APPENDIX 13.1 HAZARD TO LIFE ASSESSMENT FOR A PLANNED DESALINATION PLANT

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1. INTRODUCTION

1.1 Background

1.1.1.1 A planned desalination plant is located at the southeast corner of the TKO 137. Whilst it is not classified as a Potentially Hazardous Installation (PHI) due to the implementation of the On-Site Chlorine Generation (OSCG) System, there are still potential risks associated with the storage, transport and use of Dangerous Goods (DGs) involved in the OSCG operation.

1.2 Scope of Work

1.2.1.1 The Hazard to Life Assessment requirements for the desalination plant are shown below:

(a) Identify hazardous scenarios associated with the operation of the desalination plant and then determine a set of relevant scenarios to be included in a QRA;

(b) Execute a QRA of the set of hazardous scenarios determined in (a), expressing population risks in both individual and societal terms;

(c) Compare individual and societal risks with the criteria for evaluating hazard to life as stipulated in Annex 4 of the TM; and

(d) Identify and assess practicable and cost-effective risk mitigation measures.

1.3 Hong Kong Risk Guidelines (HKRG)

1.3.1.1 Annex 4 of the EIAO-TM specifies the Individual and Societal Risk Guidelines. The Hong Kong Government Risk Guidelines (HKRG) per the EIAO TM Annex 4 states that the individual risk is the predicted increase in the chance of fatality per year to an individual due to a potential hazard. The individual risk guidelines require that the maximum level of off-site individual risk should not exceed 1 in 100,000 per year i.e. 1×10^{-5} per year. Societal risk expresses the risks to the whole population. It is expressed in terms of lines plotting the cumulative frequency (F) of N or more deaths in the population from incidents at the installation. Two F-N risk lines are used in the HKRG that demark “Acceptable” or “Unacceptable” societal risks. To avoid major disasters, there is a vertical cut-off line at the 1,000 fatality level extending down to a frequency of 1 in a billion years. The intermediate region indicates the acceptability of societal risk is borderline and should be reduced to a level which is “as low as reasonably practicable” (ALARP). It seeks to ensure that all practicable and cost-effective measures that can reduce risk are considered. The HKRG is presented graphically in **Plate 1.1**.

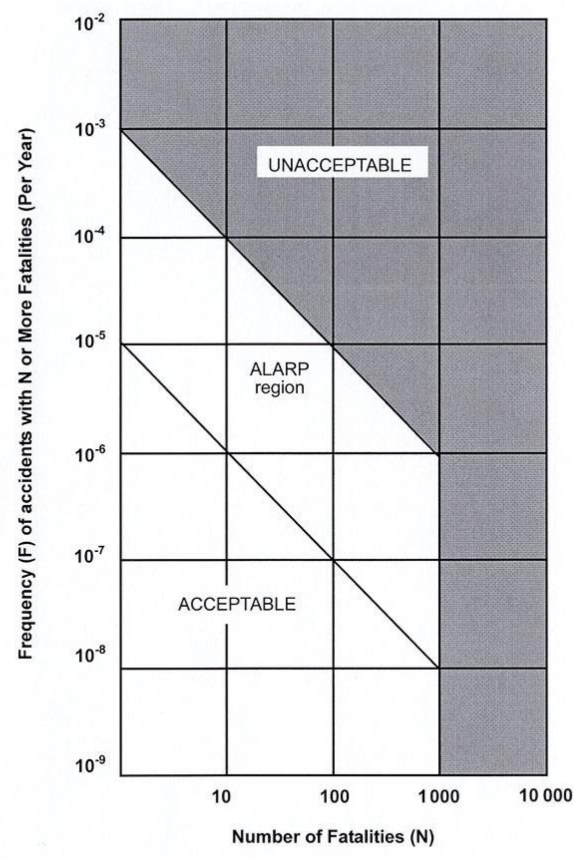

Plate 1.1 Societal Risk Guidelines

1.4 Assessment Approach

1.4.1 The QRA consisted of the following six main tasks:

(a) **Data / Information Collection and Update**: Collected relevant data / information necessary for the hazard assessment;

(b) **Hazard Identification**: Identified a credible set of hazardous scenarios associated with the operation of the desalination plant;

(c) **Frequency Estimation**: Estimated the frequencies of each hazardous event leading to fatalities based on the collected data with the support of justifications through the review of historical accident data and previous hazard assessment of similar projects;

(d) **Consequence Analysis**: Analysed the consequences of the identified hazardous scenarios;

(e) **Risk Integration and Evaluation**: Evaluated the risks associated with the identified hazardous scenarios. The evaluated risks were compared with the HKRG Risk Guideline to determine their acceptability; and

(f) **Identification of Mitigation Measures**: Where necessary, risk mitigation measures were identified and assessed to comply with the "as low as reasonably practicable" (ALARP) principle used in the HKRG. Practicable and cost-effective risk mitigation measures were identified and assessed as necessary. The risk outcomes of the mitigated case were reassessed to determine the level of risk reduction.

1.4.1.1 The hazard assessment covered the following assessment years:

- Year 2035* (Construction phase) – The risk imposed by the operation of the planned desalination plant to the existing, committed and planned population in 2035.

- Year 2041 (Operational phase) – The risk imposed by the operation of the planned desalination plant to the existing, committed and planned population in 2041. This scenario took into account the full population intake of the proposed development with all the planned land users being considered.

* The Project would be commissioned in phases with the construction work scheduled for commencement in Year 2025 and completion by Year 2041 for full population intake. Based on the latest phasing plan, the Main Phase target intake is Year 2035 for sites located in the vicinity of the desalination plant (i.e. G4, PU5-PU6, E3-E5, OU2-OU3) (**Appendix 2.1** refers). Therefore, Year 2035 was selected as the assessment year of construction phase of the Project for risk assessment associated with desalination plant.

1.4.1.2 Subsequent to the approved EIA study of the Desalination Plant at Tseung Kwan O (EIA Register No. AEIAR-192/2015) [1], an Environment Review Report (ERR) was carried out in 2017 for the Desalination Plant to ascertain the risk imposed from the proposed design changes involving the installation of an “on-site chlorine generation” (OSCG) system in replacement of the importation/ storage of liquid chlorine and plant layout change. A Detailed Design Plan for Chlorine and Carbon Dioxide Storage of Desalination Plant [2] (“Detailed Design Plan”) was later submitted to conform with Condition 2.12 of both Environmental Permits (i.e. EP-503/2015/A & FEP-01/503/2015/A) and approved in 2021. The Detailed Design Plan addressed the latest design plan for stage 1 of the Desalination Plant and made reference to the hazard to life assessment under the ERR. Extracts from ERR were included in the Detailed Design Plan [2] and referenced for essential information for the hazard to life assessment for this project.

2. SITE DESCRIPTION

2.1 Study Area

2.1.1.1 The planned desalination plant is located at the south-eastern boundary of the TKO 137. Study area of 500 m radius from centre of the desalination plant was adopted as shown in **Plate 2.1**.

2.1.1.2 With reference to the Detailed Design Plan [2], the study area of 500 m radius was adopted based on the consequence analysis of the ERR. Since there is no change in the storage quantity and operation of OSCG systems/ various chemicals including liquid carbon dioxide, the adoption of 500 m radius study area remains valid.

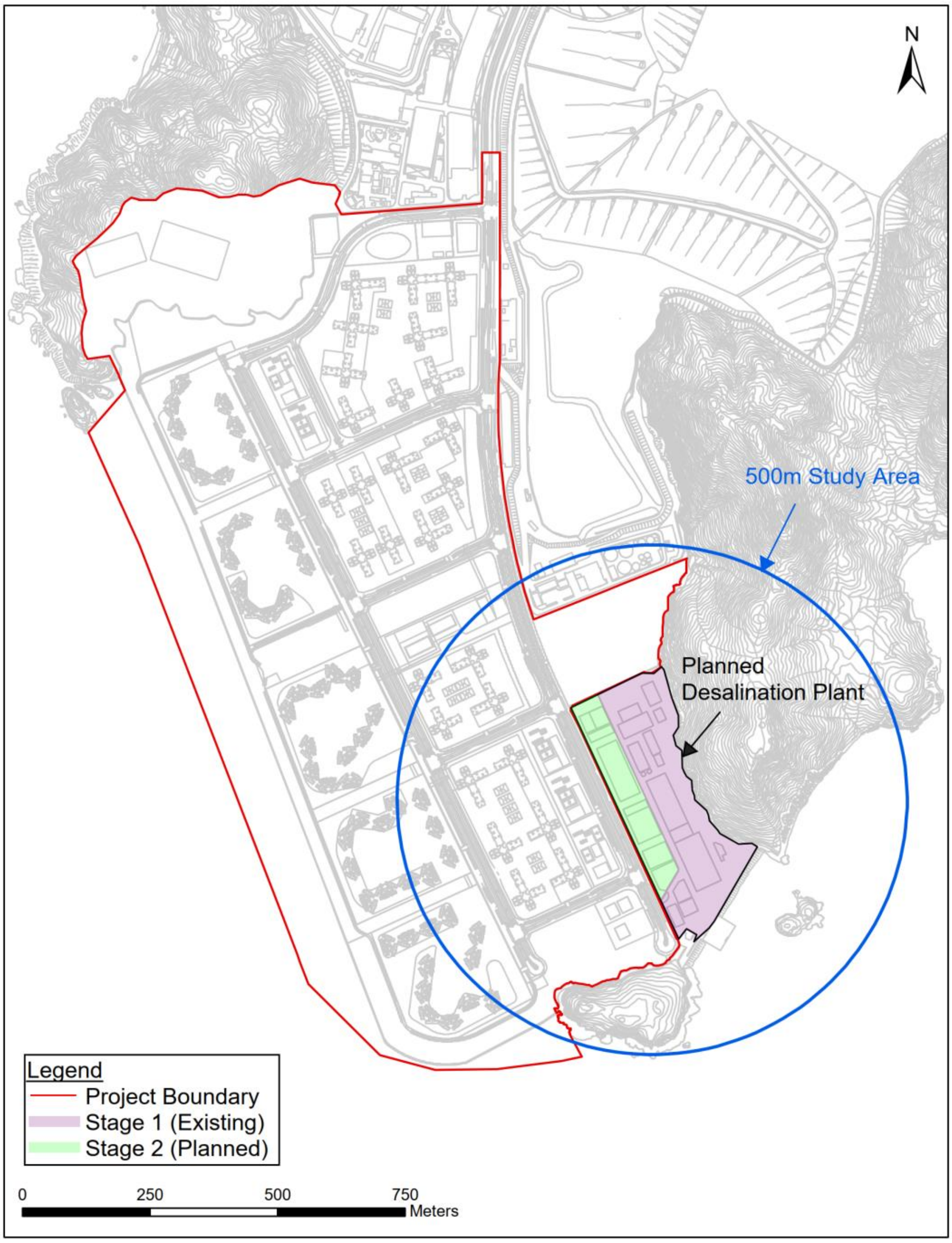

Plate 2.1 Site Location Plan

2.2 The Desalination Plant

2.2.1.1 The proposed design changes under the Detailed Design Plan [2] involve the installation of an "on-site chlorine generation" (OSCG) system in replacement of the importation/ storage of liquid chlorine with modification of the plant layout. The hazard to life assessment under the ERR as cited in the Detailed Design Plan [2] is referenced for essential information for the hazard to life assessment for this project.

<u>On-site Generation of Chlorine Gas for Disinfection of Product Water</u>

2.2.1.2 Chlorine will be used to disinfect the potable water. The latest design will involve an "on-site chlorine generation" (OSCG) system in replacement of the importation/ on-site storage of liquid chlorine. The overall equation of the electrolysis process for the OSCG is as follow:

$$2NaCl + 2H_2O \rightarrow Cl_2 + H_2 + 2NaOH \qquad (1)$$

2.2.1.3 A portion of the chlorine gas generated from the OSCG process will be converted to sodium hypochlorite solution for shock chlorination of seawater intake. Hence, importation of sodium hypochlorite solution is also not required under the latest design. During outage of the OSCG systems at TKO desalination plant or other WSD's water treatment works (WTW), sodium hypochlorite solution may be delivered to and from the TKO desalination plant by road tankers. Chlorine gas produced from the OSCG process will be directly dosed into the process water or consumed in the sodium hypochlorite conversion process with no storage requirement.

2.2.1.4 Two OSCG systems will be installed in two stages with a total chlorine generation rate of 2,250 kg/day. Each OSCG system with a capacity of 1,125 kg/day will consist of 4 chlorine gas generators (4×50%, i.e. 2 duty and 2 stand-by). Under the ultimate scenario, a maximum of 1,650 kg per day of chlorine gas would be used to produce 100 wt% sodium hypochlorite solution at 1,800 kg per day. The sodium hypochlorite solution will be stored in storage tanks at 12.5 wt% concentration. The usage rate is 40 m^3 for each shock chlorination dose which will be carried out every 5 days. The total storage quantity is 60 m^3 with provision of 3 × 10 m^3 and 2 × 15 m^3 storage tanks for Stage 1 and Stage 2 respectively. The OSCG system will allow the production of sodium hypochlorite on an on-demand basis.

2.2.1.5 Hydrochloric acid (HCl), sodium hydroxide (NaOH) and sodium bisulphite ($NaHSO_3$) will be stored in OSCG buildings for de-chlorination and neutralization. These chemicals together with sodium hypochlorite (NaOCl) will be placed in separate compartments in OSCG buildings.

<u>Chlorine Scrubbing System</u>

2.2.1.6 Emergency chlorine scrubbing system with a removal capacity of 99.5% is installed to remove any leaked chlorine in the OSCG building. The system will either adopt wet-type with packed tower/ horizontal type using sodium hydroxide as the neutralising agent or dry-type using alumina oxide substrate as the neutralising agent. The plant and equipment are installed in a separate scrubber room.

2.2.1.7 On detection of chlorine content (3 ppm or above) in the OSCG building, the normal ventilation system will stop and the scrubbing system will activate automatically. The air/ chlorine mixture in the affected areas is drawn into the scrubber by the scrubber fan (2×100%, i.e. 1 duty and 1 stand-by) via ducting which may be the same as (or entirely separate from) the ducting provided for the normal ventilation system.

2.2.1.8 An electrically-operated isolating damper is provided in the scrubber intake for recycling which opens automatically when the scrubber fan starts up. An additional isolating damper is provided to isolate the normal ventilation system when the scrubber system is operating.

2.2.1.9 The scrubber system is normally set to recycle air back to the OSCG building. The treated air may be discharged to atmosphere at roof level when the chlorine concentration is below 3 ppm (in accordance with the FSD requirements DG/TS/llOA, 3rd Revision). This is affected by means of a pair of electrically operated change-over dampers controlled manually from the local control panel. A continuous chlorine monitor is installed at a point downstream of the chlorine scrubber and upstream of the vent/recycle changeover dampers. It has a high level alarm which sounds at both the local control panel and in the main control room when the chlorine concentration exceeds a pre-set level.

2.2.1.10 For a typical setup of a wet-type packed tower chlorine scrubbing system, 12.5 – 15 wt% NaOH solution will be used. When the system is in operation, NaOH is recirculated to the distributor to provide adequate irrigation. A mist eliminator is installed upstream of the chlorine scrubber outlet to prevent entrainment of liquid into the treated air in the scrubber before being discharged to the atmosphere or returned to the OSCG building. The scrubber is also provided with a sampling point, a mixer (for preparation the NaOH solution), a direct reading transparent level gauge, an inspection window and level indication with high and low level alarms and a temperature measurement device for monitoring the temperature of caustic solution during preparation process.

Liquid Carbon Dioxide (CO_2) Operation

2.2.1.11 Carbon dioxide (CO_2) will be used for pH adjustment and remineralisation in the post treatment process. Liquid carbon dioxide will be delivered to the desalination plant by road tankers. A total of 1,600 tonnes of liquid carbon dioxide (equivalent to 90-day storage capacity) can be stored on-site by 16 cryogenic pressurised tanks. Based on the daily consumption of 18 tonnes per day, the number of 20-tonne road tanker deliveries is estimated as 329 deliveries per year. Liquid CO_2 is stored at -23°C and 17 barg for both storage tanks and road tankers.

Landfill Gas Utilization for Power Generation

2.2.1.12 Synthetic Natural Gas (SNG) will be used to generate electricity to meet part of the electricity demand for the operation of the desalination plant. Landfill gas (LFG) from the adjacent South East New Territories (SENT) Landfill will be converted into SNG by an external supplier before it is delivered to the desalination plant via an underground pipeline operating at 2.4 barg with a maximum flowrate of 2,084 m^3/hour. The generator will either be installed in a generator room or placed at an open space using a modular design and the SNG intake will be routed directly to the generator with no on-site storage of SNG.

Chemical Operations

2.2.1.13 The desalination plant also utilises various chemicals including hydrochloric acid (32 wt% HCl), sodium hydroxide (NaOH) and sodium bisulphite (38 wt% $NaHSO_3$) for de-chlorination and neutralization; sodium hypochlorite (NaOCl) to control biological growth and shock chlorination of seawater intake; 10 wt% HCl, citric acid ($C_6H_8O_7$) and anti-scalant for chemical cleaning of RO membranes; ferric chloride (5 wt% HCl) for pre-treatment and coagulation process and sulphuric acid (98 wt% H_2SO_4) for pH adjustment in the pre-treatment process. Other chemicals include polyelectrolyte and sodium meta-bisulphite are used for pre-treatment process, while hydrated lime and sodium silicofluoride are used for post-treatment process. The storage quantities and locations of various chemicals adopted for the ultimate capacity of the desalination plant (i.e. Phase 1 & 2) are summarised in **Table 2.1** and schematically shown in **Plate 2.2**.

Table 2.1 Storage Quantities & Locations of Chemicals

Chemicals	Total Storage Capacity (m^3) (1)	Location
Sodium bisulphite (38wt% $NaHSO_3$)	4	OSCG Buildings for Phase 1 & 2
Hydrochloric acid (32 wt% HCl)	4	OSCG Buildings for Phase 1 & 2
Ferric chloride (5 wt% HCl)	2,016	Chemical Building
Hydrochloric acid (10 wt% HCl)	80	Chemical Building
Sulphuric acid (98 wt% H_2SO_4)	1,380	Chemical Building
Citric acid (50 wt% $C_6H_8O_7$)	8	Chemical Building
Caustic Soda (Sodium Hydroxide)	1,944	Chemical Building, OSCG Buildings for Phase 1 & 2
Polyelectrolyte	26	Chemical Building
Hydrated Lime	1,345 tonnes	Chemical Building
Sodium meta-bisulphite	182	Chemical Building
Anti-scalant	296	Chemical Building
Sodium Silicofluoride	24 tonnes	Chemical Building
Sodium Hypochlorite (NaOCl)	60	OSCG Buildings for Phase 1 & 2

Notes:
(1) For ultimate capacity of the desalination plant (i.e. Phase 1 & 2).

2.2.1.14 Except 38% wt sodium bisulphite solution and 32% wt hydrochloric acid for OSCG purpose, there is no additional dangerous goods due to the proposed OSCG system operation in comparison with the approved EIA [1]. With reference to the Detailed Design Plan [2], there are no changes in the use, types and operation of other dangerous goods in the desalination plant except for some minor changes in the storage quantities. Therefore, the risk impacts as discussed under Section 13.6 of the approved EIA [1] remain valid. The approved EIA concluded that considering their concentrations in the atmosphere due to accidental spillage and escape factor of the surrounding population, transport, storage and use of other dangerous goods would not lead to hazard to life issue. Thus, off-site impacts of other DGs are considered insignificant and are not further assessed.

2.2.1.15 Nevertheless, sulphur dioxide may be evolved when sodium bisulphite is accidentally mixed with either hydrochloric acid, ferric chloride with 5 wt% HCl content, sulphuric acid and citric acid. Accidental mixing scenarios are further discussed in **Section 3.5**, while the associated SO_2 release rate and failure frequency were derived based on the operational details as summarised in **Table 2.2**.

Table 2.2 Summary of Chemical Operations

Chemicals	Road Tanker Deliveries Per Year (1,2,5)	Storage Tanks		Total Storage Capacity (m^3) (4)
		Quantity (3)	Capacity per Tank (m^3)	
Sodium bisulphite (38wt% $NaHSO_3$)	9	4	1	4
Hydrochloric acid (32 wt% HCl)	9	4	1	4
Ferric chloride (5 wt% HCl)	327	8	252	2,016
Hydrochloric acid (10 wt% HCl)	13	2	40	80
Sulphuric acid (98 wt% H_2SO_4)	224	10	138	1,380
Citric acid (50 wt% $C_6H_8O_7$)	4	1	8	8

Notes:
(1) Transfer rate from road tankers to storage tanks is taken as 10 l/s.
(2) Road tanker capacity of 25m^3 considered for all chemicals except for CO_2 which will be delivered by 20-tonne road tanker.
(3) All storage tanks are separate and not connected.
(4) For ultimate capacity of the desalination plant (i.e. Phase 1 & 2).
(5) 9 annual road tanker deliveries of 38wt% $NaHSO_3$ and 32 wt% HCl are considered for each phase.

