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12 Hazard to Life

12.1 Legislation, Standards and Guidelines

12.1.1.1 As stipulated in Annex 4 of Technical Memorandum - Environmental Impact Assessment Ordinance (EIAO-TM), the risk guidelines comprise two criteria shown as follows:

- **Individual Risk**: the maximum level of off-site individual risk should not exceed 1 x 10^{-5} / year, i.e. 1 in 100,000 per year.
- **Societal Risk**: the criteria are shown in **Figure 12.1**. The Societal Risk Guideline is expressed in terms of lines plotting the frequency (F) of N or more fatalities in the population from accidents at the facility of concern. For an F-N curve totally within Acceptable region, the risk level is considered as acceptable. For an F-N curve within ALARP region (As Low As Reasonably Practicable), the risk level shall be mitigated to as low as reasonably practicable and justified by cost benefit analysis. Risk level lying in the "Unacceptable" region should be reduced regardless of cost to ALARP or Acceptable region, or the concerned project should not be allowed to construct/ operate.

12.2 Methodology

12.2.1.1 In accordance with the EIA Study Brief (ESB-294/2016), the methodology to be used in the hazard assessments shall be consistent with previous studies having similar issues (e.g. OWTF).

12.2.1.2 The general procedures of Hazard Assessment (HA) include:

- **Hazard Identification:** Identify hazard scenarios associated with the transport, storage and use of chlorine and then determine a set of relevant scenarios to be included in a Quantitative Risk Assessment (QRA).
- **Frequency Assessment:** Assess the likelihood of occurrence of the identified hazard scenarios.
- **Consequence Assessment:** Assess the consequences and impact to the surrounding population.
- **Risk Assessment:** Evaluate the risk level, in terms of individual risk and societal risk. The risks will be compared with the criteria stipulated in Annex 4 of EIAO-TM to determine their acceptability. Subject to the assessment, practicable and cost-effective risk mitigation measures will be identified and assessed.

12.3 Hazardous Facility

12.3.1.1 According to the ESB-294/2016, Clause 3.4.9, hazard to life assessment will follow the criteria as stated in Section 2 of Annex 4 of the TM. Potential hazardous facilities in the vicinity include the Siu Ho Wan Water Treatment Works (SHWWTW) and Sham Shui Kok Chlorine Transhipment Dock (SSK Dock).

12.3.1.2 For the SHWWTW, as discussed in **Section 2.4**, since a small non-residential portion of the proposed development (about 8,600m^2) falls within the 1km consultation zone (CZ) of SHWWTW (**Figure 12.2**). Hence, hazard assessment is carried out to evaluate potential hazard to life during construction and operation stages due to SHWWTW against the Government risk guidelines as stipulated in **Section 12.1**.

12.3.1.3 Moreover, there is a Sham Shui Kok Chlorine Transhipment Dock (SSK Dock) at about 210m north of the Eastern Connection Road. As confirmed with WSD, the latest 1x10^{-6}/yr risk contour from the SSK Dock would not encroach onto the proposed development including the Eastern Connection Road. Furthermore, potential risk due to operation of the SSK Chlorine Transhipment Dock will only happen to a small number of vehicles using the service road over a short time period if the Road P1(SHW Section) is not available in time for connection to the eastern access of the SHD Topside Development. Away from SSK Dock, its risks die down rapidly, and contours of risk lower than 1×10^{-6}/year do not extend beyond the 1×10^{-6}/year contour. On this basis, it is therefore the risk from SSK Dock to the development is insignificant and hence would not be further considered. In addition, the projected traffic forecast for the Eastern Connection Road is very low, in the order of 500 vehicles per hour in Year 2038. In fact, this Eastern Connection Road would only be required during the implementation of Phase 4 tentatively in Year 2038.

12.4 Meteorological Conditions

12.4.1.1 According to the approved Environmental Impact Assessment reports for Integration of Siu Ho Wan and Silver Mine Bay Water Treatment Works (AEIAR-158/2011) and Organic Waste Treatment Facilities Phase 1 (AEIAR-149/2010), the meteorological data was based on the HA report of SHWWTW in 1992 by adopting the meteorological data from Chek Lap Kok Weather Station. Hence, the meteorological data in 1992 has been adopted for model validation.

12.4.1.2 Latest meteorological data (Year 2011-15) from Siu Ho Wan Anemometer Station of the Hong Kong Observatory has been collected and adopted in the consequence model. It has been rationalised into different combinations of wind direction, speed and atmospheric stability class defined in the HA report of SHWWTW. The probabilities of occurrence of each combination during daytime and night time are

presented in **Table 12.1**. The latest meteorological data has been adopted in current assessment.

Table 12.1 Meteorology data

Direction	Wind Speed and Stability [1]								
	0.5B	**0.5D**	**1F**	**3B**	**3E**	**4D**	**7D**	**15D**	**Total**
Daytime									
0 N	0.01158	0.00382	0.00152	0.00779	0.00138	0.00871	0.00210	0.00009	0.03698
22.5 NNE	0.00443	0.00422	0.00193	0.00813	0.00213	0.01250	0.00092	0.00000	0.03425
45 NE	0.00144	0.00187	0.00267	0.00325	0.00195	0.00603	0.00006	0.00000	0.01727
67.5 ENE	0.00060	0.00187	0.00213	0.00816	0.00118	0.01032	0.00037	0.00000	0.02463
90E	0.00083	0.00276	0.00388	0.01836	0.00227	0.03893	0.01457	0.00032	0.08192
112.5 ESE	0.00040	0.00112	0.00172	0.00566	0.00138	0.01437	0.00511	0.00014	0.02991
135 SE	0.00037	0.00144	0.00152	0.00986	0.00132	0.01339	0.00101	0.00000	0.02891
157.5 SSE	0.00034	0.00118	0.00213	0.01557	0.00213	0.02511	0.00238	0.00000	0.04885
180 S	0.00089	0.00218	0.00721	0.01457	0.00115	0.01733	0.00224	0.00000	0.04557
202.5 SSW	0.00026	0.00072	0.00083	0.00187	0.00032	0.00296	0.00023	0.00000	0.00718
225 SW	0.00032	0.00046	0.00052	0.00195	0.00017	0.00290	0.00152	0.00000	0.00784
247.5 WSW	0.00164	0.00089	0.00069	0.00296	0.00040	0.00399	0.00060	0.00000	0.01118
270W	0.00744	0.00201	0.00106	0.01261	0.00089	0.00773	0.00115	0.00003	0.03293
292.5 WNW	0.00655	0.00118	0.00066	0.01618	0.00066	0.00902	0.00443	0.00009	0.03876
315 NW	0.00773	0.00138	0.00055	0.01069	0.00049	0.00626	0.00135	0.00003	0.02848
337.5 NNW	0.00626	0.00132	0.00049	0.00552	0.00055	0.00805	0.00316	0.00000	0.02534
Day Total	**0.05109**	**0.02842**	**0.02951**	**0.14312**	**0.01836**	**0.18760**	**0.04120**	**0.00069**	**0.50000**

