13 HAZARD TO LIFE

13.1 Introduction

13.1.1 Background

This section of the EIA presents a summary of the analysis and findings of the Hazard to Life Assessment (also referred as Quantitative Risk Assessment (QRA)) undertaken for the proposed East West Line (TAW-HUH) Section of the Shatin to Central Link (SCL) project (the Project).

The Project consists of an 11 km extension of the Ma On Shan Line from Tai Wai Station, through Hin Keng, Diamond Hill, Kai Tak, To Kwa Wan, Ma Tau Wai, Ho Man Tin to Hung Hom. The Project involves nearly 9km to be constructed in tunnel. The route will encounter a variety of ground conditions, urban and rural environments, and a number of specific constraints in some localised areas. The majority of the tunnelling will be by mechanical methods but there will be blasting required in certain sections. Construction is expected to commence in 2012. Major civil works will be completed by 2016, and all works will be completed by 2018.

The selection of construction methods has been optimised to minimise, as far as possible, the use of explosives depending on the type of material to be excavated. Only two sections of tunnels will require excavation by Drill and Blast construction method. These are:

- Ho Man Tin to Ma Tau Wai: The section of running tunnels between Shansi Street shaft and HOM Station is proposed to be constructed as two single-track horse-shoe tunnels. This approximately 480m long section of twin tunnels would be excavated within granite using the drill & blast method; and
- Ma Chai Hang Ventilation Building to Hin Keng Portal: Drill & blast methods will be used for the construction of a twin-track single tunnel for an alignment length approximating 2450 m.

As shown above, a substantial length of the tunnels and adits (approximately 3.2 km of tunnels) will be excavated in rock. A significant amount of explosives will be required for the construction of rock caverns, tunnels and adits.

To enable a timely delivery of explosives to site and in order to meet the proposed construction work programme, one temporary Explosives Storage Magazine (Magazine) is required. It will be located at Tseung Kwan O Area 137. The site was selected considering the distance to the work areas as well as other constraints such as land availability, minimum separation distances from temporary magazine to populated area, accessibility by Mines Division, etc. (ref.1). With reference to the EIA Study Brief (ESB-191/2008), if there is use of explosives for the construction activities and the storage or blasting location is in close vicinity to populated areas, Potentially Hazardous Installation site(s), town gas installations, and LPG Gas Stations along the Project alignment a hazard to life assessment is required.

With reference to the EIA Study Brief, some work areas will be located within the consultation zone of a PHI namely the Shatin Water Treatment Works which stores chlorine in one tonne drums. No work areas will be located in the consultation zone of Ma Tau Kok Gas Production Plant or any other PHI. Based on this and as required in the EIA Study Brief Section 3.4.5.4, the hazard to life assessment for Sha Tin Water Treatment works has been carried out for the construction and operational stages of the Project. With reference to the Study Brief Section 3.4.5.5, there is no storage, transport or use of explosives within the consultation zone of the Ma Tau Kok Gas Production Plant PHI either during the construction or operation stages of the Project. Based on this, the Ma Tau Kok PHI assessment is not considered applicable for this hazard to life assessment.

The QRA for the storage, transport and use of explosives relates to the construction phase of the project, in which blasting activities are expected. There will be no explosives handled during the operational phase.

The Hazard to Life assessment under this section of the EIA, addresses, in particular, the following:

- Storage of explosives at the proposed temporary magazine (cartridged emulsion, detonating cord and detonators) including handling of explosives within the temporary magazine site;
- Transport of Explosives to the delivery points; and
- Use of explosives (cartridged emulsion, bulk emulsion manufactured at the blast site, detonating cord and detonators) including handling of explosives from the delivery points to the blast faces.

Further details of the QRA for the Project are presented in the Appendix 13.

- Appendix 13A: Hazard to Life Assessment for the Storage and Transportation of Explosives from the proposed temporary Magazine to the delivery points;
- Appendix 13B: Hazard to Life Assessment for the Use of Explosives including the explosive hazard impact assessment on PHIs and towngas facilities; and
- Appendix 13C: Hazard to Life Assessment for Shatin Water Treatment Works (STWTW) covering the construction and operational stages on the Project.

13.2 Legislation requirement and evaluation criteria

The key legislation and guidelines that are considered relevant to the development of the proposed SCL (TAW-HUH) project are as follows:

- Dangerous Goods Ordinance, Chapter 295;
- Environmental Impact Assessment Ordinance (EIAO), Chapter 499; and
- The EIA Study Brief (ESB-191/2008), Section 3.2 and Section 3.4.5.

EIAO Technical Memorandum (EIAO-TM)

The requirement for a QRA of projects that involve the storage, transport and use of dangerous goods where a risk to life is a key issue with respect to the Hong Kong Government Risk Guidelines (HKRG) is specified in Section 12 of the Environmental Impact Assessment Ordinance Technical Memorandum (EIAO-TM).

The relevant authority for a QRA study relating to a temporary explosives magazine storage facility and the transport of the explosives is the Environmental Protection Department (EPD), as specified in Annex 22 of the EIAO-TM.

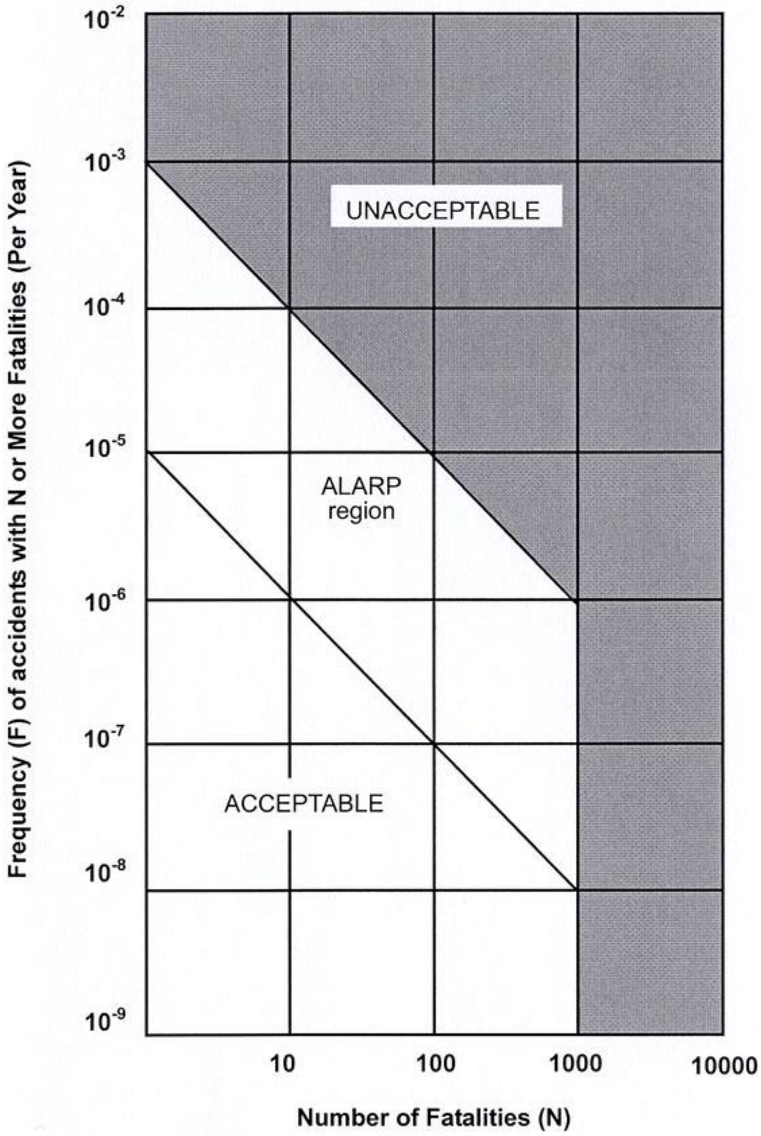
Annex 4 of the EIAO-TM specifies the Individual and Societal Risk Guidelines.

Hong Kong Government Risk Guidelines (HKRG), EIAO TM Annex 4

Individual risk is the predicted increase in the chance of fatality per year to an individual due to a potential hazard. The individual risk guidelines require that the maximum level of individual risk should not exceed 1 in 100,000 per year i.e. 1 x10-5 per year.

Societal risk expresses the risks to the whole population. The HKRG is presented graphically in *Figure 13.1*. It is expressed in terms of lines plotting the cumulative frequency (F) of N or more deaths in the population from incidents at the installation. Two F-N risk lines are used in the HKRG that demark “acceptable” or “unacceptable” societal risks. The intermediate region indicates the acceptability of societal risk is borderline and should be reduced to a level which is “as low as is reasonably practicable” (ALARP). It seeks to ensure that all practicable and cost effective measures that can reduce risk will be considered.

Figure 13.1 Hong Kong Government Risk Guidelines



13.3 Study Objectives and Methodology

The objective of the QRA study is to assess the risk to life of the general public from the hazards that arise from the storage, transport and use of the explosives that are required to facilitate the construction of the Project. The results of the QRA should then be compared with the HKRG.

The detailed requirements of the study are given in Section 3.4.5 of the EIA study brief. The main QRA requirements for the storage, transport and use of explosives are:

- To identify hazardous scenarios associated with the storage, transport and use of explosives; and possible damage scenarios to the gas installations leading to catastrophic and non-catastrophic failures of the gasholder causing gas release; and then determine a set of relevant scenarios to be included in a QRA;
- To execute a QRA of the set of hazardous scenarios determined, expressing population risks in both individual and societal terms;
- To compare the individual and societal risks with the Criteria for Evaluating Hazard to Life stipulated in Annex 4 of the EIAO-TM; and
- To identify and assess practicable and cost-effective mitigation measures (e.g. selection of the shortest practicable road transport routes to and from the storage facility etc.).

The methodology of the hazard assessment should be consistent with previous studies having similar issues.

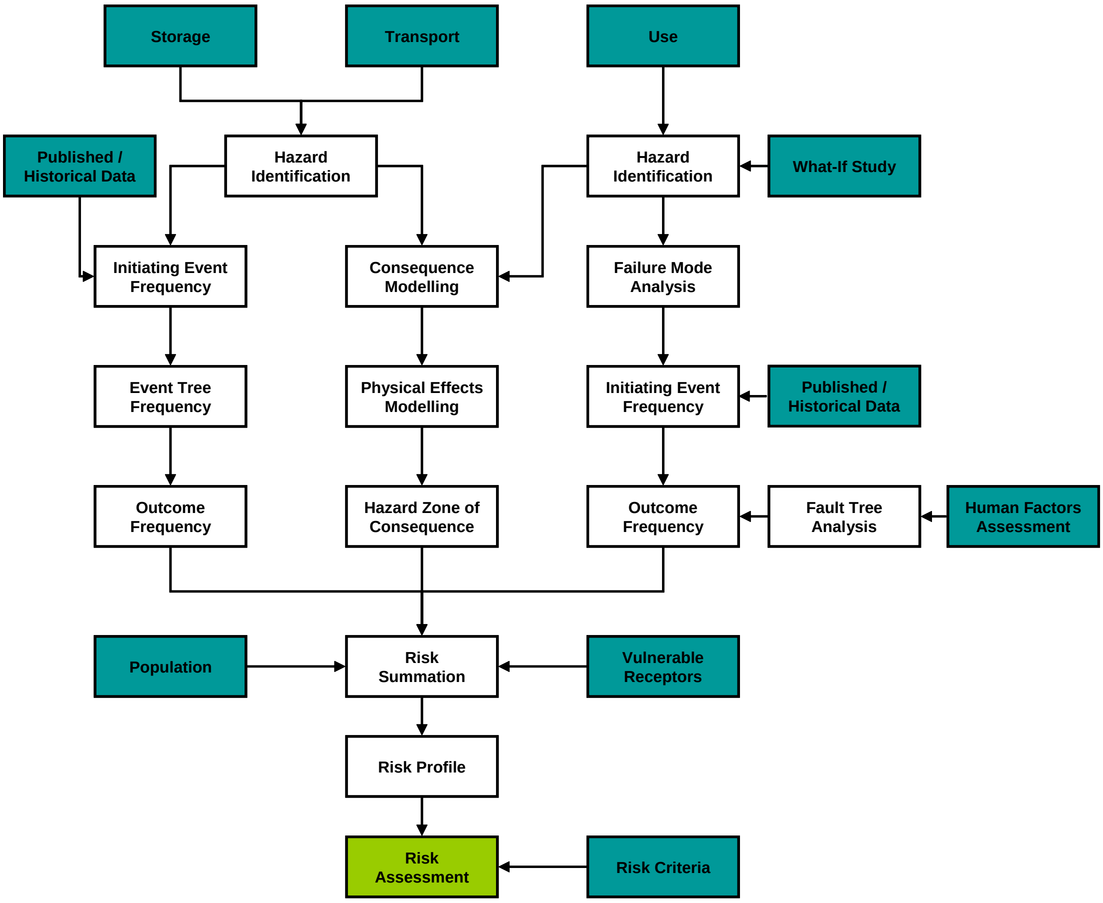
The elements of the QRA are shown schematically in *Figure 13.2*. It includes the following:

- Collection and review of relevant data for the proposed Magazines, the transport from the magazines, and the use of explosives at the works area, as well as population and vulnerable receptors, such as slopes, retaining walls etc., in the vicinity of storage, the tunnel construction and proposed transport routes;
- Hazard identification. A structured study involving a “what-if” analysis and a review of literature and accident databases were undertaken and updated. These formed the basis for identifying all the hazardous scenarios for the QRA study;
- Frequency estimation. The frequencies, or the likelihood, of the various outcomes that result from the hazards associated with the storage and transport of explosives was taken primarily from the ERM 2009 study (ref. 26), which has been accepted by the relevant authorities. The ERM 2008 study (ref. 2) was the primary reference for the hazard assessment related to the use of explosives at the work areas. Where necessary, to consider specific factors applicable for the Project, recent accident statistics, and to reflect the current knowledge on the explosives’ properties, these frequencies were modified or updated making reference, as far as possible to published references; such as the previous Hong Kong studies , UK HSE, US DoD, Dutch TNO, latest accident statistics from the Transport Department and Fire Service Department, etc.;
- For all identified hazards, the frequency assessment has been documented and the consequences were modelled;
- The frequency model related to the transport and storage of explosives was taken from the ERM 2009 study (ref. 26). The frequency model related to the use of explosives was taken from the ERM 2008 study (ref. 2) but with human factor study and Fault Trees updated to reflect the particular conditions of SCL (TAW-HUH) such as blast face areas, number of sectors at the work face, number of production holes and Maximum instant Charge (MIC) per production hole.
- The consequence models employed in this study were :
  - Blast effects including overpressure, flying debris, fireball, etc.: the ESTC model (ref.3), developed by the UK Health and Safety Commission (HSC). Although, there have been a number of recent studies suggesting that the ESTC (2000) models should be reviewed for applicability to explosive stores and transport, these models are still the recommended models in the UK and adopted in the ERM 2008 study (ref. 2);
  - Ground shock/vibrations generated from an explosion: Ground vibration models developed as part of the WIL methodology (ref. 2). Key sensitive receivers were preliminarily screened based on the threshold limits of Peak Particle Velocity (PPV), i.e. PPV ≥ 90 mm/s (for slopes), PPV ≥ 100 mm/s (for buildings), PPV ≥ 13 mm/s (for gas offtake stations) and PPV ≥ 25 mm/s (for gas pipes). and PPV ≥ 13 mm/s for historical structures and other structures that may have a lower standard of design. A detailed QRA was then conducted as per the WIL methodology (ref.2) for those features with PPV exceeding the threshold levels.
  - Gas piping failure arising from an explosion scenario: gas release occurring from an explosion scenario and subsequent possible hazardous outcomes such as fireball, jet fire and flash fires were modelled using a traditional QRA approach consistent with a number of previous Hong Kong studies for gas installations (details are provided in Appendix 13B).
- The consequence and frequency data were subsequently combined using ERM’s in-house proprietary software Riskplot TM to produce the required risk estimates. The transport part of the risk assessment, consistently with the ERM 2009 study (ref. 26), uses an in-house Explosive Transport GIS Risk Assessment tool (E-TRA) developed to account for three-dimensional blast effects on buildings and the effect of accidental explosions on elevated roads. It also accounts for traffic jam scenarios which could occur in some accidental scenarios as reported in ref.4. The E-TRA model is

summarised in Section 3.2 of Appendix 13A and has been validated against Riskplot TM.

Finally, the results from the risk assessment were compared to the EIAO-TM Criteria. Recommendations have been made where required to ensure compliance with EIAO-TM Criteria, relevant best practice, and to reduce the overall risk levels.

Figure 13.2 Schematic Diagram of QRA Process



The methodology used in this hazard assessment is consistent with previous studies. Details of the analysis can be found in Appendix 13A and 13B.

13.4 Facility Details

13.4.1 Project Overview

The Project comprises the following key elements:

- Interfaces with existing stations such as Tai Wai Station, Diamond Hill Station, Hung Hom Station;
- Interfaces with other railway extensions such as Kwun Tong Line Extension (KTE) at Ho Man Tin Station (part of KTE project);
- New stations including Hin Keng Station, Kai Tak Station, To Kwa Wan Station and Ma Tau Wai Station;
- Railway alignment sections including:
  - Hung Hom to Ho Man Tin: This section of tunnel will connect between the Winslow Garden portal and Ho Man Tin Station. It will be constructed by cut & cover method;

- Ho Man Tin to Ma Tau Wai: The section of running tunnels between Shansi Street shaft and HOM Station is proposed to be constructed as two single track horse-shoe tunnels. This approximately 480m long section of twin tunnels would be excavated within granite using the drill & blast method;
- Ma Tau Wai to To Kwa Wan: The tunnels will be constructed with twin bored single track Tunnel Boring Machine (TBM) drives to be launched at the southern end of TKW Station and retrieved at the Shansi Street Shaft to the south of MTW Station;
- To Kwa Wan to Kai Tak: The tunnel in this section will be constructed in open cut with battered side slopes;
- Kai Tak Diamond Hill: From Kai Tak Station to Prince Edward Road East approximately 400m of tunnel will be constructed by cut & cover method, including a launching shaft for a TBM to construct the tunnels towards Diamond Hill Station;
- Diamond Hill to Ma Chai Hang Ventilation Building: Excavation here would start with open cut methods, followed by cut and cover and eventually use of a TBM;
- Ma Chai Hang Ventilation Building to Hin Keng Portal: Drill & blast methods to be used, although at certain sections at reduced rates due to vibration restrictions (sensitive receivers);
- Hin Keng Portal to Tai Wai Station: A viaduct will be constructed from the Hin Keng Portal to Hin Keng Station. The alignment will continue on elevated tracks up to Tai Wai Station;
- Shafts will be mechanically excavated.

The proposed Project alignment and work areas are shown in *Figure 13.3.*

Construction is expected to commence in 2012. Major civil works will be completed by 2016, and all works will be completed by 2018. Excavation in rock by blasting will be ongoing generally from October 2013 until March 2015 for a significant length of the tunnels and adits (approximately 3.2 km).

For the purpose of this study, the alignment is divided into two areas:

- Lion Rock tunnel from Ma Chai Hang Ventilation Building to Hin Keng portal: approximately 2450 m long twin track tunnel; and
- Ho Man Tin tunnels from Shansi Street shaft to Ho Man Tin station interface: approximately 480 m long twin (two) single track tunnels.

Two categories of explosives will be used for the construction of tunnel by Drill and Blast methods. These are:

- Initiating explosives: cartridged emulsion explosives, detonating cord and detonators; and
- Blasting explosives: bulk emulsion explosives manufactured at the blast site or, in close proximity to sensitive receivers (i.e. with MIC less than 2 kg), cartridges emulsion explosives.

Cartridged emulsion and detonating cord will be delivered from the temporary explosives magazine to the various construction sites by the appointed contractors using Mines Division licensed trucks. These explosives are classified as an explosive Class 1.1D under United Nation (UN) Classification (ref.8) and as a Category 1 (Explosive and blasting agents) Dangerous Goods under the Hong Kong Dangerous Goods Ordinance.

