14 HAZARD TO LIFE

PART A Assessment for Potentially Hazardous Installations (PHIs)

Introduction

Background

14A.1 The HATS Stage 2A, **Figure 14A.1**, is to collect the sewage from 8 upgraded Preliminary Treatment Works (PTW) at the northern and south-western parts of Hong Kong Island and to convey, through over 20 km of deep sewage tunnel system, to the expanded Stonecutters Island Sewage Treatment Works (SCISTW) for centralized treatment. According to the EIA Study Brief No. ESB-129/2005 [1] Clause 3.4.8.2, Hazard to Life Assessment (HA) is required to be carried out since the proposed works sites at Aberdeen and Ap Lei Chau are located within the consultation zones of two respective Potential Hazardous Installations (PHIs), namely the Hong Kong & China Gas Company's Gas Holder Depot (PHI No. H4) (hereinafter referred to as "HKCG Depot") and the Shell LPG Transit Depot/Bulk Domestic Supply (PHI No. H5) (hereinafter referred to as "Shell Depot").

Scope of Study

14A.2 The scope of the HA is focused on addressing the following issues, together with any other key issues identified during the course of the EIA Study.

- Potential hazard impacts on two proposed works sites at Aberdeen and Ap Lei Chau which are located within the consultation zones of two respective Potential Hazardous Installations (PHIs). For the Ap Lei Chau work site, the LPG Transit Depot and Bulk Domestic Supply are 2 separate systems and are operated independently with 120m separation distance; and
- Potential impacts on the existing PHIs, namely the HKCG Depot (PHI No. H4) near Aberdeen PTW and the Shell Depot (PHI No. H5) near Ap Lei Chau PTW arising from the construction of any drop shaft, trench or underground tunnel, etc that has the propensity to cause ground subsidence (off-site accident initiator) leading to catastrophic failure of vessels, equipment or installations within the PHIs (on-site accident).

14A.3 According to the technical requirements specified in Section 3.4.8 of the EIA Study Brief [1], the HA is carried out following the criteria for evaluating hazard to life as stated in Annexes 4 and 22 of the TM [2] (Hong Kong Risk Guidelines).

14A.4 The HA includes the followings:

- assess the risks associated with all aspects of the construction and operation of the Project;
- assess the hazards associated with the storage and use of any other dangerous goods or hazardous activities present on site;
- ascertain whether the overall risks posed by the activities of the Project are acceptable, taking into account the risk guidelines set out in section 4.4 of Chapter 12 of the Hong Kong Planning Standards & Guidelines;
- recommend mitigation measures where the risk is considered in the ALARP (As Low As Reasonably Practicable) region or above, and to quantify the reduction in risk achievable by these means; and
- recommend measures, including relocation of works area(s), that would prevent accidental damage to the adjacent PHIs and their associated pipelines during construction and operation of the Project.

Study Approach

Overview

14A.5 This section outlines the approach of the HA for the construction and operational stage of the Project.

14A.6 In order to assess the risks associated with all aspects of the construction and operational stages of the Project, three assessment timeframes have been identified as follows.

- **Baseline Case** – Assessment of baseline case risk level based on current PHI operations, population and existing PTW operation conditions. If information from previous risk assessment of the two PHIs were available, technical parameters from previous studies would be adopted in assessment of the baseline case; otherwise best available information will be adopted to construct the baseline case model. Results from this baseline case would be benchmarked with selected previous studies wherever they are available.
- **Construction Stage Case** – Assessment of risk level during construction of the Project taking into account the peak construction workforce level and adjacent population at that time.
- **Operational Stage Case** – Assessment of risk level during operational stage of the Project taking into account the number of operators in PTW and adjacent population at that time.

14A.7 The HA consists of five major steps given below:

- **Study Base:** identifies details of PHIs. Meteorological data/ignition sources and population data are collected for consequence modelling and risk summation respectively. Topographical and architectural features are identified for any shielding effect to population.
- **Hazard Identification:** identifies hazards associated with the PHIs and the construction and operation activities. HAZOP workshops have been conducted in June 2007. The potential hazards identified and recorded in the Hazard Registers will be used as an input for scenarios development for analysis in the next stages.
- **Frequency Assessment:** assess the likelihood of occurrence of the identified hazardous scenarios by reviewing historical accident data or using Fault Tree Analysis. Event Tree Analysis will be adopted to determine the possible outcome from the identified hazardous events and to estimate the frequencies.
- **Consequence Assessment:** the consequences will be established for every outcome developed from initial event by using DNV's *SAFETI Professional*, Version 6.51 software to assess the impacts from gas leaks, fires, explosions, toxicity and other process hazards.
- **Risk Assessment:** evaluates the risks level, in terms of individual risk and societal risk, associated with the identified hazardous scenarios. The overall risk level will be compared with the criteria as stipulated in Annex 4 of the TM to determine their acceptability. Mitigation measures will be identified where the risk is considered in the ALARP (*As Low As Reasonably Practicable*) region or above. The reduction in risk achievable by these means will then be quantified.
- **Recommendation of Safety Measures:** Upon completion of the risk assessment, safety measures will be identified to reduce risk of accident damage to the adjacent PHIs and their associated pipelines during construction and operation of the Project. In addition, measures for reducing impacts to construction workers due to accident in PHIs will also be provided.

14A.8 Considering the differences in characteristics of the products (LPG and Towngas) storage as well as the distinct operations in these two PHIs, site-specific assessment for each PHI is conducted using the same approach as described in previous subsections.

Risk Acceptability Criteria

14A.9 As set out in Annex 4 of the EIAO TM [2], the risk guidelines comprise two measures shown as follows:

- **Individual Risk**: the maximum level of off-site individual risk should not exceed 1 in 100,000 per year, i.e. 1 x 10^{-5} / year.
- **Societal Risk**: it can be presented graphically as in **Figure 14A.2**. 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.

Study Basis

Overview of PHIs

14A.10 The plant details including storage of flammable inventories, plant facilities and operation details of the HKCG Depot and the Shell Depot are collected from the corresponding PHI owners. This information is reviewed and used to identify potential hazardous scenarios associated with the PHIs. In case that data is not fully available, engineering judgement and/or assumptions are made. These assumptions and judgement are clearly documented in the Appendix 14A.7 of this study report.

14A.11 Future development, if exists, of the PHIs is considered to ensure using the latest data for risk calculation. In additional to physical layout of the PHIs, operation details, such as LPG Road Tanker transfer schedules, are consolidated for determination of hazardous scenarios.

HKCG Depot Details

14A.12 The HKCG Depot adjoins the Aberdeen PTW at the east boundary of the depot. According to the 2007 PHI Register (as at 31st January 2007) issued by the Housing, Planning, and Lands Bureau, the Gas Holder has a storage capacity of 17.7 tonnes of Towngas, which is above the threshold limit of 15 tonnes for classification as a PHI. The designated consultation zone (CZ) of 150m from the gasholder is applied to the facility, as shown in **Figure 14A.3**.

14A.13 The HKCG Depot consists of a gas holder and a plant building in which the governor, the boosters and engines are installed.

14A.14 The gas holder is served as a temporary storage to cope with network requirement and peak shaving in winter. There are approximately 48 operations in a year for the gas holder. In each operation, the gas holder is loaded up to approximately 80% of the total capacity for maximum 24 hours. Normal inventory level is kept to 3 tonnes when the gas holder is not in operation. The gas pressure is reduced from medium pressure (MP) through spill-over governor and stored in the gas holder under low pressure (LP) via a 20m in length inlet gas pipe. Out-flowing gas is fed to booster room from the gas holder via a 20m outlet gas pipe and is pressurised to MP for distribution. Both inlet and outlet gas pipe are 600mm in diameter. There is an overhead section at 5m aboveground near the depot entrance. Layout plan of the HKCG depot is depicted in **Figure 14A.4**.

14A.15 Town gas is mainly composed of hydrogen, methane, carbon dioxide and carbon monoxide. Physical properties of the mixture are listed in **Table 14A.1** and **Table 14A.2**.

Table 14A.1 Composition of Towngas

Material	Composition (% volume)
Hydrogen	48.1
Methane	29.4
Carbon dioxide	19.5
Carbon monoxide	3

Table 14A.2 Physical Properties and Storage Conditions of Towngas

Properties	Values
Physical state	Gaseous (pressurised)
Storage pressure	7.5 – 240 kPa (MP) 2 – 7.5 kPa (LP)
Storage temperature	Ambient
Average molecular mass	15.1 kg/kmole
Specific heat ratio	1.344
Calorific value	17.27 MJ/m^3
Lower Flammability Limit	5.5%

Shell Depot Details

14A.16 The Shell Depot (PHI No. H5) adjoins the Ap Lei Chau PTW at the south boundary. According to information provided by the depot operator, the depot is composed of 2 sections, namely the storage & transit section (approximately 60m away from PTW site) for LPG products and the LPG compound for supply of LPG to consumers at South Horizons Plaza. Layout plan of the Shell Depot is shown on **Figure 14A.6**. The designated consultation zone (CZ) of 500m from the Shell Depot is applied to the facility, as shown in **Figure 14A.5**.

14A.17 The LPG compound, **Figure 14A.7**, adjoins the northern boundary of the ALC PTW site. The existing facility includes 2 units of 20-ton mounded LPG vessels and 7 units of vaporizers (5 units are hot water type and the rest are coil-heated type). Under normal operation, the 2 LPG vessels are filled up to no more than 85% of the total capacity (34 tons). Daily consumption is approximately 7 tons. Minimum stock of 28 tons is maintained for supply of 4 days in case of interrupt to delivery. Replenishment frequency is about 6 times a week. Loading process takes 2 hours during daytime only. Gaseous LPG is delivered to South Horizons through a 150mm gas pipeline. The beginning section of the pipeline is above ground running along the west boundary of the depot for about 60m. The rest is buried underground and runs across the depot towards and along the east boundary.

14A.18 Within the storage & transit section, there is a LPG cylinder shed at the north of the depot, **Figure 14A.6**. Cylinders of capacities ranging from 2kg to 49kg are stored onsite with average inventory of 2,000 cylinders. The depot operator also loads/unloads gas cylinders to/from LPG cylinder wagons of local gas distributors at LPG storage platform for consumption in Hong Kong Island South. The LPG storage platform is located at waterfront near entrance of the depot and is for temporary handling of LPG cylinders only. LPG cylinders are delivered to the store via ferry service. Apart from LPG cylinders, the ro-ro ferry pier is a landing place for LPG road tankers (9 Tons) and LPG cylinder wagons for supply of LPG in Hong Kong Island. Road tankers and cylinder wagons leave the depot via the common exit/entrance which is at middle of the southeast boundary off the Lee Nam Road. Length of the access road within the depot is about 200m. Based on data for the period between 1st and 27th September 2007 supplied by the depot operator, daily utilisation of the ferry pier is tabulated in **Table 14A.3**.

Table 14A.3 Daily Utilisation of Ferry Service Between 1st and 27th Sept 2007

Vehicle Type	Arrival	Departure
LPG Road Tanker	2 (loaded)	2 (empty)
LPG Cylinder Wagon	2 (loaded)	2 (empty)

Approach of Population Estimations

14A.19 Population Data, which indicate the presence and locations of people in surrounding areas, are collected in order to evaluate the human impact of a hazardous release from the PHIs. The manning level of the construction works and the number of operators working in the upgraded PTW are also assessed.

14A.20 Data from the Population Census are consolidated to determine the existing population in vicinity of the PHIs. For the population at locations not covered by the Population Census, a site visit was conducted to estimate the population at various locations based on observation on-site and communication with on-site personnel.

14A.21 Transient population, such as vehicle traffic, are consolidated from the Annual Traffic Census of Transport Department. The number of people travelling is derived according to traffic flow rate and traffic mix at different time modes (e.g. day, night, peak, weekend, weekday, etc). Traffic mix includes passenger car, light and heavy goods vehicle and bus.

14A.22 For future stationary and transient population, the growth rates of the population are estimated based on the Planning Department's "Projection of Population Distribution 2006-2015" for the assessment years 2009 and 2014 and data provided by Planning Department. These growth rates are applied to the 2006 residential population consolidated to obtain the population in assessment years.

14A.23 In order to reflect temporal distribution of population, time period is divided into 4 time modes namely daytime (07:00–19:00) and night-time (19:00–07:00) for both weekend and weekday. In general, assumption of temporal variation in population for different population categories is tabulated in **Table 14A.4**.

Table 14A.4 Temporal Changes in Population for Various Categories

Time period	Residential Dwellings	Shopping Centre	Industrial/Commercial Buildings
Weekday (day)	25%	50%	100%
Weekday (night)	100%	0%	10%
Weekend (day)	70%	100%	40%
Weekend (night)	100%	0%	5%

14A.24 These figures have been applied to various hazard assessments such as Comprehensive Feasibility Study for the Revised Scheme of South East Kowloon Development (SEKD) [6] in which building types are similar to those in the Aberdeen and the Ap Lei Chau projects. Since the Aberdeen PTW and the Ap Lei Chau PTW are public utilities, they are not classified as commercial/industrial buildings. Data supplied by DSD is used for both daytime and night-time populations instead.

