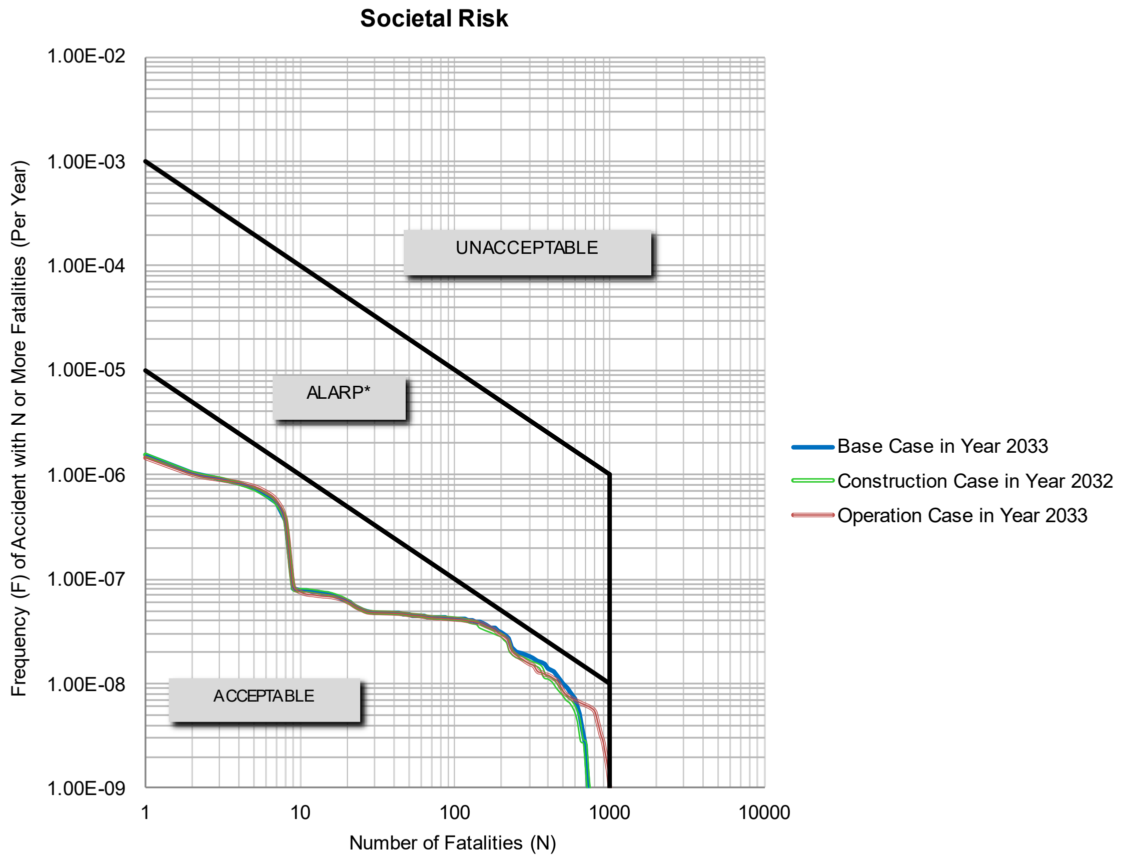


Figure 9 Societal Risk Result (Overall)

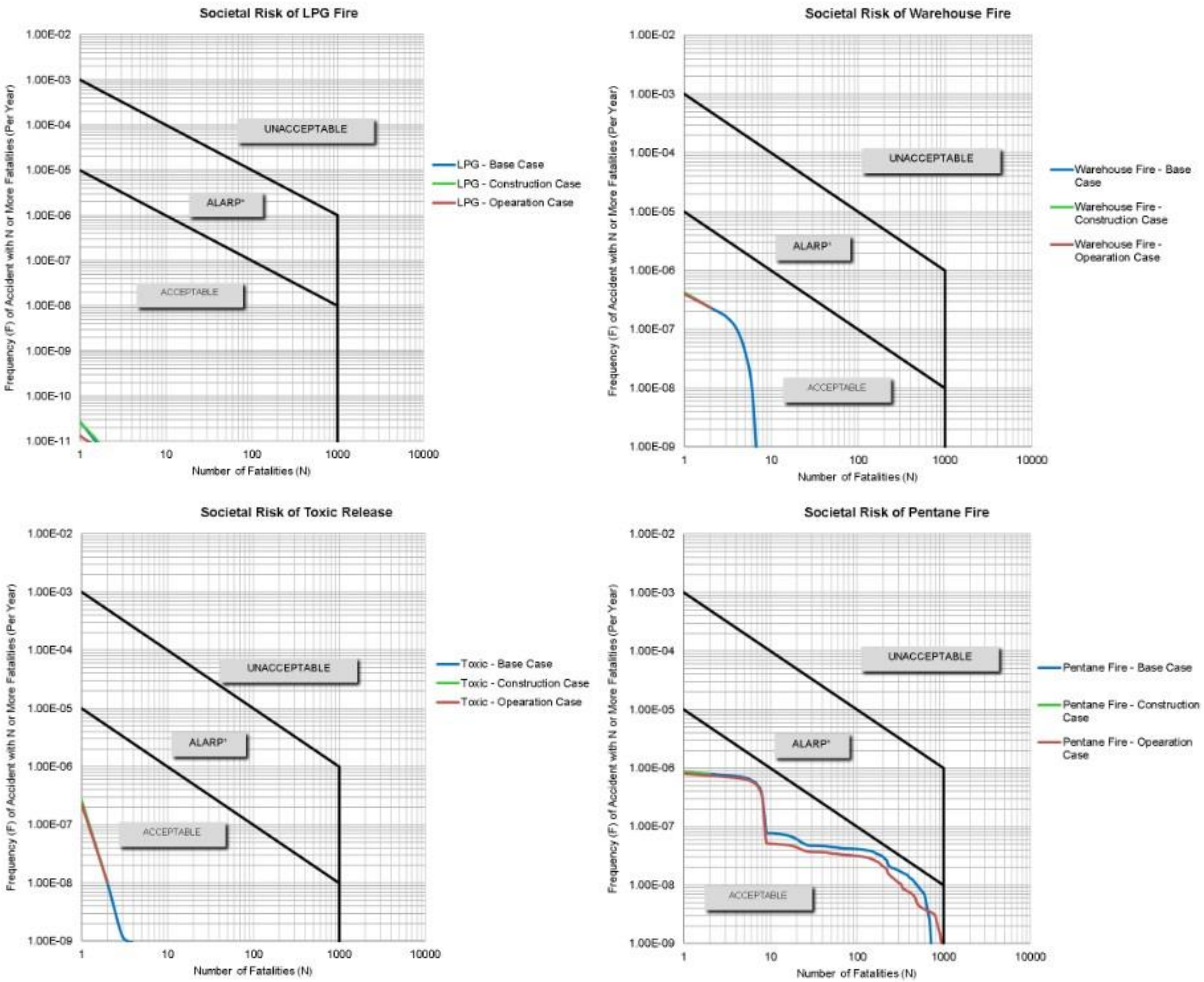


Figure 10 Societal Risk Result (Breakdown by Type of Fire / Release)

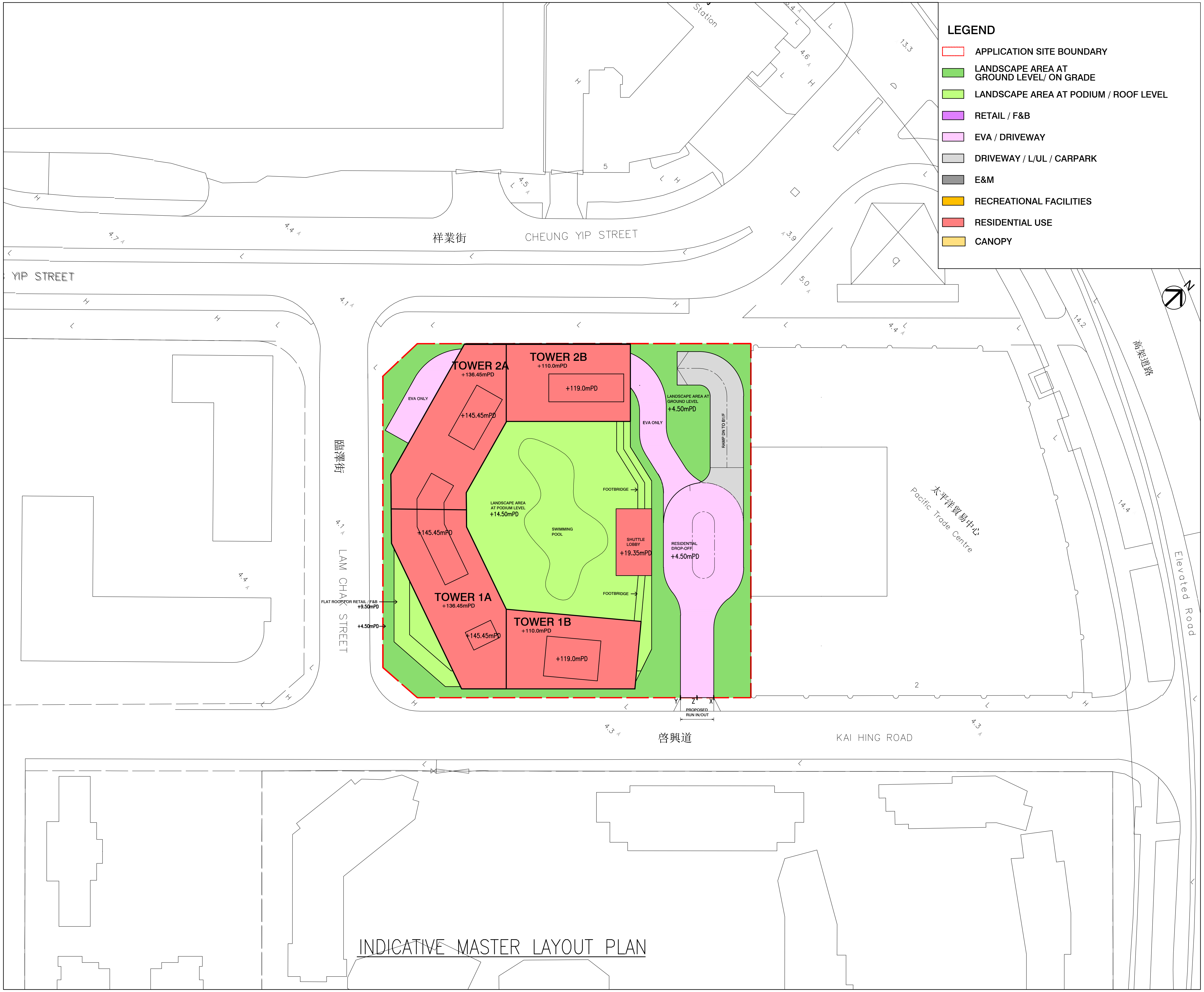
Annex A:
Layout Plan of the Proposed Development

Development Schedule

		Redevelopment of Harbourside HQ
Site Area		6,541m^2
Plot Ratio		7.0
GFA Permissible & Provided	Domestic GFA	(Permissible & Provided) 42,516.5m^2 (PR=6.5)
	Non-domestic GFA	(Permissible & Provided) (Retail / F&B) 3,270.5m^2 (PR=0.5)
	Total GFA	45,787m^2
Recreational Facilities		(Max. GFA concession) 1,913.24m^2
Total No. of Units		1,140
Domestic Site Coverage		max. 40%
No. of Storeys		Maximum 34 (Residential) +1 (Refuge) +3 (Non-domestic Floors)
Building Height		+136.45 mPD & +110.0 mPD
Floor Height		3.15m, 3.3m, 3.5m or 4m (Tower), 5m (G/F, 1/F), 4.85m (2/F)

6.5
DOM PR
0.5
ND PR

1140
Total no. of unit



B.D. REFERENCE	屋宇署檔案
F.S.D. REFERENCE	消防處檔案
W.W.O. REFERENCE	水務署檔案
CAD FILE NAME	檔案編號
NOTES	注釋