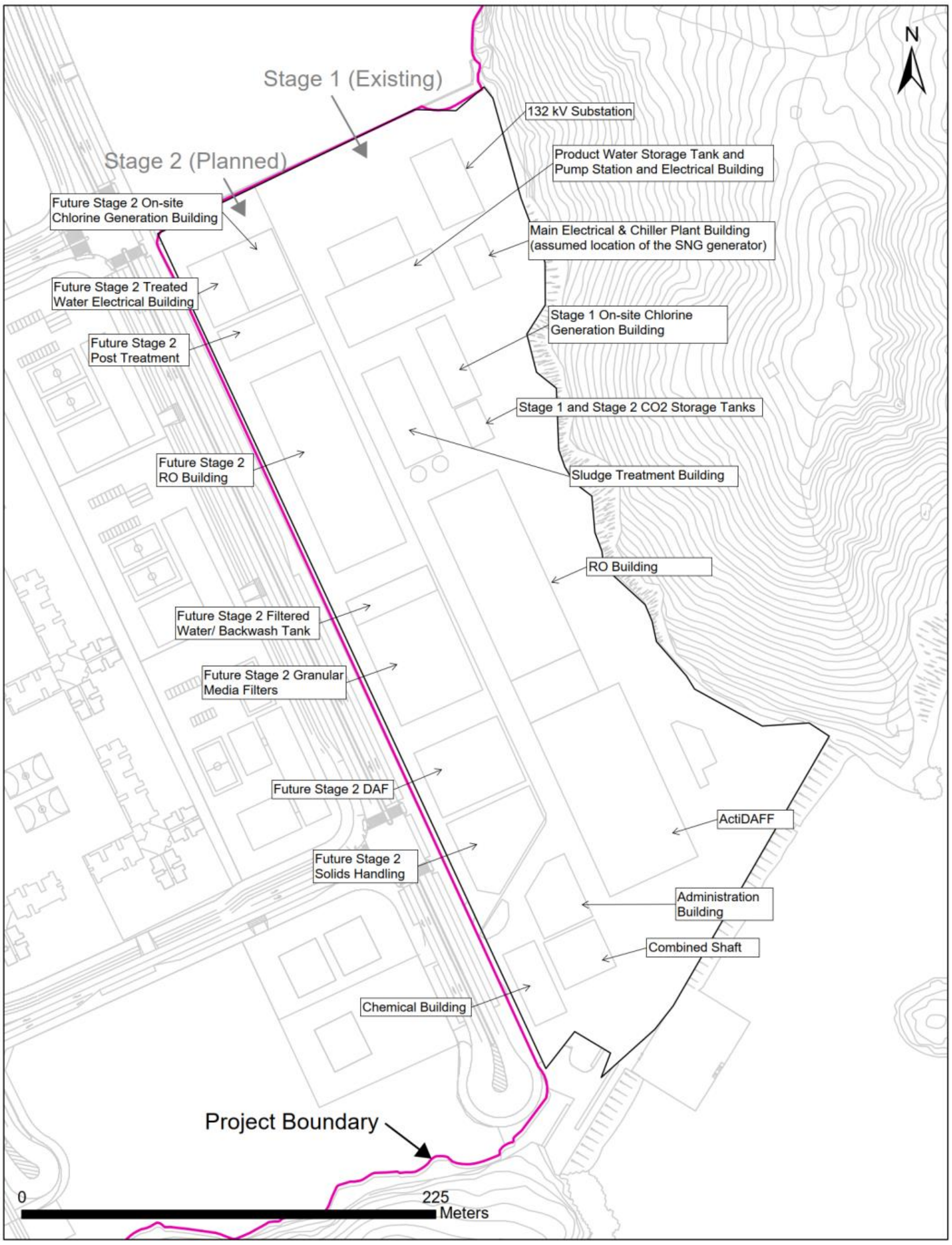

Plate 2.2 Site Layout Plan of the Desalination Plant

2.3 Population

2.3.1 Surrounding Populations

2.3.1.1 Societal risk is a measure of the consequence magnitude and the frequency of the hazardous events. To establish the impact of any release (expressed as the number of people likely to be affected) in the future, it is necessary to have a good knowledge of the future surrounding population levels. These include residential population, government, institutional or community population, educational population and transport population but exclude staff of the desalination plant since they are considered as voluntary risk takers.

2.3.1.2 The locations of population groups and roads considered for both assessment years are presented in **Plate 2.3**. Details on the estimated population for each population group are provided in **Annex A**.

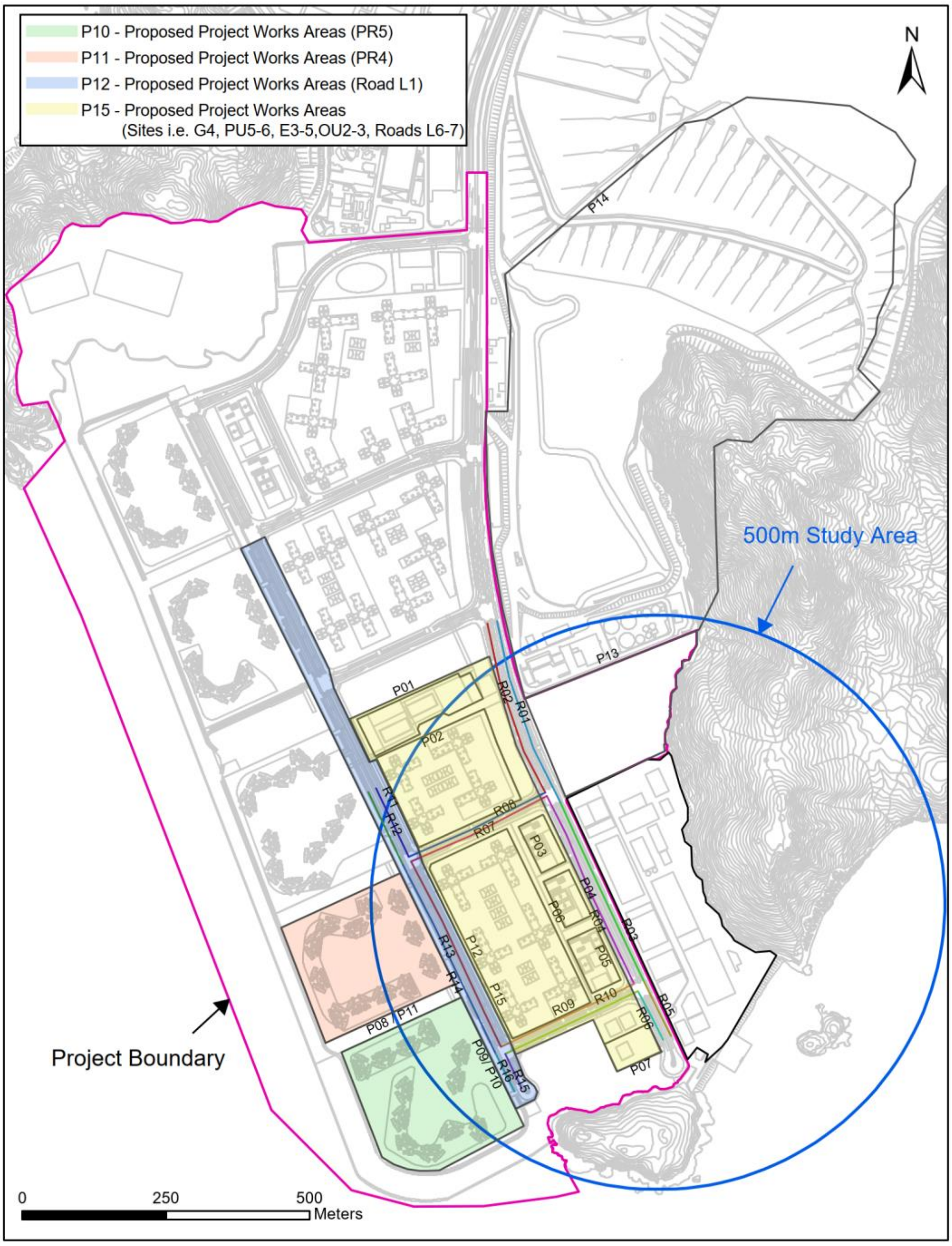

Plate 2.3 Locations of Population Groups and Road

Land and Building Population

2.3.1.3 Estimation of land and building populations was based on the latest information provided in the development schedule of the Draft RODP, while the worker estimate at SENT landfill extension (SENTX) was advised by EPD. An average of 5% population was considered to be outdoor for residential, government/ institution or community population [17], while 100% population was assumed to be outdoor for users at the proposed green fuel station (ID P08), construction workers at proposed project works areas (ID P11-13,17) and workers at SENTX (ID P16).

Table 2.3 Land and Building Population Data

ID	Description	Population	
		Year 2035	Year 2041
P01	Integrated Government Complex (includes Swimming Pool Complex with Sports Centre, Public Market, Community Hall, Health Centre) (G4)	-	509
P02	Public Housing (PU5)		
	Residential	-	11864
	Employment	-	1246
P03	Primary School (E3)	-	1404
P04	Primary School (E4)	-	1404
P05	Secondary School (E5)	-	2412
P06	Public Housing (PU6)		
	Residential	-	19380
	Employment	-	2452
P07	Proposed Green Fuel Station (OU3)	-	10
P08	Private Housing (PR4)		
	Residential	-	3372
	Employment	-	1432
P09	Private Housing (PR5)		
	Residential	-	3255
	Employment	-	1515
P10	Proposed Project Works Areas (PR5)	150	-
P11	Proposed Project Works Areas (PR4)	150	-
P12	Proposed Project Works Areas (Road L1)	150	-
P13	Proposed Effluent Polishing Plant	142	142
P14	SENT Landfill Extension	25	25
P15	Proposed Project Works Areas (Sites. i.e. G4,PU5-6, E3-5, OU2-3, Roads L6-7)	300	-

Note: Vulnerable population factor of 3.3 is applied to sensitive populations i.e. primary school (P03 and P04).

<u>Road Population</u>

2.3.1.4 The traffic data was based on the latest Annual Traffic Census (ATC) published by Transport Department (TD) [3] and the Traffic Impact Assessment (TIA) report prepared for this Assignment. The traffic population was predicted based on the following equation:

$$Traffic\ Population = \frac{No.of\ Person\ per\ vehicle \times No.of\ Vehicle\ per\ hour \times Road\ Length}{Speed}$$

2.3.1.5 Based on the latest ATC [3], the occupancies for each vehicle type and vehicle mix were taken at the core station no. 5021 (Tseung Kwan O Tunnel (from Toll Plaza to Tseung Kwan O Tunnel Rd RA)) to represent the road traffic for this assessment, as summarised in **Table 2.4**.

Table 2.4 Vehicle Occupancy

	Class of Vehicle(1)				
	Motorcycle	**Private Car**	**Taxi**	**Private Light Bus**	**Public Light Bus**
Occupancy at Peak hour	1.1	1.4	2	5.2	14

	Class of Vehicle(1)				
	Goods Vehicle		**Non-franchised Bus**	**Franchised Bus**	
	Light	**Medium/ Heavy**		**Single Deck**	**Double Deck**
Occupancy at Peak hour	1.4	1.2	13.8	2	33.8

Notes:
(1) The occupancy at peak hour was generally adopted except for private light bus and single deck franchised bus where occupancy at 16 hours were conservatively applied.

2.3.1.6 The traffic population was assumed to be 100% outdoor. The estimated road population considered for both assessment years are presented in **Table 2.5** and the detailed calculations are provided in **Annex A**.

Table 2.5 Estimated Road Population

ID	Description	Traffic Speed (km/hr)	Maximum Population			
			Year 2035		**Year 2041**	
			Daytime	**Night-time**	**Daytime**	**Night-time**
R01	Road L8	50	41	27	32	21
R02		50	39	24	37	22
R03		50	51	32	21	15
R04		50	54	30	30	18
R05		50	7	7	7	7
R06		50	7	7	7	7
R07	Road L6	50	-	-	15	12
R08		50	-	-	15	12
R09	Road L7	50	-	-	14	12
R10		50	-	-	12	11
R11	Road L1	50	-	-	12	11
R12		50	-	-	11	11
R13		50	-	-	20	15
R14		50	-	-	17	13
R15		50	-	-	7	7
R16		50	-	-	7	7

2.3.2 Time Modes

2.3.2.1 Four representative time modes as presented in **Table 2.6** were applied in this hazard assessment to address the variation in levels of activities that could lead to a release and the variation in population in the assessment area with time.

Table 2.6 Definitions of Time Modes

Time Period	Definition	Proportion of Time
Weekday Day	Mon-Fri, 7am-7pm	35.71%
Weekday Night	Mon-Fri, 7pm-7am	35.71%
Weekend Day	Sat-Sun, 7am-7pm	14.29%
Weekend Night	Sat-Sun, 7pm-7am	14.29%

2.3.3 Occupancies of Population Groups

2.3.3.1 The assumptions of the occupancy rate for various time modes including the indoor ratio considered for the population groups are summarised in **Table 2.7**.

Table 2.7 Occupancies of Population Groups at Different Time Modes

Population Group	Percentage of Occupancy at Different Time Modes				Indoor Ratio
	Weekday Day	Weekday Night	Weekend Day	Weekend Night	
Retail	100%	10%	100%	10%	95%
Residential	50%	100%	70%	100%	95%
Educational	100%	0%	50%	0%	95%
Green Fuel Station	100%	100%	100%	100%	0%
Construction Site	100%	10%	50%	10%	0%
Industrial	100%	10%	50%	10%	95%

2.4 Meteorology

2.4.1.1 Meteorological data is required for consequence modelling and risk calculation. Consequence modelling (dispersion modelling) requires wind speed and stability class to determine the degree of turbulent mixing potential whereas risk calculation requires wind-rose frequencies for each combination of wind speed and stability class.

2.4.1.2 Meteorological data was obtained from Tseung Kwan O Weather Station where wind speed, stability class, weather class and wind direction are available. This data represented the weather conditions over a five-year period (i.e. between 2019 – 2023). Six combinations (2B, 1D, 3D, 6D, 2E and 1F) and five combinations (1D, 3D, 5D, 2E and 1F) of wind speed and stability class were chosen for daytime and night-time meteorological conditions respectively. These combinations were considered adequate to reflect the full range of observed variations in these quantities. It is not necessary and efficient to consider every combination observed. The principle is to group these combinations into representative weather classes that together cover all conditions observed.

2.4.1.3 Once the weather classes have been selected, frequencies for each wind direction for each weather class can then be determined. The frequency distributions for the daytime and night-time meteorological conditions are summarised in **Table 2.8**.

Table 2.8 Weather Class-Wind Direction Frequencies at Tseung Kwan O Weather Station

Daytime							
Direction	2B	1D	3D	6D	2E	1F	Total (%)
0 – 30	3.60	1.05	1.95	0.06	1.33	1.91	9.9
30 – 60	7.54	1.05	4.74	0.02	2.10	1.40	16.8

Daytime							
Direction	**2B**	**1D**	**3D**	**6D**	**2E**	**1F**	**Total (%)**
60 – 90	12.84	1.10	5.25	0.07	1.79	1.15	22.2
90 – 120	7.91	1.05	2.13	0.02	0.53	0.77	12.4
120 – 150	3.22	0.55	1.10	0.04	0.40	0.53	5.8
150 – 180	1.71	0.36	0.53	0.01	0.26	0.33	3.2
180 – 210	8.70	0.68	1.45	-	0.18	0.41	11.4
210 – 240	6.97	0.71	2.17	-	0.51	0.59	10.9
240 – 270	1.03	0.39	0.48	-	0.21	0.41	2.5
270 – 300	0.42	0.17	0.09	-	0.03	0.20	0.9
300 – 330	0.24	0.16	0.08	-	0.02	0.42	0.9
330 – 360	0.85	0.35	0.44	-	0.31	0.94	2.9
All (%)	55.0	7.6	20.4	0.2	7.7	9.1	100.0

Night-time						
Direction	**1D**	**3D**	**5D**	**2E**	**1F**	**Total (%)**
0 – 30	0.37	1.02	0.02	5.34	10.7	17.4
30 – 60	0.22	1.98	0.07	9.04	6.9	18.2
60 – 90	0.30	1.64	0.03	5.71	4.3	12.0
90 – 120	0.26	0.55	0.01	2.72	3.0	6.5
120 – 150	0.05	0.47	0.03	2.49	2.9	6.0
150 – 180	0.03	0.23	0.02	1.51	1.7	3.5
180 – 210	0.02	0.15	-	1.24	1.9	3.3
210 – 240	0.04	0.29	-	4.00	4.6	9.0
240 – 270	0.04	0.03	-	3.42	4.7	8.2
270 – 300	0.08	0.02	-	0.28	2.1	2.5
300 – 330	0.11	0.02	-	0.16	4.8	5.1
330 – 360	0.26	0.15	-	1.07	6.8	8.3
All (%)	1.8	6.5	0.2	37.0	54.5	100.0

3. HAZARD IDENIFICATION AND ANALYSIS

3.1 Introduction

3.1.1.1 A hazard is described as the property of a material or activity with the potential to do harm. Potential hazards associated with on-site chlorine generation (OSCG) including chlorine, by-products such as hydrogen and sodium hydroxide solution, sodium bisulphite solution, sodium hypochlorite solution, synthetic natural gas, as well as liquid carbon dioxide were identified.

3.2 Chlorine Gas

Hazardous Properties of Chlorine

3.2.1.1 Chlorine gas will be consumed following the electrolysis process. The chlorine generators are located inside the OSCG building with provision of safety measures implemented in the OSCG system and the OSCG building. Vacuum system will be used for transmission of chlorine gas in the OSCG system. Given chlorine gas will not be pressurized, a puncture on piping would not lead to leakage of chlorine. The OSCG building will be provided with mechanical ventilation at 6 Air Changes Per Hour (ACPH) for the OSCG building to maintain a safe environment under the normal operation, as well as chlorine gas and hydrogen gas detectors.

3.2.1.2 Some of the key hazardous characteristics of chlorine [4] include:

- Chlorine gas is heavier than air and as a result will tend to accumulate in low places when released to the atmosphere and flow downhill in still air. However, slight breezes or thermal turbulence will cause it to move upward, so people are not necessarily safe simply because they are above the point of release;
- Chlorine gas has a greenish-yellow colour which is only visible at high concentrations many times higher than the danger level (see **Table 3.1** below); and
- Chlorine gas is a respiratory irritant. Symptoms caused by inhalation of chlorine include headaches, pain, difficult breathing, burning sensation of the chest, nausea and watering of the eyes.

3.2.1.3 The physiological effects of chlorine are summarised in **Table 3.1**.

Table 3.1 Physiological Effects of Chlorine

Concentration (ppm)	Effects
0.2-3.5	Threshold of odour perception in most individuals
3-5	Tolerated without undue ill effect for half to one hour.
5-8	Slight irritation of the mucous membranes of the upper respiratory tract and of the eyes.
15	Effects are immediate. Irritation of nose, throat and eyes with cough and lachrymation.
30	Immediate cough with a choking sensation, retrosternal chest pain and a sense of constriction in the chest.
40-60	Development of a chemical tracheo-bronchitis and pulmonary oedema.
1000	Concentration likely to be fatal after a few deep breaths.

3.2.1.4 The toxic effect of chlorine and the associated hazards have already been well identified in the approved EIA [1], ERR as cited in the Detailed Design Plan [2] and other previous studies relevant to chlorine. There is no incident record associated with on-site chlorine generation system from databases including MHIDAS (Major Hazard Incident Data Service), ARIA and eMARS. However, there was a recent incident record for Phase 1 of the OSCG system at Ngau Tam Mei Water Treatment Plant (NTMWTW) during testing and commissioning period. According to the QRA for Phase 2 of the on-site chlorine generation system [5]:

"The caustic ejection pump did not start dosing caustic to the hypo tank after the set point was reached. Due to insufficient caustic dosing, chlorine gas was not converted to sodium hypochlorite in the hypo tank. The chlorine scrubber was activated and the normal ventilation was shut down upon detection of 3 ppm chlorine gas by several chlorine leak detectors near the OSCG Phase 1. It was later found out that the chlorine gas might be leaked from the loosen bolts at flanges around the anolyte tank and the chlorine / chlorinated brine line.

The root cause investigation of the chlorine leak is still on-going at the stage when preparing this QRA. The initial findings suggested that the incident was caused by a combination of programme control errors and improper mechanical installations. It is believed that such errors are only more probable during the testing and commissioning period and the likelihood can be much reduced during the operation of the OSCG."

<u>Direct Chlorine Discharge to the Atmosphere</u>

3.2.1.5 The release scenario of chlorine gas direct to the surrounding is considered not credible as the OSCG system does not have direct connection to the vent pipe.

<u>Continuous Indoor Chlorine Release</u>

3.2.1.6 Chlorine pipeline is under negative pressure during normal operation and would not leak from holes at flange joints or along chlorine pipeline when the negative pressure can be maintained. The full bore rupture of a 50 mm diameter chlorine pipeline on the common header for chlorine dosing was identified as the worst case release scenario. With reference to the ERR as cited in the Detailed Design Plan [2], the maximum hazard distance from scenarios with leak size less than 25 mm is below 30 m. The separation distance from the centre of OSCG building to the nearest site boundary (i.e. western boundary) is about 34 m, while the exhaust points/ louvers of OSCG buildings to the nearest site boundary (i.e. northern boundary) is about 51 m. Thus, leak failure scenarios would not lead to toxic impact to off-site population. However, the full bore rupture was found to cause off-site impacts under the ERR as cited in the Detailed Design Plan [2] and was further assessed in this study.

3.2.1.7 The release pressure is relatively low during chlorine generation from the electrolysis process. The release pressure is estimated from the discharge model for the rupture scenario in which the release rate is assumed equivalent to the chlorine generation rate. The chlorine generation rate is 1,125 kg per day per system, which equates to a chlorine release rate of 0.013 kg/s at source. Based on the OSCG building volume of 4,000 m^3 and 6 ACPH ventilation rate, the 10-minute average release rate to atmosphere for the OSCG system are estimated to be 5 g/s for full bore rupture.