Detonators will also be used to initiate the blast at the working face. As used in this project, they are classified as Class 1.4B or 1.4S explosives under the UN classification system and Category 1 (Explosives and Blasting Agents) under the Hong Kong Dangerous Goods Ordinance, and will be transported from magazine to work areas by a dedicated truck, which is identical to, but independent of the truck carrying the emulsion explosives and detonating cord. Detonators approved for use in Hong Kong are of the Non-Electric Type, i.e. initiated by shock tube.

Explosives classified as Class 1.1 is defined as substances and articles which have a mass explosion hazard while Class 1.4 explosives present no significant hazard outside the packaging. To comply with the classification, it is required to ensure that the explosive is safe to transport, to pass a series of classification tests in accordance with the UN test manual, 2009 (ref.7). Due to different properties of explosives, a compatibility class is also assigned, as applicable to this Project. Type "B" is defined as "An article containing a primary explosive substance and not containing two or more protective features" and type "S" is defined as "The substance or article so packed or designed that any hazardous effects arising from accidental functioning are limited to the extent that they do not significantly hinder or prohibit fire fighting or other emergency response efforts in the immediate vicinity of the package".

Bulk emulsion precursor will be transported to the blast sites by the appointed third party supplier. It is classified as an oxidising agent Class 5.1 under the UN Classification system and as Category 7, i.e. strong supporter of combustion under the Hong Kong Dangerous Goods Ordinance. Prior to sensitizing, it is not considered as an explosive, and hence outside the scope of this QRA. Bulk emulsion will not be stored within the temporary magazine.

13.4.2 Statutory/ Licensing Requirements

The statutory / licensing requirements with respect to the explosives (Cat. 1 Dangerous Goods) or the oxidizing substances (Cat. 7 Dangerous Goods) used to prepare explosives at the construction work area as well as relevant government departments/ authorities' advice and practice on the proposed transport and storage of explosives for the blasting activities are summarized below.

<u>Category 1 Explosives and Blasting Agents</u>

- Responsible authority: The Commissioner of Mines
- Applicable regulations/ guidance notes:
  - Supply of detonators and cartridged emulsion explosives (under the Dangerous Goods (General) Regulations Cap. 295B);
  - Approved explosives for blasting in Hong Kong (under the Dangerous Goods (General) Regulations Cap. 295B);
  - Blast design (under the Dangerous Goods (General) Regulations Cap. 295B);
  - Blast loading and execution (under the Dangerous Goods (General) Regulations Cap. 295B);
  - Removal of explosives (under Regulation 4 of the Dangerous Goods (General) regulations Cap. 295B);
  - Approval of an explosives delivery vehicle (under CEDD's "Guidance Note on Requirements for Approval of an Explosive Delivery Vehicle" (ref.9));
  - Explosive delivery vehicle design features and safety requirements (under CEDD's "Guidance Note on Requirements for Approval of an Explosive Delivery Vehicle" (ref.9);
  - Explosive magazine (under CEDD's document "How to Apply for a Mode A Explosives Store Licence" (ref.10));
  - Explosives produced at site (under Regulation 31A of the Dangerous Goods (General) Regulations Cap. 295B); and
  - Explosives load per truck (in accordance with the Removal Permit under the Dangerous Goods (General) Regulations Cap. 295B).

<u>Category 7 Strong Supporters of Combustion</u>

- Responsible authority: Fire Services Department
- Applicable regulations:

- Storage of oxidizing agents (under Dangerous Goods (General) Regulations Cap. 295B)

This Project will use cartridged emulsion explosives as initiating explosives. For blasting explosives, bulk emulsion will be used; however, cartridges emulsion explosives may be used as blasting explosives in close proximity to sensitive receivers. Therefore, the storage and transport requirements for explosives are the minimum required quantities for the Project.

13.4.3 Temporary Storage Magazine Details

A temporary magazine site is proposed to be built at Tseung Kwan O Area 137. The design, construction and operation of the temporary magazine will comply with the general requirements from the Commissioner of Mines (ref.10).

The temporary magazine is generally designed to store sufficient quantities of explosives for two days so as to allow blasting to be carried out 24 hours per day and provide a buffer in the event of delivery interruption to the temporary magazine by Mines Division. However, there will be periods during peak explosives requirements where one day storage capacity is envisaged. If storage capacity is not able to satisfy demand on a specific day, direct delivery by Mines Division can be requested, or a blast can be rescheduled until the following day when the magazine stores are replenished.

The temporary Magazine is required to serve the delivery points at Ma Chai Hang (MCH) Ventilation Building, Shansi Street Shaft and Hin Keng Portal. Potential magazine site locations in Hong Kong close to the blasting locations have been investigated. The site at Tseung Kwan O Area 137, although remote from the work areas, has been retained as the only practicable site candidate meeting Mines Division separation distance requirements. It is in a remote area with no public access nearby and is very convenient for the Mines Delivery with a pier nearby for deliveries.

The temporary Magazine comprises 4 stores each capable of storing 250 kg of explosives. A storage chamber for detonators equivalent to two days supply is provided next to each explosives chamber. The detonators have a very low explosive mass and contain less than 1 gram of high explosives per detonator. The net explosive quantity within each detonator chamber will be less than 2 to 3 kg. The temporary magazine site at Tseung Kwan O Area 137 will also be used for the KTE project with the SCL (TAW-HUH) stores located adjacent to the dedicated KTE explosive stores. The four SCL (TAW-HUH) stores will be dedicated to this Project.

The work areas and the associated explosives using contract packaging for the temporary magazine are shown in *Table 13.1*. The quantities (kg) of explosives mentioned in the report are represented in gross weight, unless they are clearly specified as TNT eqv. kg.

Each of the magazine buildings is a single-storey, detached and bunded structure, which is fenced and secured in accordance with the Commissioner of Mines' requirements. Details of the requirements are defined in the CEDD document "How to Apply for a Mode A Explosives Store Licence" (ref.10). Surface road access suitable for 11-tonne trucks is also provided for delivery of explosives.

Table 13.1 Project Contracts and Work Areas (Blasting only)

Contract No.	Storage Magazine	2 Day Explosive Storage Requirement per contract	Delivery Point (Work Area)
Lion Rock Tunnel (MCH to HIK)	TKO Area 137	500 kg (2x250kg stores)	MCH Road (Ma Chai Hang Ventilation Building)
			Hin Keng Estate Access Road (Hin Keng Portal)

Contract No.	Storage Magazine	2 Day Explosive Storage Requirement per contract	Delivery Point (Work Area)
Ho Man Tin Tunnels	TKO Area 137	500 kg (2x250kg stores)	Shansi Street (Shansi Street Shaft)

13.4.4 Transport Route Details

Mines Division will deliver explosives by the shortest practicable route to the temporary Magazine on a daily basis (once per day), from where explosives will be transferred to the work areas by the contractors for the daily or twice-daily blasts depending on requirements for construction. Loads will be limited to a maximum of 200 kg per truck or less in accordance with the Removal Permit issued by Mines Division.

The explosives will be delivered to the various construction work areas using the public roads as shown in *Figure 13.4*. The proposed delivery points from the temporary magazine are shown in *Table 13.1*.

According to the current construction programme, delivery of explosives to the three delivery points will be required from late 2013 to early 2015. The delivery programme to each work area will overlap significantly.

In addition to cartridged emulsion and detonating cord, detonators will also be transported. Detonators will be transported in a separate and dedicated licensed vehicle.

The licensed explosives delivery vehicles (LGV pick-up trucks) for delivery of explosives from the temporary site magazine to the worksites, used as the basis for this QRA, will have the following safety features:

- Diesel powered;
- Driver's cabin is separated by a distance of not less than 150mm from the cargo compartment of the vehicle;
- Manual fuel isolation switch;
- The exhaust system is located as far from the cargo compartment as possible. The modification of the exhaust system will be approved by the Transport Department;
- All electrical wiring or electrical devices will be shrouded in fire resisting conduits;
- Fuel tank will be protected from accidental damage, and designed to prevent accumulation of spilt fuel on any part of the vehicle;
- The required number of fire extinguishers shall be agreed with Mines Division;
- Fire resistant material will be fitted between the wheel arches and the goods compartment;
- Hand-held lightning detector provided in the vehicle for lightning detection during loading and unloading of explosives;
- Lockable wood lined steel or aluminium receptacles mounted on the vehicle tray; and
- Fold down / up explosives warning signs and red strobe beacons.

In addition, a fire screen will be fitted between the cab and the load compartment and between the load compartment and the chassis.

13.4.5 Use of Explosives Details

Explosives will be used for the construction of the Lion Rock tunnel and the Ho Man Tin tunnels.

The initial excavation of the tunnels will be by mechanical methods. Drill and blast excavation will then be adopted for about 10 m for trial blasting, followed by full face excavation if ground conditions are suitable. Blasting cover protection will be provided to all shaft/portal prior to blasting being carried out.

The following safeguards will be implemented during blasting.

Vibration Monitoring. It is a requirement to monitor every blast in Hong Kong to record blast induced ground vibrations. A blasting engineer is responsible for ensuring that the controlling and other nominated sensitive receivers for each blast are monitored to record the vibration levels in terms of Peak Particle Velocity (mm/sec).

Trial Blasts. Trial blasts will be carried out for the first series of blasts for the tunnels and different areas or sectors of the project if required. The trial blasts will be used to demonstrate that the different types of blasting are safe, and the blasting monitoring and control procedures are effective. The trial blasts are conducted with cartridged emulsion explosives.

Advance Notice of Blasts. As part of the process of issuing a License to Possess and a Permit to Use dangerous goods, Mines Division will require that highly visible warning notices/signs be posted at several locations to warn the public that blasting will take place. These warning signs will be posted near the intended blasting location, even though all blasts will be conducted underground. The Contractor is required to write the blasting date and time on the notice.

Contractors are required by Law to have a comprehensive Safety Management System and this is implemented and supervised by on-site safety teams. Independent third party auditors make annual checks of documentation and safety records.

13.4.6 Base Case and Worst Case for Quantitative Risk Assessment

The actual construction programme will depend on the detailed design and appointed contractors. It may also depend on the actual achievable progress rates which may vary due to specific site conditions (e.g. geology). To consider the uncertainty in the envisaged construction programme, a Base Case, which accounts for expected programme variations, and a Worst Case, which presents the worst programme scenario, have been considered for the assessment.

<u>Base Case Programme for Hazard to Life Assessment</u>

Based on the envisaged construction programme and sequence of works, the annual travel distance by explosive vehicles, carrying cartridged emulsion and detonating cord, will reach a peak in the period between December 2013 and November 2014, with an annual number of deliveries of 1,127 and a travel distance is around 28,000 km. This period is referred as the peak explosive delivery period which is taken to represent the Base Case scenario for the Hazard to Life Assessment. The delivery frequency has been estimated on the basis that, for a given delivery point, each delivery will be made to each blast face independently of the other blast faces even if the load could be transported on the same truck. This approach, although slightly conservative, accounts for expected delivery variations during the peak delivery period, within which, separate deliveries will be generally undertaken.

The total number of trips has been estimated based on the typical licensing limit of 200 kg explosives per truck.

In the Base Case, it was considered that blasting could be carried out at predetermined time during the day following the envisaged construction programme. A distribution of delivery time has thus been considered based on the construction programme.

The Base Case programme is summarized in *Table 13.2*.

Table 13.2 Summary of Explosives Deliveries and Transport Quantities (for Base Case)

Delivery Point	Explosive Deliveries in Peak Delivery Period (trips/y)	Peak Transport Quantity (kg/trip)
MCH Ventilation Building	513	162
Shansi St Shaft	334	200
Hin Keng Portal	280	200
Total	1127	-

<u>Worst Case Programme for Hazard to Life Assessment:</u>

The Hazard to Life Assessment also covers the Worst Case scenario. It addresses the possibility that, due to construction uncertainties or contractors' methods of working, the contractors propose an actual construction programme which differs from the envisaged construction programme. Such a case may result in a higher number of delivery trips. Return trips loaded with explosives will generally be avoided; however, due to some construction uncertainties, a number of return trips could be made. Overall, in the worst case, a 20% increase in the number of deliveries compared to the base case scenario may result based on previous project experience.

In this project, for a particular delivery point, it is possible that the explosive load required for each delivery will be higher than that indicated in the envisaged programme due to particular site conditions and blasting requirements; however, the explosive load to be transported will be, as a worst case, the maximum explosive load for the site (sum of the loads for each blast face within the same work site). The delivery load, in the Worst Case Scenario, has been selected as the sum of the loads for each blast face within the same work site bearing in mind the licensing limit of 200kg for the truck.

In this Worst Case Scenario, explosives could be delivered at peak day times.

The Worst Case programme is summarized in *Table 13.3.*

Table 13.3 Summary of Explosives Deliveries and Transport Quantities (Worst Case)

Delivery Point	Explosive Deliveries in Worst Case (trips/y)	Transport Quantity (kg/trip)
MCH Ventilation Building	616	162
Shansi St Shaft	401	200
Hin Keng Portal	336	200
Total	1353	-

Figure 13.3 Proposed Alignment and Work Areas

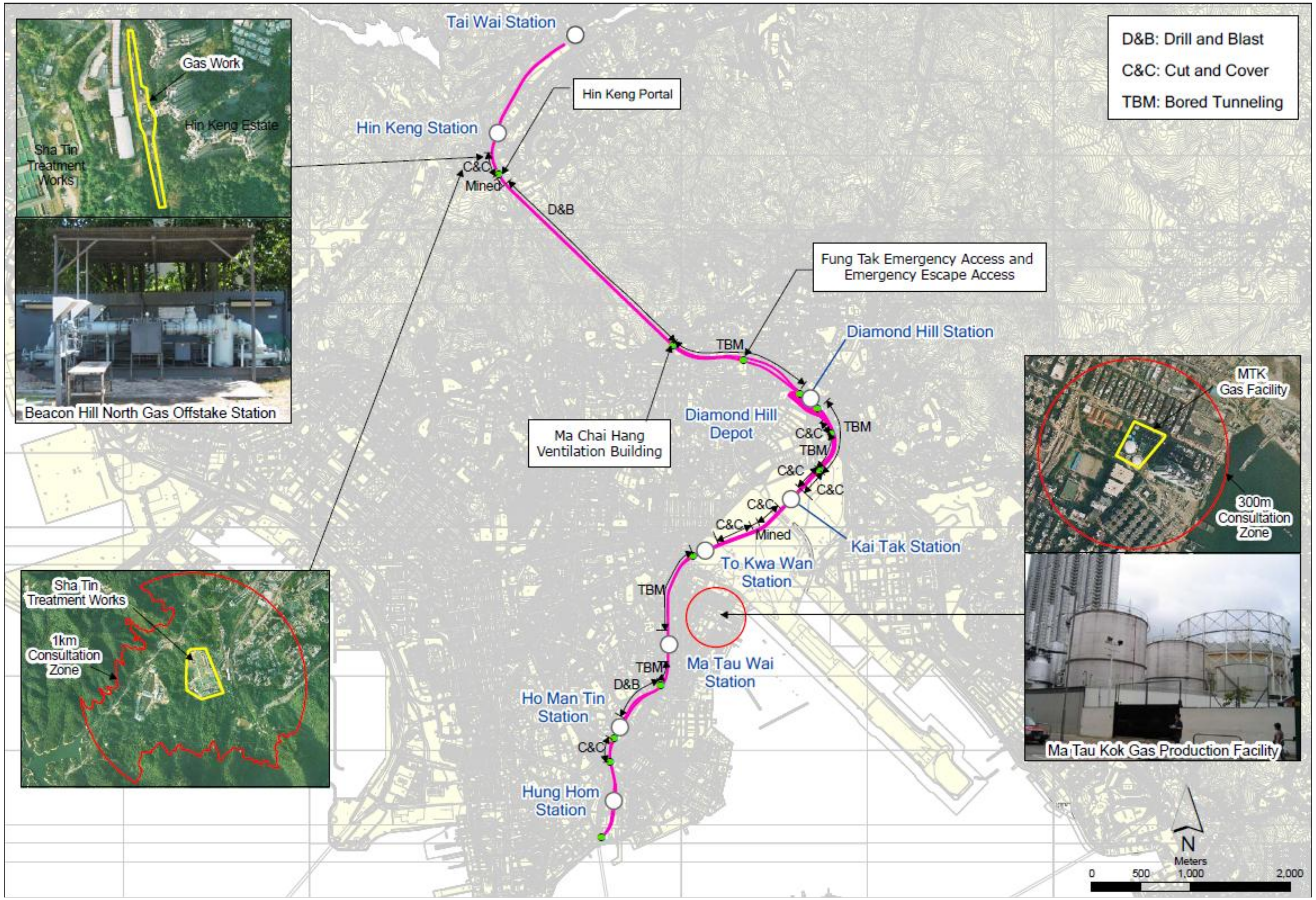
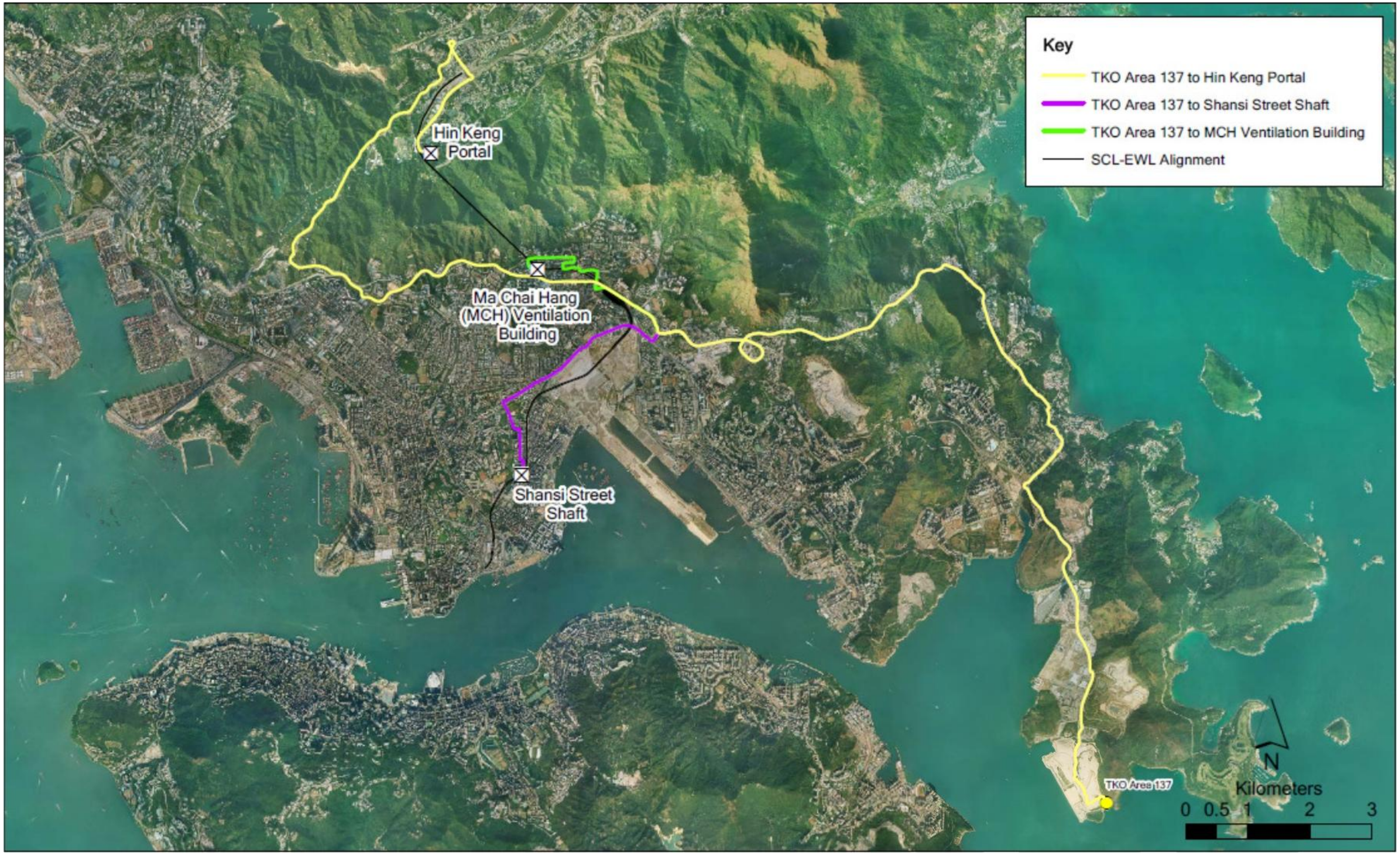


Figure 13.4 Project Alignment, Proposed Magazine Location and Explosives Transport Routes



13.5 Population Data

Population within the vicinity of the temporary explosives magazine is estimated based on site surveys and information gathered from Geographic Information System (GIS) database 2007/2008 data (ref.11) and aerial maps. There are no known (current or future) buildings or any other structures in the hazard zone of the proposed temporary Magazine.