NO. 修定號	REVISIONS 修定內容	DATE 日期	BY 經手人

DLN

DLN Architects Limited
劉榮廣伍振民建築師有限公司

46-47 Floor, Tower One, Times Square Matheson Street, Causeway Bay, Hong Kong
香港銅鑼灣勿地臣街時代廣場一座46至47樓

t +852 2895 6888 f +852 2576 4074 email general@dln.com.hk www.dln.com.hk

ALL MEASUREMENTS MUST BE CHECKED AT THE WORK BY THE CONTRACTOR
所有尺寸應由承建商於工地核實
DO NOT SCALE FROM DRAWINGS 尺寸不應由圖紙直接量度
ALL PRINTS, SPECIFICATIONS AND THEIR COPYRIGHT ARE THE PROPERTY OF THE ARCHITECT AND SHALL BE RETURNED AT THE COMPLETION OF THE WORK
所有印刷、規格說明及所有的版權屬於建築師及應在工程完結後歸還建築師

PROJECT 項目名稱

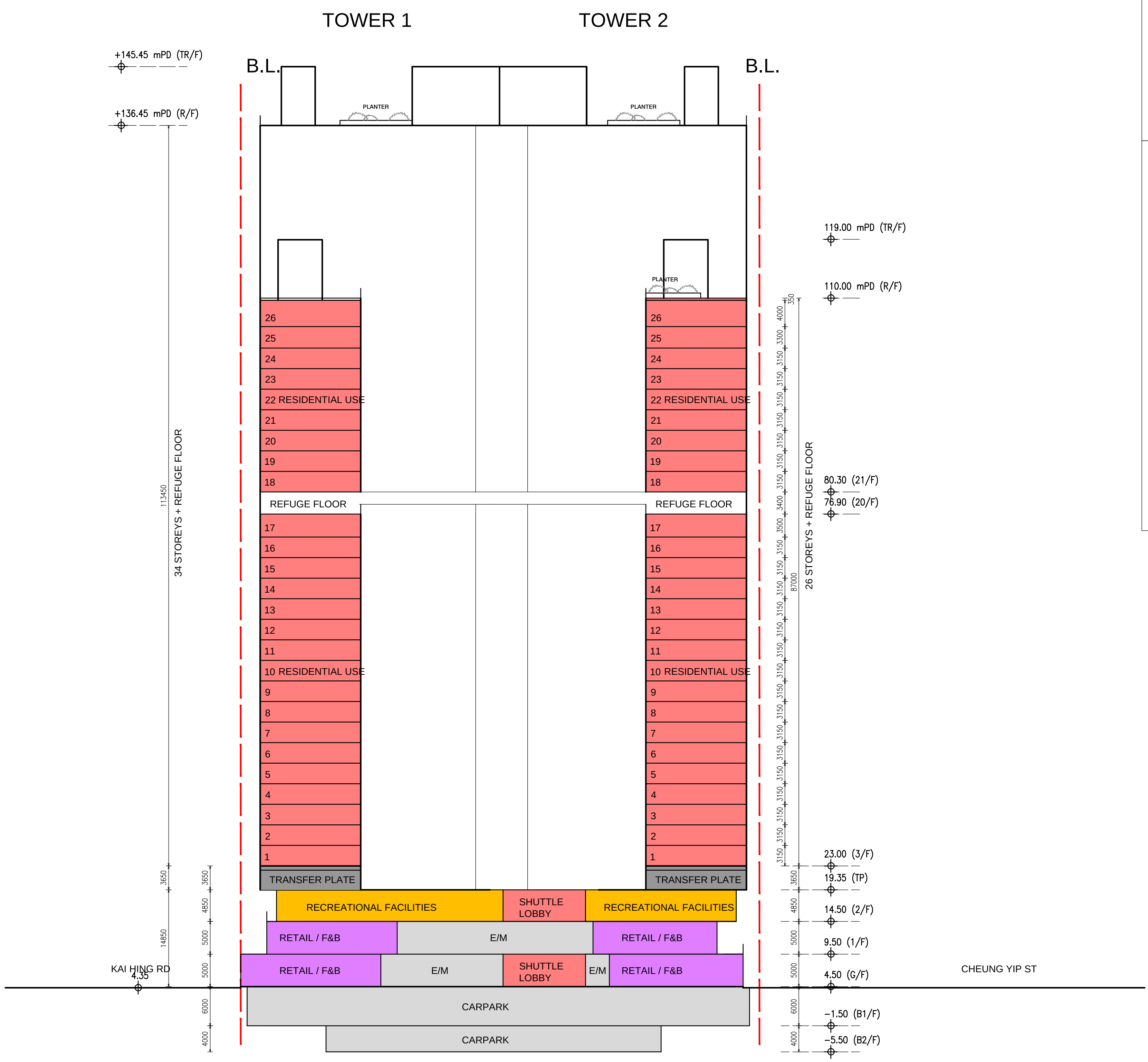
PROPOSED COMPOSITE DEVELOPMENT AT 8 LAM CHAK STREET, KOWLOON – N.K.I.L. 6215

TITLE 標題

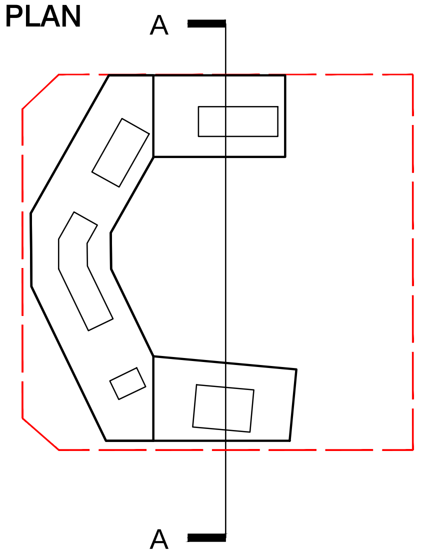
INDICATIVE MASTER LAYOUT PLAN

SCALE 比例: 1:800(A3)	DATE 日期: AUG 2025
DRAWN BY 製作人: DT	CHECKED BY 檢查: –
JOB NO. 工程項目: N3591–H	DRAWING NO. 圖號: –

H:\Dwgs\ACAD\Submission Plans (TPB)\2026-03-03 6.5+0.5\2026-02-03 S16 6.5+0.5.dwg, 1:1, Project No.: N3591-H



KEY PLAN



LEGEND

- APPLICATION SITE BOUNDARY
- LANDSCAPE AREA AT GROUND LEVEL/ ON GRADE
- LANDSCAPE AREA AT PODIUM / ROOF LEVEL
- RETAIL / F&B
- EVA / DRIVEWAY
- DRIVEWAY / L/UL / CARPARK
- E&M
- RECREATIONAL FACILITIES
- RESIDENTIAL USE

B.D. REFERENCE	屋宇署檔案
F.S.D. REFERENCE	消防處檔案
W.W.O. REFERENCE	水務署檔案
CAD FILE NAME	檔案編號
NOTES	注釋

NO. 修定號	REVISIONS 修定內容	DATE 日期	BY 經手人

DLN
DLN Architects Limited
劉榮廣伍振民建築師有限公司
46-47 Floor, Tower One, Times Square
Matheson Street, Causeway Bay, Hong Kong
香港銅鑼灣勿地臣街
時代廣場一座46至47樓
t +852 2895 6888 f +852 2576 4074
email general@dln.com.hk www.dln.com.hk

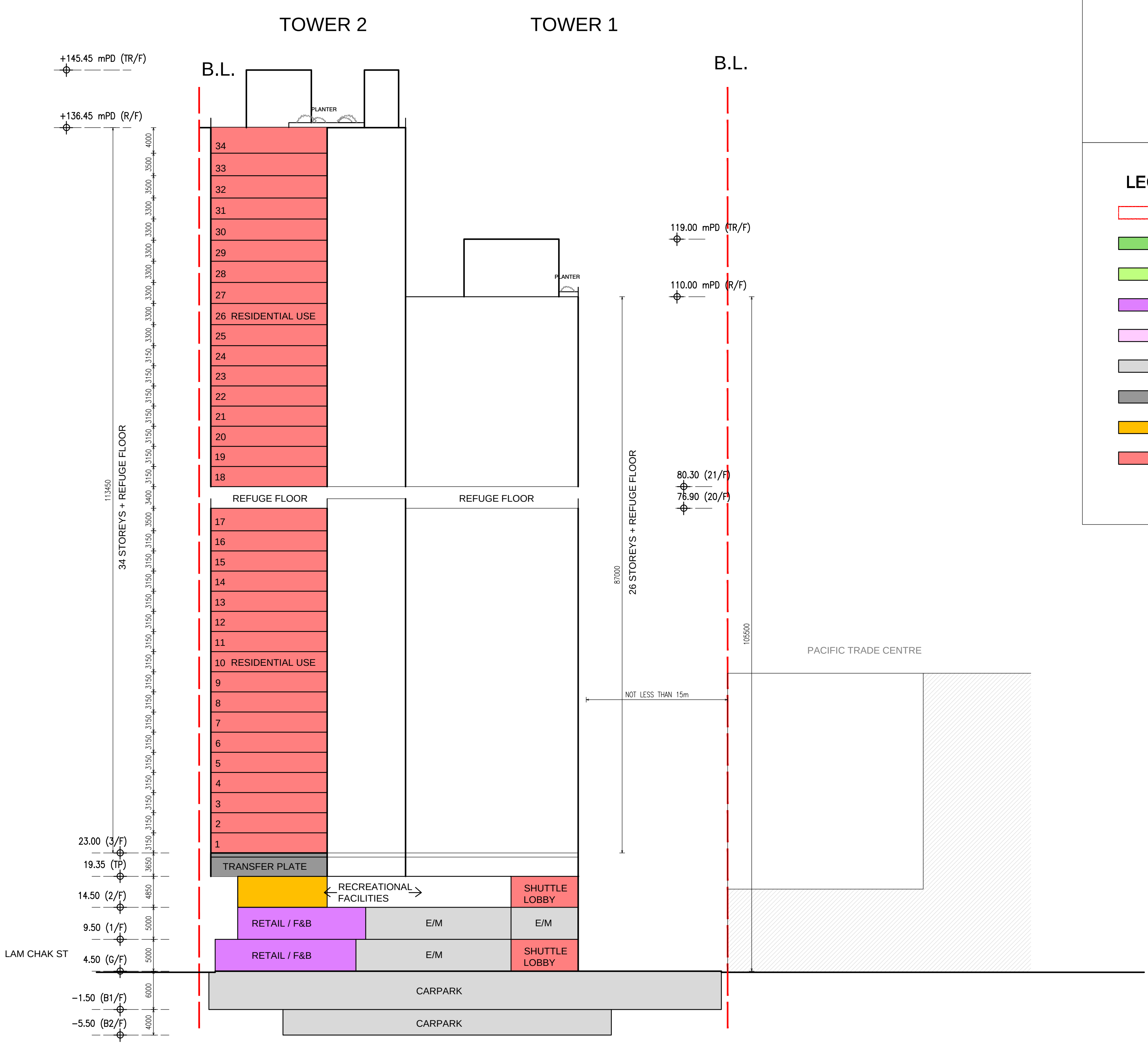
PROJECT 項目名稱

PROPOSED COMPOSITE DEVELOPMENT
AT 8 LAM CHAK STREET, KOWLOON
– N.K.I.L. 6215

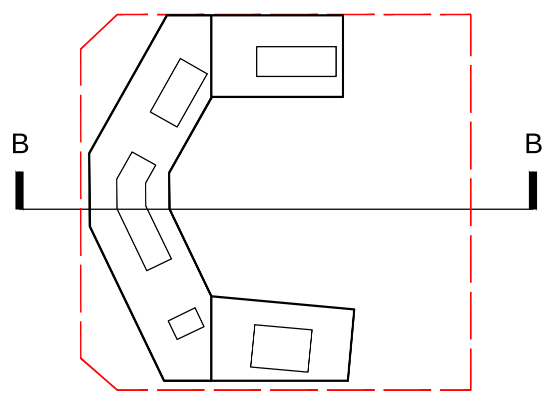
TITLE 標題

INDICATIVE SECTION A–A

SCALE 比例 1:800(A3)	DATE 日期 AUG 2025
DRAWN BY 製作人 DT	CHECKED BY 檢查 –
JOB NO. 工程項目 N3591–H	DRAWING NO. 圖號 –