Direction	Wind Speed and Stability								
	0.5B	0.5D	1F	3B	3E	4D	7D	15D	Total
Night time									
0 N	0.00000	0.00003	0.00392	0.00000	0.00406	0.00916	0.00177	0.00000	0.01894
22.5 NNE	0.00000	0.00000	0.00538	0.00000	0.00761	0.01339	0.00066	0.00000	0.02704
45 NE	0.00000	0.00006	0.00853	0.00000	0.00715	0.00615	0.00003	0.00000	0.02192
67.5 ENE	0.00000	0.00000	0.00941	0.00000	0.00455	0.00358	0.00043	0.00011	0.01809
90E	0.00000	0.00006	0.01923	0.00000	0.01605	0.04072	0.01087	0.00040	0.08733
112.5 ESE	0.00000	0.00006	0.01688	0.00000	0.01414	0.02412	0.00635	0.00011	0.06167
135 SE	0.00000	0.00000	0.01239	0.00000	0.01099	0.01399	0.00106	0.00000	0.03843
157.5 SSE	0.00000	0.00000	0.01886	0.00000	0.01574	0.02650	0.00209	0.00000	0.06318
180 S	0.00000	0.00003	0.07420	0.00000	0.01053	0.01133	0.00100	0.00000	0.09709
202.5 SSW	0.00000	0.00000	0.00621	0.00000	0.00169	0.00206	0.00029	0.00000	0.01024
225 SW	0.00000	0.00003	0.00269	0.00000	0.00083	0.00232	0.00060	0.00006	0.00652
247.5 WSW	0.00000	0.00000	0.00258	0.00000	0.00195	0.00306	0.00014	0.00003	0.00775
270W	0.00000	0.00003	0.00378	0.00000	0.00298	0.00509	0.00046	0.00009	0.01242
292.5 WNW	0.00000	0.00000	0.00206	0.00000	0.00177	0.00318	0.00106	0.00009	0.00816
315 NW	0.00000	0.00000	0.00166	0.00000	0.00172	0.00432	0.00155	0.00000	0.00924
337.5 NNW	0.00000	0.00003	0.00166	0.00000	0.00203	0.00612	0.00212	0.00000	0.01196
Night Total	**0.00000**	**0.00031**	**0.18944**	**0.00000**	**0.10379**	**0.17510**	**0.03048**	**0.00089**	**0.50000**
24 Hour Total	**0.05109**	**0.02873**	**0.21894**	**0.14312**	**0.12215**	**0.36270**	**0.07168**	**0.00158**	**1.00000**

Note:

[1] – The wind speeds are quoted in units of meters per second, such as 3m/s. The wind stability classes refer to: A – Turbulent, B – Very Unstable, C – Unstable, D – Neutral, E – Stable and F – Very Stable

12.5 Population Data

12.5.1 Assessment Area

12.5.1.1 Since the maximum hazard distance from the hazard of SHWWTW is 2.8km, this hazard assessment will be considered as the Assessment Area of 2.8km from the SHWWTW. Considering that the chlorine is not able to reach the population behind the hill, the area behind the hill is therefore not included in the Assessment Area.

12.5.2 Population Assumptions

12.5.2.1 The review of statutory and departmental plans reveals that the eastern part of the assessment area is covered by the Siu Ho Wan Layout Plan No. L/I-SHW/1A, whilst the far northwestern and southwestern ends of the assessment area are marginally covered by the Approved Tung Chung Extension Area Outline Zoning Plan No. S/I-TCE/2 and Tai Ho Development Permission Area Plan No. DPA/I-TH/2 respectively. Major planned/committed developments identified from these plans within the Assessment Area e.g. Organic Waste Treatment Facilities Phase 1 (OWTF-P1) have been considered in the QRA.

12.5.2.2 A sensitivity test was included in the Steering Group Report on Hazard Assessment, Planning Study and Action Plan of SHW WTW with a hypothetical population of 20,000 at the MTR Railway Depot. The results indicated that the additional 20,000 population would not lead to unacceptable impact in the safety perspective. It is noted that the 20,000 population assumption is not a development restriction and the subject area has been changed over the past 25 years. Since the SHD Topside Development proposal would introduce a population of 40,000, the quantitative risk assessment has included this increase in population. As shown in **Section 12.7.2**, the cumulative societal risk would still fall within the "ALARP" region.

12.5.2.3 Given the nature of industrial premises including North Lantau Refuse Transfer Station, Kowloon Motor Bus Siu Ho Wan Bus Depot, City Bus Siu Ho Wan Bus Depot, etc., the number of working population within these industrial premises should not change significantly for the given operation. It is reasonable to assume that the working population within these premises in the assessment year could remain unchanged as compared to that at base year. The number of working population within these industrial premises has adopted the population projections adopted in the QRA of the approved Organic Waste Treatment Facilities Phase 1 (OWTF-P1) EIA Report (AEIAR-149/2010), and its subsequent Environmental Review Report for Variation of Environmental Permit (VEP-488/2015).

12.5.2.4 Transient population for the road network within the Assessment Area has been derived based on road traffic flow predictions for Year 2038.

These traffic forecast has been submitted to and approved by Transport Department (TD).

12.5.2.5 For railway population, the maximum capacity for passenger density level of 6 people per m^2 in Year 2036 of the AEL as presented in the LegCo Paper (April 2016) [12-9] has been adopted. For the TCL, i.e. between Tung Chung and Tsing Yi Station, the maximum capacity for passenger density level of 6 people per m^2 in Year 2036 is adopted from the LegCo Paper (July 2015) [12-10].

12.5.2.6 As no ferry and only limited marine service for the North Lantau Refuse Transfer Station, i.e 2 trips per day, within the Assessment Area, contribution from sea-based transient population is considered negligible. Off-site population assumptions adopted in the QRA are presented in **Table 12.3**.

12.5.3 Population Scenario

12.5.3.1 According to the EIA Study Brief, HA shall be carried out to evaluate the potential hazard to life during the construction and operational phases of the Project due to SHWWTW. As such, the population scenario has been considered at the construction year and operation year of the development, in which the construction workers and population in the construction and operational phases are maximum.

12.5.4 Assessment Year

12.5.4.1 For construction phase, the highest number of 1000 construction workers has been adopted in the study. The topside development will be implemented in phases during the construction period. According to the construction programme (**Table 2.3**), some of the work fronts for the installation of sewage pipes in Year 2038 would be close to the SHWWTW.

12.5.4.2 For operational phase, while there will not be any residential towers within the CZ, all the residential towers of the proposed Development Scheme are situated within the Assessment Area, the design population is 37,800, together with the proposed commercial/retail facilities, educational uses, and the proposed SHO and SHD, have been included in the QRA.

12.5.4.3 According to the tentative construction programme and implementation programme (**Table 2.3**), both residential population and construction workers would exist simultaneously. Based on the building layout and construction work fronts, Year 2038 is the worst year representing both the construction and operational phase scenario. Hence, Year 2038 is selected for the assessment. This cumulative scenario is therefore conservative.

12.5.4.4 **Table 12.2** summarises the approach to update the population data for the assessment year of 2038. **Figure 12.3** shows the extent of

population distribution to be adopted in the present study. The off-site and on-site population data are presented in **Table 12.3** and **Table 12.4** respectively.

Table 12.2 Approach to update the population data within the influence zone (2.8km) of SHWWTW

Population Type	Assessment Year
Residential	Currently, there is no existing residential population within the 1km consultation zone of SHWWTW. The residential population in the assessment year has been based on the information from the Project Proponent.
Industrial	The current population for industry is based on the following reports: • Environmental Review Report (ERR) for Variation of Environmental Permit (VEP-488/2015) for OWTF-Phase 1 • Approved EIA report for OWTF-Phase 1 Given the nature of industrial premises (including Siu Ho Wan Sewage Treatment Works, North Lantau Refuse Transfer Station etc.), it is considered that the number of working population within these industrial premises should not increase for the given operation. Hence, it is reasonable to assume that the working population within these premises in the assessment year could remain unchanged as compared to that at base year. Population of SHO (i.e. 585) and reprovisioned SHD (i.e. 200) have been included.
Transient population (land)	Transient population includes road population and railway population. The road population has been determined from the local traffic forecast model. The railway population on TCL/AEL or in SHO platform have been estimated based on the maximum capacity of TCL/ capacity of AEL from LegCo Paper No. CB(1)1132/14-15(01) /CB(4)854/15-16(07) train frequency and the number of persons per train.