14A.25 Population indoor is well protected by the building structure and therefore impacts to indoor populations are relatively lower than that of the outdoor populations. Therefore, escape and shielding factors are applied to the population data to ensure a realistic assessment. While population is usually protected by building or population site, indoor ratio of 95% is assumed for buildings [3].

Population for Aberdeen Site

14A.26 There is a seafront, Kai Lung Wan, to the south of the HKCG Depot. A gradual hill slope can be found to the north of the gas holder. Buildings sit on the same ground level as the HKCG Depot at the east and the west direction. Shielding effect of topographical features is not considered as significant. Populations in the following locations adjacent to the Aberdeen PTW Site are considered in this study.

- The Aberdeen PTW
- Concrete batching plant at 70m west of the PTW
- Tin Wan Praya Road
- Shek Pai Wan Road
- Wah Kwai Estate and associated social facilities/ recreational facilities
- Ka Lung Court and associated recreational facilities
- Hing Wai Ice & Cold Storage
- Hing Wai Centre
- Open area car park opposite to the HKCG Depot
- Aberdeen West Typhoon Shelter

14A.27 The numbers of personnel currently present on the PTW site are up to 22 during daytime and 6 during night-time. Due to recent advances in plant instrumentation and control, it is assumed that the present staffing level required to operate the PTW would be relatively lower than that in late 1970s when the PTW was first commissioned. Furthermore, the number of operation personnel on the PTW site will be reduced to 18 during construction phase. After completion of construction (from 2014 onwards), the number of operation personnel on the PTW site will remain the same as at present.

14A.28 During construction stage, i.e. from 2009 to 2014, the upgrading works of the PTW mainly include demolition/reconstruction of existing structure in small scale, low-rise buildings and installation of electrical and mechanical equipment. Yet, this would have to be conducted over a relatively long period of 3.5 years, as the activities must be done in phases to minimize interruption to PTW operation. It is estimated that the total number of HATS construction workers for the PTW works would be 60 in which 40 is for PTW upgrading works, 14 is for aboveground SCS works and 6 is for underground SCS works during construction stage. However, PTW works and SCS tunnelling works will be carried out in separate construction phases. Thus, the maximum number of construction workers at any time will be 40 from PTW upgrading works. And it is assumed that no construction worker would work overnight.

14A.29 Consultation with the current operator of the concrete plant has revealed that the number of personnel currently present on site is about 49 (comprising 12 plant staff and 37 concrete truck drivers), corresponding to an average production of 25,000m^3 of concrete per month. Previously, during the peak periods before 2004 when the plant ran at 47,000m^3 per month, there was as many as 80 staff (20 plant staff and 60 drivers) on site. To take a conservative approach, maximum population of the concrete plant in the assessment is 80.

14A.30 The Consultant was informed that the current lease for the concrete plant will expire in 2008. It is unclear if the concrete plant will continue to operate after 2008. According to circulation between Planning Department and other relevant authorities, strong local requests for closing down the plant have been received since 1990's and no in-principle objection to changing the use of the site even without a replacement site for the plant has been received from relevant authorities, **Appendix 14A.3**. Although Commission of Tourism has proposed a conceptual design of using the site for coach parking, no further detailed information is available at this stage. Therefore, it is assumed that the concrete plant will still be operating during the construction phase of the PTW and onwards for conservativeness in this assessment.

14A.31 Summary on population data being adopted in the assessment is tabulated in **Table 14A.5**.

Table 14A.5 Population Data for the Aberdeen Project

Population Group	Existing (Year 2006)	Construction Phase (Year 2009)	Operation Phase (Year 2014)
Wah Kwai Estate (1)	11,284	10,842	10,569
Wah Kwai Community Centre (3)	60	58	56
Wah Kwai Vocational and Re-habilitation Centre (3)	150	144	140
Wah Kwai Shopping Centre (2)	500	480	468
Wah Kwai Bus Terminus (3)	100	96	94
Wah Kwai Open Area Car Park (3)	8	8	8
Wah Kwai Outdoor Playgrounds (at 4 locations) (3)	80	80	80
Wah Kwai Sport Courts (at 3 locations) (3)	60	60	60
Wah Kwai Sitting-out Areas (at 2 locations) (3)	40	40	40
Ka Lung Court (1)	5,264	5,058	4,931
Ka Lung Court Outdoor Playgrounds (at 1 location) (3)	20	20	20
Ka Lung Court Sport Courts (at 2 locations) (3)	20	20	20
TinWan Praya Rd Car Park (3)	8	8	8
Dairy Farm Ice & Cold Storage (4)	60	60	60
Hing Wai Ice & Cold Storage (3)	60	60	60
Hing Wai Centre (3)	600	600	600
Aberdeen West Typhoon Shelter (3)	50	50	50
Shek Pai Wan Playground (3)	20	20	20
Shek Pai Wan Road (3,5)	92	111	94
Tin Wan Praya Road (3,5)	13	13	13
Concrete Plant (3)	80	80	80
Aberdeen PTW DSD Operators (6)	22	18	22
Aberdeen PTW Construction Site (7)	0	40	0

Sources:
(1) HK Census/ Planning Department
(2) Based on data available from The Link
(3) Site/ Telephone survey
(4) Estimated from Hing Wai Ice & Cold Storage
(5) Based on Traffic Census –100% and 25% of Aberdeen Praya Road for Shek Pai Wan Road and Tin Wan Praya Road respectively
(6) Data from DSD
(7) Project consultants; consider only aboveground workers at the PTW work area

Population for Ap Lei Chau site

14A.32 There is a steep slope at east of the Shell Depot along Lee Nam Road. By taking into account this topographical feature, only 700m of Lee Nam Road is exposed to the risk imposed by the depot. Although there is a playground at junction of Ap Lei Chau Bridge Road and Lee Nam Road, it is protected by the slope and is not considered in this assessment.

14A.33 At the top of the slope, Ap Lei Chau No. 2 Fresh Water Service Reservoir is located approximately 100m east of the LPG depot at 80m elevated height. Besides, it is outside the maximum fireball diameter obtained from consequence modelling (PHAST model) and is far beyond the LPG cloud height. Workers at the service reservoir are protected by the topographical feature and are not further considered in the assessment.

14A.34 Although there are more than 30 residential buildings together with the Marina Square located inside the South Horizons Area, only population at residential blocks are accounted for as they either have direct line of sight to the Shell depot or at perimeter of the South Horizons development. Besides, it is also assumed that a building is shielded by itself and other buildings at various degrees in fireball events. Upper floors of a building are also protected from impact of a vapour cloud.

14A.35 Having taken into account the topographical features, populations in the following locations adjacent to the Ap Lei Chau PTW Site are considered in this study.

- The Ap Lei Chau PTW
- South Horizons
- Lee Nam Road
- Hong Kong School of Motoring Driving Centre
- Material store for Highway Department to the south of the PTW
- Dah Chong Hong (industrial building)
- Horizon Plaza (industrial building)

14A.36 The numbers of personnel currently present on the PTW site are up to 4 during daytime and 2 during night-time. The number of personnel will be reduced to 3 and 2 at daytime and night-time respectively during construction phase. After completion of construction (from 2014 onwards), the number of operation personnel on the PTW site will remain the same as at present.

14A.37 During the HATS Stage 2A peak construction periods, around 50 workers with approximately 10% at indoor and 15 (11 for aboveground work and 4 for underground work) construction personnel related to PTW upgrading and tunnel construction (including spoil removal truck) respectively will be present in daytime at any one time. It is assumed that no workers will work at night-time.

14A.38 Summary on population data being adopted in the assessment is tabulated in **Table 14A.6**.

Table 14A.6 Population Data for the Ap Lei Chau Project

Population Group	Existing (Year 2006)	Construction Phase (Year 2009)	Operation Phase (Year 2014)
South Horizons Blocks 7 to 33A (1)	26,819	27,252	27,800
Horizon Plaza (6)	3,000	3,180	3,480
Dah Chong Hong (6)	750	795	870
Driving School (2)	50	50	50
Highway Department Material Store (2)	2	2	2
Lee Nam Road (3)	16	16	16
Ap Lei Chau PTW – DSD Operators (4)	4	3	4
Ap Lei Chau PTW Construction Site (5)	0	61	0

Sources:
(1) HK Census/ Planning Department
(2) Site/ Telephone survey
(3) Based on Traffic Census – 20% of Ap Lei Chau Bridge Road
(4) Data from DSD
(5) Project consultants; consider only aboveground workers at the PTW work area
(6) Estimation based on floor area

Meteorological Data

14A.39 Meteorological conditions affect the consequence of gas release in particular the wind direction, speed and stability which influences the direction and degree of turbulence of gas in the dispersion process. Meteorological data for year 2006 from Wong Chuk Hang weather station of the Hong Kong Observatory are collected and adopted in the consequence model to determine the various gas dispersion, fire and explosion effect. 6 sets of weather class (combination of wind speed-stability class) for both daytime and night-time are identified in accordance with [7] and adopted in the risk assessment. Summary on meteorological data analysis is tabulated in **Table 14A.7**.

Table 14A.7 Meteorological Data Analysis

Day						
Wind Direction	**Weather Class**					
	B 3.1	**D 1.7**	**D 3.8**	**D 7.8**	**E 2.9**	**F 1.4**
0	0.0160	0.0062	0.0052	0.0002	0.0027	0.0107
30	0.0170	0.0045	0.0090	0.0000	0.0035	0.0067
60	0.0292	0.0055	0.0102	0.0000	0.0062	0.0110
90	0.0959	0.0090	0.0400	0.0092	0.0092	0.0155
120	0.1815	0.0200	0.0498	0.0155	0.0110	0.0217
150	0.1146	0.0157	0.0085	0.0007	0.0015	0.0150
180	0.0152	0.0057	0.0010	0.0000	0.0007	0.0055
210	0.0100	0.0042	0.0000	0.0000	0.0000	0.0047
240	0.0355	0.0057	0.0010	0.0000	0.0000	0.0075
270	0.0280	0.0052	0.0010	0.0000	0.0002	0.0055
300	0.0212	0.0032	0.0035	0.0000	0.0015	0.0052
330	0.0245	0.0035	0.0082	0.0005	0.0035	0.0105
Night						
Wind Direction	**Weather Class**					
	B 1.0	**D 1.9**	**D 4.1**	**D 7.5**	**E 3.0**	**F 1.3**
0	0.0000	0.0000	0.0058	0.0003	0.0053	0.0671
30	0.0000	0.0003	0.0178	0.0006	0.0122	0.0395
60	0.0000	0.0000	0.0131	0.0003	0.0145	0.0448
90	0.0000	0.0000	0.0913	0.0170	0.0465	0.0737
120	0.0000	0.0000	0.0810	0.0145	0.0493	0.0940
150	0.0000	0.0000	0.0036	0.0006	0.0047	0.0604
180	0.0000	0.0000	0.0003	0.0000	0.0000	0.0365
210	0.0000	0.0000	0.0000	0.0000	0.0003	0.0351
240	0.0000	0.0003	0.0014	0.0000	0.0025	0.0398
270	0.0000	0.0000	0.0006	0.0000	0.0022	0.0323
300	0.0000	0.0000	0.0050	0.0003	0.0011	0.0259
330	0.0000	0.0000	0.0134	0.0017	0.0072	0.0359

Source of Ignition

14A.40 The presence of ignition sources is a primary concern in case of inflammable gas release. Ignition sources (other than onsite one), such as dwellings and vehicles along carriageways, contribute to delayed ignition in VCE and flash fire. The energy level, timing, location of ignition sources in the vicinity of the PHIs and hence the probability of ignition of gas cloud is reviewed and assessed.

14A.41 Two types of ignition source are defined in the risk model. Transportation polylines are defined for roads. The presence time of a road is calculated from its traffic density, average vehicle speed and total length of the road segments. Traffic data is consistent with those for population calculation. Ignition probability is taken as 0.5. Another ignition source, due to activities of population such as cooking and using electrical appliances, is assigned implicitly to all population groups by SAFETI.

Hazard Events at the Existing HKCG Depot

Overview

14A.42 The hazardous event of the HKCG Depot is gas leakage that may lead to fire, explosion and toxicity. Gas leakage could be initiated by external events such as damage of gas installations by third parties. Historical data sources, previous risk assessment report [5] and MHIDAS database have been reviewed. Generic hazardous events associated with the operation of the HKCG Depot are listed in **Table 14A.8**.