KEY PLAN



LEGEND

- APPLICATION SITE BOUNDARY
- LANDSCAPE AREA AT GROUND LEVEL/ ON GRADE
- LANDSCAPE AREA AT PODIUM / ROOF LEVEL
- RETAIL / F&B
- EVA / DRIVEWAY
- DRIVEWAY / L/UL / CARPARK
- E&M
- RECREATIONAL FACILITIES
- RESIDENTIAL USE

B.D. REFERENCE	屋宇署檔案
F.S.D. REFERENCE	消防處檔案
W.W.O. REFERENCE	水務署檔案
CAD FILE NAME	檔案編號
NOTES	注釋

NO. 修定號	REVISIONS 修定內容	DATE 日期	BY 經手人

DLN Architects Limited
劉榮廣伍振民建築師有限公司
46-47 Floor, Tower One, Times Square
Matheson Street, Causeway Bay, Hong Kong
香港銅鑼灣勿地臣街
時代廣場一座46至47樓
t +852 2895 6888 f +852 2576 4074
email general@dln.com.hk www.dln.com.hk

ALL MEASUREMENTS MUST BE CHECKED AT THE WORK BY THE CONTRACTOR
所有尺寸應由承建商於工地核實
DO NOT SCALE FROM DRAWINGS 尺寸不應由圖紙直接量度

PROJECT 項目名稱

PROPOSED COMPOSITE DEVELOPMENT
AT 8 LAM CHAK STREET, KOWLOON
– N.K.I.L. 6215

TITLE 標題

INDICATIVE SECTION B-B

SCALE 比例 1:800(A3)	DATE 日期 AUG 2025
DRAWN BY 製作人 DT	CHECKED BY 檢查 –
JOB NO. 工程項目 N3591-H	DRAWING NO. 圖號 –

Annex B: Calculation of Transient Population

B1. Calculation of Average Occupancy

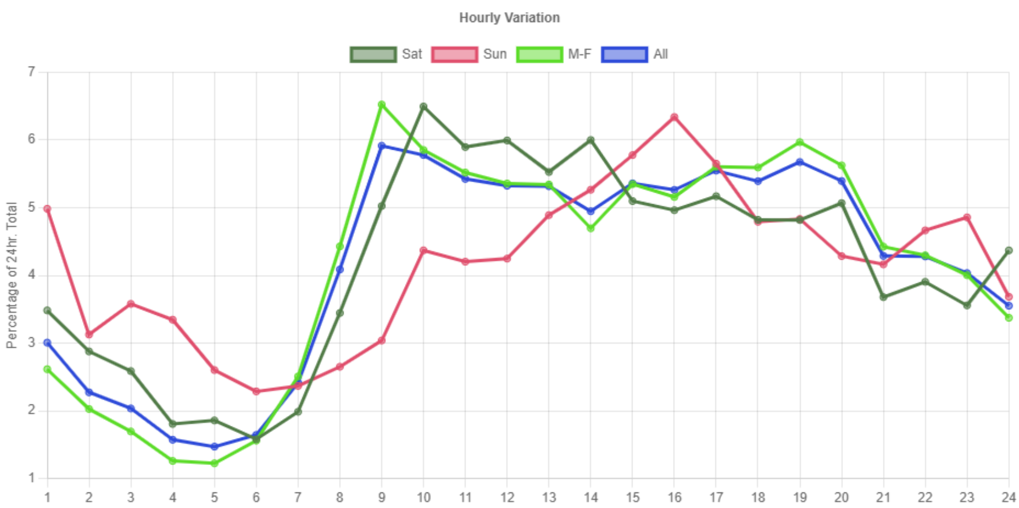
The average occupancies of vehicles on roads concerned are estimated from statistics of nearby traffic stations in Annual Traffic Census 2024.

Station No.	**3004**		**4219**	
Link	Kai Tak Tunnel		Kwun Tong Bypass	
Vehicle Type	**Pro**	**Ocp**	**Pro**	**Ocp**
Motor Cycle	3.6	1.1	3.1	1.1
Private Car	48.7	1.4	57	1.3
Taxi	23.2	1.9	12.3	2.1
Private Light Bus	0.7	2.7	0.8	4.2
Public Light Bus	0.1	8.2	1	11.7
Light Goods Vehicle	14.1	1.4	15.2	1.3
M&H Goods Vehicle	4.6	1.2	7	1.1
Non Fr. Bus	1.8	8.3	1.3	15.4
SD Fr. Bus	0.1	1	0.1	0.7
DD Fr. Bus	3.2	27.2	2.3	49.9
Average Occupancy	2.46		2.81	

Note:
(1) *Average occupancy* $= \sum(Probability_i \times Occupancy_i)/\sum Probability_i$

B2. Calculation of Traffic Variation within the Day

The traffic flow variation on roads within the study area is assumed as same as the that at Kai Tak Tunnel which is the major road link to the area.



Station No.	Road	Ratio of Day-time and Night-time Traffic Flow		Ratio to WDD Traffic Flow	
		Day	Night	Day	Night
3004	Kai Tak Tunnel	61%	39%	100%	63%

B3. Estimation of Traffic Flow

Traffic flow on concerned roads are projected from annual traffic statistics of nearest traffic stations in the past 9 years.

Traffic Station	Annual Average Daily Traffic (AADT)								
	2016	2017	2018	2019	2020	2021	2022	2023	2024
Cheung Yip Street (Station No. 4606)	8,310	7,610	5,450	5,820	5,920	7,320	7,350	15,890	15,240
Wai Yip Street (Station No. 3686)	24,800	24,690	24,580	24,080	23,900	24,800	23,620	25,000	23,460
Kwun Tong Bypass (Station No. 3023)	96,730	97,360	95,620	97,380	90,600	90,430	95,920	112,420	102,550

ID	Road	AADT in 2024	Ave. Annual Traffic Growth	Predicted AADT in 2033	Day Hourly Traffic (veh/hr)	Night Hourly Traffic (veh/hr)
RD01	Cheung Yip Street	15,240	-	15,240 (1)	781	489
RD02	Lam Chak Street	-	-	3,048 (2)	156	98
RD03	Kai Hing Road	-	-	3,048 (2)	156	98
RD04	Hoi Bun Road	-	-	15,240 (3)	781	489
RD05	Wai Yip Street	23,460	-	23,460	1,202	753
RD06	Kwun Tong Bypass	102,550	1.0%	112,217	5,749	3,325
RD07	Shing Cheong Road	67,740	1.2%	77,333(4)	3,962	2,264

Note:

(1) The vast increase of traffic on Cheung Yip Street in 2024 to 2025 was caused by construction traffic to/from NAH construction site. Such construction traffic is considered as temporary situation until completion of NAH in 2026. Nevertheless, the AADT in 2023 is conservatively adopted as future traffic flow in 2033.
(2) Assume as 20% of that of Chueng Yip Street for minor local access road.
(3) Assume as same as that of Chueng Yip Street, which are both local distributors.
(4) Assume as 50% of that of Chueng Yip Street for minor local access road.