Table 12.3 Off-site population data within the influence zone of SHWWTW in Year 2038

Location ID	Name	Population	Indoor Population Ratio	Outdoor Population Ratio	Proportion			
					Working Day TM1	Saturday Day TM3	Sunday Day TM3	Night TM4
1	North Lantau Refuse Transfer Station	42 [1]	0.80	0.20	1.00	0.05	0.05	0.05
2	Kowloon Motor Bus Siu Ho Wan Bus Depot	40 [1]	0.70	0.30	1.00	0.10	0.10	0.10
3	City Bus Siu Ho Wan Bus Depot	45 [1]	0.70	0.30	1.00	0.10	0.10	0.10
4	Siu Ho Wan Vehicle Pound Examination Centre and Weigh Station	10 [1]	0.40	0.60	1.00	0.20	0.20	0.20
5	Organic Waste Treatment Facilities-Staff	35 [1]	0.90	0.10	1.00	1.00	1.00	0.10
	Organic Waste Treatment Facilities-Visitors	40 [1]	0.50	0.50	1.00	0.00	0.00	0.00
6	Siu Ho Wan Sewage Treatment Works	40 [1]	0.80	0.20	1.00	0.50	0.50	0.50
7	New Lantau Bus Co. Siu Ho Wan Depot	40 [1]	0.70	0.30	1.00	0.10	0.10	0.10
8	Discovery Bay Tunnel Administration Building	15 [1]	0.80	0.20	1.00	0.33	0.33	0.33
9	Siu Ho Wan Government Maintenance Depot	100 [1]	0.90	0.10	1.00	0.20	0.20	0.20
12	North Lantau Expressway	3,224 [2]	0.75 [4]	0.25	1.00	1.00	1.00	0.54
13	Cheung Tung Road	279 [2]	0.75 [4]	0.25	1.00	1.00	1.00	0.49

Location ID	Name	Population	Indoor Population Ratio	Outdoor Population Ratio	Proportion			
					Working Day TM1	Saturday Day TM3	Sunday Day TM3	Night TM4
14	Railway – Tung Chung Line (TCL) and Airport Express (AEL)	5,398 [3]	1.00	0.00	1.00	1.00	1.00	0.58

Note:
[1] For location ID 1-9, base population is adopted from the ERR of the VEP-488/2015 for the OWTF-Phase 1. No industrial population growth is adopted as no new planned population from OZP and expansion for the existing facilities. There is a columbarium developments in the vicinity of SHW WTW. However, as there is no implementation programme of the developments, the columbarium developments would not be included in the study.
[2] For location ID 12-13, the transient population is adopted from the traffic forecast in Year 2038.
[3] For location ID 14, the railway population is estimated based on the maximum capacity of TCL in 6ppsm according to the LegCo Paper "Tung Chung New Town Extension Study - Provision of Supplementary Information Requested by Members" (No. CB(1)1132/14-15(01)) and the capacity of AEL is referred to the LegCo Paper "Capacity and Loading of trains in the MTR Network" (No. CB(1) 854/15-16(07)) .
[4] Indoor population ratio is determined by the equivalent indoor factor of 0%, 50% and 75% for LD90, LD50 and LD03 respectively.

Table 12.4 On-site population data

Location ID	Name	Population	Indoor Population Ratio	Outdoor Population Ratio	Proportion				Base height (mAG)	Maximum height (mAG)
					Working Day	Saturday Day	Sunday Day	Night		
10	MTRC Railway Depot	200 [1]	0.90	0.10	1.00	0.20	0.20	0.20	0	12.8
11	Proposed Residential Development	37,800 [2]	0.95	0.05	0.50	0.70	1.00	1.00	20.3	98.3
	Private Recreational Facility (Club House)	1,650	0.95	0.05	0.50	0.70	1.00	0.10	12.8	22.8
	Commercial / Retail	1,500	0.95	0.05	0.50	0.70	1.00	0.10	12.8	20.2
	Education	4,515	0.95	0.05	1.00	1.00	0.01	0.01	20.2	41.2
	Proposed SHO	585	0.00 [3]	1.00 [3]	1.00	1.00	1.00	1.00	0	12.8

Location ID	Name	Population	Indoor Population Ratio	Outdoor Population Ratio	Proportion				Base height (mAG)	Maximum height (mAG)
					Working Day	Saturday Day	Sunday Day	Night		
15	Construction Workers (Topside development)	600 [4]	0.00	1.00	1.00	1.00	0.00	0.00	12.8	12.8
	Construction Workers (SHO and SHD replanning works)	350 [4]	0.00	1.00	1.00	1.00	0.00	0.00	0	0
16	Construction Workers (Sewage Pumping Station and Pipe Work)	50 [4]	0.00	1.00	1.00	1.00	0.00	0.00	0	0
17a	Construction Workers for Eastern connection access on Sham Shui Kok Drive		0.00	1.00	1.00	1.00	0.00	0.00	0	0
17b	Eastern connection access on Sham Shui Kok Drive	91 [5]	0.75 [6]	0.25	1.00	1.00	1.00	0.49	0	0

Note:
[1] For location ID 10, working population upon full operation of the replanned depot is provided by MTR Corporation.
[2] The podium of the proposed development is about 20m above ground and the average building height is about 60m. It should be noted that there is no other planned residential development fall within the 1km consultation zone of SHWWTW.
[3] No indoor protection is adopted for conservative assessment.
[4] For location ID 15-16, the population is provided by the project proponent. Construction activities at location ID 15 and 16 are assumed to take place simultaneously for conservative assessment.
[5] The transient population is adopted from the traffic forecast in Year 2038.
[6] Indoor population ratio is determined by the equivalent indoor factor of 0%, 50% and 75% for LD90, LD50 and LD03 respectively.

12.5.5 Time Variation Mode

12.5.5.1 The time variation mode reflects the variations of population in each location during working days, peak traffic hour, weekend and night. Detailed description and frequency per year for each time variation mode is presented in **Table 12.5**.

Table 12.5 Definition of time variation mode

Time Variation Mode (TM)	Description	Period	Weighting per day	Frequency per year [1]
1	Working Daytime	Monday to Friday	12 hours	0.3571
2	Saturday Daytime	Saturday	12 hours	0.0714
3	Holiday Daytime	Sunday	12 hours	0.0714
4	Nighttime	Monday to Sunday	12 hours	0.5000

Note:
[1] The frequency per year for each time variation mode is calculated as follows:
For example TM1, assuming the working daytime represents a period from Monday to Friday with 12 working hours each day, frequency per year = (12×5) / (24×7)=0.3571

12.5.6 Transient Population - Road

12.5.6.1 The transient population using the roads has been estimated based on the number of predicted vehicle trips and the typical number of persons inside the vehicles (**Table 12.6**) using the following formula. The detail calculation on the road transient population is shown as **Appendix 12.1.**

Transient Population (Road) = Traffic Volume (km) / Min. Speed (km/hr) × peak hour traffic flow (vehicle/hr) × Vehicle Type Composition × Persons per Vehicle