Table 14A.8 Hazards Associate with Operation of HKCG Depot

Hazard event	Potential Cause
Spontaneous failure	• Gas holder failure • Pipework failure • Flange gasket failure • Valve leakage failure • Pump failure
Partial failure	• Gas holder leakage • Pipework leakage • Blown seal
External event	• Earthquake • Car crash • Aircrafts crash • Ship collision at seafront • Landslide • Severe environmental events • Lightning Strike • Dropped Object • Subsidence • External Fire • Collapse and Strike by object • Vibration

Gas Holder Failure

14A.43 The gas holder at Aberdeen is column guided water-seal type and is sited on piled foundation to rock level. This piled foundation provides sufficient bearing to support the loading of the gas holder and it is not susceptible to ground settlement. Steel rigid frame with steel columns for guiding the movement of the gas holder crown is erected surrounding the gas tank. The crown is fitted with rollers for smooth movement. The crown is supported by the gas stock when the gas holder is filled with Towngas. The gas holder is designed to withstand wind loading applied to the floating roof and transfer wind load to the columns.

14A.44 Under additional strain, the gas holder may be distorted and may not operate properly. Subsequently, alignment of guide rollers or guiding columns could be changed. Crown movement can be hindered by structural deformation. Those damages may develop into other failure modes (such as crack, distortion, dislocation, fracture and destruction). Moreover, a jammed crown could lead to tank overpressure and blown-seal when Towngas is pumping continuously into the gas holder. Similarly, a jammed crown could lead to tank under-pressure and collapse of roof when Towngas is drawing continuously from the gas holder.

14A.45 Damage to the gas holder or its structure may lead to disruption of gas supply. In the severe case, such damage may lead to gas leakage and even structural failure. External interferences increase shear load and weaken welding lines and joints as well as impose additional strains to gas holder sheeting. Failure of gas holder can be caused by external stress. Thus, risk of gas release is increased.

14A.46 Failure of gas holder can be cold catastrophic, which may be caused by corrosion, fatigue due to thermal and pressure loading, material or construction defect, leading to instantaneous release of Towngas. In cold partial failure, it results in continuous release of Towngas to the atmosphere through a crack or leak.

Governor and Inlet Pipeline Failure

14A.47 Governors controls and regulates pressures of gas inflow from the medium pressure network to the gas holder and is sensitive to interferences. In case of minor accident, interferences would disturb inflow of gas towards the gas holder. In case of overpressure, inlet pipeline would be overloaded and lead to full bore rupture or leak at the pipeline. In the worst scenario, it triggers failure of the gas holder leading to lifting off the floating roof or blown seal. Damage to gas governor may lead to large scale Towngas release from distribution network side in short period of time. However, emergency isolation of gas supply for a particular section of pipework can effectively stop the leak.

Outlet Pipeline and Booster Failure

14A.48 Booster pressurises gas stock and feeds gas stock from gas holder back to distribution network. Damage to booster leads to interruption of gas supplied from the gas holder. It would result in pressure drop in the distribution network when demand from consumers is high.

14A.49 Failure along pipeline may also be caused by undetected corrosion, fatigue, material or construction defect, or associated with flange gasket/valve leakage failure leading to instantaneous gas release. In cold partial failure, it results in continuous gas release to the atmosphere through a crack or leak.

Flange/Gasket and Valve Leak Failures

14A.50 Failures of gaskets and valve leak would only tend to give relatively small scale of leakage and will not contribute to the off-site risk. The results from gasket failure will not be considered separately but absorbed into pipework failure in the study.

External Events

<u>Car crash</u>

14A.51 No unauthorised vehicle is allowed and speed restriction is imposed within the HKCG Depot. Besides, safety markings and marked protective fencing are provided to the above ground pipelines near the entrance and the gas holder. Based on statistical data for fatal traffic accident involving medium and heavy goods vehicles between year 2002 and year 2006, accident rate of 6.37×10^{-9} per km.year is calculated. Car crash leading to failure of gas facility is estimated 5.81×10^{-7} per year from fault tree analysis (Appendix 14A.5).

<u>Earthquake</u>

14A.52 In Hong Kong, buildings and infrastructures are designed to withstand earthquakes up to Modified Mercali Intensity (MMI) VII. It is estimated that MMI VIII is required to provide sufficient intensity to result in damage to specially designed structure. It is assumed that failure in earthquake is possible for gas holder leakage, pipeline rupture and leakage only and probability of failure in earthquake is assumed 0.01 [11]. The probability of earthquake occurrence at MMI VIII and higher is very low comparing with other places and is estimated to be 1.0×10^{-5} per year [5].

<u>Aircraft crash</u>

14A.53 The distance between the nearest arrival flight path and the Depot is more than 2 miles. The distance between the Depot and Chek Lap Kok International Airport is over 5 miles which is the criteria for the consideration of airfield accident. At such distances, the PHI site is not covered by critical takeoff and landing phases. The frequency of aircraft crash is estimated using the methodology of the HSE [9] which has been applied to LNG Terminal EIA study [5] and other EIA studies. The number of runway movements of aircraft is extracted from yearly statistics of the Hong Kong International Airport between years 1998 and 2006. Movement number in year 2009 and 2014 is estimated by linear regression. Accident rates on depot being hit by an aircraft for years 2006, 2009 and 2014 are 1.4×10^{-13}, 1.6×10^{-13} and 2.0×10^{-13} per year respectively. Since the calculated accident rates are much smaller than order of 10^{-9}, failure caused by aircraft crash is not considered further in the assessment.

<u>Ship collision at seafront</u>

14A.54 Ships anchoring at Kai Lung Wan are mostly fishing boats and barges for the adjacent concrete plant. Size of ships is rather small and low in profile and speed. Besides, seafront is protected by a seawall. Ship collision at seafront leading to gas facilities failure does not exist.

<u>Landslide</u>

14A.55 The HKCG Depot is at least 40m from toe of a slope of 20-35m height Slope No. 11SW-C/F 348. The slope is not classified as dangerous hillside slope and does not require non-routine maintenance. There is no record of severe landslide for the slope. The slope is well maintained, fully covered by vegetation and it is separated by Tin Wan Praya and an open area car park.

<u>Severe environmental event</u>

14A.56 Loss of containment due to severe environmental event such as typhoon or tsunami (large scale tidal wave) is not possible as the Depot is designed to withstand wind load for local typhoon while Hong Kong is not threatened by tsunami.

<u>Subsidence</u>

14A.57 Subsidence is usually slow in movement and such movement can be observed and remedial action can be taken in time. Besides, the Depot has been built for more than 30 years. During construction phase, the increase of probability of subsidence is derived from the EGIG pipeline failure database [10], taking the failure frequency for “ground movement” and assuming it will always lead to a full bore pipe rupture. After considering the length of pipe section (40 m) and duration of tunnelling work (4 months of out 12 months in 1 year, equivalent to time fraction 0.33), the frequency of subsidence leading to pipework failure at Aberdeen PTW is 3.88×10^{-7} per year.

<u>External fire</u>

14A.58 External fire means the occurrence of fire event which lead to the failure of the gas holder or other facilities. The key potential concern relates to the gas holder and pipelines being affected by the on-site diesel tank. By considering location of the diesel tank, the tank is installed underground. Fire fighting equipment is also provided. Therefore, it can be assumed that such external fire will not lead to any disastrous outcome.

<u>Lightning strike</u>

14A.59 The frequency of a lightning strike on properly protected building is extremely low in Hong Kong. Risk resulting from lightning strike on the gas holder and facilities is extremely low, as the steel frame embracing the gas holder is the tallest structure within the Depot on which 2 units of lightning rod are installed. With sufficient protection system, no further consideration is given for effect of lightning strike in this assessment.

<u>Dropped object</u>

14A.60 Production process of the concrete plant right next to the HKCG Depot is carried out in enclosed environment. Moreover, there is a concrete fence wall next to Tin Wan Praya Road. The depot is protected from flying debris generated by moving vehicles. Although the gas holder and pipelines are installed aboveground, there is no potential damage from dropped object.

Collapse and Strike by object & Vibration

14A.61 There is no risk of damage to the gas depot by collapse and strike of surrounding object in the existing setup. This factor is further elaborated in sections regarding construction activities in the Aberdeen PTW.

Hazard Events Initiated by Aberdeen PTW and Safety Measures

Overview

14A.62 A systematic brainstorming HAZOP workshop was conducted in June 2007 for the HKCG Depot. Participants include the representatives from HKCG, risk specialist and subject engineers. Details of hazards identified are given in the hazard register attached in **Appendix 14A.1** of this document. All these identified hazards are evaluated for development of the risk model.

14A.63 Referring to Paragraph 72 of judgment from the Court of Final Appeal (FACV 28/2005): "…it is appreciated that a QRA, in order to satisfy the exigencies of Annex 4, must be both generic and project-specific, that the methodology searches for the relevant scenarios in the history of projects of the same genus- and thus identifies scenarios for the purposes of para. (i) – then quantifies risk by reference to that history and the specific features of the instant project …". A review of historical incidents has been conducted to identify hazardous scenarios and frequencies of occurrence of these scenarios.

14A.64 Impact on the HKCG Depot due to activities of construction and operations as well as the DG storage of the Project is assessed. The following subsections summarised the hazardous scenarios identified from the activities of the Project during construction and operational stage.

14A.65 Amongst all external events in **Table 14A.8**, risk of occurrence for subsidence, external fire and dropped objects would be increased by construction activities of the PTW works. These activities are further developed to various hazardous scenarios in the following subsections.

Construction and Operation activities in Aberdeen PTW

14A.66 Review on construction and operation activities have been conducted prior to the HAZOP workshops held in June 2007. These activities and the hazards identified in the workshops are recorded in Hazard Registers as attached in **Appendix 14A.1** for the Aberdeen site. These hazards and the relative information are the basis for further development of the risk model.

14A.67 It has been confirmed that construction activities will be conducted within the 150m CZ of the HKCG Depot (except that the production shaft of the tunnel is outside the zone). Activities related to the Project in vicinity of the HKCG Depot are listed below and are indicated on **Figure 14A.8**.

- *Upgrading of PTW* - Relevant construction works will last for about 3.5 years and will involve demolition of existing buildings and construction of new buildings & structures, installation of electrical and mechanical equipment, reconstruction of a section of the existing seawall as well as laying of sewers, drainage pipes, and other utility lines. Shallow excavation (less than 5m) will be required for construction of the treatment plant building, except for manholes/pits and the grit traps where excavation at these locations could be down to depths of about 8m below ground level. Sheet piling and non-percussive piling works will also be undertaken.
- *Construction of Drop Shaft and Tunnels* - A sewage tunnel "P" of finished diameter 1,500mm (approximate excavated diameter to be 3,000mm) will be constructed underneath Tin Wan Praya Road at depth of around 70m below ground in solid bedrock. Construction method will be "drill and blast". Construction of the tunnel "Q" connecting a drop shaft at the Ap Lei Chau PTW will adopt Horizontal

Directional Drill (HDD) methods with no explosive to be involved. Mechanical boring method will be adopted for construction of drop shaft and riser shaft at the Aberdeen PTW. Again, no blasting work will be involved.

- *Reconstruction of Seawall* – 29m of the existing seawall will be demolished and reconstructed to cater for PTW upgrading works and a new seawater intake connecting to the new seawater pumping house. Another 24m of seawall will be demolished and reconstructed only for the PTW upgrading works. Extent of the affected seawall (Total 53m) is indicated in **Figure 14A.9**.
- *Temporary Storage* - Tunnel construction plants, materials and equipment will be stored at a work area opposite to the HKCG Depot on the other side of Tin Wan Praya Road.

14A.68 The upgraded PTW, as shown in the layout plan **Figure 14A.10**, will be operated in a similar fashion to the existing one although the treatment capacity will be increased. An administration office building, a maintenance workshop, and a spare parts store will be established in the upgraded PTW. It will serve as DSD's depot for Hong Kong Island South region. A DG store will be set up as a depot to support regional need. Lubricants, paints, gas cylinders for gas welding and bleach will be stored in this store.

Hazardous Scenarios – Construction Stage

14A.69 External interferences affecting the normal operation of the HKCG may originate from the following,

- Excessive vibration
- Ground movement/settlement
- Strike by other objects from the PTW construction area
- Fire impingement or high thermal radiation

14A.70 In general, potential damage initiated by these hazards is listed below.

- damage of Gas Holder
- damage of Pipeline inside the HKCG Depot
- damage of other gas installation, such as booster, pump and governor inside the HKCG Depot

14A.71 Hazards with potential impact to the adjacent HKCG Depot have been identified during the aforementioned HAZOP workshop. These hazards and the potential outcomes due to construction works are categorised and tabulated in **Table 14A.9**. Detailed evaluation of the potential impacts is followed.