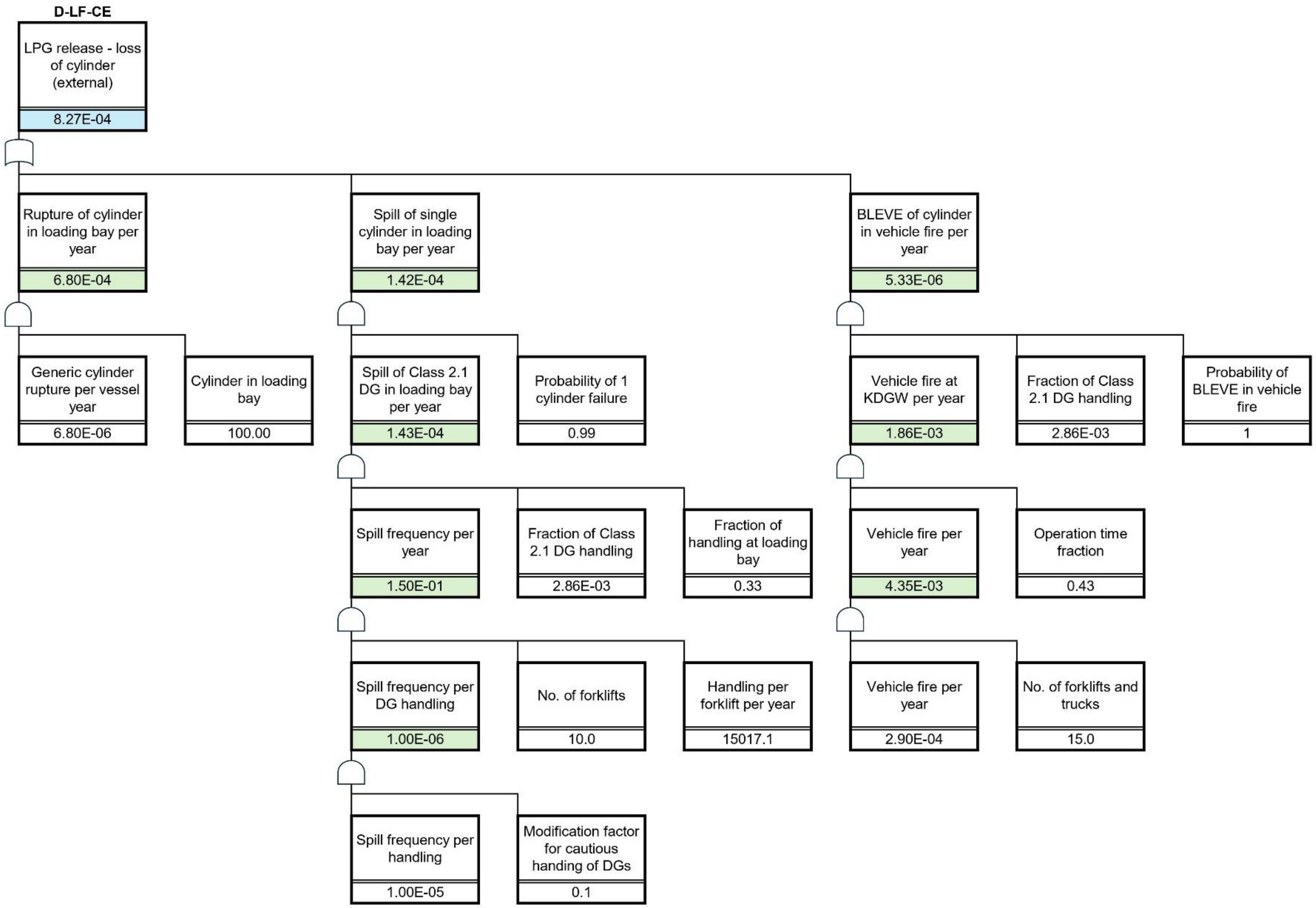
B4. Calculation of Transient Population

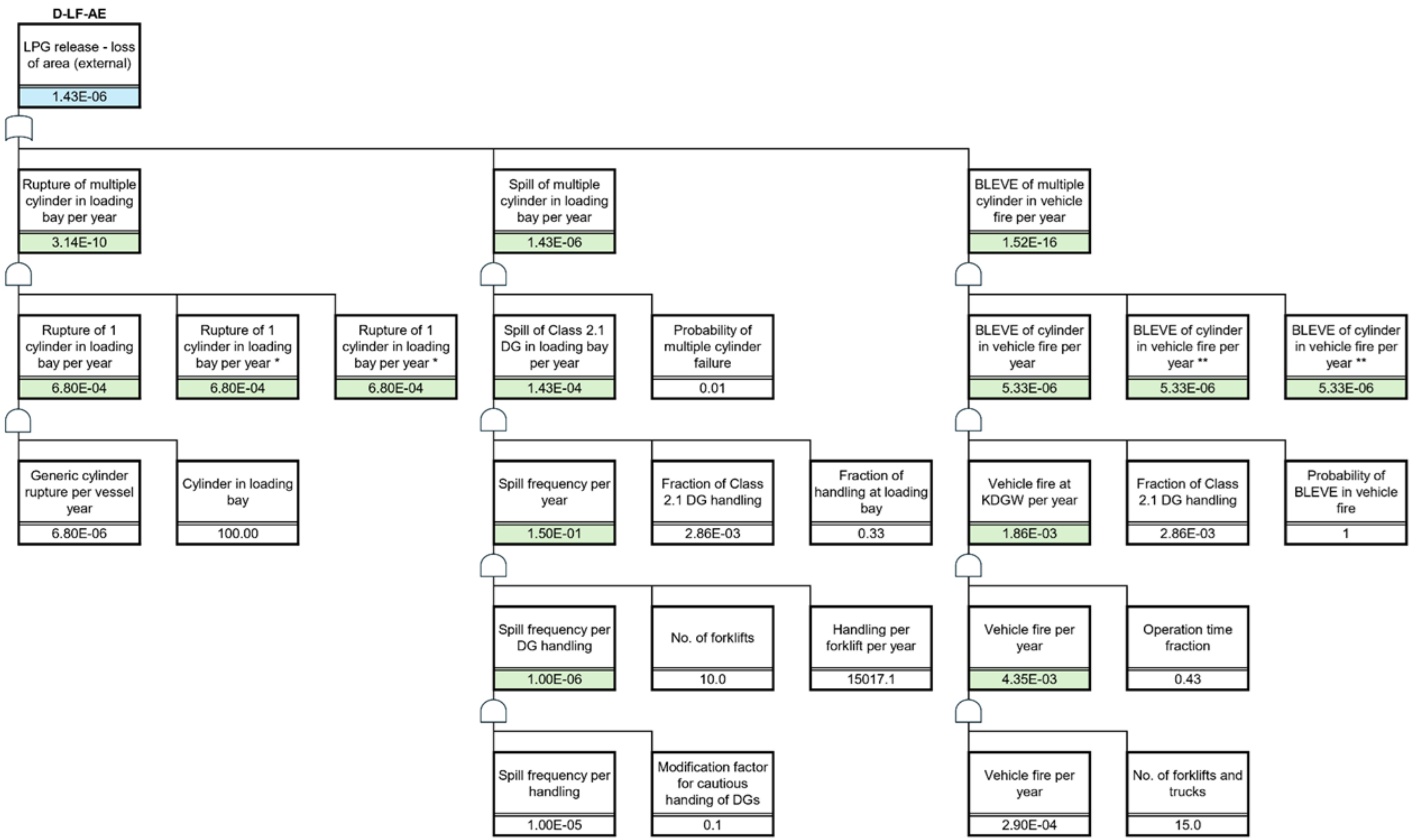
ID	Road	Average Occu-pancy	Speed (km/hr)	Road Length (m)	Daytime Traffic Popula-tion	Pedes-trian	Daytime Popula-tion
RD01	Chueng Yip Street	2.46	50	490	22	20	44
RD02	Lam Chak Street	2.46	50	80	1	10	11
RD03	Kai Hing Road	2.46	50	260	2	20	22
RD04	Hoi Bun Road	2.46	50	700	22	20	42
RD05	Wai Yip Street	2.46	50	410	25	20	45
RD06	Kwun Tong Bypass	2.81	80	710	144	0	144
RD07	Shing Cheong Road	2.46	50	295	58	0	58

Note:

(1) Daytime Traffic Population = Morning Peak Hour Traffic × Average Occupancy × Road Length / Speed

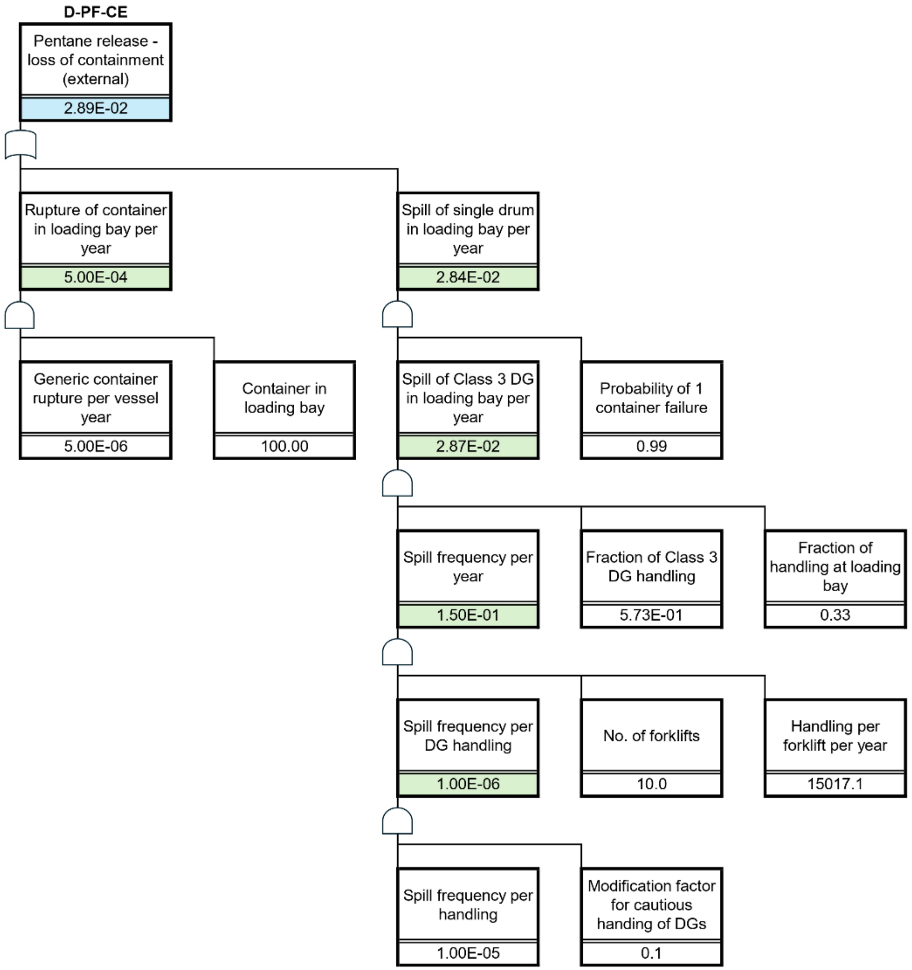
Annex C:
Fault Tree Analysis

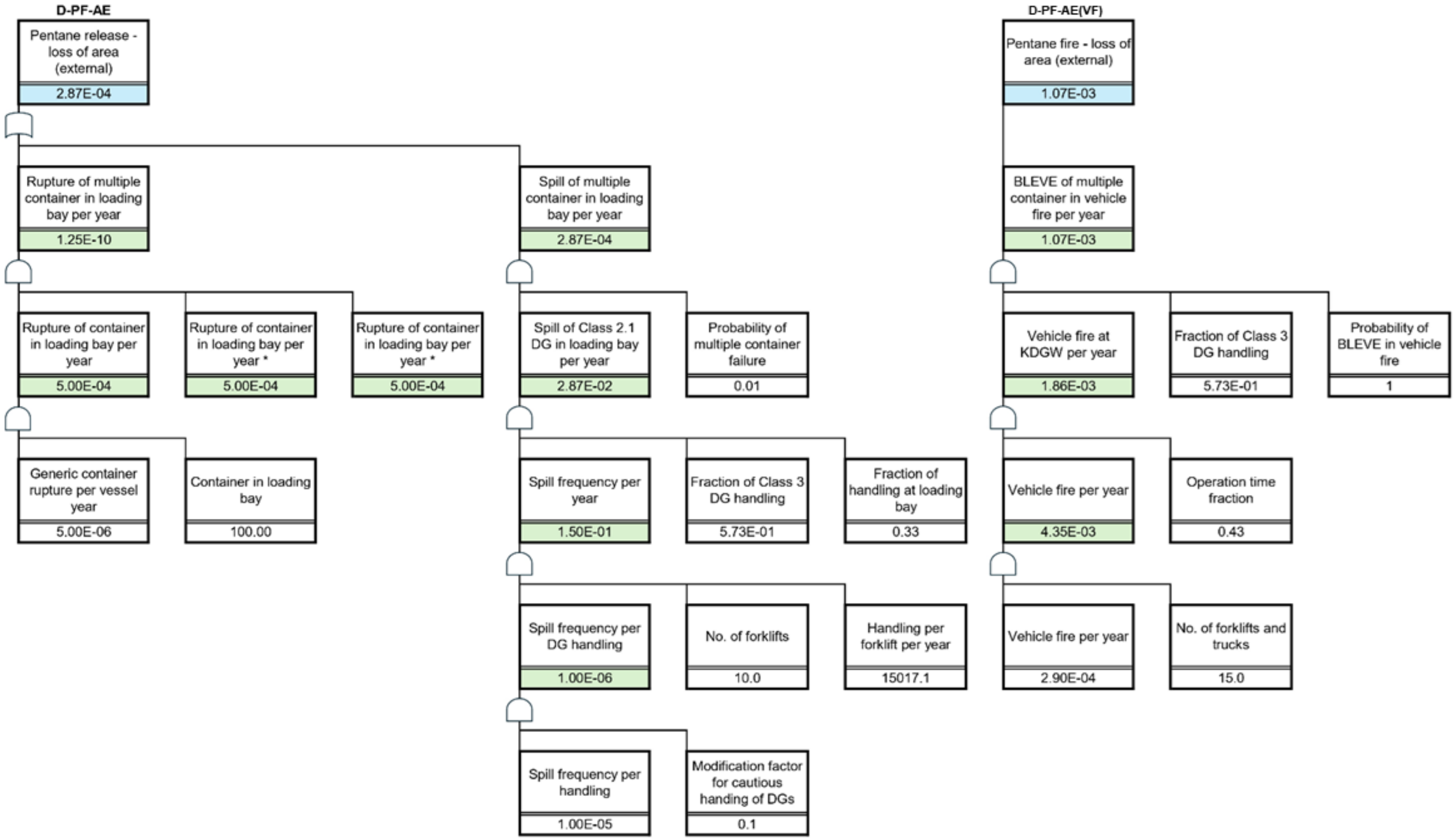

D-LF-CE
LPG release - loss of cylinder (external)
8.27E-04
Rupture of cylinder in loading bay per year
6.80E-04
Spill of single cylinder in loading bay per year
1.42E-04
BLEVE of cylinder in vehicle fire per year
5.33E-06
Generic cylinder rupture per vessel year
6.80E-06
Cylinder in loading bay
100.00
Spill of Class 2.1 DG in loading bay per year
1.43E-04
Probability of 1 cylinder failure
0.99
Vehicle fire at KDGW per year
1.86E-03
Fraction of Class 2.1 DG handling
2.86E-03
Probability of BLEVE in vehicle fire
1
Spill frequency per year
1.50E-01
Fraction of Class 2.1 DG handling
2.86E-03
Fraction of handling at loading bay
0.33
Vehicle fire per year
4.35E-03
Operation time fraction
0.43
Spill frequency per DG handling
1.00E-06
No. of forklifts
10.0
Handling per forklift per year
15017.1
Vehicle fire per year
2.90E-04
No. of forklifts and trucks
15.0
Spill frequency per handling
1.00E-05
Modification factor for cautious handing of DGs
0.1