Table 12.6 Assumption of persons per vehicle

Class of Vehicle	Persons per Vehicle
Motor Cycle	1.1
Private Car	1.9
Taxi	2.2
Private Light Bus/ Public Light Bus	8.0
Franchised Bus (Signal deck)	29.0
Franchised Bus (double deck)	65.5
Non-franchised Buses	34.7
Light goods vehicles	1.7
Medium/Heavy goods vehicles	1.3

Note: Based on the occupancy in Year 2015 from Lantau Link (Core Station 5027) from Transport Department - The Annual Traffic Census 2015

12.5.7 Transient Population - Railway

12.5.7.1 The transient population using the railway has been estimated based on the maximum capacity of Tung Chung Line and Airport Express from LegCo Paper No. CB(1)1132/14-15(01)) and CB(4)854/15-16(07) respectively, train frequency and the number of persons per train using the following formula:

Transient Population = Number of trains in both directions per hour× Number of persons per train × Rail length in assessment area (km) / Train Speed (km/hr)

12.5.7.2 The detailed calculation on the railway transient population is shown as **Appendix 12.1**.

12.5.8 Sensitive Population

12.5.8.1 The vulnerable populations including the young, the elderly and the infirm will be more sensitive to the effects of the chlorine than other populations. According to Withers and Lees (1985a [12-6], 1985b [12-7]), the fatality rate for the vulnerable population is 3.3 times higher than for the average population. This factor has been adopted in this study by increasing the fatality rate applied to the vulnerable populations, i.e Education of ID-11.

12.6 Siu Ho Wan Water Treatment Works

12.6.1 Overview

12.6.1.1 According to the approved Environmental Impact Assessment reports for Integration of Siu Ho Wan and Silver Mine Bay Water Treatment Works (AEIAR-158/2011), the maximum chlorine storage capacity of SHWWTW is 73 tonnes (drums). A chlorine scrubbing system with capacity of 1 air change / 6 minutes is installed in the chlorine storage room. Sodium hydroxide (NaOH) is used to neutralise the chlorine. When the chlorine concentration of 1 ppm is detected inside the room (low level alarm), the exhaust fans would be automatically stopped. If 3 ppm concentration is reached (high level alarm), scrubber system would be automatically turned on until the concentration drop to 1 ppm. The scrubbing system is put under test every month and would be stopped for about 2 days for yearly maintenance.

12.6.1.2 All chlorine handling operation is confined to the enclosed unloading area and chlorine storage room reinforced with concrete panels. Negative pressure is maintained inside the store.

12.6.2 Review of Hazard Identifications

12.6.2.1 Historical chlorine incident review has been conducted to identify any failure cases which are not addressed in the previous HA reports. The Accidental Release Information Program (ARIP) database, U.S Chemical Safety Board database (U.S. CSB) and the United Nations Environment Program (UNEP) database for disasters have been reviewed. The historical incidents in the Major Hazard Incidents Data Service (MHIDAS) database is another hazard database. However, the MHIDAS database is no longer updated nor hosted by UK HSE.

12.6.2.2 The review result (i.e. refer to **Appendix 12.2**) revealed that the failure cases in the databases, including, spontaneous failures for drums, liquid line and gas line, chemical corrosion for evaporators of liquid line, handling and external impact by aircraft crashes addressed in previous EIA reports, [12-1], [12-2]. As a result, the failure cases in the previous EIA reports were considered valid and adopted in this study.

12.6.2.3 Morover, there is an Organic Waste Treatment Facilities-Phase 1 to the North of SHW WTW. According to the approved EIA report - OWTF and the Environmental Review Report of VEP-488/2015 for OWTF-Phase 1, the greatest influence distance which may cause structural damage to the chlorine store, i.e VCE of the gas buffer tank, is 85m. As, the distance between chorine storage in SHWWTW and gas buffer tank in OWTF-Phase 1 is 120m, it is considered that the hazard due to the biogas storage would not have impact on the operation of the chlorine facilities inside the SHWWTW. Hence, there is no knock-on effect to the SHWWTW due to the OWTF-Phase 1.

12.6.3 Hazard Scenarios

12.6.3.1 According to the approved OWTF EIA [12-2] , four types of hazard scenarios due to the operation of the SHWWTW have been identified as follows:

- Drum failure;
- Liquid Pipework and fittings failure;
- Gaseous Chlorine release; and
- Effects of contain and absorb system.

12.6.3.2 **Table 12.7a** and **Table 12.7b** summarize the chlorine outflow rates from SHWWTW for different hazard scenarios. For the current design of SHWWTW, any leaked chlorine would be confined inside the chlorine store with ventilation off and be absorbed by the chlorine scrubber. There are three cases that the leaked chlorine would be released from the building to the surrounding:

1) Ventilation fails on;
2) Ventilation off, but absorber fails;
3) Building structure collapse.

12.6.3.3 "Vent On" means "Ventilation on, scrubber system on, or failure". In case the ventilation system fails to shut down during chlorine release events, the chlorine gas would be exhausted outside the building.

12.6.3.4 The ventilation system would be off normally during chlorine release events. In case the scrubber system also fails, the chlorine release inside the building would increase the pressure inside the building and resulting a slow rate of outflow outside the building. This situation called "Vent Off, Scrubbing System Failure".

12.6.3.5 During "Building Collapse", the failure will cause a simultaneous loss of building containment. Thus, the effect of the ventilation and scrubber system will not be considered.

12.6.3.6 The chlorine store is constructed by reinforced concrete panels, chlorine releases in small magnitude earthquakes and spontaneous failures would be contained within the chlorine store. However, the reinforced concrete panels are not able to maintain strong magnitude earthquakes. Hence, building collapse is adopted for the outcome of earthquake.

Table 12.7a Chlorine outflow rates from the building with reinforced concrete panels – SHWWTW

Scenario	Failure Mode	Hole Size	Initial Release (kg/s)	Outflow Rate from Building to Atmosphere [1]		
				Vent On (kg/s)	Vent Off, Scrubbing System Failure (kg/s)	Building Collapses (kg/s)
Drum Failure	Spontaneous	Small (6mm)	0.24	0.2	0.03	--
		Large (15mm)	1.7	0.4	0.2	--
		Rupture	1 tonne Rupture	1.7	1.7	--
	Handling	Small (6mm)	0.24	0.2	0.03	--
	External Impacts	Earthquake	1 tonne Rupture	--	--	Instantaneous 1 tonnes
		Aircraft, light aircraft crash (2011)	2 tonne Rupture	--	--	Instantaneous 2 tonnes
		Aircraft (2011)	73 tonnes Rupture	--	--	Instantaneous 73 tonnes
Liquid Pipework Failure	Spontaneous	6mm	0.24	0.2	0.03	--
	External Impact	6mm	0.24	--	--	0.24
	Evaporators	6mm	0.24	0.2	0.03	--
Liquid fittings failure	Handling	15mm	1.7	0.4	0.2	--
	External Impact	15mm	1.7	--	--	1.7
Gaseous chlorine release failure	Spontaneous	6mm	0.24	0.2	0.03	--
	External Impact	6mm	0.24	--	--	0.24

Table 12.7b Summary of release sizes from releases during chlorine transportation

Hole Size	Release Rate (kg/s)	Mass Released
Small Leaks	0.24	1 tonne
Large Leaks	1.7	1 tonne
Catastrophic Failures	1 tonne Rupture	1 tonne
Large Leaks	7.65	4.5 tonnes

12.6.4 Frequency Analysis

12.6.4.1 The frequency of failure scenarios applied in the previous studies is compared with the generic frequency based on the historical incidents. Detail of the generic frequency comparison is presented in **Appendix 12.3**. The comparisons have shown that the outcome frequencies adopted in the previous report were conservative and thus the previous outcome frequencies are considered appropriate in this study.