Population data used for the transport risk assessment have been collected by a combination of site survey, Base District Traffic Model (BDTM) 2011, Annual Traffic Census 2007 (ref.12), Road Traffic Accident Statistics 2007 (ref.13&14), Centamap (2009) and GIS tools. For areas where information is not available, assumptions have been used consistently with the previously approved studies. Three types of population have been considered.

- Pedestrian population on footpaths and pavements next to delivery routes;
- Road population; and
- Building population.

The approach to modelling the risks during transport of explosives is fully 3-dimensional and GIS based. It also accounts for the potential increased risk when explosives trucks travel on elevated roads.

The population data adopted in the QRA is detailed in Appendix 13A.

13.6 Hazard Identification

Hazard identification consisted of a review of the following:

- Explosives properties;
- Scenarios presented in previous relevant studies;
- Historical accidents; and
- Discussions with explosives and blasting specialists.

13.6.1 Hazards of Explosives

Explosives present a hazard to both property and people. This hazard manifests itself in the following ways:

- Blast and pressure wave;
- Flying fragments or missiles;
- Thermal radiation; and
- Cratering and Ground shock.

In the case of explosions, the biggest damage is usually caused by the blast effects. The blast and pressure waves can cause injury to sensitive human organs such as the ears and lungs. However, considerable overpressures are required for fatalities to occur, and consequently people need to be fairly close to the scene of the direct explosion effects to be significant.

Other effects due to the blast or overpressure are associated with damage to buildings and other structures/ objects or the impact of debris and fragments from damaged building structure, and the vehicle or container in which the explosives are held. Moreover, injury may occur when people are displaced or swept away, or due to the violent movement of internal organs within the body.

An explosion may result in the formation of a short duration fireball since the fuel content of the emulsion is oxidised. However, although it is generally the case that the thermal hazards from an explosives detonation event is of less concern than the blast and fragment hazards.

13.6.2 Review of Incidents

A review of reported safety incidents involving storage, transport and disposal of explosives (in industrial applications) was carried out. Records were retrieved mainly from the UK Health and Safety Executive (UK HSE)'s Explosives Incidents Database Advisory Service (EIDAS) (ref.15), US Mine Safety and Health Administration (MHSA) (ref.16) and Western Australia's Department of Consumer and Employment Protection (DOCEP) (ref.17). The records provided are also supplemented with information obtained from various sources. An analysis of accident data is provided in Section 5 and Section 6 of Appendix 13A.

13.6.3 Scenarios for Hazard Assessment

The following table *(Table 13.4)* provides a summary of the scenarios considered in this QRA.

Table 13.4 Scenarios Considered in the QRA study

Tag	Scenario
Storage of Explosives	
ST01	Detonation of full load of explosives in one store in the TKO Area 137 magazine site
ST02	Detonation of full load of explosives in one contractor truck on the access road within TKO Area 137 magazine site boundary
Transport of Explosives	
ST03	Detonation of full load of explosives in one contractor truck on public roads – from TKO Area 137 site to MCH Shaft delivery point
ST04	Detonation of full load of explosives in one contractor truck on public roads – from TKO Area 137 site to Shansi Street delivery point
ST05	Detonation of full load of explosives in one contractor truck on public roads – from TKO Area 137 site to Hin Keng Portal delivery point
Use of Explosives	
U01	Higher than expected vibrations generated at the blast face due to human errors or other reasons such as manufacturing defects causing deviation from the confirmed design
U02	Vibrations due to the detonation of a full load of explosives within the tunnel whilst transferring explosives to the appropriate blast site. As per WIL study (ERM, 2008), vibrations may be generated at the truck location due to an uncoupled explosion.
U03	Blast effects including debris and overpressure due to the detonation of a full load of explosives within the tunnel. Blast effects are modelled at the shaft/portal ignoring decay factors along the tunnel.
U04	Blast and vibration effects due to accidental explosion of the full load of explosives while transferring explosives from the delivery points to the shafts/portals

13.7 Frequency analysis

Deflagration or detonation explosion may occur during the transportation of explosives from the temporary magazine to the construction sites. This accidental explosion can be caused by spontaneous fire (non-crash fire), fire after a vehicle crash (crash fire), impact initiation in crash (crash impact) or spontaneous explosion during the normal condition of transport which may occur if the cargo load contains 'unsafe explosives'.

In this study, a fault tree has been developed to assess the overall explosion frequency as applicable to the Project contractors' trucks based on the latest information available on the explosives properties, vehicle incident frequencies provided by the Transport Department and Fire Services Department, and the specific explosive transport vehicle design and operation to be used as part of the Project. The details of the frequency assessment are provided in Section 6 of Appendix 13A.

13.7.1 Frequency analysis for Transport of Explosives

Based on Hong Kong vehicle accident data, the frequencies of explosives initiation during road transport are estimated as 7.69 x 10-10/km for the truck on non-expressway and 6.87 x 10-10/km on expressway, using a fault tree approach. The fault tree model has considered the frequencies of non-crash fire, crash fire, crash impact and unsafe explosive. Adjustment factors were applied to the model to account for the probabilities of explosive initiation due to thermal stimulus or crash impact.

13.7.2 Frequency analysis for Storage of Explosives

The overall initiating event frequency within the temporary storage magazine is based upon the UK HSE recommended value of 1 x 10-4 per storehouse year. Additional risk due to manual transfer of explosives, lightning strike, aircraft crash, hill/ vegetation fire, earthquake and other site specific considerations to the SCL (TAW-HUH) project were also considered but their contribution was negligible (see Section 6 of Appendix 13A).

13.7.3 Frequency analysis for Use of Explosives

A failure mode analysis was carried out to determine the potential failure modes associated with the use of explosives, leading to higher vibration. The scenario of 2 or more maximum instant charges (MIC) detonated at the same time was identified for the risk assessment. Fault tree analysis was conducted, in conjunction with human factor assessment to determine the occurrence frequency of 2 or more MIC detonated at the same time (see Section 4 of Appendix 13B).

Table 13.5 summarises the overall frequency for failure scenarios leading to higher than expected vibrations for the whole SCL (TAW-HUH) project. The blast linear length refers to the total pull length by the drill and blast operation. For the SCL (TAW-HUH) alignment, the blast linear length includes the Lion Rock Tunnel and the Ho Man Tin tunnels

For the Worst Case scenario, the overall number of blasts is increased by 20% to account for potential deviation from the envisaged construction programme.

Table 13.5 Overall Frequency for Failure Scenarios leading to Higher Vibration for the Whole Project Phase (Scenario U01 in Table 13.4)

Sections	Total Blast Linear Length	Occurrence Frequency for multiple MIC detonated at the same time (Occurrence for the whole project)				
		2MIC	3MIC	4MIC	5MIC	6MIC
SCL (TAW-HUH) Alignment	3.2 km	1.32E-01	3.81E-04	2.19E-06	2.19E-06	2.19E-06
Sections	**Blast Linear Length**	**Occurrence Frequency for multiple MIC detonated at the same time for 10 m (Occurrence per 10 m) ***				
		2MIC	**3MIC**	**4MIC**	**5MIC**	**6MIC**
SCL (TAW-HUH) Alignment	10 m	5.16E-04	1.49E-06	8.55E-09	8.55E-09	8.55E-09

Note: * Referring to Section 4 of Appendix 13B, the frequency per 10 m has been increased by 25% to account for a higher density of blast in the sections of concern where sensitive receivers can be impacted. This is consistent with WIL methodology (ref 2).

For an accidental explosion of the full load (200 kg) when delivering explosives from the delivery point to the blast face, a frequency of 7.69 × 10 -10 per truck-km was used, as described in the QRA for Explosives Transport and Storage (Appendix 13A). This approach is consistent with previous studies and the value of the explosion initiation frequency is considered conservative since speed control will be exercised and traffic within the tunnel is not heavier than public roads. For conservatism, reduction factors were not considered for the probability of fire following a vehicle crash (crash fire) and impact initiation in crash.

Due to the transport length within the tunnel will vary as the blasting proceeds, the average transport length was assumed as half the tunnel length for all deliveries in accordance with the WIL study (ref 2). The overall transport length thus comprises the length of the access path combined with half of the tunnel length. The frequency of ground vibration for the two delivery sections is given in *Table 13.6*.

Table 13.6 Frequency of Accidental Explosion due to Detonation of Full Load during Delivery to Blast Site (Scenarios U02 to U04 in Table 13.4)

Delivery Scenario	Description	Frequency (/yr)
D01	Initiation of explosives during explosives delivery from delivery point at Hin Keng Estate Access Road to Hin Keng Portal.	5.91E-09
D02	Initiation of explosives during explosives delivery from Hin Keng Portal to Lion Rock Tunnel blast site.	7.53E-08
D03	Initiation of explosives during explosives delivery from Ma Chai Hang Ventilation Building to Lion Rock Tunnel blast site.	1.83E-07
D04	Initiation of explosives during explosives delivery from delivery point at Shansi Street to Shansi Street Shaft at Ho Man Tin.	6.36E-09
D05	Initiation of explosives during explosives delivery from Shansi Street Shaft to Ho Man Tin Tunnel (North) blast site.	4.59E-08
D06	Initiation of explosives during explosives delivery from Shansi Street Shaft to Ho Man Tin Tunnel (South) blast site.	4.62E-08

For accidental explosions scenarios occurring within the tunnel (Delivery Scenarios D02 ,D03, D05 and D06), the blast effects have been considered at the tunnel shaft/portal (Scenario U03 in *Table 13.4*) while the vibration effects have been considered at the truck location (Scenario U02 in *Table 13.4*) in accordance with the WIL study (ref 2).

For the Worst Case scenario, the number of blasts have been increased by 20% to account for potential deviation from the envisaged construction programme.

13.8 Consequence analysis for Storage and Transport of Explosives

The probability of fatality due to blast over-pressure, have been estimated using the method detailed by the UK HSE Explosives Storage and Transport Committee (ref.3) The fatality contours are calculated at 90%, 50%, 10%, 3% and 1% fatality. Details of the model and the results are given in Section 7 of Appendix 13A.

Special features such as slopes and service reservoirs along the transport routes or near the temporary magazine site were identified with respect to the potential secondary hazards. These aspects of risk were evaluated separately, and were found either insignificant or already covered by applying the blast overpressure-fatality model (i.e. ESTC model (ref.3)).

13.9 Consequence analysis for Use of Explosives

This section gives a brief summary of the approach adopted to model the consequences of an explosion during construction of the tunnels. Details are given in Appendix 13B.

The use of blasting to excavate tunnels in rock presents a hazard to both property and people. In this study, three different levels of consequences were assessed. This is consistent with the WIL study (ref 2).

- Primary effects: Ground vibration and blast effects;
- Secondary effects: Effects associated with building/slope collapse or the impact of debris and fragments from damaged features, effects on PHIs (e.g. Sha Tin Water Treatment Works and Ma Tau Kok Gas Production Plant and associated facilities) and towngas installations along the Project alignment (e.g. Beacon Hill North Gas Offtake Station, underground towngas pipelines and LPG Gas station); and
- Tertiary effects: Landslides, rupture of gas pipings and subsequent fire, etc.

The probability of fatality due to blast effects, have been estimated using the method detailed by the UK HSE Explosives Storage and Transport Committee (ESTC) (ref.3). The probability of fatality due to the possible damage / failure of a building, or slope, due to ground shock has also been modelled using methods detailed with the Hong Kong CEDD Geo Reports (ref. 27). The fatality contours are calculated at 1%, 3%, 10%, 50% and 90% fatality.

Ground shock or vibration levels at a given receptor will depend on the distance between the receptor and the blasting point. The estimation of ground vibration levels has used the method published in the Hong Kong CEDD Geo Guide 4 Cavern Engineering (ref. 27).

Secondary and tertiary effects were modelled consistently with the WIL methodology (ref. 2). Consequences from possible subsequent gas releases were modelled using PHAST.

13.10 Risk Summation

13.10.1 Individual Risk Results

The individual risk (IR) contours associated with the Project are shown in *Figure 13.5*, *Figure 13.6*, and *Figure 13.7*. In *Figure 13.6* and *Figure 13.7*, the ‘indoor’ refers to the population located inside buildings, and the ‘outdoor’ refers to the population located outside buildings i.e. in open area. At the same distance from a potential explosion, persons located inside buildings are more vulnerable to explosion than persons located outside buildings as they are exposed to more hazards such as debris from broken windows, etc. This explains a higher individual risk for indoor population.

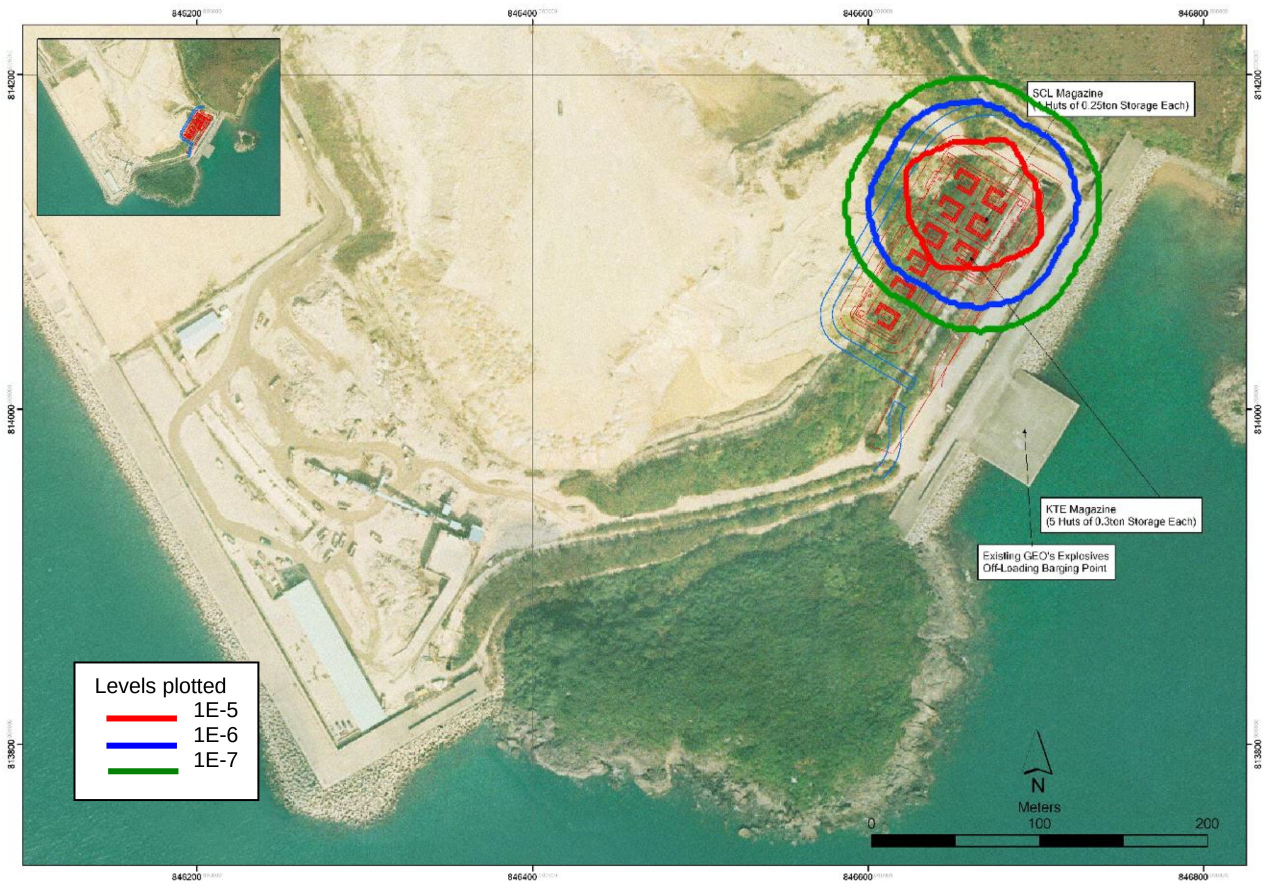
For the delivery routes, the IR data represent the highest individual risk, occurring on the road in the same lane as the explosives delivery truck. It is observed that the maximum IR is about 8.8×10E-8 per year. This is a low risk when compared to Hong Kong Risk Guidelines which require the offsite IR from a fixed installation to be below 10-5 per year.

The temporary storage magazine is in a remote area. The individual risk contours of 1 x 10-5 per year extend outside the site boundary. However this impacts only on grassland areas where there is no continuous presence of people. The presence of people in these areas will be rare, with the nearest building being the Construction & Demolition material sorting facilities located about 400 m to the west of the temporary magazine site. A presence factor of 2 hours/day (about 8%) has been given to an outside person being present in the area within 100 metres of the temporary magazine. The most exposed population group will be Mines Delivery personnel who will be making/ receiving deliveries at the jetty. Such persons are not expected to be present more than 8% of the time (up to 4 personnel in 2 trucks, 2 hours per day, 6 days per week) which would translate to a presence factor of 0.08. The IR for specific individuals offsite would therefore be about one order of magnitude less than that indicated by the IR contours, and clearly less than 10-5 per year for all the off-site areas. Hence it can be concluded that individual risk is acceptable.

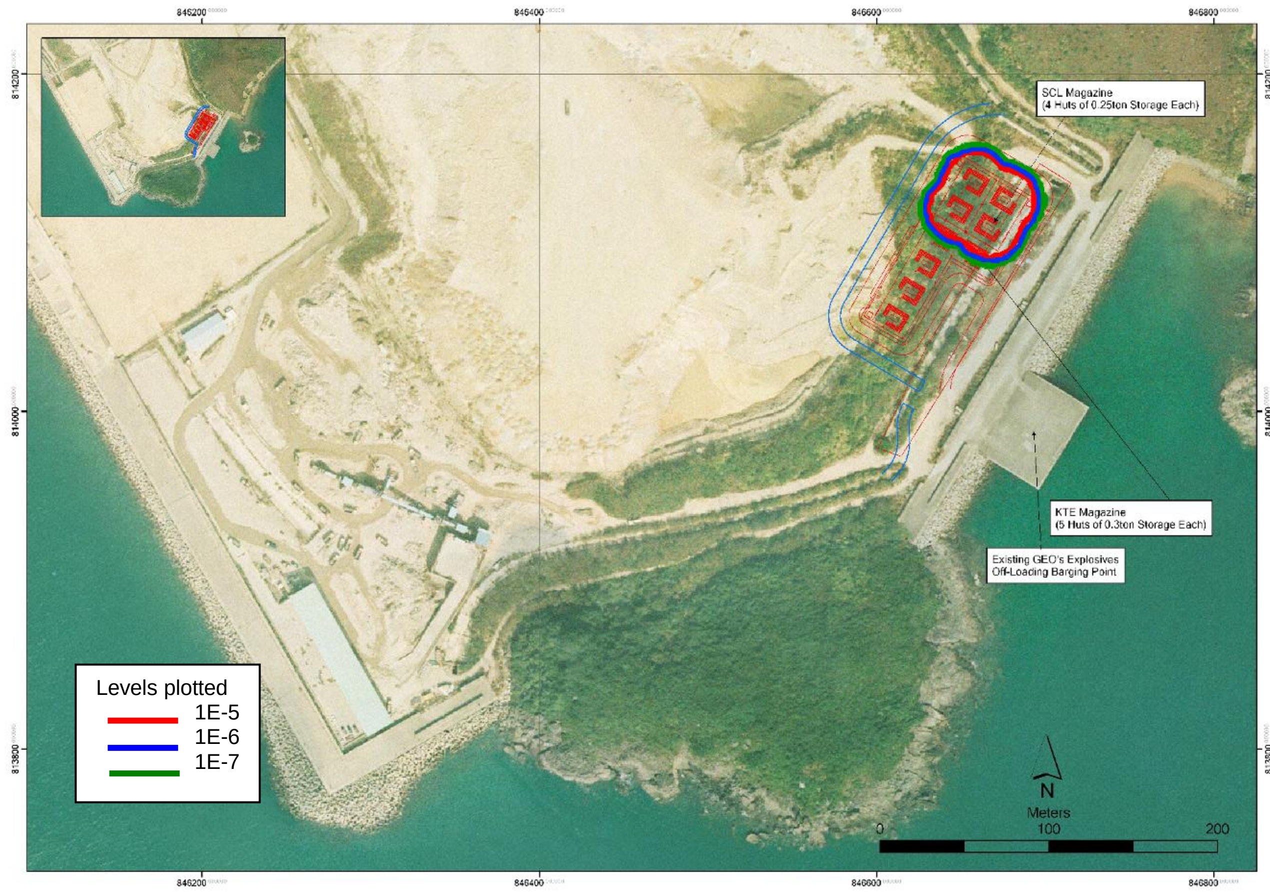
Figure 13.5 Maximum IR for the Delivery Routes from TKO Area 137 Magazine

Figure 13.6 IR of Proposed TKO Area 137 Magazine

Indoor



Outdoor



13.10.2 Societal Risk Results

The societal risk results for explosives storage, transport and use for SCL (TAW-HUH) have been combined to produce the overall societal risk results for the base case and the worst case *(Figure 13.7)*.