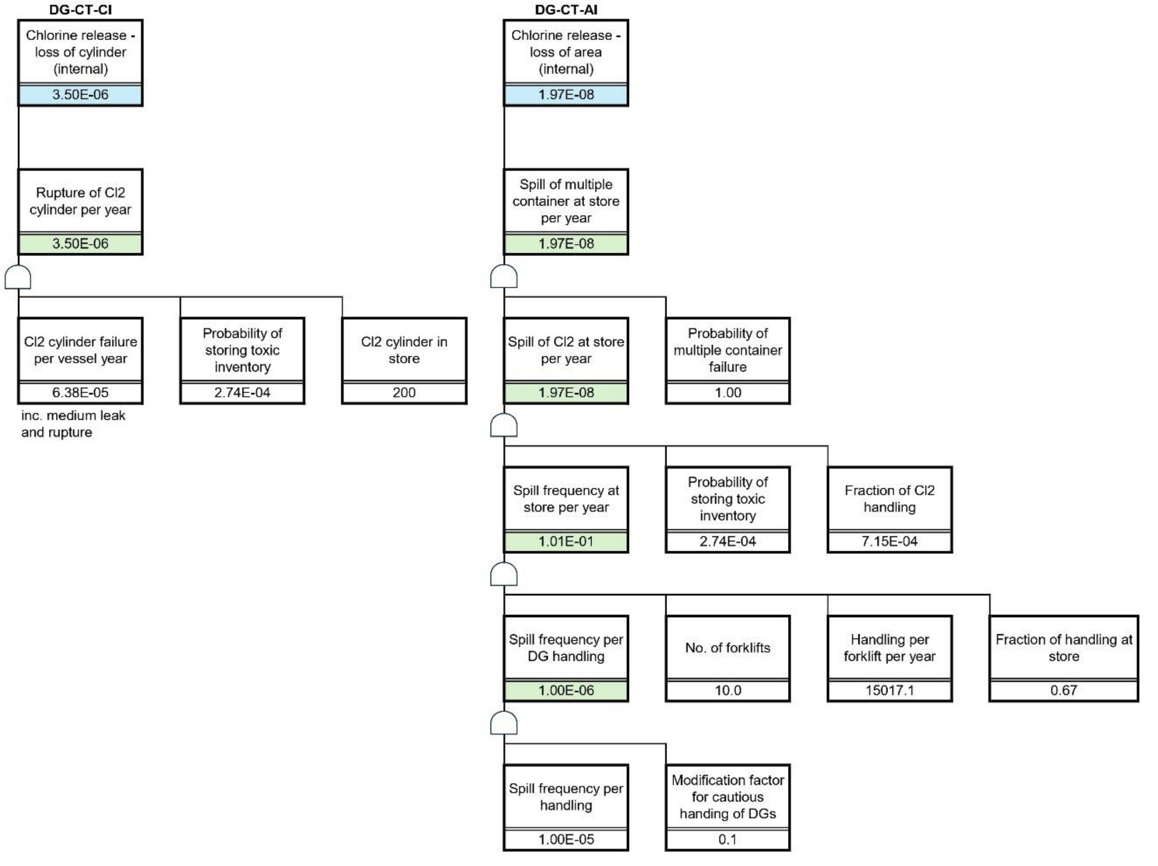
* Details of tree not explicitly shown. Refer the tree of "Rupture of 1 cylinder in loading bay per year" on the left.

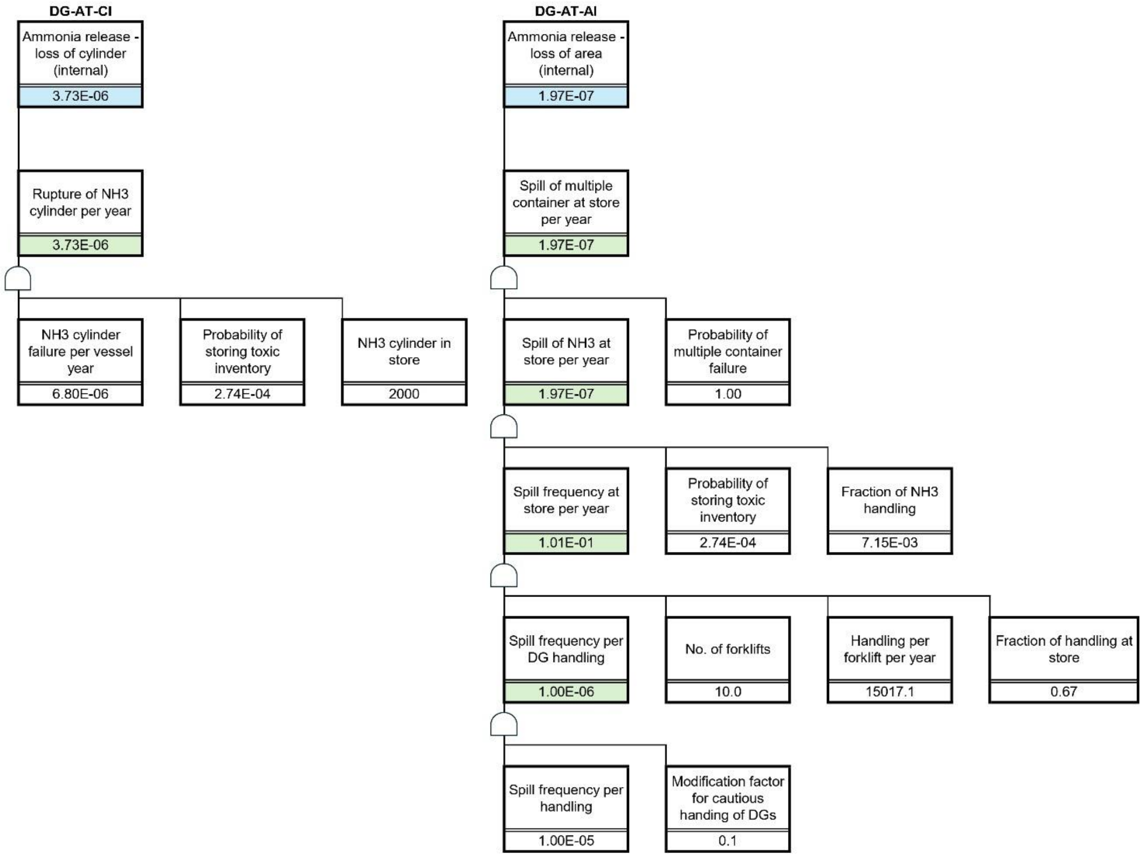
* Details of tree not explicitly shown. Refer the tree of "BLEVE of cylinder in vehicle fire per year" on the left.

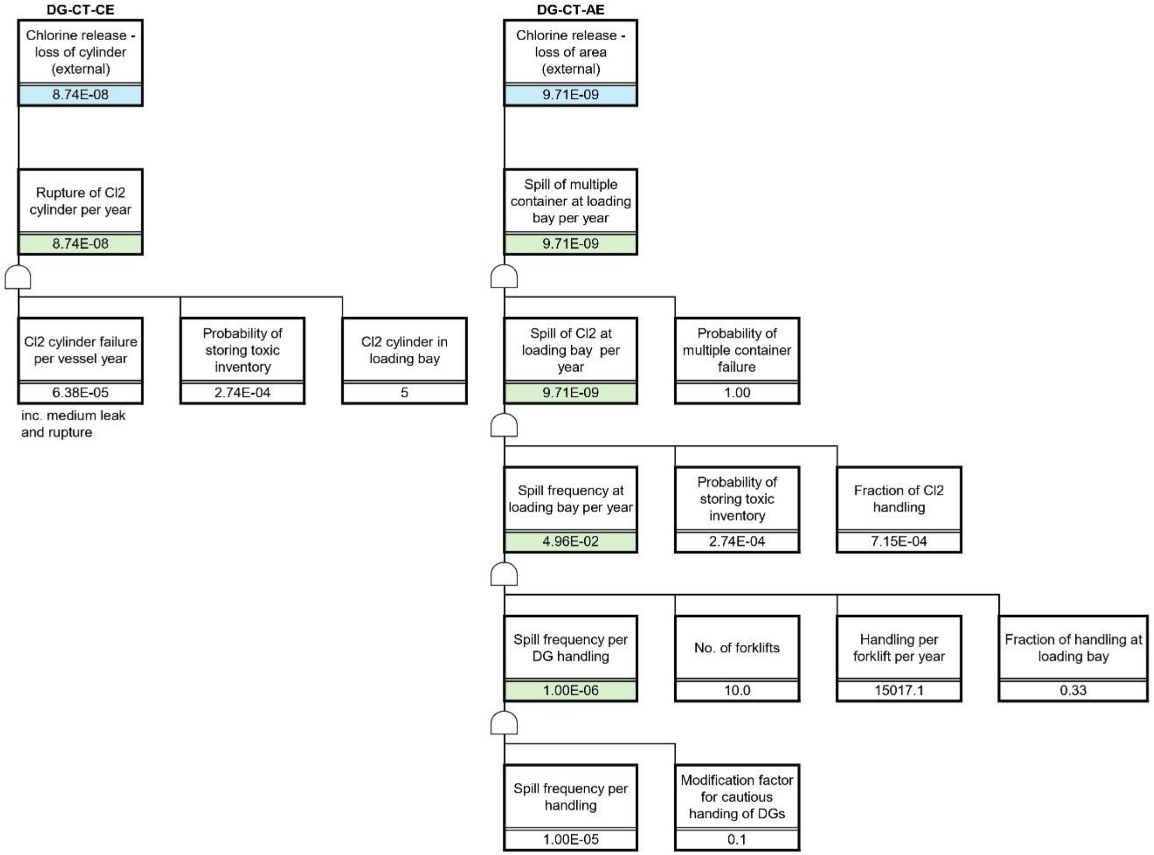

D-PF-CE
Pentane release - loss of containment (external)
2.89E-02
Rupture of container in loading bay per year
5.00E-04
Spill of single drum in loading bay per year
2.84E-02
Generic container rupture per vessel year
5.00E-06
Container in loading bay
100.00
Spill of Class 3 DG in loading bay per year
2.87E-02
Probability of 1 container failure
0.99
Spill frequency per year
1.50E-01
Fraction of Class 3 DG handling
5.73E-01
Fraction of handling at loading bay
0.33
Spill frequency per DG handling
1.00E-06
No. of forklifts
10.0
Handling per forklift per year
15017.1
Spill frequency per handling
1.00E-05
Modification factor for cautious handing of DGs
0.1

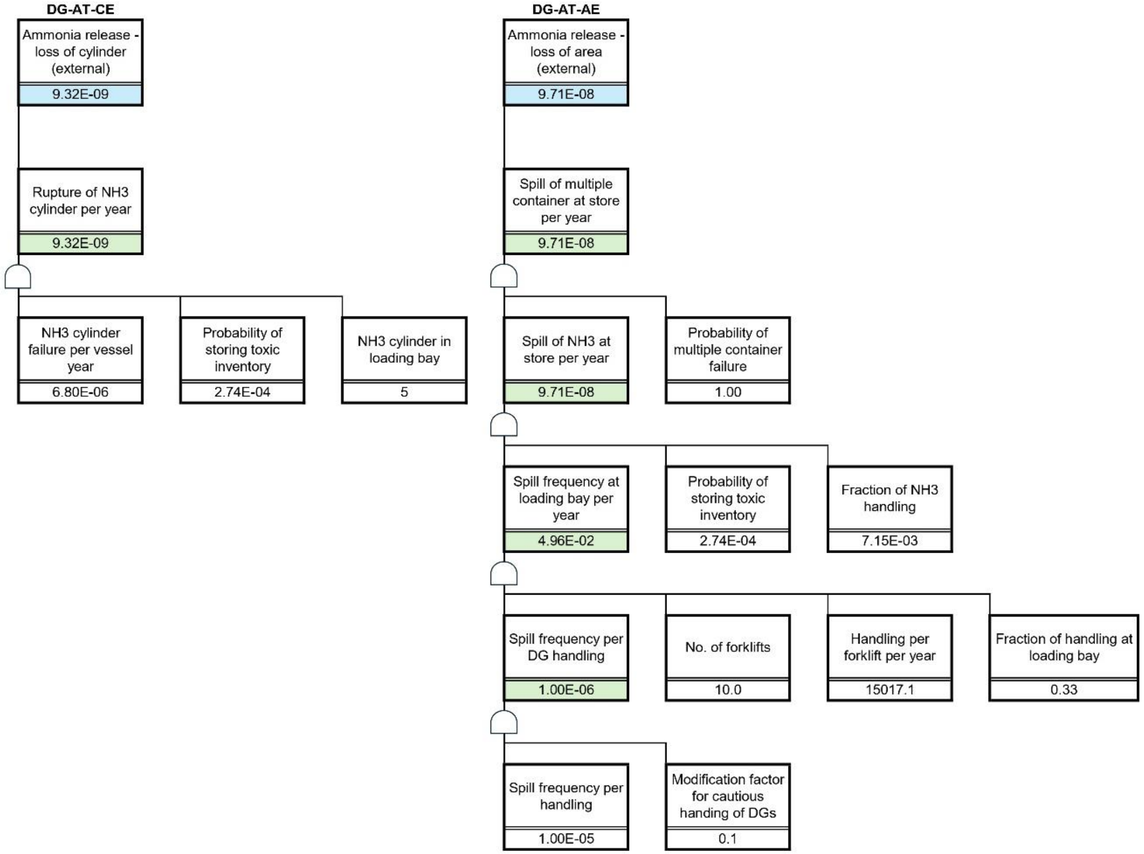


* Details of tree not explicitly shown. Refer the tree of "Rupture of container in loading bay per year" on the left.