3.3 Hydrogen Gas

3.3.1.1 Hydrogen is a by-product from the electrolysis process. There will not be any storage for the hydrogen gas by-product. Under normal operation, it is diluted to 1% of LFL before discharging to the atmosphere. Nonetheless, failures of pipeline, joints or valves would lead to a hydrogen gas release. Hydrogen gas is flammable, colourless and odourless with density 13 times lighter than air. When it is ignited, flash fire or explosion may be resulted.

External Release Through Vent Pipe

3.3.1.2 If the on-duty air blower fails, the stand-by air blower will start and the generator will trip. Risk of fire hazard for the discharging hydrogen would occur when there is insufficient fresh air for dilution and the generator continues operation. Referring to the ERR as cited in the Detailed Design Plan [2], hydrogen gas generation rate is 0.18 g/s per generator and the maximum hazard distance for flash fire is about 3 m. Owing to the relatively small release rate, release through vent pipe would not lead to fire or explosion. Therefore, the impact of hydrogen is not further assessed in this study.

Indoor Release

3.3.1.3 Failure of pipelines from electrolysers containing hydrogen-caustic solution mixture or vent pipe for hydrogen within the OSCG building would lead to indoor release of hydrogen. Whilst provisions of blower and force ventilation system, as well as hydrogen detectors are available, potential for localized explosion may still occur due to inadequate dilution of the hydrogen gas.

3.3.1.4 Referring to the ERR as cited in the Detailed Design Plan [2], the maximum hazard distance for an explosion at 2 psi overpressure is estimated as 11 m based on the discharge of 108 g hydrogen to fill up the whole OSCG skid with a congested volume of about 57 m^3. The explosion impact was conservatively assessed using the Multi-Energy explosion with confined strength 10. Simultaneous damages to HCl / other storage compartments for incompatible chemicals are not envisaged. Although the explosion would temporarily disrupt the OSCG process but it would not result in continuous release of chlorine gas. Furthermore, owing to the large separation distances between OSCG skid and other hazardous sources, hydrogen explosion would not cause any secondary impacts to other hazardous sources within the desalination plant nor lead to off-site impact. Therefore, the impact of hydrogen is not further assessed in this study.

3.4 Sodium Hydroxide Solution

3.4.1.1 Sodium hydroxide (NaOH) is a by-product from the electrolysis process and one of the dangerous goods to be used in the desalination plant. NaOH when reacts with acids will produce water and corresponding salts. Considering the chemical reaction does not generate toxic gas, NaOH will not lead to hazard to life issue. Therefore, the impact of NaOH is not further assessed in this study.

3.5 Sodium Bisulphite Solution

3.5.1.1 38% wt sodium bisulphite ($NaHSO_3$), when mixed with incompatible chemicals will produce sulphur dioxide. Accident records from ARIA relating to mixing of incompatible chemicals during refilling process relevant to the operation of desalination plant as identified in the ERR excerpts [2] remain valid.

3.5.1.2 Accidental mixing in loading operation with other dangerous goods including 32 wt% HCl, $FeCl_3$ with 5 wt% HCl content, 10 wt% HCl, 98 wt% H_2SO_4 and 50 wt% $C_6H_8O_7$ were identified. The chemical reactions with hydrochloric acid, sulphuric acid and citric acid follow the chemical equations below:

$$NaHSO_3 + HCl \rightarrow H_2O + NaCl + SO_2 \quad (1)$$

$$2NaHSO_3 + H_2SO_4 \rightarrow 2H_2O + Na_2SO_4 + 2SO_2 \quad (2)$$

$$3NaHSO_3 + C_6H_8O_7 \rightarrow 3H_2O + Na_3C_6H_5O_7 + 3SO_2 \quad (3)$$

3.5.2 The approach for the assessment of sodium bisulphite and assumptions considered for the estimation of the sulphur dioxide (SO_2) generated as stated in the ERR excerpts [2] were adopted.

3.5.2.1 Scenarios for accidental mixing due to human error by supplier are listed below, while the associated release rate of SO_2 and duration are summarised in **Table 3.2**.

- Scenario 1A / 1B – wrong product (32 wt% HCl) is delivered and unloaded to the right tank (38 wt% $NaHSO_3$ tank) at OSCG building for Phase 1 / 2
- Scenario 2A / 2B – wrong product (38 wt% $NaHSO_3$) is delivered and unloaded to the right tank (32 wt% HCl tank) at OSCG building for Phase 1 / 2
- Scenario 3A / 3B – wrong product ($FeCl_3$ with 5 wt% HCl content) is delivered and unloaded to the right tank (38 wt% $NaHSO_3$ tank) at OSCG building for Phase 1 / 2
- Scenario 4 – wrong product (38 wt% $NaHSO_3$) is delivered and unloaded to the right tank ($FeCl_3$ tank with 5 wt% HCl content) at chemical building
- Scenario 5A / 5B – wrong product (10 wt% HCl) is delivered and unloaded to the right tank (38 wt% $NaHSO_3$ tank) at OSCG building for Phase 1 / 2
- Scenario 6 – wrong product (38 wt% $NaHSO_3$) is delivered and unloaded to the right tank (10 wt% HCl tank) at chemical building
- Scenario 7A / 7B – wrong product (98 wt% H_2SO_4) is delivered and unloaded to the right tank (38 wt% $NaHSO_3$ tank) at OSCG building for Phase 1 / 2
- Scenario 8 – wrong product (38 wt% $NaHSO_3$) is delivered and unloaded to the right tank (98 wt% H_2SO_4 tank) at chemical building
- Scenario 9A / 9B – wrong product (50 wt% $C_6H_8O_7$) is delivered and unloaded to the right tank (38 wt% $NaHSO_3$ tank) at OSCG building for Phase 1 / 2
- Scenario 10 – wrong product (38 wt% $NaHSO_3$) is delivered and unloaded to the right tank (50 wt% $C_6H_8O_7$) at chemical building

Table 3.2 Estimated Release Rate of Sulphur Dioxide for All Scenarios

Scenarios	Source	Chemical	Qty for Reaction (m^3)	Density (kg/l)	Available Qty for Reaction (mole)	Mixing Rate (mole/s)	Duration (s)	SO_2 Release Rate (kg/s)	Notes
1A/1B	Road Tanker	32 wt% HCl	0.5	1.16	5092	102	25	6.5	(1,2)
	Storage Tank	38 wt% $NaHSO_3$	0.5	1.33	2428				
2A/2B	Road Tanker	38 wt% $NaHSO_3$	0.5	1.33	2428	49	50	3.1	(1,2)
	Storage Tank	32 wt% HCl	0.5	1.16	5092				
3A/3B	Road Tanker	$FeCl_3$ (5 wt% HCl)	0.5	1.37	940	19	50	1.2	(1,2)
	Storage Tank	38 wt% $NaHSO_3$	0.5	1.33	2428				
4	Road Tanker	38 wt% $NaHSO_3$	25	1.33	121420	49	2500	3.1	(3,4)
	Storage Tank	$FeCl_3$ (5 wt% HCl)	126	1.37	236790				
5A/5B	Road Tanker	10 wt% HCl	0.5	1	1372	27	50	1.8	(1,2)
	Storage Tank	38 wt% $NaHSO_3$	0.5	1.33	2428				
6	Road Tanker	38 wt% $NaHSO_3$	20	1.33	97136	49	1130	3.1	(1,5)
	Storage Tank	10 wt% HCl	20	1	54870				
7A/7B	Road Tanker	98 wt% H_2SO_4	0.5	1.84	9200	368 ($NaHSO_3$)	7	23.6	(1,2)
	Storage Tank	38 wt% $NaHSO_3$	0.5	1.33	2428				
8	Road Tanker	38 wt% $NaHSO_3$	25	1.33	121420	49 ($NaHSO_3$)	2500	3.1	(3,6,7)
	Storage Tank	98 wt% H_2SO_4	69	1.84	1269600				
9A/9B	Road Tanker	50 wt% $C_6H_8O_7$	0.5	1.24	1615	97 ($NaHSO_3$)	25	6.2	(1,2,7)
	Storage Tank	38 wt% $NaHSO_3$	0.5	1.33	2428				
10	Road Tanker	38 wt% $NaHSO_3$	4	1.33	19427	49 ($NaHSO_3$)	400	3.1	(1,8,7)
	Storage Tank	50 wt% $C_6H_8O_7$	4	1.24	12919				

Notes:
(1) Road tanker's quantity for reaction is determined by the target storage tank size (50% of the storage tank capacity).
(2) Road tanker capacity of 25 m^3 and storage tank size of 1 m^3 are assumed. 2 storage tanks at each OSCG building.
(3) Road tanker's quantity for reaction is limited by its capacity.
(4) Road tanker capacity of 25 m^3 and storage tank size of 252 m^3 are assumed. 8 storage tanks at chemical building.
(5) Road tanker capacity of 25 m^3 and storage tank size of 40 m^3 are assumed. 2 storage tanks at chemical building.
(6) Road tanker capacity 25 m^3 and storage tank size 138 m^3 are assumed. 10 storage tanks at chemical building.
(7) The molar ratio in the chemical reaction is 2:1 (sodium bisulphite : sulphuric acid)/ 3:1 (sodium bisulphite : citric acid).
(8) Road tanker capacity 25 m^3 and storage tank size 8 m^3 are assumed. 1 storage tank at chemical building.

3.6 Sodium Hypochlorite Solution

3.6.1 Sodium hypochlorite (NaOCl) solution is a corrosive substance in clear light yellow to greenish-yellow liquid form with a chlorine-like odour. It is not flammable. It decomposes and releases corrosive chlorine gas when it is in contact with acids.

3.6.1.1 The relevant hazards associated with the proposed OSCG system would come from off-site delivery of sodium hypochlorite to the desalination plant under emergencies and on-site use / storage of sodium hypochlorite. With reference to the approved EIA [1], the hazard caused by accidental mixing of sodium hypochlorite and incompatible chemicals during the transfer process to storage tanks was identified. With the safety measures in place (e.g. tank color coding, tank feeding pipe lock out system and use of different coupler/ size) to prevent feeding wrong chemicals into the NaOCl tanks, and import of NaOCl from the same chemical supplier for other chemicals is not required, the risk of accidental mixing during delivery is eliminated.

3.6.1.2 Sodium hypochlorite solution generated on-site will be stored in OSCG buildings. Although incompatible chemical hydrochloric acid will also be placed in the same building, they will be stored in separate compartments with provision of bund in each compartment to contain any spillages. With reference to Appendix B-7 of the Detailed Design Plan [2], separate pipeline routing was proposed for preventing sodium hypochlorite from accidental mixing with incompatible chemicals due to leaking pipelines. Furthermore, separate trench containments made of impervious materials for sodium hypochlorite pipeline and other incompatible chemicals pipelines will be used to ensure leakages could be contained without leading to accidental mixing of incompatible chemicals. With the implementation of preventive measures as described in **Section 3.9.1.2**, risk of mixing of incompatible chemicals for the storage and/or along the pipe alignment is eliminated.

3.7 Synthetic Natural Gas

3.7.1.1 SNG is considered flammable due to high methane content. The composition and physical properties of SNG as supplied by HKCG for the preparation of ERR [2], are summarised in **Table 3.3**.

Table 3.3 Compositions and Properties of Landfill Gas and Synthetic Natural Gas

Parameter		LFG	SNG
Composition	CO_2	≤ 45%	20 - 30%
	CH_4	> 45%	45%
	N_2	≤ 15%	20 - 32%
	O_2	≤ 2%	2%
	H_2S	≤ 250 ppmv	< 1 ppmv
	H_2O	60°C saturated	Dew point < 10°C
Physical Properties	Calorific Value (MJ/Sm^3)	-	17.13 - 17.41
	Wobbe Index (MJ/Sm^3)	-	17.7 - 18.3
	Specific Gravity	-	< 0.95

3.7.1.2 SNG is delivered to the desalination plant via an underground pipeline operating at 2.4 barg and routed directly to the power generator that will either be installed in a generator room or placed at an open space using a modular design. Hazards of SNG may come from gas releases to the surrounding and indoor release due to pipeline / equipment failures. Potential for fire or explosion when the gas is ignited.

Gas Release to the Surrounding

3.7.1.3 This is likely to occur when the generator is installed outdoor. Referring to the ERR excerpts [2], the maximum hazard distance for a jet fire at 4 kW/m^2 is 24 m for a continuous release with flow rate of 2 kg/s. The flame length of the jet fire is 18 m and the jet fire would not cause any secondary impacts to other hazardous sources within the desalination plant. Therefore, the impact of SNG is not further assessed in this study.

Indoor Release

3.7.1.4 The generator room would be filled up with flammable gas at LFL concentration in 60 seconds due to the high gas flow rate. According to the ERR excerpts [2], approximately 63 kg of gas would be accumulated indoor assuming the ignition would occur when 50% space of the 1,300 m^3 generator room is filled up with flammable gas. The maximum hazard distance for an explosion at 2 psi overpressure is estimated as 47 m based on Multi-Energy explosion model with confined strength 10. Considering the separation distances between the generator to the nearest site boundary/ OSCG building (phase 1) / liquid carbon dioxide storage area are more than 47 m, failure of SNG power generator and associated facilities resulting in explosion and fire impingement would not cause any secondary impacts to other hazardous sources within the desalination plant nor lead to off-site impact. Therefore, the impact of SNG is not further assessed in this study.

3.8 Liquid Carbon Dioxide

3.8.1.1 Carbon dioxide is not considered to be particularly toxic. However, it causes oxygen depletion effects. The effects of oxygen depletion are described by the British Cryogenics Council as the four stages of asphyxiation and are shown in the **Table 3.4**.

Table 3.4 Summary of Asphyxiation Stages

Asphyxiation stage	Oxygen concentration (% v/v) / effects
1st	21 to 14% Reducing: Increased pulse and breathing rate with disturbed muscular coordination
2nd	14 to 10%: Faulty judgement, rapid fatigue and insensitivity to pain
3rd	10 to 6%: Nausea and vomiting, collapse and permanent brain damage
4th	Less than 6%: Convulsion, breathing stopped and death

3.8.1.2 Without adequate venting or pressure-relief devices on the containers, enormous pressures can build up. The pressure can cause an explosion known as "boiling liquid expanding vapour explosion" (BLEVE). Unusual or accidental conditions such as an external fire, or a break in the vacuum which provides thermal insulation, may cause a very rapid pressure rise. Historical incidents involving liquid carbon dioxide from reference sources including Accident records from MHIDAS, Energy Institute and Global Congress on Process Safety 2013 as identified in the approved EIA [1] remain valid.

3.8.1.3 The design of CO_2 storage tanks including the storage capacity, pressure relief system and other safety features etc. as stated in the approved EIA [1] and Detailed Design Plan [2] remain valid. In view of the estimated frequency of CO_2 storage tank BLEVE is as low as 3.13×10^{-10} per year [1] and there is no offsite impact due to onsite storage, use and transport of CO_2, contribution of CO_2 storage tank BLEVE is considered insignificant to the overall risk and was not considered further in this study.

3.8.1.4 With reference to the approved EIA [1], the maximum hazard distance for toxic impact of liquid carbon dioxide at 1% fatality probability is 39 m. Considering the minimum separation distance from the centre of the liquid carbon dioxide storage area to the nearest off-site population is over 100 m, failure of on-site liquid carbon dioxide storage would not lead to toxic impact to off-site population. However, off-site transport of liquid carbon dioxide has off-site impact and further assessed in this study.

3.9 External Events

3.9.1.1 External events with the potential to result in a release at the desalination plant include:

- Earthquake;
- Aircraft crash;
- Vehicle impact;
- Landslide;
- Hill fire;
- Subsidence;
- Severe Environmental Event;
- Lightning; and
- Third Party Damage.

Earthquake

3.9.1.2 Hong Kong is located in a region of low seismicity where an earthquake is an unlikely event. Nonetheless, an earthquake has the potential to cause damage to the process equipment and pipework. The damage could occur due to ground movement or vibration leading to spontaneous failure of pipelines causing simultaneous failure of containments of incompatible chemicals. With reference to the ERR extracts [2], the following preventive measures will be implemented to avoid accidental mixing of incompatible chemicals in this simultaneous failure scenario:

- Chemicals will be stored in separate compartments with bunds designed to contain entire storage quantity in case of tank failure, to prevent from mixing of spillage. Bunds will be installed with linings to prevent chemical leakage from bunds through cracks.
- Double containment will be provided for HCl pipelines in OSCG buildings.
- Alignment of HCl pipeline is away from pipelines for other incompatible chemicals in OSCG buildings.
- Floor surface gradient will be used for directing spillage of incompatible chemicals to different locations such that HCl will be collected to a separate drain system.
- Separate drain system for HCl will be provided to collect spillage from pipelines inside OSCG building and outside storage compartment.
- Only one storage tank will be connected to delivery pipeline at any one time to minimize the amount of spillage.
- During operation, pipe pressure will be continuously monitored and pumps will be shut down immediately when irregular pressure drops occur.

- Vibration sensing system will be installed along pipelines. Pumps will be immediately shut down if excessive vibration is detected to minimize the amount of leakage through damaged pipelines.

Aircraft Crash

3.9.1.3 Aircraft crash is not considered a credible external event as the calculated aircraft frequencies were found to be in the order of 10^{-10} as estimated using the method given in HSE (1997) [6]. The detailed calculation is presented in **Annex B**.

Vehicle Impact

3.9.1.4 Only authorized vehicles will be permitted to enter the desalination plant, and speed will be restricted for vehicle movements within the site. Furthermore, CO_2 storage area are surrounded by security fence. Therefore, on-site vehicle impact is considered negligible. Nonetheless, there is a possibility of truck rollover during off-site transport of liquid CO_2. Thus, vehicle impact was accounted for in the liquid CO_2 assessment.

Landslide

3.9.1.5 A slope is located along the eastern boundary of the desalination plant. According to the latest design, a flexible barrier will be built within the desalination plant along the eastern boundary to completely contain debris flow. Whilst the liquid carbon dioxide storage area is at 30m from the toe of slope, a 1.5 m high protective barrier will also be constructed at the road side of the internal access road as a secondary protection to safeguard the liquid CO_2 storage area from soil debris in case of barrier failure. In worst case, debris flow would only cause leakage of connecting pipelines with these preventive measures in place. Therefore, slope failure would not lead to additional hazard or damage, including boiling liquid expanding vapour explosion (BLEVE), to the liquid CO_2 storage tanks and surrounding population.

Hill Fire

3.9.1.6 Whilst the slope is covered by vegetation, branches of trees or shrubs are not expected to reach the desalination plant. With the construction of the flexible barrier and a 1.5 m high protective barrier at the eastern boundary of the desalination plant, as well as OSCG system is protected by the 2 hour fire-rated structures, hill fire impact is considered negligible and not further considered in this Study.

Subsidence

3.9.1.7 Subsidence is usually slow in movement and such movement can be observed and remedial action can be taken in time. Therefore, the probabilities of severe environmental events and subsidence would be very small or negligible, so these external events were not further considered in this Study.

Severe Environmental Event

3.9.1.8 Loss of containment due to severe environmental events such as typhoon or tsunami (i.e. a tidal wave following an earthquake) was considered to be insignificant as majority of the hazardous facilities are located inside OSCG/ chemical buildings. Meanwhile, the CO_2 storage area is located at least 250 m from the waterfront and it is protected from the direct impact of tsunamis by other civil structures (such as Reverse Osmosis building and ActiDAFF) that are located between the CO_2 storage area and the waterfront. Therefore, the probabilities of failure due to severe environmental events would be very small or negligible and thus not further considered in this assessment.

Lightning

3.9.1.9 The installation is expected to be protected with lightning conductors to safely earth direct lightning strikes. Besides, the proposed development would also provide shielding effect to prevent the desalination plant being struck by lightning. With sufficient protection system, no further consideration was given for the effect of lightning strike in this assessment.

Third Party Damage

3.9.1.10 Third party damage includes activities causing incidents such as work on other underground utilities, drilling for ground sampling, construction work on adjoining areas, etc. The desalination plant is surrounded by boundary fence to avoid illegal entrance of third party. Thus, third party damage was not further considered in this assessment.

4. FREQUENCY ANALYSIS

4.1 General

4.1.1.1 Subsequent to the hazard identification and analysis in the previous section, the next step is to estimate the likelihoods of various release scenarios. There are combinations of hazard initiating events, as identified in the previous section, which would lead to release of chlorine, sulphur dioxide and liquid carbon dioxide.

4.2 Base Failure Frequencies

4.2.1.1 The base failure frequencies/ probabilities of human error that were adopted in this assessment are presented in **Table 4.1**.