12.6.4.2 According to the approved OWTF EIA [12-2], the release frequencies of Siu Ho Wan WTW for different scenarios inside WTW are summarised in **Table 12.8** to **Table 12.9** respectively.

Table 12.8a Summary of release frequencies to outside building of SHWWTW

Scenario	Failure Mode	Hole Size	Initial Release (kg/s)	Contain and Absorb Failure Mode (per year)		
				Vent On	Vent Off, Scrubbing System Failure	Building Collapses
Drum Failure	Spontaneous	Small (6mm)	0.24	4.02×10^{-5}	4.02×10^{-5}	--
		Large (15mm)	1.7	3.07×10^{-5}	3.07×10^{-5}	--
		Rupture	--	2.92×10^{-6}	2.92×10^{-6}	--
	Handling	Small (6mm)	0.24	1.35×10^{-5}	1.35×10^{-5}	--
	External Impacts	Earthquake	1 tonne Rupture	--	--	7.30×10^{-4} [1]
		Aircraft, light aircraft crash (2011)	2 tonnes Rupture	--	--	7.70×10^{-8}
		Aircraft (2011)	73 tonnes Rupture	--	--	4.20×10^{-8}
Liquid Pipework Failure	Spontaneous	6mm	0.24	1.50×10^{-7}	1.50×10^{-7}	--
	External Impact	6mm	0.24	--	--	5.50×10^{-5}
	Evaporators	6mm	0.24	2.00×10^{-6}	2.00×10^{-6}	--
Liquid Fittings Failure	Handling	15mm	1.7	2.96×10^{-6}	2.96×10^{-6}	--
	External Impact	15mm	1.7	--	--	5.50×10^{-5}
Gas Line Failure	Spontaneous	6mm	0.24	6.00×10^{-8}	6.00×10^{-8}	--
	External Impact	6mm	0.24	--	--	5.00×10^{-6} [1]

Note:
[1] Building collapses is assumed for "Drum Failure, External Impacts, Earthquake" and "Gas Line Failure, External Impacts, 6mm" for conservative assessment. Since the effect of ventilation and scrubber system will not be considered in "Building collapse" scenario, the 0.01 failure rate adopted in the approved OWTF EIA has be taken out.

Table 12.8b Chlorine Outflow Rates from the Access Road to SHWWTW

Mass Released (t)	**Small Leaks (6mm) (per year)**	**Large Leaks [1] (15mm) (per year)**	**Catastrophic Failures (per year)**
1	4.32×10^{-6}	2.54×10^{-5}	1.90×10^{-7}
4.5	-	2.69×10^{-6}	-

Note:
[1] The release rates for 1 and 4.5 tonne in large leak case are 1.7 kg/s and 7.65kg/s respectively.

Table 12.9a Summary of frequency and relevant plume dimension table for all hazard scenarios inside SHWWTW

Hazard Scenario no.	Component	Failure Mode	Hole Size	Initial Release (kg/s)	Contain and Absorb Failure Mode	Dilution	Outflow Rate from Building to Atmosphere (kg/s)	Frequency (per year)	Plume Dispersion Table (Appendix 12.3)
1	Drum Failure	Spontaneous	Small (6mm)	0.24	Vent On	60	0.2	4.02E-05	Table b
2					Vent Off, Scrubbing System Failure	10	0.03	4.02E-05	Table a
3			Large (15mm)	1.7	Vent On	60	0.4	3.07E-05	Table i
4					Vent Off, Scrubbing System Failure	10	0.2	3.07E-05	Table b
5a			Rupture	1 tonne Rupture	Vent On	60	1.7	2.92E-06	Table d
5b					Vent Off, Scrubbing System Failure	60	1.7	2.92E-06	Table d
6		Handling	Small (6mm)	0.24	Vent On	60	0.2	1.35E-05	Table b
7					Vent Off, Scrubbing System Failure	10	0.03	1.35E-05	Table a
8		External Impacts	Earthquake	1 tonne Rupture	Building Collapses	60	instantaneous	7.30E-04	Table e

Hazard Scenario no.	Component	Failure Mode	Hole Size	Initial Release (kg/s)	Contain and Absorb Failure Mode	Dilution	Outflow Rate from Building to Atmosphere (kg/s)	Frequency (per year)	Plume Dispersion Table (Appendix 12.3)
9			Aircraft, light aircraft crash (2011)	2 tonne Rupture	Building Collapses	60	instantaneous	7.70E-08	Table f
10			Aircraft (2011)	73 tonnes Rupture	Building Collapses	60	instantaneous	4.20E-08	Table g
11	Liquid Line	Spontaneous	Small (6mm)	0.24	Vent On	60	0.2	1.50E-07	Table b
12					Vent Off, Scrubbing System Failure	10	0.03	1.50E-07	Table a
13		External Impact			Building Collapses	60	0.24	5.50E-05	Table j
14		Evaporators			Vent On	60	0.2	2.00E-06	Table b
15					Vent Off, Scrubbing System Failure	10	0.03	2.00E-06	Table a
16	Fittings	Handling	Large (15mm)	1.7	Vent On	60	0.4	2.96E-06	Table i
17					Vent Off, Scrubbing System Failure	10	0.2	2.96E-06	Table b
18		External Impact			Building Collapses	60	1.7	5.50E-05	Table d
19	Gas Line	Spontaneous	Small (6mm)	0.24	Vent On	60	0.2	6.00E-08	Table b

Hazard Scenario no.	Component	Failure Mode	Hole Size	Initial Release (kg/s)	Contain and Absorb Failure Mode	Dilution	Outflow Rate from Building to Atmosphere (kg/s)	Frequency (per year)	Plume Dispersion Table (Appendix 12.3)
20					Vent Off, Scrubbing System Failure	10	0.03	6.00E-08	Table a
21		External Impact			Building Collapses	60	0.2	5.00E-06	Table b
Total								1.03E-03	-

Table 12.9b Summary of frequency and related plume dimension table for hazard scenarios in access road to Siu Ho Wan WTW

Hazard Scenario no.	Component	Failure Mode	Hole Size	Mass Released	Outflow Rate (kg/s)	Frequency (per year)	Plume Dispersion Table (Appendix 12.3)
23	Drum Failure	Spontaneous	Small (6mm)	1 tonne release	0.24	4.32E-06	Table c
24			Large (15mm)	1 tonne release	1.7	2.54E-05	Table d
25				4.5 tonne release	7.65	2.69E-06	Table h
26			Catastrophic Failure	1 tonne release	Instantaneous	1.97E-07	Table e

12.6.5 Chlorine Toxicity

12.6.5.1 Chlorine is classified as a highly toxic chemical and can cause fatality under high concentrations within very short exposure time. The toxic effects are well documented in various publications. The "UK Health and Safety Executive (HSE) General Guidance on Emergency Planning within the Control of Industrial Major Accident Hazards (CIMAH) regulations for Chlorine Installations" promulgates the following data:

Table 12.10 Toxic effects of chlorine

Concentration (ppm)	Effects
1000	May be fatal with brief exposure
400 – 300	A predicted average lethal concentration for 50% of active healthy people for 30 minutes
150 – 100	More vulnerable people might suffer fatality from 5-10 minute exposure
20 – 10	Causes immediate irritation of nose, throat and eyes with coughing and lachrymation for half to 1 hour exposure
10	Causes coughing in less than 1 minute exposure
3 – 6	Causes stinging or burning sensation but can be tolerated without undue ill effect for up to 1 hour

12.6.6 Consequence Modelling

12.6.6.1 The dispersion of chlorine is assumed to follow the nature of dense gas. To ensure consistency with the approved EIA report for Integration of Siu Ho Wan and Silver Mine Bay Water Treatment Works (AEIAR-158/2011), the dispersion distances identified at that study has been adopted. The plume dimensions for different release cases and weather condition combinations of SHWWTW are given in **Appendix 12.4**.