DG-CT-CI
Chlorine release - loss of cylinder (internal)
3.50E-06
Rupture of Cl2 cylinder per year
3.50E-06
Cl2 cylinder failure per vessel year
6.38E-05
inc. medium leak and rupture
Probability of storing toxic inventory
2.74E-04
Cl2 cylinder in store
200
DG-CT-AI
Chlorine release - loss of area (internal)
1.97E-08
Spill of multiple container at store per year
1.97E-08
Spill of Cl2 at store per year
1.97E-08
Probability of multiple container failure
1.00
Spill frequency at store per year
1.01E-01
Probability of storing toxic inventory
2.74E-04
Fraction of Cl2 handling
7.15E-04
Spill frequency per DG handling
1.00E-06
No. of forklifts
10.0
Handling per forklift per year
15017.1
Fraction of handling at store
0.67
Spill frequency per handling
1.00E-05
Modification factor for cautious handing of DGs
0.1


DG-AT-CI
Ammonia release - loss of cylinder (internal)
3.73E-06
Rupture of NH3 cylinder per year
3.73E-06
NH3 cylinder failure per vessel year
6.80E-06
Probability of storing toxic inventory
2.74E-04
NH3 cylinder in store
2000
DG-AT-AI
Ammonia release - loss of area (internal)
1.97E-07
Spill of multiple container at store per year
1.97E-07
Spill of NH3 at store per year
1.97E-07
Probability of multiple container failure
1.00
Spill frequency at store per year
1.01E-01
Probability of storing toxic inventory
2.74E-04
Fraction of NH3 handling
7.15E-03
Spill frequency per DG handling
1.00E-06
No. of forklifts
10.0
Handling per forklift per year
15017.1
Fraction of handling at store
0.67
Spill frequency per handling
1.00E-05
Modification factor for cautious handing of DGs
0.1


DG-CT-CE
Chlorine release - loss of cylinder (external)
8.74E-08
Rupture of Cl2 cylinder per year
8.74E-08
Cl2 cylinder failure per vessel year
6.38E-05
inc. medium leak and rupture
Probability of storing toxic inventory
2.74E-04
Cl2 cylinder in loading bay
5
DG-CT-AE
Chlorine release - loss of area (external)
9.71E-09
Spill of multiple container at loading bay per year
9.71E-09
Spill of Cl2 at loading bay per year
9.71E-09
Probability of multiple container failure
1.00
Spill frequency at loading bay per year
4.96E-02
Probability of storing toxic inventory
2.74E-04
Fraction of Cl2 handling
7.15E-04
Spill frequency per DG handling
1.00E-06
No. of forklifts
10.0
Handling per forklift per year
15017.1
Fraction of handling at loading bay
0.33
Spill frequency per handling
1.00E-05
Modification factor for cautious handing of DGs
0.1


DG-AT-CE
Ammonia release - loss of cylinder (external)
9.32E-09
Rupture of NH3 cylinder per year
9.32E-09
NH3 cylinder failure per vessel year
6.80E-06
Probability of storing toxic inventory
2.74E-04
NH3 cylinder in loading bay
5
DG-AT-AE
Ammonia release - loss of area (external)
9.71E-08
Spill of multiple container at store per year
9.71E-08
Spill of NH3 at store per year
9.71E-08
Probability of multiple container failure
1.00
Spill frequency at loading bay per year
4.96E-02
Probability of storing toxic inventory
2.74E-04
Fraction of NH3 handling
7.15E-03
Spill frequency per DG handling
1.00E-06
No. of forklifts
10.0
Handling per forklift per year
15017.1
Fraction of handling at loading bay
0.33
Spill frequency per handling
1.00E-05
Modification factor for cautious handing of DGs
0.1

Annex D:
Event Tree Analysis

Figure D – 1 Event Tree Analysis for LPG

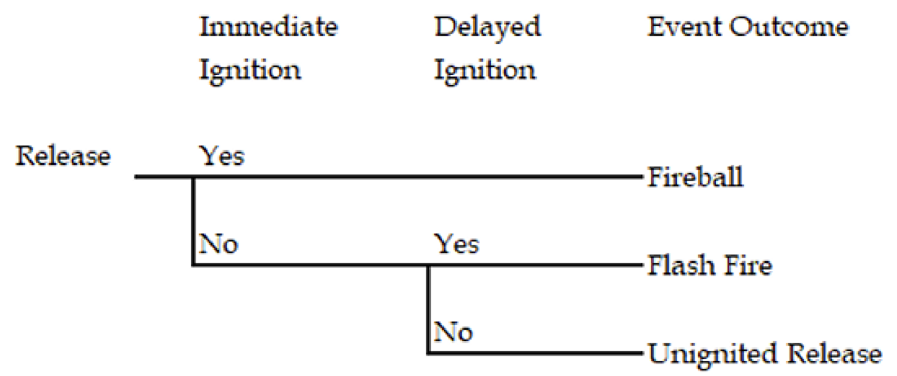


Figure D – 2 Event Tree Analysis for Pentane

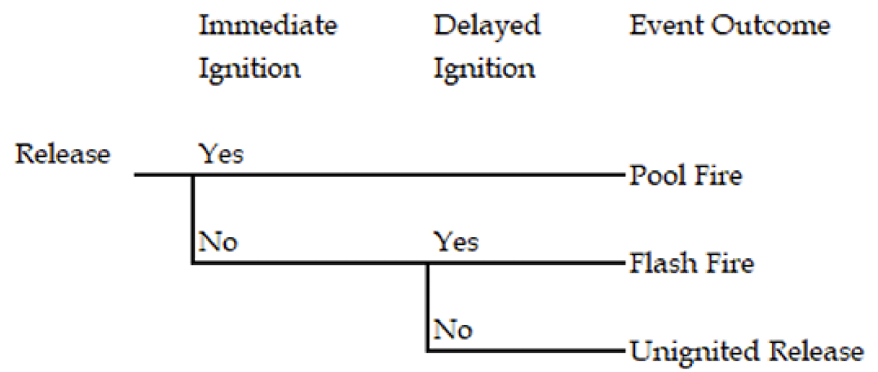
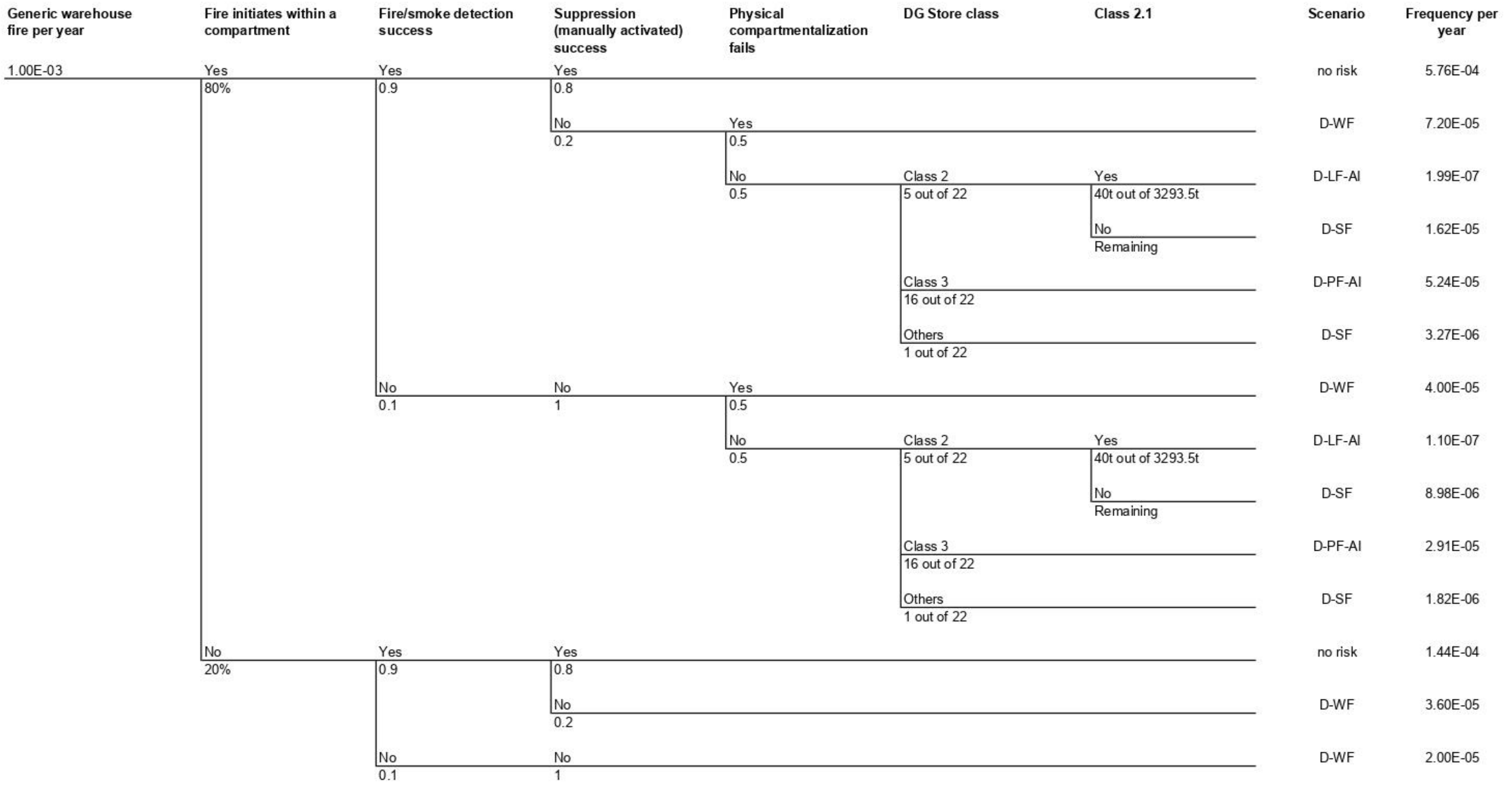


Figure D – 3 Event Tree Analysis for Warehouse Fire



Scenario	Overall Frequency per year
D-WF	1.68E-04
D-SF	3.02E-05
D-LF-AI	3.09E-07
D-PF-AI	8.15E-05
Total	**2.80E-04**

Annex E:
Atmospheric Stability Class-Wind Speed Frequencies

Table E – 1 Day Time Atmospheric Stability Class-Wind Speed Frequencies at Kai Tak Weather Station (Year 2024)

Wind Speed	Stability Class						Total
	A	B	C	D	E	F	
0-2	6.4%	4.7%	0.0%	5.6%	0.0%	7.5%	24.2%
2-4	4.5%	20.2%	9.2%	12.7%	5.8%	0.8%	53.1%
4-6	0.0%	7.9%	5.6%	6.7%	0.3%	0.0%	20.5%
6-8	0.0%	0.0%	0.6%	1.4%	0.0%	0.0%	2.0%
>8	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.2%
Total	10.9%	32.7%	15.5%	26.5%	6.1%	8.3%	100.0%

Table E – 2 Night Time Atmospheric Stability Class-Wind Speed Frequencies at Kai Tak Weather Station (Year 2024)

Wind Speed	Stability Class						Total
	A	B	C	D	E	F	
0-2	0.0%	0.0%	0.0%	1.0%	0.0%	40.9%	41.9%
2-4	0.0%	0.0%	0.0%	14.9%	25.2%	5.1%	45.2%
4-6	0.0%	0.0%	0.0%	10.6%	0.5%	0.0%	11.2%
6-8	0.0%	0.0%	0.0%	1.5%	0.0%	0.0%	1.5%
>8	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.2%
Total	0.0%	0.0%	0.0%	28.2%	25.8%	46.0%	100.0%

Annex F: Summary of Industry Incident Review

A review of warehouse fires from the UK ICHEME Loss Prevention Bulletin, covering the period 1980- 1994 [24] and from MHIDAS database [16], are presented in Table F-1 and Table F-2 respectively.