Table 4.1 Summary of Base Failure Frequencies

Item	Failure Rate	Reference Source/ Remarks
Release of Chlorine Gas		
Pipework failure (full bore rupture) for chlorine gas	1×10^{-6} /m/yr	Pipe diameter 0-49mm assumed [7]
Failure of 2 or more chlorine detectors	2.1×10^{-5}	This is assumed based on fail-dangerous failure frequency for chlorine leak detector of 2.5×10^{-3} per year, monthly proof test and a common mode failure beta factor of 0.2 [8]
No trip signal to ventilation fan(s)	1×10^{-4}	[8]
Failure to close air damper on demand	2.6×10^{-3}	This is assumed based on damper failure frequency of 6.2×10^{-2} per year and monthly proof test [8]
Operating staff fail to shutdown ventilation system immediately by manual means	0.1	Assuming highly complex task, considerable stress, little time to perform it [9]
Human error	0.01	[1]
Release of Sulphur Dioxide		
Wrong product delivered by supplier	1×10^{-4} per operation	[10]

Item	Failure Rate	Reference Source/ Remarks
Operator fails to check product sample	1×10^{-4} per operation	[10]
Operator and WSD staff fail to identify the empty tank for refill	0.01	[11]
Release of Liquid Carbon Dioxide		
Rupture failure of double containment refrigerated tank	1.25×10^{-7} / tank year	[12]
Leak failure of double containment refrigerated tank	1×10^{-5} / tank year	[12]
Failure of relief valve	1×10^{-3} per demand	[13]
Frequency of spontaneous truck fire	4.00×10^{-9} per truck-km	[14]
Truck rollover frequency	1.90×10^{-7} per truck-km	[14]
Truck impact frequency	4×10^{-7} per truck-km	[14]
Conditional probability of vessel rupture in traffic accident	4.25×10^{-3}	[15][16]
Conditional probability of large leak on vessel in traffic accident	4×10^{-3}	[15][16]
Conditional probability of small leak (all sizes including pipe, valve etc.) in traffic accident	0.15	[15][16]
Driver fails to put out the fire with vehicle fire extinguisher	0.5 per demand	[17]
Fire services fail to control fire	0.5 per demand	[17]

Chlorine Gas from OSCG

4.2.1.2 With reference to the ERR excerpts [2], the failure frequency of chlorine pipelines is estimated as 6E-05 per year based on the length of chlorine pipeline of 60 m per OSCG system and the base failure frequency of 1×10^{-6} /m/yr [7]. Only full-bore rupture of pipeline is considered as flange failure and pipe leak would not lead to offsite impact as concluded in the ERR excerpts [2]. The frequency of occurrence for chlorine discharging to the atmosphere is derived from the event tree as shown in **Annex C**. The event tree took into account failures of various safeguard measures including chlorine detector, chlorine scrubber and ventilation system. The frequency of occurrence for chlorine discharging to the atmosphere is estimated 1.38×10^{-6} per year per OSCG system.

Sulphur Dioxide

4.2.1.3 The frequencies of occurrence for accidental mixing scenarios were derived based on the delivery frequencies as summarised in **Table 2.2** together with the failure probabilities as summarised in **Table 4.1**. The event frequency for each scenario is summarised in **Table 4.2**, while the fault trees are presented in **Annex D**. Since the overall frequency of occurrence for sodium bisulphite is 6.76×10^{-8} per year, the risk impact is further assessed.

Table 4.2 Failure Frequencies of Sulphur Dioxide Hazard

Scenarios	Description	Frequencies (per year)
1A/1B	Wrong product (32 wt% HCl) in $NaHSO_3$ tank	9.00E-10
2A/2B	Wrong product ($NaHSO_3$) in 32 wt% HCl tank	9.00E-10
3A/3B	Wrong product ($FeCl_3$) in $NaHSO_3$ tank	9.00E-10
4	Wrong product ($NaHSO_3$) in $FeCl_3$ tank	3.27E-08
5A/5B	Wrong product (10 wt% HCl) in $NaHSO_3$ tank	9.00E-10
6	Wrong product ($NaHSO_3$) in HCl 10% tank	1.30E-09
7A/7B	Wrong product (H_2SO_4) in $NaHSO_3$ tank	9.00E-10
8	Wrong product ($NaHSO_3$) in H_2SO_4 tank	2.24E-08
9A/9B	Wrong product ($C_6H_8O_7$) in $NaHSO_3$ tank	9.00E-10
10	Wrong product ($NaHSO_3$) in $C_6H_8O_7$ tank	4.00E-10

Liquid Carbon Dioxide

4.2.1.4 Failure frequencies for off-site transport of liquid carbon dioxide were derived based on generic failure frequencies presented in **Table 4.1**. The failure frequencies for the 20-tonne road tankers are summarised in **Table 4.3**, while the fault trees are presented in **Annex E**.

Table 4.3 Failure Frequencies of Liquid Carbon Dioxide Hazard

Description	Frequencies (per year)
Road tanker BLEVE	9.72E-12
Road tanker rupture failure	8.25E-07
Road tanker large leak failure (50 mm leak)	7.77E-07
Road tanker small leak failure (25 mm leak)	2.91E-05

5. CONSEQUENCE AND IMPACT ANALYSIS

5.1 Introduction

5.1.1.1 Consequence and impact analysis were conducted to provide a quantitative estimate of the likelihood and number of deaths associated with the range of possible outcomes (i.e. BLEVE (CO_2 only) and toxic gas releases etc.) which would result from the failure cases identified in the previous sections. The consequence assessment consists of two major parts, including:

- Source term modelling – to determine the appropriate discharge models to be used for calculation of the release rate, duration and quantity of the release; and
- Effect modelling – to determine dispersion modelling, and explosion modelling from the input of source term modelling.

5.1.1.2 Releases from hazardous sources and their consequences were modelled using SAFETI 8.7.

5.2 Impact Assessment

5.2.1 Chlorine Probit Equation

5.2.1.1 The following Probit equation in TNO Green Book [18] is used in this study to estimate the likelihood of fatality due to exposure to chlorine:

$$Pr = -14.3 + lnC^{2.3}t$$

where Pr = probit value

C = chlorine concentration (mg/m^3); and

t = exposure time (minutes).

5.2.1.2 The correlation between the chlorine concentration and the probability of fatality for the TNO Probit, assuming 10 minutes exposure duration, is summarised in **Table 5.1**.

Table 5.1 Chlorine Toxicity Relationship

Chlorine Concentration (ppm)	Probit Value for 10 minute Exposure	Probability of Fatality (LD = Lethal Dose)
251	3.12	0.03 (LD03)
557	5.00	0.50 (LD50)
971	6.28	0.90 (LD90)

5.2.2 Liquid Carbon Dioxide

5.2.2.1 The following probit equation [19] is used to estimate the likelihood of fatality due to the asphyxiation effect of CO_2:

$$Pr = -90.8 + 1.01lnC^{8}t$$

where Pr = probit value

C = CO_2 concentration (ppm); and

t = exposure time (minutes).

5.2.2.2 The correlation between CO_2 concentration and the probability of fatality, assuming 10 minutes exposure duration, is summarised in **Table 5.2**.

Table 5.2 Liquid Carbon Dioxide Toxicity Relationship

CO_2 Concentration (ppm)	Probit Value for 10 minute Exposure	Probability of Fatality (LD = Lethal Dose)
7.21E+04	1.91	0.001 (LD001)
7.93E+04	2.67	0.01 (LD01)
9.02E+04	3.72	0.1 (LD10)
1.41E+05	7.33	0.99 (LD99)

5.2.3 Sulphur Dioxide

5.2.3.1 The following probit equation is used to estimate the likelihood of fatality due to the SO_2:

$$Pr = -19.2 + lnC^{2.4}t$$

where Pr = probit value

C = SO_2 concentration (mg/m^3); and

t = exposure time (minutes).

5.2.3.2 The correlation between SO_2 concentration and the probability of fatality, assuming 10 minutes exposure duration, is summarised in **Table 5.3**.

Table 5.3 Sulphur Dioxide Toxicity Relationship

SO_2 Concentration (mg/m^3)	Probit Value for 10 minute Exposure	Probability of Fatality (LD = Lethal Dose)
2.53E+03	1.91	0.001 (LD001)
3.48E+03	2.67	0.01 (LD01)
5.38E+03	3.72	0.1 (LD10)
2.42E+04	7.33	0.99 (LD99)

5.3 Ignition Sources

5.3.1 General

5.3.1.1 To calculate the risk from flammable materials, information on ignition sources presented in the study area needs to be identified. The risk calculation program (MPACT) in SAFETI predicts the probability of a flammable cloud being ignited (delayed ignition) as the cloud moves downwind over ignition sources.

5.3.2 Line Source

5.3.2.1 Roads are defined as line sources in SAFETI. The following assumptions were applied to estimate the presence factor of the line source and the ignition probability:

(a) The probability of ignition for a vehicle was taken to be 0.4 in 60 seconds [20]; and

(b) The traffic density was based on the projected traffic flow adopted for population estimation as detailed in **Annex A**.

5.3.2.2 Ignition line sources are summarized in **Table 5.4**.

Table 5.4 Summary of Road Ignition Sources

ID	Description	Traffic Speed (km/hr)	Traffic Density (veh/hr)			
			Year 2035		Year 2041	
			Daytime	Night-time	Daytime	Night-time
R01	Road L8	50	992	498	1020	513
R02		50	1103	477	1232	532
R03		50	1128	544	1035	488
R04		50	1189	517	1113	475
R05		50	315	145	330	147
R06		50	311	144	336	151
R07	Road L6	50	-	-	193	87
R08		50	-	-	122	71
R09	Road L7	50	-	-	230	92
R10		50	-	-	203	103
R11	Road L1	50	-	-	187	97
R12		50	-	-	222	112
R13		50	-	-	555	291
R14		50	-	-	661	333
R15		50	-	-	172	90
R16		50	-	-	172	90

5.3.3 Area Source

5.3.3.1 SAFETI considers a residential population as an ignition source (as a result of activities such as cooking, smoking, heating appliances etc.). The ignition probability was derived from the population densities in the concerned area by SAFETI.

5.4 Protection Factors

5.4.1.1 In the event of a toxic release, people at area with lower concentration of gas, may be able to obtain protection by moving indoors or directly out of the cloud. Nonetheless, the probability of escape was not applied to person outdoors as a conservative approach and thus toxic vulnerability of 1 was considered. For person indoors, the toxic vulnerability was assumed to be one tenth of the outdoor toxic vulnerability. Furthermore, height protection factor was not applied for people on the upper floors of high rise buildings in this Study.

5.4.2 Protection afforded to persons indoors in a building

5.4.2.1 It was generally assumed that the respective outdoor/ indoor population are 5% and 95% at the time of an accident.

6. RISK EVALUATION

6.1 Introduction

6.1.1.1 In this section, the risks arising from the desalination plant were evaluated in terms of both individual and societal risks.

6.1.2 Individual Risk

6.1.2.1 Individual risk is a measure of the risk to a chosen individual at a particular location. As such, this is evaluated by summing the contributions to that risk across a spectrum of incidents that could occur at a particular location.

Risk Level

6.1.2.2 The risk levels were estimated based on 100% occupancy with no allowance made for shelter or escape, as specified in the user manual of SAFETI 8.7. The HKRG criterion for individual risk is that no person off-site should be subject to an additional risk of 1×10^{-5} per year.

6.1.3 Societal Risk

6.1.3.1 Societal risk is a measure of the overall impact of an activity upon the surrounding community. As such, the likelihoods and consequences of the range of incidents postulated for that particular activity are combined to create a cumulative picture of the spectrum of the possible consequences and their frequencies. This is usually presented in the form of a FN curve, which is a graphical representation of the cumulative frequency (F) of N or more fatalities plotted against N on a log-log scale and the acceptability of the results can be assessed against the societal risk criterion under the HKRG. Furthermore, societal risk can also be described by the Potential Loss of Life (PLL), in terms of predicted equivalent fatalities per year. The PLL is calculated from the frequency (f) and fatalities (N) associated with each outcome event as follows:

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

Risk Level

6.1.3.2 The expression of the level of societal risk is more complex than that for individual risk but, in essence, comprises three regions:

(a) "Unacceptable" – a region within which the risks may be regarded as unacceptable;

(b) "Acceptable" – a region within which the risks may be regarded as acceptable; and

(c) "ALARP" – a region between the two in which measures should be taken to demonstrate the risks as "as low as reasonably practicable" (ALARP). In other words, consideration is given not only to the level of risk but also the cost and practicality of reducing it.

6.1.3.3 After comparison to the HKRG, if the FN curve is within the ALARP (As Low As Reasonably Practicable) region, the associated risk should be reduced to a level 'as low as reasonably practicable' by practicable risk mitigation measures. Practicability of risk mitigation measures is usually evaluated by cost-benefit analysis (CBA). Calculation of the Implied Cost of Averting Fatality (ICAF) for each mitigation measures identified shall be performed and compared with the value of life to determine whether the implementation of the identified mitigation measures is reasonably practicable.

6.2 Chlorine

Individual Risk

6.2.1 As observed in **Plate 6.1**, the maximum individual risk for the chlorine hazard is 1×10^{-7}/yr and the off-site individual risk does not exceed 1×10^{-5} /yr. Thus, the individual risks for the chlorine hazard complies with the HKRG.

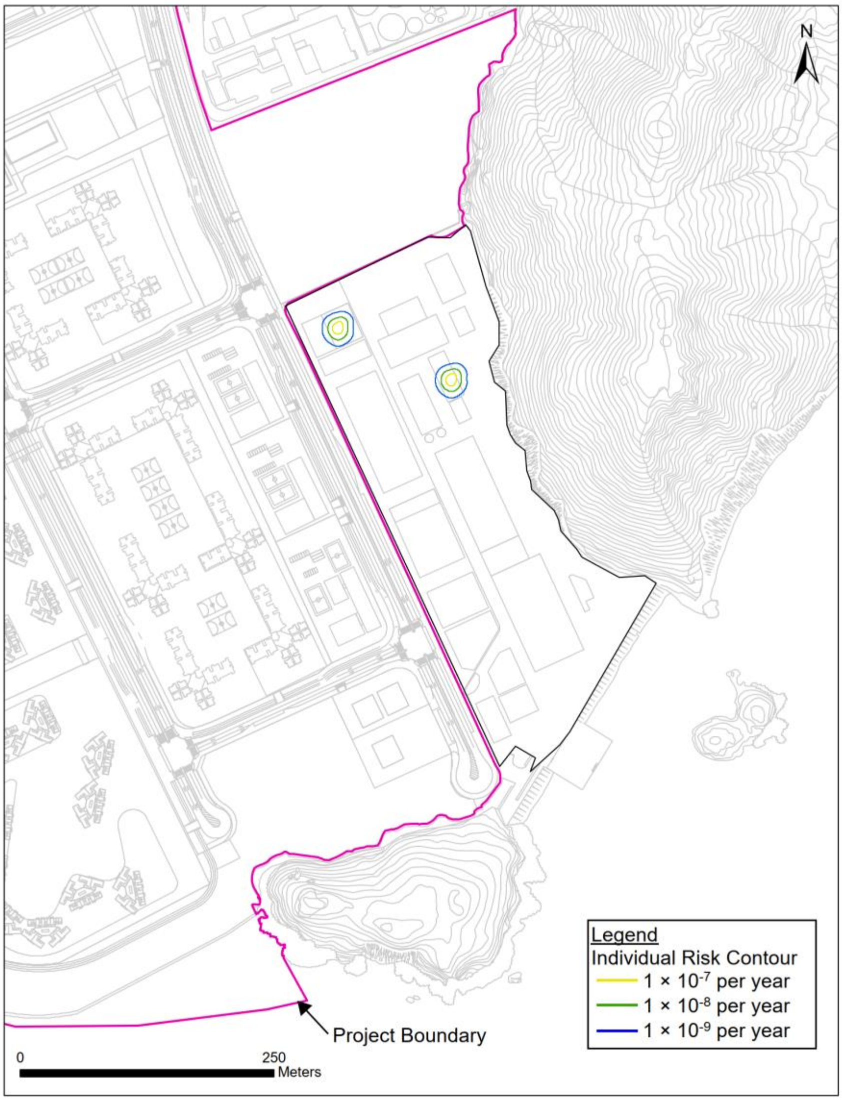

Plate 6.1 Individual Risk Contours for Chlorine Assessment

Societal Risk

6.2.1.1 The potential loss of life (PLL) for the facility were found to be negligible indicating no offsite impact.

6.3 Sulphur Dioxide

Individual Risk

6.3.1 As observed in **Plate 6.2**, the maximum individual risk for the sulphur dioxide hazard is 1×10^{-8}/yr and the off-site individual risk does not exceed 1×10^{-5} /yr. Thus, the individual risks for the sulphur dioxide hazard complies with the HKRG.

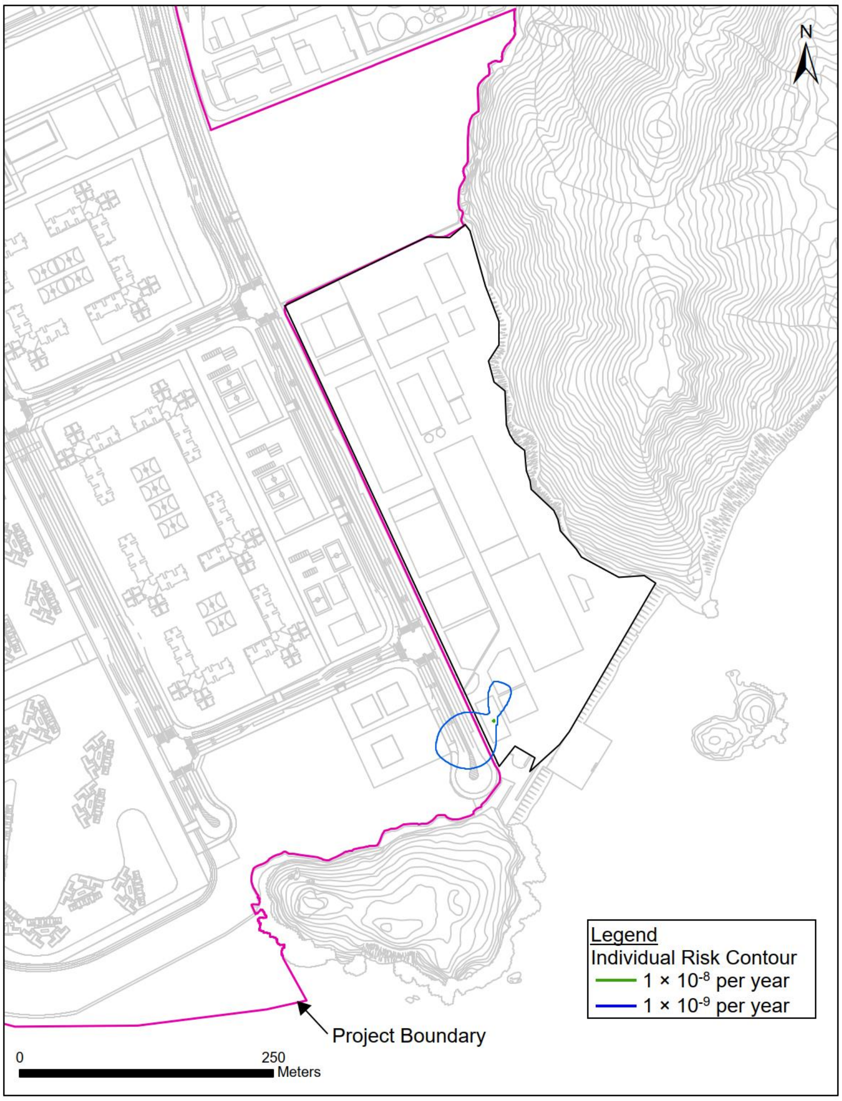

Plate 6.2 Individual Risk Contours for Sulphur Dioxide Assessment

Societal Risk

6.3.1.1 The societal risks associated with sulphur dioxide hazard fall within the "Acceptable" region in both assessment years as presented in **Plate 6.3**. Furthermore, the potential loss of life (PLL) for the facility were found to be about 1.0×10^{-8} per year and 1.3×10^{-8} per year for year 2035 and 2041 respectively.

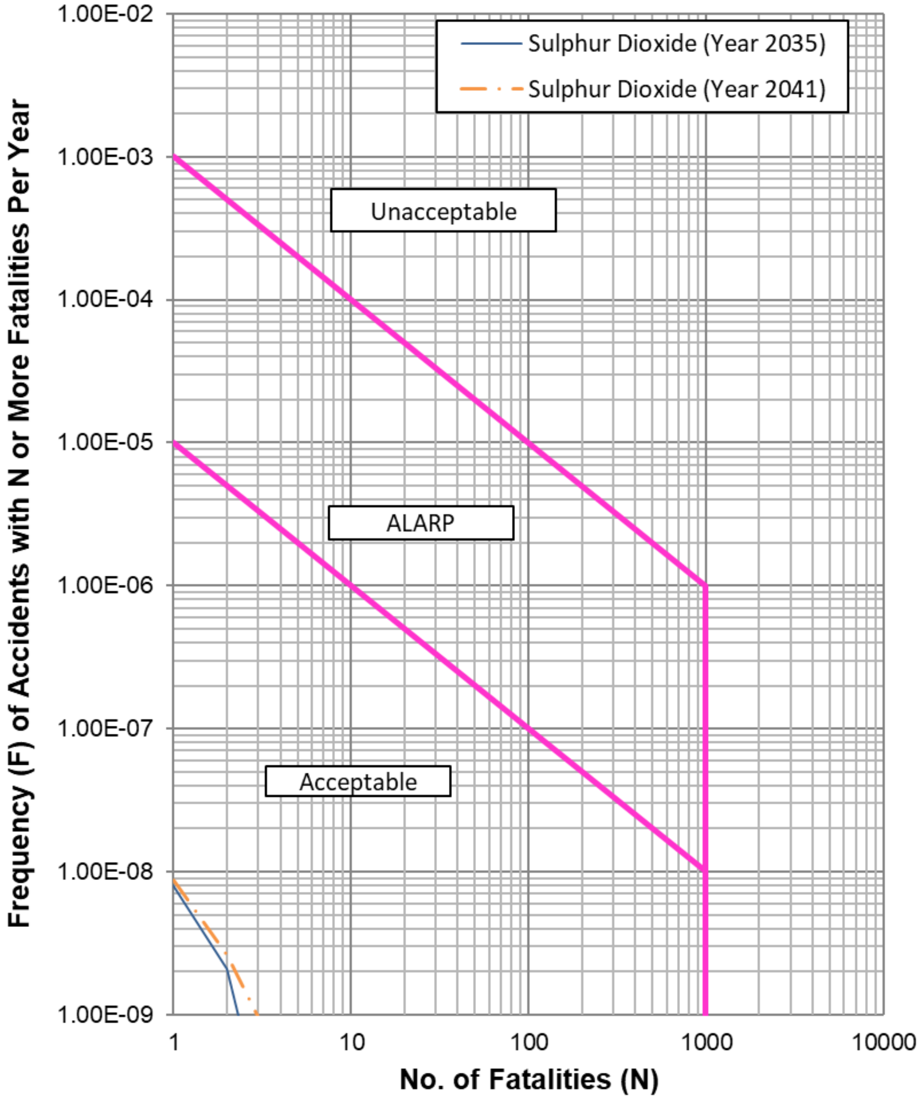

Plate 6.3 Societal Risk Curves for Sulphur Dioxide Assessment

6.4 Liquid Carbon Dioxide

Individual Risk

6.4.1 As observed in **Plate 6.4**, the maximum individual risk for the liquid carbon dioxide hazard is 1×10^{-7}/yr and the off-site individual risk does not exceed 1×10^{-5} /yr. Thus, the individual risks for the liquid carbon dioxide hazard complies with the HKRG.