12.6.7 Indoor Gas Build-up

12.6.7.1 According to the approved EIA report for Integration of Siu Ho Wan and Silver Mine Bay Water Treatment Works (AEIAR-158/2011), the maximum indoor concentration Ci thus derived for outdoor concentration of C_o and duration of t_c (10 minutes) is:

$$C_i = C_o[1-e^{-\lambda t_c}]$$

12.6.7.2 For a typical ventilation rate λ of 0.5 air changes per hour, C_i is normally one-tenth (1/10) of the outdoor concentration after 10 minutes. For the same outdoor chlorine concentrations of interest, the percentage of fatality for average population indoors has been calculated based on the one-tenth of the outdoor concentration after 10 minutes.

12.6.8 Escape and Protection Factors

12.6.8.1 The possibility of persons outdoors escaping to a less exposed location indoors and thus reducing their dose from the outdoor to the indoor rate was reviewed. The escape rate is related to the toxic gas concentration of the dispersion cloud. Referring to the previous HA report for SHWWTW, it is considered that 80% of persons outdoors in areas of 3% lethality would escape indoors, 20% of persons in areas of 50% lethality would escape indoors and 0% in 90% lethality areas would escape indoors. The escaped persons are taken to receive an indoors dose whilst those remaining outdoors would receive the full dose. Taking into account the indoor concentration build-up and the possible escape, the percentage of fatality against toxic gas concentration are summarized in **Table 12.11**.

Table 12.11 Fatality rate for indoor and outdoor population

Toxic Gas Cloud Concentration (LD)	Fatality for Outdoor Population	Fatality for Indoor Population
90	0.90	0.090
50	0.41	0.050
3	0.0084	0.003

12.6.8.2 For road population, an equivalent indoor proportion of 75%, is adopted for Chung Tung Road and North Lantau Expressway. The equivalent indoor proportion is calculated by assuming the equivalence indoor factor for LD90, LD50 and LD03 is 0%, 50% and 75% respectively [12-8].

12.6.9 Chlorine Cloud Height

12.6.9.1 For the calculation of the risk level, the chlorine cloud heights under different scenarios has been adopted based on the findings of approved EIA report for Tsuen Wan Bypass, widening of Tsuen Wan Road between Tsuen Tsing Interchange and Kwai Tsing Interchange, and associated junction improvement works (AEIAR-124/2008):

- Continuous release 30m
- 1 tonne instantaneous release 6m
- 2 tonnes instantaneous release 9m
- 73 tonnes instantaneous release 25m

12.6.9.2 Population lower than the cloud height would be affected. For example, population at 8m will affected by continuous release, 2 tonnes and 73 tonnes instantaneous release. In general, population higher than 30m would be protected.

12.6.9.3 Height protection is applied to the proposed development only, i.e. no height protection is applied to the off-site population. The information of building height can be referred to **Figure 2.2** and **Table 12.4**.

12.6.9.4 As discussed in **Section 12.6.1**, the chlorine storage area within SHWWTW would provide storage up to 73 drums of chlorine gas, the capacity of 1 drum is 1 ton. The chlorine storage area is approximately 50m by 10m in dimension and is located at a terrain level of approximately 30mPD which is about 24m above the level of NLH. **Figure 12.4** shows the relative locations of the chlorine storage area, the neighbouring landuses / terrain, NLH, Sham Shui Kok Drive, Cheung Tung Road, the open seashore and the proposed development at Siu Ho Wan.

12.6.9.5 A consequence analysis has been conducted with DNV GL Phast model to demonstrate chlorine gas dispersion. The results showed that given its higher molecular mass than ambient, chlorine gas will sink upon release and gradually reach the ground. Depending on different meteorological conditions, chlorine will reach ground level within 10 to few hundred meters from the release point for the case in SHWWTW. Thus, during chlorine release events (see **Section 12.6.3** for the description of the events identified), the chlorine gas would follow the existing terrain and flow towards NLH at around 300m away and eventually reach the open seashore at some 400m away. It should be noted that within the northwestern part of the CZ of SHWWTW, the open seafront occupies approximately 1000m which is more than 60% of the total length of the coastline within the CZ (i.e. 1600m). The remaining small portion of some 30% at the periphery of the CZ would be the proposed SPS, the North Lantau RTS, Sham Shui Kok Chlorine Transshipment Dock and the headland in Sham Shui Kok. The proposed and existing buildings would be relatively low (i.e. 5-12mPD) and only the headland could reach up to some 40mPD at the northern tip of the CZ. The QRA model has taken into account the above effect, hence the chlorine cloud is modelled from ground level (i.e. 30m cloud height is 30m from ground level).

12.6.10 Mitigation Measures

12.6.10.1 According to the approved EIA report of the approved Organic Waste Treatment Facilities Phase 1 (OWTF-P1) EIA Report (AEIAR-149/2010), and confirmation from WSD, the chlorine buildings are constructed by reinforced concrete panels. Chlorine releases in small magnitude earthquakes and spontaneous failures would be contained within the chlorine buildings. However, according to the WSD, the reinforced concrete panels are not able to maintain strong magnitude earthquakes. Hence, for conservative assessment purposed, the release of building collapses under external impact has been maintained in the assessment.

12.6.11 Model Validation

12.6.11.1 An in-house GIS based risk model has been developed and calibrated against the findings for background population (Base Case) of previous QRA in the approved EIA report for Integration of Siu Ho Wan and

Silver Mine Bay Water Treatment Works (AEIAR-158/2011). The comparison of Individual Risk Contours and F-N curve for base case from the developed model and the approved EIA study AEIAR-158/2011 for SHWWTW is shown in **Appendix 12.5**. The result from the developed model is in line with the previous study and thus the present model is suitable for use in this study.

12.7 Quantitative Risk Assessment

12.7.1 Individual Risk

12.7.1.1 The individual risk contour of SHWWTW is presented in **Figure 12.5**. The site boundary of the proposed development has been overlaid onto the risk contours.

12.7.1.2 The individual risk levels are calculated for a hypothetical person spending 100% of their time outdoors in the Assessment Area, as such, IR is independent of the surrounding population densities. With reference to **Appendix 12.5**, there are off-site areas where the IR exceeded the 1×10^{-5}/year criterion. It should be noted that these areas are mostly along the hillside around the northwest to southeast boundary of SHW WTW. Due to the constraints in accessibility, there would hardly be any population in these areas. Besides, there is no proposed construction works for the topside development within these particular areas. Hence, the individual risk result is in compliance with the criteria stipulated in Annex 4 of EIAO-TM.

12.7.2 Societal Risk

12.7.2.1 The result of Quantitative Risk Assessment has been presented in this section. For conservative assessment, a representative scenario that both maximum workers in construction phase and full population intake in operational phase have been taken into account for the project.