Table 14A.9 Hazards with Potential Impact to HKCG Depot

Hazardous Scenario	Damage Outcomes	Construction Activities	Potential Cause	Hazard Log Ref.
Ground settlement inside Gas Holder Depot	Ground Collapse damage Gas Holder	Excavation near Gas Holder - PTW - excavation for Tunnel P - Construction of seawater pump house	Unexpected drawing down of groundwater table	1, 11
	Ground Collapse damage Gas Holder and/or Booster/Governor	Tunnelling - Drop shaft construction (inside Aberdeen PTW) by mechanical boring - Tunnel Q construction by horizontal directional drilling (HDD) - Tunnel P construction by "drill and blast"	Unexpected drawing down of groundwater table during tunnel/shaft construction	8, 9, 12
Structural Damage of Gas Holder and Pipework	Gas Holder foundation and water seal damage;	Mobilising and usage of PTW construction or tunnelling equipment. e.g. Crane operation accidentally hitting gas holder	Loss of Stability or Mechanical Failure of construction equipment (e.g. drill rig, backhoe, bulldozer, dump truck, site vehicle etc) and overturn/ crashes into the Gas Holder site	5, 10
		Tunnel Q construction by horizontal directional drilling (HDD)	Construction of Tunnel Q strayed from design alignment	9
		PTW Upgrading Piling Work and Demolition of existing PTW structures; demolition and reconstruction of seawall	Excessive ground vibration	2, 3, 7
	Gas Holder Wall and Guiding Frame Damage	Production shaft construction	Fly rocks due to drill and blast construction method	13
	Governor, Booster and gas pipework Damage	Tunnel P construction by "drill and blast"	Ground vibration and air overpressure due to blasting	12
		Demolition of existing PTW structures	Excessive vibration	3
Fire/ Explosion Hazard affect Gas Depot	Gas Holder damage due to missile of explosion	Installation of electrical and mechanical equipment	Ignition of flammable material (DGs or Construction material) due to Hot Works. Explosion due to fire escalation inside construction site	4/6
	Gas Holder damage due to missile of explosion	Temporary storage of construction plant, equipment, and materials in temporary works area opposite the Gas Holder/ PTW site	Ignition of flammable material (DGs or Construction material) due to Hot Works. Explosion due to fire escalation inside construction site	14,16

14A.72 Drill and blast method is to be adopted only in rock head level for the construction of the production shaft which is located more than 150m away from the Gas Holder. The soil depth at the production shaft would be in the range of 4 to 5 m. Two boreholes will be carried out at the production shaft to obtain Site Investigation (SI) information for detailed design purpose. During blasting operation, protection against sideways projection of flyrock will be provided by the shaft walls, and protection against vertical ejection through the top of the shaft will be provided by a steel roof. A steel roof over the shaft is required to ensure there is no risk of flyrock ejecting form the shaft. The arrangement would be specific to the chosen method of working, and details would be provided in the Contractors method statement for blasting and to be approved by the Supervising Officer of the design and build contract and Mines Division of CEDD. Therefore the risk of flyrock is minimized with proper measures. Moreover, the throw distance of a flyrock using Terrock's Flyrock model [12] is predicted to be less than 120m which is below the 200m separation distance between the production shaft and the Gas Holder. Given standard precautionary measures implemented by contractor, no serious concern to ground level is envisaged regarding flyrocks. Therefore, no damage of gas holder will be caused by flyrocks in blasting activities. Flyrock damage to gas holder is not further assessed.

14A.73 Tunnel P is about 2.5km long located within volcanic rocks. It has been characterised that volcanic rocks in the area is relatively abrasive and hard, which is not favourable to Tunnel Boring Machine (TBM) operation. In fact, some areas along Tunnel P are associated with geological features such as Telegraph Bay fault and Wah Kwai Embayment where more frequent probing and extensive grouting may need to be applied. Comparing with TBM method, Drill and Blast (D&B) method can provide a more spacious working environment for probing, grouting and support installation works. In addition, D&B tunnel can be driven with a more effective cross-section in horseshoe shape with relatively less rock to be excavated. Furthermore, some tight radius curves are required in the vicinity of Cyber Port area, which impose difficulty on TBM operation. Hence, it is in favour of D&B excavation for this tunnel.

14A.74 Emulsion based cartridge explosive will be deployed in construction of Tunnel P because of the small charge-weight requirement. Delivery of detonator and explosive will not be on the same truck. Besides, the emulsion cannot be detonated until a gassing agent has been introduced. Explosive transport is via Shek Pai Wan Road and the route is ended at the production shaft which is outside of the CZ as shown in **Figure 14A.11**. Delivery trucks will not pass through the section of Tin Wan Praya Road next to the HKCG Depot. Thus, the Depot will not be damaged by accidental detonation of the explosive in transport.

14A.75 A blasting assessment report for the project has been prepared under separate cover. Calculation has been carried out for estimating the amount explosive to be used within the CZ for construction of Tunnel P, **Figure 14A.12**. The calculation is based on the assumption of 5mm/s PPV at the foundation of the gas holder. This value is much lower than the proposed allowable limit for gas pipelines, 25mm/s, stated in communications with HKCG, **Appendix 14A.4**. In the calculation, maximum charge-weight per delay 0.79kg is estimated to be applied to the closest section to the HKCG Depot at where the true distance is about 47.8m. Although higher charge-weight per delay for construction the rest of Tunnel P will be used and will pass the nearest section, emulsion and gassing agent will not be mixed until the rock surface has been reached. Explosive will not be accidentally detonated when it is transported inside the Tunnel P. Thus, the HKCG Depot will not be subject to excessive vibration due to use of explosive.

14A.76 As there will be 2 blasts per day maximum, explosive can be delivered on demand and no overnight storage of explosive onsite is required.

14A.77 After the information on the use of explosives in this project has been reviewed, hazard to the HKCG Depot due to use and handling of explosive within the project area is not an issue.

14A.78 Tunnel Q will start from ground surface on Aberdeen side, drop to a maximum depth of 76mPD and then rise to the ground surface again at Ap Lei Chau. The nearest separation distance between tunnel Q and HKCG gasholder on the plan is 21.5m. Using HDD for construction of Tunnel Q, pilot hole will be drilled under close supervision to avoid deviation from design alignment during tunnel construction. Periodic monitoring and checking of construction of Tunnel Q at every 25m will be implemented and will not cause damage to the HKCG Depot because of drilling at an improper location.

14A.79 **Figure 14A.13** shows the interface diagram for drop shaft construction and PTW upgrading work. In the diagram, work area for HDD works is right next to the east boundary of the HKCG Depot. Mobile crane will be used for assemble of construction equipment and drilling rig at ground level within the HDD work area. Crane outreach height for assemble of drilling rig is estimated between 8m and 12m. Besides, there is minimum

5m separation distance between the work area west boundary and the gas holder. It should provide sufficient buffer for HDD works.

14A.80 For construction of PTW administration building and workshop, a tower crane may be used. It is feasible that the tower crane is erected near the drop shaft location. While the administration building would be 2 to 3 storey in height, the height of the tower crane would not cause any threat to the gas holder with the maximum crane height of 20m.

14A.81 The erection, operation and dismantle of tower crane will follow all regulations, requirements and code of practice for safe use of tower crane by Labour Department. In addition, specific risk assessment will be conducted before the erection and operation of the crane to ensure safety and stability of crane operations. Control measures can be taken to ensure no damage to the gas holder even in collapse accident of mobile crane. A crane may topple or collapse towards the load carrying end. Such accidents can be avoided with a well planned site layout and engineering mean. Control measures within the HDD work area may impose the following restrictions,

- use of tall mobile crane.
- lifting height of a crane.
- angular movement and location of crane.

14A.82 Potential ground settlement adjacent to the HKCG due to the construction of Tunnel P has been estimated by the project geotechnical engineers as shown in **Figure 14A.14**. The magnitude of potential settlement is around 8mm.

14A.83 The gasholder is a piled structured which is founded on Grade III rock which will not be affected by this magnitude of settlement. For pipeline, usually a higher value of 25mm can be used for settlement analysis. Nevertheless, monitoring would be carried out during tunnel construction to closely monitor any ground movement. Instrumentation such as settlement marker can monitor the ground settlement. Piezometer can be used to monitor the ground water table which may eventually cause ground settlement.

14A.84 Alert and action limits will be set such that construction works will be stopped when vibration or ground settlement exceed the corresponding action limit. Construction works will proceed further only if sources of settlement/vibration have been identified and rectification of the problem has been completed.

14A.85 In addition to hazards identified in the HAZOP workshop, control and monitoring measures were recommended in the workshop and these measures are recorded in the Hazard Register for future implementation. Example of these measures include establishment of effective communication channel between HKCG operators and PTW operators in case of emergency evacuation initiated from either side, regular meeting with HKCG and closer and more frequent supervision in early construction period from both HKCG and construction team representatives.

14A.86 Based on the aforementioned control measures and monitoring procedures, any ground settlement, soil movement and vibration during construction can be well controlled and kept below allowable limits. Thus, there is no damage to the gas holder and the associated facilities due to construction of the project works

Hazardous Scenario – Operational Stage

14A.87 During the HAZOP workshop, it was confirmed that the operation of upgraded PTW will be similar to that of the current practice. There will be no adverse impact on the HKCG Depot during operational stage.

14A.88 It was also advised that a DG store would be set up within the PTW to support regional need of DSD operations. Besides the DG store, limited quantities of chemicals for general operation and maintenance of the PTW would be handled and stored in the maintenance workshop. Estimated quantities and types of chemical to be handled and stored in the upgraded Aberdeen PTW are given in **Table 14A.10**. Safety of the DG store is evaluated by quantifying hazard ranges for various chemicals in the following sections.

Table 14A.10 Estimated Quantities for Chemicals Handled in the Upgraded Aberdeen PTW

Substance	Quantity
Grease	25 x 18 Litre
Paint	50 x 3.78 Litre
Gasoline	11 x 1.8 Litre
Diesel	4 x 18 Litre
Thinner	70 x 0.95 Litre
Oxygen gas	2 cylinders
Acetylene	2 cylinders

Note: According to the list of dangerous goods tabulated in Dangerous Goods (General) Regulations, Chapter 295B, Laws of Hong Kong (DG(G)R)), the on-site storage of these DGs require a DG Licence.

14A.89 Gasoline, thinner and diesel release flammable vapour which may cause flash fire when it meets an ignition source. Pool fire is another hazard when it is ignited at spill. However, quantity of gasoline/diesel to be stored within the project site is no more than a full tank of a passenger car/truck. Besides, they are kept in small containers, 1.8L and 18L for gasoline and diesel respectively. Large quantity spillage is not foreseen. As a result of consequence modeling, a pool fire diameter and a flame length of less than 3m are predicted. Buffer distance of at least 3m should be provided in order to prevent the HKCG Depot from fire damage.

14A.90 Acetylene and oxygen cylinders will be used for welding purpose. Acetylene can form explosive mixture in air. Hazard range of acetylene is assessed through consequence modelling. In case of cylinder rupture, fireball of 11m radius is predicted. In continuous release, jet flame lengths are 13m and 24m for 5mm and 10mm leaks respectively. Thus, hazard will not go beyond the project site.

14A.91 Grease and paint are chemically stable with high boiling points 310^{o}C and 100^{o}C respectively. They are both flammable but grease is not volatile. Fire and extremely high temperature should be avoided. Fire is the major hazard for these 2 chemicals. Apart from fire, paint in closed container may cause explosion. Although both chemicals emit smoke and fumes in fire, they do not have off-site hazard.

14A.92 Based on this preliminary assessment, hazard due to onsite DGs storage can be contained within the project site. The DG storage will not pose risk or cause damage to the HKCG Depot.

Hazard Events at the Existing Shell Depot

Overview

14A.93 Historical data sources, previous risk assessment reports [5][6] and MHIDAS database, etc, have been reviewed. Generic Hazard events associated with the Shell Depot are tabulated in **Table 14A.11** below.

Table 14A.11 Hazards Associate with Operation of Shell Depot

Hazard event	Potential Cause
Spontaneous failure	• Storage vessel / cylinder Failures • LPG Road Tanker failures (both transit and LPG vessel refilling) • Pipework failures • Vaporizer failures • Flexible hose failures • Flange gasket failures • Valve leak failures • Outlet pipeline failure
Loading from LPG Road Tanker to vessel	• Vessel filling hose misconnection • Vessel filling hose disconnection error • Disconnection with valve open • LPG Road Tanker drive away • LPG Road Tanker impact onto LPG facilities • LPG Road Tanker collision during unloading • Loading pipework over pressurisation • Storage vessel overfilling
External event	• Earthquake • Aircrafts crash • Car crash • Natural terrain landslide • Severe environmental events • Lightning strike • Dropped object • Subsidence • External fire • Collapse and strike by object • Vibration

Spontaneous Failure

Storage Vessel Failure

14A.94 Storage vessel failure can be cold catastrophic leading to instantaneous release or cold partial failure resulting in continuous release of LPG to the atmosphere. The generic failure rate of $1.8x10^{-7}$ per vessel year [3] has been adopted for cold spontaneous catastrophic failure. For partial failure, a generic value of $5.0x10^{-6}$ per vessel year [3] has been adopted. The vessel is assumed stress relieved and 100% radiograph tested.