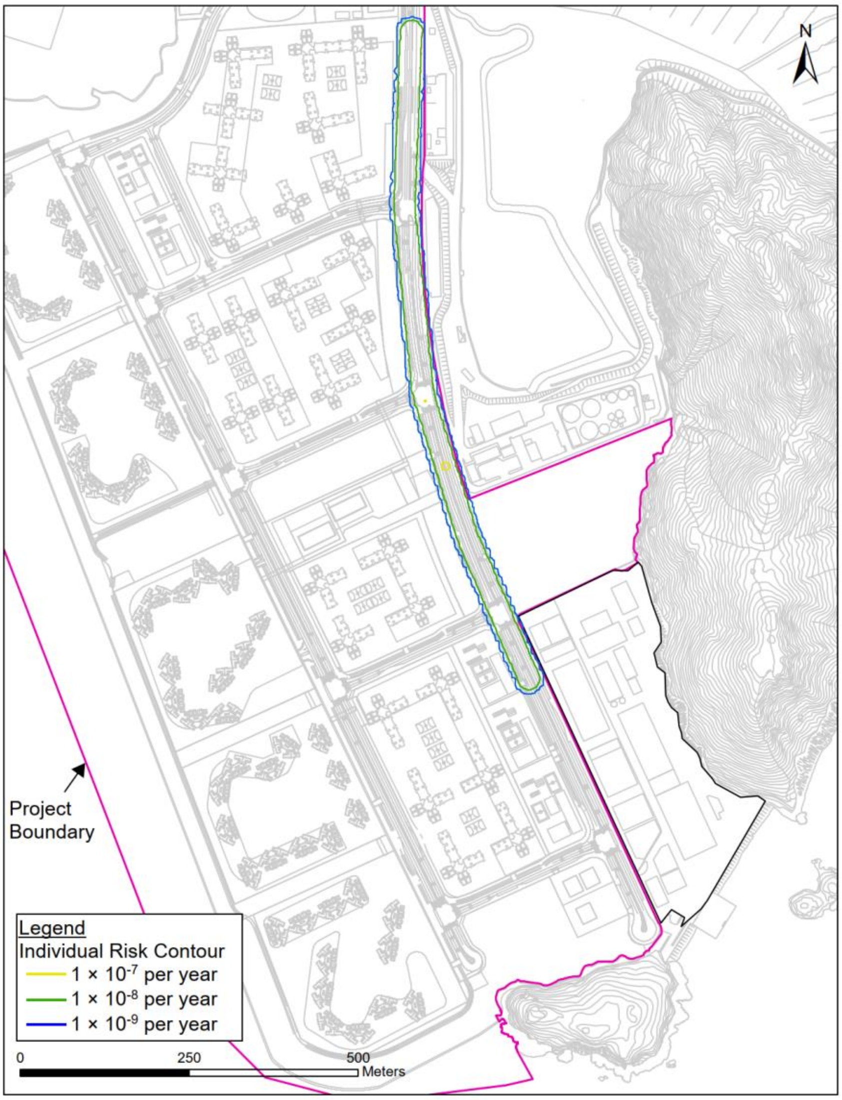

Plate 6.4 Individual Risk Contours for Liquid Carbon Dioxide Assessment

Societal Risk

6.4.1.1 The societal risks associated with liquid carbon dioxide hazard fall within the "Acceptable" region in both assessment years as presented in **Plate 6.5**. Furthermore, the potential loss of life (PLL) for the facility were found to be 2.5×10^{-6} per year and 2.0×10^{-6} per year for year 2035 and 2041 respectively.

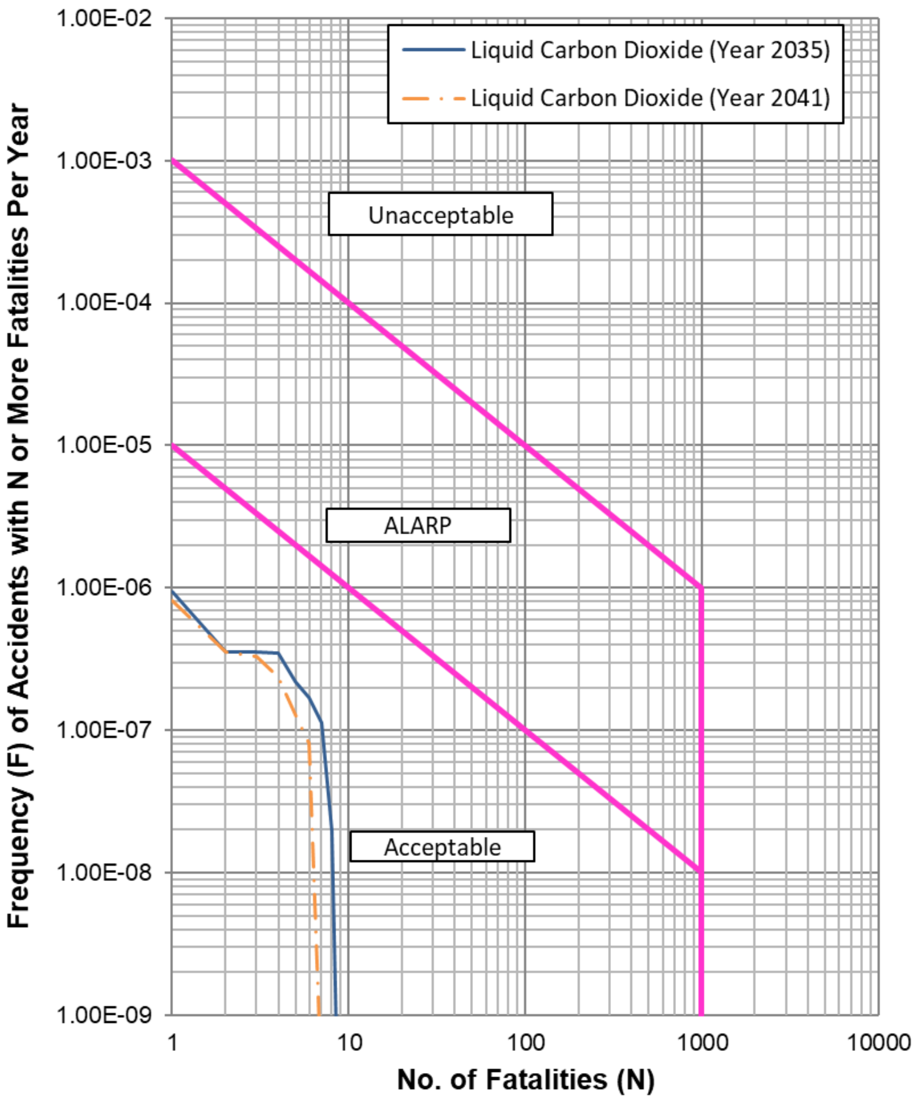

Plate 6.5 Societal Risk Curves for Liquid Carbon Dioxide Assessment

6.5 Cumulative Impacts

6.5.1 Cumulative risks in terms of individual risk contours and FN curves are shown in **Plate 6.6** and **Plate 6.7**. As there is no off-site risk larger than 1×10^{-5} /year and the FN curve for cumulative risk is within the "Acceptable" region, cumulative risk level is considered acceptable. Furthermore, the potential loss of life (PLL) for the facility were found to be about 2.5×10^{-6} and 2.0×10^{-6} per year for year 2035 and 2041 respectively. The top ten most significant contributing events for the assessed scenarios are tabulated in **Table 6.1**. For both assessment years, liquid CO_2 road tanker rupture failure was found to be the major contributor to the overall risk with an estimated PLL contribution of about 1.9×10^{-6} per year and 1.5×10^{-6} per year for 2035 and 2041 respectively (i.e. about 76% of the total PLL).

6.5.2 Additionally, the PLL breakdown by population groups for the assessed scenarios are tabulated in **Table 6.2**. It was found that road L8 (i.e. R01 & R02) accounted for 1.85×10^{-6} per year (i.e. about 73% of total PLL) during construction phase and 1.58×10^{-6} per year (i.e. about 81% of total PLL) during operational phase.

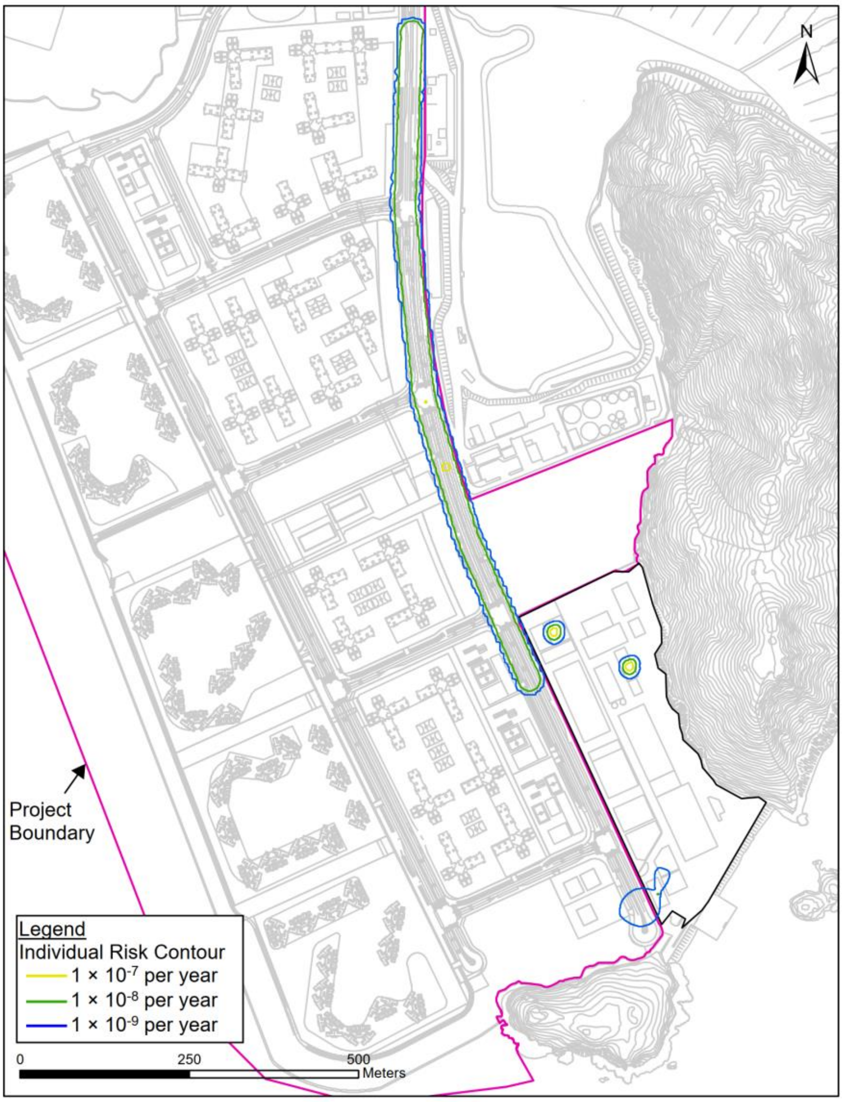

Plate 6.6 Cumulative Individual Risk Contours

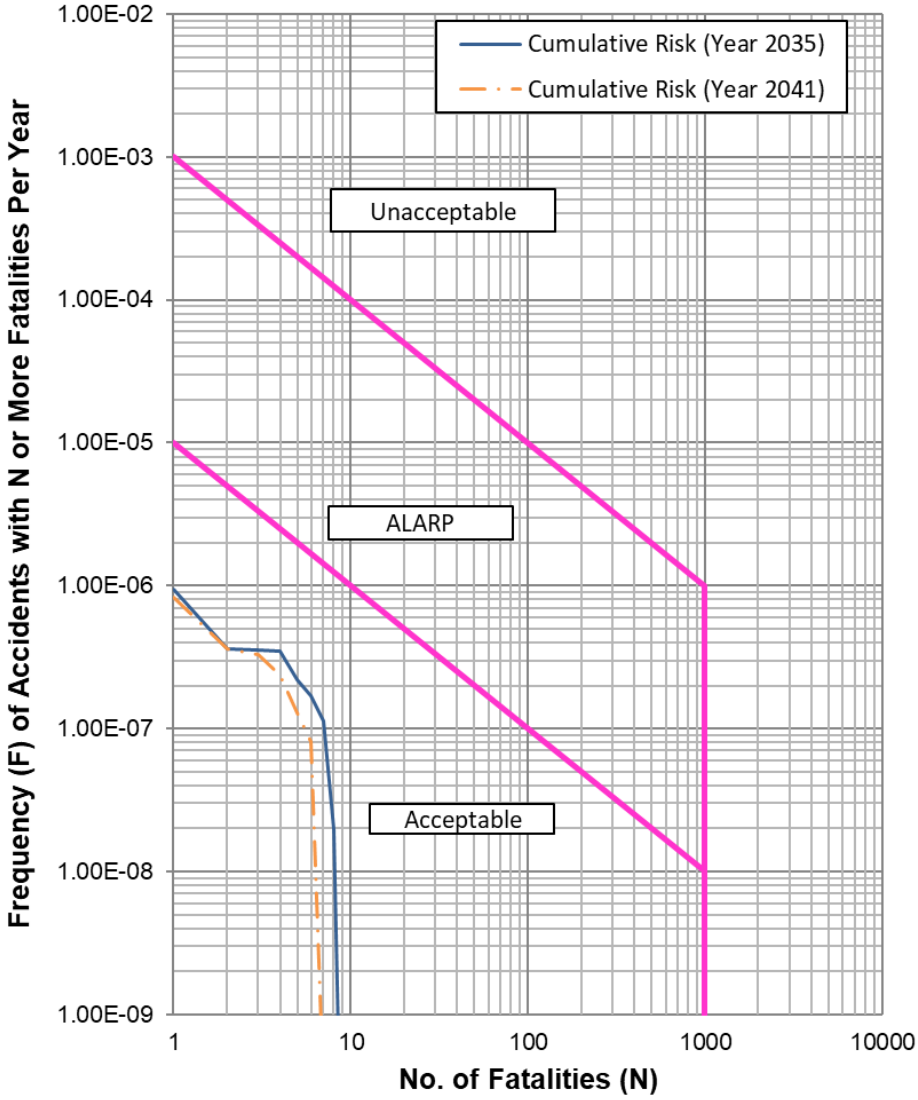

Plate 6.7 Cumulative Societal Risk Curves

Table 6.1 PLL Breakdown Summary by Major Events (All Assessed Scenarios)

Year 2035		
Event Description	**PLL (per year)**	**PLL (%)**
Liquid CO_2 road tanker rupture failure	1.94E-06	76.7%
Liquid CO_2 road tanker small leak failure (25 mm leak)	5.36E-07	21.2%
Liquid CO_2 road tanker large leak failure (50 mm leak)	4.33E-08	1.7%
Wrong product ($NaHSO_3$) in $FeCl_3$ tank (Scenario 4)	6.05E-09	0.2%
Wrong product ($NaHSO_3$) in H_2SO_4 tank (Scenario 8)	4.14E-09	0.2%
Wrong product ($NaHSO_3$) in HCl 10% tank (Scenario 6)	1.01E-10	<0.01%
Liquid CO_2 road tanker BLEVE	5.91E-11	<0.01%
Wrong product ($NaHSO_3$) in $C_6H_8O_7$ tank (Scenario 10)	8.29E-12	<0.01%
Wrong product (H_2SO_4) in $NaHSO_3$ tank (Scenario 7B)	1.69E-13	<0.01%
Wrong product (32 wt% HCl) in $NaHSO_3$ tank (Scenario 1B)	5.19E-14	<0.01%
Others	3.48E-14	<0.01%
Total	**2.53E-06**	**100%**

Year 2041		
Event Description	**PLL (per year)**	**PLL (%)**
Liquid CO_2 road tanker rupture failure	1.49E-06	76.2%
Liquid CO_2 road tanker small leak failure (25 mm leak)	4.18E-07	21.4%
Liquid CO_2 road tanker large leak failure (50 mm leak)	3.47E-08	1.8%
Wrong product ($NaHSO_3$) in $FeCl_3$ tank (Scenario 4)	7.60E-09	0.4%
Wrong product ($NaHSO_3$) in H_2SO_4 tank (Scenario 8)	5.21E-09	0.3%
Liquid CO_2 road tanker BLEVE	2.61E-10	0.01%
Wrong product ($NaHSO_3$) in HCl 10% tank (Scenario 6)	1.09E-10	<0.01%
Wrong product ($NaHSO_3$) in $C_6H_8O_7$ tank (Scenario 10)	8.59E-12	<0.01%
Wrong product (H_2SO_4) in $NaHSO_3$ tank (Scenario 7B)	7.44E-14	<0.01%
Wrong product (32 wt% HCl) in $NaHSO_3$ tank (Scenario 1B)	2.29E-14	<0.01%
Others	1.55E-14	<0.01%
Total	**1.96E-06**	**100%**

Table 6.2 PLL Breakdown Summary by Population Groups (All Assessed Scenarios)

Year 2035		
Population Description	**PLL (per year)**	**PLL (%)**
R01 - Road L8	1.00E-06	39.6%
R02 - Road L8	8.52E-07	33.6%
R04 - Road L8	4.16E-07	16.4%
R03 - Road L8	2.54E-07	10.0%
P15 - Proposed Project Works Areas (Sites. i.e. G4,PU5-6, E3-5, OU2-3, Roads L6-7)	4.12E-09	0.2%
R06 - Road L8	3.00E-09	0.1%
R05 - Road L8	2.98E-09	0.1%
P13 - Proposed Effluent Polishing Plant	2.20E-12	<0.01%
P12 - Proposed Project Works Areas (Road L1)	5.00E-13	<0.01%
P14 - SENT Landfill Extension	4.50E-13	<0.01%
Others	0.00E+00	0%
Total	**2.53E-06**	**100%**

Year 2041		
Population Description	**PLL (per year)**	**PLL (%)**
R02 - Road L8	7.98E-07	40.7%
R01 - Road L8	7.81E-07	39.8%
R04 - Road L8	2.38E-07	12.1%
R03 - Road L8	1.10E-07	5.6%
R08 - Road L6	1.16E-08	0.6%
R07 - Road L6	8.43E-09	0.4%
P07 - Green Fuel Station	4.03E-09	0.2%
R06 - Road L8	3.00E-09	0.2%
R05 - Road L8	2.98E-09	0.2%
P05 - Secondary School	1.79E-09	0.1%
Others	1.20E-09	0.1%
Total	**1.96E-06**	**100%**

7. CONCLUSIONS AND RECOMMENDATIONS

7.1.1.1 A hazard assessment was conducted to assess the risks associated with the operation of the planned desalination plant in year 2035 and year 2041 (full population intake). The assessment methodology and assumptions are based on the relevant Environment Review Report and approved EIA (EIA Register No. AEIAR-192/2015). The cumulative risk of the proposed desalination plant, through interaction or in combination with other existing, committed and planned developments involving DGs in the vicinity of the proposed desalination plant has also been assessed.

7.1.1.2 For all hazards assessed, both the individual and societal risk levels were found to meet relevant requirements stipulated in the HKRG, i.e. the off-site individual risk level is far below 1×10^{-5} per year and the societal risk falls into the “Acceptable” region. Therefore, no mitigation measure is required.