The Base Case represents the risks associated with the envisaged blasting programme. It can be seen that the risks lie in the ALARP region.

The Worst Case represents the maximum risks associated with the worst blasting scenario. The risks, as expected, are higher than the base case but still within the ALARP region.

Figure 13.8 shows the F-N curve for the Base Case with a breakdown by storage, transport and use. It is observed that risks from the temporary magazine and use of explosive are negligible compared to the transport risks. Indeed, the temporary magazine is located in a remote area with very low population density nearby. The risk related to use of explosives is also low compared to transport due to the stringent controls in place throughout the blasting process.

The F-N curves for both base case and worst case are within the As Low as Reasonably Practicable (ALARP) Region as per HK EIAO-TM. Therefore, mitigation measures need to be considered to reduce the risk. The ALARP assessment is provided in Section 9 of Appendix 13A.

The potential Loss of Life (PLL) for the base case and the worst case are given in *Table 13.7* and *Table 13.8* respectively. The PLL for this project has been evaluated at 4.85 x 10-4 per year. The maximum PLL value for the Project is estimated at 6.32 x 10-4 per year, which is obtained from the worst case.

Figure 13.7 F-N Curves for Storage, Transport and Use of Explosives

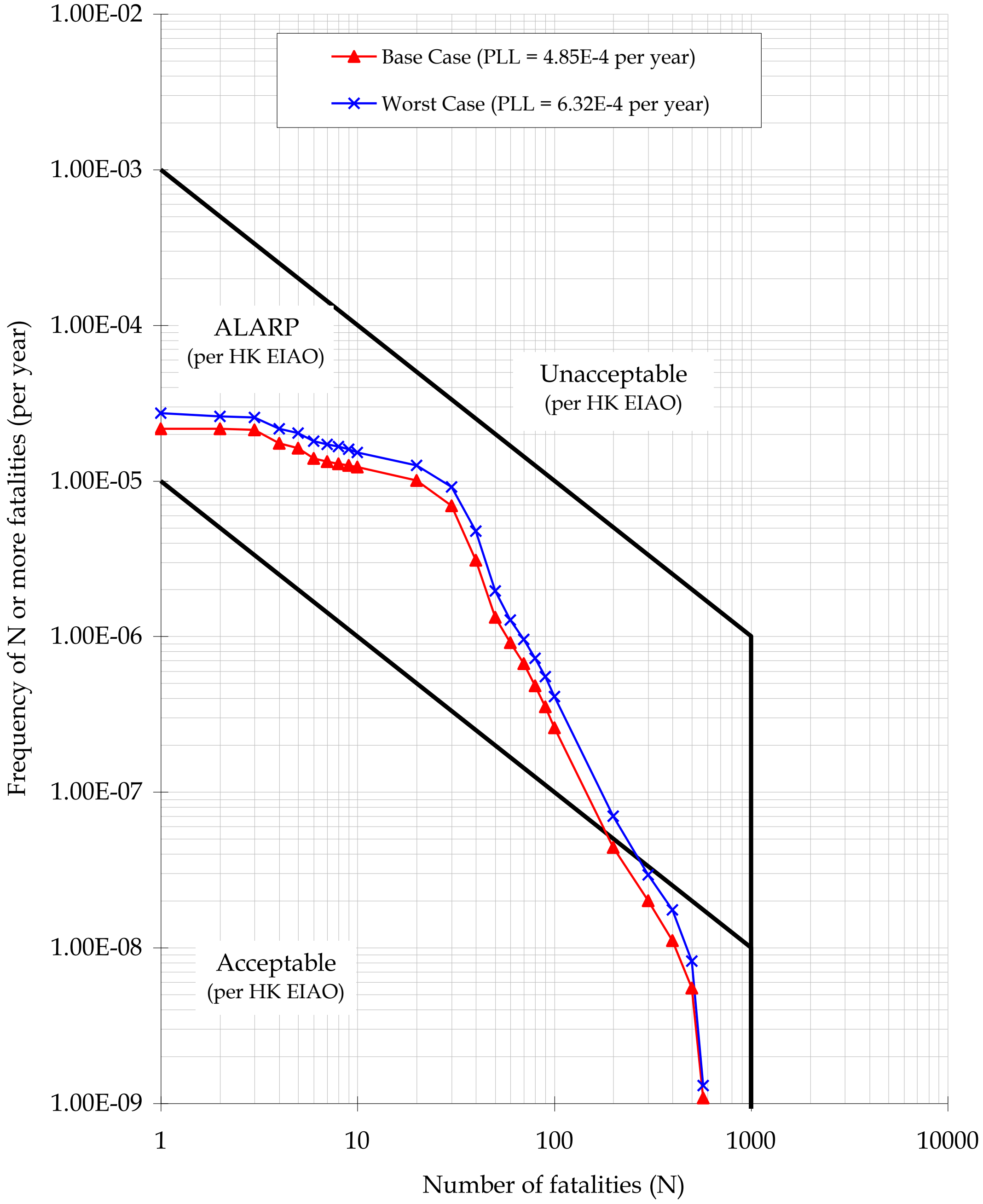


Figure 13.8 F-N Curve for Base Case with Breakdown by Transport, Storage and Use

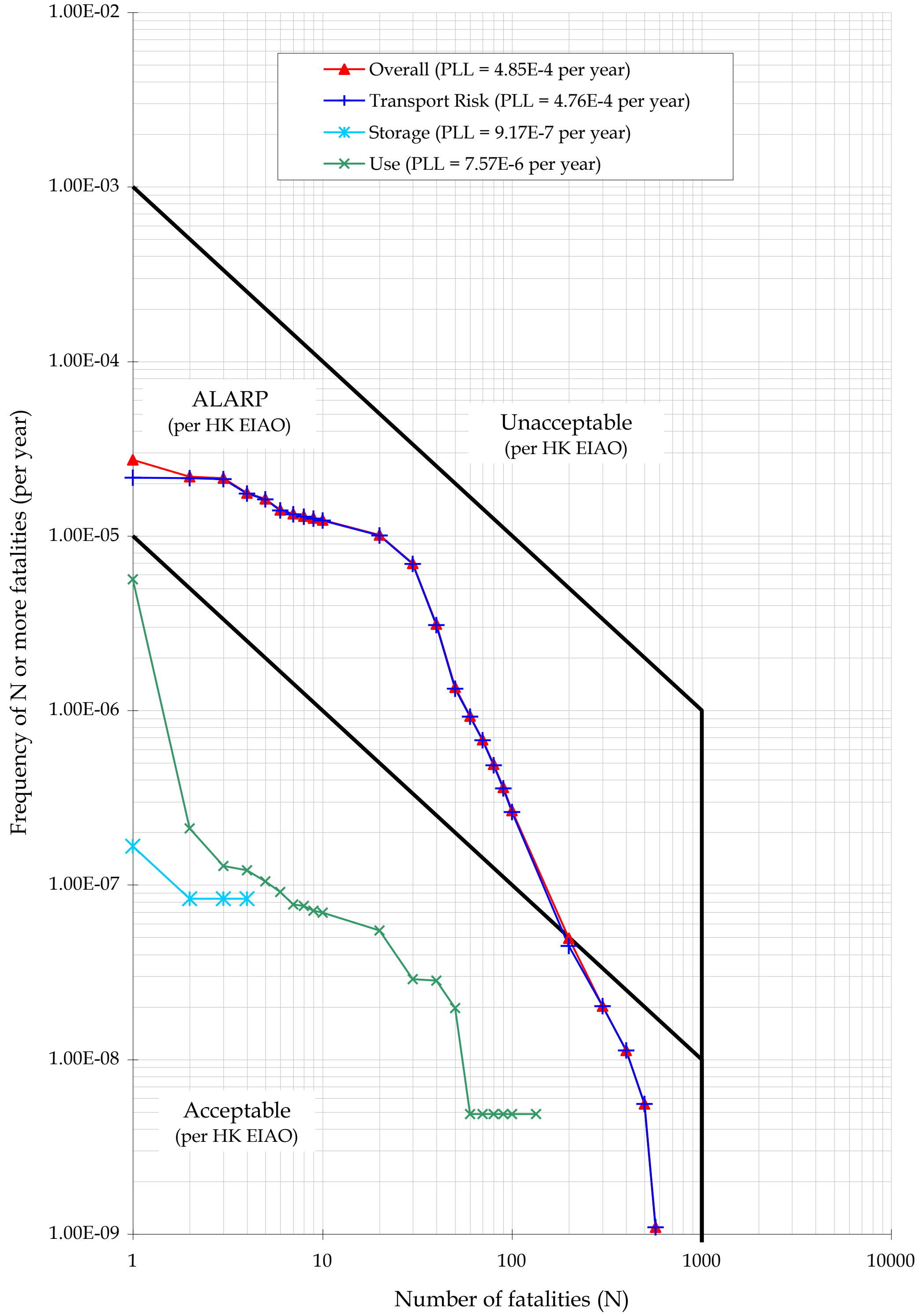


Table 13.7 Potential Loss of Life for Base Case

Base Case	**PLL (per year)**	**Percentage Contribution (%)**
Storage of Explosives		
TKO Area 137 Magazine	9.17E-07	0.19%
Transport of Explosives		
TKO Area 137 to Ma Chai Hang Ventilation Building	1.80E-04	37.11%
TKO Area 137 to Shansi Street Shaft	1.34E-04	27.63%
TKO Area 137 to Hin Keng Portal	1.62E-04	33.40%
Use of Explosives		
Construction of Lion Rock Tunnel (Ground shock from blast face)	4.73E-06	0.98%
Construction of Ho Man Tin Tunnels (Ground shock from blast face)	6.99E-07	0.14%
Full load detonation of explosives during transport to blast faces for Lion Rock Tunnel (Blast effect)	3.41E-07	0.07%
Full load detonation of explosives during transport to blast faces for Lion Rock Tunnel (Ground shock)	8.62E-09	0.00%
Full load detonation of explosives during transport to blast faces for Ho Man Tin Tunnels (Blast effect)	2.12E-07	0.04%
Full load detonation of explosives during transport to blast faces for Ho Man Tin Tunnels (Ground shock)	1.32E-06	0.27%
Gas piping rupture due to Ground shock and Blast effect (Tertiary Effect)	1.58E-07	0.03%
LPG Gas Station Failure (Tertiary Effect)	1.07E-07	0.02%
Total	4.85E-04	100.00%

Table 13.8 Potential Loss of Life for Worst Case

Worst Case	**PLL (per year)**	**Percentage Contribution (%)**
Storage of Explosives		
TKO Area 137 Magazine	9.17E-07	0.15%
Transport of Explosives		
TKO Area 137 to Ma Chai Hang Ventilation Building	2.32E-04	36.71%
TKO Area 137 to Shansi Street Shaft	1.74E-04	27.53%
TKO Area 137 to Hin Keng Portal	2.16E-04	34.18%
Use of Explosives		
Construction of Lion Rock Tunnel (Ground shock from blast face)	5.68E-06	0.90%
Construction of Ho Man Tin Tunnels (Ground shock from blast face)	8.38E-07	0.13%
Full load detonation of explosives during transport to blast faces for Lion Rock Tunnel (Blast effect)	4.09E-07	0.06%
Full load detonation of explosives during transport to blast faces for Lion Rock Tunnel (Ground shock)	1.03E-08	0.00%
Full load detonation of explosives during transport to blast faces for Ho Man Tin Tunnels (Blast effect)	2.54E-07	0.04%
Full load detonation of explosives during transport to blast faces for Ho Man Tin Tunnels (Ground shock)	1.58E-06	0.25%
Gas piping rupture due to Ground shock and Blast effect (Tertiary Effect)	1.90E-07	0.03%
LPG Gas Station Failure (Tertiary Effect)	1.28E-07	0.02%
Total	6.32E-04	100.00%

13.10.3 ALARP Assessment

Since the risks posed by the project, for both cases considered, are within the ALARP region specified in EIAO-TM Annex 4, this implies that risk reduction measures and / or alternate options should be explored for the Project.

It was found that the risks arising from explosives transport are much more significant than that of explosives storage; hence the ALARP assessment focuses on the transportation aspects of explosives.

Where the risk falls into the ALARP region, the risks associated with each probable hazardous event should be reduced to a level ‘as low as reasonably practicable’. This firstly requires the identification of any ‘practicable’ options regardless of their cost. A mitigation option is considered ‘practicable’ if an engineering solution exists and can be implemented on the SCL (TAW-HUH) project regardless of the cost without affecting the project construction programme. Secondly, the extent to which the risk should be reduced is usually measured as a trade off between the risk reduction, i.e. the safety benefits and the cost of the risk reduction measure. A mitigation option is considered ‘reasonable’ if the cost of implementing the option is not grossly disproportionate to the achieved safety benefits.

Risk mitigation measures may take the form of engineered measures, controls in the zones most impacted by the hazardous scenarios presented by this project, or operation and procedural controls.

<u>Approach to ALARP Assessment</u>

The approach consists of identifying potential justifiable mitigation measures, assessing their practicability for this project and evaluating their cost and comparing with the safety benefits of implementing the measures. Combinations of mitigation measures are also considered.

The safety benefits are evaluated as follows:

Safety Benefits = Value of Preventing a Fatality x Aversion Factor x Reduction in PLL value

x Design life of mitigation measure

The Value of Preventing a Fatality (VPF) reflects the tolerability of risk by the society and therefore the monetary value that the society is ready to invest to prevent a fatality. For the purpose of this assessment and for consistency with previous studies, the Value of Preventing a Fatality is taken as HK$33M per person, which is the same figure as used in previous Hazard Assessment studies (derived from ref.5 but updated to current prices.

Depending on the level of risk, the value of preventing a fatality may be adjusted to reflect people’s aversion to high risks or scenarios with potential for multiple fatalities. The methodology for application of the ‘aversion factor’ follows that developed by EPD (ref.18), in which the aversion factor is calculated on a sliding scale from 1 (risks at the lower boundary of the ALARP region of the Risk Guidelines) up to a maximum of 20 (risks at the upper boundary of the ALARP region). The adjusted VPF using the aversion factor of 20 is HK$660M. This value is a measure of how much the society is willing to invest to prevent a fatality, where there is potential for an event to cause multiple fatalities.

With reference to Appendix 13A, the maximum justifiable expenditure for this Project is calculated as HK$ 0.62M assuming the design life of mitigation measure is 1.5 years based on the construction phase of the SCL (TAW-HUH) project during which storage and transport of explosives will be involved, with the PLL of 6.23 x 10-4 per year, which is obtained from the Worst Case.

For an 'achievable' mitigation measure to be potentially justifiable, its cost should be less than the Maximum Justifiable Expenditure.

Potential Justifiable Mitigation Measures

The potential options that have been examined in the ALARP assessment include the following categories.

- Options eliminating the need for a temporary Magazine or eliminating the risk (e.g. Use of alternative methods of construction ('hard rock' TBMs));
- Options reducing significantly the distance run by contractors' explosive trucks such as closer magazine sites and alternative routes. The temporary magazine and route options considered are summarised below:
  - Based on SCL/KTE Magazine Site Selection Report (MTR 2), numerous alternative magazine sites to TKO Area 137 for the area were considered (41 in total)

However, none of the alternative candidate sites could either meet the Commissioner of Mines' external separation requirements or are located farther than the proposed magazine. Therefore, no alternative temporary magazine site option has been considered for the ALARP assessment.

Based on a review of the possible transport routes for this project, Po Lam Road and Anderson Road have been presented as alternative routes for explosives deliveries from the TKO Area 137 magazine site to the Ma Chai Hang Ventilation Building and Shansi Street Shaft and Sai Sha Road (via Sai Kung) has been presented as an alternative route for explosives deliveries from the TKO Area 137 magazine site to the Hin Keng Portal. These route options have been selected for further cost-benefit evaluation;

- Options reducing significantly the quantities of explosives to be used such as use of 'hard rock' TBM or alternatives to cartridged emulsion.
  - It is possible to use smaller explosive charges for initiating explosives such as 'cast boosters'. The main explosive component of 'cast boosters' is PETN. Using such explosives will reduce the weight of explosives to be transported. However, PETN has a higher TNT equivalency. This will also not eliminate the need for detonating cord. This option has been selected for further cost benefit evaluation.
- Options considering improved explosive truck design; and
- Options considering better risk management systems and procedures.

In summary, the following options have been considered for cost-benefit analysis.

- Option 1: Alternative Routes - Po Lam Road, Anderson Road and Sai Sha Road (via Sai Kung)
- Option 2: Use of Smaller Quantities of Explosives

The PLL for Options 1 and 2 are compared to the PLL for the appropriate Worst Case (the relevant alternative routes for specific delivery points and the use of cast boosters for the whole project). This was used as the basis for the cost-benefit analysis/ ALARP assessment presented in *Table 13.9.*

Other options considered practicable have been either recommended for implementation or assessed comparing the implementation cost with the maximum justifiable expenditure. The evaluation for each option is shown in *Table 13.10*. More details are available in Section 9 of Appendix 13A.

Table 13.9 Potential Loss of Life for Worst Case, Options 1 and 2

Case	**MCH/ Shansi St**	**Hin Keng Portal**	**Overall**
	PLL per year	***PLL per year***	***PLL per year***
Worst Case (Transport and Storage)	4.06×10^{-4}	2.16×10^{-4}	6.23×10^{-4}
Option 1: Alternative Routes - Po Lam Road, - Anderson Road, - Sai Sha Road (via Sai Kung)	 4.23×10^{-4} 4.21×10^{-4} -	 - - 2.68×10^{-4}	
Option 2: Use of Smaller Quantities of Explosives	-	-	3.39×10^{-4}

Table13.10 ALARP Assessment Results

Option Description	Practicability	Implementation Cost	Safety Benefits or Justifiable Expenditure	ALARP Assessment Result
Use of alternative methods of construction (TBMs)	Not Practicable	> HK$ 100M	HK$ 0.62M	Neither practicable nor justified.
Use of Magazines Closer to the Construction Sites	Not Practicable	-	-	Closest practicable magazine site to the construction sites has been selected
Use of different explosive types (different types of detonating cord)	Pose some limitations	HK$ 1M	No safety benefit	Not Justified
Alternative Routes (Option Case 1)	Practicable	-	Negative	Clear Water Bay Road preferred
Use of Smaller Explosives Quantities (Option Case 2)	Practicable	> HK$ 0.50M	HK$ 0.28M	Use of cast boosters is not cost effective. The cast booster option will be explored further in line with the use of best practice in explosives selection. [1]
Safer explosive truck (reduced fire load)	Practicable	-	-	Based on low implementation costs, this option has been directly incorporated in recommendations
Reduction of Accident Involvement Frequency (training programme etc.)	Practicable	-	-	Based on low implementation costs, this option has been directly incorporated in recommendations
Reduction of Fire Involvement Frequency (better emergency response, extinguisher types etc.)	Practicable	-	-	Based on low implementation costs, this option has been directly incorporated in recommendations

Note: [1] Please refer to Hazard to Life Assessment Final Report, Section 9.6.3, 5th paragraph of Appendix 13A.