12.7.2.2 Based on the frequency analysis and consequence modelling for different hazard scenarios discussed in **Sections 12.6,** the Societal Risk Plots (Cumulative Frequency F against number of fatalities N) have been derived for the following cases:

- Base case in Year 2038;
- Project Only - Risk on construction workers (construction activities including SHD topside development, SHO and SHD replanning, SPS and Eastern connection access along Sham Shui Kok Drive) and residential population (full population intake) in the proposed development with transient population in Eastern connection access along Sham Shui Kok Drive, and
- With Project - Cumulative risk on base case population and proposed development during both construction phase and operational phase are presented in **Figure 12.6**.

12.7.2.3 The results for these three scenarios are presented in **Figure 12.6** and tabulated in **Table 12.12**.

Table 12.12 FN values for different cases

Number of fatalities	Base Case	Project Only	With Project
1	1.98E-05	6.12E-07	2.05E-05
2	1.18E-05	6.05E-07	1.20E-05
3	9.88E-06	5.49E-07	1.02E-05
4	8.88E-06	5.32E-07	9.03E-06
5	8.07E-06	4.80E-07	8.49E-06
6	5.23E-06	4.66E-07	7.88E-06
7	4.10E-06	4.66E-07	5.15E-06
8	4.10E-06	4.66E-07	4.10E-06
9	3.82E-06	4.66E-07	3.83E-06
10	3.62E-06	4.58E-07	3.62E-06
20	1.67E-06	1.03E-07	1.78E-06
30	5.94E-07	1.37E-08	6.20E-07
40	5.43E-07	6.80E-09	5.46E-07
50	4.75E-07	6.60E-09	5.17E-07
60	4.60E-07	6.26E-09	4.61E-07
70	4.59E-07	4.72E-09	4.60E-07
80	4.58E-07	3.73E-09	4.59E-07
90	4.58E-07	3.70E-09	4.58E-07
100	3.93E-07	2.92E-09	4.41E-07
200	4.30E-08	1.72E-09	7.94E-08
300	9.04E-09	1.60E-09	1.25E-08
400	2.33E-09	1.15E-09	5.05E-09
500	1.33E-09	8.05E-10	2.91E-09
600	8.46E-10	-	1.94E-09
700	-	-	1.65E-09
800	-	-	1.19E-09
900	-	-	8.75E-10

12.7.2.4 As seen from **Figure 12.6**, for fatalities N less than 230, the Cumulative Frequency falls into "ALARP" region. Further analysis is required to demonstrate the risk as low as reasonably practicable.

12.7.3 Potential Loss of Life

12.7.3.1 The Potential Loss of Life (PLL) value is the summation of the product of each f-N pair. The PLL values under construction phase and operation phase due to the risk impact from SHWWTW are shown in **Table 12.13a** and the breakdown of the PLL by scenario and population of the With Project scenario is shown in **Table 12.13b** and **Table 12.13c** respectively.

Table 12.13a Breakdown of PLL values

Cases	PLL (per year)	% of Total PLL
Base case	2.44E-04	93.4%
Project Only	1.71E-05	6.6%
With Project	2.61E-04	100%

Table 12.13b Breakdown of PLL Values by Scenario

Hazard Scenario no	Component	PLL					
		0-1	>1-10	>10-100	>100-1000	>1000	Total
8	Drum Failure/ External Impacts/Earthquake/ Building Collapses	6.13E-05	6.52E-06	0.00E+00	0.00E+00	0.00E+00	6.78E-05 (26.0%)
18	Fittings/ External Impact/1.7 kg/s release/ Building Collapses	8.23E-06	1.52E-05	5.05E-05	0.00E+00	0.00E+00	7.39E-05 (28.3%)
24	Drum Failure (Onsite Transportation)/ Spontaneous/1 tonne release	4.79E-07	2.43E-05	0.00E+00	0.00E+00	0.00E+00	2.48E-05 (9.5%)
25	Drum Failure (Onsite Transportation)/ Spontaneous/4.5 tonne release	3.25E-07	1.14E-06	5.76E-06	6.89E-05	0.00E+00	7.61E-05 (29.2%)
Other							1.84E-05 (7.0%)
Total							2.61E-04 (100%)

Table 12.13c Breakdown of PLL Values by Population ID

Population Group	PLL (per year)	% of Total PLL
North Lantau Expressway	7.73E-05	29.6%
Organic Waste Treatment Facilities	7.21E-05	27.6%
Railway - Tung Chung Line (TCL) and Airport Express Line (AEL)	4.36E-05	16.7%
City Bus Siu Ho Wan Bus Depot	2.39E-05	9.1%
Other off-site Population [1]	2.75E-05	10.5%
Proposed Development [2]	1.71E-05	6.6%
Total	2.61E-04	100%

Note:

[1] Includes off-site population in **Table 12.3** but not includes North Lantau Expressway (ID 12),

Organic Waste Treatment Facilities (ID 5), Railway - Tung Chung Line (TCL) and Airport Express Line (AEL) (ID 14) and City Bus Siu Ho Wan Bus Depot (ID 3)
[2] Includes all on-site population in **Table 12.4**

12.7.3.2 As seen from **Table 12.13a**, it is observed that the percentage of PLL of the proposed development during both construction and operation phase is 6.57%.

12.7.4 Uncertainty Analysis

12.7.4.1 This QRA analysis has adopted on a number of conservative assumptions and based on 'cautious best estimates':

- Ultimate population has been adopted;
- The maximum number of construction workers has been adopted;
- Peak traffic flows have been adopted for all the hours during daytime of Working Day, Saturday and Sunday;
- The maximum capacities of TCL and AEL have been adopted for all the hours during daytime of Working Day, Saturday and Sunday; and

12.7.4.2 Hence, the QRA has adopted conservative assumptions and the F-N curve shown in **Figure 12.6** is considered conservative. The F-N curve would therefore remain in the ALARP region even uncertainty is considered.

12.7.5 Cost-Benefit Analysis

12.7.5.1 In order to select and justify the most suitable risk mitigation, a cost-benefit analysis (CBA) has been undertaken to consider a wide range of mitigation measures. CBA has been widely used in HA studies to evaluate the cost-effectiveness of various mitigation measures and demonstrate that all reasonably practicable measures have been taken to reduce risks.

12.7.5.2 In this study CBA has been applied by calculating the implied cost of averting a fatality (ICAF) for various mitigation measures identified in **Table 12.14**. Options 1, 2, 5 and 6 are at-source mitigation measures that require implementation by SHW WTW operator, i.e. WSD. Should any of these options be deemed cost effective for risk control in CBA, Project Proponent would liaise with WSD for further feasibility study. The ICAF value is calculated as follows:

12.7.5.3 ICAF = Cost of mitigation measure/(Reduction in PLL value × Design life of mitigation measure).

12.7.5.4 ICAF is a measure of the cost per life saved over the lifetime of the project due to implementation of a particular mitigation measure. It may be compared with the value of life to determine whether a mitigation measure is reasonably practicable to implement, i.e. if ICAF is less than the value of life, then the mitigation measure should be implemented.

In this study the value of life is taken as HK$33M, which is the same figure as used in previous HA report.

12.7.5.5 Depending on the level of risk, the value of life figure may be adjusted to reflect people's aversion to high risk. According to WSD 2001, the aversion factor is taken as 20, as the F-N curve, although in the lower ALARP region of the Risk Guidelines, runs close to the 1000 fatalities cut-off line. The adjusted value of life using the aversion factor of 20 is thus HK$660M.

12.7.5.6 The ICAF values for various mitigation measures identified are presented in **Table 12.14**. As shown in **Table 12.14**, no option could meet the reasonably practicable criterion of ICAF which is less than the "adjusted value of life". Hence, no mitigation measure has been recommended for implementation at the SHW WTW.