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Annex A

Population Data

Annex A - Population Data

Table A1 - Surrounding Population Estimates

ID	Population Group	Land_ID	Land Use Zoning	Maximum Population (Year 2035)	Maximum Population (Year 2041)	Indoor Ratio	% of Occupancy				Population (Year 2035)				Population (Year 2041)			
							Weekday Day	Weekday Night	Weekend Day	Weekend Night	Weekday Day	Weekday Night	Weekend Day	Weekend Night	Weekday Day	Weekday Night	Weekend Day	Weekend Night
P01	Integrated Government Complex (includes Swimming Pool Complex with Sports Centre, Public Market, Community Hall, Health Centre)	G4	G/IC	-	509	0.95	1	0.1	1	0.1	-	-	-	-	509	51	509	51
P02	Public Housing (PU5)	PU5	RSc															
	Residential	PU5	RSc	-	11864	0.95	0.5	1	0.7	1	-	-	-	-	5932	11864	8304	11864
	Employment	PU5	RSc	-	1246	0.95	1	0.1	1	0.1	-	-	-	-	1246	125	1246	125
P03	Primary School	E3	E	-	1404	0.95	1	0	0.5	0	-	-	-	-	1404	0	702	0
P04	Primary School	E4	E	-	1404	0.95	1	0	0.5	0	-	-	-	-	1404	0	702	0
P05	Secondary School	E5	E	-	2412	0.95	1	0	0.5	0	-	-	-	-	2412	0	1206	0
P06	Public Housing (PU6)	PU6	RSc															
	Residential	PU6	RSc	-	19380	0.95	0.5	1	0.7	1	-	-	-	-	9690	19380	13566	19380
	Employment	PU6	RSc	-	2452	0.95	1	0.1	1	0.1	-	-	-	-	2452	245	2452	245
P07	Green Fuel Station	OU3	OU	-	10	0	1	1	1	1	-	-	-	-	10	10	10	10
P08	Private Housing (PR4)	PR4	R2															
	Residential	PR4	R2	-	3372	0.95	0.5	1	0.7	1	-	-	-	-	1686	3372	2358	3372
	Employment	PR4	R2	-	1432	0.95	1	0.1	1	0.1	-	-	-	-	1432	143	1432	143
P09	Private Housing (PR5)	PR5	R2															
	Residential	PR5	R2	-	3255	0.95	0.5	1	0.7	1	-	-	-	-	1630	3255	2280	3255
	Employment	PR5	R2	-	1515	0.95	1	0.1	1	0.1	-	-	-	-	1515	151	1515	151
P10	Proposed Project Works Areas (PR5)	PR5	-	150	-	0	1	0.1	0.5	0.1	150	15	75	15	-	-	-	-
P11	Proposed Project Works Areas (PR4)	PR4	-	150	-	0	1	0.1	0.5	0.1	150	15	75	15	-	-	-	-
P12	Proposed Project Works Areas (Road L1)	Road	-	150	-	0	1	0.1	0.5	0.1	150	15	75	15	-	-	-	-
P13	Proposed Effluent Polishing Plant	OU4	OU	142	142	0.95	1	0.1	0.5	0.1	142	14	71	14	142	14	71	14
P14	SENT Landfill Extension	-	-	25	25	0	1	0.1	0.5	0.1	25	3	13	3	25	3	13	3
P15	Proposed Project Works Areas (Sites. i.e. G4,PU5-6, E3-5, OU2-3, Roads L6-7)	-	-	300	-	0	1	0.1	0.5	0.1	300	30	150	30	-	-	-	-
R01	Road L8	Road	Road	41	32	0	-	-	-	-	41	27	41	27	32	21	32	21
R02	Road L8	Road	Road	39	37	0	-	-	-	-	39	24	39	24	37	22	37	22
R03	Road L8	Road	Road	51	21	0	-	-	-	-	51	32	51	32	21	15	21	15
R04	Road L8	Road	Road	54	30	0	-	-	-	-	54	30	54	30	30	18	30	18
R05	Road L8	Road	Road	7	7	0	-	-	-	-	7	7	7	7	7	7	7	7
R06	Road L8	Road	Road	7	7	0	-	-	-	-	7	7	7	7	7	7	7	7
R07	Road L6	Road	Road	-	15	0	-	-	-	-	-	-	-	-	15	12	15	12
R08	Road L6	Road	Road	-	15	0	-	-	-	-	-	-	-	-	15	12	15	12
R09	Road L7	Road	Road	-	14	0	-	-	-	-	-	-	-	-	14	12	14	12
R10	Road L7	Road	Road	-	12	0	-	-	-	-	-	-	-	-	12	11	12	11
R11	Road L1	Road	Road	-	12	0	-	-	-	-	-	-	-	-	12	11	12	11
R12	Road L1	Road	Road	-	11	0	-	-	-	-	-	-	-	-	11	11	11	11
R13	Road L1	Road	Road	-	20	0	-	-	-	-	-	-	-	-	20	15	20	15
R14	Road L1	Road	Road	-	17	0	-	-	-	-	-	-	-	-	17	13	17	13
R15	Road L1	Road	Road	-	7	0	-	-	-	-	-	-	-	-	7	7	7	7
R16	Road L1	Road	Road	-	7	0	-	-	-	-	-	-	-	-	7	7	7	7

Annex A - Population Data

Table A2 - Road Population

Daytime Road Population

			Traffic Flow (veh/hr) at Daytime (Year 2035)										
	Road Length (km)	Designed Speed (km/h)	Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R01 - Road L8													
Total Vehicle per hour	0.338	50	26.9	453.8	142.1	15.2	0.0	141.0	80.8	17.2	2.9	112.5	992
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	5	2	1	0	2	1	2	1	26	41
Person (%)	-		2%	12%	5%	2%	0%	5%	2%	5%	2%	63%	100%

			Traffic Flow (veh/hr) at Daytime (Year 2035)										
	Road Length (km)	Designed Speed (km/h)	Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R02 - Road L8													
Total Vehicle per hour	0.313	50	31.9	522.8	173.8	18.9	0.0	143.1	82.0	20.5	2.7	107.8	1103
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	5	3	1	0	2	1	2	1	23	39
Person (%)	-		3%	13%	8%	3%	0%	5%	3%	5%	3%	59%	100%

			Traffic Flow (veh/hr) at Daytime (Year 2035)										
	Road Length (km)	Designed Speed (km/h)	Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R03 - Road L8													
Total Vehicle per hour	0.344	50	28.7	481.5	152.3	16.4	0.0	175.2	101.9	18.3	3.8	150.0	1128
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	5	3	1	0	2	1	2	1	35	51
Person (%)	-		2%	10%	6%	2%	0%	4%	2%	4%	2%	69%	100%

			Traffic Flow (veh/hr) at Daytime (Year 2035)										
	Road Length (km)	Designed Speed (km/h)	Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R04 - Road L8													
Total Vehicle per hour	0.361	50	31.9	524.9	173.1	18.8	0.0	171.7	100.2	20.5	3.6	143.7	1189
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	6	3	1	0	2	1	3	1	36	54
Person (%)	-		2%	11%	6%	2%	0%	4%	2%	6%	2%	67%	100%

			Traffic Flow (veh/hr) at Daytime (Year 2035)										
	Road Length (km)	Designed Speed (km/h)	Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R05 - Road L8													
Total Vehicle per hour	0.103	50	10.0	165.5	53.5	5.8	0.0	50.6	23.7	6.4	0.0	0.0	315
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7
Person (%)	-		14%	14%	14%	14%	0%	14%	14%	14%	0%	0%	100%

			Traffic Flow (veh/hr) at Daytime (Year 2035)										
	Road Length (km)	Designed Speed (km/h)	Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R06 - Road L8													
Total Vehicle per hour	0.095	50	10.0	165.5	53.5	5.8	0.0	47.9	22.4	6.4	0.0	0.0	311
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7
Person (%)	-		14%	14%	14%	14%	0%	14%	14%	14%	0%	0%	100%

Note:
[1] Person per vehicle is based on the occupancy in Year 2022 from Station 5021 (Tseung Kwan O Tunnel (from Toll Plaza to Tseung Kwan O Tunnel Rd RA)) from Transport Department - The Annual Traffic Census 2022.

Night-time Road Population

			Traffic Flow (veh/hr) at Night-time (Year 2035)										
	Road Length (km)	Designed Speed (km/h)	Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R01 - Road L8													
Total Vehicle per hour	0.338	50	13.2	248.7	115.7	3.0	0.0	35.3	9.2	5.5	1.3	66.1	498
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	3	2	1	0	1	1	1	1	16	27
Person (%)	-		4%	11%	7%	4%	0%	4%	4%	4%	4%	59%	100%

			Traffic Flow (veh/hr) at Night-time (Year 2035)										
	Road Length (km)	Designed Speed (km/h)	Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R02 - Road L8													
Total Vehicle per hour	0.313	50	15.4	236.6	106.4	7.1	0.0	35.7	9.7	7.7	1.0	57.2	477
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	3	2	1	0	1	1	1	1	13	24
Person (%)	-		4%	13%	8%	4%	0%	4%	4%	4%	4%	54%	100%

			Traffic Flow (veh/hr) at Night-time (Year 2035)										
	Road Length (km)	Designed Speed (km/h)	Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R03 - Road L8													
Total Vehicle per hour	0.344	50	14.0	256.3	118.7	3.7	0.0	43.8	11.7	6.0	1.7	88.1	544
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	3	2	1	0	1	1	1	1	21	32
Person (%)	-		3%	9%	6%	3%	0%	3%	3%	3%	3%	66%	100%

			Traffic Flow (veh/hr) at Night-time (Year 2035)										
	Road Length (km)	Designed Speed (km/h)	Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R04 - Road L8													
Total Vehicle per hour	0.361	50	15.5	244.6	110.6	6.6	0.0	42.9	11.4	7.6	1.4	76.3	517
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	3	2	1	0	1	1	1	1	19	30
Person (%)	-		3%	10%	7%	3%	0%	3%	3%	3%	3%	63%	100%

			Traffic Flow (veh/hr) at Night-time (Year 2035)										
	Road Length (km)	Designed Speed (km/h)	Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R05 - Road L8													
Total Vehicle per hour	0.103	50	4.8	82.3	37.7	1.7	0.0	12.6	3.4	2.2	0.0	0.0	145
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7
Person (%)	-		14%	14%	14%	14%	0%	14%	14%	14%	0%	0%	100%

			Traffic Flow (veh/hr) at Night-time (Year 2035)										
	Road Length (km)	Designed Speed (km/h)	Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R06 - Road L8													
Total Vehicle per hour	0.095	50	4.8	82.3	37.7	1.7	0.0	12.0	3.2	2.2	0.0	0.0	144
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7
Person (%)	-		14%	14%	14%	14%	0%	14%	14%	14%	0%	0%	100%

Note:
[1] Person per vehicle is based on the occupancy in Year 2022 from Station 5021 (Tseung Kwan O Tunnel (from Toll Plaza to Tseung Kwan O Tunnel Rd RA)) from Transport Department - The Annual Traffic Census 2022.

Table A2 Road Population

Table A2 - Road Population

Daytime Road Population

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Daytime (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R01 - Road L8													
Total Vehicle per hour	0.338	50	29.2	492.8	154.3	16.5	4.2	163.0	76.2	18.6	1.6	63.3	1020
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	5	3	1	1	2	1	2	1	15	32
Person (%)	-		3%	16%	9%	3%	3%	6%	3%	6%	3%	47%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Daytime (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R02 - Road L8													
Total Vehicle per hour	0.313	50	36.6	599.8	199.4	21.7	5.5	176.6	82.7	23.5	2.1	84.5	1232
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	6	3	1	1	2	1	3	1	18	37
Person (%)	-		3%	16%	8%	3%	3%	5%	3%	8%	3%	49%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Daytime (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R03 - Road L8													
Total Vehicle per hour	0.344	50	29.6	497.2	157.2	16.9	5.6	199.7	93.5	18.9	0.4	15.5	1035
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	5	3	1	1	2	1	2	1	4	21
Person (%)	-		5%	24%	14%	5%	5%	10%	5%	10%	5%	19%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Daytime (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R04 - Road L8													
Total Vehicle per hour	0.361	50	32.0	526.5	173.6	18.9	7.4	201.0	94.1	20.6	1.0	38.4	1113
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	6	3	1	1	3	1	3	1	10	30
Person (%)	-		3%	20%	10%	3%	3%	10%	3%	10%	3%	33%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Daytime (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R05 - Road L8													
Total Vehicle per hour	0.103	50	9.8	163.3	52.8	5.7	0.0	62.6	29.3	6.3	0.0	0.0	330
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7
Person (%)	-		14%	14%	14%	14%	0%	14%	14%	14%	0%	0%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Daytime (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R06 - Road L8													
Total Vehicle per hour	0.095	50	10.1	167.6	54.1	5.8	0.0	62.6	29.3	6.5	0.0	0.0	336
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7
Person (%)	-		14%	14%	14%	14%	0%	14%	14%	14%	0%	0%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Daytime (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R07 - Road L6													
Total Vehicle per hour	0.262	50	5.7	93.5	31.4	3.4	0.0	11.5	5.4	3.7	0.9	37.1	193
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	1	1	1	0	1	1	1	1	7	15
Person (%)	-		7%	7%	7%	7%	0%	7%	7%	7%	7%	47%	100%

Night-time Road Population

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Night-time (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R01 - Road L8													
Total Vehicle per hour	0.338	50	14.3	270.4	125.8	3.2	2.1	40.7	10.9	5.9	0.8	38.3	513
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	3	2	1	1	1	1	1	1	9	21
Person (%)	-		5%	14%	10%	5%	5%	5%	5%	5%	5%	43%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Night-time (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R02 - Road L8													
Total Vehicle per hour	0.313	50	17.7	271.7	122.2	8.1	2.4	44.0	12.2	8.9	0.8	43.9	532
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	3	2	1	1	1	1	1	1	10	22
Person (%)	-		5%	14%	9%	5%	5%	5%	5%	5%	5%	45%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Night-time (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R03 - Road L8													
Total Vehicle per hour	0.344	50	14.5	265.0	122.7	3.8	2.8	49.7	13.8	6.2	0.2	8.9	488
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	3	2	1	1	1	1	1	1	3	15
Person (%)	-		7%	20%	13%	7%	7%	7%	7%	7%	7%	20%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Night-time (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R04 - Road L8													
Total Vehicle per hour	0.361	50	15.5	245.6	111.1	6.6	3.2	50.1	13.6	7.6	0.4	21.5	475
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	3	2	1	1	1	1	1	1	6	18
Person (%)	-		6%	17%	11%	6%	6%	6%	6%	6%	6%	33%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Night-time (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R05 - Road L8													
Total Vehicle per hour	0.103	50	4.8	81.4	37.3	1.7	0.0	15.6	4.3	2.2	0.0	0.0	147
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7
Person (%)	-		14%	14%	14%	14%	0%	14%	14%	14%	0%	0%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Night-time (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R06 - Road L8													
Total Vehicle per hour	0.095	50	4.9	83.8	38.4	1.7	0.0	15.6	4.3	2.2	0.0	0.0	151
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7
Person (%)	-		14%	14%	14%	14%	0%	14%	14%	14%	0%	0%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Night-time (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R07 - Road L6													
Total Vehicle per hour	0.262	50	2.8	41.0	18.3	1.4	0.0	2.9	0.8	1.4	0.3	18.5	87
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	1	1	1	0	1	1	1	1	4	12
Person (%)	-		8%	8%	8%	8%	0%	8%	8%	8%	8%	33%	100%

Table A2 Road Population

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Daytime (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R08 - Road L6													
Total Vehicle per hour	0.262	50	3.0	51.3	15.6	1.7	0.0	9.2	4.3	1.9	0.9	34.4	122
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	1	1	1	0	1	1	1	1	7	15
Person (%)	-		7%	7%	7%	7%	0%	7%	7%	7%	7%	47%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Night-time (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R08 - Road L6													
Total Vehicle per hour	0.262	50	1.5	30.4	14.3	0.2	0.0	2.3	0.6	0.6	0.4	21.1	71
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	1	1	1	0	1	1	1	1	4	12
Person (%)	-		8%	8%	8%	8%	0%	8%	8%	8%	8%	33%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Daytime (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R09 - Road L7													
Total Vehicle per hour	0.257	50	5.9	95.4	32.6	3.6	5.5	36.8	17.2	3.8	0.7	28.8	230
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	1	1	1	1	1	1	1	1	5	14
Person (%)	-		7%	7%	7%	7%	7%	7%	7%	7%	7%	36%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Night-time (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R09 - Road L7													
Total Vehicle per hour	0.257	50	2.8	38.7	17.0	1.6	2.4	9.2	2.4	1.5	0.3	16.1	92
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	1	1	1	1	1	1	1	1	3	12
Person (%)	-		8%	8%	8%	8%	8%	8%	8%	8%	8%	25%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Daytime (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R10 - Road L7													
Total Vehicle per hour	0.255	50	5.1	87.5	26.4	2.8	4.2	42.2	19.8	3.2	0.3	11.7	203
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	1	1	1	1	1	1	1	1	3	12
Person (%)	-		8%	8%	8%	8%	8%	8%	8%	8%	8%	25%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Night-time (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R10 - Road L7													
Total Vehicle per hour	0.255	50	2.5	52.6	24.8	0.2	2.1	10.5	2.9	0.9	0.1	6.7	103
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	1	1	1	1	1	1	1	1	2	11
Person (%)	-		9%	9%	9%	9%	9%	9%	9%	9%	9%	18%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Daytime (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R11 - Road L1													
Total Vehicle per hour	0.132	50	5.1	85.6	26.6	2.8	1.8	22.2	10.4	3.2	0.7	28.2	187
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	1	1	1	1	1	1	1	1	3	12
Person (%)	-		8%	8%	8%	8%	8%	8%	8%	8%	8%	25%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Night-time (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R11 - Road L1													
Total Vehicle per hour	0.132	50	2.5	47.8	22.3	0.5	0.8	5.6	1.5	1.0	0.3	14.6	97
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	1	1	1	1	1	1	1	1	2	11
Person (%)	-		9%	9%	9%	9%	9%	9%	9%	9%	9%	18%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Daytime (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R12 - Road L1													
Total Vehicle per hour	0.140	50	6.8	113.6	36.3	3.9	1.4	23.4	10.9	4.4	0.5	21.1	222
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	1	1	1	1	1	1	1	1	2	11
Person (%)	-		9%	9%	9%	9%	9%	9%	9%	9%	9%	18%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Night-time (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R12 - Road L1													
Total Vehicle per hour	0.140	50	3.3	58.6	27.0	1.0	0.7	5.8	1.6	1.5	0.3	12.8	112
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	1	1	1	1	1	1	1	1	2	11
Person (%)	-		9%	9%	9%	9%	9%	9%	9%	9%	9%	18%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Daytime (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R13 - Road L1													
Total Vehicle per hour	0.359	50	17.0	287.7	89.5	9.6	5.5	71.7	33.5	10.8	0.7	28.8	555
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	3	2	1	1	1	1	2	1	7	20
Person (%)	-		5%	15%	10%	5%	5%	5%	5%	10%	5%	35%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Night-time (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R13 - Road L1													
Total Vehicle per hour	0.359	50	8.3	160.7	75.0	1.7	2.4	17.9	4.7	3.4	0.3	16.1	291
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	2	2	1	1	1	1	1	1	4	15
Person (%)	-		7%	13%	13%	7%	7%	7%	7%	7%	7%	27%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Daytime (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R14 - Road L1													
Total Vehicle per hour	0.366	50	21.8	365.5	116.1	12.5	4.2	78.2	36.5	14.0	0.3	11.7	661
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	4	2	1	1	1	1	2	1	3	17
Person (%)	-		6%	24%	12%	6%	6%	6%	6%	12%	6%	18%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Night-time (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R14 - Road L1													
Total Vehicle per hour	0.366	50	10.7	192.4	88.9	3.0	2.1	19.6	5.2	4.6	0.1	6.7	333
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	2	2	1	1	1	1	1	1	2	13
Person (%)	-		8%	15%	15%	8%	8%	8%	8%	8%	8%	15%	100%

Table A2 Road Population

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Daytime (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R15 - Road L1													
Total Vehicle per hour	0.066	50	5.7	95.9	29.8	3.2	0.0	23.4	10.9	3.6	0.0	0.0	172
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7
Person (%)	-		14%	14%	14%	14%	0%	14%	14%	14%	0%	0%	100%