13.10.4 Cumulative Risk Assessment

Cumulative risk assessment analyses the combined risks of fatality arising from exposure to hazards due to storage, handling and transport of dangerous goods in various projects being undertaken concurrently.

The projects that potentially interface with the SCL (TAW-HUH) Project are: the Harbour Area Treatment Scheme Stage 2A (HATS2A) project, the Kwun Tong Line Extension (KTE), Central Kowloon Route (CKR), and the Shatin to Central Link – Cross Harbour Section. Among the projects mentioned, the HATS2A project has been identified as potentially overlapping with SCL (TAW-HUH) according to the project schedules and information on geographical location for explosives activities. HATS2A is an on-going project with the blasting period up to November 2013, which potentially overlaps with SCL (TAW-HUH) explosives delivery schedule for two months period on some section of explosives delivery routes. Projects other than HATS2A are not geographically aligned with the SCL (TAW-HUH) placement (alignment, worksites, magazine site or transport routes) or not chronologically aligned with the blasting programme.

Therefore, cumulative risk is considered for HATS2A project and SCL (TAW-HUH) according to the current best available blasting information from relevant authorities and project proponent. Risk assessment for HATS2A delivery route sections that overlaps with SCL (TAW-HUH) has been described in Annex A of Appendix 13A.

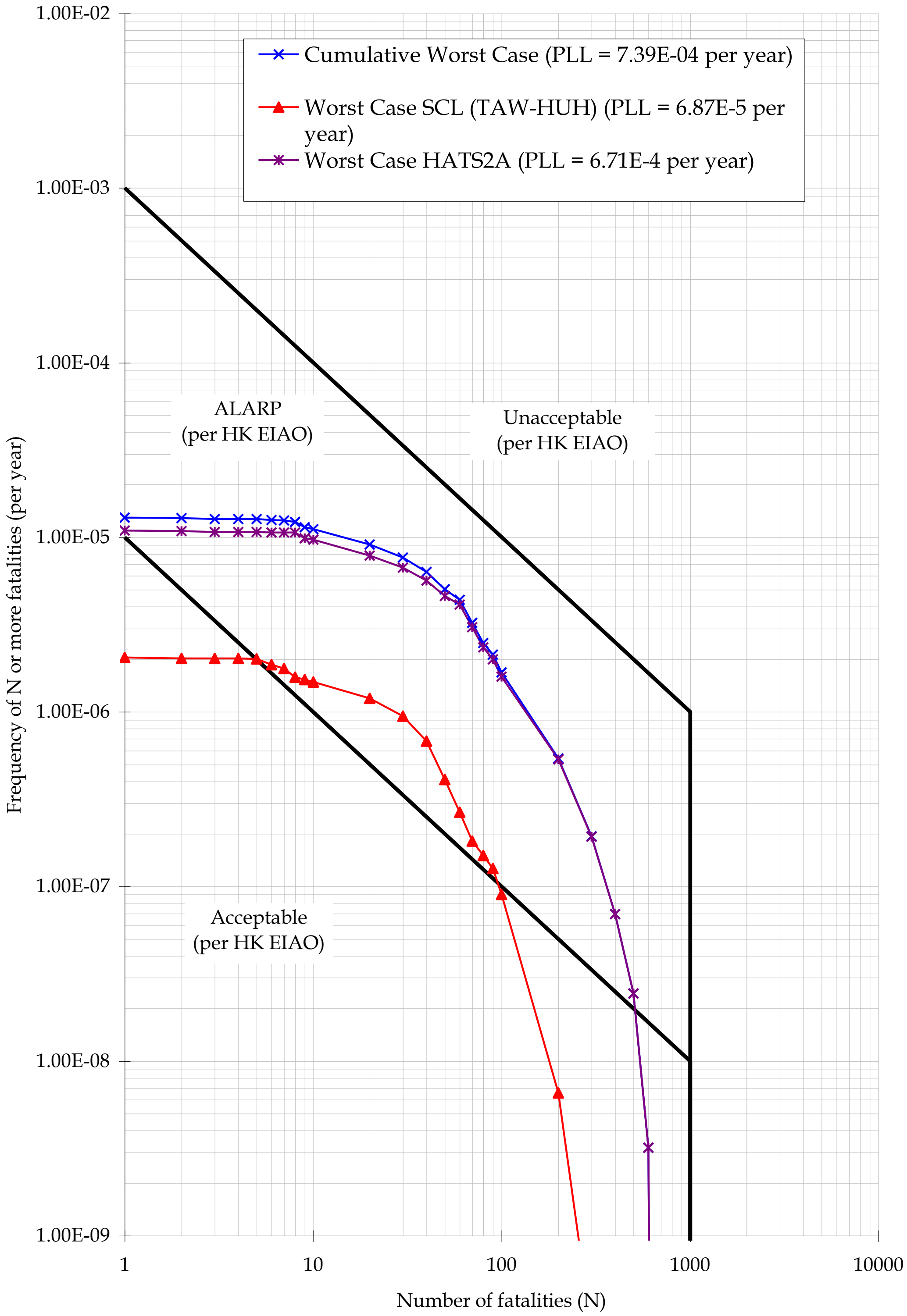
The cumulative risk of the worst case scenario with the consideration of a 20% increase in the number of deliveries for both projects and conservatively an overlap period of 1 year for the explosives delivery programme has been assessed. The resulting F-N curve remains within the ALARP region (as shown in Figure 13.11), and the presented conclusions would still apply. In this worst case the maximum individual risk (IR) for the common routes has been aggregated.

As can be seen from Figures 13.9 in a worst case scenario, the cumulative individual risk is less than 1E-05, and therefore acceptable according to the risk criterion.

The pier in TKO Area 137 is used for the delivery of explosives for other projects however the transport of explosives by Mines Division is out of scope of this assessment and no cumulative risk assessment is considered in TKO Area 137.

Figure 13.9 The Maximum IR for the delivery route in common for the SCL (TAW-HUH) and HATS 2A Projects

Figure 13.11 F-N Curves showing the Cumulative Societal Risk for the common delivery routes for the HATS2A and SCL (TAW-HUH) Projects in the Worst Case of a 1 year overlap



As can be seen the risk from the combined projects remains within the ALARP region. ALARP assessment has been conducted for the SCL (TAW-HUH) project for the storage and transport of explosives and presented in Section 9 of Appendix 13A.

13.11 PHI Hazard Assessment for Construction and Operation Phases of the Project

13.11.1 Introduction

This Section summarises methodology and results of the Hazard Assessment (HA) for the Shatin Water Treatment Works (STWTW) in connection with the construction and operation of the Shatin to Central Link (SCL). The detailed HA report is provided as Appendix 13C.

The STWTW is designated as a Potentially Hazardous Installation (PHI). Part of the proposed SCL railway extension and Hin Keng Station will be located within the 1000m Consultation Zone of the Chlorine Store of the STWTW and therefore a hazard assessment is required.

Purpose of the PHI Hazard Assessment

Section 3.4.5 of the EIA Study Brief for this project (ESB-191/2008) specifies Hazard to Life assessments to be conducted. Part of this requirement addresses risks in relation to Shatin WTW as follows:

The Applicant shall carry out hazard assessment to evaluate potential hazard to life during construction and operation stages of the Project due to Sha Tin Water Treatment Works.

The hazard assessment shall include the following:

(i) Identify hazardous scenarios associated with the on-site transport, storage and use of chlorine at Sha Tin Water Treatment Works and then determine a set of relevant scenarios to be included in a Quantitative Risk Assessment (QRA);

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

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

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

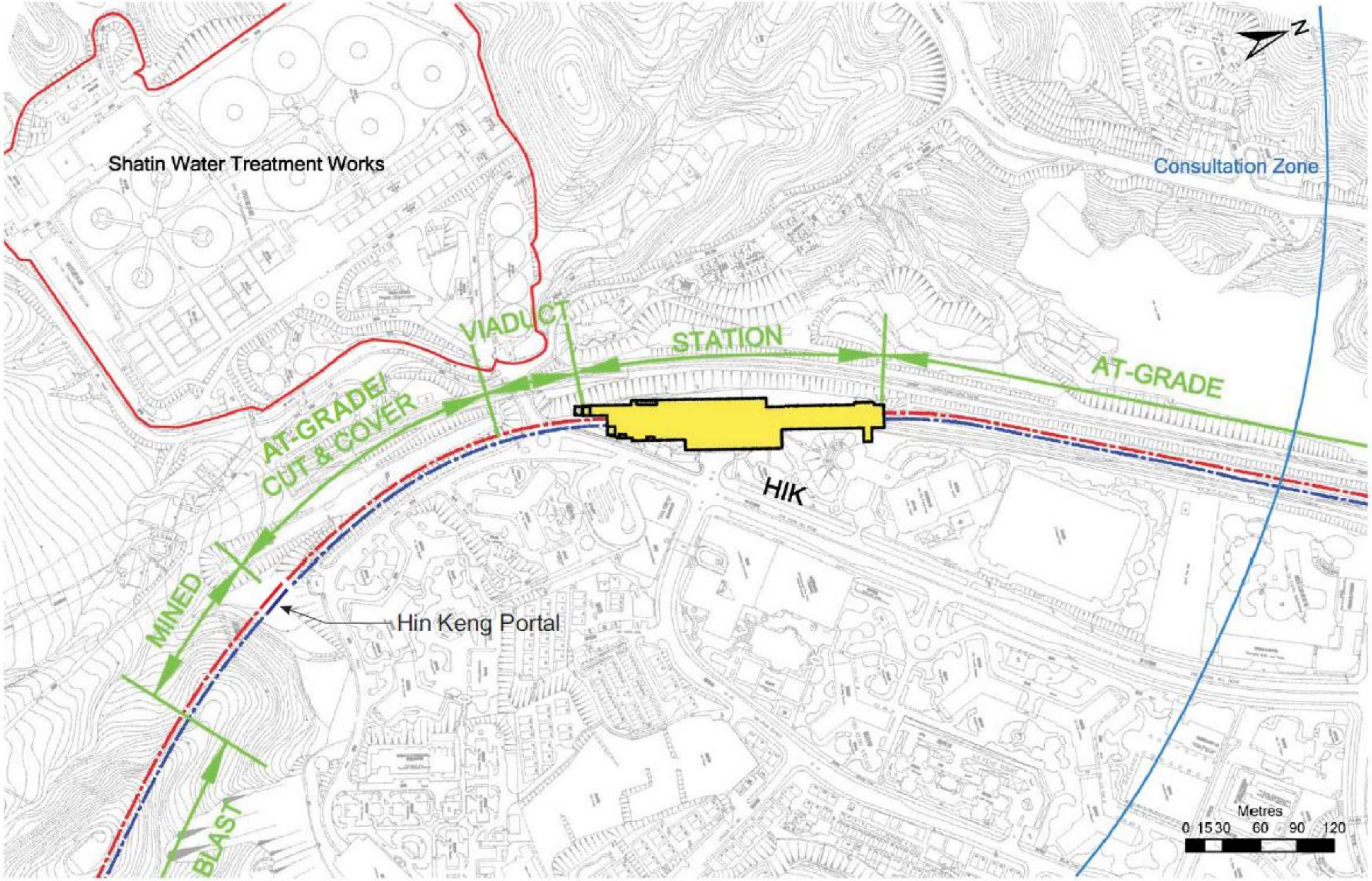
The methodology to be used in the hazard assessment should be consistent with previous studies having similar issues (e.g. “Reassessment of Chlorine Hazard for Eight Existing Water Treatment Works” commissioned by Water Supplies Department).

The STWTW is designated as a Potentially Hazardous Installation (PHI) owing to its use and storage of chlorine in 1 tonne drums. Part of the railway alignment and the future station at Hin Keng will be located within the 1000m Consultation Zone of the Chlorine Store of the STWTW *(Figure 13.12).*

Societal risks from a PHI depend on surrounding population levels. Consultation Zones are established around PHIs to control developments in the vicinity and prevent population accumulating to the point where societal risks may become unacceptable. Any new development within the Consultation Zone of a PHI that may lead to an increase in population requires a hazard assessment to be conducted to ensure that the societal risks remain acceptable. The purpose of this assessment, therefore, is to assess risks from STWTW to the surrounding population including the construction and operational phases of SCL and Hin

Keng Station. The criteria and guidelines for assessing Hazard to Life are stated in Annexes 4 and 22 of the Technical Memorandum (EIAO-TM Criteria).

Figure 13.12 Hin Keng Station and SCL Alignment



13.11.2 Previous QRA study for Shatin WTW

In 1997, the Water Supplies Department (WSD) commissioned ERM to carry out a Reassessment of Chlorine Hazards for Eight Existing Water Treatment Works.

The approved methodology for these QRA studies is detailed in the 8 WTW Study Methodology Report (ref. 19).

Results for the STWTW (ref. 20) showed that:

- The risk was in the 'ALARP region'; and
- The maximum number N of fatalities was assessed at over 900

The previous QRA study for STWTW (ERM, 2001) was based on the following operational data:

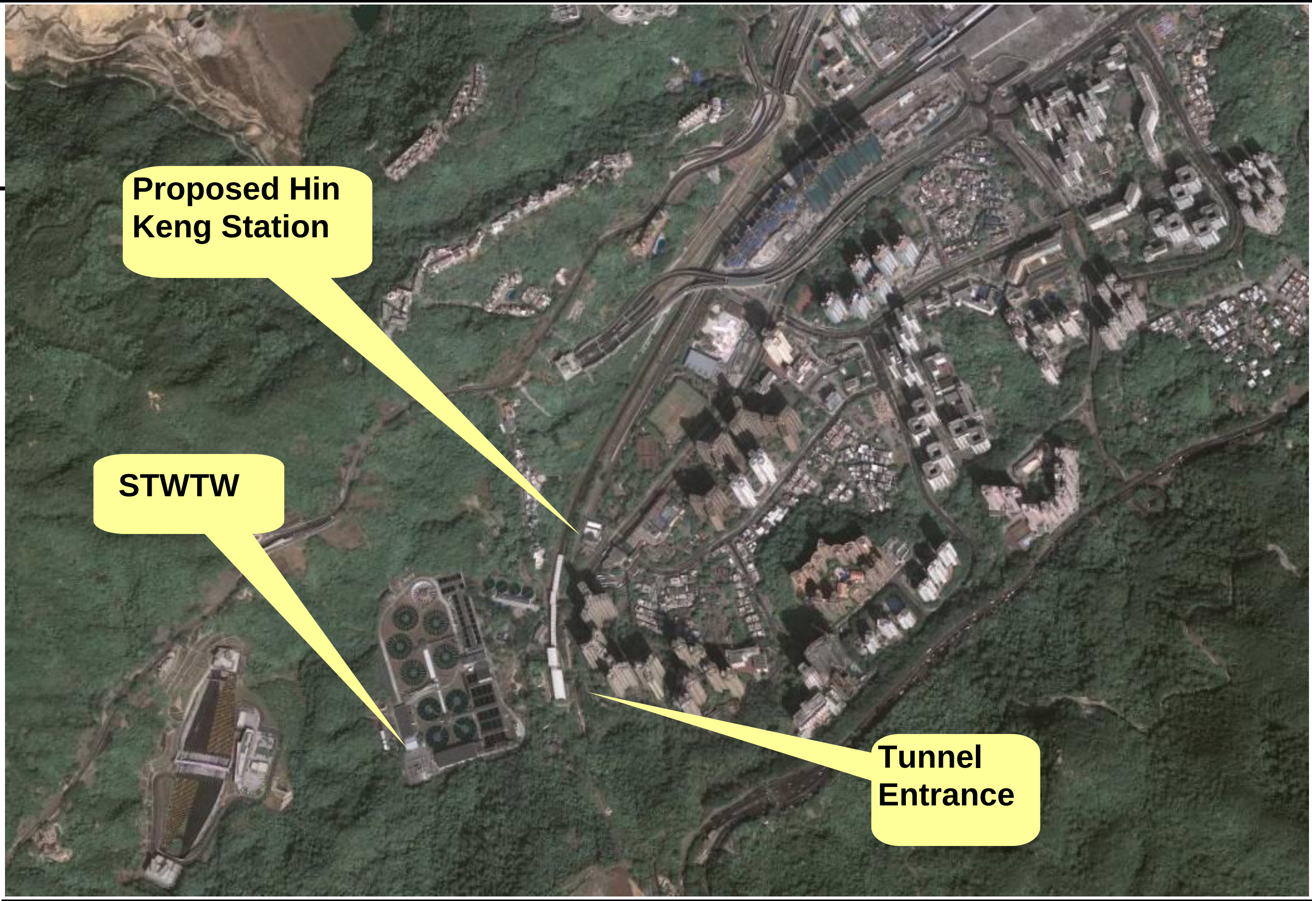
- 223 tonnes of chlorine storage;
- 7.5 mg/l dosing giving a consumption of 3359 tonnes/year; and
- Population based on 1997 data, projected to year 2006.

13.11.3 Shatin WTW

<u>Location</u>

Shatin WTW is located at the head of a valley on Keng Hau Road, Hin Tin to the south-west of Shatin new town. The site is approximately rectangular in shape and measures 400m north to south by 300m east to west. The treatment plant comprises a South Works and a North Works. The chlorination house is located in the south-west corner of the site. The site location is shown in *Figure 13.13*.

Figure 13.13 Shatin WTW and its Surrounding



Basic Operating Data

Detailed description of STWTW operations and relevant safety features is given in Appendix 13C.

Water Supplies Department is planning a major STWTW refurbishment programme, which is scheduled to commence in mid-2012. During the refurbishment, since parts of the plant will have to be temporarily shut down, the water throughput will decrease and accordingly, chlorine storage and usage levels will be significantly reduced. Following completion of the refurbishment at the end of 2016 water throughput will return to 1,227 Mld.

Chlorine dosage levels were assumed at 7.5 mg/l in ERM (2001) but current dosing levels are below 2 mg/l. This will be further reduced to 1.7 mg/l following the refurbishment, due to the introduction of new treatment technology. This will result in a permanent reduction in chlorine usage once refurbishment is completed in 2016. Details are presented in Table 13.11.

Table 13.11 Scenarios Considered in QRA

Scenario	Assessment year	Maximum Chlorine Storage at WTW (tonnes)	Weighted Average Chlorine Storage Time Distribution Assumed in the QRA (tonnes, % of time)	Average Chlorine Usage at WTW (tonnes per year)
Scenario 1: SCL Construction (before WTW refurbishment starts)[1]	2011	221	203 (10%)[1] 183 (80%) 158 (10%)	896
Scenario 2: Simultaneous SCL Construction and WTW refurbishment	2014	158	158 (100%)	642
Scenario 3: SCL Operation Period 1 (after completion of WTW refurbishment)	2016	190	190 (20%) 150 (80%)	761
Scenario4: SCL Operation Period 2 (surrounding population growth taken into account)	2031	190	190 (20%) 150 (80%)	761
Assumed in 2001 QRA	2006	223	223 (100%)	3359

Notes:
(1): If necessary, the period for which WSD will maintain this time distribution will be agreed between MTRC and WSD after the details of the SCL construction programme and the SCL construction workforce mobilization plan are known.

<u>Surrounding Topography</u>

Shatin WTW is located at 30m above the Principal Datum (PD) and is surrounded on three sides by hills rising to approximately 300m. To the north-east the land slopes gently downwards towards the town of Shatin. The topography is of particular relevance; since chlorine is a dense gas the spread of chlorine cloud from any large release would be restricted by the neighbouring hills and directed towards the populated areas.

13.11.4 SCL Facilities

Of interest to this QRA is the proposed Hin Keng Station as well as the SCL alignment and construction works areas within the Consultation Zone of STWTW. The proposed location of the Hin Keng Station and the SCL alignment in relation to the STWTW are shown in *Figure 13.13.*

The proposed Hin Keng Station construction site is located approximately 450m to the north-east of Shatin WTW chlorine store, but only some 90 m from the WTW site entrance and its access road which is used by the trucks delivering chlorine to the WTW. Similarly, the SCL tunnel entrance work area is located about 375 m from the chlorine store and 150 m from the WTW access road.