Table F-1 Summary of Warehouse Incidents reported in ICHEME

Date	Location	Description	Cause	Fatalities
1980	Essex, UK	100 chemicals involved in fire at warehouse.	Not cited	
1980	Cleveland UK	12000 bags (1te bags) of terephthalic acid stored as powder destroyed by fire in warehouse. Molten metal from oxy-acetylene torches during hotwork ignited inventory.	Hotwork / human error	
1980	Cleveland UK	1500 bags (1te bags) of terephthalic acid stored in bags as powder involved in fire. Also stored and involved was 31,000l of paraffin, some of which exploded.	Malicious damage	
1980	Yorkshire, UK	Chemical steel drum overheated by heater and burst, igniting other chemicals in store. 200 different chemicals involved.	Overheating	
1982	Salzburg, Austria	400te fertilizer and pesticide involved in fire from a welding spark.	Hotwork	
1982	Leeds, UK	1.5 Million Litres of paraquat solution and diquat. 20te of octyl phenal entered drains leading to environmental damage.	Not cited	
1982	Pennsylvania, USA	Warehouse destroyed in 9 hours. Cause thought to be ignition from electric forklift and rupture of an aerosol. Sprinkler system not sufficient to control fire, since the system was designed for general storage. Random stacking of flammable liquids rendered the system ineffective.	Forklift electrical fault	
1982	Manchester, UK	2000te chemical, including sodium chlorate stored. A fire and explosion occurred leading to 60 injuries. Vandalism suspected. Investigation revealed no segregation of chemicals in stores leading to rapid escalation.	Vandalism	
1982	Suffolk, UK	1380 te of fertilizer ignited due to stray welding spark. Storage included ammonium nitrate.	Hotwork	

Date	Location	Description	Cause	Fatalities
1983	Buffalo, USA	A 0.5 te propane tank leaked and explosion occurred. The tank was being moved by a forklift and rolled off, fracturing a valve.	Forklift dropped load	6
1984	Canada	Heavy rain penetrated warehouse causing release of acetylene from calcium carbide. Explosion and fire occurred.	Heavy rain	
1984	Sheffield, UK	Fire in furniture store, with small chemical store. Fire destroyed warehouse, with the exception of a protected area. Fire due to heater in cabin.	Fault electrical heater	
1984	Auckland, NZ	70x60m warehouse containing 1414 te mixed chemicals (including 28 te Chlorine in cylinders) caught fire. Chemicals included paraquat and a range of others. Chemicals released into drains polluting estuary. Warehouse had no fixed fire protection system or segregation system.	Not cited	1
1985	Melbourne, Australia	Fire and explosion in chemical store involving pesticide. Rivers polluted.	Not cited	
1986	Nova Scotia, Canada	Chemical warehouse caught fire. 23 injured.	Not cited	
1986	Chesapeake, USA	15000 te of sodium nitrate and potash destroyed in warehouse by lightning strike.	Lightning Strike	
1986	Florida, USA	Chemical warehouse fire led to Chlorine fumes. Electrical fault suspected.	Electrical fault	
1986	Basle, Switzerland	1.5 acre chemical warehouse fire. Firewater runoff including mercury compounds led to significant river pollution in 5 countries.	Not cited	
1987	Seoul, South Korea	Warehouse of highly flammable and explosive materials holding 3000 barrels. Explosions led to collapse of 3 houses nearby and the roof of an airport building	Not cited	4

Date	Location	Description	Cause	Fatalities
1987	Nantes, France	Cable passing over metal beams inside a warehouse short circuited and started to burn. Sparks fell onto 450te of fertilizer. And led to a large fire. Fire was confined to the stored fertilizer and did not spread to nearby ammonium nitrate.	Short Circuit	
1988	Dorset, UK	6 bay building used as a chemical store. Fire broke out in end bay, storing oxidizing chemicals. Fire check wall separated it from the rest of the building. Drums of solvent stored outside of bay exploded. Incompatible products had been stored in the bay. Due to overloaded system.	Storage of incompatibles	
1988	Canada	Fire involving plastics led to fumes over Quebec.	Not cited	
1988	Sibenik, Yugoslavia	17000 te of chemical fertilizer in warehouse fire.	Not cited	
1988	Hull, UK	Fire/explosion at paint factory. Acetone on forklift spilled and ignited by electrical apparatus.	Fork lift spill and electrical ignition	1
1989	New Jersey, USA	140l hydrobromic acid drum broke open during transfer. Toxic vapour developed.	Handling – spontaneous failure	
1990	Avon, UK	2 events of yellow phosphorus under water in drums caught fire. First event involved 1 drum, second multiple drums. Drum corrosion exposed the inventory to air leading to fire.	Generic failure/corrosion	
1991	Bangkok, Thailand	Explosion/fireball, with phosphorous in chemical warehouse	Not cited	15
1991	Canada	Toxic smoke from a fire with sodium, phosphorous, cyanide. Evacuation of 300 people	Not cited	
1992	Delhi, India	Explosion in acid/chemical warehouse	Not cited	43
1992	Bradford, UK	Explosions of raw material warehouse led to fire. No fatalities, large scale environmental damage.	Not cited	

Date	Location	Description	Cause	Fatalities
1993	Shenzen, China	Small explosion spread to 8 warehouses storing flammable materials. Explosion followed on fire reaching gas storage depot and chemical warehouse	Not cited	15
1993	Texas, USA	Propane cylinders exploded in paper/plastic warehouse. Sprinkler system destroyed quickly in fire. Roof collapsed.	Not cited	
1994	Karachi, Pakistan	50-60 te of pesticide destroyed in fire.	Not cited	

Table F-2 Summary of Warehouse Incidents reported in MHIDAS

Cause	Description	Number of Records
Generic fire	Internal/external causes not cited. Large scale warehouse fire with external consequences	177
Generic/Spontaneous failure cylinders/drums	Spontaneous failure (e.g. erosion / corrosion / design fault, maintenance error, handling error)	17
Manual handling	Spillage leading to release/fire	14
Lightning strike	Lighting strike escalating to fire/release in warehouse	2
Forklift fault	Electrical/mechanical failure in forklift leading to fire	4
Arson/sabotage	Targeted arson/sabotage at warehouse leading to escalation	15
Hotwork	Hotwork in warehouse generating spark on inventory and subsequent fire	5
Vehicle fire	Escalation of vehicle fire to warehouse loading bay/stores	3
Extreme temperature	Overheating of inventory - exposure to sun	1
Heavy rain/flooding	Fire / wash out of inventory	2
Negligence	Poor management, no ignition control, no segregation, illegal store keeping, low/illegal standard, abandoned facilities	11
Arson/human error	Arson/external fire not directed at warehouse spreads to warehouse	2
Fire in supporting equipment/office failure	Office/Supporting equipment (e.g. compressor) fire spreads	8
Electrical cabling failure	Overhead cabling fire leading to fire	1
Vehicle Collision	Collision with inventory at loading bay leading to fire	2

Cause	Description	Number of Records
Dropped load	Forklift / overturn / lorry / heavy object dropped & shed load damages inventory leading to release/fire	12
Forklift impact	Puncturing of inventory by forklift	16
Piercing	Sharp object punctured inventory during transfer	3
Aircraft impact	Aircrash hits gas mains leading to warehouse fire	1
Electrical fault	Non-ex equipment/short circuit	7

Annex G: Correspondence with the Planning Department

From: Helen Ka Wing IP/PLAND <hkwip@pland.gov.hk>
Sent: Monday, 26 January 2026 10:18 am
To: Chloe Kung, Wing Chun
Cc: Ernest CM FUNG/PLAND; Amy Ho, Yee Kei
Subject: Re: Enquiry of Advices on Population Data for QRA, 8 Lam Chak Street, Kowloon Bay
Attachments: RtC_PlanD.pdf

Follow Up Flag: Follow up
Flag Status: Completed

Dear Chloe,

Noted for IDs 06a and 06b, reference has been made to the existing industrial building.
Please revise the remark as following as the PR restriction on OZP is referring to the new commercial developments on site.

> 15-storey industrial buildings with site area of 5,343m^2 ~~and maximum plot ratio of 9.5~~. Assume usable floor area as 80% of total floor area. Assume 60% of area as warehouse use and 40% of area as industrial use as observed in site survey. Estimated by worker density of 25m^2/worker for industrial and 700m^2/worker for warehouse.

No further comments on the remaining items please.

Thanks and regards,
Helen
TP/K12, K DPO, PlanD
Tel: 2231 4971

Internal
K-22/34
Site Record

From: Chloe Kung, Wing Chun <chloewckung@meinhardt.com.hk>
Sent: Friday, January 23, 2026 6:24 PM
To: Helen Ka Wing IP/PLAND <hkwip@pland.gov.hk>
Cc: Ernest CM FUNG/PLAND <ecmfung@pland.gov.hk>; Amy Ho, Yee Kei <amyykho@meinhardt.com.hk>
Subject: RE: Enquiry of Advices on Population Data Near Lam Chak Street, Kowloon Bay

Ref 92071

Dear Helen,

Thank you for your advises on the estimated population data for the QRA study. Attached please find our detailed responses to your comments, along with the revised population estimation.

Should you have any questions, please feel free to contact me at the undersigned or our Ms Amy Ho at 2859 5478.

Your assistance is greatly appreciated.

Best Regards,

Chloe Kung
Engineer

MEINHARDT

your FIRSTCHOICE | Innovative • High-quality • Value-added Solutions

Meinhardt Infrastructure and Environment Limited

Direct: +852 2859 1353
www.meinhardt-china.com
www.meinhardtgroup.com
www.meinhardt-china.com/facebook

From: Helen Ka Wing IP/PLAND <hkwip@pland.gov.hk>
Sent: Monday, 12 January 2026 5:12 pm
To: Chloe Kung, Wing Chun <chloewckung@meinhardt.com.hk>
Cc: Amy Ho, Yee Kei <amyykho@meinhardt.com.hk>; Ernest CM FUNG/PLAND <ecmfung@pland.gov.hk>
Subject: Re: Enquiry of Advices on Population Data Near Lam Chak Street, Kowloon Bay

Dear Chloe,

Regarding the population figures shown in the QRA reports for the pre-application submission at 8 Lam Chak Street's, please find our comments below:

- For IDs 03 and 04, please advise the source of the assumed domestic household size of 2.5.
- For ID04, please note the latest planning permission for the site (No. A/K22/31-2). The updated number of flat unit is 1,450.
- For IDs 06a and 06b, the site falls within the "Commercial(2)" zone on the Kai Tak OZP (No. S/K22/8). Please review and confirm if the assumptions in population figures are based on the existing industrial building or the planned commercial developments. If it is pertaining to the planned commercial developments, it is not necessary to differentiate the lower and upper potions of the building, conversely, please elaborate in the "Remark" column that the presented figures are for the future proposed commercial development. The quoted site area and PR are correct.
- For IDs 07a and 07b, the whole development is called the Quayside, it is not necessary to differentiate the developments into upper and lower portions. The development parameters are not accurate, the total office area is about 74,000 m^2, and the retail floor area is about 7,900 m^2.
- For IDs 08, 09 and 10, the sites fall within the "Commercial(2)" zone on the Ngau Tau Kok and Kowloon Bay OZP (No. S/K13/34). As shown on the MPC Paper No. 10/21 on 10.12.2021, the total office area for the Proposed Commercial Development is 130,510 m^2, the total area for retails is 55,610 m^2 and total area for hotel is 14,880 m^2. Please adjust the assumptions accordingly.
- For IDs 11a and 11b, please note the subject proposed development falls within this area. Please review if the figures should be replaced by the proposed development parameters in this pre-application submission.