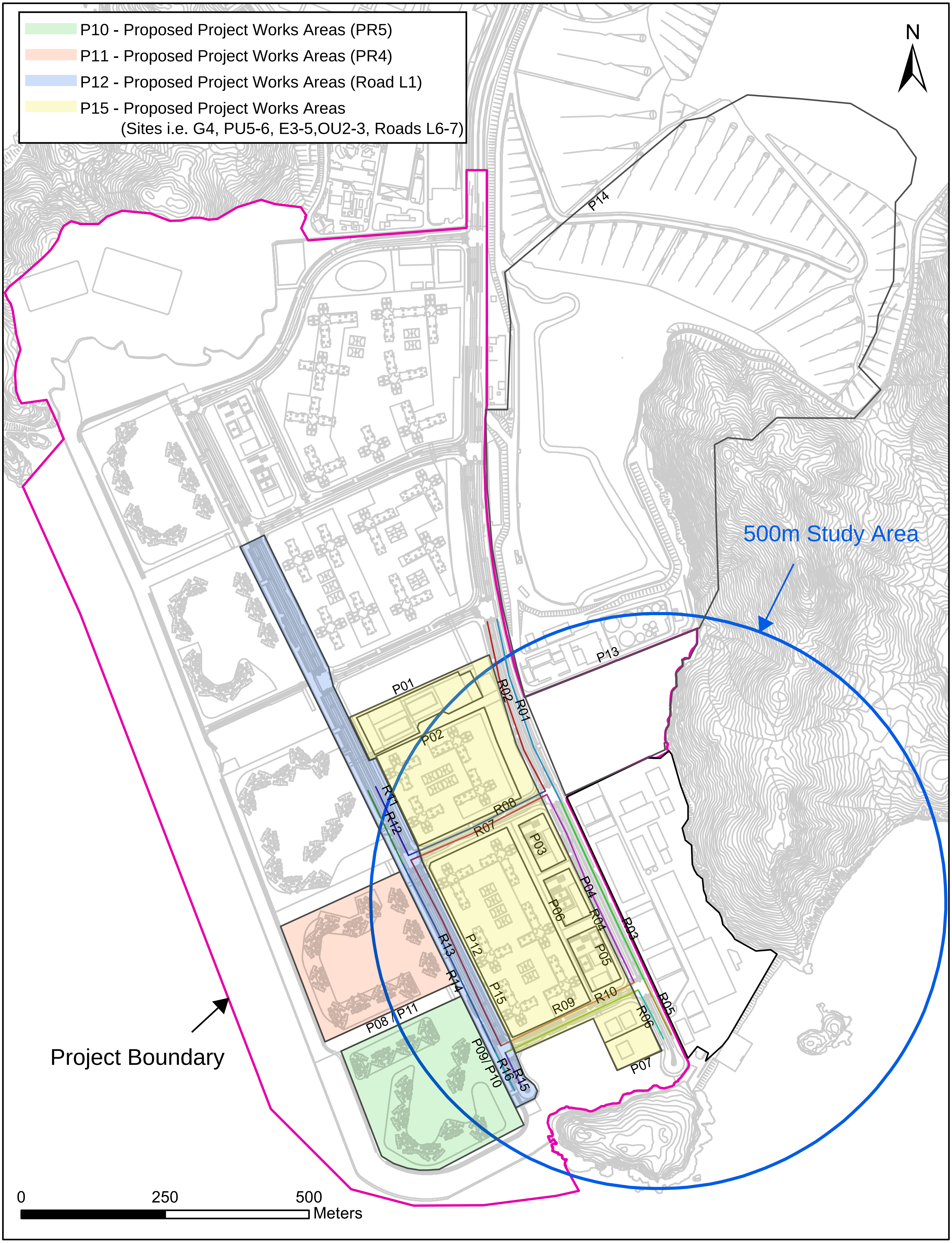
	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Night-time (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R15 - Road L1													
Total Vehicle per hour	0.066	50	2.8	53.6	25.0	0.6	0.0	5.8	1.6	1.1	0.0	0.0	90
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7
Person (%)	-		14%	14%	14%	14%	0%	14%	14%	14%	0%	0%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Daytime (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R16 - Road L1													
Total Vehicle per hour	0.074	50	5.7	95.9	29.8	3.2	0.0	23.4	10.9	3.6	0.0	0.0	172
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7
Person (%)	-		14%	14%	14%	14%	0%	14%	14%	14%	0%	0%	100%

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Night-time (Year 2041)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
R16 - Road L1													
Total Vehicle per hour	0.074	50	2.8	53.6	25.0	0.6	0.0	5.8	1.6	1.1	0.0	0.0	90
Person per vehicle [1]	-		1.1	1.4	2	5.2	14	1.4	1.2	13.8	2	33.8	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7
Person (%)	-		14%	14%	14%	14%	0%	14%	14%	14%	0%	0%	100%

Note:
[1] Person per vehicle is based on the occupancy in Year 2022 from Station 5021 (Tseung Kwan O Tunnel (from Toll Plaza to Tseung Kwan O Tunnel Rd RA)) from Transport Department - The Annual Traffic Census 2022.

Note:
[1] Person per vehicle is based on the occupancy in Year 2022 from Station 5021 (Tseung Kwan O Tunnel (from Toll Plaza to Tseung Kwan O Tunnel Rd RA)) from Transport Department - The Annual Traffic Census 2022.



P10 - Proposed Project Works Areas (PR5)
P11 - Proposed Project Works Areas (PR4)
P12 - Proposed Project Works Areas (Road L1)
P15 - Proposed Project Works Areas
(Sites i.e. G4, PU5-6, E3-5,OU2-3, Roads L6-7)
N
P14
P13
500m Study Area
P01
P02
R02
R01
R11
R12
R08
R07
P03
P04
P06
R04
R03
P05
R13
P12
R14
P15
R09
R10
R05
R06
P08 / P11
P07
P09/ P10
R16
R15
Project Boundary
0
250
500
Meters

Annex B

Aircraft Crash Frequency Calculation

Annex B - Aircraft Crash Frequency Calculation

The model considers specific factors such as target area of the planned desalination plant and its longitudinal (x) and perpendicular (y) distances from the runway threshold for landing and take-off movement. The aircraft 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; R is the probability of an accident per movement (landing or takeoff). F(x,y) gives the spatial distribution of crashes and is given by:

For aircraft landing, for x > -3.275km,

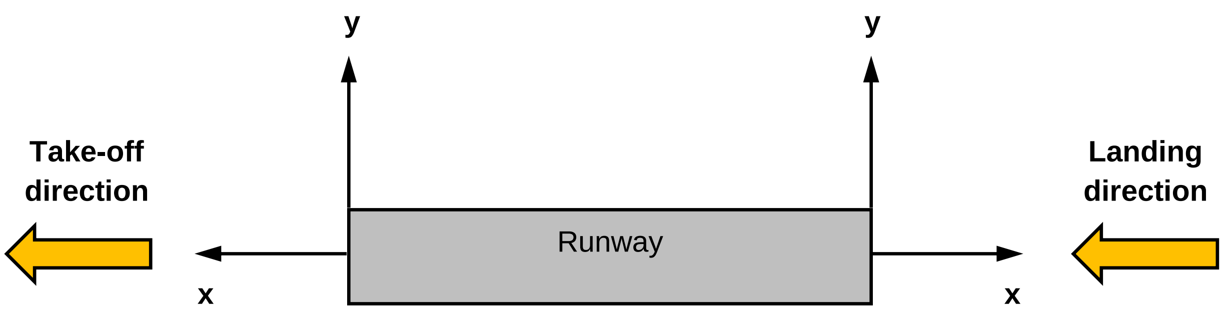
$$F_L(x,y) = \frac{(x+3.275)}{3.24} e^{\frac{-(x+3.275)}{1.8}} \left[\frac{56.25}{\sqrt{2\pi}} e^{-0.5(125y)^2} + 0.625 e^{-\frac{|y|}{0.4}} + 0.005 e^{-\frac{|y|}{5}} \right] \quad (2)$$

For aircraft takeoff, for x > -0.6km,

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

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. This case applies for 07L and 07R runways for arrival flight path and 25L and 25R runways for departure flight path.

Distances between the planned desalination plant and the runways are measured and transformed into longitudinal (x) and perpendicular (y) distances in the Aircraft Crash Coordinate System according to the following figure.



The probability of an accident per movement R is interpreted from NTSB data for fatal accidents in the U.S. involving scheduled airline flights during the period 1986-2005. The 10-year moving average suggested a downward trend with recent years showing a rate of about 2×10^{-7} per flight. There are only 13.5% of accidents associated with the approach to landing, 15.8% associated with take-off and 4.2% are related to the climb phase of the flight[1]. Thus it is assumed that the accident frequency for the approach to landings is taken as 2.7×10^{-8} per flight and for take-off is 4.0×10^{-8} per flight.

[1] Aviation Statistical Reports, US National Transportation Safety Board.

Annex B - Aircraft Crash Frequency Calculation

According to the statistic of Civil International Air Transport Movements of Aircraft[2], the total aircraft movements of 427,766 were recorded in 2018, which is the maximum total movements recorded since 2009. Due to the outbreak of COVID-19 in Hong Kong, the number of aircraft movements has significantly reduced between 2020 and 2022. As a conservative approach, the number of runway movements of aircraft N is estimated by projecting the yearly statistics of the Hong Kong International Airport in 2009-2018[2]. Number of movements at year 2035 and 2041 were estimated by linear regression for landing and take-off cases respectively. The movement number adopted in the calculation were divided by 4 to take into account that only a quarter of landing or take-off use a specific runway.

The aircraft crash frequencies are obtained by multiplying g(x,y) to the target area, which is estimated to be 2.2×10^{-3} km^2 for the OSCG buildings.

The calculations are presented in **Table 1** and the total crash frequency per year is summarised in **Table 2**.

[2] "Air Traffic Statistics." Civil Aviation Department, HKSAR. https://www.cad.gov.hk/english/statistics.html

Annex B - Aircraft Crash Frequency Calculation

Table 1 Calculation for Aircraft Crash Frequency

Year	Runway	x (km)	y (km)	F(x,y)	N (per year)	R (per flight)	Crash Frequency (per unit area)	Target Area (km^2)	Crash Frequency (per year)
2035	25R Landing	35.2	-6.0	9.0E-12	119544	2.7E-08	2.9E-14	2.20E+03	6.4E-11
2035	25L Landing	34.8	-4.4	1.6E-11	119544	2.7E-08	5.0E-14	2.20E+03	1.1E-10
2035	07LTake-off	35.2	-6.0	4.9E-16	119539	4.0E-08	2.3E-18	2.20E+03	5.1E-15
2035	07R Take-off	34.8	-4.4	3.4E-15	119539	4.0E-08	1.6E-17	2.20E+03	3.5E-14
2041	25R Landing	35.2	-6.0	9.0E-12	158796	2.7E-08	3.9E-14	2.20E+03	8.5E-11
2041	25L Landing	34.8	-4.4	1.6E-11	158796	2.7E-08	6.7E-14	2.20E+03	1.5E-10
2041	07LTake-off	35.2	-6.0	4.9E-16	158796	4.0E-08	3.1E-18	2.20E+03	6.8E-15
2041	07R Take-off	34.8	-4.4	3.4E-15	158796	4.0E-08	2.1E-17	2.20E+03	4.7E-14

Table 2 Total Aircraft Crash Frequency

	Total Crash Frequency (per year)	
	Year 2035	**Year 2041**
Landing	1.75E-10	2.32E-10
Take-off	4.05E-14	5.38E-14
Total	**1.75E-10**	**2.32E-10**

Annex C

Event Tree For Indoor Release of Chlorine

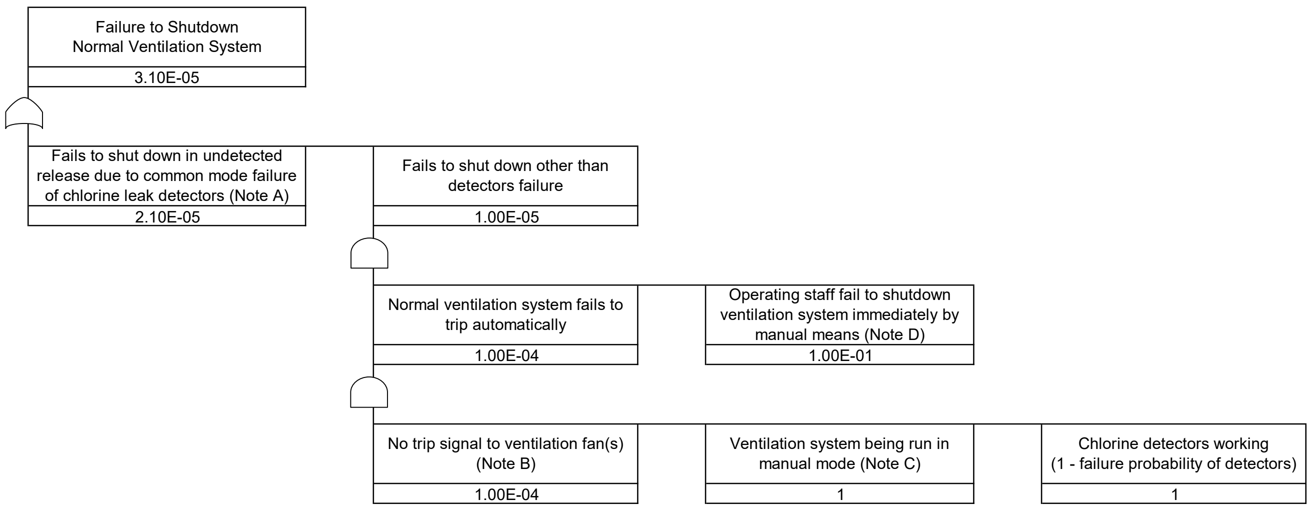
Event Tree for Indoor Chlorine Release

Initiating Event	Shutdown of normal ventilation system? (Figure 1a)	Containment Effective? (Figure 1b)	Outcome	Event Frequency (/yr)
Chlorine Release (/yr) 6.00E-05	N 3.10E-05		Forced ventilation of chlorine to atmosphere	1.86E-09
	Y 1.00E+00	N 2.29E-02	Chlorine release to atmosphere by expansior	1.38E-06
		Y 9.77E-01	No significant hazard	5.86E-05

Scrubbing efficiency >99.9985% in one pass through the scrubber

Chlorine release to atmosphere **1.38E-06**

Figure 1a - Failure to Shutdown Normal Ventilation System



Notes:

A The primary concern is chlorine releases from pipework in OSCG building. At least 2 chlorine detectors in OSCG building are assumed. Common mode failure of these detectors will dominate the overall failure frequency.

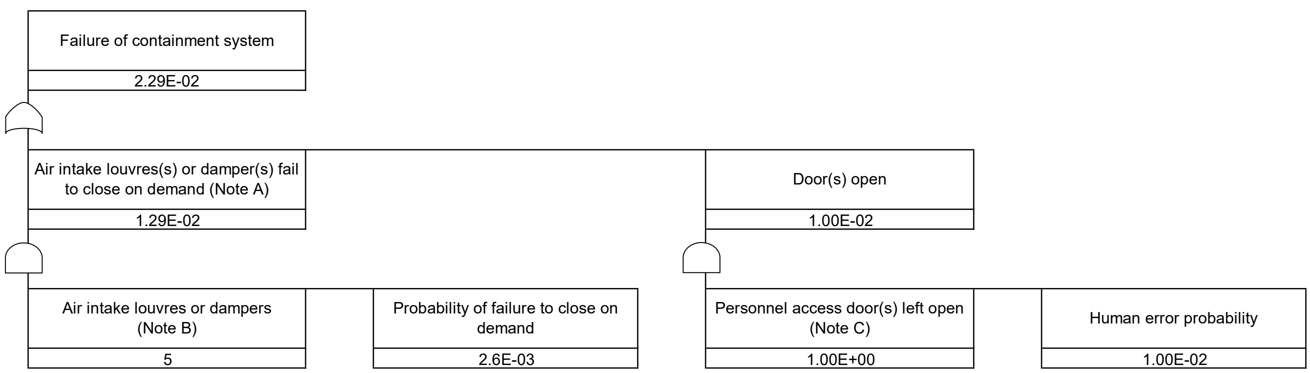
B The primary concern is failure of the normal ventilation fans to trip. It is considered the ventilation fans have self-closing dampers on the fan outlet. Even if one of these dampers were remain open (unlikely given the fail-safe design), then with the chlorine absorption system running the chlorine bearing air will preferentially pass to the scrubber. Taken as typical probability of failure of relay (fail-safe design).

C A manual mode is provided for the normal ventilation system.

D It is conservatively assumed that the probability of human error for manual shutdown failure in emergency situation is 0.1.

= AND Gate = OR Gate

Figure 1b - Failure of Containment System



Notes:

A Mechanical failure of the air intake louvres (including the air intake dampers with a forced air supply).

B An electrically-operated isolating damper is provided in the scrubber intake for recycling, which opens automatically when the scrubber fan starts up. An additional isolating damper is provided to isolate the normal ventilation system when the scrubber system is operating. The scrubber system is normally set to recycle air back to the OSCG building. This is affected by means of a pair of electrically operated change-over dampers controlled manually from the local control panel. 5 dampers are conservatively assumed.

C Assuming all personnel entering and exiting the OSCG building would probably induce human error of not closing the door.

= AND Gate = OR Gate

Annex D

Fault Tree For Release of Sulphur Dioxide

Scenario 1A/1B

Wrong product (32% HCl) delivered by supplier	Operator fails to check product sample	Operator and WSD staff fail to identify the empty tank for refill
1.00E-04	1.00E-04	1.00E-02
per operation	-	-

AND

Wrong product (32% HCl) in $NaHSO_3$ tank	Number of operations $NaHSO_3$ delivery
1.00E-10	9
per truck	operation per year

AND

Wrong product (32% HCl) in $NaHSO_3$ tank
9.00E-10
per year

Scenario 2A/2B

Wrong product ($NaHSO_3$) delivered by supplier	Operator fails to check product sample	Operator and WSD staff fail to identify the empty tank for refill
1.00E-04	1.00E-04	1.00E-02
per operation	-	-

AND

Wrong product ($NaHSO_3$) in HCl tank	Number of operations (32% HCl delivery)
1.00E-10	9
per truck	operation per

AND

Wrong product ($NaHSO_3$) in 32% HCl tank
9.00E-10
per year

Scenario 3A/3B

Wrong product ($FeCl_3$) delivered by supplier	Operator fails to check product sample	Operator and WSD staff fail to identify the empty tank for refill
1.00E-04	1.00E-04	1.00E-02
per operation	-	-

AND

Wrong product ($FeCl_3$) in $NaHSO_3$ tank	Number of operations ($NaHSO_3$ delivery)
1.00E-10	9
per truck	operation per year

AND

Wrong product ($FeCl_3$) in $NaHSO_3$ tank
9.00E-10
per year

Scenario 4

Wrong product ($NaHSO_3$) delivered by supplier	Operator fails to check product sample	Operator and WSD staff fail to identify the empty tank for refill
1.00E-04	1.00E-04	1.00E-02
per operation	-	-

AND

Wrong product ($NaHSO_3$) in $FeCl_3$ tank	Number of operations $FeCl_3$ delivery
1.00E-10	327
per truck	operation per

AND

Wrong product ($NaHSO_3$) in $FeCl_3$ tank
3.27E-08
per year

Scenario 5A/5B

Wrong product (HCl 10%) delivered by supplier	Operator fails to check product sample	Operator and WSD staff fail to identify the empty tank for refill
1.00E-04	1.00E-04	1.00E-02
per operation	-	-

AND

Wrong product (HCl 10%) in $NaHSO_3$ tank	Number of operations ($NaHSO_3$ delivery)
1.00E-10	9
per truck	operation per year

AND

Wrong product (HCl 10%) in $NaHSO_3$ tank
9.00E-10
per year

Scenario 6

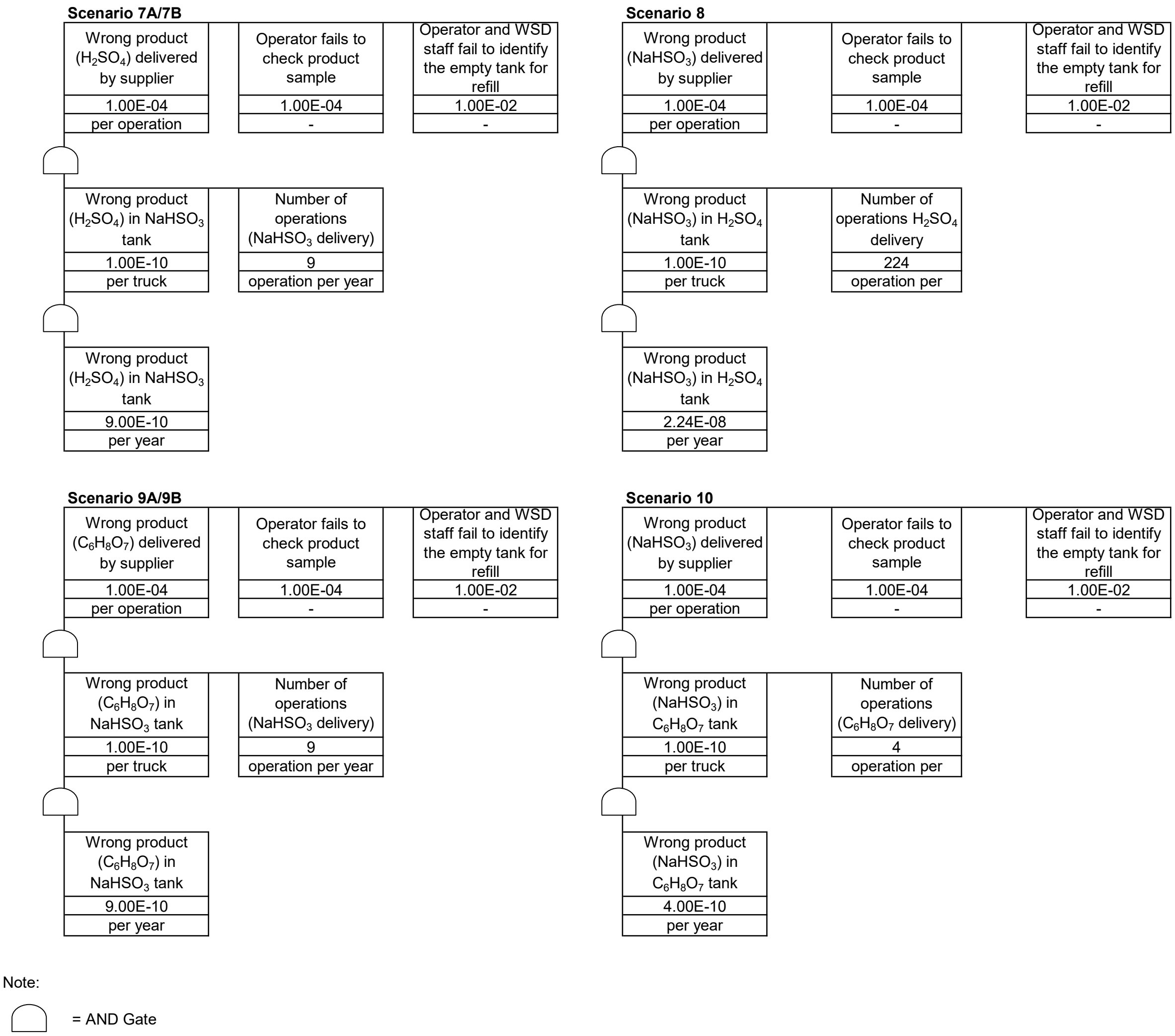
Wrong product ($NaHSO_3$) delivered by supplier	Operator fails to check product sample	Operator and WSD staff fail to identify the empty tank for refill
1.00E-04	1.00E-04	1.00E-02
per operation	-	-