LPG Road Tanker Failure

14A.95 LPG road tankers in Hong Kong are covered with fire proof coating and equipped with many safety features so that they can be treated as a considerably well secured device. Catastrophic and partial failure modes are similar to those of vessels. The catastrophic and partial failure rates of a LPG road tanker for the study are $2.0x10^{-6}$ and $5.0x10^{-6}$ per year [3] respectively.

LPG Cylinder Failure

14A.96 Cylinders of small size are stored in stack. Apart from cylinder shell, failure can also be initiated from cylinder valve. Cylinders may have cold catastrophic leading to instantaneous release or cold partial failure resulting in continuous release. Since LPG cylinders are subject to full inspection and re-qualification every 5 years and undergone leak test at filling plant, failure rates for LPG road tanker [3] are also applied to LPG cylinder for similarity in non-stationary nature. The catastrophic and partial failure rates of a LPG cylinder for the study are 1.0×10^{-6} [7] and 2.6×10^{-6} [14] per cylinder year respectively.

14A.97 A side wall of LPG Storage Shed up to ceiling height and solid fence wall of 3m high is erected along the site boundary next to Lee Nam Road and adjoining boundary with South Horizons to prevent LPG cylinder fragments from hitting outdoor population (no direct line of sight to LPG cylinders at ground level along Lee Nam Road and at South Horizons). Besides, the LPG Storage Shed is fitted with a metal sheet roof which can confine travelling distance of debris. Although façades of some dwellings at South Horizons have direct line of sight to LPG cylinders, indoor population is protected by building structures. **Figure 14A.15** illustrates architectural features which provide protection to ground population from projectiles. Since there is no direct line of sight from ground level population, there is no direct impact to ground level population and is not further considered in the assessment.

14A.98 Cylinder fragments flying through a window façade in a BLEVE accident which may lead to fatality of indoor population at South Horizons. Frequency of flying fragment in BLEVE is estimated to be 4.36×10^{-9} per year. Calculation is based on the frequency of leak failure of a cylinder 2.6×10^{-6} per cylinder year, probability of immediate ignition 0.005, vertical and horizontal view angles as shown in **Figure 14A.15**. Fraction of window pane along a vertical building façade and horizontal building façade has been considered. From findings of the recent TNO report [13], BLEVE occurs after a time varying from 5 minutes to 25 minutes when it is placed on a fire. In accordance with PHAST modelling results, leak size <5mm can lead to continuous release over 5 minutes. Such leak size is equivalent to damage caused by impact of forklift truck in moving of cylinders during operation hours. This leads to further assumption that 50% of leak failure can cause BLEVE. While cylinders are stored in stacks, 50% of fragments are considered being contained by stacks of cylinders. In a site survey, 1664 cylinders of various sizes were found in the transit depot. Since the transit depot is utilised to handle both fully loaded and empty cylinders, 50% of cylinders are considered fully loaded and can cause BLEVE. Event frequency for flying fragment and number of fatalities are considered low in comparison with other events. This event is not further assessed in the study.

14A.99 According to a recent review of compressed gas safety by Cadwallader [8], a runaway or almost runaway cylinder involves opening/removal of valve or regulator. Operation of the transit depot involves movement of LPG pellets of cylinders using forklift trucks. Due to human error, cylinder valve may be broken or cylinder body may be punctured by a forklift truck. However, downward or sideward force is generated and leads to spinning of the cylinder. While the transit depot is fenced off with wire mesh and solid wall, a runaway cylinder would not cause offsite fatality.

<u>Pipework Failure</u>

14A.100 Failure of pipework can generally be classified into two types - guillotine (full bore rupture) and partial failure (pipe splits less than the pipe diameter). Risk from partial failure is considered not significant to the overall risk. However, this study also takes into account consequences from both guillotine and partial failures. A generic guillotine failure rate of 1.0×10^{-6} per metre per year [3] has been adopted. Failure rate for partial failure is taken as 3.3 times of the guillotine failure rate [7], 3.3×10^{-6} per metre per year. However, it is noted that the effect of guillotine failure is significant only if leak(s) is failed to be isolated. In other words, it requires the failure of other safety systems to substantiate the event. Fault tree analysis technique is adopted to account such “failure to isolate” risks.

<u>Flexible Hose Failure</u>

14A.101 LPG road tankers carry a flexible hose for LPG unloading to LPG storage vessels. A generic guillotine failure rate of 9×10^{-8} per hour [3] is adopted. An Excess Flow Valve (EFV) is fitted immediately upstream of the hose. Similar to pipework failure, the effect of partial failure of the hose is small but is also considered in the assessment with failure rate of 3.3 times guillotine failure rate applied.

Flange/Gasket and Valve Leak Failures

14A.102 Failures of gaskets and valve leak would only tend to give relatively small scale of leakage and will not contribute to the off-site risk. The results from gasket failure will not be considered separately but absorbed into pipework failure in the study.

Loading from LPG Road Tanker to Vessel Failure

Hose Misconnection

14A.103 This study only considers misconnection errors which results in hose coming completely apart, giving a full-bore release. Small leaks will be rectified instantaneously by the truck driver or his assistant, and hence are not considered. A failure rate of $3x10^{-5}$ per operation [3] resulting from human error which leads to misconnection is adopted.

Hose Disconnection Error

14A.104 This is initiated by human error which requires a complete disregard of normal operating procedure as well as the failure to preventing it from happening. A failure rate of $2x10^{-6}$ per operation [3] for an operator to disconnect a hose during loading operation has been used in the study.

Disconnection with Valve Open

14A.105 The event is significant only if the release is fed from the storage vessel and when the vessel is over-pressurised with failure of the associated safety valves (i.e. a Non-return Valve in the present case), as well as driver's failure to shut down the Manual Valve 0.5 per operation [3] together with the hose disconnection error.

LPG Road Tanker Drive Away

14A.106 A drive-away error could be resulted from repositioning of truck during delivery or inadvertent drive-away before completion of replenishment. The outcome of this failure matches those of hose misconnection. A number of measures such as the use of wheel chocks, interlocks on shutters and parking brake have been implemented in Hong Kong. Moreover, there is a dedicated bay area for the parking of the truck so that repositioning during delivery will not occur. Furthermore, the driver is also responsible for the unloading process. Therefore, probability of driving away before completion is very low and a failure rate of $4x10^{-6}$ per operation [3] has been adopted in the study.

LPG Road Tanker Impact

14A.107 LPG Road Tanker impact refers to the LPG installation being hit by a LPG road tanker causing damage to the installation, pipework, the road tanker itself, the LPG road tanker fittings or the hose connection pipework. Failure rate of $1.5x10^{-4}$ per operation [3] for "tanker impact during unloading" is adopted.

LPG Road Tanker Collision during Unloading

14A.108 A dedicated loading bay for parking of the LPG road tanker is provided and a speed bump at entrance of the LPG compound is installed. Frequency of $1x10^{-8}$ per operation [3] for vehicle impact into an unloading LPG road tanker is adopted and fed into fault tree analysis.

Loading Pipework over Pressurisation.

14A.109 It is possible that a LPG road tanker driver makes an error while unloading from the road tanker to the storage vessel. Over pressurisation of the liquid filling line would be resulted should the operator forget to open all relevant valves on the pipe/hose. However, over-pressurisation protection system of the LPG road tanker should fail and other failure to isolate leak system (e.g. possibility of the leak being isolating using manual valves) does not work. The concerned scenario will have a much lower probability to happen than the "misconnection" error event (which will lead to a similar outcome) and the misconnection error has already accounted for this factor.

LPG Storage Tank Overfilling

14A.110 The on-site practice in unloading LPG to the storage vessel is that the vessel will only be filled to up to 85% of the maximum capacity, through monitoring with a level gauge during loading operation. The reserved capacity is able to contain a full load of replenishment. It is also an offence in Hong Kong for a person to overfill a LPG storage vessel. Even if overfilling did occur, the below failure events are also required to occur for failure of the storage vessel as a result of the over pressurisation. Storage tank overfilling frequency is taken as $2x10^{-2}$ per operation [3].

- failure of the truck pump overpressure protection system;
- failure of pressure relief valve (PRV) on storage tank;
- failure of driver and his assistant to detect problem and to take effective mitigation action.

Human Error

14A.111 In equipment failure, it is possible for staff to rectify the problem before any hazard event occurs. Two staff is responsible for the unloading process (i.e. the driver and one site staff). As the staff should have undergone training programme for the job, the probability that the problem cannot be rectified before hazard event occurs can be assumed to be lower than 0.5. In this assessment, a probability of 0.5 is assumed for human error [3].

Supply line from Vessel to Vaporiser Failure

14A.112 Similar to spontaneous failure of pipework, failure of this supply line can be guillotine or partial failures. LPG transforms from liquid state to gaseous state through heating of vaporisers. Vaporiser failure would cause release of liquid state LPG in the worst case. There are 2 types of vaporizer in use with production rates of 500kg/hr and 1000kg/hr. Failure rate of $1x10^{-6}$ per m per year [3] is assumed and all failures are considered full bore rupture events in the worst scenario. By assuming an average coil length 8m per vaporizer, failure frequency of $8x10^{-6}$ per unit per year is calculated.

Outlet Pipeline Failure

14A.113 Similar to spontaneous failure of pipework, failure of this supply line can be guillotine or partial failures. However, LPG is in gaseous state after it has passed vaporisers.

Movement of LPG Road Tankers/Cylinder Wagons inside Depot

14A.114 A LPG road tanker/cylinder wagon in transport is subject to the same failure hazards as it is stationary. LPG road tankers and cylinders wagons may experience spontaneous failure as well as collision impact or subsequent fire impact in a severe traffic accident. Although speed restriction is imposed within the depot, serious accidents are considered to be possible within the depot for conservativeness. By reference to historical incidents and SEKD [6] study, the following hazards can lead to gas release from LPG road tankers,

- BLEVE/ Fireball - engulfed in fire with fire protection system failure
- Cold catastrophic failure – spontaneous failure in transport, LPG road tanker rupture in traffic accident or thermal expansion of an overfilled LPG road tanker with PRV failure
- Partial failure – LPG road tanker shell leak, access hatch leak and un-isolated pipework leak lead to liquid release. PRV spontaneous failure and PRV leak in traffic accident lead to gaseous release

14A.115 Hazards lead to gas release from LPG cylinder wagon including,

- Cold catastrophic failure – spontaneous failure in transport or cylinders rupture in traffic accident

Queuing of LPG Road Tanker/Cylinder Wagon at Depot

14A.116 All LPG road tankers/cylinder wagons waiting for aboard ferry at the Depot. Their arrival time is not far apart. Moreover, fully loaded LPG road tankers arriving by ferry leave the transit depot as soon as they disembark. Cylinder wagons arriving by ferry unload to the LPG cylinder shed. An average wait time of 20-30 minutes per LPG road tanker/ cylinder wagons is considered reasonable and conservative. Since parked LPG road tankers/ cylinder wagons have their engine turned off, fire hazard to the queuing LPG road tankers/ cylinder wagons due to traffic accident fire are considered not possible. Except multiple BLEVE hazard, other hazards relevant to movement of road tankers/ cylinder wagons inside the Depot are also applicable to queuing vehicles.

External Events

Car crash

14A.117 No unauthorised vehicle is allowed and speed restriction is imposed within the Shell Depot. Besides, the depot is fenced off from Lee Nam Road with a concrete wall. It is possible that minor traffic accident occurs along the internal access road when the access road to the LPG compound merges with the access road to the transit & LPG cylinders depot. Damage to the LPG compound and LPG road tanker in car crash have been considered in “LPG Road Tanker Impact” and “LPG Road Tanker Collision during Unloading” sections.

Earthquake

14A.118 In Hong Kong, buildings and infrastructures are designed to withstand earthquakes up to Modified Mercali Intensity (MMI) VII. It is estimated that MMI VIII is required to provide sufficient intensity to result in damage to specially designed structure. It is assumed that failure in earthquake is possible for gas holder leakage, pipeline rupture and leakage only and probability of failure in earthquake is assumed 0.01 [11]. The probability of earthquake occurrence at MMI VIII and higher is very low comparing with other places and is estimated to be 1.0×10^{-5} per year [5].