13.11.5 Meteorological Conditions

For the sake of consistency, this study uses the same meteorological data set as was used in the previous QRA (ref. 20), i.e. the data recorded at the Shatin weather station in the year

1996 by the Hong Kong Observatory. The weather data have been rationalised into different combinations of wind direction, speed and atmospheric stability class. The probabilities of occurrence of each combination during day and night are presented in Appendix 13C (*Table 2.2*).

13.11.6 Population Data

The approach to the population data used in this study is as per the 2001 QRA for Shatin WTW (ref. 20). The population data from the 2001 study were updated to reflect the current situation and the current projections to the assessment years for construction and operational phases of the project.

All the population levels were defined for a number of GIS-based polygon, point and line population units, based on the latest information from sources such as 2006-based by-census available from the Centamap website, Education Bureau website, 2007 Annual Traffic Census (ref. 12), site surveys and telephone interviews etc.

SCL construction worker population and the passenger data for MTR trains and stations are based on the information provided by MTR.

The population data methodology and the final population data used in this study are detailed in Appendix 13C. The total population levels are greater than those used in the 2001 QRA (ref. 20) due to general population growth in the area.

13.11.7 Hazard Identification

Hazard identification exercise was based on the review of past accidents and Hazard and Operability (HAZOP) Study performed for STWTW. Details are provided in Appendix 13C.

Various possible mechanisms for a chlorine release identified during the HAZOP study and the review of past accidents have been categorised in terms of the releasing inventory, hole size and phase of release as shown in *(Table 13.12).* The table also screens out scenarios considered to present negligible off-site risk.

Table 13.12 Characterisation of Chlorine Release Scenarios

Chlorine release scenario	Outcome	Releasing inventory (tonnes)	Hole size (diameter)	Phase
1. ACCESS ROAD				
1.1 Truck fire	Considered to result in melting of the fusible plugs on up to three drums (1):	3	3x6mm	liquid
1.2 Fire on the roadside	Considered to present negligible off-site risk as truck does not park on site other than within chlorine building	-	-	-
1.3 Manoeuvring accident	Considered to result in a single drum – small leak (eg valve gland failure)	1	3mm	liquid
1.4 Rollover	Single drum - small leak(e.g. valve gland failure) Single drum - medium leak(e.g. guillotine failure of drum valve) Three drums - medium leak (e.g. guillotine failure of drum valves on three drums) Fire (outcomes as item 1.1 above)	1 1 3	3mm 8mm 3x8mm	liquid liquid liquid
1.5 Collision	Single drum - rupture Fire (outcomes as item 1.1 above)	1	-	liquid
1.6 Load-shedding	Single drum - small leak	1	3mm	liquid

Chlorine release scenario	**Outcome**	**Releasing inventory (tonnes)**	**Hole size (diameter)**	**Phase**
	Single drum - medium leak	1	8mm	liquid
1.7 Spontaneous drum failure	Single drum - medium leak Single drum - large leak (e.g. dislodgement of a fusible plug) Single drum – rupture	1 1 1 (inst)	8mm 20mm -	liquid liquid liquid
2. DRUM HANDLING				
2.1 Dropped drum	Single drum - medium leak Single drum - large leak (e.g. dislodgement of fusible plugs) Single drum - rupture	1 1 1 (inst)	8mm 20mm -	liquid liquid liquid
2.2 Collision of drum with another object	Considered to present negligible off-site risk as crane operates at low speed and drum valves are protected by steel caps.	-	-	-
2.3 Accidental impact of drum on pigtail during setdown at standby position	Pigtail - guillotine failure	1	4.5mm	two-phase
2.4 Dropped drum due to overextension of truck crane	Considered to present negligible off-site risk as truck crane would only rarely be used	-	-	-
2.5 Dropped drum due to incorrect alignment of monorail track	As item 2.1 above			
3. CONTAINERS IN STORAGE				
3.1 Leaking chlorine drums	Single drum - medium leak Single drum - large leak Single drum - rupture	1 1 1 (inst)	8mm 20mm -	liquid liquid liquid
3.2 Overfilled drums leading to overpressurisation on thermal expansion	As item 3.1 above			
3.3 Impurities in chlorine drum leading to explosion or leak	As item 3.1 above			

Chlorine release scenario	**Outcome**	**Releasing inventory (tonnes)**	**Hole size (diameter)**	**Phase**
3.4 Object falls onto chlorine containers	Considered to present negligible off-site risk as there are no objects likely to fall which could cause significant damage to the drums.	-	-	-
3.5 Fire (external or internal)	Considered to present negligible off-site risk as chlorine stores are 2 hour fire-rated structures. The most significant internal source of fire is considered to be the chlorine truck. However, pessimistically, all truck fires are modelled as occurring outdoors	-	-	-
3.6 External explosion	Considered to present negligible off-site risk as there are no significant sources of external explosion present	-	-	-
3.7 Lightning strike	Considered to present negligible off-site risk as the chlorine store is lightning protected and the time spent by the truck on the access road is minimal	-	-	-
3.8 Extreme wind	Considered to present negligible off-site risk as chlorine store is designed for typhoon loading	-	-	-
3.9 Flooding	Considered to pose negligible risk as could only affect empty drums	-	-	-
3.10 Construction activities	No construction activities inside the chlorine store are anticipated during the construction and operational phases of this project.	-	-	-
3.11 Subsidence	Considered to present negligible off-site risk	-	-	-
3.12 Earthquake[2]	Overhead crane dislodged from rails: Single drum-rupture Roof collapse: Multiple drum-rupture	1 (inst) 42 (inst) [5]	-	liquid
3.13 Aircraft crash	Roof collapse: Multiple drum-rupture (similar to earthquake)	42 (inst)[5]	-	liquid
3.14 Sabotage	Considered to present negligible off-site risk (issues of site security were considered in the HAZOP studies and appropriate actions have been raised.)	-	-	-
3.15 Vehicle crash	Considered to present negligible off-site risk due to robustness of chlorine store	-	-	-
3.16 Electromagnetic interference	Considered to present negligible off-site risk as precautions are adopted in the design of the electrical systems.	-	-	-
4. CONNECTION AND DISCONNECTION OF CHLORINE CONTAINERS				
4.1 Human error or equipment failure during connection or disconnection of drums	Pigtail - guillotine failure	1	4.5mm	two-phase
5. CHLORINATION SYSTEM				

Chlorine release scenario	Outcome	Releasing inventory (tonnes)	Hole size (diameter)	Phase
5.1 - 5.5 Failures associated with the chlorination system pipework	Liquid chlorine pipework - guillotine failure	1.05[(3)]	4.5mm[(4)]	two-phase
5.6 - 5.7 Failure of evaporator	Evaporator - leak or rupture	1.05	4.5mm	two-phase

Notes

(1) In the 2001 QRA a mixture of “old” and “new” chlorine drums was assumed (with 6 and 1 fusible plug, respectively). According to the recent WSD information, the “old” drums are no longer in use, so only the “new”-type drums are considered

(2) For assessment of effects of earthquake on chlorine store see Appendix 13C (Annex G)

(3) Inventory of drum (1 tonne) and evaporator (50kg)

(4) Diameter of liquid chlorine pipework is 20mm but limiting orifice size is that of pigtail, i.e. 4.5mm.

(5) The values listed are for 221 tonnes storage. For reduced storage scenarios they are reduced in proportion to the storage levels (see discussion in Appendix 13C Annex G).

13.11.8 Consequence Analysis

Methodology

The assessment of the consequences of a chlorine release essentially involves three steps:

- modelling the initial release of chlorine (whether inside or outside the chlorine building);
- modelling the dispersion of chlorine in the atmosphere;
- assessing the toxic impact to people off-site (whether indoors or outdoors).

In this study, the methodology for the consequence analysis follows that of the Eight WTWs Study as detailed in the Methodology Report (ref. 19) and the STWTW QRA (ref. 20) and is summarised below. Details are provided in Appendix 13C.

Initial Release of Chlorine

The initial release of chlorine or 'source term' is modelled using standard discharge rate formulae as detailed in ref. (19). Releases direct from the chlorine container are the most significant and, in the case of chlorine drums, these are modelled as liquid releases.

The rapid flashing of chlorine which occurs following a liquid leak from a drum is conservatively assumed to result in 100% entrainment of the liquid as aerosol with no rain-out. For catastrophic (instantaneous) liquid releases the rapid boiling of the chlorine on contact with the ground is assumed to result in entrainment of twice the initial flash fraction as aerosol, following Lees (ref. 21). The remainder of the liquid chlorine is modelled as a spreading, evaporating pool.

For releases of chlorine within the chlorine building, a simple 'perfect mixing' model is used to account for the initial dilution of chlorine. Instantaneous releases of 1 tonne of chlorine are assumed to result in pressurisation of the building to the extent that there could be a release of chlorine via weak points in the building structure, e.g. door seals. Continuous releases are assumed to be entirely contained, except in the event of failure of the Contain and Absorb system for which two modes of failure are considered: normal ventilation remains on or a door is left open.

Dispersion of Chlorine in the Atmosphere

Following the Eight WTWs Study, advanced techniques are used for prediction of the dispersion of chlorine in the atmosphere. The effects of buildings and variable ground terrain on the dispersion of chlorine in the atmosphere are modelled. The modelling of the dispersion of chlorine in the atmosphere involves three elements:

- Wind tunnel simulations;
- Computational Fluid Dynamics (CFD); and
- Flat terrain dispersion modelling.

The wind tunnel and CFD studies represent the 'state of the art' in dense gas dispersion modelling and provide the only rigorous means of accounting for the effects of buildings and complex terrain. Wind tunnel testing has been used to investigate a range of release conditions, wind directions and wind speeds in near-neutral atmospheric conditions. CFD has been used to determine the influence of atmospheric stability on the dispersion of chlorine and provide a broad comparison against the wind tunnel results for neutral stability. Both the wind tunnel testing and CFD modelling have included off-site high rise buildings as well as on-site buildings as these have a significant influence on the dispersion of the chlorine.

The role of the flat terrain dispersion modelling has been to provide the 'source term' for both the wind tunnel and CFD studies. The model used was DRIFT (ref. 22), an integral dispersion model developed by AEA Technology under the sponsorship of the UK Health and Safety Executive.

Toxic Impact Assessment

The probit equation used to estimate the likelihood of fatality due to exposure to chlorine is that recommended for use in QRA studies by the Dutch Government (ref. 23); it incorporates the findings of recent investigation into chlorine toxicity.

Table 13.13 shows the relationship between the chlorine concentration and the probability of fatality for the TNO probit assuming a 10 minute exposure.

Table 13.13 Chlorine Toxicity Relationship

Chlorine concentration (ppm)	Probit value for 10 min exposure (TNO probit)	Probability of fatality (LD = Lethal Dose)
251	3.17	0.03 (LD03)
557	5.00	0.50 (LD50)
971	6.28	0.90 (LD90)

In risk assessments for toxic gas releases it is a common practice to take into account the possibility of escape of exposed persons. This is because at lower concentrations of the gas, people may be able to obtain protection by moving indoors or directly out of the cloud.

The escape modelling methodology followed in this study is similar to that developed by the UK Health and Safety Executive (ref. 24). It assumes that a person out of doors will have a probability of escape dependent on the chlorine cloud concentration, with escape occurring either directly out of the cloud or to a nearby building. The methodology takes into account the dose received during escape as well as the subsequent dose in the place of refuge. Suitable conservative assumptions are made for the time of escape bearing in mind the debilitating effect of the chlorine gas.

Incorporating all the above considerations it is possible to calculate an ‘effective’ outdoors fatality probability, i.e. the fatality probability that can be applied to the total outdoor population at any given location taking into account the probability of escape.

The consequence analysis gives three fatality probability contours for each release scenario, corresponding to 3%, 50% and 90% nominal outdoor fatality probability. The effective outdoors fatality probabilities corresponding to these levels of fatality are shown in *Table 13.14*.

Table 13.14 Effective Outdoors Probability of Fatality

Nominal outdoor fatality probability (for a person remaining outdoors)	% of population attempting escape	Effective outdoor fatality probability (taking into account the probability of escape)
90%	0%	90%
50%	80%	31%
3%	80%	0.7%

Following similar previous studies undertaken in Hong Kong and elsewhere, it is assumed that the probability of fatality for a person indoors is 10% of that for a person remaining outdoors, i.e. nominal outdoor fatality probability.

Protection is also considered for people on the upper floors of high rise buildings. This is based on data on the typical height of a chlorine cloud provided by the dispersion modelling.

Certain groups of people, i.e. the young, the elderly and the infirm will be more sensitive to the effects of chlorine than others. This is taken into account in the QRA by increasing the fatality rate applied to certain sensitive receivers such as nurseries, primary schools, old people homes and hospitals.

In line with data published in ref. (25) and risk criteria applied to sensitive developments in the UK and Australia, the fatality rate for these groups of people is set a factor of 3.3 higher than for the average population.

<u>Consequence Analysis Results</u>

Initial Release of Chlorine

The results of the 'source term' modelling of chlorine releases are summarised in Appendix 13C (*Table 4.3*).It is apparent from that table that releases from a drum due to melting of the fusible plugs or dislodgement of the plugs occur sufficiently rapidly to cause emptying of the drum in a short period of time (within a few minutes). Therefore these release cases are treated as effectively instantaneous releases.

It is also apparent that the chlorine building has a significant effect in modifying the release of chlorine to the atmosphere, given failure of the Contain and Absorb system. The rate of chlorine release is reduced dramatically (e.g. for a medium leak the rate of chlorine to atmosphere is reduced from 1.4 kg/s to 0.3 kg/s or 0.13 kg/s) and the chlorine becomes diluted in the building air. The failure mode of the Contain and Absorb system 'Normal ventilation remains on' is a more severe case than 'Door left open' in terms of the chlorine release rate to atmosphere. This is because the normal ventilation (typically 2.6 air changes per hour) provides a more rapid release of chlorine to the environment than if a door is left open (normal ventilation shutdown, chlorine scrubber system in operation).

Chlorine Dispersion Modelling Results

The results of wind tunnel testing for Shatin WTW are presented in Appendix 13C (*Table 4.4* and Annex B). The key findings of the wind tunnel testing may be summarised as follows:

- the wind tunnel results show that the LD03 contour only exceeds the site boundary for 1 tonne instantaneous releases. For 1.4 kg/s and 0.5 kg/s continuous releases the LD03 does not extend off-site; and
- the LD contours for the 1 tonne instantaneous release cases are strongly influenced by the topography and buildings near Shatin WTW. In particular:

- the chlorine clouds are constrained by the hills surrounding the WTW on three sides. However it is noted that the LD03 contour does extend to an elevation of 100m above Principal Datum (NNE wind direction) with significant concentrations of chlorine also present at greater elevations (e.g. 30 ppm at 200m above PD); and
- the nearest high rise blocks of the Hin Keng Estate act as an effective barrier to chlorine dispersion in the WSW direction with the chlorine cloud instead diverting down the Shatin valley (i.e. following the path of least resistance).

The results of the CFD modelling for Shatin WTW and Tai Po Tau WTW are presented in Appendix 13C (*Table 4.5* and Annex C). The key findings may be summarised as follows:

- Atmospheric stability does not significantly influence the hazard range of either a 1.4 kg/s continuous release of chlorine or a 1 tonne instantaneous release of chlorine for the two weather conditions of most interest in this study (i.e. D - neutral stability and F - stable conditions). This is because, in the presence of buildings and complex, heavily-vegetated terrain, atmospheric stability has less of an influence on chlorine dispersion;
- For B (unstable conditions) the CFD results for Tai Po Tau WTW indicate that the chlorine hazard range is significantly reduced compared to neutral conditions (i.e. a factor of 2.5 shorter for a 1 tonne instantaneous release). HSL indicate that this is due to the unstable wind field which significantly enhances vertical dispersion of the chlorine. However, as B conditions account for no more than 20% of the weather in Hong Kong, this is not considered a significant factor for the QRA (i.e. risks are not considered to be significantly overestimated by ignoring B conditions); and
- For F (stable conditions) the CFD results for Tai Po Tau WTW indicate that, whilst the chlorine hazard range is not significantly affected by atmospheric stability, the direction of travel of the chlorine cloud may be affected. At Tai Po Tau WTW, the chlorine releases in F conditions more closely followed the topographic contours than the equivalent releases in D conditions, which followed the direction of the wind.

The results of the flat terrain dispersion modelling using DRIFT are presented in Appendix 13C (*Table 4.6* and Annex A). From the modelling results it is possible to derive a relationship between the chlorine release rate (or release quantity) and the downwind hazard range. The relationship is used in the QRA, as described below.

Table 13.15 compares the key results from the wind tunnel testing, CFD modelling, and DRIFT flat terrain dispersion modelling.

Table 13.15 Comparison of Wind Tunnel, CFD and DRIFT Results (Neutral stability, 2m/s wind speed)

Release case	**Maximum extent of LD03 contour (m)**		
	Wind tunnel	CFD	DRIFT
0.2 kg/s continuous	<125	-	182
1.4 kg/s continuous	<125	260	550
1 tonne instantaneous	250-650	255	600

From *Table 13.15* the following key points emerge:

- the chlorine hazard range predicted by the wind tunnel testing and CFD modelling is generally shorter than that predicted by the DRIFT flat terrain dispersion modelling, particularly for continuous-type releases. This highlights the importance of modelling the effects of buildings and complex terrain, which act to increase turbulence and cause greater mixing of the chlorine. (It should also be noted that there is an inherent limitation in models such as DRIFT, whereby the surface roughness chosen must be small in relation to the cloud height. For dense gas release this limits the scope of DRIFT-type simulations to relatively smooth terrain, which is not applicable to Hong Kong conditions);

- the hazard range predicted by the wind tunnel testing for the 1.4 kg/s continuous release case is significantly shorter than that predicted by the CFD modelling (less than half). The reason for this is not certain, however an independent technical review of the wind tunnel testing highlighted the limitation of modelling this type of release in the wind tunnel (1:500 scale) due to the difficulty of accurately simulating turbulence close to the ground near the source of the release. It is possible, therefore, that in the wind tunnel the degree of turbulence was greater than would occur in practice for this type of release. In view of this, the QRA uses the CFD modelling results for this release, in preference to those generated by the wind tunnel; and
- the hazard range predicted by the wind tunnel for 1 tonne instantaneous releases are greater than those predicted by the CFD modelling. The reason for this is not clear, however as the wind tunnel results err on the conservative side (whilst eliminating the pessimism in the DRIFT-type predictions for these releases) they have been used in preference in the QRA.

Rationalisation of Chlorine Dispersion Modelling Results

The preceding sections have discussed the results arising from the various strands of work on chlorine dispersion modelling. The following paragraphs summarise how these results have been applied in the QRA. More details are provided in Appendix 13C (Annex D).

Wind tunnel testing: the wind direction-specific cloud shapes generated in the wind tunnel have been used directly in the QRA. This has been achieved through use of Graphical Information Systems (GIS) software which is described in further detail below. Another output of the wind tunnel testing was the influence of wind speed on the chlorine hazard range. From the wind tunnel test results for all eight WTWs a simple scale factor was derived to modify the cloud contours for the 2m/s wind speed case to determine those for the 5m/s case.

CFD modelling: the CFD modelling results show no significant influence of atmospheric stability on the chlorine hazard range (for D and F conditions), therefore this parameter is not considered further in the QRA. However the CFD results for the 1.4 kg/s continuous release case (D2 weather conditions), which are consistent for Shatin WTW and Tai Po Tau WTW, are used in the QRA in preference to those from the wind tunnel.

DRIFT modelling: the DRIFT flat terrain dispersion modelling results are not used directly in the QRA. However the relationships derived from the DRIFT modelling for the chlorine release rate/quantity versus hazard range are used to scale the wind tunnel results for the complete range of release scenarios which need to be considered in the QRA.