12.7.5.7 It should be noted that there is only the proposed SPS within the 1km consultation zone of SHWWTW. Planned comprehensive residential development (including residential, commercial/retail and educational and transport facilities) is outside the consultation zone. In addition, the podium of the proposed development is about 20m above ground and the average building height is about 60m, which is much higher than the maximum height of the dense gas chlorine of 30m. Hence, residential population is protected by the elevated podium design.

12.7.5.8 Ventilation systems for both topside facilities in the podium and the depot have been reviewed. All louvers for the topside facilities in the podium would be located outside the CZ of SHW WTW whereas some of those for the depot would be located within CZ which are, however, will only serve as exhaust outlets. Scenarios leading to a hazard distance of 2.8km are generally of low occurrence frequencies and most scenarios would have hazard distances confined within the CZ. Since there is no fresh air intake points within the CZ, the intake of chlorine in case of chlorine release is considered not likely. Hence, ventilation control for the topside facilities in the podium and the depot are not necessary.

12.7.5.9 To ensure that the construction workers are appropriately evacuated in the event of chlorine release from SHWWTW, adequate training and drills should be provided to the construction workers for efficient evacuation as precautionary measures.

Table 12.14 Cost benefit analysis results

Mitigation measure		Cost estimate (HK$M)	PLL reduction (per year)	Design life (years)	ICAF [1] (HK$M)	Practicable (if ICAF <$660M [2])	Remarks	PLL Reduction	Reference
Option 1	Reduction of chlorine storage at SHWWTW	10	4.79E-07	50	4.17E+05	N	Reduction of storage of chlorine drum to half and building alternative storage elsewhere	50% reduction in PLL due to the store roof collapse	AEIAR-167/2012[12-4]
Option 2	Enhancement of seismic of performance of chlorine storage	5	9.59E-07	50	1.04E+05	N	Measures include Strengthening of columns of chlorine store Replacement of the roof with a light-weight structure Building additional structure to protect the drums	100% reduction in PLL due to the store roof collapse	AEIAR-167/2012[12-4]
Option 3	Suspension of construction work during chlorine deliveries	3	2.24E-06	5	2.68E+05	N	Construction workers are required to evacuate to safe (indoors) location during the chlorine deliveries	100% reduction of construction workers PLL due to chlorine truck accidents in access road	AEIAR-167/2012[12-4]

Mitigation measure		Cost estimate (HK$M)	PLL reduction (per year)	Design life (years)	ICAF [1] (HK$M)	Practicable (if ICAF <$660M [2])	Remarks	PLL Reduction	Reference
Option 4	Limitation of working hours and number of construction workers in the area near SHWWTW	10	6.40E-07	5	3.13E+06	N	Apart from cost, this measure will have programme implication	20% reduction of construction workers PLL	AEIAR-167/2012[12-4]
Option 5	Provision of ozone system to replace chlorine disinfection system	50	1.31E-04	50	7.65E+03	N	This measure involves full replacement of pre-chlorination process. Post-chlorination is still required for prevention of post contamination while distribution of treated water leaving water treatment works	50% reduction in PLL for all hazardous cases	--
Option 6	Provision of disinfection system using sodium hypochlorite to replace chlorine	44	2.61E-04	50	3.37E+03	N	This measure involves full replacement of chlorine disinfection system which is subject to the confirmation of its compliance of disinfection by-product criteria with the associated dosage limitation for dealing with adverse raw water quality.	100% reduction in PLL for all hazardous cases	--

Note:

[1] ICAF = Cost of mitigation measure / (Reduction in PLL value x Design life of mitigation measure)

[2] The value of life is taken as HK$33M, aversion factor is taken as 20. Therefore the adjusted value of life using the aversion factor of 20 is HK$660M

12.8 Hazard-to-life Caused by Elements to be Implemented by SHO and SHD Replanning Works

12.8.1.1 As discussed in **Section 1.3**, the latest implementation strategy has recommended the following items in EIA Study Brief ESB-296/2016 will be separately implemented by the SHO and SHD Replanning Works project which will be addressed in a separate Schedule 2 EIA.

- Railway depot replanning works within the existing site boundary;
- Podium deck and property enabling works for the topside development;
- A new SHO and associated track works, as well as local roads and emergency vehicular access (EVA); and
- Provision of the sewerage network with sewage pumping station to cater sewage generated by SHO and SHD Replanning Works.

12.8.1.2 A series of practicable measures to avoid, minimise and mitigate the potential hazard-to-life during both construction and operational phases have been discussed in **Section 12.7.4**. However, these mitigation measures are not cost effective and good site management practices such as provision of emergency plan for efficient evacuation shall be implemented. In fact, the majority of the depot is located outside the CZ. Only a very small portion of around 8600 m^2 would be within the CZ. For this portion of depot area, it would be designated for depot exit and entry only, where there are no permanent manned facilities.

12.9 Conclusion

12.9.1.1 The potential hazardous sources SHWWTW and SSK Dock are identified near the proposed development. SHWWTW is the only PHI with its consultation zone (CZ) marginally encroached into the SHD while the risk induced by SSK Dock is negligible. The proposed development scheme has avoided locating residential within the CZ to minimise potential risk.

12.9.1.2 For the SHWWTW, an Quantitative Risk Assessment has been conducted to the proposed development and the transient population in eastern connection access.

12.9.1.3 According to the assessment, the proposed site boundaries have been overlaid onto the risk contours and demonstrated that the proposed site does not encroach into the 10^{-5}/ year criterion.

12.9.1.4 The societal risk plots indicate that F-N curves of the overall risk cases from SHWWTW fall into the "ALARP" region. Investigation of potential mitigation measures options are subject to the cost benefit analysis evaluation. The results indicate that no mitigation measures options are cost effective. Nevertheless, precautionary measures such

as provision of emergency plan for efficient evacuation including good practice (i.e. adequate training and drills for construction workers) of chlorine released from SHWWTW during construction phases shall be implemented to further reduce the risk level.

12.10 References

[12-1] AEIAR-158/2011, "Integration of Siu Ho Wan and Silver Mine Bay Water Treatment Works"

[12-2] AEIAR-149/2010, "Organic Waste Treatment Facilities, Phase I

[12-3] VEP-488/2015, "Environmental Review Report (ERR) for Variation of Environmental Permit for OWTF-Phase 1"

[12-4] AEIAR-167/2012, "Shatin to Central Link – Tai Wai to Hung Hom Section"

[12-5] AEIAR-022/1999, "Route 16 Investigation Assignment from West Kowloon to Sha Tin"

[12-6] Withers, R.M.J. and F.P. Lees (1985a), "The Assessment of Major Hazards: The Lethal Toxicity of Chlorine. Part 1. Review of Information on Toxicity". Journal of Hazardous Materials, 12, 231-282.

[12-7] Withers, R.M.J. and F.P. Lees (1985b), "The Assessment of Major Hazards: The Lethal Toxicity of Chlorine. Part 2. Model of Toxicity to Man". Journal of Hazardous Materials, 12, p. 283-302.

[12-8] AEIAR-124/2008, "Tsuen Wan Bypass, widening of Tsuen Wan Road between Tsuen Tsing Interchange and Kwai Tsing Interchange, and associated junction improvement works"

[12-9] Paper No. CB(4)854/15-16(07), Legislative Council Panel on Transport Subcommittee on Matters Relating to Railways, Capacity and Loading of trains in the MTR Network (April 2016)

[12-10] Paper No. CB(1)1132/14-15(01), Development Bureau, Tung Chung New Town Extension Study - Provision of Supplementary Information Requested by Members (July 2015)