Aircraft crash

14A.119 The distance between the nearest arrival flight path and the Depot is more than 2 miles. The distance between the Depot and Chek Lap Kok International Airport is over 5 miles which is the criteria for the consideration of airfield accident. At such distances, the PHI site is not covered by critical takeoff and landing phases. The frequency of aircraft crash is estimated using the methodology of the HSE [9] which has been applied to LNG Terminal EIA study [5] and other EIA studies. The number of runway movements of aircraft is extracted from yearly statistics of the Hong Kong International Airport between years 1998 and 2006. Movement number in year 2009 and 2014 is estimated by linear regression. Accident rates on depot being hit by an aircraft for years 2006, 2009 and 2014 are 6.4×10^{-14}, 7×10^{-14} and 8.7×10^{-14} per year respectively. Since the calculated accident rates are much smaller than order of 10^{-9}, failure caused by aircraft crash is not considered further in the assessment.

Landslide

14A.120 Soil/rock slopes Slope No. 15NW-A/C2 and 15NW-A/C3 are located at 15m from east boundary of the Shell Depot and are separated by Lee Nam Road. The slopes are not classified as dangerous hillside slope and do not require non-routine maintenance. Surface protection was applied with 50% and 100% shotcrete for the 2 slopes.

Severe environmental event

14A.121 Loss of containment due to severe environmental event such as typhoon or tsunami (large scale tidal wave) is not possible as the LPG vessel is mounded. However, typhoon may tumble LPG cylinder stacks at the LPG cylinder shed. Damage to a cylinder is possible when it falls from stack. While Hong Kong is not threatened by tsunami, damage by large scale tidal wave is not possible.

Subsidence

14A.122 Subsidence is usually slow in movement and such movement can be observed and remedial action can be taken in time. Besides, the Depot has been operating over 15 years. The probability of hazardous event due to subsidence is therefore assumed zero.

External fire

14A.123 External fire means the occurrence of fire event which lead to the failure of the gas related facilities. The key potential concern relates to the LPG compound being affected by the fire of LPG road tanker and LPG transit depot being affected by fire in collision accident.

14A.124 In Hong Kong, LPG delivery trucks are provided with safety features to prevent the spread of fire from an engine or cab fire to the LPG tank and are shielded with fire proof coating. Fire extinguishers are also provided. The regulations also require that the vessel be effectively screened with fire-resisting shields from the interior of the cab, fuel tank, electrical generator, engine, etc. Mounded LPG vessels are protected from fire attack. Therefore, it can be assumed that such external fire will not lead to gas release outcome.

14A.125 In severe collision accident, fire-resisting shields on LPG road tankers/cylinder wagons can be damaged and cannot isolate a fire effectively. Fire hazard on movement of DG vehicles are considered within the transit depot.

Lightning strike

14A.126 The frequency of lightning strike on a properly protected building is extremely low in Hong Kong. Risk resulting from lightning strike on facilities of the depot is extremely low as the depot is fitted with lightning rod. With sufficient protection system, effect of lightning strike is not further studied in this assessment.

Dropped object

14A.127 There is no industrial activity close to the Shell Depot. Moreover, there is a concrete fence wall next to Lee Nam Road. The depot is protected from flying debris generated by moving vehicles.

Collapse and Strike by object & Vibration

14A.128 There is no risk of damage to the gas depot by collapse and strike of surrounding object in the existing setup. This factor is further elaborated in sections regarding construction activities in the Ap Lei Chau PTW.

Hazard Events Initiated by Ap Lei Chau PTW and Safety Measures

Overview

14A.129 A systematic brainstorming HAZOP workshop was conducted in June 2007 for the Shell Depot. Participants include representatives from Shell Depot, risk specialist and subject engineers. Details of hazards identified are given in the hazard register attached in **Appendix 14A.2**. All these identified hazards are evaluated for development of the risk model.

14A.130 The hazardous event of the Shell Depot is LPG (Gas/Liquid) release that may lead to fire and explosion. LPG leakage could be initiated by external events such as damage of gas installations by construction activities in PTW site.

14A.131 Referring to Paragraph 72 of judgment from the Court of Final Appeal (FACV 28/2005): "…it is appreciated that a QRA, in order to satisfy the exigencies of Annex 4, must be both generic and project-specific, that the methodology searches for the relevant scenarios in the history of projects of the same genus- and thus identifies scenarios for the purposes of para. (i) – then quantifies risk by reference to that history and the specific features of the instant project …". Hazardous scenarios and frequencies adopted in this assessment have been based on review of historical incidents.

14A.132 The Ap Lei Chau PTW is located in the 500m-consultation zone of the Shell Depot as indicated in **Figure 14A.6**. The impact generated from tunnel construction and the upgrading of the PTW and hazards associated with the Shell Depot have been identified and presented in the following sections.

14A.133 Among all external events in **Table 14A.11**, only subsidence, external fire, collapse and strike by object and vibration are potential hazards generated from the construction activities of the PTW. These activities are further developed to various hazardous scenarios in the following subsections.

Construction and Operation Activities in Ap Lei Chau PTW

14A.134 Review on construction and operation activities have been conducted prior to the HAZOP workshops held in June 2007. These activities and the hazards identified in the workshops are recorded in Hazard Registers as attached in **Appendix 14A.2**. These hazards and the relative information are used as the basis for further development of the risk model.

14A.135 Construction activities in the vicinity of the Ap Lei Chau PTW are listed below. A general layout of the PTW site is presented in **Figure 14A.16**.

- *Upgrading of PTW*. Relevant construction works will last for about 3.5 years and will involve demolition of existing buildings and construction of new buildings & structures, installation of electrical and mechanical equipment, laying of sewers, drainage pipes, and other utility lines, as well as non-percussive piling and ground excavations to depths up to 11m below ground level for the Transfer Pumping Station(in which sheet piling would be adopted for temporary support during excavation); and
- *Construction of Drop Shaft and Tunnel "Q".* Construction of a tunnel connecting to the Aberdeen PTW by HDD and a permanent drop shaft adopting mechanical methods and no explosive will be involved.

14A.136 The primary function of PTW will remain the same as the existing one. The layout plan for the upgraded PTW is shown in **Figure 14A.17**. Sewage will continue to enter the PTW via the existing sewer system. It will be pumped through the various treatment units in the PTW before it is discharged into the deep tunnel system.

Hazardous Scenarios - Construction Stage

14A.137 The distance between the ALC PTW north boundary and the entrance of Shell Depot is more than 100m. The LPG cylinder shed is even further away from the north boundary at 140m. Since work area for the ALC PTW is relatively far away from the LPG cylinder shed and the transit depot, construction works of the PTW does not have direct impact on the LPG cylinder store and transit tankers/cylinder wagons. However, hazards caused by toppling/dropping of gas cylinders from loading platform which is initialised by ground settlement, are further elaborated in the assessment.

14A.138 External interferences affecting the normal operation of the Shell Depot may originate from the following,

- Excessive vibration
- Ground movement/settlement. Differential ground displacement is the most concerned in ground settlement as it causes shear stress to components
- Strike by other objects from the PTW construction area
- Fire impingement or high thermal radiation

14A.139 In general, potential damages initiated by these hazards are listed below.

- Liquid release due to damage of LPG storage vessel/ LPG cylinder
- Liquid release due to damage of LPG road tanker
- Gas/Liquid release due to damage of pipeline

- Gas/Liquid release due to damage of other gas installation e.g. vaporizers

14A.140 Owing to the close proximity, it is more likely that the LPG compound and its facility are affected by the ALC PTW site and its activities. Hazards, which are caused by construction works of the PTW, with potential impact to the adjacent Shell Depot have been categorized and tabulated in **Table 14A.12**.

Table 14A.12 Hazards with Potential Impact to Shell Depot

Hazardous Scenario	Damage Outcomes	Construction Activities	Potential Cause	Hazard Log Ref
Ground settlement inside LPG Compound/ cylinder store	Ground Collapse underneath LPG Tank, underneath vaporizers rooms and/or underneath LPG Road Tanker Unloading Bay, LPG cylinder shed	Excavation at PTW site about 11m deep	Unexpected drawing down of groundwater table.	1
	Ground Collapse underneath LPG Tank, underneath vaporizers rooms and/or underneath Load Road Tanker Unloading Bay, LPG cylinder shed	<u>Tunnelling</u> - Drop shaft construction (inside Ap Lei Chau PTW) by mechanical boring - Tunnel Q construction by horizontal directional drilling (HDD)	Unexpected drawing down of groundwater table.	7, 8
Structural damage to gas Installation	LPG Tank, vaporizers, LPG Road Tanker and gas pipework damage	Mobilising and usage of construction equipment (e.g. backhoe, bulldozer, dump truck, site vehicle etc)	Loss of Stability or Mechanical Failure of construction equipment (e.g. drill rig, backhoe, bulldozer, dump truck, site vehicle etc) and overturn/ crashes into the Shell LPG facility may cause structural damage.	5
		Tunnel Q construction by horizontal directional drilling (HDD)	Construction of Tunnel Q strayed from design alignment to cause unexpected damage to the nearby LPG facility	8
		Piling Works	Excessive ground vibration leading to structural damage of LPG facility.	2
		Demolition of existing PTW structures (and substructures)	Excessive vibrations due to inappropriate method of demolition	3, 9
Fire/Explosion Hazard to Gas Depot	LPG Tank, LPG Road Tanker and outdoor pipework damage due to missile of explosion at PTW site	Installation of electrical and mechanical equipment	Fire escalation from construction site	4, 6
	LPG Tank, LPG Road Tanker and outdoor pipework damage due to missile of explosion at PTW site (Fire Escalation)	Temporary storage of construction plant, equipment, and materials in temporary works area (during Construction Stage)	Ignition of flammable material (DGs or Construction material) due to Hot Works.	10

14A.141 Regarding vibration due to construction activities, mitigation measures, such as using of non-percussive piling methods and vibration monitoring, will be implemented to ensure that the velocity and amplitude of vibration will not damage to the Shell Depot. Therefore, this hazard is not assessed further in this study. Details of the monitoring and control measures are stated at end of this section.

14A.142 For construction of Tunnel Q using HDD, pilot hole will be drilled under close supervision to avoid deviation from design alignment during tunnel construction. Periodic monitoring and checking of Tunnel Q construction every 25 meters will be implemented. The Shell Depot would not be damaged due to misalignment of tunnel construction underneath the depot.

14A.143 There is neither materials store nor nake flame at or near the adjoining boundary. Besides, there are a 10m buffer (access road within the PTW site) and a 3m high fence wall separating the PTW site and the LPG compound. Thus, fire at the PTW site would not affect the LPG compound.

14A.144 In the interface diagram for drop shaft construction and PTW upgrading work as shown in **Figure 14A.18**, the drop shaft and temporary work site for tunnelling work is at least 60m away from the south boundary of the Shell Depot. Mobile crane will be used for assembling of construction equipment and drilling rig at ground level within the work site. Crane outreach height for assembling of drilling rig is estimated between 8m and 12m. Use of crane within the work site does not impose any risk of direct mechanical damage to the Shell Depot.

14A.145 For construction of the new PTW building, a mobile crane or tower crane may be erected. There are 2 possible locations for erection of the tower crane and are indicated in **Figure 14A.19**. The new PTW building is approximately 11m from ground level while the rest of structures such as shelter for grit trap and switch room vary from 4m to 12m. Crane Location 1 is adjacent to the new building and approximately 10m from the Shell Depot boundary. Use of crane at such close proximity to the LPG compound would impound risk of damage to the associated facilities in case of mechanical failure. Crane Location 2 is viable from safety point of view while it can provide more than 10m buffer distance from the end boom. Outreach of cranes is illustrated on **Figure 14A.19**.

14A.146 While a mobile crane may topple or collapse towards the load carrying end, damage to the LPG compound due to such accidents can be avoided by controlling orientation, swing angle, lifting height of the crane as well as always facing crane jibs away from or parallel to the adjoining site boundary with the LPG compound. With this fail-safe arrangement, a collapsed crane will not fall on the Shell Depot even sitting at Crane Location 1.

14A.147 Climbing and dismantling of a tower crane is the most common cause of fatal accident involving particular hazards relating to the carrying of unbalanced load. In such accidents, crane arms may run across the PTW site and hit the LPG compound. However, the damage can be avoidable by turning crane jibs parallel to the adjoining boundary or away from the depot when carrying out this process.

14A.148 Load slipping and lifting accessory failing cause load falling which may damage LPG compound. Safety zone will be set out such that a loading arm is also kept away from the depot boundary. Protective fencing consisting of mesh will also be used to catch projectiles or debris of fallen load.

14A.149 Due to the relatively large separation distance and nature of use, direct impact of PTW construction activities on the transit and LPG cylinder depot does not exist. However, ground settlement may lead to damage to LPG cylinder shed and LPG cylinder platform. Collapsed structures subsequently cause rupture of cylinders because of collapse of cylinder stacks and collision between cylinders. However, ground settlement will be monitored and controlled within allowable limits. Significant ground settlement will be avoided. Preliminary monitoring procedures are described in later sections.