Chlorine Cloud Height

Information on the height of a chlorine cloud has been obtained from the wind tunnel simulations, CFD modelling and DRIFT flat terrain dispersion modelling. This is useful for determining the degree of protection of people inside high rise buildings. Details are provided in Appendix 13C.

13.11.9 Rationalisation of Chlorine Release Scenarios and Estimation of Scenario Frequencies

Rationalisation of Chlorine Release Scenarios

The consequence analysis from wind tunnel testing and CFD modelling shows that it is only certain, severe types of chlorine release which could produce fatal off-site concentrations of chlorine. The release cases which fall into this category are external continuous releases of 1.4 kg/s or more (equivalent to guillotine failure of a drum valve) and instantaneous releases of 1 tonne or more whether external or internal.

These results mean that many of the chlorine release scenarios identified in *Table 13.12* can be eliminated from further consideration in the QRA. Details are provided in Appendix 13C. The results of this 'rationalisation' process are shown in *Table 13.16* which groups the release scenarios into 'events' having identical release characteristics (i.e. the same release rate, duration and phase of release).

Table 13.16 Release Scenarios Included in QRA

Event Ref	Component scenarios	Release rate (or quantity) to atmosphere	Type of release	Release location
RU1TSML	Rollover Loadshedding Spontaneous leak	1.4 kg/s	Continuous	Access road
RU1TMML	Rollover Truck fire	4.2 kg/s	Continuous	Access road
RU1TSRU	Truck impact Truck fire Spontaneous failure	1 tonne	Instantaneous	Access road
EU1TMRU	Earthquake: roof collapse, ground acceleration 0.7g	26.8(1) tonnes	Instantaneous	Chlorine store
EU1TMRU1G	Earthquake: roof collapse, ground acceleration 1g	26.8(1) tonnes	Instantaneous	Chlorine store
AU1TMRU	Aircraft crash	26.8(1) tonnes	Instantaneous	Chlorine store

Note (1): the values listed are for 221 tonnes storage. For reduced storage scenarios they are reduced in proportion to the storage levels. For large instantaneous releases, such as the rupture of 42 drums in an earthquake, only 64% of the chlorine is estimated to be released instantaneously to atmosphere as vapour and entrained aerosol. This comprises the initial vapour flash fraction (19%) plus the entrained aerosol (2 x 19%) plus the contribution from the evaporating chlorine pool over the first minute (7%).

Frequency Estimation

Having identified the chlorine release scenarios of interest, the next step in the Hazard Assessment is to determine their frequency of occurrence. This is based on the approach adopted in ref. (20).

The base frequency data used in the frequency calculations are shown in Appendix 13C (*Table 5.4*). Actual frequencies are determined from these base failure data and the operational parameters of the WTW such as chlorine use, chlorine storage levels, length of the access road etc. The resulting total event frequencies are presented in *Table 13.17*.

Table 13.17 Event Frequencies

Event Ref	Component scenarios	Frequencies (per year)	Time periods during which event could occur
RU1TSML[1]	Rollover Loadshedding Spontaneous leak *Total*	3.21E-6 7.79E-7 2.54E-7 *4.24E-6*	All except Night All except Night All except Night
RU1TMML[1]	Rollover Truck fire	2.35E-7 4.52E-7	All except Night All except Night

Event Ref	Component scenarios	Frequencies (per year)	Time periods during which event could occur
	Total	*6.87E-7*	
RU1TSRU[1]	Truck impact Spontaneous drum failure *Total*	7.66E-7 1.25E-7 *8.91E-7*	All except Night All except Night
EU1TMRU	Earthquake	4.0E-8	All
EU1TMRU1G	Earthquake	1.25E-8	All
AU1TMRU	Aircraft crash	1.44E-9	All

Note 1: Frequencies for the access road events are proportional to the number of chlorine trucks per year and are shown here for the WTW chlorine usage of 896 tonnes (150 trucks) per year. Frequencies for other scenarios were reduced according to the annual number of trucks and the length of the access route assumed.

13.11.10 Quantitative Risk Assessment

Risk Assessment Methodology

The QRA combines information on the consequences of chlorine releases with information on the likelihood of releases to generate two measures of risk -individual risk and societal risk. Individual risk is the chance of death per year to a specified individual at a specific location. Societal risk is the risk to the population as a whole.

The QRA has been undertaken using a GIS-based software GISRisk, developed for the 8WTW project. The GIS component of the software enables the complex cloud shapes generated by the wind tunnel to be input directly into the QRA. It also provides a graphical interface by which the population data, chlorine cloud (LD) contours and individual risk contours can be viewed on a base map of the area. GISRisk is an application of standard, well-validated, commercial software, i.e. ESRI's ARCVIEW GIS software, Microsoft Access and Microsoft Excel. The main outputs from the software are as follows:

- Individual risk in the form iso-risk contours overlaid on a base map of the area;
- Societal risk in the form of an FN curve, which is a graphical representation of the cumulative frequency (F) of N or more fatalities plotted against N on a log-log scale; and
- Societal risk in the form of a Potential Loss of Life (PLL) value, which expresses the risk to the population as a whole and for each scenario and its location. The PLL is an integrated measure of societal risk obtained by summing the product of each f-N pair, as below:

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

Risk Criteria

The Hong Kong Planning Standards and Guidelines (HKPSG), Chapter 12 require that development proposals within the Consultation Zone of a Potentially Hazardous Installation (PHI) should be assessed against Government Risk Guidelines (HKRG) to ensure that risks to the public are confined to within acceptable limits. Acceptable risk levels are defined as follows:

- Individual Risk: The maximum involuntary individual risk of death associated with accidents arising at PHIs should not exceed 1 chance in 100,000 per year (10-5/yr); and
- Societal Risk: The societal risk associated with a PHI should comply with the FN diagram (*Figure 13.1*). Three areas of risk are shown:

Acceptable where risks are so low that no action is necessary;

Unacceptable where risks are so high that they should usually be reduced regardless of the cost or else the hazardous activity should not proceed; and

ALARP (As Low As Reasonably Practicable) where the risks associated with each probable hazardous event at the PHI should be reduced to a level as low as reasonably practicable, usually measured as a trade off between the risk reduction afforded and the cost of that reduction. Risk mitigation measures may take the form of either engineered measures at the PHI or development (i.e. population) controls in the vicinity of the PHI. In the case of a new development within the Consultation Zone of an existing PHI the onus is on the developer to implement such measures as are necessary to ensure that risk levels at the development site are ALARP.

Scenarios Considered for Base Case Assessment

Four scenarios have been considered in the QRA including two stages of the construction phase and the two periods of the SCL operation. The main assumptions of these scenarios, based on the WTW operational data and supplementary information from WSD are listed in *Table 13.11.* The chlorine storage levels and their time distribution for the future scenarios have been agreed with WSD.

Results of the QRA

The FN curves for each scenario listed in *Table 13.11* are presented in *Figure 13.14* to Figure *13.17*. *Table 13.19* summarises the maximum N numbers derived from these figures. PLL results are discussed in detail in Appendix 13C.

Scenario 1 (SCL Construction before WTW refurbishment)

FN curve for the 2011 construction Phase Scenario is shown in *Figure 13.14*. The risks to total population within consultation zone and SCL construction population are in the "ALARP" zone of HKRG. The risk to SCL construction population, when considered on its own, falls within the "acceptable" region.

Scenario 2 (Simultaneous SCL Construction Phase and WTW Refurbishment)

For the 2014 construction phase (*Figure 13.15*), during the WTW refurbishment period FN curve is again in the "ALARP" region, even that the additional population of the refurbishment workers, located very close to the potential chlorine release locations is taken into account.
The risk to SCL construction population, when considered on its own, falls within the "acceptable" region.

Scenarios 3 and 4 (Operational Phase Periods 1 and 2)

The Societal Risk results for the Operational Phase fall in the "ALARP" region of the HKRG *(Figures 13.16 and 13.17)*. The risks to the SCL population alone (considering HIK Station and the train populations) lie within "acceptable" region.

Figure 13.14 FN Curves: Scenario 1 (SCL Construction before WTW Refurbishment)

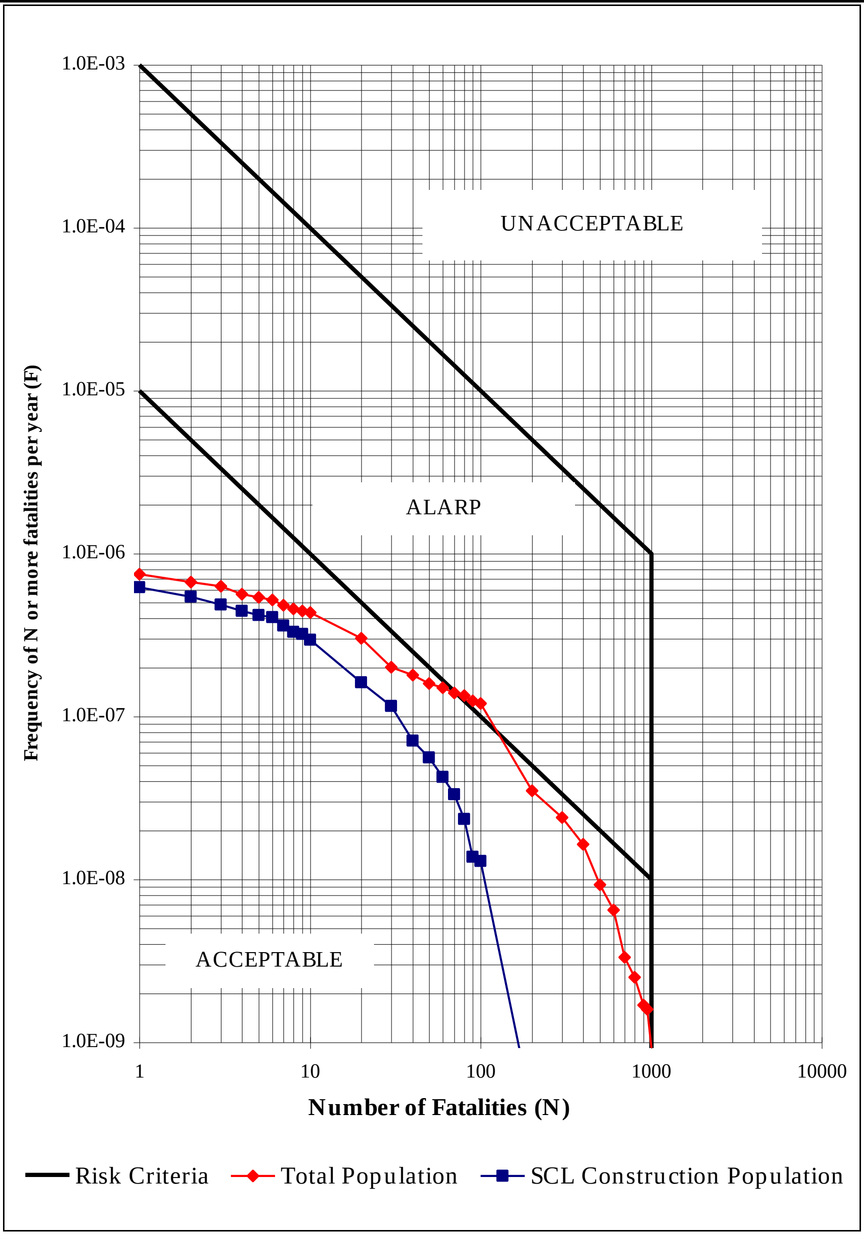


Figure 13.15 FN Curves: Scenario 2 (Simultaneous SCL Construction and WTW Refurbishment)

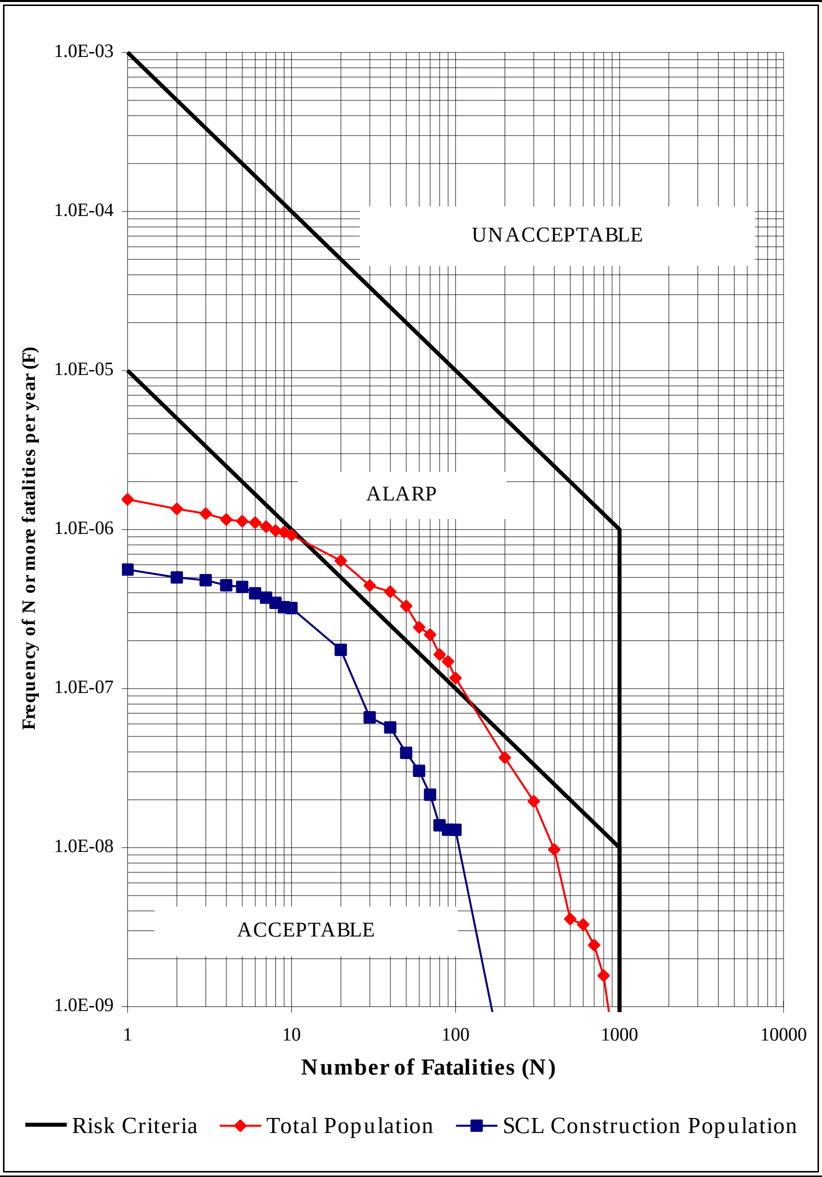


Figure 13.16 FN Curves: Scenario 3 (Operational Phase 2016)

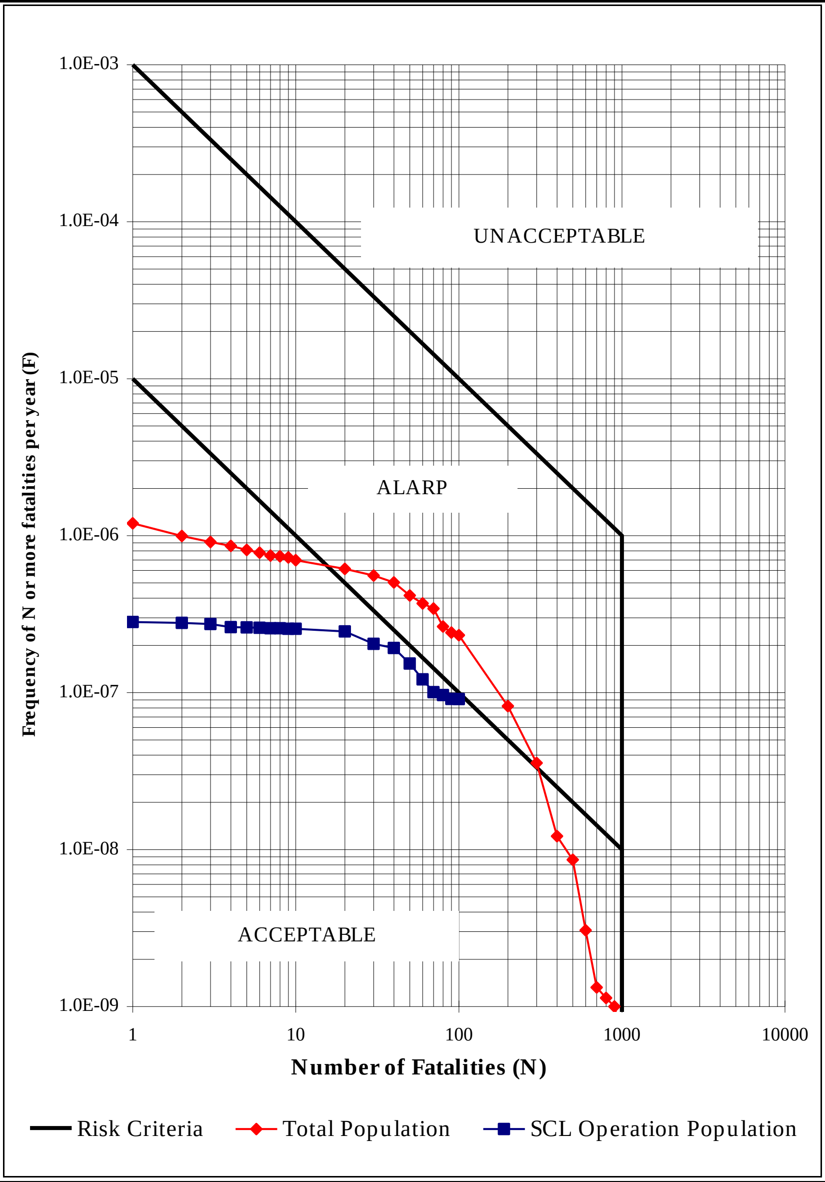


Figure 13.17 FN Curves: Scenario 4 (Operational Phase 2031)

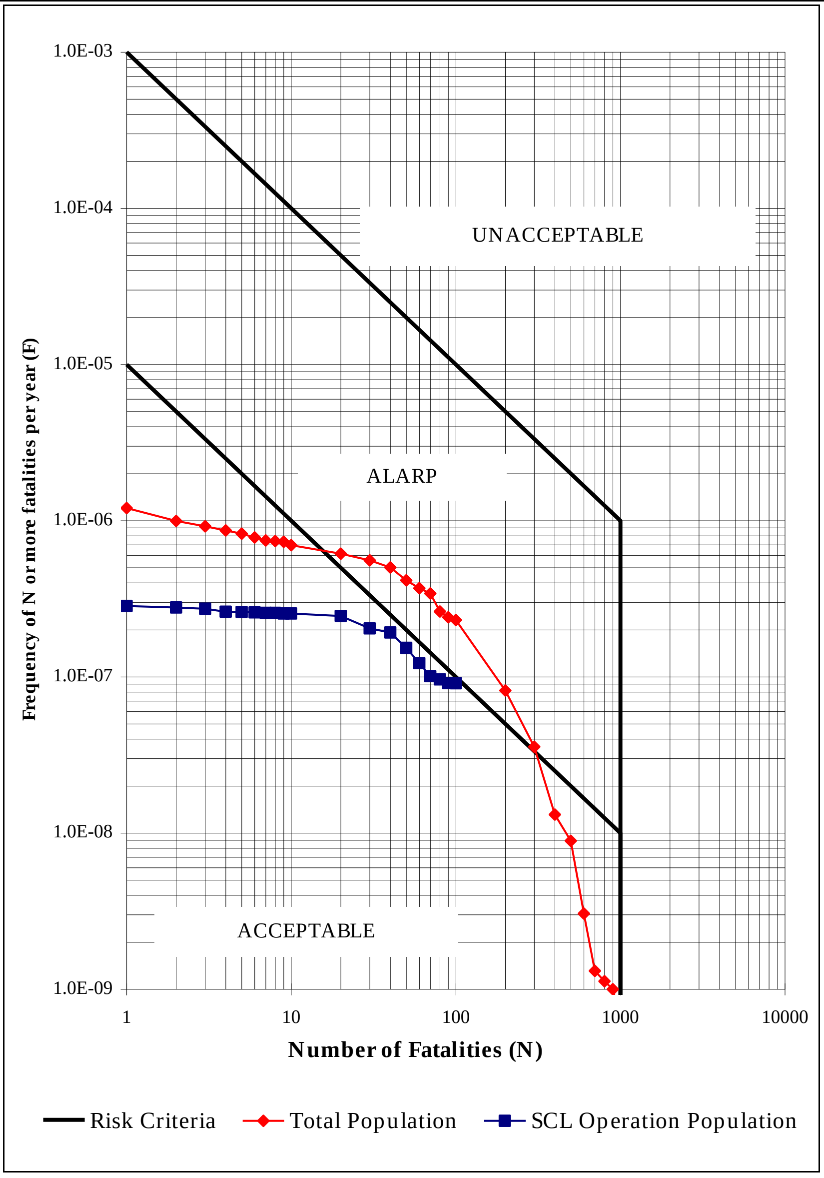


Table 13.18 Maximum N Value within the FN Chart for the Scenarios considered in QRA

Scenario	**Assessment year**	**Max N for F > 1 x 10^{-9}**
Scenario 1: SCL Construction before WTW refurbishment [1]	2011	990
Scenario 2: Simultaneous SCL Construction and WTW refurbishment	2014	864
Scenario 3: SCL Operation Period 1 (after completion of WTW refurbishment)	2016	900
Scenario4: SCL Operation Period 2 (surrounding population growth taken into account)	2031	900
2001 QRA (ref. 20)	2006	980

Societal Risk Result Analysis and Discussion

The high number of fatalities shown in the figures above and *Table 13.18* are due to the low frequency/high fatality events such as a multiple drum failures which can result from the chlorine store roof collapse during a significant (ground acceleration greater than 0.7g) earthquake.