- For ID 14, the site falls within the "Commercial(1)" zone on the Ngau Tau Kok and Kowloon Bay OZP (No. S/K13/34). As shown on the MPC Paper No. 10/21 on 10.12.2021, the total office area for the Proposed Commercial Development is 144,470 m^2, the total area for retails is 55,130 m^2 and total area for transport facility is 5,000 m^2. Please adjust the assumptions accordingly.

Happy to discuss if you have any further questions.

Thanks and regards,
Helen
TP/K12, K DPO, PlanD
Tel: 2231 4971

Internal
K-22/34
Site Record

規劃署 Planning Department
劃出更多可能 · 創造無限機遇 Planning a Future of Boundless Opportunities

From: Chloe Kung, Wing Chun <chloewckung@meinhardt.com.hk>
Sent: Monday, January 12, 2026 11:10 AM
To: Helen Ka Wing IP/PLAND <hkwip@pland.gov.hk>
Cc: Amy Ho, Yee Kei <amyykho@meinhardt.com.hk>
Subject: FW: Enquiry of Advices on Population Data Near Lam Chak Street, Kowloon Bay

Dear Helen,

As per our tele-conversation, attached please find the mentioned document for your action.
I have also included the email previously sent to Patrick below for your reference.

Many thanks!

Best Regards,

Chloe Kung
Engineer

MEINHARDT
your FIRSTCHOICE | Innovative • High-quality • Value-added Solutions

Meinhardt Infrastructure and Environment Limited

Direct: +852 2859 1353
www.meinhardt-china.com
www.meinhardtgroup.com
www.meinhardt-china.com/facebook

From: Chloe Kung, Wing Chun
Sent: Monday, 29 December 2025 5:46 pm
To: 'pwywong@pland.gov.hk' <pwywong@pland.gov.hk>
Cc: Amy Ho, Yee Kei <amyykho@meinhardt.com.hk>
Subject: Enquiry of Advices on Population Data Near Lam Chak Street, Kowloon Bay

Dear Patrick,

We just spoke, we are the risk consultants undertaking a Quantitative Risk Assessment (QRA) for a S16 planning application of proposed comprehensive development in Kowloon Bay, near a dedicated LPG filling station and a Dangerous Goods (DG) Godown operated by Kerry Logistics Network Limited.
Pre-submission of QRA reports regarding the risks related to the LPG Filling Station and the DG Godown have been prepared and submitted to the Electrical and Mechanical Services Department (EMSD). Comments were received and we were requested to seek Planning Department's advices on our estimated population data within the study area (See attached file - Population Estimation.pdf).

In this connection, we will appreciate for your assistance to:

1. Review and comment on our estimated surrounding population within the study area; and
2. Advise if there will be any future approved development within the study area.

It will be much appreciated if you can advise on the above matter before ***12th Jan 2026***.

Thank you for your kind attention. Should you have any questions, please feel free to contact me at the undersigned or our Ms Amy Ho at 2859 5478.

Looking forward to your reply. Many thanks.

Chloe Kung
Engineer

MEINHARDT

your FIRSTCHOICE | Innovative • High-quality • Value-added Solutions

Meinhardt Infrastructure and Environment Limited

Direct: +852 2859 1353
www.meinhardt-china.com
www.meinhardtgroup.com
www.meinhardt-china.com/facebook

Annex H: Methodology of Aircraft Crash Rate Calculation

The calculation model for aircraft crash frequency takes into account specific factors such as the target area of the proposed hazard site and its longitudinal (x) and perpendicular (y) distances from the runway threshold as depicted below.

The crash frequency per unit ground area (per km^2) is calculated as:

$$g(x,y) = NRF(x,y) \quad (1)$$

where

N is the number of runway movements per year and

R is the probability of an accident per movement (landing or take-off).

F(x,y) gives the spatial distribution of crashes and is given by:

Landings

$$F_L(x,y) = \frac{x+3.275}{3.24} e^{\frac{-(x+3.275)}{1.8}} [\frac{56.25}{\sqrt{2\pi}} e^{-0.5(125y)^2} + 0.625 e^{-\frac{|y|}{0.4}} + 0.005 e^{-\frac{|y|}{5}}] \quad (2)$$

$$\text{For x} > -3.275\text{km}$$

Take-off

$$F_T(x,y) = \frac{x+0.6}{1.44} e^{\frac{-(x+0.65)}{1.2}} [\frac{46.25}{\sqrt{2\pi}} e^{-0.5(125y)^2} + 0.9635 e^{-4.1|y|} + 0.08 e^{-|y|}] \quad (3)$$

$$\text{For x} > -0.6\text{km}$$

Equations 2 and 3 are valid only for the specified range of x values. If x lies outside this range, the impact probability is zero.

The number of flights at Chek Lap Kok has been estimated as 420,803 based on the 10-year average growth rate (2014 -2024) of 6.20% calculated from the air traffic statistics provided by the HKIA as shown in **Figure H-1**.

Figure H – 1 Hong Kong International Airport Civil International Air Transport Movements of Aircraft, Passenger and Freight

Hong Kong International Airport
Civil International Air Transport
Movements of Aircraft, Passenger and Freight
(1998 - 2026)

Year Month	Aircraft				Passenger @				Freight ᵝ (Tonne)			
	Landing	Take-off	Total	Year-on-year % change	Arrival	Departure	Total	Year-on-year % change	Unloaded	Loaded	Total	Year-on-year % change
2013	186 048	186 032	372 080	+5.8	29 486 280	29 787 247	59 273 527	+6.5	1 488 324	2 638 789	4 127 113	+2.5
2014	195 520	195 488	391 008	+5.1	31 308 655	31 592 369	62 901 024	+6.1	1 585 096	2 791 253	4 376 349	+6.0
2015	203 043	203 005	406 048	+3.8	33 872 410	34 198 872	68 071 282	+8.2	1 596 230	2 783 908	4 380 139	+0.1
2016	205 793	205 773	411 566	+1.4	34 932 225	35 165 991	70 098 216	+3.0	1 648 331	2 872 697	4 521 028	+3.2
2017	210 339	210 320	420 659	+2.2	36 213 685	36 248 551	72 462 236	+3.4	1 723 901	3 213 528	4 937 429	+9.2
2018	213 899	213 867	427 766	+1.7	37 182 732	37 177 097	74 359 829	+2.6	1 781 098	3 236 756	5 017 854	+1.6
2019	209 904	209 891	419 795	-1.9	35 657 254	35 630 298	71 287 552	-4.1	1 606 820	3 096 769	4 703 590	-6.3
2020	80 330	80 336	160 666	-61.7	4 445 813	4 368 411	8 814 224	-87.6	1 448 209	2 972 103	4 420 312	-6.0
2021	72 403	72 407	144 810	-9.9	540 667	804 210	1 344 877	-84.7	1 635 514	3 350 742	4 986 256	+12.8
2022	69 352	69 377	138 729	-4.2	2 648 724	2 990 290	5 639 014	+319.3	1 391 074	2 778 051	4 169 125	-16.4
2023	138 054	138 056	276 110	+99.0	19 884 862	19 504 600	39 389 462	+598.5	1 238 846	3 059 275	4 298 122	+3.1
2024	181 592	181 663	363 255	+31.6	26 713 614	26 203 748	52 917 362	+34.3	1 267 673	3 632 681	4 900 354	+14.0
2025 #	197 329	197 379	394 708	+8.7	30 633 412	30 190 947	60 824 359	+14.9	1 328 542	3 709 328	5 037 871	+2.8
2026 #¶	17 223	17 222	34 445	+2.4	2 801 000	2 673 000	5 474 000	+4.1	111 000	301 000	412 000	+5.5

Figure H – 2 Aircraft Crash Coordinate System

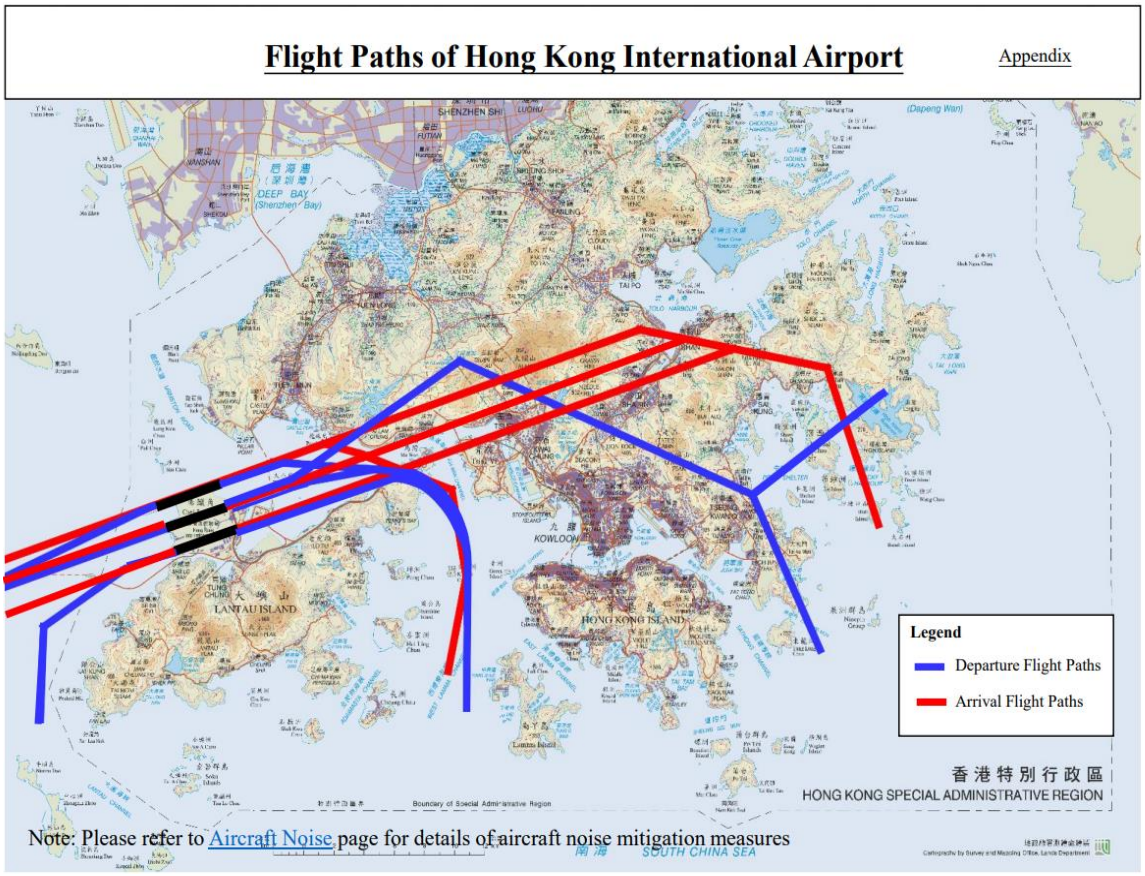


Figure H – 3 Aircraft Crash Coordinate System