AND

Wrong product ($NaHSO_3$) in HCl 10% tank	Number of operations (HCl 10% delivery)
1.00E-10	13
per truck	operation per

AND

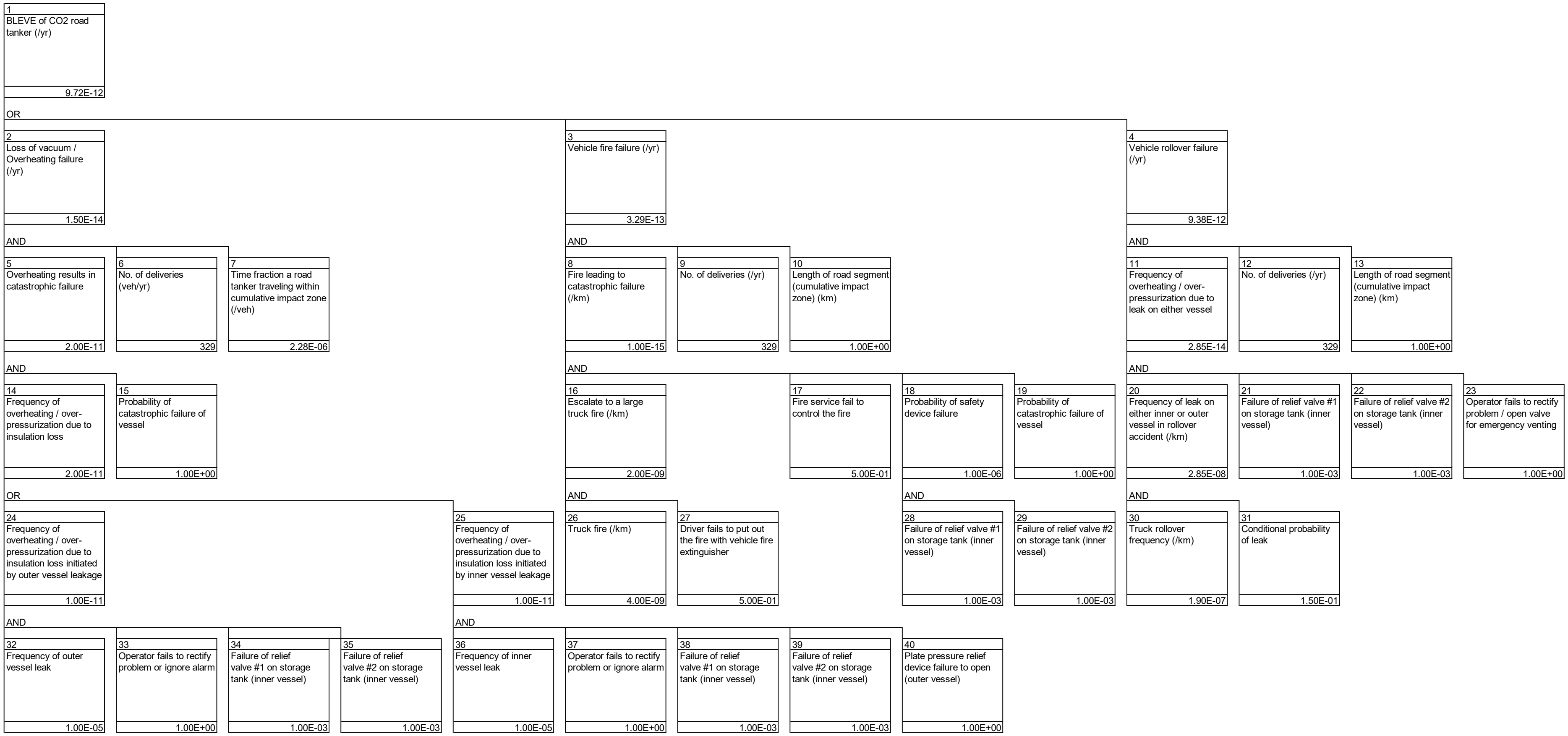
Wrong product ($NaHSO_3$) in HCl 10% tank
1.30E-09
per year


Scenario 7A/7B
Wrong product (H_2SO_4) delivered by supplier
1.00E-04
per operation
Operator fails to check product sample
1.00E-04
-
Operator and WSD staff fail to identify the empty tank for refill
1.00E-02
-
Wrong product (H_2SO_4) in $NaHSO_3$ tank
1.00E-10
per truck
Number of operations ($NaHSO_3$ delivery)
9
operation per year
Wrong product (H_2SO_4) in $NaHSO_3$ tank
9.00E-10
per year
Scenario 8
Wrong product ($NaHSO_3$) delivered by supplier
1.00E-04
per operation
Operator fails to check product sample
1.00E-04
-
Operator and WSD staff fail to identify the empty tank for refill
1.00E-02
-
Wrong product ($NaHSO_3$) in H_2SO_4 tank
1.00E-10
per truck
Number of operations H_2SO_4 delivery
224
operation per
Wrong product ($NaHSO_3$) in H_2SO_4 tank
2.24E-08
per year
Scenario 9A/9B
Wrong product ($C_6H_8O_7$) delivered by supplier
1.00E-04
per operation
Operator fails to check product sample
1.00E-04
-
Operator and WSD staff fail to identify the empty tank for refill
1.00E-02
-
Wrong product ($C_6H_8O_7$) in $NaHSO_3$ tank
1.00E-10
per truck
Number of operations ($NaHSO_3$ delivery)
9
operation per year
Wrong product ($C_6H_8O_7$) in $NaHSO_3$ tank
9.00E-10
per year
Scenario 10
Wrong product ($NaHSO_3$) delivered by supplier
1.00E-04
per operation
Operator fails to check product sample
1.00E-04
-
Operator and WSD staff fail to identify the empty tank for refill
1.00E-02
-
Wrong product ($NaHSO_3$) in $C_6H_8O_7$ tank
1.00E-10
per truck
Number of operations ($C_6H_8O_7$ delivery)
4
operation per
Wrong product ($NaHSO_3$) in $C_6H_8O_7$ tank
4.00E-10
per year
Note:
= AND Gate

Annex E

Fault Tree For Release of Liquid Carbon Dioxide

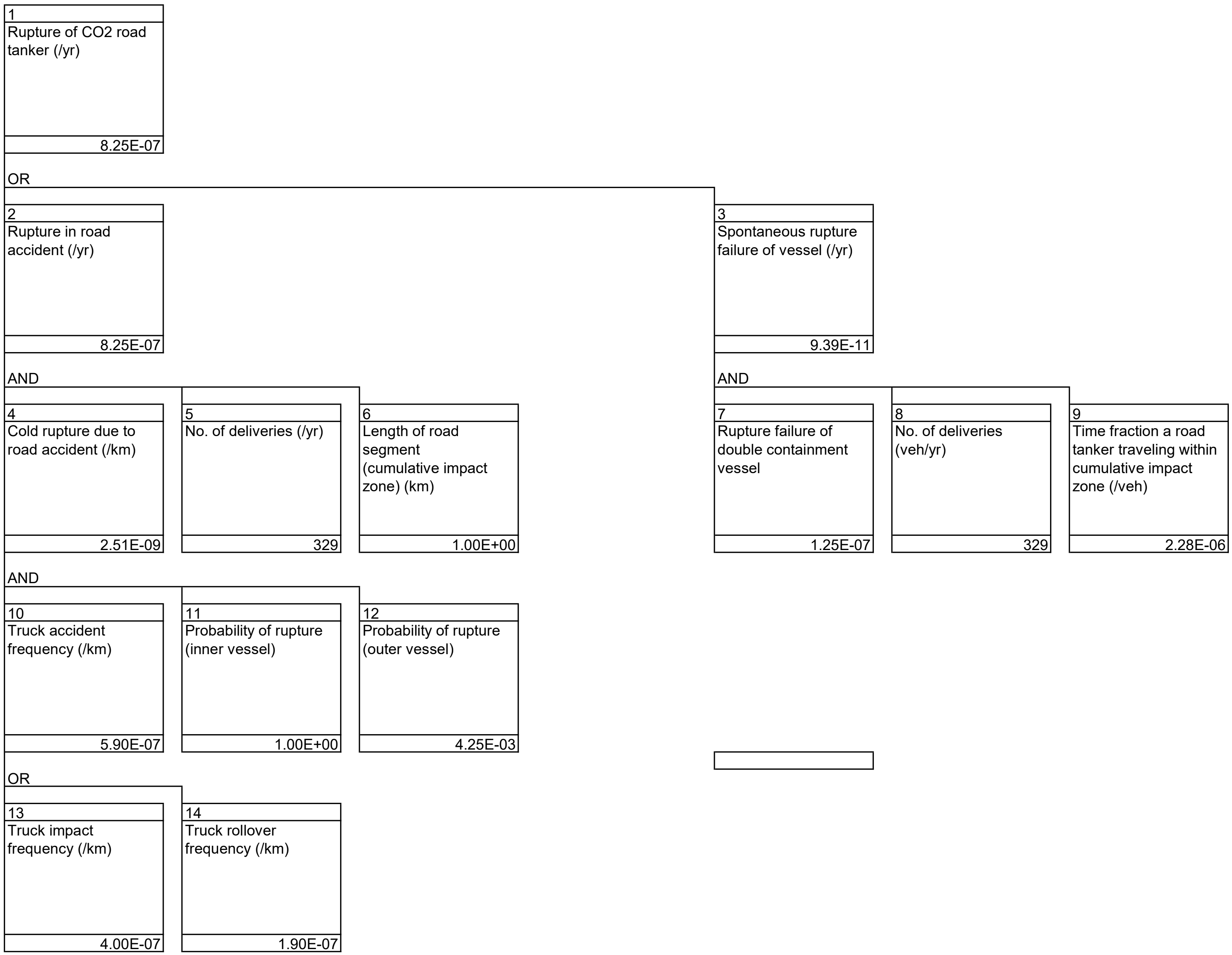
Fault Tree for CO2 Road Tanker BLEVE (offsite)



Remarks:
Box 23/ 33/ 37 = 1 - assume the driver does not have sufficient time to respond
Box 40 = 1 - assume plate pressure relief device is not installed
Box 4 - according to findings of the HAZID workshop, BLEVE may occurs when both inner and outer vessels are punctured in a rollover accident. However, the initial conditions are the same as or similar to the operating conditions when both vessels is ruptured or punctured at the same time.
Since the initial conditions do not fall within the BLEVE zone, BLEVE is unlikely to occur. On the other hand, damage to either vessel leads to loss of vacuum and change of initial conditions. Therefore, leak failure of either vessel is considered in the fault tree.
Box 31 - refer to 'WA of transport of LPG and Naphtha, Methodology report, DNV, 1996''
Box 38, 39 - Inner vessel leakage leads to loss of vacuum insulation. The increase in pressure in the insulation space would trigger the plate pressure relief device on the outer vessel. In case the plate pressure relief device fails to open, temperature and pressure in the inner vessel would increase.
Over-pressurization and BLEVE can only occur if pressure relief valves on the inner vessel fail to open.

Annex E - Fault Tree For Release of Carbon Dioxide

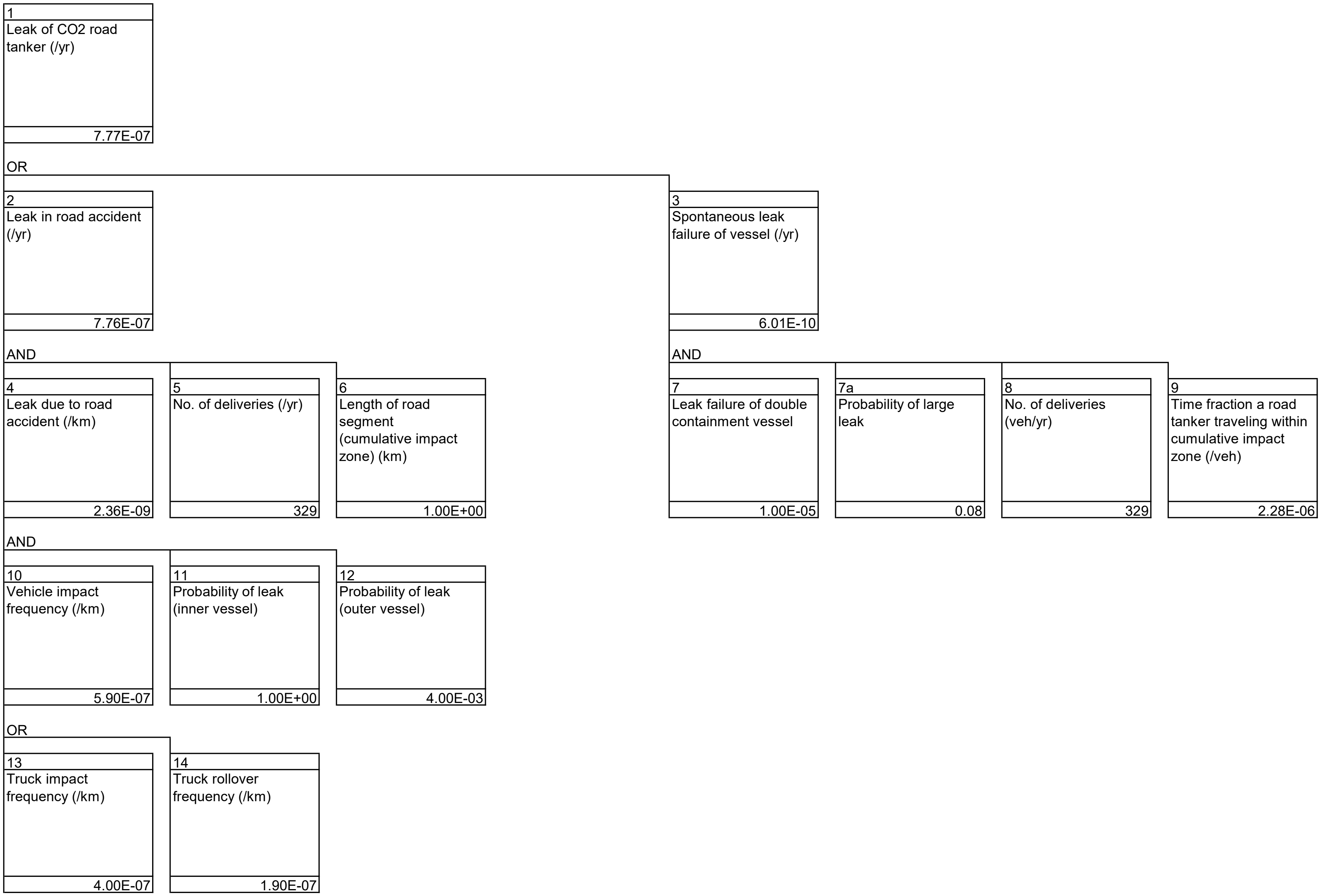
Fault Tree for CO_2 Road Tanker Rupture Failure (offsite)



Remarks:
Box 11 - assume inner vessel does not provide additional protection in collision

Annex E - Fault Tree For Release of Carbon Dioxide

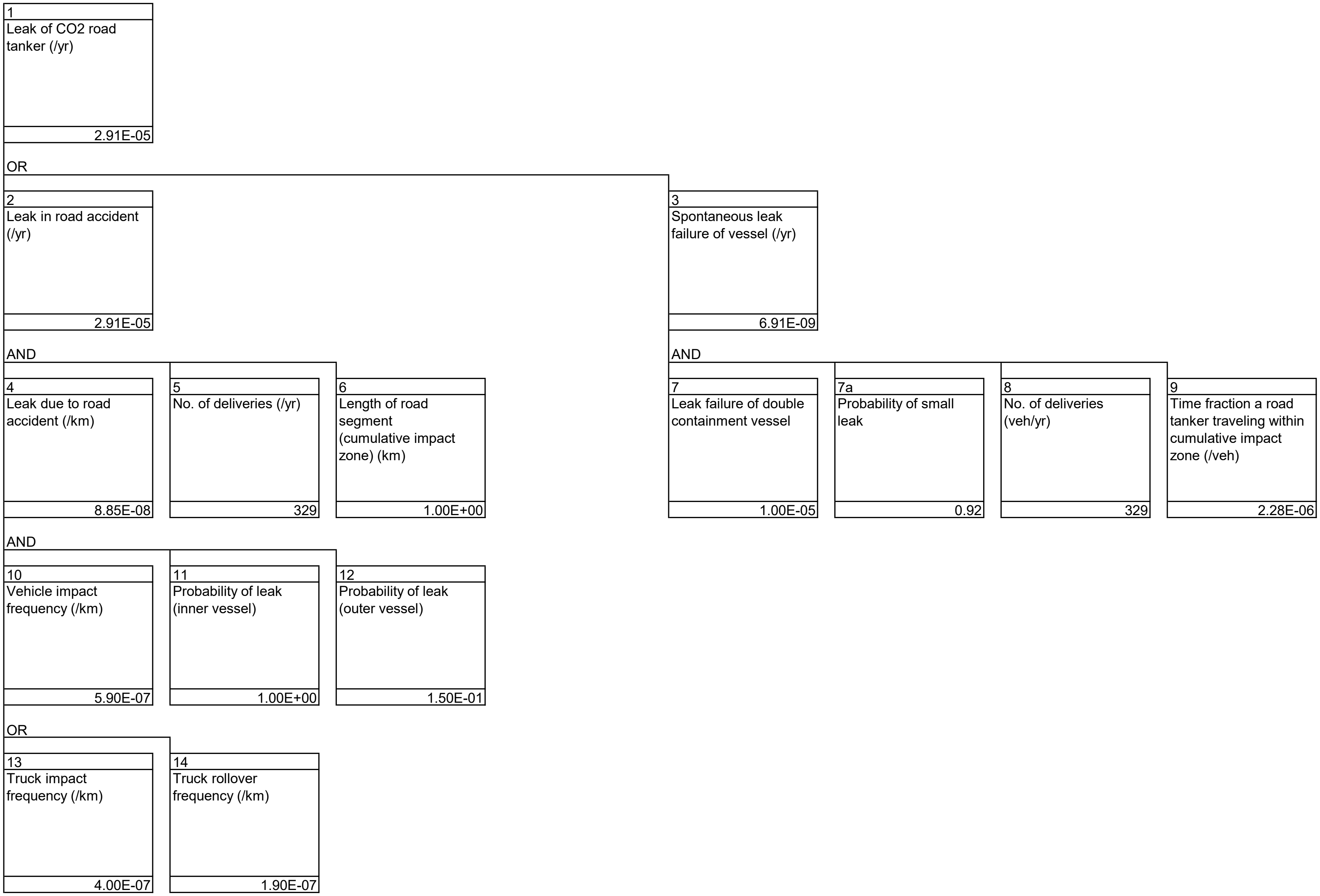
Fault Tree for CO2 Road Tanker Large Leak (offsite)



Remarks:
Box 7a - leak failure rates for pressure vessel : major failure (50mm leak) = 5E-6 per year; minor failure (<50mm leak) = 5.5E-5 per year; major failure ~8% of leak failure
(ref. src: Failure Rate and Event Data for use within Risk Assessments (28/06/2012))
Box 11- assume inner vessel does not provide additional protection in collision

Annex E - Fault Tree For Release of Carbon Dioxide

Fault Tree for CO2 Road Tanker Small Leak (offsite)



Remarks:
Box 7a - leak failure rates for pressure vessel : major failure (50mm leak) = 5E-6 per year; minor failure (<50mm leak) = 5.5E-5 per year; minor failure ~92% of leak failure
(ref. src: Failure Rate and Event Data for use within Risk Assessments (28/06/2012))
Box 11- assume inner vessel does not provide additional protection in collision

Annex F

Consequence Analysis

Annex F – Consequence Analysis

Chlorine Dispersion

Scenario	Hazard Distance at LD03 Contour (m)					
	2B	1D	3D	6D	2E	1F
Full Bore Rupture	10	20	16	12	25	47

Sulphur Dioxide Dispersion

Scenarios	Hazard Distance at LD01 Contour (m)					
	2B	1D	3D	6D	2E	1F
1A/1B	159	147	172	166	133	104
2A/2B	102	106	112	111	108	88
3A/3B	56	59	61	58	61	55
4	102	106	112	111	113	109
5A/5B	71	75	77	77	77	67
6	102	106	112	111	113	108
7A/7B	179	165	192	244	141	115
8	102	106	112	111	113	109
9A/9B	175	162	188	238	137	113
10	102	106	112	111	113	106

Carbon Dioxide Dispersion

Scenarios	Hazard Distance at LD01 Contour (m)					
	2B	1D	3D	6D	2E	1F
Rupture (20 tonnes)	20	20	22	22	21	21
Large Leak (20 tonnes - 50mm)	27	28	28	27	28	28
Small Leak (20 tonnes - 25mm)	14	15	14	13	15	15