While the earthquake scenarios are dominant for the high N values of the FN curve, the chlorine truck accident scenarios that can affect only the populations close to WTW and on their own contribute to about 560 fatalities have higher frequencies than earthquakes, and contribute about 50% to 80% to the total PLL.

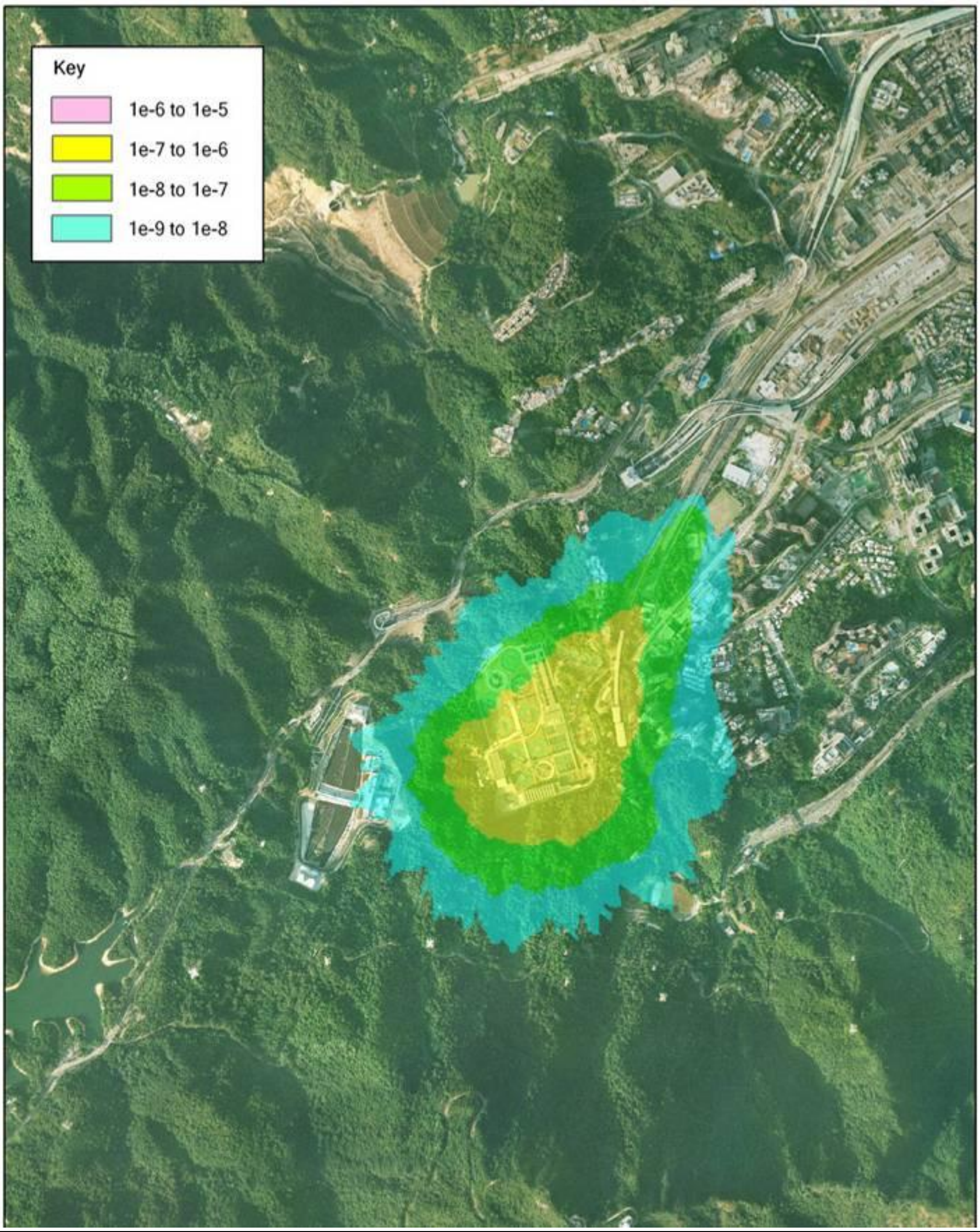
For more discussion of the societal risk results see Section 6.3.2 of Appendix 13C.

Individual Risk

The individual risk levels are calculated for a hypothetical person spending 100% of their time outdoors in the vicinity of the Shatin WTW.

Figure 13.18 presents the individual risks obtained for the Scenario 1, but assuming the maximum chlorine storage of 221 tonnes and 896 tonnes usage. Risks for other scenarios will be slightly lower due to the lower average chlorine storage and dosage levels *(Table 13.11)*. As can be seen, the risks are low and nowhere outside the WTW site boundary does the individual risk exceed 10-5 per year. It is therefore concluded that Shatin WTW complies with the individual risk criteria.

Figure 13.18 Individual Risk Contours



Results Summary

The 2001 STWTW QRA predicted the societal risk within the "ALARP" region of the HKRG, but very close to the 1000 fatality criterion. Any increase in population due to natural growth or any new development including transient construction workforce might therefore be expected to result in exceedance of the HKRG criteria (ie N>1000).

Nevertheless, societal risk levels for all scenarios studied are within the ALARP region (N<1000). This is due to the lower chlorine storage and use anticipated during and after the WTW refurbishment. For the SCL construction period before the WTW refurbishment begins, WSD has agreed to maintain the chlorine storage time distribution (see the first row of *Table 13.11*) that will not lead to an exceedance of the N<1000 criterion.

In terms of the Potential Loss of Life, the SCL construction contributes about 42%, and 19% of the total PLL value for the 2011 and 2014 scenarios, respectively, while for both operational phase scenarios (2016 and 2031) the PLL for the SCL passengers and HIK Station population amounts to about 33% of the total PLL. Of the background population units, the highest contribution to PLL results from Hin Keng Estate and road population of Che Kung Miu Road, and, during the WTW refurbishment, from the refurbishment workforce

The individual risk levels are low and in compliance with HKRG.

13.11.11 ALARP Assessment

Since the societal risk levels for all scenarios considered lie in the ALARP zone of the HKRG, mitigation measures are required to reduce the risks to levels As Low As Reasonably Practicable. In order to select and justify the most suitable risk mitigation, a detailed analysis has been carried out (Appendix 13C, Section 7) concluding that none of the proposed mitigating options could be deemed practicable based on the cost-benefit analysis.

Nevertheless, the following measures reducing the risks to the SCL staff, construction workers and passengers are recommended for implementation as a matter of good practice:

- Installation of on-site gas monitors in all relevant SCL construction/operation areas;
- Establishment of emergency response and evacuation plans (co-operation of various parties/departments required. For the operational phase the emergency plan should also include adequate procedures for controlling the tunnel ventilation system and stopping of the SCL train traffic in order to prevent the trains moving into the affected areas.); and
- Safety/emergency response/evacuation training and drills for all personnel

13.12 Conclusions

A QRA has been carried out to assess the hazard to life issues arising from the storage, transport and use of explosives during construction of the SCL (TAW-HUH) Project.

The criterion of Annex 4 of the EIAO-TM for Individual Risk is met with regards to the hazards to life posed by transport, storage and use of explosives. The assessment results show that the societal risk for the storage and use of explosives lies within the acceptable region, and the transport of explosives lies within the ALARP region when compared to the criteria stipulated in the EIAO-TM. A detailed ALARP assessment has been undertaken considering a wide range of mitigation measures and the results show compliance with the ALARP principles provided that the following recommendations are followed.

The criterion of Annex 4 of the EIAO-TM for Societal Risk is also met with regards to the hazards to life posed by the Shatin Water Treatment Works during both construction and operational phases of the project. The assessment results show that the societal risk lies within the ALARP region of the HKRG. An ALARP assessment has been carried out by identifying all practicable mitigation measures and the results show compliance with the ALARP principles provided that the following recommendations are followed.

13.13 Recommendations

Following the ALARP principles, the following recommendations are justified and should be implemented to meet the EIAO-TM requirements:

- The truck design should comply with the Requirements for Approval of an Explosives Delivery Vehicle (CEDD 2) and limit the amount of combustibles in the cabin. The fuel carried in the fuel tank should also be minimised to reduce the duration of any fire;
- The explosive truck accident frequency should be minimized by implementing a dedicated training programme for both the driver and his attendants, including regular briefing sessions, implementation of a defensive driving attitude. In addition, drivers should be selected based on good safety record, and medical checks;
- The contractor should as far as practicable combine the explosive deliveries for a given work area;
- Only the required quantity of explosives for a particular blast should be transported to avoid the return of unused explosives to the magazines.
- Whenever practicable, a minimum headway between two consecutive truck convoys of 10 min is recommended; and
- The explosive truck fire involvement frequency should be minimised by ensuring the implementation of a robust emergency response and training to make sure the adequate fire extinguishers are used and attempt is made to evacuate the area of the incident or securing the explosive load if possible. All explosive vehicles should be equipped the required amount and type of fire extinguishers and shall be agreed with Mines Division;
- The Contractor should as far as practicable use the preferred transport route; and
- The Contractor should coordinate explosives deliveries with the delivery of chlorine to Shatin Water Treatment Works in order to avoid overlapping.

General Recommendations

Blasting activities including storage and transport of explosives should be supervised and audited by competent site staff to ensure strict compliance with the blasting permit conditions. The following general recommendation should also be considered for the storage and transport of explosives:

- The security plan should address different alert security level to reduce opportunity for arson / deliberate initiation of explosives. The corresponding security procedure should be implemented with respect to prevailing security alert status announced by the Government.

- Emergency plan (i.e. magazine operational manual) shall be developed to address uncontrolled fire in magazine area and transport. The case of fire near an explosive carrying truck in jammed traffic should also be covered. Drill of the emergency plan should be carried out at regular intervals.
- Adverse weather working guideline should be developed to clearly define procedure for transport explosives during thunderstorm.
- The magazine storage quantities need to be reported on a monthly basis to ensure that the two day storage capacity is not exceeded.

Storage of Explosives in Magazine Store

The magazine should be designed, operated and maintained in accordance with Mines Division guidelines and appropriate industry best practice. In addition, the following recommendations should be implemented:

- A suitable work control system should be introduced, such as an operational manual including Permit-to-Work system, to ensure that work activities undertaken during the operation of the magazine are properly controlled.
- There should be good house-keeping within the magazine to ensure that combustible materials are not allowed to accumulate.
- The magazine shall be without open drains, traps, pits or pockets into which any molten ammonium nitrate could flow and be confined in the event of a fire.
- The magazine building shall be regularly checked for water seepage through the roof, walls or floor.
- Caked explosives shall be disposed of in an appropriate manner.
- Delivery vehicles shall not be permitted to remain within the secured fenced off magazine store area.
- Good housekeeping outside the magazine stores to be followed to ensure combustibles (including vegetation) are removed.
- A speed limit within the magazine area should be enforced to reduce the risk of a vehicle impact or incident within the magazine area.
- Traffic Management should be implemented within the magazine site, to ensure that no more than 1 vehicle will be loaded at any time, in order to avoid accidents involving multiple vehicles within the site boundary. Based on the construction programme, considering that 6 trucks could be loaded over a peak 2 hour period, this is considered feasible.
- The design of the fill slope close to the magazine site should consider potential washout failures and incorporate engineering measures to prevent a washout causing damage to the magazine stores.

Transport of Explosives

General Recommendations:

The following measures should be considered for safe transport of explosives:

- Detonators shall not be transported in the same vehicle with other Class 1 explosives. Separation of vehicles should be maintained during the whole trip.
- Location for stopping and unloading from truck to be provided as close as possible to shaft, free from dropped loads, hot work, etc. during time of unloading.
- Develop procedure to ensure that parking space on the site is available for the explosive truck. Confirmation of parking space should be communicated to truck drivers before delivery. If parking space on site cannot be secure, delivery should not commence.

- During transport of the explosives within the tunnel, hot work or other activities should not be permitted in the vicinity of the explosives offloading or charging activities.
- Ensure lining is provided within the transportation box on the vehicle and in good condition before transportation.
- Ensure that packaging of detonators remains intact until handed over at blasting site.
- Emergency plan to include activation of fuel and battery isolation switches on vehicle when fire breaks out to prevent fire spreading and reducing likelihood of prolonged fire leading to explosion.
- Use only experienced driver(s) with good safety record.
- Ensure that cartridged emulsion packages are damage free before every trip.

Contractors Licensed Vehicle Recommended Safety Requirements:

- Battery isolation switch;
- Front mounted exhaust with spark arrestor;
- Fuel level should be kept as far as possible to the minimum level required for the transport of explosives;
- Minimum 1 x 9 kg water based AFFF fire extinguisher to be provided;
- Minimum 1 x 9 kg dry chemical powder fire extinguisher to be provided;
- Horizontal fire screen on cargo deck and vertical fire screen mounted at least 150mm behind the drivers cab and 100mm from the steel cargo compartment, the vertical screen shall protrude 150mm in excess of all three (3) sides of the steel cargo compartment;
- Cigarette lighter removed;
- Two (2) battery powered torches for night deliveries;
- Vehicles shall be brand new, dedicated explosive transport vehicles and should be maintained in good operating condition;
- Daily checks on tyres and vehicle integrity;
- Regular monthly vehicle inspections;
  - Fuel system
  - Exhaust system
  - Brakes
  - Electrics
  - Battery
  - Cooling system
  - Engine oil leaks
- Vehicle log book in which monthly inspections and maintenance requirements are recorded; and
- Mobile telephone equipped.

Recommended Requirements for the Driver of the Explosive Vehicles:

The driver shall:

- be registered by the Commissioner of Mines and must be over the age of 25 years with proven accident free records and more than 7 year driving experience without suspension.
- hold a Driving License for the class of vehicle for at least one (1) year;
- adopt a safe driving practice including having attended a defensive driving course;

- pass a medical check and is assessed as fit to drive explosives vehicles;
- not be dependent on banned substances;

Some of the following requirements may also apply to the vehicle attendant(s).

- The driver is required to attend relevant training courses recognized by the Commissioner of Mines. The training courses should include the following major subjects, but not limited to:
  - the laws and Regulations relating to the transport of explosives;
  - security and safe handling during the transport of explosives;
- Attend training courses provided by the explosives manufacturer or distributor, covering the following:
  - explosives identification;
  - explosion hazards; and
  - explosives sensitivity;
  - the dangers which could be caused by the types of explosives;
  - the packaging, labelling and characteristics of the types of explosives;
  - the use of fire extinguishers and fire fighting procedures; and
  - emergency response procedures in case of accidents.

The driver should additionally be responsible for the following:

- The driver shall have a full set of Material Safety Data Sheets (MSDS) for each individual explosive aboard the vehicle for the particular journey;
- The MSDS and Removal Permit (where applicable) shall be produced to any officer of the Mines Division of CEDD upon request;
- A card detailing emergency procedures shall be kept on board and displayed in a prominent place on the drivers door;
- Before leaving the magazine the driver together with and/or assisted by the shotfirer shall check the following:
- Packaging integrity and labelling;
- Check that the types and quantities of explosives loaded onto the vehicle are as stipulated in the Removal Permit(s);
- Check that the explosive load does not exceed the quantities stated in the removal permit;
- Check the condition and integrity of the cargo compartment or box;
- Check that detonators are not loaded in the explosives cargo compartment and vice versa;
- Check that the cargo is secured and cannot be damaged during the delivery;
- Ensure that the appropriate placards and a red flag are displayed before leaving the magazine;
- Be competent to operate all equipment onboard the vehicle including fire extinguishers and the vehicle emergency cut-off switches;
- Prohibit smoking when the vehicle is loaded with explosives;
- When explosives are loaded, ensure the vehicle is not left unattended;
- Be conversant with emergency response procedures.

Specific Recommended Requirements for the Explosive Vehicle Attendants:

When the vehicle is loaded with explosives, it shall be attended by the driver and at least one (1) other person authorized by the Commissioner of Mines. The vehicle attendant shall:

- Be the assistant to the driver in normal working conditions and in case of any emergency
- Be conversant with the emergency response procedures
- Be competent to use the fire extinguishers and the vehicle emergency cut-off switches
- One of the vehicle attendant(s) should be equipped with mobile phones and the relevant MSDS and emergency response plan.

Type of Explosives & their Disposal

For explosive selection, the following should be considered

- Cartridged Emulsions with perchlorate formulation should be avoided;
- Cartridged Emulsions with high water content should be preferred.

If disposal is required for small quantities, disposal should be made in a controlled and safe manner by a Registered Shotfirer.

Use of Explosives

The following recommendations should be considered for the safe use of explosives.

- Blast charge weight (MIC) should be within the maximum MIC as specified for the given section.
- Temporary mitigation measures such as blast doors or heavy duty blast curtains should be installed at the access adits, shafts/ portals and at suitable locations underground to prevent flyrock and control the air overpressure.
- Blasting from multiple faces as well as different locations will be carried out for this project. Good communication and control will need to be adopted in ensuring that the works are carried out safely.
- It is intended that complete evacuation of the underground tunnels need not be carried out and secure refuge areas should be identified to workers in the area.
- A Chief Shotfirer and a Blasting Engineer shall be employed in addition to the normal blasting personnel to ensure that the works are coordinated between blasting areas and between adjacent contracts.
- Shotfirer to be provided with a lightning detector, and appropriate control measures should be in place.
- A speed limit for the diesel vehicle truck and bulk emulsion truck in the tunnel should be enforced. The truck may be escorted while underground to ensure route is clear from hazards and obstructions.
- Hot work should be suspended during passage of the diesel vehicle truck and bulk emulsion truck in the tunnel.
- For any construction works related to use of explosives near gas facilities and gas pipes, the requirements of the Code of Practice on Avoiding Danger from Gas Pipes must be respected, in particular, to ensure liaison/coordination with HKCG with sufficient notice of planned works and to follow prescribed emergency procedures in case of leaks.
- A detailed liaison between the contractor and HKCG should be established. HKCG should be notified about the blasting schedule in written format within a reasonable period of time prior to blasting in order to ensure the gas safety during the construction period. Also, liaison should be made with HKCG to develop an emergency plan.

Shatin Water Treatment Works PHI

The following measures reducing the risks to the SCL staff, construction workers and passengers are recommended for implementation as a matter of good practice:

- Installation of on-site gas monitors in all relevant SCL construction/operation areas;
- Establishment of emergency response and evacuation plans (co-operation of various parties/departments required. For the operational phase the emergency plan should also include adequate procedures for controlling the tunnel ventilation system and stopping of the SCL train traffic in order to prevent the trains moving into the affected areas.); and
- Safety/emergency response/evacuation training and drills for all personnel

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