14A.150 Strategy for ground settlement and vibration monitoring is similar to the one for the Aberdeen PTW. Preliminary monitoring locations and plan are described in later sections. Alert and action limits will be set such that construction works will be stopped when vibration or ground settlement exceed the corresponding action limit. Construction works will proceed only after sources of settlement/vibration have been identified and rectification of the problem has been completed.

14A.151 Based on the aforementioned control measures and monitoring procedures, amplitude of ground settlement, soil movement and vibration can be well controlled and kept below allowable limits. Thus, construction of the ALC PTW will not cause damage to the Shell Deport.

Hazardous Scenarios - Operational Stage

14A.152 During the HAZOP workshop, it is confirmed by PTW operator that the operation of upgraded PTW will be similar to that of the current practice. Small amount of DGs similar to those current used for maintaining the existing PTW would be stored on site during future operations. Operation of the upgraded ALC PTW would not have any adverse impact on the Shell Depot.

Frequency Assessment

Overview

14A.153 The aim of the frequency assessment is to estimate the likelihood of the initial events to occur and then the frequencies of hazardous outcomes. Subsequent to the initial event, various outcomes may be developed.

Frequency Estimation of Failure Events

Aberdeen Gas Holder

14A.154 Frequencies for rupture failure $5x10^{-6}$ per year for process vessel [7], leak failure for 200mm equivalent hole-size $4x10^{-5}$ per year [6] and blown seal failure for 1m equivalent hole-size $4x10^{-5}$ per year [6] are adopted. Based on the design of the Aberdeen gas holder, Towngas is trapped and sealed by a 30-feet high water tank when the gas holder is not in operation. Hence, possibility of blown seal failure does not exist when it is not in operation. Blown seal may occur at the water seal only if the gas holder is overfilled during operation mode.

14A.155 In accordance with [7], full bore rupture and leak failure frequencies for gas/liquid pipework are $1x10^{-7}$ per m.year and $5x10^{-7}$ per m.year respectively. After these values are localised for pipe length, frequencies of failure for full bore rupture and leakage are $4x10^{-6}$ per year and $2x10^{-5}$ per year respectively by assumption total pipeline length of 40m.

14A.156 Since the gas depot neither locates underneath existing flight path nor adjacent to an unstable slope, no adjustment to the failure frequencies is made for these 2 factors. Similarly, no adjustment to failure frequencies for gas pipeline and gas holder is made as gas depot site is not particularly subject to attack from various environmental factors such as large scale tidal wave which have been discussed in the "external events" section. The aforementioned failure rates together with other external events such as car crash and subsidence are adopted in the Fault Tree Analysis (Appendix 14A.5) to develop the hazardous outcome frequencies for the HKCG Depot are tabulated in **Table 14A.13**.

Table 14A.13 Frequencies of Initial Failure Events for the HKCG Depot

Outcome	Failure per year	
	Existing/Operation	Construction
Gas Holder Rupture	$5.00x10^{-6}$	$5.00x10^{-6}$
Gas Holder Leakage (200mm diameter)	$4.07x10^{-5}$	$4.07x10^{-5}$
Blown Seal Failure (1000mm diameter)	$4.07x10^{-5}$	$4.07x10^{-5}$
Pipeline Rupture	$4.16x10^{-6}$	$4.55x10^{-6}$
Pipeline Leakage (50mm diameter)	$2.06x10^{-5}$	$2.06x10^{-5}$

Ap Lei Chau Shell Depot

14A.157 For Ap Lei Chau Site, equipment failure rates as documented in Appendix 3 of the QRA Methodology Paper [3] have been used for Fault Tree Analysis (**Appendix 14A.5**) to develop the hazardous outcome frequencies for the LPG compound, which is presented in **Table 14A.14**.

Table 14A.14 Frequencies of Initial Failure Events for the Shell LPG Compound

Outcome	Failure per year
Cold Catastrophic Failure of LPG Vessel	6.72E-07
Cold Catastrophic Failure of LPG Road Tanker	1.48E-07
Cold Partial Failure of LPG Vessel	1.17E-05
Cold Partial Failure of LPG Road Tanker	3.62E-07
Failure of Liquid-Inlet Pipework (rupture)	5.14E-07
Failure of Liquid-Inlet Pipework (leak)	7.69E-07
Failure of Liquid Supply Line to Vaporiser (rupture)	4.00E-06
Failure of Liquid Supply Line to Vaporiser (leak)	1.30E-05
Failure of Vaporiser	3.64E-08
Failure of Flexible Hose (rupture)	3.82E-05
Failure of Flexible Hose (leak)	3.92E-05
Failure of Gas Outlet Pipework (rupture)	4.00E-06
Failure of Gas Outlet Pipework (leak)	1.30E-05
Failure of LPG cylinder at Store (rupture)	2.00E-03
Failure of LPG cylinder at Store (leak)	5.20E-03

14A.158 For transit operation of the depot, failure frequencies are calculated by referring SEKD Study [6], number of vehicles movement in the depot and length of the internal access road (0.2km). Failure frequencies for transport risk are summarised in **Table 14A.15**.

Table 14A.15 Frequencies of Failure Events due to Transport Risk at the Shell Transit Depot

Event	Likelihood (per vehicle km)	Release mass (kg)	Hole size (mm)	No. of vehicles per day	No. of vehicles per year	Frequency per year
LPG road tanker						
BLEVE	2.70E-12	9000	n/a	2	730	3.94E-10
cold rupture	2.60E-09	9000	n/a	2	730	3.80E-07
large leak - liquid	1.80E-08	9000	50	2	730	2.63E-06
large leak (vapour)	2.10E-09	9000	50	2	730	3.07E-07
medium leak (liquid)	6.80E-09	9000	25	2	730	9.93E-07
LPG cylinder wagon						
BLEVE	1.30E-09	50	n/a	2	730	1.90E-07
Rupture	2.80E-08	50	n/a	2	730	4.09E-06

Notes: frequency = likelihood per vehicle.km x no. of vehicles per year x length of access road

14A.159 Taking into account time waiting for abroad or disembarkation, it is assumed each LPG road tanker/cylinder wagons staying in the transit depot for 25 minutes. This time factor is adopted to derive frequencies of failure events associating with DG vehicles at the transit depot. Failure frequencies are calculated by referring SEKD study [6] for events likelihood, number of vehicles movement in the depot and time at the depot. BLEVE is not considered as LPG road tankers/cylinder wagons do not engaged in fire hazard while they are parked. Failure frequencies for stationary risk at transit depot are summarised in **Table 14A.16**.

Table 14A.16 Frequencies of Failure Events due to Stationary Risk at the Shell Transit Depot

	Likelihood (per vehicle year)	Release mass (kg)	hole size (mm)	No. of Vehicles per day	No. of Vehicles per year	Freq. per year
LPG road tanker						
cold rupture	4.00E-08	9000	n/a	2	730	1.39E-09
Large leak (liquid)	3.60E-08	9000	50	2	730	1.25E-09
Large leak (vapour)	3.60E-08	9000	50	2	730	1.25E-09
Medium leak (liquid)	3.60E-08	9000	25	2	730	1.25E-09
LPG cylinder wagon						
Rupture	6.80E-06	50	n/a	2	730	2.36E-07

Notes: frequency = likelihood per vehicle year x no. of vehicles per year x wait-time in fraction of a year

Frequency Estimation of Hazardous Outcomes

14A.160 For the LPG and the Towngas storage, the final outcomes of gas installation damage are due to gas/liquid release. For instance, fire hazard may be resulted if an ignition source is present.

14A.161 To determine the outcomes frequencies, the base frequencies for initial events are inputted to event trees together with the probabilities of damage of the gas installation as well as the probabilities of gas ignition. Factors, such as type of release, operation of excess flow valve, leakage isolation, presence of ignition source, timing of ignition, geographic location, environmental conditions and meteorological conditions are taken into account.

14A.162 SAFETI's built-in event trees are applied for calculating frequency of hazardous outcomes.

Consequence Assessment

Overview

14A.163 Upon completion of frequency estimation for the hazardous outcomes, the consequence assessment then estimates impact of each outcome in the area of concern. In SAFETI, built-in event tree is used for determination of consequence by considering type of release, presence of ignition sources, timing of ignition, geographic location, environmental and meteorological conditions.

14A.164 For the Ap Lei Chau project site, it is assumed that all LPG released will be flashed to vapour so that flash fire can be formed instead of pool fire for delayed ignition. Similarly, flash fire can be formed for release of town gas. This assumption leads to the worst scenario as pool fire is usually a localised hazard event while extent of a flash fire is larger than a pool fire.

14A.165 The consequence assessment consists of two major parts, they are:

- Source term modelling – to determine the amount and rate of gas release; and
- Effect modelling – to determine the toxic, flammable and explosion effect to offsite population.

Source Term Modelling

Aberdeen

14A.166 Towngas is modelled as mixture of hydrogen, methane, carbon dioxide and carbon monoxide. For instantaneous failure, whole content of the gas holder (17.7 tons and 3 tons for operation mode and normal mode respectively) is used. In case of continuous release, release parameters such as release rate and exit velocity are calculated by discharge model according to storage conditions. Release duration is based on capacity of the gas holder. Release parameters together with release duration are then fed into dispersion model to calculate the effect.

14A.167 For pipelines connecting to a gas distribution network, continuous release without shutdown mechanism is assumed. For pipelines connecting to a storage tank, release duration is based on time to empty the whole content.

Ap Lei Chau

14A.168 LPG model is a mixture of butane and propane in 7:3 ratios. For the LPG Compound, 85% of the total storage capacity is used by taking into account the day-to-day practice of the operator. Since there are 2 vessels in operation, release quantity in catastrophic failure of the vessel is based on maximum storage quantity (17 tons) for a single vessel. In continuous release, 34 tons release quantity (equivalent to total storage capacity) is used. 9 tons release mass (full capacity of a LPG road tanker) is used for LPG road tanker related events.

14A.169 Since LPG cylinders store keeps cylinder from 2 kg to 49 kg, 49 kg is assumed for release quantity. This amount is equivalent to single cylinder failure of 49-kg cylinder.

14A.170 While the transit facility serves LPG road tankers and cylinder wagons, all road tankers are assumed having capacity of 9 tons and are fully loaded. Release quantity for LPG cylinder in wagons is taken as 49kg from a 49-kg cylinder, as same as those for LPG cylinders store.

Effect Modelling

14A.171 PHAST consequence model of the SAFETI 6.51 by DNV is used for calculation of hazardous area under various consequences. The following section briefly describes mathematical models applied to various fire and dense gas dispersion in the consequence model.

Gas Dispersion

14A.172 The UDM model without rainout effect is used for the dispersion of towngas/LPG for non-immediate ignition scenarios to obtain more conservative results. The model takes into account various transition phases, from dense cloud dispersion to buoyant passive gas dispersion, in both instantaneous and continuous releases. Besides, toxic effect is evaluated using the UDM dispersion model when the cloud reaches population sites for release of Towngas without ignition.

14A.173 Upon release of flammable gas, a number of possible outcomes may occur depending on whether the gas is ignited immediately or ignited after a period of time. The dispersion characteristics are influenced by meteorological conditions and material properties, such as density, of the released gas.

14A.174 Fire scenarios of different kinds may be developed in the presence of ignition source in the proximity of gas release. If no ignition source exists, the gas cloud may disperse downwind and be diluted to the concentration below its Lower Flammable Limit (LFL). In this case, the gas would become too lean to ignite and have no harmful effect.

Boiling Liquid Expanding Vapour Explosion (BLEVE)

14A.175 A BLEVE is a sudden rupture due to fire impingement of a vessel containing liquefied flammable gas under pressure, which results in a fireball as the flashing liquid ignited. BLEVE Blast model in SAFETI is applied.

Fireball

14A.176 For immediate ignition of an instantaneous gas release, a fireball will be formed. Fireball is more likely for immediate ignition of instantaneous release from LPG vessels/tankers due to cold catastrophic failure although it is possible for late explosion. Instantaneous ignition of a certain mass of fuel (flammable gas/LPG) results in explosion and fire of hemispherical shape. Heat is evolved by radiation. The principal hazard of fireball arises from thermal radiation. Due to its intensity, its effects are not significantly influenced by weather, wind direction or source of ignition. Sizes, height, shape, duration, heat flux and radiation will be determined in the consequence analysis.

Jet Fire

14A.177 A jet fire is typically resulted from ignition of gas/liquid discharging from a pressurised containment. Major concerns regarding jet fire are jet flame and the heat radiation effect generated from the jet flame. Thermal effect of the jet fire on adjacent population is quantified in the consequence model.

Flash Fire

14A.178 A flash fire is the consequence of combustion of gas cloud resulting from delayed ignition. The flammable gas cloud can be ignited at its edge and cause a flash fire of the cloud within the LFL and Upper Flammable Limit (UFL) boundaries. In case of continuous release, fire is flashed back to the release source and leads to jet fire. Major hazards from flash fire are thermal radiation and direct flame contact. Since the flash combustion of a gas cloud normally lasts for a short duration, the thermal radiation effect on people near a flash fire is limited. Humans who are encompassed outdoors by the flash fire will be fatally injured. A fatality rate of 1 is assumed.

Vapour Cloud Explosion (VCE)

14A.179 A vapour cloud explosion can occur when a flammable vapour is ignited in a confined or partially confined situation. Although VCE is unlikely for both project sites where vessels installed aboveground, the risk model SAFETI has accounted for the VCE hazard according to probabilities for delayed ignition in consequence modelling. The program models the delayed ignition effect by considering the flammable cloud area and location of ignition sources at each time step.

Fatality Rate Estimation

14A.180 To determine the fatality rate, the following Probit equations will be used to determine lethal doses for various hazard scenarios.

Thermal radiation [8]
$Pr = -36.38 + 2.56 \ln (Q^{1.33} \times t)$ where Q is the thermal radiation intensity in W/m^2.

Toxic gas dispersion for Towngas [4]
$Pr = -50.95 + 3.7 \ln (C \times t)$ where C is concentration in ppm.

Hazard Distances for Aberdeen

14A.181 From the consequence modeling results generated by PHAST model, hazardous distances of various fire scenarios for Aberdeen have been determined. Details of hazardous distances for these scenarios are given as follows.

14A.182 As a result of consequence modelling using PHAST, the representative fireball size can be obtained from the gas holder rupture event with radius around 80m and lift-off height around 160m. Such fireball covers a small section of Tin Wan Praya Road and an open area car park to the north, Concrete Plant to the west and the Aberdeen PTW to the east.

14A.183 The extent of flame length can be as far as 52m for jet fire hazard which can be found in pipeline rupture event. Flammable cloud can disperse downstream 50m in pipeline rupture. Although flammable cloud can reach up to downstream 222m (weighed average for all weather classes) in gas holder rupture event, it would be ignited by ignition sources along Tin Wan Praya Road, Concrete Plant and the Aberdeen PTW and cause late explosion or flash fire and would not disperse to the maximum distance.

14A.184 Toxic effect of Towngas is not significant and does not have offsite risk.

Hazard Distances for Ap Lei Chau

14A.185 From the consequence modelling results generated by PHAST model, hazardous distances of various fire scenarios for Ap Lei Chau have been determined. However, street lamps and lighting system within the Shell Depot would ignite vapour cloud within the depot in a release event and the vapour cloud would not disperse to the predicted distances. Details of hazardous distances for these scenarios are given as follows.

14A.186 Maximum effect distance for fireball hazard occurring within the LPG compound is 58m radius corresponding to road tanker failure with a lift-off height up to 116m. Since the 17 tonne of LPG in each vessel are mounded within compartments with sand, possibility of a fireball from these vessels is negligible and hence its effect is not evaluated. Jet fires (flame length) can go up to 30m in LPG vessel leak and supply line/vaporiser failure. Both fireballs and jet flames cover only a section of Lee Nam Road and part of the Ap Lei Chau PTW. Extent of flammable cloud is more significant in vessel/tanker rupture events with 190m downwind distance. However, only a small section of Lee Nam Road and part of the PTW are affected by the rest of events.

14A.187 For the transit facility, maximum fireball size is obtained from LPG road tanker BLEVE with radius up to 65m and lift-off height of 125m. Jet fire flame length can be up to 55m in LPG road tanker leak. Flammable cloud in LPG road tanker rupture can disperse downwind up to 150m without immediate ignition.

14A.188 For LPG cylinder store, cylinder rupture (49kg release mass) can produce 11m in radius fireball with lift-off height up to 25m. The fireball does not impose any offsite risk. In case of leakage, the flammable cloud has downwind distance less than 30m without immediate ignition.

Risk Assessment

General

14A.189 The frequency and consequence for each scenario are to be combined in this stage in order to estimate the followings:

- Individual risk contours; and
- Societal risk present in FN Curves.

14A.190 Risk estimates from the assessment are then compared with the acceptability criteria stipulated in Annexes 4 and 22 of the TM for evaluating hazard to life. Risk ranking exercise is also carried out to select priorities for mitigation actions, if any.

Individual Risk

14A.191 Individual risk (IR) contours of construction phase (Year 2009 scenario) for Aberdeen and Ap Lei Chau projects are illustrated on **Figure 14A.20** and **Figure 14A.21** respectively and these contours represent the worst scenario adopted. Since there is only minor increase in event frequencies due to construction activities of the project, IR contours for existing scenario and operation phase has no noticeable difference with those for construction phase. The highest IR determined is $1x10^{-6}$ per year and no higher level of IR contour is found for the Aberdeen project. The individual risk for the Ap Lei Chau Shell Depot, as a whole, can satisfy the assessment criterion. The SAFETI MPACT adopts the calculated individual risk to predict societal risk.

Societal Risk

Aberdeen

14A.192 Societal risks in terms of FN curves for existing, construction phase and operation phase scenarios are plotted on the same graph **Figure 14A.22** for ease of comparison. Societal risk for all scenarios is within the acceptable region of the risk guidelines.

14A.193 For construction phase, frequency of accidents increases slightly in comparison with the existing risk level and the increase in fatalities is due to construction workers at the PTW worksite.

14A.194 Societal risk in operation phase almost overlaps with the one for existing case. No addition risk is generated by the operation of the upgraded PTW.

Ap Lei Chau

14A.195 Societal risks for LPG Transit Depot and LPG Compound in terms of FN curves are shown on the **Figure 14A.23A** and **Figure 14A.23B** respectively. For ease of comparison, results for existing, construction phase and operation phase scenarios are plotted on the same graph. The existing risk level for LPG Compound and LPG Transit Depot falls into the acceptable region.

14A.196 For construction phase, societal risk for the LPG Compound increases but still keeps in the acceptable region. On the other hand, societal risk for the LPG Transit Depot is similar to the existing scenario and it is in the acceptable region. This indicates the project work site is not significantly affected by the LPG Transit Depot.

14A.197 Societal risk in operation phase is very similar to the existing scenario. No addition risk is generated by the operation of the upgraded PTW. The societal risk for the Ap Lei Chau Shell Depot, as a whole, is at acceptable level during construction and operational phase.

Mitigation and Monitoring Measures

Mitigation Measures

Ground Settlement

14A.198 The main strategy for groundwater and settlement control will focus on limiting groundwater inflows to acceptable levels. Groundwater inflow into the tunnels can be limited by pre-grouting ahead of the tunnel face, post-grouting of the tunnel or sealing the tunnel with a relatively impermeable lining at a short distance behind the working face, thereby limiting the duration and total volume of groundwater inflows into each section of tunnel. Pre-grouting ahead of the tunnel face is considered to be the most effective method of controlling groundwater inflow where linings are not installed close to the working face. Post-grouting would be used where the pre-grouting efforts are found to be inadequate.

Ground Vibration

14A.199 Ground vibration would be minimized using non-percussive pre-bored H-Piles for piling works. Ground vibration control can be achieved through close monitoring of soil movement. Monitoring of vibration resulted from construction works to ensure the velocity and amplitude of vibration as recommended by relevant government authorities will not be exceeded. Monitoring plan will include setting up monitoring points at fixed locations adjacent to more sensitive structures which have lower vibration or air overpressure tolerance. The monitoring will be carried out at ground level with sensors mounted on small concrete bases embedding into undisturbed ground. Each sensor will be able to record both ground vibration and air overpressure. For the Tunnel P, monitoring will be carried out using a moving array of sensor locations as the tunnel is advanced. These will be largely sited above or close to the tunnel alignment and mounted on small concrete bases embedding into undisturbed ground. For some particularly sensitive structure within the HKCG, sensor will be located at the structure, farther from the blast, to ensure the vibration limit at the structure is not exceeded.

14A.200 Other mitigation measures include,

- Follow Standard and Guidelines given in Gas Production & Supply: Code of Practice for Avoiding Danger from Gas Pipes
- Close supervision is recommended during peak construction period
- The safeguards for this potential impact will be further confirmed in detailed design stage

Crane Operation

14A.201 Damage to PHIs due crane operation is avoidable through the following design factors,

- Location and orientation of crane installation
- Appropriate lifting height
- Restriction on swing angle
- Special attention should be paid for climbing and dismantling of a tower crane.
- No overloading
- Set out safety zone

DGs Store

14A.202 Effect distances for different DGs have been evaluated. As long as buffer distance of 25m can be provided, use and storage of DGs do not have adverse impact on the PHIs.

Monitoring Measures

Ground Settlement

14A.203 Ground settlement is to be monitored by a series of geotechnical instrumentations. A series of ground settlement markers and piezometers are to be installed in the vicinity of the proposed tunnel and near the HKCG Depot are presented in **Figure 14A.24**. Monitoring of groundwater and settlement will form an important part of the strategy to confirm the effectiveness of the mitigation measures and to adjust the inflow limits if necessary. In order to cater for unforeseen problems encountered during the construction stage, additional monitoring and instrumentation system will be installed in the vicinity of the HKCG Depot at a later stage by the Contractor before the commencement of construction works. Typical allowable limits for well maintained buildings and historic buildings are 25mm and 5mm respectively. Allowable limit of 13mm is proposed (**Appendix 14A.4**) and the actual allowable limit is subject to further requirements of CEDD and relevant authorities. Gas facilities should be able to withstand ground settlement (including differential settlement) within the allowable limit.

Ground Vibration

14A.204 Monitoring plan will include setting up monitoring points at fixed locations adjacent to more sensitive structures which have lower vibration tolerance. The monitoring will be carried out at ground level with sensors mounted on small concrete bases embedding into undisturbed ground. Each sensor will be able to record ground vibration. For some particularly sensitive structure within the Shell Depot such as LPG compound, sensor will be located at the structure, farther from the vibration source, to ensure the vibration limit at the structure is not exceeded. Allowable limit of 5mm/s PPV was proposed to HKCG (**Appendix 14A.4**). The same criteria will be also applied to the Shell Depot.

Gas Leakage Detection for Ap Lei Chau Site

14A.205 It was advised, during the HAZOP meeting, that no gas leakage detection alarm is installed in the Shell Depot. It is recommended to install gas detection/alarming system to provide warning to Shell operator and Construction Site staff in case of gas leakage. This provides an early warning for operation staff and construction staff in case of gas release. Specific emergency procedures should be developed, together with Shell Depot Operation

Team, and documented in an emergency plan to cater for gas leakage scenarios before the construction stage.

Emergency Plan and Procedures

14A.206 The following measures are recommended as "Best Practice" for DSD to implement during construction stage for both Aberdeen and Ap Lei Chau sites.

a) Emergency evacuation procedures should be formulated and DSD should ensure all workers on site should be familiar with these procedures as well as the route to escape in case of gas release incident occur. Diagrams showing the escape routes to a safe place should be posted in the site notice boards and at the entrance/exit of site.
b) The emergency procedures should specify means of providing a rapid and direct warning (e.g. Siren and Flashing Light) to construction workers in the event of gas release in the gas facilities.
c) The construction site officer of DSD should establish a communication channel with the gas operation personnel during construction stage. In case of any incidents in the gas facilities that need site evacuation, operation staff of gas facilities should advise the DSD's site officer to evacuate the construction workers.
d) Induction Training should be provided to any staff before working at the both work site.
e) Periodic drills should be coordinated and conducted to ensure all construction staffs are familiar with the evacuation procedures. Upon completion of the drills, a review on every step taken should be conducted to identify area of improvement.

Conclusion

14A.207 For both project sites, potential damages to HKCG Depot and Shell Depot can be avoided with implementation of safety measures and close monitoring procedures. Operation of these PHIs will not be disturbed and gas supply will not be disrupted provided that vibration and ground settlement caused by construction works can be controlled within allowable limits. Noticeable change in individual risk during construction phase is not observed while the $1x10^{-5}$ per year maximum level of off-site individual risk stipulated in Annex 4 of the EIAO TM can be satisfied for both HKCG Gas Holder and Shell Depot.

14A.208 Societal risk for both PHIs does not increase significantly due to construction works of HATS project and are within the acceptable level during construction and operation phases. Although the LPG Compound can be maintained to acceptable level in construction phase of the Ap Lei Chau PTW, installation of gas detection system at the LPG Compound together with ground vibration monitoring can bring the risk level further down as an early warning to safeguard construction workers at the project site.

14A.209 Hazard to life assessment has been carried out in accordance with Annexes 4 and 22 of the TM for the proposed work sites at Aberdeen and Ap Lei Chau due to in vicinity of the HKCG Depot and Shell Depot respectively. Both PHIs can satisfy individual risk and societal risk criteria stipulated in the EIAO TM throughout construction and operation phases.

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